

This special supplement of *The International Journal of Oral & Maxillofacial Implants* presents the proceedings of the Third ITI Consensus Conference, which took place in August 2003 in Gstaad, Switzerland. The ITI (International Team for Implantology) is a scientific association with more than 350 members from 34 countries. The ITI organizes consensus conferences at 5- to 6-year intervals to discuss relevant topics in implant dentistry.

The first (1993) and second (1997) ITI consensus conferences primarily discussed basic surgical and prosthetic issues in implant dentistry. For the third Consensus Conference in 2003, the ITI Education Committee decided to focus the discussion on 4 special topics that have received much attention in recent years and for which numerous “novel” techniques have been advocated at major implant conferences for clinical application in daily practice. The ITI Education Committee elected a group leader for each of the 4 topics. The Consensus Conference Program Committee, composed of the chairman of the ITI Education Committee and the 4 group leaders, selected for each topic a working group of 15 to 20 clinicians and researchers with related expertise in the topic. Each group leader selected 2 to 4 assistants from his working group, who decided what needed to be addressed and who helped prepare for the consensus conference by writing review papers. The 4 topics and the group leaders were as follows:

- Group 1: Implants in extraction sockets (Leader: Christoph F. Hämmerle)
- Group 2: Esthetics in implant dentistry (Leader: Urs C. Belser)
- Group 3: Loading protocols for dental implants (Leader: David L. Cochran)
- Group 4: Implant survival and complications (Leader: Niklaus P. Lang)

The objectives of the ITI Consensus Conference were to review the current literature in peer-reviewed journals and discuss where sufficient evidence is available for certain clinical procedures and where evidence is currently lacking. In addition, each group was asked to review the prepared manuscripts, discussing them in detail and modifying them until agreed upon by all, and so reach a consensus on these papers. Based on these discussions, each group was asked to establish statements, which also included some clinical recommendations, and to put these statements forward at a plenary session, which included all conference participants. These statements were discussed extensively and altered as needed until they were accepted by all the conference participants.

The review papers and consensus statements published in this special supplement to *The International Journal of Oral & Maxillofacial Implants* are intended to serve as a guide to clinicians in the diagnosis, treatment planning, and management of patients requiring dental implant therapy. With the consensus statements as guidelines, it is hoped that clinicians will be better prepared to make informed surgical and prosthodontic treatment decisions that will further enhance the quality of care and predictability of treatment outcome for their patients.

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Immediate or Early Placement of Implants Following Tooth Extraction: Review of Biologic Basis, Clinical Procedures, and Outcomes

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Purpose: The aim of this article was to review the current literature with regard to survival and success rates, along with the clinical procedures and outcomes associated with immediate and delayed implant placement. **Materials and Methods:** A MEDLINE search was conducted of studies published between 1990 and June 2003. Randomized and nonrandomized clinical trials, cohort studies, case-control studies, and case reports with a minimum of 10 cases were included. Studies reporting on success and survival rates were required to have follow-up periods of at least 12 months. **Results:** Thirty-one articles were identified. Most were short-term reports and were not randomized with respect to timing of placement and augmentation methods used. All studies reported implant survival data; there were no reports on clinical success. Peri-implant defects had a high potential for healing by regeneration of bone, irrespective of healing protocol and bone augmentation method. Sites with horizontal defects (HD) of 2 mm or less healed by spontaneous bone fill when implants with rough surfaces were used. In the presence of HDs larger than 2 mm, or when socket walls were damaged, concomitant augmentation procedures with barrier membranes and bone grafts were required. Delayed implant placement allowed for resolution of local infection and an increase in the area and volume of soft tissue for flap adaptation. However, these advantages were diminished by simultaneous buccolingual ridge resorption and increased requirements for tissue augmentation. **Discussion:** Immediate and delayed immediate implants appear to be predictable treatment modalities, with survival rates comparable to implants in healed ridges. Relatively few long-term studies were found. Successful clinical outcomes in terms of bone fill of the peri-implant defect were well established. However, there was a paucity of data on long-term success as measured by peri-implant tissue health, prosthesis stability, and esthetic outcomes. **Conclusions:** Short-term survival rates and clinical outcomes of immediate and delayed implants were similar and were comparable to those of implants placed in healed alveolar ridges. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):12–25

Key words: bone regeneration, dental implants, delayed implants, extraction socket, immediate implants, implant survival, literature review

Since the first report of the placement of a dental implant into a fresh extraction socket,¹ there has been increasing interest in this technique for implant treatment (for reviews see Schwartz-Arad and Chaushu² and Mayfield³). The advantages of

immediate implant placement have been reported to include reductions in the number of surgical interventions and in the treatment time required.^{4,5} It has also been suggested that ideal orientation of the implant,^{6,7} preservation of the bone at the extraction site,^{8–10} and optimal soft tissue esthetics⁶ may be achieved.

However, it has been reported that immediate implant placement may be adversely affected by the presence of infection^{11–13} and lack of soft tissue closure and flap dehiscence over the extraction site,¹⁴ particularly when barrier membranes have been used for guided bone regeneration.^{15–20} Treatment outcomes for both submerged and nonsubmerged placements may be affected by lack of tissue volume²¹ and thin tissue biotypes. In addition,

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Table 1 Human Histologic Studies Presenting Data on Osseous Regeneration in Extraction Sockets

Study	Duration	No. of patients	Sites	First appearance of osteoid	Initial calcification	Substantial bone fill of socket
Amler et al (1960) ³²	50 days	Not stated	Varied	7 days	18 days	38 days (⅔ fill)
Boyne (1966) ³³	19 days	12	Maxillary teeth	10 days	—	—
Amler (1969) ³⁴	50 days	Not stated	Varied	7 days	20 days	40 days (⅔ fill)
Evian et al (1982) ³⁵	16 weeks	10	Varied	—	4 to 6 weeks	10 weeks (complete fill)

incongruity between the shape of the implant body and that of the socket wall may lead to gaps between the bone and the implant. At the present time, there is a lack of consensus on the need for immediate implants and the optimal regenerative techniques to be used with them.^{2,3} The clinician must therefore decide whether augmentation procedures are necessary and, if so, the most efficacious technique to use. To overcome the problems of immediate implantation, alternative techniques have been described, calling for implant placement at various intervals following initiation of wound healing subsequent to tooth extraction.^{14,22-27}

This article will examine the biologic basis, as well as the indications and clinical outcomes, of immediate and delayed implant placement. It will not deal with techniques for delayed implant placement following soft and hard tissue augmentation at the time of tooth extraction (for a review on this topic, see Adriaens²⁸). An understanding of extraction wound healing and subsequent bone resorption, regeneration, and remodeling of the healing socket is necessary to provide a basis for reviewing the outcomes of implants placed early after tooth extraction.

LITERATURE REVIEW AND SEARCH RESULTS

A MEDLINE search was conducted to identify clinical articles published between 1990 and June 2003. The search terms used were “immediate” and “implants,” “implants” and “extraction sockets,” “delayed-immediate” and “implants,” “delayed” and “implants,” “delayed implants” and “extraction,” “delayed placement” and “implants,” and “early placement” and “implants.” In addition, the bibliographies of 2 review articles were checked for

appropriate studies.^{2,3} The reference lists of identified studies were then searched for additional citations. Randomized clinical trials and nonrandomized cohort studies, case control studies, and case series with a minimum of 10 cases were included. In addition, studies reporting on success and survival rates needed to have follow-up periods of at least 12 months.

A total of 31 studies that met the criteria for this review were identified. Of these studies, 18 provided data on survival rates of immediate and delayed implants. Nineteen studies provided clinical, radiographic, and re-entry data on healing around immediate and delayed implants.

HEALING OF EXTRACTION SOCKETS

Histologic Events

The events that occur in a healing extraction socket have been identified by examination of animal histologic material²⁹⁻³¹ and human biopsies (Table 1).³²⁻³⁵ Five stages of healing have been described.³⁴ In the first stage, an initial clot forms as a coagulum of red and white blood cells derived from the circulation. In the second stage, granulation tissue replaces the clot over a 4- to 5-day period. Cords of endothelial cells are associated with budding capillaries. In the third stage, connective tissue gradually replaces granulation tissue over 14 to 16 days. The connective tissue is characterized by the presence of spindle-shaped fibroblasts, collagen fibers, and a metachromatic ground substance. In the fourth stage, calcification of osteoid is apparent, commencing at the base and periphery of the socket. Early osteoid is seen at the base and periphery of the socket by 7 to 10 days. Bone trabeculae almost completely fill the socket by 6 weeks. In the fifth stage, complete epithelial closure of the socket is achieved

Table 2 Studies Measuring Mean Apicocoronal and Buccolingual Change in Ridge Dimensions Following Tooth Extraction

Study	Healing time (mo)	Vertical change (mean \pm SD)	Buccolingual change (mean \pm SD)
Lekovic et al (1997) ³⁹	6	-0.86 \pm 0.14 mm	—
Lekovic et al (1998) ⁴⁰	6	-1.50 \pm 0.26 mm	—
Camargo et al (2000) ⁴²	6	1.00 \pm 2.25 mm	3.06 \pm 2.41 mm
Lasella et al (2003) ⁴³	4 to 6	-0.90 \pm 1.60 mm	-2.63 \pm 2.29 mm
Schropp et al (2003) ⁴¹	12	-0.7 mm (-1.4/-0.2)*	-5.9 mm (-7.7/-4.7)*

*Indicates 25th/75th percentiles.

after 24 to 35 days. Substantial bone fill occurs between 5 and 10 weeks.³²⁻³⁴ By 16 weeks, bone fill is complete, with little evidence of osteogenic activity at this time.³⁵

Maximum osteoblastic activity, seen as a proliferation of cellular and connective tissue elements, with osteoblasts laying down osteoid around immature islands of bone, occurs between 4 and 6 weeks after extraction. After 8 weeks, the osteogenic process appears to slow down.³⁵

External Dimensional Changes at Extraction Sockets

Morphologic changes in healing extraction sockets have been described by cephalometric measurements,^{36,37} study cast measurements,³⁸⁻⁴¹ subtraction radiography,⁴¹ and direct measurements of the ridge following surgical re-entry procedures.^{39,40,42,43}

Measurements from diagnostic casts allow assessment of the gross morphologic changes that take place during healing and reflect changes in both the bone and overlying mucosa.⁴¹ Approximately 5 to 7 mm of horizontal or buccolingual ridge reduction, representing about 50% of the initial ridge width, occurs over a 6- to 12-month period. Most of this change takes place during 4 months of healing.^{38,44} A corresponding apicocoronal or vertical height reduction of 2.0 to 4.5 mm accompanies the horizontal change.^{43,45} Greater apicocoronal changes take place at multiple adjacent extraction sites than at single extraction sites.^{41,44,45}

The dimensional changes of the bone in healing sockets have been reported via intraoperative measurements (Table 2³⁹⁻⁴³). Loss of between 3.1 and 5.9 mm of buccolingual ridge width was observed in studies with observation periods of 4 to 12 months.³⁹⁻⁴³ Schropp and coworkers measured dimensional changes in 46 healing sockets in 46 patients.⁴¹ The extraction sites were confined to the premolars and molars in both jaws. All but 2 patients agreed to not wear a prosthetic replace-

ment during the healing phase. It was found that a reduction in buccolingual width of approximately 50% (from 12.0 to 5.9 mm) took place over a 12-month period, with two thirds of this change occurring in the first 3 months after extraction. These changes were slightly greater in molar sites than in premolar sites, and in the mandible compared with the maxilla. At 3 months after tooth extraction, a reduction in apicocoronal ridge height of 0.8 mm was noted on the buccal aspect.

Apicocoronal crestal bone height reductions of 0.7 to 1.5 mm have been reported after 4 to 6 months.^{39,40,42,43} In contrast, a gain in ridge height of 0.4 mm after 12 months was observed in one study.⁴¹

A variety of factors may influence the dimensional changes of the bone following tooth extraction, and it is clear that current knowledge is limited in many areas. Systemic factors may include the patient's general health and habits (eg, smoking). Local factors include the reasons for extraction, the number and proximity of teeth to be extracted, the condition of the socket before and after tooth extraction, the influence of tissue biotype on healing, local differences between sites in the mouth and the dental arches, and the type of interim prosthesis used.

Internal Dimensional Changes Within Extraction Sockets

Healing events within the socket reduce the dimensions of the socket over time. Vertical socket height reduction of 3 to 4 mm, or approximately 50% of the initial socket height, has been reported after 6 months of healing.^{39,40} Horizontal socket width reduction of 4 to 5 mm, or approximately two thirds of the original socket width, has been shown to have occurred by 6 months of healing.^{39,40,42}

A radiographic analysis using subtraction radiography over a 12-month period confirmed that bone formation within the socket occurred simultaneously with loss of alveolar crest height.⁴¹ Most of

this bone gain and loss occurred in the first 3 months following tooth extraction. In the same study, linear measurements of radiographs showed that crestal bone levels at the tooth surfaces adjacent to the extraction sites remained relatively unchanged over the 12-month observation period (mean 0.1 mm loss). In contrast, mesial and distal bone height levels in the extraction sockets were reduced by 0.3 mm. The level of bone that regenerated in the extraction sockets did not reach the level of the bone at the adjacent teeth.

Dimensional Changes in Damaged Extraction Sockets

The rate and pattern of bone resorption may be altered if pathologic or traumatic processes have damaged one or more of the bony walls of the socket. It is likely in these circumstances that fibrous tissue may occupy a part of the socket, thereby preventing normal healing and osseous regeneration from taking place.²⁸ There are insufficient data on the differences in rates and patterns of the healing of intact versus damaged extraction sockets.

Dimensional Changes of the Mucosa

It is generally believed that the form of the mucosa closely follows the changes in the underlying bone. An apical shift in the coronal bone may be followed by a similar shift in the position of the mucosa. However, in a study comparing healing of undisturbed sockets with healing of sockets grafted with freeze-dried bone allograft and a collagen membrane,⁴³ the authors reported that the thickness of the mucosa at the buccal aspect of the ridge crest increased by 0.4 mm after 4 months in the control group. The grafted group showed a loss of tissue thickness of 0.1 mm. The differences between test and control groups were significant.

Although complete epithelialization of the socket is established by the fifth week of healing, organization and maturation of the collagen in the underlying lamina propria takes longer to occur. Matrix synthesis begins at 7 days and peaks at 3 weeks; this is followed by a continuous process of maturation until complete tensile strength is restored several months later.⁴⁶ Lack of tensile strength in the mucosa of healing extraction sockets may result in wound dehiscence. Dehiscence rates of 5% to 24% have been reported at delayed implant sites treated with both resorbable and nonresorbable membranes, despite the presence of adequate tissue volume to achieve primary closure.^{22,47}

CLASSIFICATION OF TIMING OF IMPLANT PLACEMENT AFTER TOOTH EXTRACTION

Several classifications have been proposed for the timing of implant placement following tooth extraction. In the classification of Wilson and Weber, the terms *immediate*, *recent*, *delayed*, and *mature* are used to describe the timing of implant placement in relation to soft tissue healing and the predictability of guided bone regeneration procedures.¹⁴ However, no guidelines for the time interval associated with these terms were provided. In the recent classification of Mayfield, the terms *immediate*, *delayed*, and *late* are used to describe time intervals of 0 weeks, 6 to 10 weeks, and 6 months or more after extraction, respectively.³ The interval between 10 weeks and 6 months was not addressed.

Most of the studies reviewed described immediate implant placement as part of the same surgical procedure and immediately following tooth extraction. The exceptions were Schropp and associates,²⁷ who defined immediate implantation as implants placed between 3 and 15 days (mean 10 days) following tooth extraction, and Gomez-Roman and coworkers,⁴⁸ who defined it as occurring between 0 and 7 days afterward. The majority of studies that described delayed implant placement used a delay period of 4 to 8 weeks after extraction. In a report published by Hämmerle and Lang, placement was delayed for 8 to 14 weeks.²⁵ In an additional 3 reports, implant placement was considered delayed when it occurred between 6 weeks and 6 months after extraction^{47,49} and between 1 week and 9 months.⁴⁸ This variation indicates a lack of uniformity in the interpretation of the terms *immediate*, *delayed*, and *late*.

Thus, it is necessary to introduce clearer definitions of implant placement that are based on the morphologic, dimensional, and histologic changes following tooth extraction and on common practice derived from clinical experience.

CLINICAL OUTCOMES

Several studies have reported on clinical, radiographic, and bone defect changes that take place following placement of immediate and delayed implants (Tables 3 and 4). Ten studies reported on healing of immediate implants only,^{17,18,51-53,57-61} and 3 studies dealt only with delayed implants.^{25,54,55} Several articles compared immediate with delayed placement,^{22,27,62} or immediate with late placement.^{50,56} A total of 6 papers provided comparative data on immediate, delayed, and late place-

ment.^{10,24,26,47-49} The majority of the comparative reports were not randomized with respect to placement and augmentation techniques.

Healing of Immediate and Delayed Implant Sites

Following observation periods of between 1 and 4.5 years, no significant differences were reported to occur in radiographic crestal bone levels or in probing of pockets at immediate, delayed, or late implantation sites.^{10,22,48,50,56}

The majority of studies reported that peri-implant defects associated with immediate implants healed with significant bone fill, irrespective of the placement protocol (submerged versus nonsubmerged) and augmentation method used.^{51-53,57-61} However, significantly better bone fill (5.7 mm versus 3.2 mm) and less crestal bone resorption were reported at immediate implant sites treated with demineralized freeze-dried bone combined with nonresorbable barrier membranes, versus sites treated with a nonresorbable barrier membrane alone.¹⁷ An exception to these positive findings above was reported in a study of immediate implants in 15 patients.¹⁸ Substantial bone regeneration was observed histologically in only 3 of 15 tissue samples taken at the time of membrane removal. The results were compromised by wound dehiscences that resulted in early exposure of nonresorbable membranes in 10 of 15 patients. In other studies, premature exposure of nonresorbable membranes was reported to be associated with reduced volumes of regenerated bone in the peri-implant defects.^{17,47,60} However, lower incidences of premature membrane exposure were observed using collagen membranes.^{47,58}

Peri-implant defects encountered at the time of delayed placement have been reported to heal with significant reduction in defect dimensions. In the absence of augmentation techniques, defect height (DH) reduction was greater at sites with no horizontal defects (ie, the peri-implant space) compared to sites where horizontal defects were present (3.4 mm versus 1.1 mm).⁵⁴ Highly successful outcomes for defect area (DA) reduction (86% to 97% reduction) were reported in dehiscence defects treated with collagen barrier membranes and anorganic bovine bone mineral.^{25,55}

Comparisons between immediate and delayed implantation sites showed a trend toward higher percentages of DH and DA reduction at delayed sites (range between studies for DH, 86% to 97%; for DA, 86% to 97%) compared with immediate sites (DH 77% to 95%; DA 77% to 95%). The exception was in the study of Schropp and coworkers,

in which DH reductions were comparatively modest (48% immediate; 34% delayed).²⁷ In most cases, differences between groups for DH and DA reductions were not statistically significant.^{24,47,49} However, Nemcovsky and colleagues found significantly better DH and DA reduction at delayed sites compared with immediate sites.⁶²

Localized pathologic processes may lead to damage of one or more walls of the extraction socket, with the formation of dehiscence defects.^{24,26,27,50,51} Sockets with dehiscence defects may lack the potential for complete bone regeneration, and the risk of long-term complications may be increased with immediate implants placed at these sites.¹⁴ However, several reports have shown that bone regeneration may be achieved in dehiscence sites adjacent to immediate implants using a variety of augmentation techniques, including a nonresorbable expanded polytetrafluoroethylene (e-PTFE) membrane and demineralized freeze-dried bone allograft,⁵¹ a resorbable collagen membrane and anorganic bovine bone,²⁴ and autogenous bone alone.^{27,52} In a comparative study, significantly greater defect height reduction was achieved in dehiscence sites with delayed compared to immediate implant placement (88.8% versus 77.4%).²⁶ Interestingly, early placement (immediate and the earlier delayed) showed consistently better reduction of dehiscence defects than did late implantation in healed alveolar ridges.^{24,26,47,49} Defect morphologies with early implantation present with 2 or 3 intact bony walls, whereas defects with late implantation tend to present as 1-wall or no-wall defects.²⁴ A report that 70% of 3-wall defects associated with immediate or early delayed implants healed without augmentation confirms the high potential for bone regeneration at these sites.²⁷ The location of the implant in relation to the socket appears to be a critical determinant of the outcome of regenerative treatment at dehiscence sites. Thus, implants should be placed well within the confines of the socket to ensure a maximum number of bone walls and to take advantage of the healing potential of the socket.

Survival Rates

Eighteen studies were identified that fulfilled the selection criteria for this review (Table 5^{10, 11,13,22,24,48,50-54,56,61,63-67}). Only 4 studies involved nonsubmerged healing following immediate placement.^{48,53,56,63} The majority of studies used a submerged healing protocol that required a second surgical procedure for abutment connection. Because the study of Polizzi and associates was a 5-year follow-up of a 3-year report of Grunder and coworkers, only the former study was included in the

Table 3 Clinical Studies Presenting Clinical and Radiographic Data of Healing at Immediate and Delayed Implant Sites and Comparing Immediate with Delayed or Late Placement

Study	Implant system/surface	Randomization	Augmentation method,* healing protocol	No. of patients/implants		Observation period (mean, mo)	Mean radiographic crestal bone loss (mm)		Mean probing pockets (mm)				
				Immediate	Delayed (delay period)		Late	Immediate	Delayed	Late	Immediate	Delayed	Late
Yukna (1991) ⁵⁰	Calcitek/ HA	No	5; SUB	28 [†] /14	—	28 [†] /14	0.9	—	0.8	3.8 (REC 0.2)	—	3.2 (REC 0.3)	
Mensdorff-Pouilly et al (1994) ²²	IMZ/HA, Brånemark/ MF	No	Various: 0, 1, 5, 1+3; SUB	31/93	36/97 (6 to 8 wk)	12.4	0.5	0.3	—	2.5	1.9	—	
Brägger et al (1996) ⁵⁶	ITI/TPS	No	T = 1 only, C1 = ND; C2 = HS; NSUB	Group I: 15/20; group C1: 6/8	—	12	—	—	—	T: 2.54; C1: 2.47	—	C2: 2.70	
Watzek et al (1995) ¹⁰	IMZ/HA, Brånemark/ MF	No	Various: 0, 1+3, or 4; SUB	20 [†] /97	20 [†] /26 (6-8 wks)	27.1	1.0	0.8	0.5	1.8	2.9	1.5	
Gomez-Roman et al (1997) ⁴⁸	Frialit/HA, Frialit TPS	No	1% sites required; NSUB	376 [†] /86 (within 1 wk of extraction)	376 [†] /164 (1 wk to 9 mo after extraction)	54	1	1	1	3	3	3	

When not reported, values were derived from data contained in the original article.

*0 = no augmentation; 1 = e-PTE membrane; 2 = collagen membrane; 3 = autogenous bone; 4 = anorganic bovine bone; 5 = hydroxyapatite; 6 = demineralized, freeze-dried bone.

[†]Indicates total number of patients for all groups.

SUB = submerged; NSUB = nonsubmerged; ND = no defects present; HS = healed sites; REC = recession; HA = machine finished; TPS = titanium plasma-sprayed.

Table 4 Clinical Studies Presenting Surgical Re-entry Data on Peri-implant Bone Defect Changes Following Healing at Immediate and Delayed Implant Sites and Comparing Delayed Implant Placement with Immediate and/or Late Implant Placement

Study	Implant system/surface	Random	Augmentation method*	No. of patients/implants			Observation period (mean, mo)	Re-entry bone-defect changes
				Immediate	Delayed (delay period)	Late (delay period)		
Gelb (1993) ⁵¹	Brånemark/MF	No	Various: 1, 1+6, 6; SUB	35/50	-	-	4 (mandible); 6 (maxilla)	Immediate: 100% thread coverage for all techniques, except in 1 case of a no-wall defect treated with treatment 6 only = 76% coverage to 0.2 mm [†] (slightly less gain when buccal dehiscence present)
Becker et al (1994) ⁵²	Brånemark/MF	No	3 only; SUB	30/54	-	-	Not stated	Immediate: VH 5.5 mm reduced to 0.5 mm [†] ; HD 3.7 mm reduced to 0.2 mm [†]
Gher et al (1994) ¹⁷	ITI/TPS and Calcitek/HA	Yes	Test: 1+6, control: 1 only; SUB	Test: 20/22; control: 16/21	-	-	6 -1.53 mm	Immediate: Crestal bone loss from most coronal bone crest: test = , control = -1.59 mm; crestal bone loss from most apical part of crest: test = +1.39 mm, control = -0.11 mm (<i>P</i> < .05 between groups); Bonefill: test = 5.68 mm, control = 3.18 mm (<i>P</i> < .05 between groups)
Lang et al (1994) ⁵³	ITI/TPS	No	1 only; NSUB	16/21	-	-	5 to 7	Immediate: 20 of 21 sites with complete bone regeneration
Augthun et al (1995) ¹⁸	Brånemark/MF	No	1; SUB	15/20	-	-	6	Immediate: Histology: Evidence of bone formation in only 3 of 15 tissue samples
Zitzmann et al (1996) ⁴⁹	Brånemark/MF	No	2+4; SUB	50 [†] /25	50 [†] /21 (6 wk to 6 mo)	50 [†] /23 (> 6 mo)	4 to 6	Immediate: Defect area reduction of 89% [†] Delayed: Defect area reduction of 86% [†] Late: Defect area reduction of 76% [†]
Zitzmann et al (1997) ⁴⁷	Brånemark/MF	Yes	1+4, 2+4; SUB	25 [†] /27	25 [†] /17 (6 wk to 6 mo)	25 [†] /40 (> 6 mo)	4 to 6	Immediate: Defect area reduction with e-PTFE membrane = 85% [†] ; with collagen membrane = 95% [†] Delayed: Defect area reduction with e-PTFE membrane = 94% [†] ; with collagen membrane = 97% [†] Late: Defect area reduction with e-PTFE membrane = 80% [†] ; with collagen membrane = 90% [†]
Nir-Hadar et al (1998) ⁶⁴	Not stated	No	0; SUB	-	14/21 (6 to 8 wk)	-	3 to 6	Delayed: VH of defect 2.5 mm reduced to 0.4 mm with no HD present [†] ; VH of defect 3.9 mm reduced to 0.5 mm with HD present [†] ; HD 1.6 mm reduced to 0 mm [†]
Hämmerle et al (1998) ⁶⁷	ITI/TPS	No	1; NSUB	10/11	-	-	5	Immediate: VH reduction from 4.7 mm at baseline to 2.1 mm at re-entry [†] ; 94% defect fill [†]
Zitzmann et al (1999) ²⁴	Brånemark/MF	No	2+4; SUB	75 [†] /31	75 [†] /23 (6 wk to 6 mo)	75 [†] /48 (> 6 mo)	4 to 6	Immediate: Defect area reduction of 92% Delayed: Defect area reduction of 92% Late: Defect area reduction of 80%

Table 4 Clinical Studies Presenting Surgical Re-entry Data on Peri-implant Bone Defect Changes Following Healing at Immediate and Delayed Implant Sites and Comparing Delayed Implant Placement with Immediate and/or Late Implant Placement (continued)

Study	Implant system/surface	Random	Augmentation method*	No. of patients/implants			Observation period (mean, mo)	Re-entry bone-defect changes
				Immediate	Delayed (delay period)	Late (delay period)		
Nemcovsky and Artzi (1999) ⁵⁸	Calcitek and SteriOss, MF and HA	No	1+4 vs 4 only; SUB	29/33	-	-	6 or 9	Immediate: VH reduction from 1.9 mm to 0.3 mm with no membrane [†] ; VH reduction from 4.6 mm to 0.7 mm with membrane [†] Delayed: Defect area reduction of 97%
Nemcovsky et al (2000) ⁵⁵	Calcitek/TPS and Calcitek/MTX	No	2+4; SUB	-	21/28 (5 to 7 wk)	-	6 to 8	Delayed: Defect area reduction of 97%
Van Steenberghe et al (2000) ⁶⁰	Brånemark/MF	No	4 at defects with HD > 3 mm; SUB	15/21	-	-	6	Immediate: Defect fill: Complete in 10 sites, partial in 9 sites, bone loss in 2 sites
Rosenquist and Ahmed (2000) ⁵⁹	Brånemark/MF	No	Homologous bone membrane; SUB	25/34	-	-	6	Immediate: VH reduction from 8.5 mm to 0.3 mm [†]
Hämmerle and Lang (2001) ²⁵	ITI/TPS	No	2+4; NSUB	-	10/10 (8 to 14 wk)	-	6 to 7	Delayed: Defect area reduction of 86% [†]
Goldstein et al (2002) ⁶¹	Brånemark/MF and 3i /MF	No	6 ± barrier membranes; SUB	38/47 (27 sites with peri-implant defects)	-	-	Mean 6.5	Immediate: 100% defect fill
Nemcovsky et al (2002) ⁶²	Sulzer and SteriOss, MTX, TPS, and HA	No	2+4; SUB	19/23	24/31 (4 to 6 wk)	-	6 to 8	Immediate: Defect height reduction of 77.4%, defect area reduction of 90.2% ($P < .05$ between groups) Delayed: Defect height reduction of 91.2%, defect area reduction of 97.2% ($P < .05$ between groups)
Nemcovsky and Artzi (2002) ²⁶	Sulzer Calcitek/MTX, TPS, and HA	No	All sites with buccal dehiscence defects, 2+4; SUB	19/23	25/39 (4 to 6 wk)	22/40 (HS)	6 to 8	Immediate: Defect height reduction of 77.4%, defect area reduction of 90.2% Delayed: Defect height reduction of 88.8%, defect area reduction of 95.6% Late: Defect height reduction 72.5% ($P < .05$ between the 3 groups); defect area reduction of 87.6% ($P < .05$ between the 3 groups)
Schropp et al (2003) ²⁷	3i /Osseotite/AE	Yes	3 (in dehiscence defects); SUB	23/23 (mean 10 d)	23/23 (mean 14.1 wk)	-	6	Immediate: Defect reduction: HW = 48%, [†] HD = 59%, [†] VH = 48% [†] Delayed: Defect reduction: HW = 39%, [†] HD = 77%, [†] VH = 34% [†]

When not reported, values were derived from data contained in the original article.

*0 = no augmentation; 1 = e-PTFE membrane; 2 = collagen membrane; 3 = autogenous bone; 4 = anorganic bovine bone; 5 = hydroxyapatite; 6 = demineralized freeze-dried bone allografts.

[†]Indicates total number of patients for all groups.

[‡]Indicates significant change ($P < .05$) from baseline within the treatment group.

AE = acid-etched; MF = machine-finished; TPS = titanium plasma-sprayed; HA = hydroxyapatite coated; MTX = microtextured; HD = horizontal defect width (mesiodistal); HW = horizontal defect depth (buccolingual); VH = vertical defect height (apico-coronal); SUB = submerged; HS = healed sites; NSUB = nonsubmerged.

Table 5 Clinical Studies with Follow-up Periods of 1 Year or More Reporting Survival Rates of Immediate and Delayed Implants and Comparing Delayed with Immediate Implants

Study	Type of study	Implant system/surface	SUB/NSUB	Immediate		Delayed		Delayed placement time	Follow-up period (mean)	Survival rate (%)	
				No. of patients	No. of implants	No. of patients	No. of implants			Immediate (CSR)	Delayed (CSR)
Ashman (1990) ⁶⁴	Pros	Steri-Oss/MF	SUB	16	16	–	–	–	6 to 24 mo (NG)	94.1	–
Yukna (1991) ^{50*}	Pros	Calcitek/HA	SUB	14	14	–	–	–	8 to 24 mo (16 mo)	100	–
Gelb (1993) ⁵¹	Retro	Brånemark/MF	SUB	35	50	–	–	–	8 to 44 mo (17 mo)	98.0	–
Becker et al (1994) ⁵²	Pros	Brånemark/MF	SUB	49	49	–	–	–	1 y	93.9	–
Mensdorff-Pouilly et al (1994) ²²	Retro	57 IMZ/HA, 40 Brånemark/MF	SUB	31	93	36	97	6 to 8 wk	1 to 4 y (12.4 mo)	92.5 (80 mo)	94.9 (60 mo)
Lang et al (1994) ⁵³	Pros	ITI/TPS	NSUB	16	21	–	–	–	21 to 42 mo (30.3 mo)	100	–
Watzek et al (1995) ¹⁰	Retro	20 IMZ/HA, 5 Brånemark/MF	SUB	20 [†]	97	20 [†]	26	6 to 8 wk	4 to 83 mo (27.1 mo)	99.0	92.3
De Wijs et al (1995) ⁶⁵	Pros	IMZ/HA	SUB	–	–	81	173	3 mo or later	3 to 64 mo (33.5 mo)	–	96.1 (3y)
Rosenquist and Grenthe (1996) ¹¹	Pros	Brånemark/MF	SUB	51	109	–	–	–	1 to 67 mo (30.5 mo)	93.6	–
Brägger et al (1996) ⁵⁶	Pros	ITI/TPS	NSUB	21	28	–	–	–	1 y	100	–
Gomez-Roman et al (1997) ^{48*}	Pros	Frialit-2/HA and TPS	NSUB	376 [†]	86	376 [†]	164	1 wk to 9 mo	1 to 5 y (4.5 y)	97.1 (4.5 y)	99.4 (4.5 y)
Cosci and Cosci (1997) ⁶⁶	Retro	Integral and Onmiloc/HA	SUB	353	423	–	–	–	1 to 7 y (NG)	99.5	–
Nir-Hadar et al (1998) ⁵⁴	Pros	Brånemark/MF	SUB	–	–	14	21	4 to 8 wk	1 y	–	95.2
Zitzmann et al (1999) ²⁴	Retro	Brånemark/MF	SUB	75 [†]	31	75 [†]	33	6 wk to 6 mo	1 y	96.8	93.9
Polizzi et al (2000) ¹³	Pros	Brånemark/MF	SUB	143 [†]	217	143 [†]	47	3 to 5 wk	5 y	92.4 maxilla, 94.7 mandible (5 y) [‡]	92.4 maxilla, 94.7 mandible (5y) [‡]
Schwartz-Arad et al (2000) ⁶⁷	Pros	NS; 47 MF, 9 HA	SUB	43	56	–	–	4 to 60 mo	15 mo	89.3	–
Gomez-Roman et al (2001) ⁶³	Pros	Frialit-2/GB, AE	NSUB	104	124	–	–	–	5 to 6 y	97.0 (5.6 y)	–
Goldstein et al (2002) ⁶¹	Pros	Brånemark/MF and 3i/MF	SUB	38	47	–	–	–	1 to 5 y (39.4 mo)	100	–

When not reported, calculations for survival rates were derived from data contained in the original paper.

*Includes data on late implant placement.

[†]Indicates total number of patients for all groups.

[‡]Indicates survival rates for immediate and delayed placement were combined.

Surfaces: MF = machined; TPS = titanium plasma-spray coated; HA = hydroxyapatite-coated; GB = grit-blasted; AE = acid-etched

Healing protocol: SUB = submerged healing; NSUB = nonsubmerged healing

CSR = cumulative survival rate derived from life-table analysis.

Pros = prospective; Retro = retrospective; NG = not given; NS = not stated

review.^{12,13} Eleven studies reported on the survival rates of immediately placed implants, with mean observation periods ranging from 1 to 5.6 years.^{11,51–53,56,61,63–67} One study reported on survival rates of delayed implants following an observation period of 12 months.⁵⁴

Six reports were identified as comparative studies. One study compared immediate with late implant placement after a mean of 16 months.⁵⁰ The remaining 5 studies compared survival rates between immediate and delayed implants^{10,13,22,24} and between immediate, delayed, and late placement⁴⁷ with observation periods of 1 to 5 years. No statistical differences in survival rates for immediate, delayed, and late placement techniques were reported in the comparative data. Most reports were of short duration, with only 4 studies presenting cumulative survival data on mean follow-up periods of 3 to 5 years.^{13,48,61,63}

When grouped according to implant surface characteristics, there were 3 studies of hydroxyapatite-coated implants (610 implants; survival rates of 96.1% to 100%), 8 studies of machined-surface implants (620 implants; survival rates of 93.6% to 100%), 2 studies of titanium plasma spray-coated implants (130 implants; survival rate of 100%), 1 study of grit-blasted/acid-etched implants (124 implants; survival rate of 97.0%), and 4 studies of mixed surfaces (496 implants; survival rates of 89.3% to 99.4%). In general, the trend suggested that immediate and delayed implants had similar short-term survival rates and that these survival rates were comparable to rates for conventional placement in healed ridges.

There were no reports of the long-term clinical success of immediate or delayed implants. To make a comprehensive assessment of the clinical success of immediate and delayed implants, additional parameters are required that describe the health of the peri-implant tissues, function of the prosthetic reconstruction, and esthetic results. Therefore, the long-term success of immediate and delayed implants as measured by these parameters remains undefined.

Management of Local Pathology

A number of studies have demonstrated that the survival rate of implants placed following extraction of teeth with root fractures, perforations, and combined endodontic-periodontal problems is similar to that of implants placed in healed ridges.^{68–71} However, implants placed in sites where teeth have been affected by chronic periodontitis have been associated with slightly elevated failure rates.^{11–13} There is currently a lack of definitive evidence regarding the

effect of local pathology on the success and survival of immediate implants.

Systemic Antibiotics

In most of the studies reviewed, broad-spectrum systemic antibiotics were used in conjunction with immediate and delayed implant placement.^{11,20,27,50–53,72} However, the effect of systemic antibiotics on treatment outcome is unknown; thus, controlled studies are needed.

Bone Integration of Immediate and Delayed Implants

The basic prerequisites for successful bone healing in immediate and delayed implant sites are the same as for implants placed in healed alveolar ridges. In addition, a space often exists between the surface of the implant and the socket walls that needs to be filled with bone to achieve an optimal outcome. This bone healing is dependent on stabilization of the initially formed coagulum in this space. Animal experimental studies have shown that both the distance from the bone to the implant and the surface characteristics of the implant are critical factors for stabilization of the coagulum.^{73–76} Clot stabilization and bone formation may be adversely affected by lack of intact bony walls. In such situations, techniques utilizing barrier membranes and/or membrane-supporting materials have been shown to be effective in regenerating bone and allowing osseointegration to occur.^{17,75}

In the intact socket, a critical component of the peri-implant defect is the size of the horizontal defect (HD), which is the longest distance in a perpendicular direction from the implant surface to the socket wall.²⁰ It has been demonstrated that for implants with a HD of 2 mm or less, spontaneous bone healing and osseointegration take place if the implant has a rough surface.^{20,77–79}

In 2001, a well-designed study examined 96 experimental titanium plasma-sprayed mini-implants in 48 patients.⁷⁸ Half of the implants were placed into extraction sockets with HDs of 2 mm or less; the other half were placed into mature bone and served as controls. No membranes or grafts were used, and primary soft tissue closure was done. Examination of the test implants following surgical re-entry at 6 months showed complete bone fill of the previous defects. Subsequent histologic examination showed no statistically significant differences between test and control sites in the percentage of bone-to-implant contact and initial level of bone-to-implant contact between test and control sites.

HDs in excess of 2 mm have been shown to not heal predictably with bone.²⁰ However, it may be

possible to achieve predictable bone fill in such situations by using collagen barrier membranes and implants with a sandblasted and acid-etched surface.⁷⁹ A combination of a barrier membrane and a bone graft has been shown to enhance the percentage of bone-to-implant contact in large HDs in an animal model.⁷⁴

CLINICAL INDICATIONS

Esthetics

Although esthetics are frequently cited as a reason for immediate implant placement,⁶ data are lacking on esthetic outcomes following immediate implant placement.^{80,81} However, adjunctive techniques to mobilize flaps^{55,58,82,83} and to augment soft tissue volume^{72,84–86} for wound closure at immediate implant sites may be beneficial in achieving acceptable esthetic results. Novel techniques, including nonsubmerged immediate implant placement^{53,56,63} and flapless procedures,^{87,88} need further evaluation with respect to esthetic outcomes.

When implant placement is delayed for a period of time after tooth extraction, soft tissue healing may provide opportunities to maximize tissue volume to achieve proper flap adaptation and acceptable soft tissue esthetics. However, this advantage is offset by resorption of bone and loss of ridge dimensions. In one report, a delay of 3 months or more after tooth extraction in the anterior maxilla resulted in such an advanced stage of resorption that only narrow-diameter implants could be used.⁶⁵ Thus, timing of implant placement following tooth removal may be important to take advantage of soft tissue healing but without risk of losing bone volume through resorption. The data to support enhanced soft tissue esthetic outcomes with delayed implant placement are lacking.

Augmentation Procedures

Several reports have shown that bone augmentation techniques may not be required where the distance between the implant body and bony wall is less than 2 mm.^{78,89–92} If barrier membranes are used, wound dehiscence may lead to early exposure of nonresorbable membranes and reduced quality and volume of bone regeneration in the peri-implant defects.^{17,18,47,60} Lower incidences of premature membrane exposure have been reported in studies using collagen membranes.^{47,58}

Delaying implant placement for several weeks after tooth extraction allows time for bone regeneration to occur at the base and periphery of the socket,^{32,33} thereby reducing the dimensions of the

socket and avoiding the need for augmentation procedures.⁵⁴ However, the concomitant resorption of buccal bone may increase the need for augmentation buccolingually. An interesting observation was a lower incidence of wound dehiscence and membrane exposure with delayed implant placement, irrespective of the type of membrane used.^{26,47}

CONCLUSIONS

There have been a number of reports on the subject of immediate and delayed implants with observation periods of 12 months or more. However, longitudinal studies with mean follow-up periods between 3 and 5 years were limited to 4 reports. Most reports were nonrandomized with respect to timing of the placement and augmentation methods used. Despite these limitations, short-term survival rates of immediate and delayed implants appear to be similar. Furthermore, survival rates for immediate and delayed implants appear comparable to those of implants placed conventionally in healed alveolar ridges. Studies of healing of immediate nonsubmerged implant sites are limited. Further examination of this protocol for placement is required.

As an alternative to immediate implant placement, delayed placement has several advantages. These include resolution of infection at the site and an increase in the area and volume of soft tissue for flap adaptation. However, these advantages are diminished by concomitant ridge resorption in the buccolingual dimension. Thus, 4 to 8 weeks appears to be the optimal period to defer implant placement to allow adequate soft tissue healing to take place without undue loss of bone volume.

Peri-implant defects associated with immediate and delayed implants have a high potential for bone regeneration. At sites with HDs of 2 mm or less, spontaneous bone regeneration and osseointegration may be expected when implants with a rough surface are used. At sites with HDs greater than 2 mm, or where one or more walls of the socket are missing, concomitant augmentation procedures with combinations of barrier membranes and bone grafts are required. No conclusions can be drawn from the available data regarding the optimal bone augmentation technique in these situations. However, if membranes are used, resorbable membranes appear to be effective and are associated with lower rates of wound dehiscence and membrane exposure than nonresorbable materials.

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Consensus Statements and Recommended Clinical Procedures Regarding the Placement of Implants in Extraction Sockets

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INTRODUCTORY REMARKS

High clinical success rates have been reported when implants are placed according to standard indications. This has encouraged efforts to improve the success rates for implants placed in more demanding clinical situations. One of these indications is tooth replacement with implants placed into extraction sockets. Although the first clinical procedures for the placement of implants immediately following tooth removal were described long ago, it is only recently that the details of such clinical approaches have been studied in greater detail.

One of the aims of the present consensus meeting was to scrutinize the available literature to identify predictable and successful procedures for replacing extracted teeth with implant-supported reconstructions. In addition, where the data from the literature were inconclusive or absent, the clinical experience of the members of the consensus group was used as the basis for the recommendations.

In order to reach this aim, 2 reviews were written for group 1 in preparation for the consensus meeting. One review focused on implant placement immediately following tooth extraction, while the other focused on the delayed and late placement of implants. During the consensus meeting, it was decided by majority vote of the group that the 2 reviews be merged into a single paper. The purpose of this merger was to present 1 comprehensive review of the topic of timing of implant placement into extraction sockets and to avoid the presentation of duplicate information.

In addition to the data reported in the review, all information published in the literature before the

consensus meeting served as a basis for the consensus statements. Unpublished literature, which could not be scrutinized by all group members, was not considered in the decision process.

Topics were openly discussed within the group, and all participants were given the chance to express their interpretation of the data available in the literature. After thorough discussion, consensus was reached by taking a vote among the group participants. If a significant majority was obtained, the consensus statement in question was accepted. In situations where no significant majority could be reached, the discussions were either continued until such a majority was reached or, if a significant majority could not be reached, no consensus statement was produced on the topic in question. These same procedures were followed for reaching consensus on the new classification.

Although classifications that define timing for implant placement have been published in the past, the group agreed that the development of a new classification was necessary to incorporate increased knowledge in this field and to reflect the procedures commonly applied in clinical practice. There was consensus that such a classification should be based on morphologic, dimensional, and histologic changes that follow tooth extraction and on common practice derived from clinical experience. The classification adopted by the consensus group, which has not yet been validated, is depicted in Table 1. Key aspects of this classification are the following:

1. In clinical practice the decision to place an implant following tooth extraction is usually determined by the attainment of specific soft and hard tissue characteristics of the healing socket. These events do not necessarily follow rigid time frames and may vary according to site and patient factors. To avoid time-based descriptions, this classification uses numeric descriptors—types 1 to 4—that reflect the hard and soft tissue changes observed.

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Table 1 Protocols for Implant Placement in Extraction Sockets and Their Advantages and Disadvantages

Classification	Definition	Advantages	Disadvantages
Type 1	Implant placement immediately following tooth extraction and as part of the same surgical procedure	<ul style="list-style-type: none"> • Reduced number of surgical procedures • Reduced overall treatment time • Optimal availability of existing bone 	<ul style="list-style-type: none"> • Site morphology may complicate optimal placement and anchorage • Thin tissue biotype may compromise optimal outcome • Potential lack of keratinized mucosa for flap adaptation • Adjunctive surgical procedures may be required • Procedure is technique-sensitive
Type 2	Complete soft tissue coverage of the socket (typically 4 to 8 wk)	<ul style="list-style-type: none"> • Increased soft tissue area and volume facilitates soft tissue flap management • Resolution of local pathology can be assessed 	<ul style="list-style-type: none"> • Site morphology may complicate optimal placement and anchorage • Treatment time is increased • Socket walls exhibit varying amounts of resorption • Adjunctive surgical procedures may be required • Procedure is technique-sensitive
Type 3	Substantial clinical and/or radiographic bone fill of the socket (typically 12 to 16 wk)	<ul style="list-style-type: none"> • Substantial bone fill of the socket facilitates implant placement • Mature soft tissues facilitate flap management 	<ul style="list-style-type: none"> • Treatment time is increased • Adjunctive surgical procedures may be required • Socket walls exhibit varying amounts of resorption
Type 4	Healed site (typically more than 16 weeks)	<ul style="list-style-type: none"> • Clinically healed ridge • Mature soft tissues facilitate flap management 	<ul style="list-style-type: none"> • Treatment time is increased • Adjunctive surgical procedures may be required • Large variations are present in available bone volume

- The classification clearly separates healing of the extraction socket into aspects of soft tissue healing and hard tissue healing.
- The type 1 procedure is chosen when an implant is placed immediately following extraction of a tooth. When advanced or complete soft tissue healing is desired, the type 2 procedure is preferred to immediate placement (type 1). When hard tissue healing is desired, types 3 and 4 are chosen to allow time for bone healing to occur.

Advantages and disadvantages of the 4 classifications are listed in Table 1.

CONSENSUS STATEMENTS

Socket Healing

Results of clinical, radiologic, and histologic studies indicate that bony healing of extraction sites proceeds with external resorption of the original socket walls and a varying degree of bone fill within the socket.

Bone Regeneration

Studies in humans and animals have demonstrated that at implant sites with a horizontal defect dimen-

sion (HDD; ie, the peri-implant space) of 2 mm or less, spontaneous bone healing and osseointegration of implants with a rough titanium surface takes place.

In sites with HDDs larger than 2 mm and/or nonintact socket walls, techniques utilizing barrier membranes and/or membrane-supporting materials have been shown to be effective in regenerating bone and allowing osseointegration.

Although scarce, the majority of the comparative data regarding the success of bone regeneration at peri-implant defects suggests no differences between type 1 and types 2 and 3 procedures.

Further comparative analyses of different methods of bone augmentation with regard to successful bone formation and stability over time are required.

Long-term analysis of the stability of the regenerated bone is focused almost exclusively on radiographic assessments of the interproximal bone and implant survival. There is a need for studies to evaluate the fate of the buccal bone plate—whether regenerated or not—over time.

Adjunctive Medication

In most studies reviewed, broad-spectrum systemic antibiotics were used in conjunction with implant placement types 1, 2, and 3. Controlled studies

evaluating the effect of systemic antibiotics on treatment outcomes are needed.

Survival of Implants

The survival rate of immediately placed implants (type 1) was reported in numerous studies to be similar to that of implants placed into healed ridges (type 4).

In the few studies available, short-term survival rates of implants placed in conjunction with types 2 and 3 procedures appear similar to those placed in types 1 and 4 approaches.

There have been relatively few reports on the subject of types 2 and 3 implant procedures, and only 2 of them were randomized with respect to timing of placement and augmentation methods used. Longitudinal studies of greater than 3 years' duration were limited to 2 reports.

There is evidence to suggest that the survival rate for implants placed immediately following extraction of teeth associated with local pathology is similar to that of implants placed into healed ridges. Further controlled studies are required to provide definitive information about the management of these situations.

Esthetic Outcomes

Esthetically pleasing treatment outcomes have received considerable attention in recent years; however, there are no controlled studies available evaluating esthetic treatment outcomes in types 1, 2, and 3 procedures.

PROPOSED CLINICAL APPROACHES

Patient Assessment

All candidates for extraction-site implants should meet the same general screening criteria as regular implant patients, regardless of the timing of implant placement.

Antibiotics

The literature is inconclusive regarding antibiotic use in conjunction with implant therapy. There is general agreement that the use of antibiotics is advantageous when augmentation procedures are performed.

Tooth Extraction

Extraction techniques that result in minimal trauma to hard and soft tissues should be used. The sectioning of multirooted teeth is advised. All granulation tissue should be removed from the socket.

Site Evaluation

Site evaluation is critical to the determination of appropriate treatment modalities. Factors of concern include:

- Overall patient treatment plan
- Esthetic expectations of the patient
- Soft tissue quality, quantity, and morphology
- Bone quality, quantity, and morphology
- Presence of pathology
- Condition of adjacent teeth and supporting structures

Primary Implant Stability

The implant should not be placed at the time of tooth removal if the residual ridge morphology precludes attainment of primary stability of an appropriately sized implant in an ideal restorative position.

Thin Biotype

When treating patients with a thin, scalloped gingival biotype—even those with an intact buccal plate—concomitant augmentation therapies at the time of implant placement (type 1) are recommended because of the high risk of buccal plate resorption and marginal tissue recession.

If buccal plate integrity is lost, implant placement is not recommended at the time of tooth removal. Rather, augmentation therapy is performed, and a type 3 or 4 approach is utilized.

Thick Biotype

In cases involving a thicker, less scalloped gingival biotype with an intact buccal plate, the need for concomitant augmentation therapies at the time of implant placement (type 1) may be reduced, since thick biotypes have a decreased risk of buccal plate resorption in comparison with thinner biotypes. As buccal plate integrity is lost, the need for augmentation therapies increases.

When the buccal plate is compromised, negatively impacting the predictability of treatment outcomes, immediate implant placement is not indicated (type 1); rather, a type 2, 3, or 4 procedure is carried out. When the HDD is greater than 2 mm, concomitant augmentation therapy needs to be performed.

Adjunctive augmentation therapies may be indicated in any of the above situations to optimize esthetic treatment outcomes.

Implant Placement

The 3-dimensional positioning of the implant should be restoratively driven.

Outcome Analysis of Implant Restorations Located in the Anterior Maxilla: A Review of the Recent Literature

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Purpose: To document the literature regarding outcomes of implant restorations in the anterior maxilla to formulate consensus statements with regard to esthetics in implant dentistry, to provide guidelines to clinicians, and to articulate remaining questions in this area to be addressed by future research.

Materials and Methods: The following areas of the recent literature were scrutinized: treatment outcomes of implant therapy for partial edentulism (including maxillary anterior tooth replacement); anterior maxillary single-tooth replacement; effect of implant design, diameter, and surface characteristics; soft tissue stability/contours around anterior implant restorations; ceramic abutments; influence of surgical techniques; and finally, evaluation of patient satisfaction. **Results:** The use of dental implants in the esthetic zone is well documented in the literature, and numerous controlled clinical trials show that the respective overall implant survival and success rates are similar to those reported for other segments of the jaws. However, most of the published studies do not include well-defined esthetic parameters. Currently, the literature regarding esthetic outcome is inconclusive for the routine implementation of certain surgical approaches, such as flapless surgery and immediate implant placement with or without immediate loading/restoration in the anterior maxilla. Considering anterior single-tooth replacement in sites without tissue deficiencies, predictable treatment outcomes, including esthetics, can be achieved because of tissue support provided by adjacent teeth. The replacement of multiple adjacent missing teeth in the anterior maxilla with fixed implant restorations is poorly documented. In this context, esthetic restoration is not predictable, particularly regarding the contours of the interim-plant soft tissue. **Discussion and Conclusions:** This review has demonstrated that scientific documentation of esthetically relevant and reproducible parameters is rather scarce. Most of the reported outcome analyses primarily focus on implant survival. Elements of anterior implant success such as maintenance or reestablishment of harmoniously scalloped soft tissue lines and natural contours should be included in future studies. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):30-42

Key words: anterior maxilla, ceramic abutments, dental implants, esthetic implant restorations, fixed implant suprastructures, treatment outcomes

The aim of this section was to scrutinize the most recent literature (1997 to 2003, with some rare exceptions) with respect to publications

addressing treatment outcome of implant therapy performed in the esthetic zone in general and the topic of long-term stability of esthetic implant restorations in particular. It is inherent in the nature of a theme comprising numerous subjective parameters, in this particular field of clinical dentistry, that solid scientific and clearly evidence-based data are rather scarce. However, a number of reviews, technical notes, practical guidelines, and procedures, not infrequently in the form of case reports but nevertheless providing valuable information, have been published during the last few years. Consequently, the authors tried to address this situation by pointing out articles in which recommendations were given without a scientifically proven basis. Furthermore, it appeared opportune to limit this review to

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studies related to fixed implant restorations located in the partially edentulous anterior maxilla, and to distinguish between single-tooth replacement and multiple-unit implant restorations carried out in the appearance zone. MEDLINE was used to find relevant English-language articles; searches were performed using key words such as “implants,” “anterior maxilla,” “outcomes,” and “esthetics.”

Since this article is part of a consensus conference, a number of unanimously supported statements have been defined that should provide the reader with relevant guidelines for both teaching activities and clinical practice.

Finally, an attempt was made to identify questions that remain unanswered and should be addressed by future research to define more rational, predictable, and reproducible clinical protocols.

TREATMENT OUTCOMES OF IMPLANT THERAPY FOR PARTIAL EDENTULISM, INCLUDING MAXILLARY ANTERIOR TOOTH REPLACEMENT

Numerous recently published studies have focused on treatment outcomes of implant therapy in partially edentulous patients in general and related to maxillary anterior tooth replacement in particular.¹⁻¹⁹ Selected publications that appear to have an impact when it comes to the discussion of esthetic aspects will be reviewed chronologically in this section.

From a retrospective study comprising 1,920 IMZ implants (Interpore International, Irvine, CA), Haas and associates² reported a significantly lower cumulative survival rate for maxillary implants (37.9% at 100 months of follow-up) than for mandibular implants (90.4% at 100 months of follow-up). Implants placed in the anterior region of the maxilla failed significantly more often than those placed in the posterior region. Length and diameter of the implants had no significant influence on the cumulative survival rate.

Eckert and Wollan³ published a retrospective evaluation of up to 11 years of a total of 1,170 implants placed in partially edentulous patients and found no differences in survival rates related to the anatomic location of the implants. A meta-analysis concerning implants placed for the treatment of partial edentulism was carried out by Lindh and coworkers.⁴ The 6- to 7-year survival rate for single-implant crowns was 97.5%, while the survival rate of implant-supported fixed partial dentures (FPDs) was 93.6%.

Wyatt and Zarb⁵ published a longitudinal study on 77 partially edentulous patients, involving 230 implants and 97 FPDs, with an observation period

of up to 12 years (mean 5.41 years) after loading. The average implant success rate was 94%, while the continuous stability of the related prostheses (fixed partial dentures) corresponded to 97%. This study comprised 70 anterior and 31 posterior maxillary implants. No significant differences with respect to longevity could be detected either between anterior and posterior locations or between maxillary and mandibular implant restorations.

A 3-year prospective multicenter follow-up report (designed as a randomized clinical trial [RCT]) on the immediate and delayed-immediate placement of implants was published by Grunder and coworkers,⁶ comprising 264 implants placed in 143 patients. Over a period of 3 years, the implant survival rate was 92.4% in the maxilla and 94.7% in the mandible.

Moberg and colleagues⁷ published a prospective evaluation of single-tooth restorations supported by ITI hollow-cylinder dental implants (Institut Straumann, Waldenburg, Switzerland) placed in the anterior maxilla involving 30 implants. After a mean observation period of 3.4 years, the cumulative success rate was 96.7%. Nineteen implants had been restored with octa-abutments and screw-retained metal-ceramic crowns, while 10 implants received all-ceramic crowns cemented to conical solid abutments. Only minor bone loss had occurred around the implants, and no other significant complications were observed.

The long-term results of 1,964 implants (Brånemark [Nobel Biocare, Göteborg, Sweden]; Frialit-1 and Frialit-2 [Friadent, Mannheim, Germany]; IMZ [Interpore International]; and Linkow [Linkow, New York, NY]) over 16 years were recently evaluated retrospectively to determine the respective success.⁸ For all systems, mandibular implants were generally more successful than maxillary implants. The overall preprosthetic loss rate was 1.9%, and 4.3% of implants were lost after prosthetic treatment. Single-tooth replacements were among those with the most predictable treatment outcomes.

The survival and stability of 6 implant designs from the time of placement to 3 years later were evaluated in a multicenter study involving more than 2,900 implants.⁹ When considering the post-loading analysis, the authors concluded that uncoated implants (commercially pure titanium and titanium alloy screws) showed increased stability following loading (up to 99.4% survival) in comparison to hydroxyapatite (HA)-coated implants, which showed a slight decrease in stability.

The same authors,¹⁰ analyzing the same clinical material published in the previous study, emphasized that reporting of implant survival rates based on the

postloading method provides more favorable survival rates. Accounting for all implants, however, provides a more accurate method of determining survival.

Davarpanah and coworkers¹¹ carried out a prospective controlled multicenter clinical trial comprising 1,583 3i implants (Implant Innovations, Palm Beach Gardens, FL) with a 1- to 5-year observation period. With a cumulative implant survival rate of 96.5%, their data confirmed the high overall degree of predictability of implant therapy in partially edentulous jaws. More specifically, they found a slightly higher survival rate in the maxilla (97.2%) than the mandible (95.8%), but a similar survival rate in anterior (96.7%) and posterior (96.5%) segments. In addition, this clinical study gives evidence of high success rates using different threaded implant designs.

Leonhardt and associates¹² followed long-term (10 years) a cohort of 15 prospectively documented patients who had been treated for advanced periodontal disease and thereafter had been enrolled in a maintenance program. The reported cumulative implant survival rate was 94.7% after 10 years. Furthermore, the results of the study suggested that the presence of certain putative periodontal pathogens in implant sites may not be associated with impaired implant treatment. The authors claimed that these species were most probably part of the normal resident microbiota of most individuals and may therefore be found at random in both stable and progressing peri-implant sites.

Biologic outcomes of implant-supported restorations in the treatment of partial edentulism were investigated in a longitudinal clinical evaluation.¹³ A total of 1,956 Brånemark System implants were placed in 660 patients between 1982 and 1998. The resulting estimated cumulative survival rates were 91.4% for all implants and 95.8% for all restorations over a period of 16 years. Neither jaw site nor implant position (anterior/posterior) had any significant effect on the outcomes.

The radiographic analysis of the same clinical material,¹⁴ assessing marginal bone height maintenance, confirmed the excellent prognosis of the currently utilized implants to support restorations in the treatment of partial edentulism. More specifically, no statistically significant differences in bone level change were predicted either for anterior or posterior sites or for single-tooth implant restorations or connected implants.

The clinical effectiveness of fixed implant prosthodontic management of anterior maxillary partial edentulism was recently investigated in 19 cases in a long-term prospective study.¹⁵ In this study, the implant-supported FPDs had been followed for an average of 12 years (range from 7 to 16

years). The overall survival rate of the implants was 92%, thus demonstrating a high survival rate for Brånemark System implants supporting FPDs for the management of anterior partial edentulism.

More recently, Carr and colleagues¹⁶ reported a cumulative survival rate of 97% in a retrospective cohort study of 308 patients and 674 single-stage dental implant prostheses with a follow-up of up to 7 years. No failures were recorded after 13 months. Prosthetic complications were low (less than 4%), especially for fixed implant prostheses. It was concluded that the clinical performance of 1-stage dental implant prostheses demonstrated a high level of predictability.

In a prospective multicenter clinical trial, the long-term performance of 3i machined-surface implants was investigated.¹⁷ A total of 1,179 3i standard threaded and self-tapping implants were followed for up to 6 years, including a significant number of single-tooth replacements in the anterior maxilla. The respective life table cumulative success rate was 91.1%.

There have been very few systematic reviews conducted according to the principles of evidence-based dental medicine and implementing the standards established by the Cochrane Collaboration. Two such reviews were conducted by Esposito and associates.^{18,19} In their first systematic review,¹⁸ the authors aimed to test the null hypothesis that there was no difference in clinical performance between various types of osseointegrated root-form implants, with the awareness that dental implants are currently available in different materials and shapes and with different surface characteristics. In particular, numerous implant surface modifications have been developed for enhancing clinical performance. Consequently, the authors included all RCTs of oral implants, comparing those with different materials, shapes, and surface properties and having a follow-up of at least 1 year. Thirty publications, representing 13 different RCTs, were identified. Five of these RCTs (7 publications), which reported results from a total of 326 patients, were suitable for inclusion in the review. Six implant systems were compared—Astra Tech (Astra, Mölndal, Sweden); Brånemark; IMZ; ITI; Steri-Oss (Nobel Biocare); and Southern (Irene, South Africa)—with a follow-up ranging from 1 to 3 years. There was no evidence that any of the implant systems was superior to the other. More RCTs should be conducted, with a follow-up of at least 5 years and including a sufficient number of patients, to determine whether a true difference exists.

In their second systematic review,¹⁹ Esposito and coworkers tested the null hypothesis that there was no difference between different interventions for

maintaining or re-establishing healthy tissues around dental implants. In this context, 9 RCTs were identified. Five of these trials, which represented data from a total of 127 patients, were suitable for inclusion in the review. The reviewers concluded that there is only a little reliable evidence to support the effectiveness of one intervention over another for maintaining the health of peri-implant tissues. There is a definite need for RCTs investigating the most effective approach for the treatment of peri-implantitis.

TREATMENT OUTCOMES OF IMPLANT THERAPY FOR MAXILLARY ANTERIOR SINGLE-TOOTH REPLACEMENT

A prospective study on the longitudinal clinical effectiveness of osseointegrated dental implants for single-tooth replacement reported a 100% survival rate for the 27 anterior maxillary implants involved.²⁰ The observation period ranged from 1.4 to 6.6 years (mean 2.9 years). This was one of the first studies suggesting that the osseointegration technique could be successfully adapted for use in patients with a single missing tooth.

In a retrospective study of 236 patients treated with single-tooth implant restorations in the anterior maxilla,²¹ a Kaplan-Meier survival rate of 89% was found for an observation period of 10 years. The failure rate for lateral incisor replacement was lower than that for the central incisors. Furthermore, 5% of the related prosthetic suprastructures had to be replaced during the 10 years of observation.

Excellent 5-year multicenter results for 71 single-tooth replacements in the anterior maxilla (implant success rate of 96.6%) were reported by Henry and coworkers.²² However, this group mentioned an associated 10% esthetic failure rate.

Kemppainen and colleagues²³ prospectively documented 102 implants (Astra and ITI) for single-tooth replacement in the anterior maxilla in 82 patients and found survival rates of 97.8% and 100%, respectively, after 1 year.

In another prospective study of single-tooth maxillary anterior implants in 15 patients, there was a 100% survival rate after 2 years of function.²⁴ At crown insertion (6 months after implant placement), the mean bone level was located 0.47 mm apically from the top of the implants. No significant additional changes in crestal bone level occurred during the remainder of the study.

In a review article,²⁵ the potential effects of adult growth and aging on maxillary anterior single-tooth implants were addressed. The authors pointed out

that growth changes do occur in adults and result in adaptive changes in the teeth over time, both vertically and horizontally, and in alignment. The changes may require maintenance adjustments or possible remaking of the implant crown as a result of adult growth, wear, or the esthetic changes of aging.

Astra single-tooth implants, placed for the replacement of anterior maxillary teeth, were evaluated prospectively in a 5-year clinical trial involving 15 implants.²⁶ No implant losses were observed, and no abutment screw loosening or soft tissue problems occurred. At crown insertion, the mean bone level was 0.46 ± 0.55 mm to 0.48 ± 0.56 mm apical to the top of the implant neck, and there were no statistically significant changes in the radiographic bone level over the 5 years of the study. One crown was recemented after 18 months in function and 1 crown was replaced because of a fracture to the porcelain incisal edge.

As part of a large multicenter study, various implant-supported prosthesis designs were evaluated for effectiveness following 36 months of clinical function.²⁷ A success rate of 98.1% was found with regard to cemented anterior maxillary single-tooth prostheses, reinforcing the predictability of this specific suprastructure design.

The clinical effectiveness of angulated implant abutments was evaluated in a 5-year randomized clinical trial that included a significant number of anterior maxillary single-tooth restorations.²⁸ High overall survival rates were reported, and an increasing degree of angulation did not negatively affect the survival rate. Furthermore, good esthetic and functional outcomes were observed.

The survival rates of immediately restored single-tooth implants, placed either immediately in fresh extraction sockets or in healed sites, were studied by Chaushu and coworkers²⁹ in a controlled clinical trial. Twenty-eight immediately loaded implants, 19 placed in extraction sockets and 9 in healed sites, were followed for 6 to 24 months. The respective survival rates were 82.4% (extraction sockets) and 100% (healed sites). While the reported radiographic marginal bone loss after 3 to 6 months did not extend beyond the implant-abutment junction, no information related to soft tissue stability was provided. Within the limits of this study, it was concluded that immediate loading of single-tooth implants placed in healed sites is a possible treatment alternative, whereas immediate loading of single-tooth implants placed in fresh extraction sockets carried a risk of failure of approximately 20% in this patient population.

The influence of flap design on peri-implant interproximal crestal bone loss around maxillary anterior single-tooth implants was investigated

prospectively by Gomez-Roman.³⁰ A widely mobilized flap design that included the papillae was compared to a limited flap design that protected the papillae. The amount of interproximal crestal bone loss was associated with the type of flap design; the limited flap design led to statistically significantly less crestal bone loss.

A long-term follow-up of 76 single-tooth Brånemark System implants was recently published by Haas and associates,³¹ who reported a Kaplan-Meier survival probability of 93% after 120 months. Seventy-four percent of the sites showed healthy peri-implant soft tissues. For 15 implants (22%), bone resorption of more than 2 mm was observed on intraoral radiographs. The mean bone resorption was 1.8 mm in the maxilla and 1.3 mm in the mandible and did not increase with time.

Andersen and colleagues³² prospectively evaluated the success rate of immediately restored single-tooth ITI plasma-sprayed (TPS) solid-screw implants in the anterior maxilla. Temporary acrylic resin restorations were adjusted to prevent any direct occlusal contacts and connected 1 week after implant placement. After 6 months, the transitional restorations were replaced by definitive ceramic crowns. None of the 8 implants were lost during the 5-year observation period, and the mean marginal bone level increased by 0.53 mm (range, -0.83 to +1.54 mm) from placement to the final examination. Only minor complications were noted, and overall patient satisfaction was high.

Gibbard and Zarb³³ recently published a prospective 5-year study of implant-supported single-tooth replacements. The original study, initiated in 1986, comprised 42 consecutively treated patients with a total of 49 implants. For the preparation of this report, 30 of the remaining 42 implants were assessed during recall examinations. In addition to well-established success criteria, the study evaluated soft tissue appearance, implant mobility, occlusal parameters, proximal contacts, tightness of crown and abutment screws, and patients' responses on satisfaction questionnaires. The criteria defining success of therapy in implant prosthodontics were met by all 30 of the single-tooth implants, which had been in place for 5 or more years, emphasizing that stable long-term results can be achieved with anterior single-implant crowns.

Krennmair and coworkers³⁴ retrospectively followed 146 Frialit-2 implants over a 7-year observation period, including 38 placed in maxillary anterior single-tooth sites. The cumulative implant survival rate was 97.3% and that of the crowns was 96.4%. With the low number of abutment screw loosening (3.5%), the deep internal hexagonal

retention compared favorably to the external retention designs. The authors concluded that predominant use of long implants (98.4% were 13 mm or longer) allowed a favorable implant/crown ratio, with the potential for problem-free long-term results.

A 7-year life table analysis of the data from a prospective study of 187 ITI dental implants used for single-tooth restorations evaluated the respective clinical effectiveness.³⁵ The implants placed in the maxilla (30.5%) yielded a survival rate of 100%. It was concluded that, under standard anatomic conditions (bone site height > 8 mm, thickness > 6 mm), prosthetic restoration of partially edentulous patients with ITI single-tooth implant restorations is a predictable therapy over the long term.

Kan and colleagues³⁶ evaluated the feasibility of immediate placement and provisionalization of maxillary anterior single-tooth implants in a prospective 1-year study. Thirty-five patients with 1 implant site each were included in this study. At 12 months, all implants remained osseointegrated. The mean marginal bone loss was -0.26 ± 0.40 mm mesially and -0.22 ± 0.28 mm distally, and the mesial and distal papilla level changes from pretreatment to 12 months were -0.55 ± 0.53 mm and -0.39 ± 0.40 mm, respectively. The results of this study suggest that favorable implant success rates, peri-implant tissue responses, and esthetic outcomes can be achieved with immediately placed and provisionalized maxillary anterior single-tooth implants.

Data collected from patients who were treated with anterior maxillary single-tooth implants according to an immediate loading protocol were recently published by Lorenzoni and associates.³⁷ This prospective 1-year study comprised 9 patients who had received 12 Frialit-2 implants. At the 1-year follow-up, all implants were considered successful, revealing a mean coronal bone level change at 6 and 12 months of 0.45 mm and 0.75 mm, respectively. The authors emphasized that successful immediate loading protocols required careful and strict patient selection aimed at achieving the best primary stability and avoiding any excessive functional and nonfunctional loading.

The same group of authors³⁸ also published a comparison of immediately loaded implants ($n = 14$) and nonloaded implants ($n = 28$). No implant failures were observed up to the prosthetic restoration 6 months postplacement. The mean bone level changes at prosthetic seating were 0.9 mm resorption for the loaded implants and 0.33 mm for nonloaded implants. This difference was statistically significant.

EFFECTS OF IMPLANT DESIGN, DIAMETER, AND SURFACE CHARACTERISTICS

Friberg and coworkers³⁹ compared the standard Brånemark System implant (n = 275) to the self-tapping Mk II implant (n = 288) (Nobel Biocare) in a controlled clinical trial with an observation period of 5 years. Overall, this study revealed equal cumulative success rates for both implant types. Mandibular implants exhibited greater success rates (100%) than maxillary implants (87%) for both tested designs.

The influence of implant design and surface texture was investigated by Norton⁴⁰ by means of a radiographic follow-up of 33 implants loaded for up to 4 years. A most favorable maintenance of marginal bone around the conical collar was revealed, with a mean marginal bone loss of 0.32 mm mesially and 0.34 mm distally for the whole group.

Multicenter data in the form of a controlled clinical trial comparing 2 different surface textures (machined versus TiO₂-blasted Astra Tech dental implants) were published by Karlsson and associates.⁴¹ One hundred thirty-three implants (48 maxillary and 85 mandibular) were placed in 50 partially edentulous patients and followed for 2 years. The cumulative survival rates were 97.7% for implants and 95.7% for prostheses. There was a slight, but statistically insignificant, difference in survival rates between the 2 surfaces: 100% for TiO₂-blasted and 95.3% for machined. However, no significant differences in crestal bone loss were found between the 2 types of implants.

Andersen and coworkers⁴² evaluated the safety and effectiveness of narrow-diameter threaded implants in the anterior region of the maxilla in a prospective, controlled clinical trial. Two of the 32 reduced-diameter implants, replacing either a central or a lateral incisor, were lost after 6 months, but no other failures were subsequently observed. The radiographically assessed marginal bone loss followed the same pattern as that associated with standard-diameter implants and was a mean of 0.4 mm from the first to the last examination (3 years after loading).

In a randomized, prospective 5-year trial, Gotfredsen and Karlsson⁴³ evaluated whether there was a difference between machined and TiO₂-blasted implants (Astra Tech) regarding survival rate and marginal bone loss. Forty-eight implants were placed in the maxilla and 85 were placed in the mandible. Fixed partial dentures were fabricated and each supported by at least one machined and one TiO₂-blasted implant. No significant difference in marginal bone loss between the 2 surface groups was found during the 5-year observation period. The cumulative implant survival rates

were 100% for the TiO₂-blasted implants and 95.1% for the machined implants.

Khang and coworkers⁴⁴ recently published results from a randomized controlled trial involving 97 patients that compared dual acid-etched and machined-surface implants in various bone qualities. Of the 432 implants (247 dual acid-etched, 185 machined-surface), 36 implants failed (12 dual acid-etched and 24 machined-surface). The authors concluded that the difference in success rates was most likely attributable to the acid-etched surface characteristics. The greatest performance difference was observed in the conditions of “poor quality” or “soft” bone, where the 3-year postloading cumulative success rates were 96.8% (dual acid-etched) and 84.8% (machined-surface).

The clinical effectiveness of implants with either a sandblasted and acid-etched (SLA) or a TPS surface was recently compared in a controlled clinical trial involving 68 SLA and 68 TPS sites (ITI/Straumann).⁴⁵ One year after implant surgery, clinical and radiographic measurements were carried out. No significant differences were found with respect to the presence of plaque, bleeding on probing, mean pocket depth, or mean marginal bone loss. It was concluded that SLA implants were suitable for early loading at 6 weeks.

A randomized controlled trial conducted by Engquist and associates⁴⁶ aimed to compare Astra Tech and Brånemark System implants, primarily with respect to marginal bone changes, during an observation period of 3 years. Sixty-six patients were included in the study and randomly assigned to treatment with Astra Tech implants (n = 184) or Brånemark System implants (n = 187). The mean bone loss in the maxilla between baseline and 3 years was 0.2 ± 0.3 mm for Astra Tech implants and 0.2 ± 0.1 mm for Brånemark System implants. In this study, however, the survival rate of Astra Tech implants was significantly higher (98.9%) than that of Brånemark System implants (95.2%).

A new, biologically derived implant design that conceptually may minimize bone remodeling and promote better bone and overlaying gingival contours and stability was recently introduced by Holt and colleagues.⁴⁷ The authors claim that the proposed parabolic implant shoulder design is in harmony with the biologic width of the soft tissue around the circumference of the implant when the proximal bone is occlusal to the facial and lingual bone. This is of particular interest in esthetic areas, where interproximal bone loss between implants may cause a reduction in the height of gingival papillae.

The purpose of a prospective clinical trial carried out by Gerber and associates⁴⁸ was to examine the

influence of a 1-mm lengthening of the rough surface (TPS) on ITI Esthetic Plus implants on the peri-implant soft and hard tissues. Twelve patients with 21 implants were evaluated 10 and 32 months after implant placement. The mean DIB (distance between implant shoulder and first implant-bone contact) score was 2.19 mm after 32 months. The average DIB score of implant sites adjacent to natural teeth was 1.90 mm (leaving only 0.1 mm of rough surface uncovered). In contrast, the mean DIB scores of implant sites adjacent to other implants (2.63 mm) or distal-extension situations (2.79 mm) were significantly higher. These data indicate that not only the length of the machined implant neck, but also the neighboring structures, influence the peri-implant soft and hard tissues.

To address the still-existing controversy over the long-term clinical effectiveness of HA-coated dental implants, McGlumphy and coworkers⁴⁹ published a 5-year prospective study of 429 implants placed in 121 patients. At the time of that report, 375 implants had completed 5 years of clinical follow-up, 282 implants 6 years, and 114 implants 7 years. The cumulative survival rate was 96% at 5 years and 95% at 7 years. It was concluded from that study that the HA-coated cylindrical implants provided a predictable means of oral rehabilitation.

SOFT TISSUE STABILITY AND CONTOURS AROUND ANTERIOR IMPLANT RESTORATIONS

Soft tissue stability around implant restorations and adjacent teeth is of paramount importance within the esthetic zone. In this context, in 1997 Jemt proposed a reproducible index to assess the size of the interproximal gingival papillae adjacent to single-implant restorations.⁵⁰ Preliminary testing of the index, performed retrospectively on 25 crowns in 21 patients, indicated a significant regeneration of papillae after a mean follow-up period of 1.5 years. It was concluded that this index allows objective assessment of the soft tissue contour adjacent to single-implant restorations.

Scheller and associates⁵¹ addressed soft tissue stability in their 5-year prospective multicenter study of 99 implant-supported single-crown restorations. The authors reported overall cumulative success rates of 95.9% for implants and 91.1% for implant crowns. Soft tissue levels around implant restorations and adjacent teeth remained stable over the entire evaluation period.

Chang and colleagues⁵² carried out a comparative evaluation of crown and soft tissue dimensions

between implant-supported single-tooth replacements and the contralateral natural teeth, involving 20 patients with an implant in the esthetic zone of the maxilla and a minimal follow-up of 6 months. The results showed that, in comparison with the natural control tooth, the implant crown was longer, had a smaller faciolingual width, was bordered by a thicker facial mucosa, had a lower height of the distal papilla, showed a higher frequency of mucositis and bleeding on probing, and had greater probing depth. With regard to the papillae adjacent to the implant crown, the longitudinal evaluation revealed an improved proximal soft tissue fill. Visual analogue scale (VAS) scoring of the patients' satisfaction with the appearance of their implant crowns showed a median value of 96%, with a range from 70% to 100%. Thus the observed differences between implant crowns and natural teeth may be of minor importance for most patients' subjective appreciation of the esthetic outcome of anterior implant therapy. These findings were confirmed by the same group of authors in a study assessing esthetic outcomes of implant-supported single-tooth replacements by the patient and by prosthodontists.⁵³ In fact, parameters considered by professionals to be of significance for the esthetic result of the restorative treatment may not be of decisive importance for the patient's satisfaction.

Jemt⁵⁴ published results from a randomized clinical trial comprising 55 patients with 63 single implants, which aimed to restore the gingival contour by means of provisional resin crowns. The data indicated that the use of provisional crowns may restore soft tissue contours faster than healing abutments alone, but the papillae adjacent to single-implant restorations presented similar volume in both groups after 2 years in function. The author focused on the need for more scientific data to evaluate different clinical procedures for optimizing esthetic results in implant dentistry.

The stability of the mucosal topography around 10 anterior maxillary single-tooth implants and adjacent teeth was evaluated by Grunder.⁵⁵ The 1-year results revealed that soft tissue shrinkage on the vestibular (labial) aspect of the implant crowns was 0.6 mm on average. The soft tissue volume in the papilla area, however, increased on average by 0.375 mm, and none of the involved papillae lost volume.

In a clinical report, Wheeler and coworkers⁵⁶ addressed the various parameters likely to have an impact on tissue preservation and maintenance of optimum esthetics. The authors pointed out that recently developed tapered implants facilitate immediate implant placement, predictably preserving the osseous structure surrounding the extraction

socket. Along the same line, the use of special custom healing abutments may significantly contribute to the preservation of the crestal soft tissues, including the papillae.

The incidence of gingival recession around implants was evaluated in a 1-year prospective study comprising 63 implants.⁵⁷ The investigation, which measured the soft tissue around implants following surgery, aimed at determining whether a predictable pattern of soft tissue changes could be identified. Eighty percent of all sites exhibited recession on the buccal aspect, and the majority of the recession occurred within the first 3 months. The authors claimed that, as a general rule, one can expect approximately 1 mm of recession from the time of abutment connection surgery.

Choquet and coworkers⁵⁸ carried out a retrospective clinical and radiographic evaluation of single-tooth implants located in the maxillary anterior segment. The study comprised 26 patients and 27 implants and their respective natural control teeth. In particular, 52 papillae were available for specific esthetic evaluation. The data indicated that when the measurement from the interproximal contact point to the bone crest was 5 mm or less, the papilla was present in almost 100% of cases. When the distance was ≤ 6 mm, the papilla was present 50% of the time or less. The authors concluded that these results clearly showed the influence of the bone crest on the presence or absence of papillae between implants and adjacent teeth.

Hermann and associates⁵⁹ have emphasized that gingival esthetics strongly depends on a stable and constant vertical dimension of healthy periodontal soft tissues, commonly referred to as *biologic width*. The purpose of their experimental study was therefore to histometrically assess peri-implant soft tissue dimensions dependent on varying locations of a rough/smooth implant border in 1-piece implants or a microgap (interface) in 2-part implants in relation to the bone crest. Two-piece implants were placed according to either a submerged or a nonsubmerged protocol. The results suggest that the gingival margin is located more coronally and biologic width dimensions are more similar to natural teeth around 1-piece nonsubmerged implants compared to either 2-piece nonsubmerged or 2-piece submerged implants.

Oates and colleagues⁶⁰ evaluated long-term changes in soft tissue height on the facial surface of dental implants. One hundred six 1-stage ITI implants, located in the anterior maxilla and mandible, were analyzed in 39 patients. The purpose of the study was to assess the long-term changes in the position of the facial (vestibular) soft tissue margins following restoration of the respec-

tive implants. There were no implant failures over a period of 2 years. Overall, on the facial aspect of 61% of the 106 implants, there was 1 mm or more of soft tissue recession, whereas 19% of the implants showed 1 mm or more of gain in soft tissue height. It was concluded that the potential for significant changes in soft tissue levels (loss or gain) after completion of restorative therapy needs to be considered for implant therapy in the esthetic zone.

Organization of the connective tissue barrier around long-term loaded implant abutments was recently investigated in humans.⁶¹ Block specimens containing smooth titanium implant abutments and the surrounding supracrestal connective tissue, obtained from patients rehabilitated for at least 1 year, were investigated histologically. The histologic features comprised a connective tissue rich in collagen fibers, organized in bundles, and presenting a constant spatial arrangement similar to that found in animal trials. Circular fibers, the most common, were located externally and longitudinal fibers more internally. Radial fibers inserted on the abutment surface, similar to those of the periodontal system, were not observed in any case.

The predictability of soft tissue form around single-tooth implant restorations has been addressed in a recently published retrospective study.⁶² This photographic examination followed 55 single-implant restorations in 51 patients for a period of 1 to 9 years. Papillae regenerated in 83.9% of implants, for a mean growth of 0.65 mm mesially and 0.62 mm distally. The sulcular apex receded in 59% of patients, for a mean of 0.06 mm. Complete papilla fill was noted in 75% of patients examined. The author concluded that predictable soft tissue profiles can be achieved with a simplified implant prosthetic protocol that progresses directly from healing abutments to definitive crowns in most cases.

The effect of intracrevicular restoration margins on peri-implant health around esthetic implants was studied by Giannopoulou and coworkers⁶³ in 45 systemically healthy patients with 61 maxillary anterior implants. Clinical, microbiologic, and biochemical parameters were recorded at baseline and again after 3 years. The only statistically significant differences between baseline and follow-up examination concerned probing pocket depth and DIM (distance between implant shoulder and mucosal margin) measurements, which increased slightly. Based on an observation period of up to 9 years (mean 6.8 years at the time of the follow-up examination), it was concluded that in patients with appropriate oral hygiene, the intracrevicular position of the restoration margin does not appear to adversely affect peri-implant health and tissue stability.

CERAMIC ABUTMENTS

Andersson and associates⁶⁴ followed 57 patients for 2 years and 34 patients for 3 years in a controlled clinical trial of the CeraOne System (Nobel Biocare). Ninety-five percent of the single-tooth implants studied were restored with all-ceramic crowns. A cumulative implant success rate of 97.3% was reported at the 3-year examination. Two all-ceramic crowns fractured following trauma, but no crowns fractured when exposed to common bite forces. It was concluded that the system consistently achieved good esthetic results and efficiently avoided complications such as screw loosening and fistula formation.

In experiments with dogs, Abrahamsson and colleagues⁶⁵ examined whether the material used in the abutment part of an implant system had an influence on the quality of the mucosal barrier that formed following implant placement. The materials tested were commercially pure titanium, gold alloy, highly sintered aluminum oxide (Al₂O₃), and porcelain fused to gold. It was demonstrated that the material used in the abutment portion of the implant influenced both the location and the quality of the peri-implant mucosal attachment. Titanium and ceramic abutments permitted the formation of a mucosal attachment, which comprised epithelial and connective tissue portions that were about 2 mm and 1 to 1.5 mm high, respectively. At sites where gold alloy or metal-ceramic abutments were inserted, soft tissue recession and crestal bone resorption were observed, thereby occasionally exposing the abutment-implant junction. The authors suggested that this was the result of varying adhesive properties of the materials studied or variations in their resistance to corrosion.

In a clinical trial, the eventual influence of different implant abutment materials on bacterial colonization and the role of colonization in the development of peri-implant infections were addressed.⁶⁶ For that purpose, samples of titanium and novel ceramic abutments were adapted to the posterior region in 2 mandibular quadrants of 4 volunteers. The maximum colonization was achieved after 24 hours in the oral cavity, and the bacterial counts remained constant over the 14-day experimental period. No significant differences were observed between the 2 materials analyzed in this study.

In a randomized, controlled, multicenter trial, Andersson and coworkers⁶⁷ evaluated the short- and long-term clinical function of CerAdapt ceramic abutments (Nobel Biocare) supporting short-span FPDs. One hundred five implants had been placed in a total of 32 patients at 3 different clinics. After 2 years, a cumulative survival rate of 97.1% for

implants and a cumulative success rate of 97.2% for FPDs (94.7% for ceramic abutment-supported FPDs and 100% for titanium abutment-supported FPDs) were reported. More crown margins were placed submucosally on titanium (31%) than on ceramic (14%) abutments, and the level of the peri-implant mucosa remained relatively stable. There was some marginal bone loss recorded after 1 year, which was slightly more pronounced around the titanium (0.4 mm) than the ceramic (0.2 mm) abutments. The authors considered the results very encouraging for ceramic abutments supporting short-span FPDs. However, ceramic materials tend to undergo static fatigue, and it is therefore important to wait for the 5-year data before making statements related to the long-term prognosis of such abutments.

Kucey and Fraser⁶⁸ reviewed currently available techniques for creating the Procera custom abutment (Nobel Biocare) and described the related clinical and laboratory procedures recommended for the use of this computer-aided design/computer-assisted manufacture (CAD/CAM) implant component. The authors emphasized that well-known problems with inventory of components, incorrect abutment selection, poor tissue contours, and angulation can be avoided, or at least reduced, by using this type of abutment. Concerns about dissimilar metals and about interfaces between machined and cast components are eliminated. They furthermore concluded that the routine implementation of this technology requires experience with direct implant shoulder-level impressions, and that there is potential for complications from incomplete removal of cement.

In their randomized controlled trial, Andersson and colleagues⁶⁹ compared results after 1 to 3 years when single-tooth implant crowns were supported either by ceramic (93% success rate) or titanium (100% success rate) abutments. Stable soft tissue and marginal bone situations were found around both types of abutments. Clinicians and patients rated the esthetic results as excellent for nearly all cases. It was concluded that ceramic abutments have an excellent esthetic potential, but the associated guidelines must be meticulously followed because ceramic abutments are more sensitive to handling procedures than titanium abutments.

Boudrias and coworkers⁷⁰ presented—in the form of case reports—a newly developed, densely sintered aluminum oxide ceramic abutment, designed and machined using CAD/CAM technology. The authors pointed out that this specific manufacturing method improves clinical management of the submucosal depth of the crown-to-abutment interface and thereby enhances the esthetic qualities of the

resulting restoration. However, because of the inferior mechanical resistance in comparison to titanium abutments, the use of such ceramic abutments should be confined to the restoration of incisors and premolars not subjected to excessive occlusal load.

The bacterial colonization of zirconia ceramic surfaces was recently studied *in vitro* and *in vivo*.⁷¹ The authors found that, overall, zirconia ceramic surfaces developed for implant abutments accumulate fewer bacteria than commercially pure titanium, and may therefore be considered as a promising material for abutment manufacturing.

Cho and associates⁷² investigated the *in vitro* fracture strength of implant-supported restorations using milled ceramic abutments and all-ceramic crowns. The fracture strengths under vertical loading were greater than those under oblique loading. However, the fracture strengths of metal-ceramic crowns cemented to titanium abutments were significantly higher than those of all-ceramic crowns cemented to milled ceramic abutments, regardless of loading direction.

In 2003, Andersson and colleagues⁷³ published prospective multicenter data from a randomized controlled clinical trial comparing the long-term function of CerAdapt ceramic abutments to titanium abutments supporting short-span FPDs. An average 97.2% cumulative success rate was reported after 5 years (94.7% for ceramic and 100% for titanium abutment-supported FPDs). The authors concluded that safe long-term functional and esthetic results can be achieved with CerAdapt alumina ceramic abutments on Brånemark System implants used for short-span FPDs.

Henriksson and Jemt⁷⁴ performed a prospective 1-year follow-up study of custom-made Procera ceramic abutments for single-tooth replacement. Twenty consecutively treated patients were provided with 24 single-implant restorations using customized ceramic abutments. Thirteen crowns were cemented to the abutment and 11 restorations were fabricated by fusing the veneering material directly onto the ceramic abutment. All implants and restorations were in function after 1 year. The authors concluded that these short-term data indicate that customized ceramic abutments are successful and have similar function, regardless of their fabrication mode.

Lang and coworkers⁷⁵ evaluated *in vitro* the precision of fit between the Procera custom abutment and various implant systems. The authors concluded that the abutment's internal hexagon fit the external hexagon of all the implant systems evaluated in the study and that the Procera abutment with its screw can be universally applied. This, in combination with the related CAD/CAM feature of this system, provides a dynamic approach to solving many of the

design and spatial needs associated with the numerous clinical implant positions encountered, particularly when it comes to the anterior maxilla.

A recent *in vitro* investigation examined the fracture resistance of implant-supported all-ceramic abutments—Al₂O₃ and zirconium oxide (ZrO₂)—restored with glass-ceramic (IPS Empress; Ivoclar, Schaan, Lichtenstein) crowns.⁷⁶ Within the limitations of this study, the strength of both all-ceramic abutments exceeded the established values for maximum incisal load reported in the literature (90 to 370 N). The ZrO₂ abutments were more than twice as resistant to fracture as the Al₂O₃ abutments.

INFLUENCE OF SURGICAL TECHNIQUES

In a 5-year prospective study,⁷⁷ Zitzmann and associates recently assessed whether guided bone augmentation performed simultaneously with implant placement had an adverse effect on long-term survival rates of the implants. The study involved 41 test implants (with GBR) and 112 control implants (without GBR). The cumulative implant survival rates reported were 93% (test group) and 97% (control group). It was concluded that implants placed with or without GBR techniques have comparable survival rates after 5 years, but that bone resorption was more pronounced in GBR sites. Furthermore, the authors emphasized that the use of GBR was indicated when the initial defect size was larger than 2 mm in a vertical dimension.

In a 10-year retrospective clinical analysis evaluating the effect of so-called flapless surgery on implant survival and involving 770 implants placed in 359 patients, Campelo and Camara⁷⁸ reported a cumulative success rate that varied from 74% for implants placed in 1990 to 100% in 2000. The authors stressed the advantages of their approach and considered flapless implant surgery as a predictable procedure, provided patients are selected appropriately and proper surgical technique is meticulously followed.

EVALUATION OF PATIENT SATISFACTION

There is an increasing tendency to scientifically evaluate patients' opinions of various types of implant-supported prostheses. Often such evaluations include esthetic parameters as well. Along these lines, de Bruyn and coworkers⁷⁹ published a 3-year follow-up study of 61 implant patients treated in private practices according to 3 different well-defined therapeutic modalities. Comfort with eating, esthetics, phonetics, and overall satisfaction improved significantly with treatment, and nearly

all patients said that they would undergo the treatment again or recommend it to others. This included the subjects who had received implant-supported FPDs and who said they experienced their implant restorations as “natural” teeth.

In a similar project, the same group of authors⁸⁰ assessed the quality, after 3 years, of fixed implant restorations provided by clinicians who had previously participated in a 2-day postgraduate course focusing on implant-related treatment planning and practical training. The data clearly showed that clinicians previously inexperienced with implant prosthodontics implemented the information from a training course appropriately. They were able to provide clinically acceptable restorations (including the esthetic aspect) with a quality that was stable after 3 years of service.

A quality-of-life (QOL) assessment was carried out recently in patients with implant-supported and resin-bonded fixed prostheses for bounded edentulous spaces.⁸¹ The patients were requested to answer a self-administered QOL questionnaire with 2 major subscales: oral condition-related and general condition-related QOL scores. The authors concluded that multidimensional QOL levels of patients with an implant-supported fixed prosthesis did not exceed those of patients with a resin-bonded fixed prosthesis in a short follow-up period.

A recently published retrospective study focused on patient opinion and professionally assessed quality of single-tooth restorations of Brånemark System implants.⁸² Seventy-eight consecutively treated patients received a questionnaire covering esthetics, phonetics, and overall satisfaction. In general, the 48 patients who returned the questionnaire were very positive about these parameters. The additionally performed professional rating after a clinical and radiologic examination revealed that the objective quality was perfect in 17 cases and acceptable in 25 cases, while 1 crown needed major modification to prevent future complications.

Levi and associates⁸³ assessed patients' self-reported satisfaction with maxillary anterior dental implant treatment. Seventy-eight of 123 eligible subjects responded to the mailed, self-administered, structured questionnaire. In this limited investigation, satisfaction with implant position, restoration shape, overall appearance, effect on speech, and chewing capacity was critical for patients' overall acceptance of the dental implant treatment.

CONCLUSIONS

The present review clearly demonstrates that the use of dental implants in the esthetic zone is well

documented in the literature and that numerous controlled clinical trials show that the respective overall implant survival and success rates are similar to those reported for other segments of the jaws. However, most of these studies do not include well-defined esthetic parameters. With anterior single-tooth replacement in sites without tissue deficiencies, predictable treatment outcomes, including esthetics, can be achieved because of tissue support provided by adjacent teeth.

The replacement of multiple adjacent missing teeth in the anterior maxilla with fixed implant restorations is poorly documented. In this context, restoring esthetics is not predictable, particularly regarding the contours of the interimplant soft tissue.

Currently, the literature regarding esthetic outcome is inconclusive for the routine implementation of certain surgical approaches such as flapless surgery and immediate implant placement with or without immediate loading/restoration in the anterior maxilla.

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Optimizing Esthetics for Implant Restorations in the Anterior Maxilla: Anatomic and Surgical Considerations

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The placement of dental implants in the anterior maxilla is a challenge for clinicians because of patients' exacting esthetic demands and difficult pre-existing anatomy. This article presents anatomic and surgical considerations for these demanding indications for implant therapy. First, potential causes of esthetic implant failures are reviewed, discussing anatomic factors such as horizontal or vertical bone deficiencies and iatrogenic factors such as improper implant selection or the malpositioning of dental implants for an esthetic implant restoration. Furthermore, aspects of preoperative analysis are described in various clinical situations, followed by recommendations for the surgical procedures in single-tooth gaps and in extended edentulous spaces with multiple missing teeth. An ideal implant position in all 3 dimensions is required. These mesiodistal, apicocoronal, and orofacial dimensions are well described, defining "comfort" and "danger" zones for proper implant position in the anterior maxilla. During surgery, the emphasis is on proper implant selection to avoid oversized implants, careful and low-trauma soft tissue handling, and implant placement in a proper position using either a periodontal probe or a prefabricated surgical guide. If missing, the facial bone wall is augmented using a proper surgical technique, such as guided bone regeneration with barrier membranes and appropriate bone grafts and/or bone substitutes. Finally, precise wound closure using a submerged or a semi-submerged healing modality is recommended. Following a healing period of between 6 and 12 weeks, a reopening procedure is recommended with a punch technique to initiate the restorative phase of therapy. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):43-61

Key words: bone augmentation, endosseous dental implantation, esthetic failures, guided bone regeneration, implant esthetics, implant position, surgical procedures

Over the past 10 years, dental esthetics has been an important issue in implant dentistry. At major conferences it is common to see lectures addressing various techniques for obtaining esthetic implant restorations. In the anterior maxilla, unsuccessful

treatment outcomes can lead to disastrous clinical situations that can only be corrected with removal of the implant and subsequent tissue augmentation procedures. With this in mind, it is important to establish sound clinical concepts with clearly defined parameters that lead to successful esthetics in the anterior maxilla, with long-term stability of the peri-implant tissues. This consensus article addresses these aforementioned concepts and parameters from an anatomic and surgical perspective.

Initiation of therapy starts with an understanding of the patient's desires. In most cases, the patient's primary demand is an esthetic tooth replacement offering a nice smile. For the dental clinician, the re-establishment of esthetics and function requires knowledge of all treatment modalities. Of the fixed options, conventional fixed partial dentures and implant-supported restorations should be objectively evaluated for their potential to provide long-term

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Fig 1 Various aspects of an esthetic implant restoration can be influenced by the implant surgeon: a harmonious gingival line without abrupt changes in tissue height, intact papillae, and a convex contour of the facial aspect of the alveolar process.

function and stability in a given situation. Today, implant-supported restorations often represent the best solution, because intact tooth structure and supporting tissues can be preserved.

Esthetic parameters that have been defined for conventional dental restorations^{1,2} can also be used for implant patients during preoperative planning. These parameters can help define potential risk factors for esthetic shortcomings. The main esthetic objectives of implant therapy from a surgical point of view are the achievement of a harmonious gingival margin without abrupt changes in tissue height, maintaining intact papillae, and obtaining or preserving a convex contour of the alveolar crest³⁻⁵ (Fig 1).

Implant therapy in the anterior maxilla is challenging for the clinician because of the esthetic demands of patients and difficult pre-existing anatomy. In this area of the mouth, the clinician is often confronted with tissue deficiencies caused by various conditions. These conditions can be divided into 2 categories: anatomic and pathologic (Table 1).

Tissue deficiencies often require bone augmentation procedures such as the guided bone regeneration (GBR) technique, which uses a simultaneous or staged approach to regenerate adequate volumes of bone to allow for implant placement.⁶ Soft tissue handling, precise implant placement in a restorative-driven 3-dimensional approach,⁷ and follow-up procedures represent a variety of challenges for the implant surgeon.

To help categorize the difficulty level of a given treatment, in 1999 the Swiss Society of Oral Implantology proposed a system for classifying implant patients from surgical and prosthetic points of view. In the SAC classification system, the S rep-

Table 1 Clinical Conditions Presenting Tissue Deficiencies in the Anterior Maxilla

Conditions	Remarks
Anatomic	
Narrow alveolar crest and/or facial undercut of alveolar process	Congenitally missing teeth
Pathologic	
Dental trauma	Tooth avulsion with fracture of the facial bone plate
Posttraumatic conditions	Root ankylosis with infraocclusion, root resorption, root fractures
Acute or chronic infections	Periodontal disease, periapical lesions, endo/perio lesions
Disuse bone atrophy	Long-standing tooth loss

resents simple, A advanced, and C complex treatment procedures. In the surgical classification, all esthetic indications have been placed in either the A or C category, acknowledging the challenging clinical conditions often present in the anterior maxilla and the frequent need for bone augmentation procedures (Table 2).

To successfully meet the challenges of esthetic implant dentistry in daily practice, a team approach is advantageous and highly recommended. The team includes an implant surgeon, a restorative clinician, and a dental technician who preferably has advanced knowledge and clinical experience. In special situations, an orthodontist can supplement the team. The successful implant surgeon working in the esthetic zone should have a good biologic understanding of tissue response to implant placement, a thorough surgical education enabling performance of precise and low-trauma surgical procedures, and a large patient pool providing sufficient surgical experience with esthetic implant placement.

POTENTIAL CAUSES OF ESTHETIC IMPLANT FAILURE

Anatomic Factors

It is important for the clinician to understand that ridge anatomy includes the soft tissues and the supporting bone in all dimensions, and that soft tissue contours around an implant are heavily influenced by the bone anatomy. In recent years, numerous experimental studies have revealed that the concept of *biologic width*, once described for natural teeth,⁸ can also be applied to osseointegrated implants,

Table 2 Surgical SAC Classification* of Implant Sites With or Without Bone Deficiencies

	Simple	Advanced	Complex
Sites without bone defects	<ul style="list-style-type: none"> • Edentulous mandible with 2 implants for a removable denture (ball attachment or bar) • Distal-extension situation maxilla/mandible • Extended edentulous gap in posterior maxilla/ mandible • Extended edentulous gap in anterior mandible • Single-tooth gap in posterior area • Single-tooth gap in anterior mandible 	<ul style="list-style-type: none"> • Edentulous mandible with 4 to 6 implants for a bar-supported prosthesis or full-arch prosthesis • Edentulous maxilla for removable denture • Single-tooth gap in anterior maxilla • Extended edentulous gap in anterior maxilla 	<ul style="list-style-type: none"> • Edentulous maxilla for a fixed full-arch prosthesis
Sites with bone defects	<ul style="list-style-type: none"> • None 	<ul style="list-style-type: none"> • Implants with simultaneous membrane application • Implants placed with osteotome technique • Implants combined with "bone splitting" of the alveolar crest 	<ul style="list-style-type: none"> • All 2-stage bone augmentation procedures • Sinus floor elevation with the window technique • Combined bone and soft tissue augmentation procedures

*Classification of the Swiss Society of Oral Implantology (1999).

because the soft tissues also demonstrate relatively constant dimensions around implants.^{9–13} These animal studies have demonstrated a relatively constant thickness of the peri-implant soft tissues of approximately 3 mm. The biologic width of the peri-implant mucosa comprises the zone of supracrestal connective tissue, which measures approximately 1 mm, and the epithelial structures, including the junctional and sulcular epithelium, which measure about 2 mm in height.^{11,13,14} It should be noted that the thickness of about 3 mm was measured around implants without adjacent teeth. In patients, the soft tissues in interproximal areas are thicker because of the papillae that form at the contact point to support the emerging restoration. In addition, clinical studies have also demonstrated that there are some differences in soft tissue thickness among different gingival biotypes.¹⁵ A *thin biotype*, with a highly scalloped gingival architecture, has a reduced soft tissue thickness when compared with a *thick biotype* featuring blunted contours of the papillae.^{15,16}

Keeping these relatively constant dimensions of peri-implant soft tissues in mind, the underlying bone structure plays a key role in the establishment of esthetic soft tissues in the anterior maxilla. Two anatomic structures are important: the bone height of the alveolar crest in the interproximal areas and the height and thickness of the facial bone wall (Figs 2a and 2b). The interproximal crest height plays a role in the presence or absence of peri-implant papillae. A clinical study around teeth¹⁷ demonstrated that a distance of 6 mm or more from the

alveolar crest to the contact point reduces the probability of intact papillae (Fig 3). This observation has been confirmed with implant-supported restorations.¹⁸ It has also been shown that the height of peri-implant papillae in single-tooth gaps is independent of the proximal bone level next to the implant but is dependent on the interproximal bone height of the adjacent teeth.¹⁵ Clinical situations with reduced vertical bone on adjacent teeth are challenging, because there are currently no surgical techniques available to predictably regain lost crest height. In an attempt to regain this lost tissue, orthodontic tooth extrusion techniques have been proposed.^{19,20} However, no clinical studies with long-term results have been presented to date. To detect patients at risk for short peri-implant papillae, a detailed preoperative analysis of crest height of the adjacent teeth is necessary. It is important to openly discuss treatment limitations with the patient prior to therapy to avoid unrealistic expectations.

Having a facial bone wall of sufficient height and thickness is important for long-term stability of harmonious gingival margins around implants and adjacent teeth.^{4,21} In daily practice, implant patients frequently present with a bone wall that is missing or of insufficient height and/or thickness because of the various causes of tooth loss (Table 1). Attempts to place implants in sites with facial bone defects in the absence of bone reconstruction will frequently result in soft tissue recession, potentially exposing implant collars and leading to loss of the harmonious gingival margin.

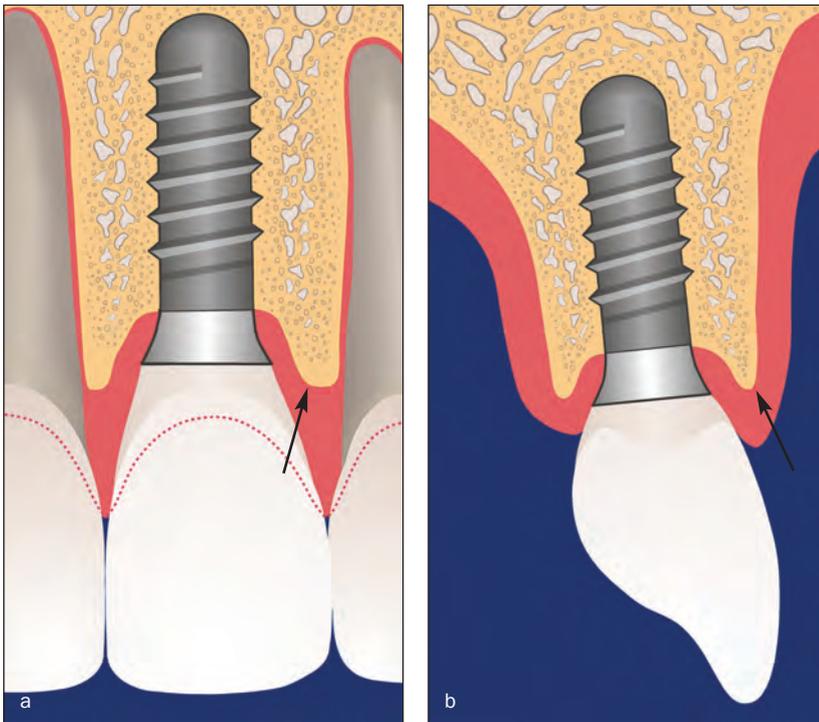


Fig 2 Esthetic peri-implant soft tissues significantly depend on 2 supporting bone structures: (a) the height of the alveolar crest at adjacent teeth, and (b) the height and thickness of the facial bone wall.

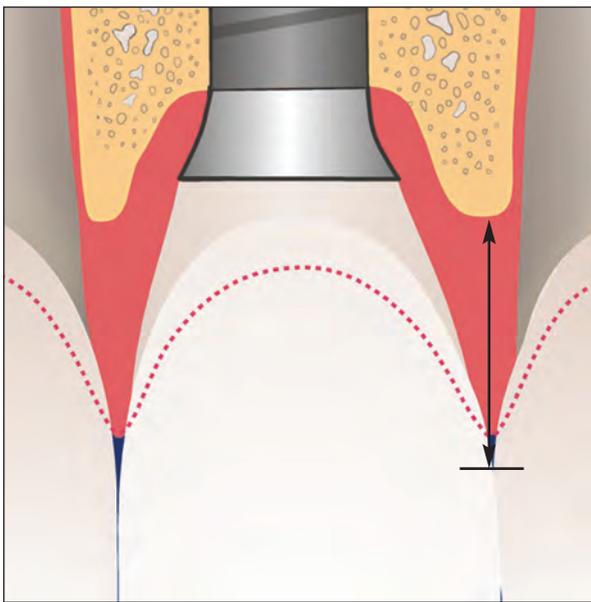


Fig 3 The presence or absence of a peri-implant papilla mainly depends on the distance (H) between the alveolar crest and the contact point. In single-tooth gaps, the bone height at adjacent teeth determines the status of the papilla.

Various surgical techniques have been proposed in the past 15 years to correct such bone defects at the facial aspect of potential implant sites, including onlay grafting,²²⁻²⁴ GBR using barrier membranes,²⁵⁻²⁹ a combination of block bone grafts and barrier membranes,^{30,31} and most recently distraction osteogenesis.³²⁻³⁴ From a scientific point of

view, the GBR technique is a well-documented procedure that can be used with either a simultaneous or a staged approach.^{6,25} Clinical studies and experience demonstrate that horizontal bone augmentation can be predictably obtained with the GBR technique,³⁰ whereas with vertical bone augmentation, a clearly more difficult procedure, it is more difficult to obtain successful results.^{35,36}

Iatrogenic Factors

Esthetic failures can also be caused by inappropriate implant positioning and/or improper implant selection. Placement of implants in a correct 3-dimensional position is a key to an esthetic treatment outcome regardless of the implant system used. This position is dependent on the planned restoration that the implant will support. The relationship of the position between the implant and the proposed restoration should be based on the position of the implant shoulder, because this will influence the final hard and soft tissue response. The implant shoulder position can be viewed in 3 dimensions: orofacial, mesiodistal, and apicocoronal. In the orofacial direction, an implant shoulder placed too far facially will result in a potential risk for soft tissue recession, because the thickness of the facial bone wall is clearly reduced by the malpositioned implant (Fig 4). In addition, potential prosthetic complications could result in restoration-implant axis problems, making the implant difficult to restore. Implants positioned too far palatally can result in emergence problems, as

Fig 4a (Left) Esthetic failure of an implant crown. The implant was placed immediately into an extraction socket. Following implant restoration, significant soft tissue recession developed within a few months, exposing the implant surface.



Fig 4b (Right) The occlusal view clearly demonstrates that the implant shoulder is located too far facially in the danger zone. This malposition was aggravated by the selection of a wide-platform implant.



Fig 4c (Left) The periapical radiograph shows an osteolytic lesion at the mesial aspect of the implant. The diameter of the implant shoulder is clearly too large.

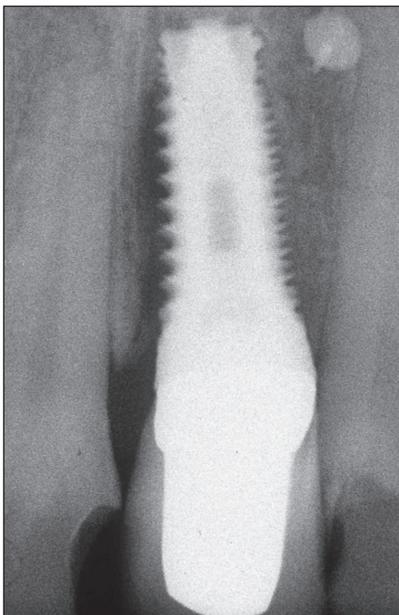
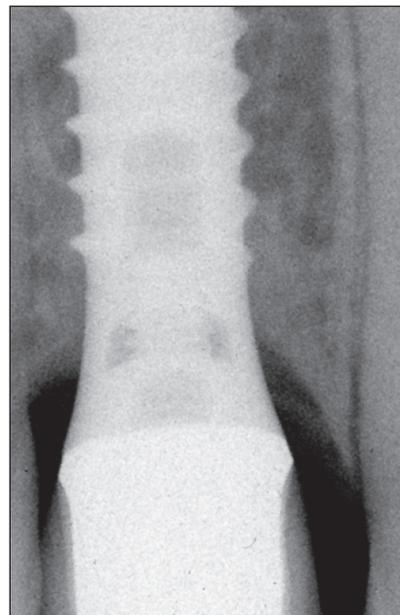


Fig 5 (Right) Following implant restoration, some peri-implant bone resorption is routinely seen on periapical radiographs. This bone "saucer" has a vertical component of about 1.5 to 2.0 mm and a horizontal component of at least 1.0 mm.



seen with ridge-lap restorations. These restorations can be unesthetic and extremely difficult to maintain, and should therefore be avoided.^{3,4,37,38}

Improper mesiodistal positioning of implants can have a substantial effect on the generation of interproximal papillary support as well as on the osseous crest on the adjacent natural tooth. Placement of the implant too close to the adjacent tooth can cause resorption of the interproximal alveolar crest to the level of that on the implant.^{39,40} With this loss of the interproximal crest height comes a reduction in the papillary height. Restorative problems exist as well. Poor embrasure form and emergence profile will result in a restoration with a long contact zone and compromised clinical outcomes. The loss of crest height on adjacent teeth is caused by the bone saucerization routinely found around the implant shoulder of osseointegrated implants. This saucerization comprises 2 dimensions: horizontal and vertical. Radiographs demonstrate that the horizontal dimension of the proximal bone saucerization measures about 1.0 to 1.5 mm from the implant surface.⁴¹ This minimal distance needs to be respected on implant placement to prevent vertical bone loss on adjacent teeth.

This saucerization can also play a role with regard to the apicocoronal position of the implant shoulder. If the implant is placed too far apically using extensive countersinking procedures, the vertical dimension of the bone saucerization will lead to unnecessary bone loss. This vertical dimension amounts to approximately 2 mm in interproximal areas when measured from the implant shoulder (Figs 3 and 5). This radiographic observation routinely seen in patients³⁹ was confirmed by experimental studies.^{14,42-44} These studies demonstrated that the position of the implant/abutment interface, often called the microgap, has an important influence on the hard and soft tissue reactions around osseointegrated implants. The more apically the microgap was located, the more bone resorption was observed. The extent of vertical bone resorption measured between 1.3 and 1.8 mm in these animal studies. Clinically, if an implant is placed with an excessive countersinking procedure, an unnecessary amount of bone loss will occur. Because this resorption will take place circumferentially (Fig 6), it will affect not only the proximal bone structure but also the height of the facial bone wall and can lead to undesired soft

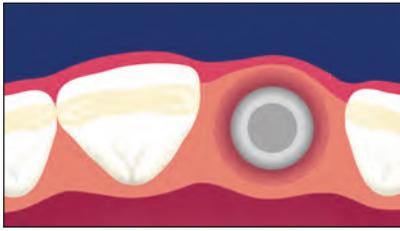


Fig 6 (Above) This peri-implant bone “saucer” is a circumferential phenomenon and can lead to a partial resorption of the facial bone wall, with subsequent soft tissue recession.



Fig 7a (Top center) Compromised esthetic result in a young female patient with a high lip line. Clinical status 4 months following implant restoration.



Fig 7b (Right) The detailed view clearly shows the loss of a harmonious gingival line following soft tissue recession at the implant crown.

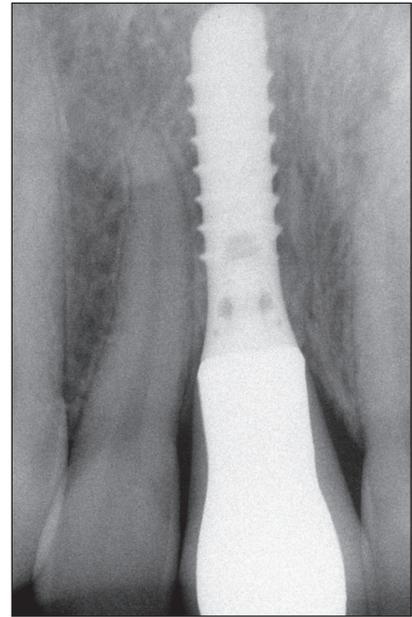


Fig 7c (Far right) The periapical radiograph demonstrates the cause of the esthetic failure: The implant shoulder was positioned too far apically, which led to the resorption of the facial bone wall.

Fig 8a (Top left) Schematic diagram of a situation with two adjacent implants. The “saucer” developed around both implants and led to a flattening between both implants, resulting in a distance (H) that clearly exceeds 5 mm.

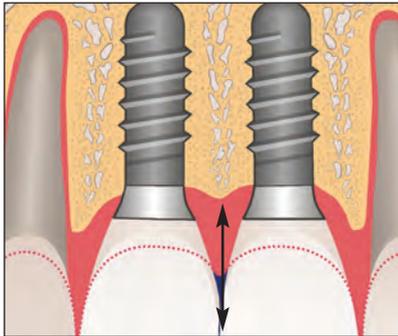
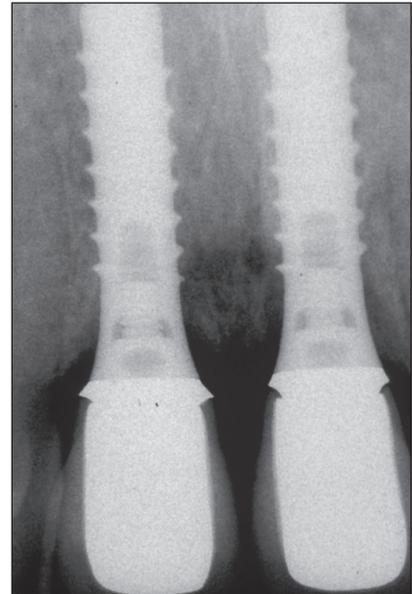


Fig 8b (Bottom left) Clinical status of 2 adjacent implants in central incisors. The interimplant papilla is approximately 2 mm shorter than adjacent papillae because of the bone resorption between the 2 implants. The short papilla is nicely compensated with prosthetic means, such as a long interproximal contact line.



Fig 8c (Right) The periapical radiograph 6 years following implant placement shows the reduction in crest height between the 2 implants.



tissue recession. Restoratively, long clinical crowns, pink porcelain, or visible metal margins will result, compromising the esthetic treatment outcome (Figs 7a to 7c). This phenomenon is also important in sites with 2 adjacent implants because the interimplant bone will be resorbed, leading to a shortened interimplant papilla⁴¹ (Figs 8a to 8c).

Esthetic failures can also be caused by improper implant selection, mainly because of the use of oversized implants. The use of “tooth-analogous”

implant diameters based solely on the mesiodistal dimension of the tooth to be replaced should be avoided. With such wide-platform or wide-neck implants, the implant shoulder may be too close to adjacent teeth and too far facially, leading to the above-mentioned complications. In the case of adjacent implant placement, wide-platform implants will reduce the amount of interimplant bone and increase the risk of extensive interimplant bone loss.

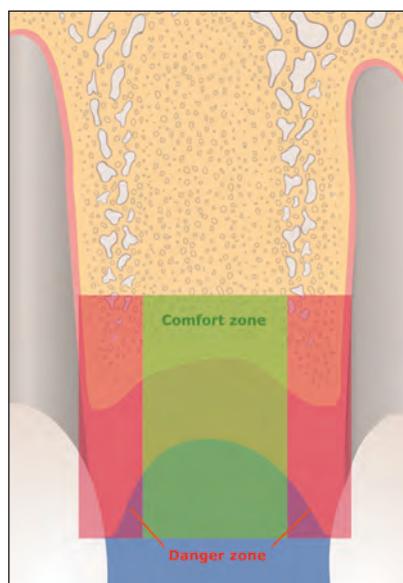


Fig 9a Correct implant position in the mesiodistal dimension. The implant shoulder should be positioned within the comfort zone, avoiding the danger zones, which are located close to adjacent root surfaces. The danger zone is about 1.0 to 1.5 mm wide.

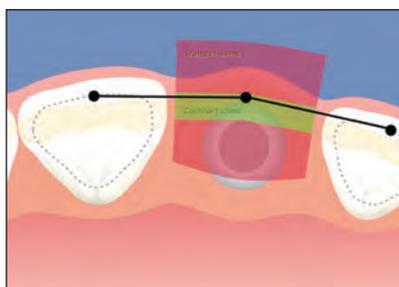


Fig 9b Correct implant position in the orofacial dimension. The implant shoulder is positioned about 1 mm palatal to the point of emergence at adjacent teeth. The danger zone is clearly entered when the implant is placed too facially; this can cause resorption of the facial bone wall with subsequent recession. A second danger zone is located too far palatally, which can require an implant crown with a ridge-lap design.

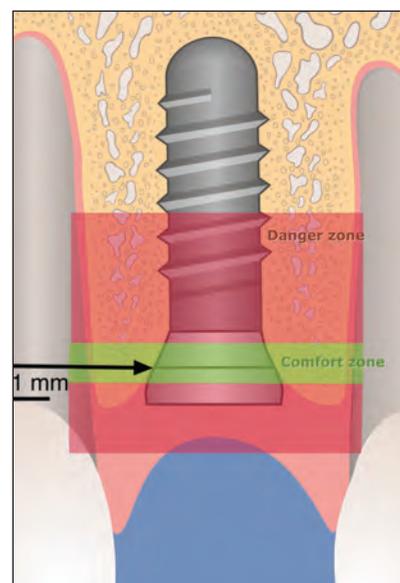


Fig 9c Correct implant position in the apicocoronal dimension. The implant shoulder is positioned about 1 mm apical to the CEJ of the contralateral tooth in patients without gingival recession. The danger zone is entered when the implant is placed too far apically using excessive countersinking, or too far coronally, which results in implant shoulder exposure at the mucosa.

IDEAL IMPLANT PLACEMENT IN THE ANTERIOR MAXILLA

As previously mentioned, esthetic implant placement is based on a restorative-driven philosophy.^{3-5,7,45} Correct 3-dimensional positioning of the planned implant restoration is the driving force in implant placement. This will allow for optimal support and stability of the peri-implant hard and soft tissues. In the anterior maxilla, the following implant types are recommended for clinical use: standard screw, wide body, narrow neck, TE 4.1/4.8, and TE 3.3/4.8 (Institut Straumann, Waldenburg, Switzerland). These implants differ in restorative shoulder and implant thread dimensions. To utilize these implants successfully in the anterior maxilla, correct implant selection relative to the mesiodistal dimension of the tooth to be replaced is critical. In this article, this dimension is referred to as *gap size*.

When planning for an ideal 3-dimensional implant position, a distinction is made between so-called “comfort” and “danger” zones in each dimension. Selection and placement of the dental implant should be based on the planned restoration in these zones. If the implant shoulder is positioned within the danger zones, one of the above-mentioned complications could occur, potentially resulting in

esthetic shortcomings. Implants positioned in the comfort zones provide the basis for an esthetic restoration. Comfort and danger zones are defined in mesiodistal, orofacial, and apicocoronal dimensions. In the mesiodistal dimension, the danger zones are located next to adjacent teeth. At present, it is not clear how wide these danger zones are. Previous publications recommended that the implant shoulder and the adjacent root surface be at least 1 mm apart.²¹ With the tulip shape of the implant shoulder on Straumann implants, this would place the implant body surface no closer than 1.5 mm to the adjacent root surface (Fig 9a). With this in mind, the minimal gap size for implant selection in the anterior maxilla, based upon the implant shoulder, can be defined (Table 3). Wide-neck implants, with their 6.5-mm shoulder diameter, are not recommended for use in the anterior maxilla. Their implant shoulder margin is likely to be located too close to adjacent teeth or too far facially, entering into the respective danger zones.

With regard to the orofacial dimension, it has been proposed that the position of the implant shoulder margin should be at the ideal point of emergence.^{3,4} The facial danger zone is located anywhere facially to the imaginary line highlighted from the point of emergence of the adjacent teeth

Table 3 Relationship Between the Mesiodistal Gap Size and the Diameter of the Implant Shoulder (Straumann Dental Implant System)

Implant type	Shoulder diameter (mm)	Minimal gap size (mm)	Ideal gap size (mm)
Standard screw (S 4.1)	4.8	7.0	8.0 to 9.0
Wide-body (S 4.8)	4.8	7.0	8.0 to 9.0
Narrow-neck (NN 3.3)	3.5	5.5	6.0 to 7.0
TE (TE 3.3/4.8)	4.8	7.0	8.0 to 9.0
TE (TE 4.1/4.8)	4.8	7.0	8.0 to 9.0

Table 4 Risk Factors in Implant Patients

Risk factors	Remarks
Medical	Severe bone disease causing impaired bone healing Immunologic disease Medication with steroids Uncontrolled diabetes mellitus Irradiated bone Others
Periodontal	Active periodontal disease History of refractory periodontitis Genetic disposition
Smoking habits	Light smoking (< 10 cigarettes per d) Heavy smoking (≥ 10 cigarettes per d)
Oral hygiene/compliance	Home care measured by gingival indices Personality, intellectual aspects
Occlusion	Bruxism

and/or planned restoration (Fig 9b). The palatal danger zone starts about 2 mm from this point of emergence and leads to an increased risk of a ridge-lap restoration. Placement of the implant orofacially in the comfort zone, which is located anywhere in between these areas, will allow for a restoration with the proper emergence profile to maintain the harmonious scalloping of the gingival margins.

The apicocoronal positioning of the implant shoulder follows the philosophy “as shallow as possible, as deep as necessary,” as a compromise between esthetic and biologic principles. As agreed upon at the last ITI consensus meeting, the position of the implant shoulder should be approximately 2 mm apical to the midfacial gingival margin of the planned restoration.²¹ This can be accomplished through the use of surgical templates that highlight the gingival margin of the planned restoration. In patients without vertical tissue deficiencies, the use of periodontal probes leveled on the adjacent cemento-enamel junction (CEJ) in single-tooth gaps has proven to be a valid alternative.²¹ It is important to note that the CEJs of adjacent teeth can vary,

depending on the tooth to be replaced, and must be taken into consideration.⁴⁶ In particular, lateral incisors are smaller and their CEJ is normally located more coronally than the CEJs of central incisors or canines. Implant placement within the apical danger zone (located anywhere 3 mm or more apical to the proposed gingival margin) can result in undesired facial bone resorption and subsequent gingival recession. The coronal danger zone is invaded with a supragingival shoulder position, leading to a visible metal margin and poor emergence profile (Fig 9c). Respecting the comfort zones in 3 dimensions results in an implant shoulder located in an ideal position, allowing for an esthetic implant restoration with stable, long-term peri-implant tissue support.

PREOPERATIVE ANALYSIS

Risk Assessment

In each patient, a detailed preoperative analysis should be performed to assess the individual risk profile and the level of difficulty of the planned therapy. Risk assessment in the anterior maxilla of potential implant patients includes several aspects (Table 4). The goal of risk assessment is to identify patients whose implant therapy carries a high risk of a negative outcome. Among the listed factors, patients with increased periodontal susceptibility and/or a history of a rapidly progressing or refractory periodontitis should be identified, because there is increasing evidence in the literature that these patients have an increased risk of biologic complications around osseointegrated implants.^{47,48} In the past 5 years, genetic testing using a swab has been recommended to identify positive interleukin-1 (IL-1) genotype patients, because these patients have an increased risk of developing periodontitis.⁴⁹⁻⁵¹ It seems that the combination of an IL-1-positive genotype and smoking further increases this risk.^{52,53} Smoking is also an important risk factor for implant complications. Several clinical studies have demonstrated increased failure rates for smokers either during the healing or the follow-up period.⁵⁴⁻⁵⁷ Recently published studies have provided the first evidence that the combination of positive IL-1 genotype and smoking also has a negative synergistic effect on peri-implant tissues, because increased bone loss and a higher frequency of biologic complications have been noted.⁵⁸⁻⁶⁰ Thus, the identification of patients with a history of periodontitis combined with smoking is important during preoperative analysis, because these patients are clearly at risk for the development of biologic peri-implant complications.

Anatomic Site Analysis: General Remarks

An optimal esthetic implant restoration depends on 4 anatomic and surgical parameters: (1) submucosal positioning of the implant shoulder, (2) adequate 3-dimensional implant positioning, (3) long-term stability of esthetic and peri-implant soft tissue contours, and (4) symmetry of clinical crown volumes between the implant site and contralateral teeth.^{3,4} With this in mind, implant placement in an optimal position begins with a restorative plan and an anatomic assessment of the single- or multiple-tooth gap (Table 5).

Assessment begins extraorally and includes the patient's smile. A keen eye is needed to determine if the smile is natural. Patients with unacceptable tooth health, shade, or position may not give a full smile when asked. Previous photographs of the patient and family interviews may help to determine the natural position of the patient's lip during a smile. As expected, patients with a high lip line will show more tissue and will require maximal efforts to maintain peri-implant tissue support throughout the planning, provisional, surgical, and restorative phases.

The dental midline, tooth size, and shade should be recorded. The intraoral exam should document excessive or irregular gingival tissue, crowding, and asymmetric teeth (eg, peg laterals), in addition to including a thorough periodontal and radiographic charting. It is paramount that orthodontic and periodontal esthetic problems be addressed either prior to or during implant rehabilitation. Tissue shaping—whether excessive or deficient—should be managed with a restorative plan by experienced clinicians.

Characteristics of the soft tissue biotype^{15,16} will play a prominent role in planning for final shoulder position of the implant. A thin biotype with highly scalloped tissue will require the implant body and shoulder to be placed more palatal to mask any titanium show-through. When implants are placed toward the palate, a slightly deeper placement (within the apicocoronal comfort zone) is required to allow for a proper emergence profile of the restoration. Adjacent implant placement challenges the treatment team's ability to place dental implants in a position that allows for subgingival shoulder location and an ideal emergence profile while maximizing the osseous crest height. In general, a patient with the combination of a high lip line and a thin biotype is extremely difficult to treat and should be considered an anatomic risk. Patients who fit into these treatment categories should be made aware of the challenges involved in obtaining an esthetic result before treatment begins.

Once the extraoral examination has been completed, a vision of the emergence and position of the

Table 5 Anatomic Site Analysis in the Anterior Maxilla

Factor	Areas for analysis
Location of the smile line	<ul style="list-style-type: none"> • High lip line • Medium lip line • Low lip line
Gingival morphotype	<ul style="list-style-type: none"> • Thin with highly scalloped gingiva • Thick with shallow scalloped gingiva
Interocclusal relationship	<ul style="list-style-type: none"> • Horizontal overlap • Vertical overlap
Dimensions of edentulous gap	<ul style="list-style-type: none"> • Mesiodistal gap size • Multiple missing tooth dimensions
Anatomy of alveolar crest	<ul style="list-style-type: none"> • Horizontal bone deficiency • Vertical bone deficiency
Status of adjacent dentition	<ul style="list-style-type: none"> • Crown integrity • Endodontic status • Periodontal status
Radiographic status	<ul style="list-style-type: none"> • Vertical bone height • Anatomic structures (eg, nasopalatal canal) • Position and axis of adjacent roots • Radiolucencies in alveolar process • Foreign bodies in alveolar process

definitive implant-supported restoration is vital for the diagnosis of hard and soft tissue deficiencies prior to implant placement. Retention of the restoration, whether with cement or screws, will play a role in positioning of the shoulder of the implant to allow for sufficient peri-implant tissue support and proper crown emergence. The use of diagnostic waxups and templates for determination of anatomic comfort and danger zones in the planning process will provide the team members with information that can help maximize esthetic outcomes. With this vision of the definitive restoration in hand, a comprehensive anatomic site analysis is possible.

Anatomic Site Analysis in Single-Tooth Gaps

As mentioned earlier, the single-tooth gap in the anterior maxilla is assessed in 3 dimensions based on a planned restoration and the surrounding teeth. Single-tooth sites offer less of a challenge because of the ability to use the adjacent teeth as landmarks in planning. With this in mind, several key analyses must still take place prior to commencing with implant placement. A diagnostic waxup highlighting tissue deficiencies and final tooth positioning can assist in this planning process.

One of the first things to be assessed is orofacial ridge anatomy, including whether there is sufficient

crest width and the presence or absence of facial bone atrophy. Deficient alveolar crest width and/or facial bone atrophy require a bone augmentation procedure so that the implant can be positioned in a correct orofacial position. Depending on the extent and morphology of the bone defect, a simultaneous or staged approach is necessary. Clinical sounding and sophisticated radiographic techniques such as conventional tomograms, dental computerized tomograms (CTs) or volume CTs can assist in diagnosing deficiencies in this dimension.

Mesiodistally, the space should be equal to that of the adjacent tooth (centrals) or the contralateral tooth (laterals and canines). Excesses or deficiencies in these dimensions must be addressed through the use of orthodontics, enameloplasty, or restorative materials prior to implant placement. For patients with diastemas, it is necessary to decide whether to eliminate or maintain the space prior to implant placement, as this will affect the mesiodistal shoulder position. Guidelines for implant selection based on gap size can be found in Table 3.

The most critical assessment remains the apicocoronal dimension. Deficient tissue in this dimension can result from several factors: periodontal disease of the adjacent tooth/teeth, atrophy, trauma, infection, or a congenital abnormality. A tissue deficit in this dimension must be addressed and managed carefully throughout the course of treatment. Because of the complexity of vertical hard/soft tissue grafting, patients with this condition are placed in a high anatomic risk group. Patients with excess tissue height require attention as well. A bone-scalloping procedure will be required to allow placement of the implant shoulder in a subgingival position. The most efficient way to examine this position is through the use of a template highlighting the proposed gingival margin position of the implant restoration.

Interocclusal space must be addressed for reasons in addition to the obvious ones. Placing the long axis of the implant through the incisal edge of anterior teeth is beneficial for patients with excessive vertical overlap. A diagnostic waxup will highlight the potential difficulties in restoring the proposed implant and managing the patient's occlusion. Prior to placement of the dental implant, a radiographic survey should be performed. A radiographic template outlining the proposed implant position in the orofacial and mesiodistal dimensions with a metallic rod will help determine if the implant will interfere with adjacent tooth structure or vital anatomy.⁴⁵ Magnification and distortion of the imaging technique can be taken into account by inserting the known dimensions of the rod into the template.

Determination of the location of the nasopalatine foramen and the distance to the adjacent teeth and the floor of the nose are necessary for proper implant selection. If sectional imaging is not necessary, the periapical radiograph will generally provide sufficient information, with greater accuracy than a panoramic radiograph.⁶¹ Proper anatomic site analysis in conjunction with restorative-driven planning will optimize predictable esthetic results in the maxillary single-tooth gap.

Anatomic Site Analysis in Extended Edentulous Spaces

Patients with extended edentulous spaces present additional anatomic challenges, making it even more difficult to produce an esthetic result with any certainty. Varying clinical situations such as missing centrals, central and lateral, lateral and canine, or even several anterior teeth are possible, leading to an array of treatment obstacles. With the loss of an adjacent tooth or teeth, planning for implant placement will require a diagnostic waxup based on sound esthetic principles, tooth morphology, and occlusal schemes. Understanding the fundamental objectives in the anterior esthetic zone—such as tooth axis, interdental closure, gingival contours, balance of gingival levels, interdental contacts, tooth dimensions, and tooth form—will help produce a waxup that will dictate to the surgeon the goals necessary for replacement of the missing teeth and tissue.⁴⁶

The replacement of 2 missing central incisors with dental implants can often lead to an acceptable esthetic result because of the symmetric gingival margin positions and the ability to form an interim-implant papilla with the redundant nasopalatine tissue commonly found in that region. Placement of the implants in a strict apicocoronal position honoring the maxim “as shallow as possible, as deep as necessary” will help maintain the interimplant crest height and provide support for the peri-implant tissues (Figs 10a to 10c).

Patients with a thin gingival morphotype will be challenging because the implants will need to be placed closer to the palate and deeper to provide for proper emergence, thus increasing the potential for loss of interimplant tissue and resulting in a “black triangle” and/or broad contact points. Patients who are missing a central and a lateral incisor or a lateral incisor and a canine are clinically more challenging because the edentulous space is smaller and the interimplant soft tissue tends to be less voluminous (Figs 11a to 11c).

Replacement of several missing teeth with implants allows for the use of fixed partial dentures

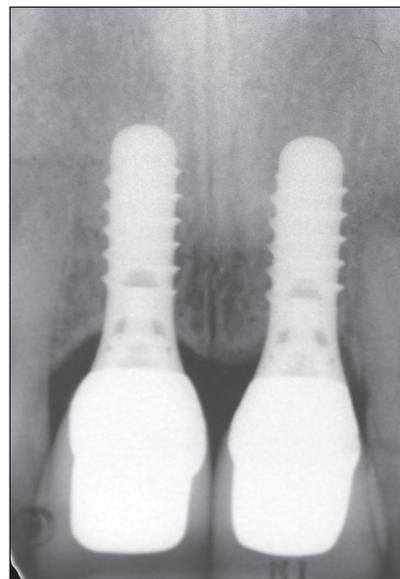


Fig 10a (Above) Two implants were placed in central incisor positions following the principle “as shallow as possible, as deep as necessary” to maintain as much of the interimplant papilla as possible.

Fig 10b (Center) Final treatment outcome shows a pleasing result, since the interimplant papilla was well maintained.

Fig 10c (Right) Periapical radiograph, taken 3 years after implant placement, shows minimal bone resorption around both implants.

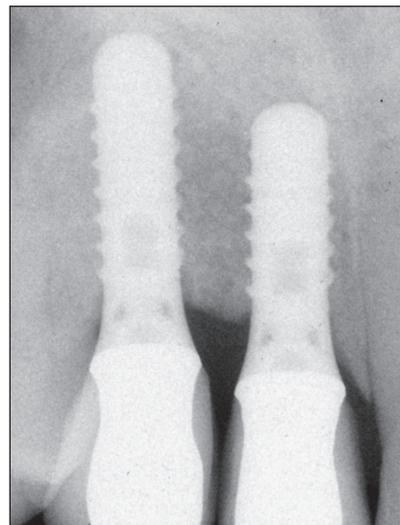


Fig 11a (Left) The esthetic result with 2 adjacent implants in the central and lateral positions is compromised because of a short interimplant papilla.

Fig 11b (Center) The esthetic result was still acceptable since the patient had a low lip line.

Fig 11c (Right) The radiograph at the 5-year examination shows stable bone crest levels with a flat bone crest between both implants.

and the opportunity to use ovate pontics to help support the tissues and form pseudo-papillae. Questions arise when bone augmentation procedures have been performed previously and pontics are used to restore the sites. Will the bone remain, or is there a need to place an implant in these sites to maintain the bone? Replacement of several missing teeth—eg, lateral-central-central-lateral—with implants requires maximizing placement in all 3 dimensions, avoiding embrasures, supragingival shoulders, and irregular gingival margins. Implant selection becomes critical, because the implant needs to provide for emergence as well as maintain peri-implant hard tissue support.

Following the template and planning procedures previously mentioned should allow the clinician to maximize the potential for an acceptable esthetic result in a difficult clinical situation. Future implant designs with anatomically contoured implant shoulders may benefit treatments of this type by improving interproximal tissue support.^{5,62,63}

SURGICAL PROCEDURES

Implant Selection

Based on the anatomic site analysis, the appropriate implant type is selected to best fit a single-tooth gap.



Fig 12a Correct implant positioning using a surgical template. The template imitates the future soft tissue margin at the implant crown.

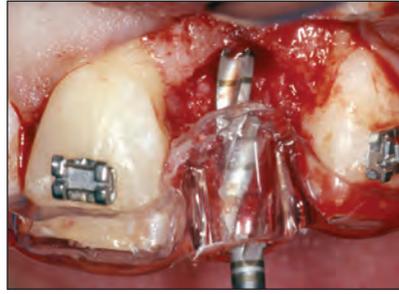


Fig 12b The spiral drill is guided by the surgical template for proper alignment.

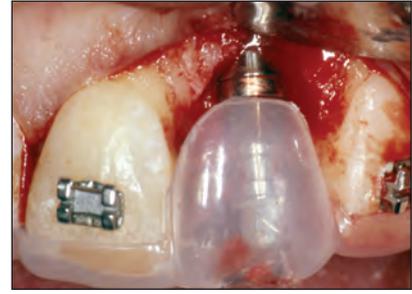


Fig 12c Status following implant placement. The implant shoulder is located about 2 mm apical to the future soft tissue margin.

In central incisors and canines, implants with a regular-neck configuration (shoulder diameter of 4.8 mm) are most often used. The minimal mesiodistal gap size for such a standard-neck implant is 7 mm, whereas 8 to 9 mm are ideal to allow a sufficient distance to adjacent roots (Table 3). The narrow-neck implant with a shoulder diameter of 3.5 mm is most often used in lateral incisor areas with a minimal gap size of 5.5 mm. The TE implants, mainly developed for placement in extraction socket defects, are offered with 2 different neck diameters: regular and wide. In the anterior maxilla, the 2 TE implant types with the regular-neck configuration (diameter of 4.8 mm) are used for standard prosthetic procedures. The wide-neck configuration (shoulder diameter of 6.5 mm) should only be used in exceptional clinical situations because of its potential for reaching too far facially and/or proximally.

Surgical Templates

The use of surgical templates in the anterior maxilla can be valuable to properly place the implant shoulder in a position that will allow for an ideal emergence profile and long-term peri-implant hard and soft tissue support.^{3,4,7} Templates are mandatory for implant treatment of extended edentulous spaces. Many variations of surgical templates exist. Good templates should have the following features: they should be easy to place and remove, they should be rigid and stable, they must allow for placement and removal of bite blocks when possible, and they must not interfere with tissue reflection and visualization of the depth indicators or the cooling of the surgical drills. A key feature of a surgical template used in the anterior maxilla is designation of the final apico-coronal, mesiodistal, and orofacial positioning of the implant shoulder. The best way to indicate these positions is to complete a diagnostic waxup highlighting the final gingival margin position, facial surface, and embrasure form of the proposed restoration. Working backward from this waxup

generates a template that will place the implant in a position that will support the planned restoration (Figs 12a to 12c) and make restoring it easier.

It is clear that templates can be helpful in making anterior esthetics more predictable and reliable. However, they are only as good as the team that uses them. Communication between the restorative clinician making the template and the surgeon using it is imperative, so that they can agree on a design that will make the placement process efficient and accurate.

Surgical Procedures in Single-Tooth Gaps

Under local anesthesia, the mucosa is opened with a crestal incision located approximately 2 to 3 mm toward the palatal aspect and extended through the sulcus of adjacent teeth to the facial aspect of the alveolar crest. This incision avoids the formation of scar tissue in the midcrestal area and ensures sufficient vascularity of the facial flap in the area of the future papillae. Facial line-angle relieving incisions are most often necessary to allow sufficient access to the surgical site (Figs 13a and 13b). In patients who need a bone augmentation procedure, this flap design also allows for tension-free wound closure with the release of the periosteum and a coronal mobilization of the flap. As an alternative, a parapapillary incision technique may be used. Implant placement without flap elevation (often called “flapless implant placement”) is considered experimental, because no clinical studies with sufficient data have been published yet.

After the incisions have been made, the facial and palatal mucoperiosteal flaps are elevated with a fine tissue elevator to guarantee low-trauma soft tissue handling. This is followed by an intrasurgical site analysis to evaluate the facial aspect of the alveolar crest. For implant sites in the central incisor area, location of the nasopalatal foramen must be determined. A crest-flattening or bone-scalloping procedure is recommended, since this facilitates easier and more precise preparation of the implant bed

and the natural shape of the alveolar crest is imitated. However, the surgeon should not remove any bone in the proximal area of adjacent teeth, because this bone is important for the support and maintenance of the papillae.

The precise position of the implant site is marked with small round burs. Correct 3-dimensional implant placement can be determined by using either a periodontal probe and landmarks of adjacent teeth²¹ or a prefabricated surgical template with a built-in gingival margin for the future implant crown.⁴⁵ Both techniques provide sufficient guidance in single-tooth gaps.

Preparation of the implant bed is carried out with standard spiral drills of increasing diameter (2.2 mm, 2.8 mm, and 3.5 mm). This technique reduces the trauma to the bone tissue and gives the surgeon a chance to change the position of the implant and/or the direction of the implant axis between drill steps. As previously outlined, the objective is to position the implant shoulder within the comfort zones in all 3 dimensions. To ensure correct esthetic implant placement, the entrance of the bone cavity has to be prepared with the profile drill to allow deeper implant placement. In addition, implants with a short neck configuration are most often used to limit the amount of bone resorption in the crestal area.

During bone preparation, different depth gauges help the surgeon to control the future implant position in the mesiodistal, orofacial, and apicocoronal directions, as well as the implant axis (Figs 13c and 13d). Pretapping of the thread is rarely done in the anterior maxilla. Most often, self-tapping implants are used, since the bone structure in the anterior maxilla is rather spongy. Implant placement is performed either with an adapter attached to a special contra-angle handpiece (at 15 rpm) or with the hand ratchet. Following implant placement, primary stability of the implant is carefully checked.

An appropriate healing cap is then selected. It is recommended that a healing cap be used that covers the implant shoulder, such as the 1.5-mm cover screw (Figs 13e and 13f) or an esthetic healing cap with a buccal bevel, which is available in 2 heights (2 mm and 3.5 mm). All these healing caps have the advantage that no bone can grow on top of the implant shoulder during healing, and the caps support the soft tissues in the proximal area. The buccal bevel of the esthetic healing cap will also allow for additional space for the interim restoration during the healing phase.

In the case of a peri-implant bone defect, either with an intact or a deficient facial bone wall, a local bone augmentation procedure is recommended.

Today, the GBR procedure, ie, applying barrier membranes in combination with bone grafts and/or bone substitutes, is routinely used (Figs 13g to 13j). The goal of GBR is to establish a thick facial bone wall of at least 2 to 3 mm to achieve sufficient and long-lasting bone support for the facial soft tissues. Improvement of soft tissue esthetics can also be achieved with soft tissue grafting at implant placement.²¹ In patients with thin soft tissues and/or a concave contour of the facial mucosa, a connective tissue graft can be used to improve the thickness and contour of the soft tissues. These grafts are harvested in the premolar area of the palate and can be sutured to the periosteum of the mucoperiosteal flap to avoid displacement of the graft during wound closure.

Prior to completion of the surgical procedure, the mucoperiosteal flap is repositioned precisely, particularly in the area of the future papillae. The surgeon has to make sure that wound closure is precise and tension-free. To achieve this, an incision of the periosteum is often necessary to release the flap in a coronal direction (Fig 13k). For suturing, fine atraumatic suture material (5-0) is recommended. Following surgery, a periapical radiograph is taken to examine the position and direction of the placed implant and its relationship to the roots of adjacent teeth (Fig 13l).

Surgical Procedures in Extended Edentulous Spaces

In implant sites with multiple missing teeth, the surgical procedure is clearly more demanding and requires optimal preoperative planning and an implant surgeon with sufficient experience. The use of an appropriate surgical template is mandatory to enable correct 3-dimensional implant positioning in the mesiodistal, orofacial, and apicocoronal directions. In sites with adjacent implants, an additional aspect needs to be considered: the interimplant distance. In such sites, bone resorption of 1 to 2 mm at the proximal aspects of the implant leads to a flattening of the interimplant bone and consequently a short interimplant papilla. A distance of at least 3 mm has been recommended between 2 adjacent implants to minimize this bone resorption.⁴¹ This recommendation seems logical based on current knowledge, but no clinical and radiographic studies are yet available to support it.

The surgical procedures with regard to incision technique, flap design, bone preparation, and implant placement in extended edentulous spaces follow the same guidelines as previously outlined. Such sites most often also have horizontal and/or vertical bone deficiencies. Therefore, bone augmentation



Fig 13a Single-tooth gap in the central incisor area. Status 8 weeks following tooth extraction. A palatal incision will be used about 3 mm from the middle of the crest.



Fig 13b The surgical site is exposed with a full-thickness flap using 2 distal-line-angle relieving incisions.

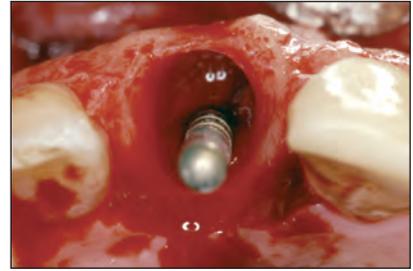


Fig 13c Following preparation with the first round burs and drills, the depth gauge is inserted to examine the future implant position and axis. Note the palatal position of the pin in relation to the extraction socket.



Fig 13d The second depth gauge, with a built-in 5-mm ring, is used to check the proximity of the future implant shoulder to adjacent root surfaces.

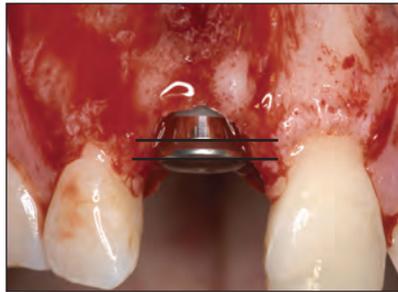


Fig 13e Status following implant placement and insertion of 1.5-mm large healing cap to cover the implant shoulder. Note the correct apicocoronary position of the implant shoulder, about 1 mm apical to the CEJ of the adjacent contralateral tooth (*line*).

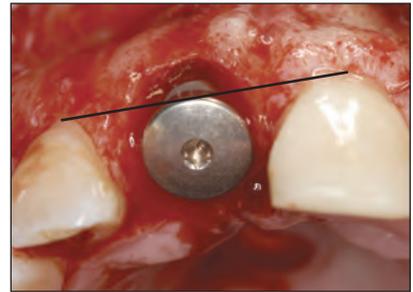


Fig 13f The occlusal view confirms the correct orofacial position of the implant shoulder being slightly palatal to the point of emergence of the contralateral central incisor (*line*). Note the minor bone defect at the facial aspect, which requires bone grafting.



Fig 13g The facial bone defect is filled with autogenous bone chips harvested in the vicinity, such as the anterior nasal spine.



Fig 13h A second layer of bone substitute is used to overaugment the surgical site. A bone filler with a low substitution rate (Bio-Oss) is preferred.



Fig 13i The augmentation material is covered with a collagen-based barrier membrane using the principles of GBR. Two membrane strips are used ("double layer technique") to improve membrane stability.



Fig 13j (Left) The occlusal view clearly shows how the alveolar crest was locally overaugmented.



Fig 13k (Center) Following incision of the periosteum, the flap is mobilized coronally, and a tension-free primary wound closure is obtained. To close the wound, 5-0 and 6-0 nonresorbable suture material is used.

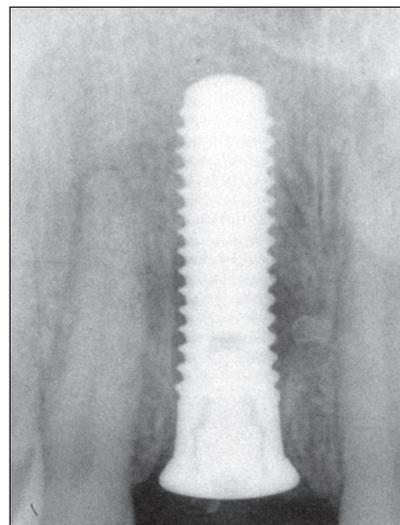


Fig 13l (Right) Periapical postsurgical radiograph. Note the minor radiolucency in the middle of the implant.



Fig 13m Soft tissue status at 8 weeks of healing. The site is ready for reopening to gain access to the implant shoulder and initiate the restorative phase.



Fig 13n The reopening was done with a 12b blade, removing some keratinized mucosa slightly palatal to the healing cap. A larger healing cap was inserted to compress the soft tissues slightly to the facial aspect.



Fig 13o Status a few weeks following placement of the provisional crown based on a titanium coping. The shape of the provisional restoration was used for soft tissue conditioning.



Fig 13p (Above) Status 12 months following implant placement. The definitive ceramometallic crown has been seated. The esthetic result is pleasing with a harmonious gingival margin and intact papillae.

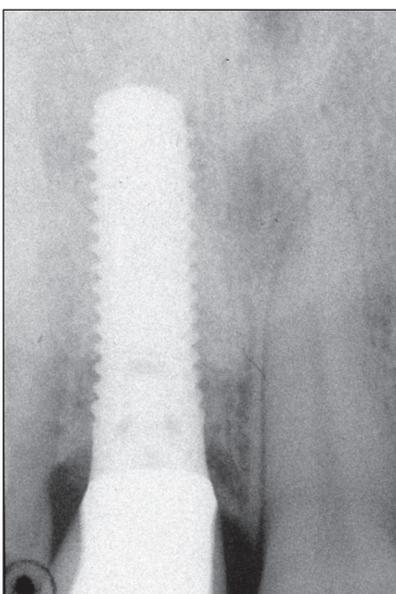


Fig 13q (Right) The periapical radiograph at 12 months with the definitive crown indicates minimal bone resorption.



Fig 13r Final treatment outcome of this 27-year-old female patient with a high lip line.

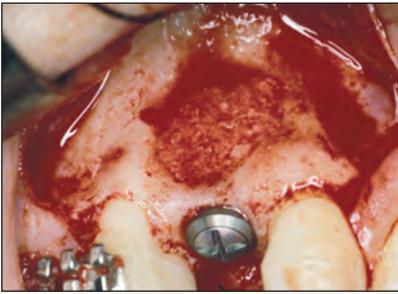


Fig 14a Intraoperative status following placement of a standard screw implant in area 13 in a correct 3-dimensional position and an intact facial bone wall in the crestal area. An apical fenestration defect was augmented with locally harvested autogenous bone grafts.



Fig 14b Submerged implant healing for 3 months was chosen for this patient in 1992.



Fig 14c Three months following implant placement, a thin facial mucosa was apparent, requiring soft tissue graft at the re-opening procedure.

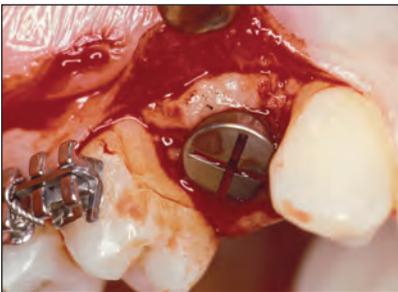


Fig 14d At re-opening, a free connective tissue graft was applied to improve the thickness of the facial soft tissues.



Fig 14e Clinical status during the phase of provisional restoration demonstrates the convex facial soft tissue margin at the right level.

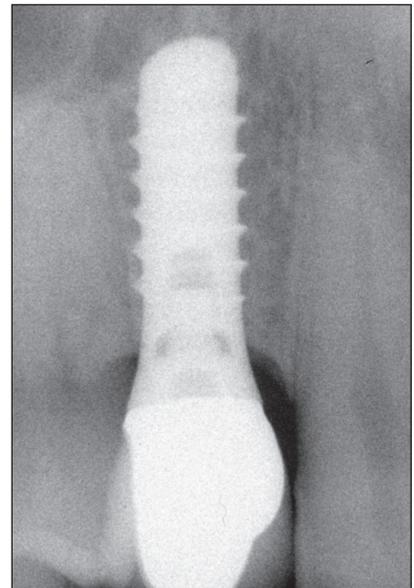


Fig 14f (Left) Clinical status at 12 years following implant placement (2004) demonstrates remarkable soft tissue stability at the mid-facial margin and nice convex contour of the facial mucosa.



Fig 14g (Center) Esthetic result with the lip line.

Fig 14h (Right) The periapical radiograph 12 years following implant placement confirms stable bone crest values around the standard screw implant.



procedures are common in sites with multiple missing teeth, using either a simultaneous or a staged approach.

Interim Restoration

Delivery of an appropriate interim restoration at the time of implant placement in the anterior maxilla is paramount for patient satisfaction and peri-implant tissue protection. Fabrication of an interim

restoration that will not place intermittent pressure on the healing cap and tissues is recommended. For this reason, removable partial dentures should be adjusted to prevent these contacts, which can cause difficulty in patients with limited interocclusal space or excessive vertical overlap. Interim restorations that are fixed to the adjacent teeth or that completely eliminate the possibility for soft tissue contacts are more beneficial for implant integration and

soft tissue maintenance. Orthodontic brackets and archwires on several teeth adjacent to the implant site, with an attached pontic, offer a low-maintenance option for patients undergoing long-term therapy, eg, hard/soft tissue grafting prior to implant placement. Patients without excessive vertical overlap can benefit from interim resin-retained fixed partial dentures that are retained with spot etching and bonding with an appropriate composite material on the adjacent teeth. In limited interocclusal space or excessive vertical overlap situations, an Essix retainer with an acrylic resin restoration can be used in the edentulous space.⁶⁴ These restorations offer good esthetic results for short periods; however, patient compliance is important in preventing rapid occlusal wear through the template material.

Postsurgical Treatment and Re-entry Procedure

During the soft tissue healing period of 2 to 3 weeks, chemical plaque control with chlorhexidine digluconate (0.12%) is recommended. Mechanical toothbrushing is abandoned at the surgical sites for at least 2 weeks. Follow-up visits are recommended after 7, 14, and 21 days, with clinical examination and wound cleaning. The sutures are removed after 7 to 10 days.

Bone healing for implants with an SLA surface (sandblasted, large-grit, acid-etched; Straumann) is sufficiently progressed after 6 weeks in standard sites without peri-implant bone defects.^{65,66} In sites with peri-implant bone defects requiring a simultaneous bone augmentation procedure, the healing period has to be extended for as many as 12 weeks depending on the extent and morphology of the bone defect present at implant placement.

At completion of the bone healing period (Figs 13m and 13n), a reopening procedure is performed with a blade or a tissue punch to expose the implant and initiate the soft tissue conditioning. A tissue punch should be used only in sites with an abundance of keratinized mucosa, because it is a process that removes valuable tissue. In most cases, the reopening is performed with a 13b blade from a slightly palatal aspect to allow for tissue pressure in a facial and proximal direction. After removal of the originally placed healing cap, a longer healing cap or provisional restoration is placed to initiate the soft tissue support (Fig 13n). With the synOcta design (Straumann), an impression can be made on the day of reopening to fabricate the provisional restoration and 3 to 6 months later for the definitive restoration (Figs 13o to 13r). Another case report with long-term follow-up is shown in Figs 14a to 14h.

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Prosthetic Management of Implants in the Esthetic Zone

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The purpose of this article is to review and project treatment procedures for areas of esthetic concern. The authors were participants in a consensus conference sponsored by ITI and held in August 2003 in Gstaad, Switzerland. This article deals with the basic prosthetic/restorative aspects in implant esthetics. It is based on a literature review performed by 16 participants from Group 2 (Buser et al) in this section of the Journal. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):62-72

Key words: dental implants, esthetics, implant abutments, implant diameter, provisional restorations

An esthetic area can be defined as any area to be restored that is visible in the patient's full smile. An esthetic implant restoration is one that resembles a natural tooth in all aspects.¹⁻⁵ The position in which the implant is placed is of utmost importance, and the implant should be thought of as an extension of the clinical crown into the alveolar bone.⁶ This is only possible if the implant is correctly located in all 3 dimensions: apicocoronally, mesiodistally, and faciolingually.¹ Any deviation from these dimensions results in a problem the dental technician can scarcely solve. Choosing the appropriate time to place the implant into function

is the surgeon's choice. The surgeon's judgment precludes timetables and other potential standards.^{7,8}

CONSIDERATIONS FOR ESTHETIC SITES

The restorative dentist needs to work with the surgeon, and both need to understand that certain principles are prerequisites for esthetic success.^{4,9-11} These may include but are not limited to the following:

1. The edentulous site must first exhibit adequate bone volume for the placement of a dental implant. If the site is deficient, there are many techniques that can be used for site development, some of which may be accomplished at time of implant placement.¹² In other instances it is best to augment the site in a separate procedure.
2. The placement position needs to be precise, as has been described in previous articles.
3. The abutment interface or connection needs to be stable.
4. The microgap between the implant and the abutment must be as small as possible.¹³

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Fig 1 Peri-implant space created around root-form dental implants.



Fig 2 Photograph of metal-ceramic implant-supported restorations in lateral incisor positions 7 years postplacement.



Fig 3 A flat gingival scallop in a mandibular posterior quadrant provides a shallow gingival crown margin interproximally.



Fig 4 Anterior implant placement dictates deeper placement and a deep interproximal margin.



Fig 5 Multiple missing tooth gaps do not require an implant for each missing tooth.



Fig 6 Fixed partial denture replacing multiple missing teeth.

5. Esthetic restorations should be designed to have an appropriate “emergence profile”¹⁴ and not a ridge lap.
6. The restoration should have the same appearance as the adjacent teeth (Figs 1 and 2).

Implant Placement Considerations

Placement depth is an important aspect of an esthetic restoration. There must be good communication between the surgeon and the restorative clinician relative to proper implant positioning. In the posterior quadrants, where the gingival scallop is relatively flat, the implant shoulder may be at the gingival level or only slightly below it (Fig 3). However, depending on tissue thickness, implants may be placed slightly deeper. This does not present a problem in most posterior situations, because a flat gingival scallop allows access for cement removal and oral hygiene by the patient.

In most esthetic areas the implant shoulder is located 2 mm below the midfacial gingival margin (Fig 4). In these sites the gingival scallop is usually more pronounced, resulting in an interproximal margin as deep as 5 to 7 mm. This shoulder location makes seating of the restoration and cement removal difficult. Therefore, the treatment of choice should be screw-retained restorations.

The placement of single implant restorations is a well-documented and predictable procedure.^{15–19}

Therefore, an implant can be the preferred treatment option in most patients. Multiple missing teeth require greater attention to detail and treatment planning.²⁰ Spacing issues and the number of implants are critical.^{21–23} Generally, it is accepted that adjacent implants are a treatment challenge because interimplant bone resorption leads to a lack of soft tissue support^{24–26} (Fig 5). In some instances involving multiple missing teeth, an implant-supported fixed partial denture may be a more desirable choice. Better esthetic results can be achieved with ovate pontics than would be possible with adjacent implants^{12,27} (Fig 6).

Interim Restorations During the Healing Period

Interim restorations may not be required outside of the esthetic zone. In the esthetic zone, there are several treatment options for patients requiring interim tooth replacement.²⁸ A simple solution for a provisional restoration at the surgery, or to serve the patient until the restorative practitioner is seen, is to place a vacuform matrix with a denture tooth. The second and most frequently used option is an interim removable partial denture (Figs 7a to 7c). It is easily fabricated and simple for the surgeon or restorative clinician to fit. Care must be taken to prevent the gingival portion of the interim partial denture from contacting an exposed healing abutment. A third option, for the more demanding



Fig 7a Single-tooth gaps in the anterior maxilla.

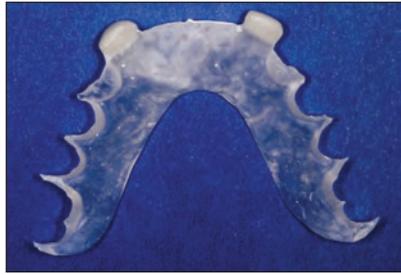


Fig 7b Interim removable partial denture.



Fig 7c Interim removable partial denture in place.



Fig 8a (Left) Healing implant in central incisor position.



Fig 8b (Right) Composite pontic bonded to adjacent teeth.



Fig 9a Prepared teeth adjacent to integrating implants.



Fig 9b Fixed provisional restoration in place.

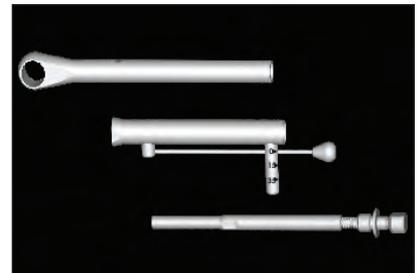


Fig 10 Straumann ratchet and torque control device.

patient who does not want a removable prosthesis, is a bonded restoration. This type of restoration may be appropriate for a patient who will require long healing periods. A denture tooth, composite pontic, or the clinical crown of the previously failed restoration may be bonded to the adjacent teeth (Figs 8a and 8b). Finally, a provisional fixed partial denture may also be used in instances where the adjacent teeth are to receive crowns as part of the final treatment (Figs 9a and 9b).

Abutment Connections

All Straumann abutments (Waldenburg, Switzerland) are seated and tightened to 35 Ncm.²⁹ Tightening of the abutment is performed using the appropriate abutment driver or the SCS screwdriver (Straumann) in conjunction with a ratchet and torque control device (Fig 10). The healing abutment is removed and the internal configuration of

the implant is irrigated with an appropriate disinfectant. The implant is rinsed with water and air dried, and the abutment is placed without adhesive or cement. Abutment connections should be performed without local anesthesia. The patient may experience sensitivity during the abutment-tightening procedure, and the clinician has the opportunity to stop prior to mobilization of the implant. In these instances, which are extremely rare, the patient can return after 1 month and the abutment can then be tightened to 35 Ncm without incident.

RESTORATIVE OPTIONS/ ABUTMENT SELECTION

There are multiple abutments for use in esthetic areas. The primary concern is accurate fit of the crown margin to the implant shoulder, with no



Fig 11a The healing abutment is removed from implant after 6 weeks of



Fig 11b A 4-mm solid abutment is placed as the restorative abutment.



Fig 11c Solid abutment driver and ratchet with torque control device tightening the solid abutment to 35 Ncm.



Fig 11d The impression coping is snapped into place and the appropriate positioning cylinder is seated.

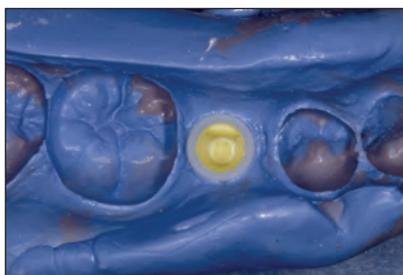


Fig 11e The impression coping is picked up in a 2-phase polyvinyl impression material.



Fig 11f A provisional restoration is placed during the period of fabricating a definitive restoration.



Fig 11g The provisional restoration has shaped the peri-implant soft tissues. This becomes more important the deeper the implant shoulder is placed.



Fig 11h An all-ceramic definitive restoration is fabricated.



Fig 11i The definitive restoration is cemented into place.

inclusion of cement.³⁰ There are several options for accomplishing this goal. Guidelines for selection can sometimes be standardized.

The solid abutment is the most frequently used abutment in the Straumann Implant System. It is the primary abutment for posterior single and multiple tooth restorations in the partially edentulous patient. It may also be used in the anterior region with the understanding that the interproximal margin is usually deep. The solid abutment is inserted into the implant after removal of the healing abutment. The abutment is torqued to 35 Ncm with the solid abutment driver and torque controller (Figs 11a to 11c). An impression cap is inserted and the positioning cylinder is seated (Fig 11d). An impression is made and sent to the laboratory for crown fabrication (Fig 11e). The solid abutment may be protected with a

protective cap or a provisional restoration can be fabricated (Fig 11f). Placement of a customized provisional restoration is advisable in esthetic situations to shape the gingival tissues (Fig 11g). A definitive restoration is fabricated and returned for placement (Figs 11h and 11i). The solid abutment is the only abutment for which an impression is made directly in the mouth. If the solid abutment is not chosen, a direct implant-level impression is preferred.

Impressions or indexing of the implant may be performed at any time. Typically, the implant is indexed either at the time of surgery or at the start of the restorative procedure. The 2-part Straumann implant has an internal octagon/Morse taper, termed *synOcta*.²⁹ This internal feature allows the implant to be indexed directly with the *synOcta* screw-retained impression coping for an open-tray



Fig 12a (Left) synOcta 1.5-mm abutments are seated and torqued to 35 Ncm.

Fig 12b (Right) Cast custom abutments, which control angulation and margin level for a cemented crown.



Fig 12c (Left) Custom abutments are seated with 4-mm occlusal screws.

Fig 12d (Right) Definitive cemented restorations.

impression, or the impression cap can be used in conjunction with the synOcta positioning cylinder for a closed-tray impression technique. If indexing is performed at the time of implant placement, the surgeon or restorative clinician places the appropriate impression coping. Using the surgical template or a separate indexing template, the impression coping is fixed to the template device with autopolymerizing resin. The laboratory will retrofit a synOcta analog to a presurgical cast. This new working cast can then be used to fabricate a provisional restoration to be delivered at the time of reopening surgery or when the restorative procedure is initiated. Neither method of making an implant-level impression obligates the restorative clinician to select the abutment during the operation. Abutment selection is made on the working cast in the laboratory. This process requires collaboration between the laboratory technician and the clinician.

The synOcta 1.5-mm abutment is the primary abutment of choice for esthetic screw-retained restorations. This technique provides a machined connection to the implant and avoids the problem of cement left deep interproximally. The abutment may be placed in the mouth at the start of the restorative procedure and an impression made, similar to what has been done with the standard octabutment. An implant-level impression may also be made as previously described, with the abutment selected in the laboratory. The laboratory technician selects the appropriate gold coping and applies wax and casts a metal framework. Porcelain is applied and baked to the substructure and a definitive crown is produced. The crown and the abut-

ment are returned to the clinician for placement. The abutment is seated and tightened to 35 Ncm. The crown is placed and retained by a 4-mm SCS occlusal screw tightened to 15 Ncm.

If the anatomy of the anterior maxilla and the resulting implant axis does not allow a direct screw-retained crown to be attached to the implant, angular corrections are necessary. There are many options to correct angulation.

The synOcta 1.5-mm abutment is chosen in the laboratory and placed on the working cast. Wax is added to a gold coping to simulate the finish line of a prepared tooth, and a casting is produced. This casting is the custom abutment for a cemented crown. The custom abutment is placed on the implant over the abutment. This screw-retained casting provides a machined margin at the microgap level while correcting angulations, and raises the marginal termination to be compatible for a cemented restoration. The custom abutment is secured by a 4-mm SCS occlusal screw tightened to 15 Ncm (Figs 12a to 12d).

The transverse screw abutment (TS) also provides a method of angulation correction, using a lingual path of insertion for the hexagonal fixation screw. The TS abutment is fitted to the laboratory working cast, and a transverse screw coping of gold or delrin is seated. The coping is modified with wax and cast to form a metal framework for porcelain application. The definitive crown and the TS abutment are then returned to the clinician for placement. Using an abutment index, the TS abutment is placed within the implant and torqued to 35 Ncm. The crown is placed and secured with a lingual set

Fig 13a (Left) The transverse screw abutment (TS) is seated and torqued to 35 Ncm.

Fig 13b (Right) The definitive crown, with hex set screw and screwdriver, ready for placement in the mouth.



Fig 13c (Left) Palatal view of the seated TS restoration. The set screw is covered with rubber-sep and composite resin.

Fig 13d (Right) Facial appearance of the final TS restoration.



screw and then hand tightened (to 10 to 15 Ncm) utilizing the TS driver (Figs 13a to 13d).

The ceramic component can also correct angulation if used as a meso-structure—yet another option for esthetic situations. Since it is tooth colored, this coping may also be valuable in areas with thin gingival tissues that would transmit unfavorable color from metallic substructures. The ceramic coping is selected in the laboratory after an implant-level impression is fitted with a synOcta 1.5-mm analog. The ceramic component is provided in the form of an immature aluminous porcelain blank, which can be prepared to provide a direct base for porcelain application or as a custom abutment for a cemented crown. An all-ceramic crown is fabricated for cementation. If screw access is favorable, the ceramic component is suitable for direct porcelain application and a screw-retained implant restoration is created. The ceramic component or crown is secured to a synOcta 2.5-mm abutment on the implant by a special 4-mm occlusal screw tightened to 35 Ncm. Screw access openings are sealed with an appropriate material (Figs 14a to 14e).

The meso-abutment is a machinable abutment made of titanium whose connection fits directly into the implant body. It may be used in place of a custom abutment on a synOcta 1.5-mm abutment. To restore a site using the meso-abutment, the laboratory technician places the abutment on the working cast and shapes it to correct any angulation problems and to alter the marginal level for a cemented restoration. A cementable crown is fabricated and returned to the clinician with the modified meso-abutment. The meso-abutment is seated into the implant and the

abutment screw is torqued to 35 Ncm. The definitive crown is then cemented (Figs 15a to 15e).

A cementable approach may also be initiated in the laboratory. The synOcta 5.5-mm abutment can be used to fabricate a definitive restoration and be delivered at the same time the definitive restoration is placed (Figs 16a to 16c).

Abutments angled at 15 and 20 degrees may also be chosen in the laboratory using an abutment selection kit and an implant-level laboratory cast. These abutments are used for cementation and have properties similar to those of solid abutments, but they are selected in the laboratory. The angled abutment may also be used for screw retention, which solves the cement removal problem in instances of deep margin placement (Figs 17a to 17c).

Cementation Procedures

Cemented crown margins placed at the implant shoulder—such as those fabricated on solid abutments, the synOcta 5.5-mm abutments, and the angled abutments—must be handled carefully. These crown margins do not have the same marginal integrity as those made on premachined gold copings. In anterior esthetic applications, these crown margins may also be quite deep interproximally. Care needs to be taken to avoid leaving any cement during the cementation procedure. Cement exclusion may be addressed by careful application of minimal amounts of cement.^{29,31,32} It is also helpful, prior to placing a cemented restoration in the mouth, to apply cement to the crown and place it on an analog or practice abutment. Excess cement is extruded and can be removed while the crown is on

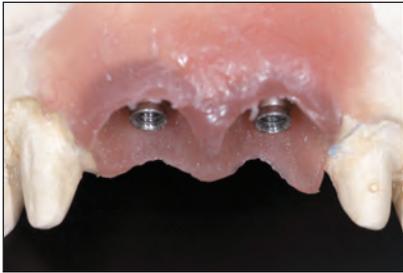


Fig 14a (Left) Provisional restoration generated by the soft tissue model, with abutment in place.

Fig 14b (Right) Immature ceramic is shaped to form a custom abutment.



Fig 14c Abutments seated and tightened to 35 Ncm.

Fig 14d Ceramic components seated with special 4-mm occlusal screw. The occlusal screw is tightened to 15 Ncm.

Fig 14e Final appearance of all-ceramic restorations.



Fig 15a (Left) The meso-abutment. Note that this is a 2-piece abutment that fits directly into the implant. This provides the same function as the synOcta 1.5-mm abutment and a cast custom abutment.

Fig 15b (Right) Unaltered meso-abutment on a soft tissue working cast.

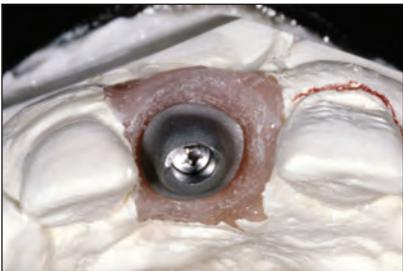


Fig 15c The meso-abutment is shaped to control angulation and cement line.

Fig 15d The meso-abutment seated in the mouth and torqued to 35 Ncm. This serves as a customized base for a cemented crown.

Fig 15e Definitive cemented porcelain-fused-to-metal restoration. Angulation and cement line are controlled with one component.

the analog. The crown is immediately removed from the analog and placed in the mouth without the application of any additional cement.

PROVISIONAL AND DEFINITIVE RESTORATIONS

It is preferable to place provisional restorations on the implant at the time the restorative procedure is

started.³³⁻³⁵ However, after impression making, it is also possible for the clinician to merely replace the healing abutment and temporary restoration that have been in place during the healing period. The most important benefit of provisionalization at the start of the restorative procedure is shaping of the peri-implant tissues.³⁶ This process will establish a natural and esthetic soft tissue form that will determine guidelines for laboratory fabrication of an anatomically appropriate soft tissue model. The provisional



Fig 16a The definitive crown and abutment will be placed at the same time by the clinician. They will fit in the mouth exactly as on the laboratory working cast.



Fig 16b The 5.5-mm abutment placed in the mouth. The abutment is torqued to 35 Ncm.



Fig 16c Definitive porcelain-fused-to-metal restoration cemented into place.



Fig 17a Three angled abutments are selected using the abutment selection kit and the working casts in the laboratory.



Fig 17b Two 15A and one 20A abutments are selected by the laboratory technician and placed in the mouth. The abutment screws are tightened to 35 Ncm.



Fig 17c Definitive restoration cemented over the three angled abutments.



Fig 18a The provisional restoration is finalized and polished in the laboratory.



Fig 18b The completed provisional restoration is seated for guided tissue shaping.



Fig 18c The shaped peri-implant space is ready to accommodate an emergence profile restoration.

restoration may be fabricated in the laboratory on a temporization coping. The clinician may also use the temporization coping chairside to fabricate a screw-retained provisional restoration. In some instances a solid abutment may also be used to support a cemented provisional restoration. In addition, with esthetic implant placement, it is difficult to fully seat a definitive restoration if the peri-implant tissues have not been shaped with emergence-profile provisional restorations (Figs 18a to 18c).

The previously mentioned restorative abutment options have little validity in esthetic situations if the laboratory does not have an accurate soft tissue

model with which to plan and fabricate the final termination point of the definite restoration and its contour. An anatomically correct cast may be fabricated by transferring the subgingival contours of the provisional restoration to the working cast. This may be accomplished with a custom impression coping or by retrofitting the provisional to the working cast.

Implant Necks

The standard-neck ITI implant is 4.8 mm wide at the implant shoulder and comes in a 4.1-mm solid screw, a 3.3-mm solid screw, a 4.1-mm TE solid screw, and a 3.3-mm TE solid screw. All restorative



Fig 19a (Left) Two narrow neck implants (NNI) at the end of a 12-week healing period.

Fig 19b (Right) Right custom abutment seated in the mouth with 1.8-mm occlusal screw tightened to 35 Ncm.



Fig 19c (Left) Left custom abutment seated in the mouth with 1.8-mm occlusal screw tightened to 35 Ncm.

Fig 19d (Right) Definitive porcelain-fused-to-metal cemented restorations in place.

options are standardized for any of the implant bodies. All components are interchangeable. It is vital that great flexibility be available in the option to not select and place a definitive abutment at the time of initiation of the restorative procedure. Therefore, an implant-level impression and laboratory selection of components are recommended if the solid abutment is not used.

The narrow-neck implant (NNI) has a neck dimension of 3.5 mm on a 3.3-mm solid screw. It is used in missing tooth gaps of 7 mm or less. Restoration of the NNI is initiated at 12 weeks after placement. The use of early loading protocols is not recommended with the NNI. The restorative procedure is initiated with an implant-level impression. Impressions may be made with a screw-retained coping for open-tray impressions or a snap coping for simplified closed-tray impressions. Components used to affix restorations to NNI include a 9-mm titanium coping, an oxidizing gold coping for porcelain application, a nonoxidizing gold coping for fabrication of custom abutments, and a 15-degree angled abutment. In most instances a restoration on the NNI is cemented over one of these abutments or copings. In some instances, conditions may be optimal for screw retention using one of the NNI gold copings as a basis for a screw-retained crown. These situations are few because of the anatomic restrictions of such a small restoration. For routine use, the titanium coping is recommended for fabrication of both provisional and definitive restorations. Each of these components allows for customization by the clinician or technician to control the cement line and to accomplish angulation changes. The screw used to

attach abutments and copings to the NNI is a titanium alloy screw 1.8 mm in diameter. The chosen abutment should be torqued to 35 Ncm at the time the definitive restoration is placed. If the implant is placed into function at 12 weeks, the provisional abutment should only be hand tightened. Definitive restorations may be seated with provisional cement; this way, if the occlusal screw securing the abutment should loosen, the crown could be removed to allow retightening of the NNI occlusal screw (Figs 19a to 19d).

There are probably few instances that will allow the use of the wide-neck implant (a 4.8-mm solid screw) with the 6.5-mm top TE implant. In those special instances requiring the 6.5-mm top, it is used with the same components that are available for the standard 6.5-mm-shoulder implant (Figs 20a and 20b).

Definitive Restorative Materials

The standard restoration for an implant-supported prosthesis is the porcelain-fused-to-high-noble-metal restoration (PFM). There is usually sufficient space to allow for adequate thickness of metal, opaque, and ceramic materials in the fabrication of natural-appearing restorations. All-ceramic restorations using aluminous or zirconia cores are also possible, especially for application with porcelain abutments. Anterior teeth and premolars can be restored without considerable risk. However, for molar implant reconstructions, the ceramic cores need to be designed very carefully to provide adequate support for layering porcelains. Failure to do this will lead to porcelain fractures.

Fig 20a (Left) Occlusal view showing the shaped peri-implant tissues.

Fig 20b (Right) Definitive emergence profile restoration cemented into place.



Occlusal Considerations

Occlusal contacts for implant restorations should follow the same principles as those for natural teeth. There should be consecutive contact between centric relation and centric occlusion. The anterior restorations, while in contact, should be slightly less than the posterior contacts by thickness of 1 piece of shim-stock. In lateral movements of the mandible, the anterior teeth should disclude the posterior teeth immediately. Lateral guidance is permissible for anterior implant restorations, if provided by good design. Implant restorations do not need to be removed from contact in lateral excursions. Guidance on anterior implant restorations should not be steep or severe and should be shared by adjacent teeth or implants whenever possible. Although there is no precise definition of overload, it is generally thought that severe forces on dental implants are destructive.^{36,37}

Certainly it is not desirable for any tooth or implant to be in hyperocclusion. Implant restorations in the anterior region need to make contact in centric relation. Contact in centric relation should be less than the posterior contacts by the amount of one piece of shim-stock.

CONCLUSIONS

There is particular concern today that a single-stage or nonsubmerged implant system used in esthetic areas may not be as predictable as clinicians would want. Throughout the course of development of the ITI Dental Implant System, there has been a major emphasis on reaching the utmost limits of what is possible.³⁸⁻⁴¹ The ITI group has stressed simplicity with the use of sound scientific principles and by making the restorative process more user-friendly. However, no clinician would consider restoring the esthetic zone a simple treatment.⁴² This group has attempted to recommend standards for prosthetic treatment in esthetic areas. However, not all individual situations can be addressed. Therefore, every

practitioner needs to be familiar with the basic principles outlined in this document. When basic protocols for treatment are followed, outcomes become more predictable. Armed with knowledge of principles and protocols, clinicians can make informed decisions that will increase their chances of treating each individual patient with success.

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Consensus Statements and Recommended Clinical Procedures Regarding Esthetics in Implant Dentistry

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INTRODUCTORY REMARKS

The group was asked to come to a consensus position related to the esthetic dimension of implant dentistry in the anterior maxilla, based on its discussion of and subsequent deliberation on 3 previously written position papers regarding the following fields: (1) outcome analysis of implant restorations located in the anterior maxilla; (2) anatomical and surgical considerations of implant therapy in the anterior maxilla; and (3) practical prosthodontic procedures related to anterior maxillary fixed implant restorations. These reports were critically reviewed and thoroughly discussed within the group, leading to a first draft of consensus statements. These were subsequently presented during a plenary session that included the members of the other 3 consensus groups. After their respective input, the statements were refined and then presented again to the plenary session for final approval.

CONSENSUS STATEMENTS AND CLINICAL RECOMMENDATIONS

In esthetic dentistry, difficulties arise in generating evidence-based statements regarding clinical procedures. Therefore, any clinical recommendations given in this section are primarily based on the expert opinion of this group. The group worked on each statement until a unanimous opinion was reached.

Long-Term Results

From the discussion of the Belser et al review of long-term results of implant treatment in the esthetic zone, the following consensus statements were drafted.

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Evidence from the Literature. The use of dental implants in the esthetic zone is well documented in the literature. Numerous controlled clinical trials show that the respective overall implant survival and success rates are similar to those reported for other segments of the jaws. However, most of these studies do not include well-defined esthetic parameters.

Single-Tooth Replacement. For anterior single-tooth replacement in sites without tissue deficiencies, predictable treatment outcomes, including esthetics, can be achieved because tissue support is provided by adjacent teeth.

Multiple-Tooth Replacement. The replacement of multiple adjacent missing teeth in the anterior maxilla with fixed implant restorations is poorly documented. In this context, esthetic restoration is not predictable, particularly regarding the contours of the interimplant soft tissue.

Newer Surgical Approaches. Currently, the literature regarding esthetic outcomes is inconclusive for the routine implementation of certain surgical approaches, such as flapless surgery and immediate or delayed implant placement with or without immediate loading in the anterior maxilla.

Surgical Considerations

From the discussion of the Buser et al review of surgical considerations of implant treatment in the esthetic zone, the following consensus statements were drafted.

Planning and Execution. Implant therapy in the anterior maxilla is considered an advanced or complex procedure and requires comprehensive preoperative planning and precise surgical execution based on a restoration-driven approach.

Patient Selection. Appropriate patient selection is essential in achieving esthetic treatment outcomes. Treatment of high-risk patients identified through site analysis and a general risk assessment (medical status, periodontal susceptibility, smoking, and other risks) should be undertaken with caution, since esthetic results are less consistent.

Implant Selection. Implant type and size should be based on site anatomy and the planned restoration. Inappropriate choice of implant body and shoulder dimensions may result in hard and/or soft tissue complications.

Implant Positioning. Correct 3-dimensional implant placement is essential for an esthetic treatment outcome. Respect of the comfort zones in these dimensions results in an implant shoulder located in an ideal position, allowing for an esthetic implant restoration with stable, long-term peri-implant tissue support.

Soft Tissue Stability. For long-term esthetic soft tissue stability, sufficient horizontal and vertical bone volume is essential. When deficiencies exist, appropriate hard and/or soft tissue augmentation procedures are required. Currently, vertical bone deficiencies are a challenge to correct and often lead to esthetic shortcomings. To optimize soft tissue volume, complete or partial coverage of the healing cap/implant is recommended in the anterior maxilla. In certain situations a nonsubmerged approach can be considered.

Prosthodontic and Restorative Procedures

From the discussion of the Higginbottom et al review of prosthodontic and restorative procedures for implant treatment in the esthetic zone, the following consensus statements were drafted.

Standards for an Esthetic Fixed Implant Restoration. An esthetic implant prosthesis was defined as one that is in harmony with the perioral facial structures of the patient. The esthetic peri-implant tissues, including health, height, volume, color, and contours, must be in harmony with the healthy sur-

rounding dentition. The restoration should imitate the natural appearance of the missing dental unit(s) in color, form, texture, size, and optical properties.

Definition of the Esthetic Zone. Objectively, the esthetic zone was defined as any dentoalveolar segment that is visible upon full smile. Subjectively, the esthetic zone can be defined as any dentoalveolar area of esthetic importance to the patient.

Measurement of Esthetic Outcomes. The following esthetic-related soft tissue parameters are proposed for use in clinical studies:

- Location of the midfacial mucosal implant margin in relation to the incisal edge or implant shoulder
- Distance between the tip of the papilla and the most apical interproximal contact
- Width of the facial keratinized mucosa
- Assessment of mucosal conditions (eg, modified Gingival Index, bleeding on probing)
- Subjective measures of esthetic outcomes, such as visual analog scales

Use of Provisional Restorations. To optimize esthetic treatment outcomes, the use of provisional restorations with adequate emergence profiles is recommended to guide and shape the peri-implant tissue prior to definitive restoration.

Location of the Implant Shoulder. In most esthetic areas, the implant shoulder is located subgingivally, resulting in a deep interproximal margin. This shoulder location makes seating of the restoration and removal of cement difficult. Therefore a screw-retained abutment/restoration interface is advisable to minimize these difficulties.

Early and Immediate Restoration and Loading of Implants in Completely Edentulous Patients

Matteo Chiapasco, MD¹

Primary stability and postponement of loading of dental implants for approximately 3 to 6 months have been considered for years the “conditio sine qua non” to allow osseointegration of dental implants. However, in recent years, an increasing number of publications on immediate and early loading of dental implants in completely edentulous patients have appeared in the literature, and high survival rates were generally reported. Nevertheless, much controversy still exists over the reliability of the reported data, frequently because the publications are of insufficient methodologic quality (insufficient follow-up, inadequate sample size, absence of randomization, lack of well-defined exclusion and inclusion criteria, lack of well-defined success criteria, etc). The objective of this study was to review the literature to evaluate the reliability of early and immediate loading of implants placed in the edentulous mandible and maxilla and rehabilitated either with implant-supported overdentures or with implant-supported fixed prostheses. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):76–91

Key words: dental implants, early loading, immediate loading, implant-supported prostheses, osseointegration

Primary stability and postponement of loading of dental implants for approximately 3 to 6 months have been considered for years the “conditio sine qua non” to allow osseointegration of dental implants. However, the necessity of waiting to load an implant was not scientifically but rather clinically based.^{1,2} It is therefore justifiable to question whether this healing period is an absolute prerequisite for obtaining osseointegration, or if under certain circumstances this period can be shortened without jeopardizing osseointegration and long-term results. In particular, it should be demonstrated whether any kind of motion transmitted to the implants during the early phases of integration can compromise the long-term results, or if there is a threshold below which micromotion may not compromise osseointegration.

Studies in the orthopedic literature^{3–6} have demonstrated the role of macromotion in tissue differentiation around endosseous implants placed in

metaphyseal bones; in these studies, macromotion induced fibrous tissue interposition between the implant surface and bone. Similar results were found with regard to dental implants. Brunski and coworkers⁷ identified early loading as a factor leading to fibrous tissue interposition at the bone-implant interface. In an experimental study in dogs, titanium blade implants were immediately loaded on one side, whereas contralateral blades were left out of function. Immediately loaded implants developed fibrous tissue encapsulation, while the non-loaded implants osseointegrated normally. These observations were confirmed by other studies with titanium screw-type implants.⁸

In contrast to the aforementioned studies, there are also reports in the experimental and clinical literature of implants exposed to early or immediate loading followed by successful osseointegration.^{9–31} In a pilot study in dogs,¹⁴ 3 different groups of titanium alloy implants were compared: a nonsubmerged early loaded group, a nonsubmerged nonloaded group, and a submerged group as a control. The latter 2 groups were loaded after osseointegration occurred. The early loaded group consisted of 3 implants splinted into 1 prosthetic restoration at 1 week postimplantation. The authors found no statistical differences between the groups with regard to the quality of osseointegration, and in none of the groups

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was fibrous encapsulation of implants found. Several studies by Piattelli and associates^{13,20-22} demonstrated in both animals and humans that not only may early loading lead to successful integration, but it may increase the quantity of bone in direct contact with the implant surface. In a study by Rocci and coworkers,³² 5 patients volunteered to have extra implants placed in the posterior mandible for the purpose of histologic examination. Nine oxidized titanium Brånemark System implants (Nobel Biocare, Göteborg, Sweden) were retrieved after 5 to 9 months in function. Two implants had been loaded the day of placement and 7 had been loaded after 2 months of healing. Morphometric measurements of the 2 immediately loaded implants showed a mean bone-to-implant contact value of 92.9%. The corresponding value for the 6 early loaded implants was 81.4%. The authors concluded that implants subjected to immediate or early loading do integrate normally. In a case report, Testori and associates³³ demonstrated histologically that osseointegration may also occur normally in the case of immediate loading. One patient received 11 implants in the edentulous mandible: 6 were immediately loaded to support a provisional fixed prosthesis, and 5 were left submerged. Two months later, 2 submerged implants and 1 immediately loaded implant were retrieved and processed for histologic analysis. All implants achieved osseointegration. The bone-to-implant contact was 38.9% for the submerged implants and 64.2% for the immediately loaded implants.

Different results between the first group of studies,³⁻⁸ in which fibrous encapsulation of immediately loaded implants occurred, and the second group of studies,⁹⁻³¹ in which osseointegration occurred, may be related to differences in study design, loading conditions with different entities of micromotion of implants, bone quality, and/or materials used. In particular, loading conditions in the orthopedic field may be very different from loading conditions in the case of dental rehabilitation. The current trend is not to consider implant motion per se as detrimental to osseointegration, but rather to consider a threshold of acceptable micromotion. The hypothesis for this concept introduced by Cameron and colleagues⁵ is that micromotion at the bone-implant interface can be tolerated below a certain threshold. This has been confirmed by other authors.³⁴⁻³⁷ These studies seem to demonstrate that micromotion up to 150 μm should be considered excessive and therefore deleterious for osseointegration. On the contrary, micromotion of less than 50 μm seems to be tolerated. Thus, the critical threshold, although dependent on implant morphology and implant surface, seems to be between 50 and 150 μm .³⁴⁻³⁷

Despite an increasing number of publications on immediate and early loading of dental implants in completely edentulous patients that report high survival rates for the loaded implants, much controversy still exists over the reliability of the reported data, because frequently the publications are of insufficient methodologic quality (insufficient follow-up, inadequate sample size, absence of randomization, lack of well-defined exclusion and inclusion criteria, lack of well-defined success criteria, etc). The main objective of this review was to evaluate the reliability of studies of early and immediate loading of implants placed in the edentulous mandible and maxilla and rehabilitated with either implant-supported overdentures or implant-supported fixed prostheses.

METHODS

A critical review of the literature was performed to determine the validity and efficacy of available information; full-length articles published in English were analyzed. Pertinent studies were retrieved initially with a computerized literature search (MEDLINE-EMBASE from 1966 to May 2003) of key words. Key words used in the search included: *edentulous jaw*, *edentulous maxilla*, *edentulous mandible*, *osseointegrated implants*, *dental implants*, *implant-supported*, *dental prosthesis*, *dental implantation*, *immediate loading*, *early loading*, *overdenture*, and *implant-supported dental prosthesis*. To expand this, a hand search of journal issues from 1966 through May 2003 was undertaken. The following journals were identified: *Clinical Oral Implants Research*, *The International Journal of Oral & Maxillofacial Implants*, *Journal of Oral and Maxillofacial Surgery*, *International Journal of Oral and Maxillofacial Surgery*, *Journal of Cranio-Maxillo-Facial Surgery*, *Journal of Prosthetic Dentistry*, *Scandinavian Journal of Plastic and Reconstructive Surgery*, *Dental Clinics of North America*, *Oral Surgery Oral Medicine Oral Pathology*, *Clinical Implant Dentistry and Related Research*, *British Journal of Oral and Maxillofacial Surgery*, *International Journal of Periodontics and Restorative Dentistry*, *International Journal of Prosthodontics*, *Journal of the American Dental Association*, *Journal of Biomedical Materials Research*, *Journal of Periodontology*, *Journal of Oral Implantology*, and *Implant Dentistry*.

Other articles were identified from the reference lists of the articles found with MEDLINE and EMBASE and from the review of the aforementioned journals. The review was restricted to publications dealing with endosseous root-form titanium implants with a minimum follow-up of 1 year. Nevertheless,

very frequently many combinations of procedures were present in the same study, and follow-ups varied considerably within the same article and between different articles. Therefore, a meta-analysis was not performed. The data abstracted from the articles were recorded on flow sheets subdivided into the following groups:

1. Immediate loading of implant-supported overdentures in the edentulous mandible
2. Early loading of implant-supported overdentures in the edentulous mandible
3. Immediate loading of implant-supported fixed prostheses in the edentulous mandible
4. Early loading of implant-supported fixed prostheses in the edentulous mandible
5. Immediate loading of implant-supported overdentures in the edentulous maxilla
6. Early loading of implant-supported overdentures in the edentulous maxilla
7. Immediate loading of implant-supported fixed prostheses in the edentulous maxilla
8. Early loading of implant-supported fixed prostheses in the edentulous maxilla

IMMEDIATE LOADING OF IMPLANT-SUPPORTED OVERDENTURES IN THE EDENTULOUS MANDIBLE

The first attempts to test immediate loading of dental implants with implant-supported overdentures were performed by Ledermann in 1979 and 1983,^{9,10} but the first publication with a relevant sample size and well-defined criteria of evaluation appeared only in 1997, authored by Chiapasco and coworkers.¹⁷ This article reported on a retrospective multicenter study involving 4 centers and 226 patients with edentulous mandibles. Well-defined inclusion and exclusion criteria for patient selection were reported, as well as the condition of the opposing arch. Only patients with good bone quality (class 1 to 3 according to the classification of Lekholm and Zarb³⁸) were included in this study. A total of 904 dental implants (ITI, Institut Straumann, Waldenburg, Switzerland; Mathys, Bettlach, Switzerland; Friatec, Friadent, Mannheim, Germany) at least 3.5 mm in diameter and 10 mm long were placed in the interforaminal area of the mandible, immediately connected with a bar, and loaded within 2 days. Of these, 776 implants were followed for a period ranging from 2 to 13 years (mean: 6.4 years). The survival rate of implants according to the criteria of Albrektsson and associates³⁹ was 96.9%, whereas the survival rate of the prostheses was 98.5%. No statistically significant dif-

ferences were found between different centers and different implant systems. This publication was followed by others concerning the same indication, also with very favorable results.

In a prospective study, Gatti and colleagues⁴⁰ presented their experience on 21 patients who received 84 ITI implants placed in the interforaminal area of the mandible that were immediately connected with a bar and loaded with an implant-supported overdenture within 24 hours. Inclusion criteria and success criteria were similar to those reported in the previous article.¹⁷ The follow-up ranged from 24 to 60 months. No implants were lost. The survival rate of implants and prostheses was 100%, while the cumulative success rate according to the criteria of Albrektsson and associates³⁹ was 96%. Splinting of implants with a U-shaped Dolder bar was considered a key factor for long-term success at that time, with the objective to minimize macromovement and micromovement of the implants.

In 2001, Chiapasco and coworkers¹⁸ published a prospective comparative study of immediate and conventional loading of mandibles with Brånemark System implant-supported overdentures. Twenty patients with edentulous mandibles were randomly assigned to 2 groups: immediate loading within 24 hours and conventional loading following a standard protocol for submerged implants (3 to 6 months' waiting period to obtain osseointegration). Well-defined inclusion criteria were similar to those presented in the aforementioned articles.^{17,38,40} The follow-up was 2 years on average and the cumulative success rate, reported according to the criteria of Albrektsson and associates,³⁹ was 97.5% in both groups, with 1 implant in each group lost shortly after the start of occlusal loading. More recently, Romeo and colleagues²⁹ published a prospective comparative study of immediate versus conventional loading of implant-supported overdentures with ITI implants with a protocol identical to that described by Chiapasco and coworkers¹⁷ in a previous publication. Twenty patients with edentulous mandibles were randomly assigned to the 2 groups. The follow-up was 2 years on average and the cumulative success rates reported according to the Albrektsson and associates,³⁹ criteria were 97.5% in both groups. One implant in each group was lost shortly after the start of occlusal loading.

Chiapasco and Gatti¹⁹ have recently published a prospective analysis on this topic. Eighty-two patients with edentulous mandibles were rehabilitated with implant-supported overdentures. Three-hundred twenty-eight screw-type endosseous implants (4 implants per patient) were placed in the intraforaminal area of the mental symphysis (164 HA-TI,

Mathys Dental Implants; 84 ITI, Institut Straumann; 40 Brånemark Conical, Nobel Biocare; 40 Frialoc, Friadent). Inclusion criteria, success criteria, and the surgical-prosthetic protocol were similar to those previously described. Of the 328 implants placed, 296 were followed from a minimum of 36 months to a maximum of 96 months, with a mean follow-up of 62 months. Seven implants were removed, while 18, although integrated, did not fulfill the success criteria. The cumulative survival and success rates of the implants were 96.1% and 88.2%, respectively.

In another study, Gatti and Chiapasco³⁰ prospectively compared the clinical outcome of standard MK II Brånemark System implants and Conical transmucosal Brånemark System implants. Ten patients were randomly assigned to the 2 groups. In both groups, 4 implants per patient were placed anterior to the mental foramina, rigidly splinted with a bar, and immediately loaded with an implant-supported overdenture. The patients were followed for a minimum of 24 months. Implants were evaluated at the time of immediate loading and 12 and 24 months after prosthetic loading with clinical peri-implant parameters. Radiographic evaluation of peri-implant bone level changes was performed with panoramic radiographs taken 12 and 24 months after the beginning of prosthetic loading. No significant differences were found between the 2 groups at 12 and 24 months. The cumulative success rate of implants according to the success criteria was 100% in both groups after 2 years of functional loading. The results of this study demonstrated that the success rate for immediately loaded mandibular implants was similar to that obtained in cases of conventional loading and that there were no significant differences between 2-piece implants and 1-piece transmucosal implants.

Over a 5-year period (1996 to 2001), Degidi and Piattelli⁴¹ treated 152 patients aged between 18 and 75 years presenting both partially and completely edentulous jaws (mandible and maxilla). These patients received a total of 646 titanium implants of different shapes and surfaces. Four hundred twenty-two implants were immediately loaded (235 placed in healed sites and 187 in postextraction sites), whereas 224 were immediately restored with provisional prostheses but were kept out of occlusion. Of the treated patients, 39 had edentulous mandibles and received 241 implants that were immediately loaded. Seventeen patients were treated with an implant-supported overdenture and received 93 implants. The follow-up ranged from 2 to 60 months. The reported survival rate of implants and prostheses was 100%. The authors reported that failures were not related to bone quality and quantity, diameter, length and position of implants, or type of abutment used.

Conclusions Regarding Immediate Loading of Implant-Supported Overdentures in the Edentulous Mandible

Only data from articles with defined survival criteria and with a minimum follow-up of 1 year were reported. A total of 7 articles were selected and reviewed. Of these publications, 2 were retrospective, 2 were prospective, and 3 were prospective and controlled (test group/immediate loading versus control group/conventional loading). Three hundred seventy-six patients with an edentulous mandible were treated and 1,529 implants were placed and immediately loaded (within 2 days of surgery). The minimum implant length was 9 mm. In the selected articles, all implants were rigidly connected with a bar. Only patients with good bone quality were selected for immediate loading. Of these implants, 1,369 were followed from a minimum of 6 months to a maximum of 13 years. Survival rate evaluation according to the Albrektsson and associates³⁹ criteria was the most commonly used system. Thirty-three implants were lost during the follow-up period, whereas 21, although still stable, did not fulfill the survival criteria. The average survival and success rates were 98% and 96.6%, respectively (range of successful implants: 88.2% to 100%; range of surviving implants: 96.0% to 100%) (Table 1).

From the analysis of the available literature, the following preliminary observations can be drawn:

1. Immediate loading of a minimum of 4 implants, rigidly connected with a bar placed in the interforaminal area of the mandible and loaded with an implant-supported overdenture, seems not to jeopardize the long-term survival and success rates of the implants, which are comparable to those obtained with standard conventional loading procedures.⁴²⁻⁴⁵
2. Good bone quality and primary stability seem to be important prognostic factors for the success of the procedure, but more objective measurement criteria, such as insertion torque values, resonance frequency analysis (RFA), and Periotest analysis (Siemens, Bensheim, Germany) were very rarely used.

EARLY LOADING OF IMPLANT-SUPPORTED OVERDENTURES IN THE EDENTULOUS MANDIBLE

In a prospective study, Payne and coworkers⁴⁶ presented their experience with early loading of Brånemark System Conical implants placed in the anterior mandible. Four patients received 4 implants

Table 1 Published Articles Relating to the Immediate Loading of Implant-Supported Overdentures in the Edentulous Mandible

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	No. of implants followed	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Chiapasco et al 1997 ¹⁷	Retro	226	904	904	776	2 to 13	24	96.9	96.9
Gatti et al 2000 ⁴⁰	Prosp	21	84	84	84	2 to 5	0	96.0	96.0
Chiapasco et al 2001 ¹⁸	Prosp/cont	10	40	40	40	2	1	97.5	97.5
Romeo et al 2002 ²⁹	Prosp/cont	10	40	40	40	2	1	97.5	97.5
Chiapasco/Gatti 2003 ¹⁹	Prosp	82	328	328	296	3 to 8	7	96.1	88.2
Gatti/Chiapasco 2002 ³⁰	Prosp/cont	10	40	40	40	2	0	100.0	100.0
Degidi/Piattelli 2003 ⁴¹	Retro	17	93	93	93	1 to 5	0	100.0	No data
Total		376	1,529	1,529	1,369		33		

Retro = retrospective; prosp = prospective; cont = controlled.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

each in the interforaminal area of the mandible. After 2 weeks on average, the implants were loaded unsplinted with implant-supported overdentures and followed for 1 year. The survival rate of implants was 100%.

In a prospective controlled study, the same group of authors⁴⁷ compared the success rates of conventionally loaded versus early loaded pairs of unsplinted ITI implants supporting mandibular overdentures. Twenty-four patients were randomly allocated with maximum concealment to the 2 treatment protocols. In the first group, the implants were allowed to heal for 12 weeks before being functionally loaded (control group), while the second group (test group) had 6 weeks of healing before the start of functional loading. Two ITI implants at least 10 mm long were placed in the interforaminal area of the mandible. Only patients with classes 1 to 3 bone according to Lekholm and Zarb³⁸ were selected. Implant stability (with Periotest and RFA), peri-implant bone resorption, and peri-implant clinical parameters were evaluated. The mean follow-up was 2 years. No implants were lost in the test group (100% success rate), and there were no statistically significant differences between the results of the test group and the control group. Peri-implant bone resorption in all cases was within the limits proposed by Albrektsson and associates.³⁹

Roynesdal and coworkers⁴⁸ presented their experience with 11 patients receiving 2 implants each in the interforaminal area of the edentulous mandible. Implants were loaded within 14 to 21 days with an overdenture supported by ball attachments. The mean follow-up after the start of prosthetic loading was 24 months. No implants were lost in the follow-up period (100% survival rate).

Glauser and colleagues,⁴⁹ as part of a case series of 41 patients, presented the results in 4 patients

who were treated with 4 Brånemark System implants that were placed in the interforaminal area of the mandible, rigidly connected with a bar, and loaded within 1 week with implant-supported overdentures. The mean follow-up was 1 year. During this period, 2 of 16 implants were lost (12.5%). The survival rate was 87.5%.

Tawse-Smith and coworkers⁵⁰ prospectively compared the success rates of 2 different dental implant systems following conventional (12-week waiting period) or early (6-week healing period) loading in patients being rehabilitated with mandibular overdentures. Forty-eight edentulous participants were randomly allocated to 2 different implant systems: Steri-Oss (Nobel Biocare) or Southern (Irene, South Africa). For each system the participants were further divided into 2 groups: conventional and early loading. Two unsplinted implants were placed in the interforaminal area of the mandible to support an overdenture. Mobility tests and marginal bone level changes, as well as peri-implant clinical parameters, were evaluated 1 and 2 years after the start of prosthetic loading. Success rates were evaluated according to the Albrektsson and associates³⁹ criteria. Success rates (including dropouts) for the Steri-Oss implants 2 years after loading were 87.5% in the control group and 70.8% in the test group; for the second implant system these values were 83.3% and 100%, respectively. The authors found the highest failure rate with unsplinted machined-surface implants (7 of 17) in the test group patients.

Raghoebar and coworkers,⁵¹ in a prospective multicenter study, presented their experience in 40 patients with mandibular edentulism who received 170 implants that were prosthetically loaded within 6 weeks. Of these patients, 30 were rehabilitated with implant-supported overdentures (4 implants

Table 2 Published Articles Relating to the Early Loading of Implant-Supported Overdentures in the Edentulous Mandible

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	No. of implants followed	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Payne et al 2001 ⁴⁶	Prosp	4	16	16	16	1	0	100.0	100.0
Payne et al 2002 ⁴⁷	Prosp/cont	12	24	24	24	2	0	100.0	100.0
Roynesdal et al 2001 ⁴⁸	Prosp/cont	11	22	22	22	0 to 2	0	100.0	100.0
Glauser et al 2001 ⁴⁹	Prosp	4	16	16	16	1	2	87.5	87.5
Tawse-Smith et al 2002 ⁵⁰	Prosp/cont	24	48	48	48	2	7	70.8	85.4
Raghoobar et al 2003 ⁵¹	Prosp	30	120	120	120	3	6	93.0	—
Total		85	230	230	230		15	0	

Retro = retrospective; prosp = prospective; cont = controlled.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

per patient in the interforaminal area of the mandible), while the remaining 10 had fixed prostheses (5 implants per patient). The patients were then followed for 3 years after the start of prosthetic loading. The overall survival rate of implants and prostheses was 93%.

Conclusions Regarding Early Loading of Implant-Supported Overdentures in the Edentulous Mandible

Only data from articles with defined inclusion criteria and survival criteria with a minimum follow-up of 1 year were used. A total of 6 articles were selected. Of these publications, 3 were prospective and controlled (test group with immediate loading versus control group with conventional loading), while 3 were only prospective. Eighty-five patients with edentulous mandibles were treated and 230 implants placed and loaded early (range, 1 to 6 weeks). The minimum implant length was 9 mm. In the selected articles, implants were either rigidly connected with a bar (2 articles) or unsplinted (4 articles). Only patients with good bone quality were selected for early loading. Eighty-five patients received 230 implants, which were followed from a minimum of 1 year to a maximum of 3 years. Fifteen implants were lost after the start of prosthetic loading. The average survival rate of the implants was 91.9% (range, 70.8% to 100%), while the overall success rate was 91.7% (range, 85.4% to 100%) (Table 2).

From the analysis of the available literature the following preliminary conclusions may be drawn:

1. Early loading of implants supporting overdentures placed in the interforaminal area of the mandible seems not to jeopardize the long-term survival and success rates of the implants, but the number of implants followed is very low and the follow-up quite short, when compared to the data

regarding immediately loaded implants supporting overdentures.

2. Both splinted and unsplinted implants seem to withstand the biomechanical demands of early loading, although lower success rates compared to success rates obtained in cases of immediately loaded splinted implants were reported in a study⁵⁰ in which unsplinted implants with a machined surface were used.
3. Good bone quality and primary stability seem to be important prognostic factors for the success of the procedure, but evaluation of these factors is quite subjective. Therefore, more objective measurement criteria such as insertion torque values, RFA, and Periotest should be used.
4. On average, survival and success rates for early loaded implants were comparable to those obtained in cases of conventionally loaded implants.⁴²⁻⁴⁵

IMMEDIATE LOADING OF IMPLANT-SUPPORTED FIXED PROSTHESES IN THE EDENTULOUS MANDIBLE

The first reports concerning immediate loading of implants in the edentulous mandible with implant-supported fixed prostheses were presented by Schnitman in 1990⁵² and thereafter in 1995⁵³ and 1997.⁵⁴ In the first 2 studies,^{52,53} 9 patients were selected and 58 Brånemark System implants were placed in the edentulous mandible. Inclusion criteria involved good bone quality and bicortical stabilization in the interforaminal area of the mandible. The follow-up ranged from 3 to 9 years and the survival rate was 85.7%. In the third study,¹⁵ 63 Brånemark System implants were placed in 10 patients and followed for up to 20 years. Twenty-eight implants were immediately loaded, providing support for fixed provisional screw-retained pros-

theses, while 35 adjacent implants were allowed to heal submerged. Following a 3-month healing period, the submerged implants were exposed and definitive reconstruction was accomplished. Of the 28 immediately loaded implants, 4 failed, while all submerged implants survived. The survival rates were 84.7% for the immediately loaded implants and 100% for the submerged implants. Statistical analysis of the submerged versus immediately loaded implants demonstrated significantly higher failure rates for immediately loaded implants. The authors stressed the following factors as important for long-term survival of implants: primary stability, threaded implant design, percentage of implant surface in contact with bone cortex, bone density, screw-retained and passive fitting fixed provisional restorations, and elimination of micromovement during the bone remodeling period with rigid splinting of implants. They also stressed that implants placed distal to mental foramina were more susceptible to failure.

Tarnow and colleagues¹⁶ reported their experience with 10 patients who received 107 implants in the edentulous mandible and maxilla (Brånemark System; ITI; Astra Tech, Mölndal, Sweden; 3i/Implant Innovations, West Palm Beach, FL). A minimum of 10 implants were placed in each patient's edentulous arch. A minimum of 5 implants were left to heal submerged and unloaded. The remaining implants were loaded on the day of surgery with provisional fixed prostheses. Of the 10 patients, 6 received implants in the mandible and 4 in the maxilla. Sixty-four implants were placed in edentulous mandibles, and 36 of these were immediately loaded. The stability of the implants was evaluated with the Periotest. The follow-up ranged between 1 and 5 years, with a survival rate of 97.4% (2 implants failed).

Balshi and Wolfinger⁵⁴ reported their experience with 10 patients receiving a total of 130 Brånemark System implants in the edentulous mandible (minimum 10 implants per patient), both anterior and posterior to the mental foramina. Forty of these implants were immediately loaded with a provisional fixed prosthesis, while the others were left to heal submerged and unloaded. Six weeks afterward, a second prosthesis was delivered. The non-immediately loaded implants were uncovered and loaded 3 months after implant placement. The follow-up period was approximately 1 year, although this was not well specified. Eight of 40 implants failed shortly after the start of loading. All implant losses occurred in patients with poor bone quality. The survival rate of the implants was 80%, while the survival rate of the prostheses was 100%.

In 1999, Brånemark and associates⁵⁵ presented a study with a new implant system (Brånemark Novum, Nobel Biocare). Fifty patients with edentulous mandibles received a total of 150 implants (3 per patient) in the interforaminal area, which were rigidly connected with a prefabricated titanium bar and immediately loaded within 1 day. The minimum length of the implants was 13 mm. Patients were followed from a minimum of 6 months to a maximum of 3 years (1 year on average). Three implants were lost, resulting in an overall survival rate of 98%, while 1 of 50 prostheses failed.

Horiuchi and coworkers²⁴ treated 12 patients with 96 implants in edentulous mandibles. Each patient received at least 5 implants with a minimum length of 10 mm and a minimum insertion torque of 40 Ncm. The follow-up ranged from 8 to 24 months. Two of 96 implants failed, giving an overall survival rate of 97.2%.

Chow and colleagues⁵⁶ presented their experience with 14 patients who received 4 implants each in the interforaminal area of the edentulous mandible. The implants were loaded with a screw-retained fixed provisional prosthesis within 24 hours. Implant survival rates after a 12-month follow-up period were determined according to the criteria of Albrektsson and associates.³⁹ For the 44 implants followed, the survival rate was 100% after 1 year.

In another study, Chow and coworkers⁵⁷ treated 27 consecutive patients with 123 Brånemark System implants placed in the interforaminal area of the mandible (14 patients were already included in the former study by the same group of authors⁵⁶). The implants were followed from a minimum of 3 months to a maximum of 30 months (15 patients were followed up for 1 year or longer). Implants were placed both in fresh extraction sockets and in healed sockets. All implants were placed with insertion torques not lower than 30 Ncm. Two patients were withdrawn from the study. Two of the 115 remaining implants failed, resulting in an overall survival rate of 98.3%.

Ganeles and associates²⁵ reported their experience in 27 patients with edentulous mandibles receiving 186 implants (ITI, Friatec, Astra Tech), 161 of which were immediately loaded using fixed provisional restorations of various designs. Only 1 implant was lost shortly after the start of loading, providing an implant survival rate of 99.4%.

Grunder⁵⁸ reported his experience in 5 patients with edentulous mandibles receiving 43 implants (3i/Implant Innovations), 31 of which were placed in fresh extraction sockets and immediately loaded with fixed provisional prostheses. Six months afterward, provisional prostheses were replaced with

definitive metal-ceramic suprastructures. After a 2-year follow-up, only 1 implant was lost, with a cumulative survival rate of 97.3%.

Cooper and coworkers²⁷ presented their experience in 10 patients treated with tooth extraction, immediate implant placement in the extraction sockets, and immediate loading of the implants. Forty-eight of 54 implants placed in the parasymphyseal region of the mandible were immediately loaded. Of these implants, 34 were placed directly into extraction sockets. After a follow-up period ranging from 6 to 128 months, the survival rate of the implants was 100%. The authors concluded that immediate loading of implants placed into fresh extraction sockets can lead to high survival rates.

Wolfinger and associates³¹ reported 3- to 5-year results for 2 groups of patients. The first group included 9 patients with a minimum of 5 years of follow-up, while the second group included 24 patients. In the first group, every patient received a minimum of 10 Brånemark System implants that were at least 7 mm long, while in the second group patients received an average of 6 implants. Implants were placed in both the anterior and posterior mandible. In the first group of patients, only 4 implants per patient were immediately loaded with acrylic resin provisional restorations, while the others were left submerged and were uncovered 3 months later. The rationale was dictated by the need for using implants as provisional support during integration of the other implants. In the second group, all implants were immediately loaded. In the first group, the survival rate of implants was 80%, while in the second group it was 97%.

Testori and colleagues⁵⁹ presented data concerning 15 patients with edentulous mandibles who received 103 Osseotite implants (3i/Implant Innovations) (5 or 6 implants per patient). The implants were loaded with a provisional screw-retained prosthesis within 36 hours. The authors reported a cumulative success rate of 98.9%.

A further report by Testori and coworkers⁶⁰ presented data from a study conducted on 62 patients treated in 4 centers. A total of 325 Osseotite implants (5 or 6 per patient) were placed in the edentulous mandible and immediately loaded. Inclusion criteria included primary stability of implants with 32 Ncm minimum torque at the time of placement and normal or dense bone corresponding to class 1 to 3 according to the Lekholm and Zarb classification.³⁸ Exclusion criteria included smoking, pregnancy, need for bone augmentation, systemic disease such as diabetes, and active infection in the sites to be implanted. Success criteria according to Albrektsson and associates³⁹ were

recorded. The temporary prosthesis was delivered 48 hours after surgery, on average, while the definitive prosthesis was delivered 6 months after surgery. Data concerning marginal bone loss were recorded from periapical radiographs. Two implants failed to integrate within 2 months of occlusal loading. The mean follow-up was 29 months (range, 12 to 60 months). The cumulative success rate was 99.4%.

Malò and colleagues⁶¹ presented a retrospective analysis of 44 patients, presenting with an edentulous mandible, who received 176 Brånemark System implants in the interforaminal region that supported fixed acrylic resin complete-arch mandibular prostheses. In addition to the immediately loaded implants, 24 of the 44 patients had 62 additional implants not incorporated in the provisional prostheses but incorporated in definitive prostheses later on. Postextraction implants were also considered in this group, and heavily angulated implants were placed close to the mental foramina to obtain a more distal position of the suprastructure without compromising inferior alveolar nerve function. The follow-up period ranged from 1 to 3 years. Survival criteria were: functional implant stability, absence of pain, and radiographic evaluation of the marginal bone level. No data regarding peri-implant bone resorption were reported. Five implants were lost in 5 patients shortly after implant loading, giving a cumulative survival rate of 96.7%. Prosthesis survival was 100%.

Engstrand and coworkers⁶² presented the long-term results of 95 patients with edentulous mandibles treated with fixed prostheses supported by 3 implants per patient placed in the anterior mandible (results for 50 of these patients were already presented in a previous article⁵⁵). The Brånemark Novum System was used. A total of 285 implants were placed; of these implants, 67% were immediately loaded, while the remaining 33% were loaded on average 5.6 days afterward (range, 1 to 40 days). The follow-up time was 1 to 5 years (mean, 2.5 years). Eighteen implants (6.3%) failed in 13 patients. Kaplan-Meier survival estimates demonstrated a probability of implant survival of 95% at 1 year, 93.3% at 3 years, and 93.3% at 5 years. Peri-implant bone loss mesial and distal to each implant was within the limits proposed by Albrektsson and associates³⁹ after 5 years of loading. The authors concluded that immediate loading of this type of implant system produced a survival rate comparable to that obtained in a traditional 2-stage procedure.

Misch and Degidi⁶³ presented the long-term results of a 2-center study performed on 31 edentulous patients; 19 presented with edentulous mandibles and 12 with edentulous maxillae. In the edentulous mandible group, 14 patients received a total of 100

implants (range, 5 to 10 implants), which were loaded the same day with a provisional acrylic resin prosthesis. Four to 7 months afterwards, definitive prostheses were fabricated. The follow-up ranged from 1 to 5 years after the start of prosthetic loading. No implants were lost and no implants presented signs of failure (excessive peri-implant bone loss, paresthesia, pain, etc). The survival and success rates of both the implants and the prostheses were 100%.

Over a 5-year period (1996 to 2001), Degidi and Piattelli⁴¹ treated 152 patients with partially or totally edentulous jaws (for details, see first section). Of the treated patients, 22 presenting with edentulous mandibles received 148 implants and were rehabilitated with implant-supported fixed prostheses. The follow-up ranged from 2 to 60 months. The reported survival rate of implants supporting fixed prostheses was 100%. The authors reported that failures were not related to bone quality or quantity; diameter, length, or position of implants; or type of abutment used.

Conclusions Regarding the Immediate Loading of Implant-Supported Fixed Prostheses in the Edentulous Mandible

Twenty articles were analyzed, but only 16 had adequate data (as defined by this review) concerning survival criteria and follow-up. Of these articles, 13 were prospective case series and 3 were retrospective case series. No randomized controlled clinical trials were found in the literature. The total number of patients treated in the selected articles was 387, and the total number of implants placed was 2,088. Of these implants, 1,804 were immediately loaded with fixed implant-supported prostheses. The follow-up ranged from 1 to 10 years. Survival rates ranged from 80% to 100% (mean, 95%; Table 3).

The available data suggest that survival rates of immediately loaded implants with implant-supported fixed prostheses compare favorably to those obtained with conventional loading.^{1,40,64-69} However, several factors must be considered. Eight of the 15 selected articles did not specify success criteria. In many of these articles a large number of implants were used for fixed implant-supported restorations. Eight articles did not specify the dentition in the opposing arch. The majority of articles did not present defined inclusion and exclusion criteria. The majority of the authors agreed that:

1. At least 4 implants are needed in the anterior mandible to support a fixed prosthesis.
2. Primary stability with insertion torques up to 35 Ncm is an important factor for long-term survival of implants.

3. Good bone quality (classes 1 to 3 according to the Lekholm and Zarb³⁸ classification) is an important factor for the long-term prognosis of implants.

As already stressed in the conclusions to the earlier sections, the application of standardized criteria to define success rates is fundamental to reaching conclusions on the long-term reliability of this procedure.

EARLY LOADING OF IMPLANT-SUPPORTED FIXED PROSTHESES IN THE EDENTULOUS MANDIBLE

Randow and coworkers²³ performed a clinical and radiographic study to compare the outcome of oral rehabilitation in the edentulous mandible by fixed suprastructures connected to implants. The implants were placed according to either a 1-stage surgical procedure and early loading (experimental group) or the original 2-stage concept (reference group). The results were presented by the same group of authors in a more recent publication by Ericsson and coworkers.⁷⁰ The second article also reported on a clinical and radiographic study comparing the outcome of oral rehabilitation of edentulous mandibles with fixed prostheses connected to implants. The implants were placed according to either a 1-stage procedure and early loading (experimental group) or the original 2-stage procedure (reference group). The groups comprised 16 and 11 patients, respectively. In the experimental group, a total of 88 implants were placed in the interforaminal area of the mandible, compared to 30 in the reference group. In the experimental group, fixed prostheses were connected to the implants 20 days after implant placement, while the fixed prostheses in the reference group were connected 4 months later. Radiographic examination was performed at the time of prosthesis delivery and then repeated at the 18-month and 60-month follow-ups. Analysis of the radiographs from the experimental group showed a mean peri-implant bone loss of 0.2 mm. In the reference group, the corresponding value was 0.0 mm. During the 60-month observation period, no implant was lost in either of the 2 groups. This study demonstrated that it was possible to successfully load dental implants soon after placement (20 days) with a permanent fixed cross-arch suprastructure.

Petersson and colleagues²⁶ compared the peri-implant marginal bone level changes in a prospective study using Brånemark System dental implants placed according to either a 1-stage or a 2-stage surgical procedure combined with early functional loading. The same patients had already been described in the previous studies by Randow and coworkers²³ and

Table 3 Published Articles Relating to the Immediate Loading of Implant-Supported Fixed Protheses in the Edentulous Mandible

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Schnitman et al 1997 ¹⁵	Prosp	10	63	28	10	4	85.7	No data
Tarnow et al 1997 ¹⁶	Prosp	6	64	36	1 to 5	2	97.4	No data
Balshi/Wolfinger 1997 ⁵⁴	Prosp	10	130	40	1	8	80.0	No data
Brånemark et al 1999 ⁵⁵	Prosp	50	150	150	0.5 to 3	3	98.0	98.0
Horiuchi et al 2000 ²⁴	Prosp	12	105	96	1 to 2	2	97.2	No data
Chow et al 2001 ⁵⁶	Prosp	14	56	56	1	0	100.0	100.0
Chow et al 2001 ⁵⁷	Prosp	27	123	123	1 to 2	2	98.3	98.3
Ganeles et al 2001 ²⁵	Prosp	27	186	161	1 to 3	1	99.0	No data
Grunder 2001 ⁵⁸	Retro	5	43	43	2	1	97.3	97.3
Cooper et al 2002 ²⁷	Prosp	10	54	48	1	0	100.0	No data
Malò et al 2003 ⁶¹	Retro	44	176	176	1 to 3	5	96.7	No data
Wolfinger et al 2003 ³¹	Prosp	24	144	144	3 to 5	5	97.0	96.5
Testori et al 2003 ⁵⁹	Prosp/mc	62	325	325	1 to 5	2	99.4	99.4
Engstrand et al 2003 ⁶²	Prosp	95	295	295	1 to 5	18	93.3	93.3
Misch/Degidi 2003 ⁶³	Prosp/mc	14	100	100	1 to 5	0	100.0	100.0
Degidi/Piattelli 2003 ⁴¹	Retro	17	148	148	1 to 5	0	100.0	100.0
Total		387	2,086	1,804				

Retro = retrospective; prosp = prospective; mc = multicenter.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

Ericsson and associates.⁷⁰ Seven patients were treated with a split-mouth technique, using a 1-stage surgical technique on one side and a 2-stage technique on the other side. In this latter group, the implants were submerged during a 3- to 4-month healing period before abutment connection and loading. In 13 patients the definitive prosthetic suprastructure was connected within 20 days of a 1-stage procedure. This group of patients received 5 or 6 implants each in the anterior edentulous mandible. Marginal bone level changes were followed for up to 5 years from implant placement. After connection of the suprastructure, the marginal bone resorption was significantly less in the early functional loading group than in groups who received implants via the 1-stage and 2-stage surgical techniques with conventional loading. However, after 18 months and after 5 years, the marginal bone was located approximately 1 mm apical to the implant abutment level in all 3 groups. The authors concluded that over the long term there was no difference in marginal bone resorption between 1-stage and 2-stage surgical procedures and a 1-stage procedure with early functional loading of dental implants. This study also indicated that elimination of the second stage of surgery might reduce early bone resorption.

In a prospective multicenter study, De Bruyn and coworkers⁷¹ evaluated the 1-year and 3-year success rates of implants loaded within 1 month after implant placement, as well as the outcome of prosthetic treatment and the opinions of patients regard-

ing the treatment procedure. A fixed 10- to 12-unit prosthesis was loaded on 3 regular-platform Brånemark System implants in the mandible. Twenty patients received 5 implants in the mandible, of which 3 were functionally loaded with the 1-stage technique (group 1). The loaded implants were placed in a tripod position, while 2 implants were placed for safety reasons but not loaded. The latter implants served as either an unloaded 1-stage control implant (group 2) or an unloaded control implant placed with a submerged technique (group 3). Immediately after surgery, the implants were loaded with a relined denture. The patients received a 10- to 12-unit prosthetic restoration an average of 31 days (range, 4 to 53 days) after surgery. Implant stability was clinically assessed at 3, 12, and 36 months. Radiographs were taken at corresponding follow-up visits to calculate the peri-implant bone level and marginal resorption. Six of 60 functionally loaded implants and 3 of 20 prostheses failed within the first year. The cumulative implant failure rate in group 1 after both 1 and 3 years was 9.5%. No implant failures occurred in groups 2 and 3. The average marginal bone resorption at 1 and 3 years was 1.6 mm and 2.1 mm, respectively, for group 1; 1.5 mm and 2.4 mm for group 2; and 0.8 mm and 0.7 mm for group 3. The results of treatment using 3 regular-platform Brånemark System implants supporting a fixed mandibular prosthesis were less favorable than the outcome that can be expected with a standard 4- to 6-implant treatment with 1-stage surgery.

Misch and Degidi⁶³ presented the long-term results of a 2-center study performed on 31 edentulous patients, 19 of whom had edentulous mandibles and 12 with edentulous maxillae. In the edentulous mandible group, 5 patients received 36 implants (range: 5 to 10 implants), which were loaded within 2 weeks with a provisional acrylic resin prosthesis. Four to 7 months afterwards, definitive prostheses were fabricated. The follow-up ranged from 1 to 5 years after the start of prosthetic loading. No implants were lost and no implants showed signs of failure (excessive peri-implant bone loss, paresthesia, pain, etc). The survival and success rates of the implants as well as the prostheses were 100%.

In a prospective multicenter study, Raghoobar and colleagues⁵¹ described their experience in 40 patients with mandibular edentulism. The patients received 170 implants, which were prosthetically loaded within 6 weeks. Of these patients, 10 were rehabilitated with implant-supported fixed prostheses (5 implants per patient). The patients were followed for 3 years after the start of prosthetic loading. The overall survival rate of implants and prostheses was 94%.

Conclusions Regarding the Early Loading of Implant-Supported Fixed Prostheses in the Edentulous Mandible

Fewer data are available on early loading than on immediate loading of implants in the edentulous mandible. Six prospective articles were analyzed, one of which was controlled with a reference group receiving conventionally loaded implants. A total of 51 patients were treated, 272 implants placed, and 234 implants subjected to early loading. Survival rates of implants ranged from 90.5% to 100%, with a mean of 97.3%, whereas the survival rate of the prostheses was 96.3% (Table 4). However, the sample of patients and implants is limited because of the fact that the same patients were analyzed in different studies.^{23,26,70}

IMMEDIATE LOADING OF IMPLANT-SUPPORTED OVERDENTURES IN THE EDENTULOUS MAXILLA

No articles concerning this topic were found. No conclusions can be drawn.

EARLY LOADING OF WITH IMPLANT-SUPPORTED OVERDENTURES IN THE EDENTULOUS MAXILLA

No articles concerning this topic were found. No conclusions can be drawn.

IMMEDIATE LOADING OF IMPLANT-SUPPORTED FIXED PROSTHESES IN THE EDENTULOUS MAXILLA

Tarnow and coworkers¹⁶ reported their experience with 10 patients who received 107 implants in the edentulous mandible and maxilla. Of these patients, 4 presented with an edentulous maxilla. The patients received 43 implants of 3 different systems (Astra Tech; 3i/Implant Innovations; Brånemark System, Nobel Biocare), with a minimum of 10 implants per patient. Of these implants, 33 were immediately loaded with provisional fixed prostheses. The follow-up ranged from 1 to 4 years. Six months after the start of prosthetic loading, provisional prostheses were substituted with definitive ones. None of the immediately loaded implants failed, leading to a survival rate of 100%.

Horiuchi and coworkers²⁴ presented their experience in 5 patients with edentulous maxillae who received 52 Brånemark System implants. Each patient received a minimum of 8 implants with a minimum length of 10 mm. Only implants with an insertion torque greater than 40 Ncm were immediately loaded with screw-retained provisional fixed prostheses, while the other implants were left to heal submerged. A total of 44 implants were immediately loaded. After a 4- to 6-month healing period, definitive prostheses were placed. Two of the 44 immediately loaded implants failed, while none of the conventionally loaded implants failed. The cumulative survival rate of immediately loaded implants was 96.5%.

Grunder⁵⁸ reported his experience in 5 patients with edentulous maxillae who received 48 3i/Implant Innovations' implants, 35 of which were placed in fresh extraction sockets. Implants were placed in both high- and low-quality bone (classes 2 to 4 according to the Lekholm and Zarb³⁸ classification). Of the 35 implants placed in fresh extraction sockets, 3 failed, as did 3 of the 13 implants placed in healed alveolar bone. The survival rate of maxillary implants was 87.5%.

Misch and Degidi⁶³ presented the long-term results of a 2-center study performed on 31 edentulous patients, 19 presenting with edentulous mandibles and 12 with edentulous maxillae. In the edentulous maxilla group, 2 patients received a total of 18 implants (range, 8 to 10 implants), which were loaded the same day with provisional acrylic resin prostheses. Four to 7 months afterward, definitive prostheses were placed. The follow-up ranged from 1 to 5 years after the start of prosthetic loading. No implants were lost and no implants presented signs of failure (excessive peri-implant bone loss, paresthesia,

Table 4 Published Articles Relating to Early Loading of Implant-Supported Fixed Protheses in the Edentulous Mandible

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Randow et al 1999 ²³	Prosp/cont	16	88	88	1.5	0	100.0	100.0
Ericsson et al 2000 ⁷⁰	Prosp/cont	16	88	88	1 to 5	0	100.0	100.0
Petersson et al 2001 ²⁶	Prosp/cont	13	70	70	1.5 to 5	0	100.0	100.0
De Bruyn et al 2001 ⁷¹	Prosp/cont	20	100	60	1 to 3	6	90.5	90.5
Misch/Degidi 2003 ⁶³	Prosp/mc	5	36	36	1 to 5	0	100.0	100.0
Raghoobar et al 2003 ⁵¹	Prosp/mc	10	50	50	3	3	93.0	93.0
Total		51	274	234		9		

Prosp = prospective; cont = controlled; mc = multicenter.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

pain, etc). The survival and success rates of the implants as well as of the prostheses was 100%.

During a 5-year period (1996 to 2001), Degidi and Piattelli⁴¹ treated 152 patients presenting both partially and completely edentulous jaws (see first section for further details). Of the treated patients, 14 with an edentulous maxilla received 133 implants that were immediately loaded. The follow-up ranged between 2 and 60 months. Two of 133 implants were lost. Therefore the overall survival rate was 98.5%, while the prosthesis survival rate was 100%.

Conclusions Regarding the Immediate Loading of Implant-Supported Fixed Protheses in the Edentulous Maxilla

Seven articles addressing this topic were found, but only 5 met the criteria of this review. Of these articles, 3 were prospective case series and 2 were retrospective case series. No randomized controlled clinical trials were found in the literature. The total number of patients treated in the selected articles was 30 and the total number of implants placed was 294, which represents a large number of implants per patient. Of these implants, 276 were immediately loaded with fixed implant-supported prostheses. The follow-up ranged from 1 to 5 years. Survival rates ranged from 87.5% to 100%, while success rates ranged from 96.5% to 100%, although it must be considered that some articles did not present well-defined success criteria (Table 5). From the analysis of these data, it appears that survival rates of implants immediately loaded with full-arch fixed prostheses compare favorably with those obtained with conventional loading.^{40,66-69} However, several factors have to be considered: (1) The number of patients and implants is very limited; (2) well-defined inclusion and exclusion criteria are lacking; and (3) the articles do not present homogeneous and thorough information regarding success

criteria concerning implants, but only rough data about the survival rates of implants. It is therefore difficult to draw any significant conclusions.

The majority of the authors suggest the following:

1. A greater number of implants are necessary in the maxilla than in the mandible to support immediately loaded full-arch prostheses.
2. Primary stability is suggested to be an important factor for long-term survival of these implants.
3. Good bone quality (classes 1 to 3 according to the Lekholm and Zarb³⁸ classification) is an important factor, but there is generally a lack of objective measurements to evaluate implant stability, such as insertion torque measurements, RFA, and/or Periotest.

Some of the authors also suggested that obtaining an insertion torque of at least 35 Ncm is an important factor for loading decisions.

EARLY LOADING OF IMPLANT-SUPPORTED FIXED PROTHESES IN THE EDENTULOUS MAXILLA

As part of a case series of 41 patients, Glauser and coworkers⁴⁹ presented the results for 3 patients with edentulous maxillae who received 18 Brånemark System implants loaded within 1 week of implant placement with provisional cross-arch fixed prostheses. The follow-up after the start of prosthetic loading was 1 year. Two implants failed, for a survival rate of 89%.

Olsson and associates⁷² presented the results for 10 patients with edentulous maxillae. Nine patients received 6 implants each, while 1 patient received 8

Table 5 Published Articles Relating to the Immediate Loading of Implant-Supported Fixed Prosthesis in the Edentulous Maxilla

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Tarnow et al 1997 ¹⁶	Prosp/cs	4	22	14	1 to 4	0	100.0	100.0
Horiuchi et al 2000 ²⁴	Prosp/cs	5	52	44	1 to 2	2	96.5	96.5
Grunder 2001 ⁵⁸	Retro/cs	5	48	48	1 to 5	6	87.5	No data
Misch/Degidi 2003 ⁶³	Prosp/mc	2	18	18	0 to 5	0	100.0	100.0
Degidi/Piattelli 2003 ⁴¹	Retro/cs	14	133	133	1	2	98.5	No data
Total		30	294	276		10		

Prosp = prospective; Retro = retrospective; cs = case series; mc = multicenter.

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

implants. Provisional prostheses were delivered after 2.5 days on average (range, 1 to 9 days). After a mean of 4 months, the provisional prostheses were replaced with the definitive ones. All implants were tested at the time of placement and loading with RFA. The mean follow-up was 12 months. Four of 61 implants were lost because of early infection. The mean RFA value at the time of implant placement was 60.1 ISQ (implant stability quotient). A survival rate of 93.4% after 1 year of prosthetic loading was reported.

Misch and Degidi⁶³ presented the long-term results of a 2-center study performed on 31 edentulous patients, 19 with edentulous mandibles and 12 with edentulous maxillae. In the edentulous maxilla group, 10 patients received a total of 90 implants (range, 8 to 10 implants each), which were loaded within 2 weeks with a provisional acrylic resin prosthesis. Four to 7 months afterward, definitive prostheses were fabricated. The follow-up ranged from 1 to 5 years after the start of prosthetic loading. No implants were lost and no implants presented signs of failure (excessive peri-implant bone loss, paresthesia, pain, etc). The survival and success rates of the implants and the prostheses were 100%.

Van den Bogaerde and colleagues⁷³ reported their experience with early loading of Brånemark System implants in partially or completely edentulous jaws. Three of the 31 treated patients had an edentulous maxilla. These patients received 23 implants, which were rigidly connected with a provisional prosthesis within 20 days of implant placement. Patients were followed up to 18 months with clinical and radiographic evaluations. The survival rate of the implants was 100%, but no success criteria were considered because of the relatively brief follow-up.

Conclusions Regarding the Early Loading of Implant-Supported Fixed Prosthesis in the Edentulous Maxilla

A total of 4 prospective articles were reviewed. All articles were represented by case series. No randomized controlled studies were found. Twenty-six patients received 192 implants that were loaded within 3 weeks of implant placement. The follow-up ranged from 1 to 5 years. The survival rate of implants ranged from 89% to 100% (mean, 95.6%; Table 6). Conclusions are similar to those for the previous section; however, the sample was too small to draw any meaningful conclusions.

GENERAL CONCLUSION

The analysis of the available publications demonstrated, on average, poor methodologic quality with regard to allocation concealment, completeness of follow-up, sample size, randomization, exclusion and inclusion criteria, type of opposing arch dentition, type of occlusion, and success criteria. A recent review published by Esposito and associates⁷⁴ demonstrated that only 2 articles presented sufficient methodologic quality (prospective, comparative randomized studies with at least 1 year of follow-up^{18,50}). Thus, the number of trials and patients was definitely too small to draw any reliable conclusions. More well-designed randomized controlled clinical trials are needed to understand how predictable the protocols are for immediate and early loading, as proposed by Esposito and associates.⁷⁴

Limited histologic data supporting the reliability of immediate loading under various clinical conditions further reduce the possibility, at present, of widespread use of immediate or early loading of implants in all clinical situations. Only sparse data are available.^{13,20-22,28,32,33} Data obtained by the analysis performed in this article and by the analysis of a

Table 6 Published Articles Relating to Early Loading of Implant-Supported Fixed Protheses in the Edentulous Maxilla

Author	Type of study	No. of patients	No. of implants placed	No. of implants loaded	Follow-up (y)	Lost implants	Survival rate (%)	Success rate (%)
Glauser et al 2001 ⁴⁹	Prosp/cs	3	18	18	1	2	89.0	No data
Olsson et al 2003 ⁷²	Prosp/cs	10	61	61	1	4	93.4	No data
Misch/Degidi 2003 ⁶³	Prosp/cs	10	90	90	1 to 5	0	100.0	100.0
Van den Bogaerde et al 2003 ⁷³	Prosp/cs	3	23	23	1.5	0	100.0	100.0
Total		23	169	169		8		

Prosp = prospective; cs = case series;

Note: The total number of implants and patients reported in the table may not correspond to the mathematical sum because sometimes different articles reported data concerning the same groups of patients.

recent review concerning immediate loading of dental implants⁷⁵ seem to indicate the following aspects:

1. The majority of articles indicate that good bone quality, primary implant stability, and splinting of implants in cases of immediate and early loading are recommended, although no uniform criteria to evaluate these parameters have been used. Measurements have included insertion torque, RFA, and Periotest values.
2. Immediate loading of full-arch mandibular fixed protheses and overdentures supported by rigidly connected implants between the mental foramina is routine and has a base of clinical evidence.
3. Early loading of implants placed in the mandible, both with overdentures and fixed protheses, seems to be a reliable technique, but more data are needed before proposing this technique as routine.
4. No meaningful data are available about immediate or early loading of edentulous maxillae with implant-supported overdentures.
5. The use of immediate or early loading of fixed implant-supported protheses in the maxilla is not supported by sufficient data to consider this treatment modality as routine, although preliminary results seem to be encouraging.
6. On average, a greater number of implants is suggested by many authors for the rehabilitation of edentulous maxillae than edentulous mandibles.

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Early and Immediately Restored and Loaded Dental Implants for Single-Tooth and Partial-Arch Applications

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Purpose: The objective of this consensus committee report was to review the available literature published predominantly in refereed journals to summarize findings, data, and conclusions as they related to reduced healing times and protocols for single-tooth and partial-arch clinical situations. Early loading of dental implants has been defined as restoration of implants in or out of occlusion at least 48 hours after implant placement, but at a shorter time interval than conventional healing. Immediate loading or restoration has been defined as attachment of a restoration in or out of direct occlusal function within 48 hours of surgical placement, **Materials and Methods:** Six articles addressing early loading, with a mixture of single-tooth and partial-arch clinical conditions and including some controlled cohort studies, were reviewed. Immediate loading or restoration of dental implants in single-tooth and partial-arch applications, was extensively reviewed. An attempt was made to isolate and categorize similar case types to discern trends and relevant factors. Variables that were considered included single- or multiple-tooth conditions, immediate or delayed placement in extraction sockets, effect of implant surface and geometry, bone quality, implant stability, surgical technique, occlusal design, effect of cigarette smoking, and stability of results. **Results:** Combined data from 6 early loading studies on single-tooth and partial-arch applications revealed 1,046 implants with a survival rate of 98.2%. Long-term data for most of the early loading studies were not yet available. Most of the publications on immediate loading or restoration of dental implants were written as case series rather than scientific studies. **Discussion and Conclusions:** In general, most publications indicated that with attention to appropriate factors, implant survival with immediate restoration was comparable to the results with conventional and early loading protocols. It should be recognized that, with few exceptions, these conclusions may be misleading statistical phenomena of the authors, as most publications were written by exceptionally experienced, highly skilled practitioners working under tightly controlled clinical conditions on a relatively small, statistically inconclusive number of implants and patients. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):92–102

Key words: dental implants, early loading, fixed partial denture, immediate function, immediate loading, immediate restoration, provisional denture

A far greater number of patients are edentulous in a single-tooth gap or partial-arch space than are completely edentulous. The opportunity to provide

implant-supported tooth replacement for these patients significantly exceeds the opportunity for those who are completely edentulous.¹ The biomechanics of implants in these situations are significantly different than in completely edentulous conditions, particularly in the context of immediate restoration of these implants. Abundant evidence clearly exists to support immediate loading of implants under full-arch clinical conditions. Limiting implant micromotion below the threshold that could interfere with osseointegration, despite occlusal function, has been well documented and elucidated in the previous section and by many authors.^{2–4} Methods to achieve this objective include placing an adequate number of (usually) threaded implants into sufficiently dense bone. Stiff restorative materials are

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used to splint implants together using the principles of cross-arch stabilization to distribute occlusal forces between the implants and immobilize them during patient function.

This article will attempt to summarize and organize the relevant literature and factors that pertain to immediate and early restoration and loading of implants in single-tooth and partial-arch applications.

METHODS

A review of the available literature from a MEDLINE search and manual journal searches revealed numerous strategies for achieving osseointegration in single-tooth and partial-arch clinical conditions. It should be noted that there is comparatively less information available on these conditions than for full-arch rehabilitation. The published information shows a tendency toward case series and case studies rather than controlled studies in this area. Further, because many publications report on case series, different clinical factors occur simultaneously. For example, authors such as Degidi and Piattelli⁵ and Glauser and coworkers⁶ report on series of patients with single and multiple implants in healed alveolar ridges and extraction sockets, who may or may not smoke, using different implant types or surfaces.

Drawing solid conclusions from data like these is hindered by the introduction of confounding or conflicting variables. Yet it is possible to recognize clinical principles, relevant trends, strategies, and insights from examining these publications.

EARLY RESTORATION AND LOADING

This ITI Consensus Conference Introductory Section has previously defined loading protocols and definitions. Prosthetic connection in occlusion to an implant within 48 hours of surgical implant placement is considered *immediate loading*. *Conventional loading* has been defined as restoration and loading of an implant after a healing period of 3 to 6 months. *Early loading* has been defined as prosthetic loading or utilization of an implant at any time period between immediate and conventional loading.

Cochran and associates⁷ reported on a longitudinal, prospective, multicenter study of early loading of 383 ITI SLA implants (Institut Straumann, Waldenburg, Switzerland) placed in the posterior jaws of 307 patients. The implants were allowed to heal for 42 to 63 days in classes 1 to 3 bone and for 84 to 105 days in class 4 bone prior to restoration.⁸ Patients who were heavy smokers or who had inad-

equated bone volume, bruxism, or immediate placement indications were excluded. At abutment placement and torque application, 3 implants were mobile and removed, while 3 rotated and 6 were associated with pain. All implants associated with either pain or rotation were allowed additional healing time and eventually became clinically integrated and were restored, resulting in a survival rate of 99.1%. Three hundred twenty-six implants had passed the 1-year evaluation period and 138 had passed the 2-year period without additional changes in clinical parameters.

Rocuzzo and colleagues⁹ reported on a prospective, split-mouth design study comparing early loading of 68 SLA implants (sandblasted, large-grit, acid-etched) restored at 6 weeks and 68 identically shaped titanium plasma-spray (TPS) surface implants restored at 12 weeks in 32 healthy patients (all implants ITI/Institut Straumann). Solid restorative abutments were torqued to 35 Ncm at the time of restoration. Four of 68 test SLA implants rotated and the patients experienced pain at the 6-week abutment placement procedure; the implants were allowed to heal an additional 6 weeks before re-torquing. None of the control implants demonstrated complications at restoration. After a 1-year evaluation, the authors noted 100% success with no significant differences in clinical parameters between the 2 groups of implants, including radiographic evaluation.

In another prospective study on ITI implants, Rocuzzo and Wilson¹⁰ reported on 36 maxillary posterior implants placed in 19 nonsmoking patients using an altered surgical protocol to increase initial implant stability. Minimal drilling was performed, in favor of bone condensation, to compact and compress maxillary trabecular bone during implant placement. Abutments were torqued to 15 Ncm after 43 days, and the implants were restored with provisional restorations in infraocclusion. After an additional 6 weeks, the abutments were torqued to 35 Ncm for definitive restoration fabrication. One implant rotated with pain at 42 days and was subsequently removed. The other 35 implants were restored uneventfully, leading to a 1-year survival rate of 97.2%. The authors reported implant clinical indices similar to the 6-week period, although marginal bone loss of 0.55 ± 0.49 mm versus the immediate postoperative radiographs was noted.

Testori and coworkers¹¹ reported on a longitudinal, prospective, multicenter early loading study of 475 Osseotite implants (3i/Implant Innovations, West Palm Beach, FL) in posterior sextants of 175 patients restored at 2 months. Patients who were

bruxers or had periodontal or systemic diseases were excluded, while smokers were not. Six of 475 implants failed to integrate within the first 2 months and were considered early failures, while 3 failed after restoration and were considered late failures. The cumulative survival rate was 97.7% after 3 years.

Bogaerde and colleagues¹² reported a prospective study of 31 nonsmoking, nonbruxing patients with 36 edentulous areas treated with 124 Brånemark System machined-surface Mk IV implants (Nobel Biocare, Göteborg, Sweden) provisionally restored 7 to 20 days after surgical placement. One hundred one of the implants were placed in partial-arch applications. One of the inclusion criteria was the ability to achieve 40 Ncm of insertion torque at implant placement, which was generally achieved by underpreparation of the diameter of the osteotomies. Provisional restorations with light occlusal contact were placed at a mean of 11 days postsurgically (maximum of 20 days postsurgically). Ninety-seven of 101 (96%) implants in partial arches integrated, with 3 early failures and 1 late loss at 6 months. Clinical and radiographic evaluation appeared to indicate stable results at 18 months, although according to the authors, many of the radiographic data were not readable or usable for analysis.

Cooper and coworkers¹³ reported on 47 patients with 53 early loaded 11- to 17-mm Astra Tech ST implants (Astra, Mölndal, Sweden) to replace 53 maxillary anterior single teeth. Patients were excluded from treatment if they were positive for bruxism, unstable posterior occlusion, daily cigarette smoking, uncontrolled periodontal disease, systemic disease, or mobility of the teeth adjacent to the planned implant site. Acrylic resin restorations were placed into occlusal contact 3 weeks after surgery, at which time abutments were torqued with hand pressure. After 8 weeks, final abutments were torqued to 20 Ncm and definitive restorations were placed. Two implants failed following provisional restoration placement, while 51 integrated, resulting in an implant survival rate of 96.2%.

Drawing conclusions from the limited literature on early loading in partial-arch applications is difficult because of the paucity of information. Table 1 summarizes the information available from the 6 studies that were reviewed, although it should be recognized that all of the articles are not directly comparable. These reports indicate that early loading of 1,046 implants in 611 patients resulted in survival or success of 1,027 implants, for a mean survival rate of 98.2%. All authors indicated high success rates of implants and restorations consistent with delayed loading protocols, but few long-term

data have yet been published. Common strategies used by most of the authors, with the exception of Bogaerde and associates,¹² appear to include rough-surfaced implants, infraocclusion, and enhanced surgical stability. None of the authors of the articles reviewed reported placement of implants in immediate extraction sockets with this loading protocol.

IMMEDIATE RESTORATION AND LOADING

Early publications on immediate restoration of single, unsplinted implants in the esthetic zone were presented as case reports and series. Kupeyan and May¹⁴ and Wöhrle¹⁵ reported on series of 10 and 14 immediately restored implants, respectively, in the maxillary anterior region. Kupeyan and Kay performed their study in healed ridges with machined titanium Brånemark System implants (Nobel Biocare), while Wöhrle reported on roughened-surface Steri-Oss Replace implants (Nobel Biocare) in immediate extraction sites. Both groups indicated that all implants clinically integrated and remained stable for the observation periods of 6 months to 3 years.

Additional case reports of small series of patients by Andersen and coworkers,¹⁶ Aires and Berger,¹⁷ Touati and Guez,¹⁸ Lorenzoni and coworkers,¹⁹ Kan and associates,²⁰ and Cannizzaro and Leone²¹ confirmed the observations of 100% survival of single-tooth replacement in the maxillary anterior region. All authors advocated maximization of implant stability by using long implants and eliminating occlusal contact in centric and excursive movements. Lorenzoni and coworkers¹⁹ advocated the use of an occlusal splint for 8 weeks to prevent loading of the restoration by nonocclusal forces such as the tongue or food bolus. Kan and associates²⁰ placed patients on a liquid diet for 2 weeks postoperatively, followed by a soft diet for 5 months. With the exception of Andersen and colleagues,¹⁶ who indicated that 2 of their 8 patients were cigarette smokers, it appears that patients who smoked more than 10 cigarettes per day or had parafunctional occlusal habits such as bruxism or clenching were excluded from treatment by most authors.

Ericsson and associates²² reported on 14 consecutive patients treated with Brånemark System MKII implants (Nobel Biocare) in the maxillary anterior area. Nonsmoking patients with negative histories for parafunctional habits had implants placed in healed ridges and immediately restored out of occlusion. Two (14%) implants failed to integrate within the first 5 months. All others were clinically integrated and maintained stable radiographic bone levels throughout the observation period of 18 months.

Table 1 Publications on Early Loading

Authors	Type of study	Implant system	No. of patients	Groups	No. of implants	No. of early loaded implants	Time before loading	Survival/success	Other
Rocuzzo et al 2001 ⁹	Pros sm	Straumann SLA versus TPS	32	68 pairs of implants	68 SLA versus 68 TPS; 136 total	68	Provisional restoration: 6 weeks SLA, 12 weeks TPS	68 (100%)	4 SLA implants rotated at 6 weeks, but subsequently healed
Testori et al 2002 ¹¹	Pros	Osseotite (3i)	175	99 single-tooth, 119 short-span prostheses, 11 full-arch	405	405	Provisional restoration: 2 months	396 (97.8%)	97.8% success
Cooper et al 2001 ¹³	Pros	Astra	47	53 single-tooth implants	53	53	Provisional restoration after 3 weeks, definitive 8 to 12 weeks	51 (96.2%)	2 implants lost
Cochran et al 2002 ⁷	Pros	Straumann SLA	307	Various	383	383	Provisional restoration: 6 weeks in type 1 to 3 bone, 12 to 15 weeks in type 4 bone	380 (99.1%)	3 rotated and were removed, 6 others painful at evaluation subsequently healed; 3 failed of 383
Rocuzzo/Wilson 2002 ¹⁰	Pros	Straumann SLA	19	Various in type 4 maxillary bone using bone condensation	36	36	6 weeks for provisional with 15 Ncm torque, 12 weeks final torque	35 (97.1%)	97.1% survival
Bogaerde et al 2003 ¹²	Pros	Brånemark System machined	31	56 implants in mandible, 45 implants in maxilla	101	101	Provisional restoration: 7 to 20 days	97 (96.0%)	96% success
Totals			611			1,046 early loaded implants			1,027 (98.2%) surviving/successful implants

Pros = prospective; sm = split-mouth.

Table 2 Publications on Single-Tooth Immediate Restorations

Authors	Type of study	Implant system/surface	No. of patients	No. of implants	Successful implants	Success rate (%)
Wöhrle 1998 ¹⁵	Pros	Steri-Oss TPS and HA	Single tooth, 14	14	14	100.0
Kupeyan/May 1998 ¹⁴	Pros	Brånemark machined	Single tooth, 10	10	10	100.0
Ericsson et al 2000 ²²	Pros	Brånemark machined	14	14	12	85.7
Hui et al 2001 ²³	Pros	Brånemark machined	13	13	13	100.0
Andersen et al 2002 ¹⁶	Pros	ITI TPS	Single tooth, 8	8	8	100.0
Rocci et al 2003 ²⁶	Pros	Brånemark machined	Not specified	27	22	81.5
Calandriello et al 2003 ²⁴	Pros	Nobel Biocare TiUnite 5.0 mm	Mandibular molars, 44	50	50	100.0
Lorenzoni et al 2003 ¹⁹	Pros	Frialit-2	Single tooth, immediate provisional, 9	12 maxillary	12	100.0
Kan et al 2003 ²⁰	Pros	Steri-Oss Replace	Single tooth, immediate provisional, 35	35 maxillary	35	100.0
Cannizzaro/Leone 2003 ²¹	Rand	Centerpulse Spline twist	Single tooth (immediate loading vs conventional), 28 (2 × 14)	46	46	100.0
Degidi/Piattelli 2003 ⁵	Retro	Multiple	Not specified	58	56	96.6
Totals				287	278	96.7

Pros = prospective; Rand = randomized; Retro = retrospective.

Hui and coworkers²³ studied 2 groups of patients with 24 implants to compare results between immediate placement of implants in 11 extraction sites and immediate placement and restoration in 13 extraction sites in the maxillary anterior region. Heavy smokers and patients with bruxism were excluded. Machined-surface Brånemark System implants 13 to 18 mm long were placed with torque values of 40 to 50 Ncm, with the authors attempting to achieve bicortical anchorage. Provisional restorations were placed the day of surgery with a design of “protected occlusion,” where implants were placed out of contact in all excursive movements. No implants were lost and no complications were encountered. The authors noted that the esthetic outcome of the immediate provisionalization group was better because the provisional restorations preserved the gingival contours.

In an article focusing exclusively on mandibular molars, Calandriello and colleagues²⁴ reported on 44 patients, including 7 smokers, who received fifty 5-mm-wide Nobel Biocare TiUnite implants at least 10 mm in length. All implants were placed in alveolar ridges that had healed for at least 4 months following tooth extraction. They found 100% implant survival at 1 year in bone quality of types 2 and 3.⁸ Despite their restorative protocol of keeping provisional restorations out of occlusion, they noted that several provisional restorations fractured, indicating that some occlusal function occurred.

Cannizzaro and Leone²¹ reported on a prospective study of 28 patients that compared immediate

loading of 46 single implants and 46 matched conventionally loaded implants. All implants were microtextured, self-tapping Centerpulse Spline Twist MTX implants (Centerpulse Dental, Carlsbad, CA) with at least 3.75-mm diameter and 13-mm length. The authors reported a 100% success rate (46 of 46) with the immediately loaded implants and a 97.8% success rate (45 of 46) in the conventionally loaded group. This study is noteworthy for the randomization of other variables, including medical compromise, cigarette smoking, and implant location in patients. Each of the groups of 14 patients included 3 moderate smokers, 1 patient with cardiac disease, 1 patient with controlled hypertension, 1 patient with controlled type 2 diabetes, and 1 patient with asymptomatic HIV infection.

Additional reports of single immediately restored implants are contained within the data from other publications of immediately restored or loaded implants. Table 2 presents the results from 11 publications that include data on single-tooth immediate restoration cases. The listed studies, though not directly comparable, include the observation that 278 of 287 implants achieved clinical osseointegration, for a survival or success rate of 96.7% by various criteria, under immediate restoration conditions. Common themes of the authors include maximization of implant stability and elimination of direct occlusal contact.

Glauser and associates⁶ sought to test the limits of immediate loading, placing 127 consecutive implants (76 maxillary and 51 mandibular) in 41

patients, including smokers. The clinical conditions included single-tooth, partial-arch, and full-arch situations in healed ridges and extraction sockets. Patients with bruxism and imperfect alveolar ridges were not excluded. Brånemark System machined Mk IV implants (Nobel Biocare), with a modest taper, were used to increase stability at the time of surgical placement. Restorations were usually placed the day of surgery and were fabricated in centric occlusal contact without excursive contact. After 1 year, results indicated that 22 implants were lost in 13 patients, including 7 maxillary implants in 1 patient, for a survival rate of 82.7%. Thirty-four percent of 41 implants in the maxillary posterior area failed, while only 9% of the other 86 implants in all other areas failed. Patients with parafunctional habits (22 implants) had failure more often (41%) than nonbruxers (105 implants, or 12%). The authors observed that implants placed in conjunction with guided bone regeneration procedures to cover exposed threads had a better survival rate (90% of 84 implants) than implants placed into adequate ridges (67% of 43 implants). Further, they noted that implants placed into immediate extraction sockets were more successful (44 of 49; 90%) than those placed into healed sites (61 of 78; 78%).

VARIABLES

Extraction Sockets

Malo and coworkers²⁵ placed 94 consecutive machined-surface Brånemark System Mk II implants (Nobel Biocare) in maxillary anterior areas of 49 non-smoking, nonbruxing patients, with 23 areas restored with fixed partial dentures and 31 single-tooth restorations. Fourteen of 57 maxillary and 13 of 37 mandibular implants were placed in fresh extraction sockets. Stability of the implants was enhanced by underdrilling the apical extent of the osteotomies to increase compression of apical bone during implant placement. Four implants placed into immediate extraction sockets failed to integrate, resulting in a success rate of 85.2% in immediate extraction sockets. All other implants achieved clinical integration. Although the protocol called for fabrication of provisional restorations out of occlusion, 12 provisional crowns loosened and three fractured, indicating that occlusal loading occurred during function.

Rocci and associates²⁶ placed 97 machined-surface Brånemark System Mk IV implants (Nobel Biocare) in the partially edentulous maxillary arches of 46 patients, 8 of whom were smokers. Bruxers were excluded. The authors used an elaborate surgical guide and flapless surgery and placed prefabricated provisional restorations.

There was no discussion of occlusal design. Eight of 97 (8%) implants were mobile within 8 weeks. Five of the lost implants were single-tooth replacements, of which 2 were immediate placements into extraction sockets.

Chaushu and colleagues²⁷ studied a group of 26 immediately restored cylindrical, press-fit hydroxyapatite-coated implants. Seventeen implants were placed in immediate extraction sockets and 9 were placed in healed alveolar ridges. Occlusal contact in centric occlusion was described as “minimized.” Three of 17 implants placed in extraction sockets failed within the first month, for a survival rate of 82.4%, while all of the implants placed in healed ridges survived. All of the failed implants were placed in the maxilla using a combination of conventional drilling and osteotome bone compression for site preparation. It is important to note that this is the only publication reviewed in this section where press-fit, cylindrical implants were evaluated for immediate restoration.

Following up on their earlier work, Malo and associates²⁸ coordinated a multicenter study with 116 machined Brånemark System implants (Nobel Biocare) with various diameters and configurations placed in 76 patients. These implants were placed in the esthetic zone using surgical techniques of underpreparation of the apical osteotomies to increase initial stability such that insertion torque was greater than 30 Ncm for all implants. Twenty-four patients in this group smoked more than 10 cigarettes per day. The authors reported a 96.5% (112 of 116) success rate for integration and 100% (22 of 22) integration in fresh extraction sockets. None of the smokers lost implants, leading the authors to conclude that initial implant stability was more important than smoking in influencing implant survival and normal healing with this group. A higher failure rate was noted with 3.3-mm-diameter implants, although this was not statistically significant because of the small sample size.

Glauser and coworkers²⁹ reported on a 38-patient series in which 102 Brånemark System Mk IV TiUnite implants were placed (Nobel Biocare); 23 were placed in immediate extraction sites and immediately loaded, 8 were placed in incompletely healed extraction sites, and 71 were placed in healed sites. Twelve smokers were included. Ninety-seven percent (99 of 102) of the implants were clinically successful at 12 months. The authors concluded that neither smoking nor immediate or recent extraction sites had an effect on survival outcome. One patient, who accounted for all of the failed implants, developed an early postoperative infection from a simultaneous guided bone regeneration procedure.

Table 3 Publications on Immediate Restorations in Extraction Sockets

Authors	Implant system	No. of implants integrated/ placed	Success rate (%)	No. of integrated/ placed control implants
Wöhrle 1998 ¹⁵	Steri-Oss TPS and HA	14/14	100.0	
Malo et al 2000 ²⁵	Brånemark MKII machined	23/27	85.2	
Hui et al 2001 ²³	Brånemark machined	13/13	100.0	11/11 unloaded in sockets
Chaushu et al 2001 ²⁷	Various HA cylindrical	14/17	82.4	9/9 in healed ridges
Malo et al 2003 ²⁸	Brånemark machined	22/22	100.0	
Glauser et al 2003 ²⁹	Brånemark TiUnite	23/23	100.0	
Cannizzaro/Leone 2003 ²¹	Centerpulse Spline Twist	46/46	100.0	45/46 unloaded in sockets
Kan et al 2003 ²⁰	Steri-Oss HA	35/35	100.0	
Overall		190/197	96.4	

Degidi and Piattelli⁵ followed 646 implants under various clinical conditions. While they did not specifically report statistics of extraction sockets versus healed ridges, they indicated that they only had 2 failures with 58 single-tooth implants. Both of these failures occurred in immediate extraction cases where bone condensation was performed for site preparation. The Frialit-2 implants (Friadent, Mannheim, Germany) used in these cases had few macro-geometric features to enhance primary stability. In addition, the authors noted that in both cases the patients exhibited parafunctional habits that applied excessive forces to the implants early in the healing process.

Eight publications that lent themselves to summation and comparison are shown in Table 3. The data pooled from subsets of patients indicate that 197 implants were placed into extraction sockets, resulting in clinical integration of 190, for a clinical success rate of 96.4%. Comparison of the results and conclusions of some articles indicate that a few authors documented poorer integration rates in immediate placement situations. Those authors who achieved high success rates in either condition include Wöhrle,¹⁵ Hui and coworkers,²³ Glauser and associates,²⁹ and Malo and colleagues,²⁸ who reported common strategies to optimize results. They favored implants with macro-geometric features such as threads to increase immediate bone-to-implant stability and contact. Surgical procedures were modified to increase apical bone density, including underdrilling and self-tapping. Occlusal loads were reduced, with provisional restorations left out of occlusion. Cigarette smoking did not appear to be a factor in achieving integration. Circumstantial reports suggest that implant site preparation through bone condensation may not be optimal for immediate restoration in extraction sockets, in comparison to early loading applications where this type of bone preparation did not appear to affect outcomes.

Single Teeth Versus Multiple Splinted Teeth

Many authors have demonstrated high success rates with immediately restored implants in partial-arch configurations. Case reports and case-control series demonstrating nearly 100% success rates have been reported by Malo and coworkers,^{25,28} Jaffin and associates,³⁰ Chatzistavrou and coworkers,³¹ Degidi and Piattelli,⁵ Calandriello and associates,³² and others. Degidi and Piattelli⁵ reported 100% success of implants (166 of 166) supporting fixed partial dentures in their nonloaded groups. Rocci and colleagues²⁶ reported significantly higher integration rates with multiple-tooth conditions (94%) than with single teeth (81%) using machined-surface implants.

Implant Surface

In a different patient series comparing the influence of implant surface on clinical results, Rocci and coworkers³³ reported a 95.5% success rate with Nobel Biocare TiUnite (roughened-surface) implants in 2- to 4-unit splints but an 85.5% success rate with machined-surface Nobel Biocare implants. This difference in success rate was more pronounced when evaluating implants placed into type 4 bone, where 45% (5 of 11) of machined-surface implants failed and only 8% (1 of 12) of roughened-surface implants failed. These findings are similar to those of Glauser and associates,^{6,29} who demonstrated poor success with machined-surface implants in poor bone quality but good success when roughened surfaces were used in these areas.

Number of Implants, Occlusion, and Placement Technique

One strategy used to enhance success rates has been to increase the number of implants. Calandriello and colleagues³² used 1 implant per tooth and obtained 98% survival. Degidi and Piattelli⁵ recommended a prosthetic unit-to-implant ratio of at least 1.4 in the maxilla and 1.5 in the mandible. They

further recommended that restorations be fabricated out of occlusion, in agreement with Malo and coworkers,²⁸ while Calandriello and colleagues³² recommended light occlusal contact in centric occlusion. In an early loading study, where most restorations were placed within 1.5 weeks of implant surgery, Bogaerde and associates¹² similarly reported high success with light occlusal contact. Most authors recommend altering implant surgical procedures to increase initial stabilization by avoiding tapping the osteotomy sites and by underdrilling the apical width of the osteotomies to increase apical compression. This was specifically mentioned by Malo and coworkers,²⁵ Calandriello and colleagues,³² and Bogaerde and associates.¹²

Bone Density and Quality

Numerous references have been made in the preceding sections regarding the impact of, or association between, bone density or quality and implant success with immediately restored or loaded implants. This implicit relationship between bone density, initial implant stability, and successful osseointegration has been generally accepted by clinicians and confirmed in the literature in relation to conventional loading protocols as described by Jaffin and Berman.³⁴ Mirroring these findings in immediate restoration and loading conditions, Rocci and coworkers²⁶ noted survival of 22 of 27 (81%) machined titanium implants placed in "soft bone" but 66 of 70 (94%) in dense bone, which was statistically significant at $P > .02$. Similarly, Glauser and associates⁶ noted the survival of 66% of implants placed in type 4 bone, but 91% in all other types of bone. In reporting 100% success for integration, Cannizzaro and Leone²¹ noted that 38 of 48 of their immediately loaded implants were placed in bone density type 2⁸ or denser. None of the implants in their study were placed in bone density of less than type 3.

Several authors refer to their stability criteria for immediately loading or restoring dental implants, regardless of bone quality. Wöhrle¹⁵ sought insertion torque of 45 Ncm for single restorations and Hui and associates²³ indicated the need for 40 to 50 Ncm. Horiuchi and coworkers³⁵ observed a mean insertion torque of 42 Ncm for implants used in mandibular full-arch immediate loading cases. Bogaerde and associates¹² recommended a minimum insertion torque of 40 Ncm. Calandriello and coworkers³² indicated that their requirements for immediate loading were a minimum insertion torque of 60 Ncm for single teeth, 45 Ncm for implants supporting partial-arch restorations, and 32 Ncm for implants supporting full-arch restorations. Andersen and coworkers,¹⁶ Malo and associates,^{25,28} Degidi

and Piattelli,⁵ and Lorenzoni and colleagues¹⁹ all indicated that their minimum insertion torque values were 30 to 35 Ncm. Glauser and coworkers²⁹ reported a mean insertion torque of 27 Ncm in their later study. Although Cannizzaro and Leone²¹ did not report insertion torque value, they reported that abutments were torqued to 30 Ncm, indicating that the implants achieved at least this degree of stability.

A few authors have begun to include resonance frequency analysis data^{36,37} in assessing implant stability. Calandriello and coworkers²⁴ reported a mean implant stability quotient (ISQ) of 76 and a minimum of 58 at implant placement for their single molar implant study using 5-mm-diameter implants. Glauser and associates²⁹ reported a mean ISQ at placement of 71 (SD = 8). Of particular interest in this study was the observation of a rapid decrease in mean ISQ value to 63 at 1 week, which gradually increased toward baseline during the 1-year observation period.

Implants with high initial stability appear to survive well under immediate restoration or loading protocols. It would seem that implants placed in softer bone are less stable than those placed in denser bone unless surgical strategies to increase stability are applied. Studies that use insertion torque values are in general agreement that the values should be at least 30 to 35 Ncm. Resonance frequency analysis may prove to be another useful method to aid in selection of the loading protocol.

Implant Surface/Geometry

Most of the data presented on immediately restored and loaded implants have been collected from studies with threaded implants. An exception is the report by Chaushu and associates,²⁷ who used press-fit cylinders and reported a relatively high failure rate (17.6%) in extraction sockets but a 100% success rate in healed ridges.

Implants with a sparse thread pattern have also been evaluated. Degidi and Piattelli⁵ used 82 Frialit-2 implants with immediate loading and reported 6 failures, for a success rate of 93.7%. In immediately restored, unloaded implant sites, they reported 2 failures of 62 Frialit-2 implants (Friadent) in extraction sockets, for a success rate of 96.6%. The 2 failures in this group occurred in extraction sockets that were prepared using bone condensation procedures. Lorenzoni and coworkers¹⁹ reported on immediate restoration of Frialit-2 implants in extraction sockets and had 100% success using occlusal splints for 2 months after placement to eliminate forces on the implants.

Few investigators have directly compared the integration rates of roughened, threaded surfaces with those of machined, threaded surfaces. Rocci

and coworkers³³ noted a significant increase in success rate when comparing Nobel Biocare TiUnite surface threaded implants with machined-surface threaded implants. They found the success rate for the roughened-surface implants to be 95.5% (63 of 66) versus 85.5% (47 of 55) for the machined threaded surfaces. The difference in success rate was particularly striking when evaluating implants placed in poor quality, type 4 bone⁸: 1 of 12 rough-surfaced implants failed, compared with 5 of 11 machined-surface implants. These results are similar to those in case series reported by Glauser and associates.^{6,29}

Alternatively shaped implants have been developed specifically for immediate restoration and loading applications. These include the Altiva NTR System (Altiva, Minneapolis, MN) and the Sargon system (Sargon Enterprises, Beverly Hills, CA). Buchs and coworkers³⁸ reported on the Altiva NTR, which is a 1-piece implant with a dual helical thread pattern designed to increase initial bone stability and eliminate prosthetic abutments and screws. The authors reported on a series of 142 implants that were used in single-tooth (51) and partial-arch (91) clinical situations. Smokers and unhealed extraction sockets were excluded from the study. Nine failures were reported, for a success rate of 93.7%. When the data were further refined, they noted success rates of 83.3% (10 of 12) in type 1 bone, 95.7% (45 of 47) in type 2 bone, 88.9% (24 of 27) in type 3 bone, and 71.4% (5 of 7) in type 4 bone.⁸ One hundred twenty-six of 142 implants were followed at least 1 year, and the implant survival rate did not change after the second month. No data are available to address success criteria of bone level stability, radiographic changes, or gingival indices for this implant system.

Jo and coworkers³⁹ reported on 286 expandable implants manufactured by Sargon and used in 75 patients. Eighty-two of 90 implants placed in extraction sockets were immediately loaded, and 164 of 196 implants placed into healed ridges were immediately loaded. The unloaded implants, including all implants placed into type 4 bone, were deemed not sufficiently stable for immediate loading and were allowed to heal conventionally. The implants were designed to allow for expansion of the apical wings of the implant to re-establish intimate contact with the surrounding bone if implant mobility was noted in the first few weeks of healing. Two hundred eight of 286 implants required apical expansion during early healing. Results indicated that 81 of 82 (98.8%) immediately restored implants placed in extraction sockets and 156 of 164 (95.1%) immediately restored implants placed in

healed ridges survived a minimum of 13 months and up to the maximum observation period of 40 months. Sixty-nine implants had 75 complications. Thirteen of these implants failed. Some of the complications appeared to be unique to the implant design. Implant fracture was not observed. As with the Altiva NTR system, long-term success criteria and data are not available for this implant system.

In summary, the available literature, which is available mostly in a case-series format, is limited and inconclusive with regard to surface and shape characteristics for implants used for immediate restoration and loading. A strong inference can be drawn that implants with increased macroscopic stabilization features such as threads and microscopic enhancements such as surface treatments appear to have improved integration rates compared with smoother designs. TPS and hydroxyapatite coatings, SLA, and increased oxidation appear to improve integration success over machined surfaces, particularly in areas of challenging bone quality. Newer designs like mechanical expansion and large helical threads may offer alternative methods of initial stabilization, but it has not yet been shown that implants with these alternative geometries can achieve long-term success as currently defined.

Stability of Results

It is clear that immediately restored and loaded implants in partial- and single-tooth applications can achieve integration using many implant systems and protocols. Other clinical outcomes that have been evaluated include hard and soft tissue changes. Ericsson and coworkers²² noted that once implants were restored, they lost a mean of 0.1 mm of bone over the 1-year evaluation period, which was similar to data obtained from their control group of delayed loaded implants. Lorenzoni and associates¹⁹ noted that implants placed with an immediate restoration demonstrated 0.45 mm mesial resorption and 0.75 mm distal crestal resorption at 6 and 12 months, which was less than that observed for a standard 2-stage approach. Hui and coworkers²³ reported crestal bone loss of no more than 0.6 mm during their 16-month observation period. Andersen and associates¹⁶ noted a mean gain of radiographic crestal bone level of 0.53 mm during their 5-year observation period. This gain was explained as closure of the vertical defects of the extraction socket walls toward the implant surface. Cannizzaro and Leone²¹ noted radiographic bone loss of 0 to 1 mm on 95.7% (44 of 46) of their immediately loaded implants and 93.3% (43 of 44) of their control group at 24 months, indicating no statistical difference between the immediately loaded and conventional treatment modalities.

Degidi and Piattelli⁵ reported mean bone loss of 1.1 mm after 5 years on 87 immediately restored or loaded implants. Rocci and associates²⁶ noted mean bone loss of 1.0 mm after 1 year, 0.4 mm during the second year, and 0.1 mm in the third year of their study. In their single-tooth, mandibular molar study, Rocci and colleagues³³ similarly measured a mean of 0.9 mm crestal bone loss with TiUnite (ie, rough-surfaced) implants and 1.0 mm with machined-surface implants. Malo and coworkers²⁸ found mean bone loss of 1.1 mm, Calandriello and associates³² measured mean bone loss of 1.2 mm, and Glauser and colleagues²⁹ measured mean bone loss of 1.2 mm in their studies after 1 year. These bone loss measurement data are similar to those reported for conventional loading protocols.^{40,41} Crestal bone resorption data were not reported for the less traditional implant designs of Sargon and Altiva NTR.

Of particular interest to clinicians when placing implants in the esthetic zone are the stability and behavior of soft tissue contours. Achieving stable osseointegration is an important element of predictable implant dentistry, but preserving or creating stable, harmonious soft tissue contours is also of paramount importance. Wöhrle,¹⁵ Hui and coworkers,²³ and Kan and associates²⁰ reported gingival marginal changes of immediately restored implants. Wöhrle¹⁵ noted minimal marginal tissue changes in 12 of 14 patients and recession of 1 to 1.5 mm in the remaining 2 implants. Hui and coworkers²³ did not report data on soft tissue stability, but noted that the esthetic results in their immediately restored sites were superior to those achieved with a staged approach because of gingival architecture preservation.

In a carefully documented study, Kan and associates²⁰ followed 35 maxillary anterior immediately restored implants placed into extraction sockets. After 1 year, they noted radiographic crestal bone loss of 0.26 mm mesially and 0.22 mm distally. Gingival marginal recession was 0.55 mm midfacially, 0.53 mm at the mesial papilla, and 0.39 mm at the distal papilla. These changes are similar to those reported for conventional loading protocols by Bengazi and coworkers⁴² and are slightly less than those reported by Small and Tarnow.⁴³ Additionally, a histomorphometric study in macaque monkeys by Siar and coworkers⁴⁴ supports the observation that no significant differences in crestal bone level or gingival margin location were seen between immediately loaded and conventionally loaded implants.

In general, the case reports and studies indicate that once immediately loaded implants integrate, they appear to have longitudinal bone loss and soft tissue stability comparable to those of conventionally loaded implants. Limited data suggest that immediate

restoration of implants in the esthetic zone might facilitate and stabilize gingival architecture more than a staged approach. No evidence suggests that deleterious gingival complications can be directly attributed to immediate restoration or loading protocols.

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Immediate Restoration and Loading of Dental Implants: Clinical Considerations and Protocols

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The use of dental implants to assist in the treatment of partial and complete edentulism is well documented. Most of the implant literature, however, reports results associated with implant survival and success when there has been adherence to rigid placement and loading protocols. Conventionally, these protocols call for the undisturbed healing of the implant—3 months in the mandible and 4 to 6 months in the maxilla. This article evaluates the literature and develops protocols for clinical procedures for the early or immediate restoration or loading of dental implants. Criteria are established for defining immediate loading, immediate restoration, early loading, and early restoration as compared to conventional protocols. The review assesses factors that influence accelerated loading and restoration decisions, including bone quality and quantity, implant design, splinting of implants, and prosthetic design. Conclusions and recommendations are made based on the experience of the consensus group charged with considering these procedures and on the current literature published on these protocols.

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Successful implant-based dental treatment has been associated with rigid protocols advocating lengthy periods of undisturbed healing.^{1–3} Originally recommended for the edentulous mandible, implant-based treatment predicated on such protocols has expanded to include the edentulous maxilla, partially dentate arches, and single missing teeth. This expansion is the result of continued treatment success for these indications, despite the perceived increase in surgical and restorative risk.

Because the recommendations for implant restoration and loading are observational in nature, clinicians have questioned their validity. Particular attention has been paid to the timing of restoration with no occlusal contact and/or loading with occlusal contact in centric occlusion or maximum intercuspation and what loading entails. Several authors have made efforts to define terminology and have suggested modifications to long-established clinical practices.

The literature addressing implant survival and treatment protocols has been addressed by other articles presented by this consensus group.^{4,5} This literature suggests that implant loading has been associated with occlusal contact and with “abutment connection or torquing” and has typically occurred between 3 and 6 months after implant placement. It should be noted that this period of healing is recommended predominantly for smooth-surfaced or machined implants, and for earlier versions of rough-surfaced implants.

Recommendations for the loading of implants characterized by a rough surface can be less than 3 months. The loading of the sand-blasted, large-grit,

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acid-etched (SLA) surface implant (Institut Straumann, Waldenburg, Switzerland), for example, has been associated with abutment torquing to 35 Ncm, has been evaluated in animal trials,⁶ and has proven successful in humans when loaded as early as 6 weeks postplacement.⁷ Although recommended, such loading is still early in comparison to the conventions established in the body of literature^{4,5} and will be considered as such. Such early loading protocols have been used for both edentulous and partially dentate patients.

Clinical parameters associated with the success of early or immediate restoration or loading have been documented. Although the decision to immediately restore or load dental implants is made prior to initiation of care, progression can only be confirmed clinically at the time of implant placement with appropriate assessment of implant stability, bone quality, and general site health. Several authors have detailed clinical factors to be considered when assessing the applicability of immediate restoration or loading.⁸⁻¹⁰ These authors emphasize the particular importance of the following:

1. Primary clinical stability of the implant(s)
2. Adequate implant splinting where appropriate
3. Provisional restorations that promote splinting and reduce or control the mechanical load applied to the implant(s)
4. Prevention of provisional restoration removal during the recommended period of implant healing
5. Incorporation of the team approach and the use of surgical templates

In addition, authors have identified risk factors associated with immediate restoration or loading of dental implants.^{8,10} These include:

1. The presence of high masticatory or parafunctional forces
2. Poor bone quality or volume
3. The presence of infection

Masticatory function as related to dental implant-based treatment, however, has been considered only rarely in the literature. Degidi and Piatelli¹¹ described differences between functional and nonfunctional loading. *Immediate functional loading* of implants involved patients receiving prostheses with occlusal function on the day of implant placement, whereas *nonfunctional immediate loading* (termed *immediate restoration* by this consensus group) involved the provision of a prosthesis 1 to 2 mm short of occlusal contact. In their study, 646

implants were positioned immediately, 422 were functionally loaded, and 224 were nonfunctionally loaded. For the group characterized by functional load, implant (98.6%) and prosthesis (98.5%) survival were clearly within previously published parameters. Further, results for immediate nonfunctional loading did not establish a clear advantage when considering implant (99.1%) or prosthesis (98.3%) survival.

Bone quality and volume, and the presence or absence of infection, are relevant to survival and success results. The positioning of implants in bone that has been given the opportunity to heal from infection and inflammation, and that may have been effectively augmented, increases the likelihood for implant stability and increases bone quality and quantity. Immediate restoration or loading of immediately placed implants in bone that has not been allowed to heal, or that has not been effectively augmented, may lead to increased risk. Assessment of occlusal load magnitude and the effects of parafunction remain subjective, and no numeric relationship exists relating these factors with implant loading, whether immediate, early, or delayed.

CLINICAL PROCEDURES

Clinical procedures will vary for immediate and early restoration and loading for edentulous and partially dentate patients. For each clinical indication, the presence or absence of immediate implant placement in extraction sockets is an additional consideration, evaluated elsewhere in this publication.

Many of the suggested considerations for immediate or early restoration or loading are not applicable in all clinical situations, as, for example, it is not possible to achieve adequate implant splinting in single-tooth sites. Further, some prostheses, by virtue of arch position and the teeth involved, may be subjected to excursive loading even when centric occlusion or maximum intercuspation contacts are absent. The ability to obtain load distribution between the remaining natural or restored teeth needs to be considered.

In addition, measurable parameters are evaluated in varying ways. Primary stability of implants, for instance, has been associated with placement torque, Periotest values (Siemens, Mannheim, Germany), and resonance frequency analyses. Possibly the most frequently used method of stability evaluation is a subjective opinion formulated by the surgeon. While each may be useful, at this point it is not possible to compare results from each group and quantify a uniformly acceptable standard for measurement of

implant stability. Therefore, as there is no consensus, a particular method of clinical evaluation of implant stability at the time of placement cannot be recommended at this time.

However, it is felt that simple assessment of implant stability throughout treatment may prove beneficial in helping practitioners to understand the possible long-term effects of immediate and early restoration or loading, allowing for more accurate identification of treatment risks.

Edentulous Arches

Clinically, it is possible to use removable or fixed prostheses in the restoration of edentulous arches. Immediate loading results for such restorations are dependent on the number of implants, the type of prosthesis, the presence or absence of splinting, the occlusal scheme, and the jaw being restored.¹²

The use of immediate or early loading of splinted implants to restore edentulous arches has been documented. Tarnow and coworkers⁸ published their experiences with the immediate loading of edentulous arches in 10 patients. The group placed 107 implants, 50 of which were immediately loaded. Two failures were recorded in the mandible of the experimental group. The authors attributed the failures to removal of the provisional prostheses for evaluation of implant healing, and this protocol was therefore discontinued. Emphasis was placed on fundamental clinical procedures, including the need for diagnostic procedures and the use of templates and provisional restorations. In conclusion, however, the authors found that immediate loading should “be attempted in edentulous arches only” and that implants should be splinted. Despite the obvious merits of this article, based on the content, such a statement cannot be justified. This conclusion would require evaluation of implants in partially dentate patients as a comparison, along with an evaluation of implants lacking in cross-arch stability.

In a retrospective evaluation of 776 immediately loaded implants followed between 2 and 13 years, implant success (96.9%) and prosthesis survival (98.5%) were found to be similar to results established for implants loaded according to conventional loading protocols.¹² For patients in this study, a bar was rigidly attached to 4 implants and an overdenture was supported and retained by means of clips (U-shaped Dolder). When the immediately positioned prosthesis opposed a maxillary denture, balanced occlusion was utilized, with group function preferred when the opposing arch was characterized by natural or restored teeth.

Credence should be given to these findings, because the study was multicenter and included

prospectively defined criteria for inclusion, exclusion, and evaluation. In addition, 4 different implant systems were used to support the prostheses, resulting in evaluation of the treatment modality and not the implant system. The same protocol was used (albeit with a single implant system) in a prospective evaluation of a separate patient population.¹³ Eighty-four immediately loaded ITI implants were placed between the mental foramina and evaluated, with similar results.

The results attained by the 2 previously described research studies have been summarized in a life table analysis of 328 implants loaded within 24 hours of implant placement.¹⁴ The authors found cumulative survival rates exceeding 96% and cumulative success rates exceeding 88.2% through 8 years of follow-up. The numeric difference between the 2 groups was associated with marginal bone loss. In this publication, the results were not related to the occlusal scheme or to the form of the opposing arch. In addition, since the restorative procedures were not detailed, passivity of the bar and the functional characteristics of the prostheses cannot be related to the results and a relationship can at best be assumed.

In a prospective evaluation of 7 patients characterized by mandibular edentulism, Lorenzoni and coworkers¹⁵ compared 14 implants that were loaded 2 to 4 days postplacement with 28 implants that were allowed to heal for 6 months prior to second-stage surgery. Two of 6 interforaminal implants in each patient were joined by a bar and loaded by way of a prosthesis subjected to normal occlusal function. The bar was fabricated in the laboratory from an impression made at implant placement, and pre-existing dentures were modified to incorporate a retentive clip. No description of prosthesis design (occlusal scheme and contact distribution) was reported. It is important to note that each patient's pre-existing prosthesis was used, although no description of quality (or evaluation criteria) was provided. Although all implants survived the follow-up period, the authors concluded that the immediately loaded implants suffered a significantly greater loss of marginal bone (0.9 ± 0.40 mm) than the non-loaded implants (0.33 ± 0.34 mm) and had significantly higher Periotest values (-3 versus -6). They concluded that while their results illustrated a statistically significant difference associated with the timing of loading, the measurable parameters were acceptable clinically, and further evaluation of long-term ramifications of these findings was required.

Such citations detail the ability to use immediate and early loading of implants to support complete mandibular dentures. Clinically, 2 or 4 implants

have been rigidly splinted across the midline with a bar. Although authors often describe the dentures as being "subjected to loading," few detail the pre-existing or the postloading occlusal scheme or contact distribution desired or obtained. Therefore, the relationship of conventional prosthodontic procedures (clinical rearticulation and occlusal adjustment) to success cannot be established. Further, the analysis of success is related only to the survival of the implants and compared to previously published protocols. An evaluation of the restorative outcome from the perspective of both the clinician and the patient is desirable.

While it appears evident that implants loaded under such circumstances are capable of surviving accelerated restoration or loading protocols, the advantage to patients needs to be clarified. Are patients more satisfied with prostheses placed immediately versus prostheses placed according to more conventional loading protocols? Such assessments should be made from functional and esthetic perspectives. Because the procedures associated with immediate and early restoration or loading are, from a prosthodontic perspective, more challenging, it is possible that the functional result may be inferior because of the clinical difficulty. Therefore, the quality of the prosthodontic outcome also needs to be addressed.

Although such an assessment has not been made with regard to overdentures, immediately restored or loaded implants have been used to improve the treatment outcomes of fixed prostheses placed in edentulous arches. In a comparative clinical trial, 14 patients received between 5 and 8 implants in the edentulous mandible.¹⁶ In the control group, 7 patients received between 5 and 7 interforaminal mandibular implants, placed according to a 2-stage procedure and provided with 3 to 4 months of undisturbed healing beneath a denture lined with tissue conditioner. The study group patients each received between 5 and 7 implants, 4 of which were placed interforaminally. The implants in this group were loaded on the day of placement with a fixed provisional prosthesis. The implants were rigidly splinted by incorporation of components in the acrylic resin denture. Two distinct methods were used to relate the implants to the existing prosthesis. The first involved picking up provisional cylinders in the patient's mouth with the prosthesis in occlusion. The second method involved articulation of the denture, which was concurrently serving as an impression tray. Provisional cylinders were attached in the laboratory and used to retain the provisional prostheses.

Although the manufacturer and type of implant were not provided, the authors reported that all

implants integrated. Patients in the control group received an average of 5.4 postplacement visits for maintenance of the tissue conditioner and repair of fractured prostheses, versus 1 postloading visit for the study group patients. All patients in the study group reported satisfaction with the prosthesis, although complaints related to the difficulty of oral hygiene maintenance were common. The authors described the lack of a removable transitional prosthesis as a clear advantage for patients, adding that "decreased chair time, psychologic advantages and reduced maintenance" are also beneficial. This illustrates a treatment improvement for patients beyond measurable parameters of implant survival, and additional evaluations of this type are encouraged.

Other groups have evaluated loading of implants with fixed restorations in the mandibular arch. In a 10-year follow-up of 28 immediately loaded implants, Schnitman and coworkers¹⁷ found survival rates (84.7%) to be significantly lower than the results achieved in the control group (100%). Jaffin and associates¹⁸ reported findings associated with 27 patients who received fixed prostheses either on the day of implant placement or within 72 hours. Prerequisites for immediate loading included acceptable clinical and radiographic evaluation of bone volume and quality, appropriate implant distribution, and the absence of an unfavorable occlusal scheme (edge to edge). All implants were placed with the aid of a template and restorative abutments were positioned. Provisional fixed prostheses were fabricated and delivered on the day of placement, or an impression was made for indirect fabrication of a provisional prosthesis to be delivered within 72 hours. Clinically, 8 of 122 immediately loaded mandibular implants failed to integrate. Seven of the 8 failures were machined-surface implants. All 27 implants placed in the maxilla were characterized by a rough surface (titanium plasma sprayed or sandblasted/acid etched) and none failed. Success was determined at 6 or 12 weeks post-implant loading and was based on lack of pain or mobility, ability to torque to recommended levels, and absence of peri-implant radiolucency. Consistent with previous publications, the clinical success of the prosthodontic procedure (immediate restoration or loading) was assessed by way of surgical parameters and implant survival. However, the authors did include a "well-balanced" occlusal scheme as a goal and requirement. The lack of removable prostheses was related to increased patient and clinician satisfaction and, although this makes intuitive sense, no description was provided regarding how this conclusion was reached.

Functional loading of fixed metal-ceramic prostheses on Mk II implants (Nobel Biocare, Göteborg,

Sweden) placed in edentulous mandibles has been evaluated.¹⁹ Although considered immediate by the authors, all prostheses were delivered within 20 days of placement, and loading should therefore be considered “early” according to definitions established by this consensus group. Five or 6 implants were placed bicortically positioned and patients were prevented from wearing any interim prosthesis for 10 days. After 10 days of healing, impressions were made, articulation procedures were undertaken, and the patient’s denture was lined with tissue conditioner. Although survival parameters were considered (integration, radiographic, and periodontal), no discussion of occlusion, delivery procedures, evaluation of passivity, or patient satisfaction was evident. These procedures, therefore, can only be considered as having no detrimental effect on implant survival. A restorative benefit (other than time) cannot be established from the information provided.

Partially Dentate Patients

As a follow-up to the work of Randow and colleagues,¹⁹ Ericsson and associates²⁰ described the immediate restoration of single missing teeth. Fourteen patients received machined-surface implants (Mk II, Nobel Biocare). Prospective description of inclusion criteria (the ability to obtain bilateral occlusal stability from the remaining teeth and adequate bone volume) was provided. An impression was made on the day of surgery and a provisional prosthesis positioned within 24 hours. All provisional restorations were characterized by minimal or no occlusal contacts and were allowed to heal for 6 months prior to fabrication of the definitive prosthesis. Several parameters were evaluated, including implant stability and marginal bone levels. These were related to implant survival and were within expectations. The authors indicated that the occlusal circumstances were to be evaluated, as was the degree of patient satisfaction. However, the results for these restorative parameters of success were not clearly evident.

Calandriello and coworkers²¹ evaluated 50 implants placed in healed sites for first (n = 42) and second (n = 8) molar replacement. Each implant was characterized by high insertion torque values (60 Ncm). Importantly, 16 of the implants were the most distal functional unit in the quadrant being restored, meaning that occlusal protection could not be obtained both mesial and distal to the restoration. Provisional crown restorations were positioned on the day of implant placement and were characterized by a centric occlusal contact. Patients were not instructed to alter oral habits—only requested to avoid hard food. Although follow-up was limited (only 24 implants were followed for

more than 12 months), no implants were lost. In contrast to recommendations made for edentulous-arch restorations, the authors routinely removed the provisional restorations to evaluate implant stability, and no detrimental effects were noted. The conclusion encouraging the immediate loading of wide-platform implants with defined form is based again on implant survival and not on parameters related to the restoration or satisfaction of the patient.

Experiences with the early restoration of ITI dental implants (Institut Straumann) characterized with a titanium plasma-sprayed surface have been reported.²² Eight implants positioned in the anterior maxilla were followed for 5 years, with evaluation centering on bone maintenance and soft tissue conditions. The first consensus group has related these parameters to the esthetic outcome of implants. No implants were lost during the follow-up period, and gains in marginal bone levels were observed. All implants were placed with bone preservation and the restoration in mind, although no detailed discussion of methodology was offered. All implants received an abutment torqued to 35 Ncm on the day of implant placement but did not receive provisional restorations until 1 week later. All provisional restorations were modified to remove incisal contacts, and diet modification was recommended.

CONCLUSIONS AND RECOMMENDATIONS BASED ON THIS REVIEW FOR THE EARLY OR IMMEDIATE RESTORATION OR LOADING OF DENTAL IMPLANTS

Surgical Considerations

1. Implant selection, position, and distribution should be guided by the restorative plan.
2. Diagnostic and surgical templates indicating the prosthodontic plan should be used where possible.
3. Care should be taken to optimize distribution of implants placed in edentulous arches and intended for immediate or early restoration or loading.
4. Minimizing biomechanical risk to implants in edentulous arches and in patients exhibiting extended edentulous regions is recommended. Effort should therefore be made to reduce the influence of cantilevers by using an appropriate number of implants and by optimizing distribution. Also, an adequate number of implants should be positioned to facilitate splinting and protection from the possible effects of micromotion.
5. Clinical stability of dental implants should be achieved. This is made possible by selecting

patients who exhibit adequate bone quality and quantity, by selecting an implant with a rough surface and adequate dimension, and by using good clinical technique to maintain contact between the implants and bone.

Restorative Considerations

1. Where possible, a clear advantage for the patient should be established prior to treatment.
2. Where possible, the biomechanical effects of the provisional restoration should be controlled by (a) limiting and distributing occlusal contact in centric occlusion or maximum intercuspation, (b) removing all excursive contacts from the provisional restorations, (c) limiting the effects of cantilevers and off-axis loading, and (d) splinting implants together where possible.
3. Traditional prosthodontic procedures associated with accuracy of fit and passivity, evaluation of occlusal scheme, and assessment of patient satisfaction should be encouraged.
4. Where possible, provisional restorations should remain in place throughout the process of healing, allowing adequate healing of the hard and soft tissues in contact with the implants and the prosthesis.
5. Clear parameters are required to evaluate the outcome of the restorative treatment.

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Consensus Statements and Recommended Clinical Procedures Regarding Loading Protocols for Endosseous Dental Implants

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INTRODUCTORY REMARKS

The group was asked to develop evidence-based reviews on topics related to various loading protocols for dental implants. Three reviews were prepared: the first addressed the literature related to different loading protocols for partially edentulous cases, the second examined the literature for loading protocols in completely edentulous cases, and the third addressed clinical procedures for the various loading protocols. Drafts of the manuscripts were prepared and distributed to the members of the group prior to the conference. The overall objective of the literature review was to determine whether a procedure could be recommended as a standard based on the available evidence. The second objective was to identify whether patients perceived a benefit associated with these procedures.

The literature included full-length articles in English on endosseous root-form titanium implants. For edentulous patients, a minimum follow-up of 1 year was required. The volume of literature found was moderate, but the level of evidence was limited at best for the procedures considered. The predominant literature was case reports. The primary goal was to identify survival of the implants and success or failure of the procedure(s), and to relate these to the implant and/or prosthesis. A secondary goal was to identify possible risk factors for the procedures.

At the consensus conference, the authors presented their manuscripts to the group for discussion. There was discussion concerning how the authors approached writing the draft, how the literature was searched and reviewed, what the major

findings were, and finally, what conclusions could be drawn. Following these presentations, group members addressed several aspects of each review, including:

- Did the review adequately address the topic?
- Has any evidence been published since the review that has a significant impact on the topic?
- Do the section members agree with the findings of the review's authors?
- What open questions remain in this area, and what might be investigated in the future regarding this topic?
- What recommendations can be made for patient treatment with regard to loading protocols?

During the discussion, several statements were made regarding immediate or early restoration and/or loading of implants in edentulous and partially edentulous patients. These are listed below, along with issues that were identified throughout the discussions.

Definition of Terms

An important aspect of the discussion of loading protocols for dental implants was to define the terms to be used, since there has been confusion in the past over definitions of terms related to restoration. The group worked to clarify these. Notably, for *immediate restoration* it had not been defined whether the prosthesis is in contact with the opposing dentition; thus it was necessary to clarify the occlusal scheme used at the time of restoration. According to the body of literature, in agreement with the previous (1997) ITI consensus, a minimum of 3 months of healing prior to implant loading had been established as *conventional loading*. However, the group felt that with increasing evidence to support reduced healing times for rough-surfaced titanium implants, the definition of conventional healing periods for these implants might be modified.

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Most of these terms were recently defined in a conference on immediate and early loading that occurred in Spain in May 2002.¹ However, the group modified these definitions for use in this report. The modified definitions are presented here:

- *Immediate restoration*: A restoration inserted within 48 hours of implant placement but not in occlusion with the opposing dentition. The group's decision to use 2 days was not based on strong biologic evidence—rather, it was based on the clinical capacity to perform procedures within a limited time frame following surgery. With regard to the term “immediate” the group felt that future research and clinical experience with peri-implant tissue healing may provide more appropriate definitions.
- *Immediate loading*: A restoration placed in occlusion with the opposing dentition within 48 hours of implant placement.
- *Conventional loading*: The prosthesis is attached in a second procedure after a healing period of 3 to 6 months.
- *Early loading*: A restoration in contact with the opposing dentition and placed at least 48 hours after implant placement but not later than 3 months afterward.
- *Delayed loading*: The prosthesis is attached in a second procedure that takes place some time later than the conventional healing period of 3 to 6 months.

Review of Loading Protocols

Changes in loading protocols are not uncommon in implant dentistry. Early work focused on the predictability of osseointegration, predominantly in edentulous mandibles. Subsequent work focused on implant integration in partially edentulous patients and various clinical indications. More recent studies have been directed at achieving quicker integration and shorter healing periods prior to implant restoration. More rapid integration has been attempted by modifying the titanium implant surface and by stimulating the surrounding tissues with growth-promoting substances such as bone grafts and growth factors. The ultimate loading protocol is immediate: providing the patient with a tooth replacement the day the implant is placed. Loading protocols can best be interpreted on the biologic basis of implant integration.

The process involved in the osseointegration of dental implants is poorly understood. Many professionals do not appreciate the fact that osseointegration is instantaneous. Osseointegration is defined as bone-to-implant contact at the light microscopic

level. As soon as an implant is placed into the jawbone, certain areas of the implant surface are in direct contact with bone, ie, osseointegrated. Cochran and coworkers² have described this as *primary bone contact*. With the ITI Dental Implant System (Institut Straumann), the instrumentation is designed such that the osteotomy preparation has a slightly smaller diameter than the implant, so that the implant has a “press-fit” against the bone tissue. This represents the predominant contact with the bone at early healing times. As healing occurs, however, this bone is remodeled, and areas of new bone contact with the implant surface appear (particularly with more osteoconductive surfaces such as the SLA [sandblasted, large-grit, acid-etched; Institut Straumann]). This remodeled bone and new bone contact, termed *secondary bone contact*, predominates at later healing times when the amount of primary contact is decreased. By understanding these concepts one can appreciate how various loading protocols are possible and can view loading protocols as dependent on 2 distinct processes.

Immediate loading protocols were first described for the completely edentulous mandible. This indication is dependent on existing bone at the implant site. In the completely edentulous anterior mandible, where bone is typically extremely dense, large amounts of primary bone contact occur. Thus, instantaneous osseointegration occurs in large amounts of cortical bone, giving the implant immediate stability. Combined with a rigid connection of the implants, this provides for stability of the entire complex and osseous healing around the implants, ie, clinical implant success. It is not surprising, then, that immediate loading of multiple implants in the edentulous mandible can be a very successful procedure. This represents one scenario for the early/immediate loading of implants and is dependent on the existing quality and quantity of osseous tissue.

Another scenario with implications for early/immediate loading protocols is dependent not only on the existing bone quality and quantity but also on the possibility of rapid formation of bone tissue around the implant. This scenario occurs in indications where the quality and quantity of bone are not ideal, eg, sites with minimal cortical (dense) bone. In these cases, the ability to stimulate bone formation becomes crucial. Thus, early loading protocols become feasible and immediate loading protocols become less likely. The use of implants with modified surfaces that increase bone-to-implant contact and removal torque values has allowed shortened healing times under these conditions. For example, Cochran and coworkers³ have demonstrated that implants with an SLA surface placed in

areas of typically lower-quality bone can be restored after just 6 weeks of healing (early loading).

This analysis suggests that shortened loading protocols should focus on (1) the amount of primary bone contact, (2) the quantity and quality of bone at the implant site, and (3) the rapidity of bone formation around the implant. In addition, 2 general scenarios are possible that relate to mechanisms of implant support that allow for reduced healing times. When existing bone of high quality and quantity is found, immediate loading of the implant may be possible. If the existing bone is not of high quality and quantity, then bone formation must occur in a relatively short time so that early loading of the implants can take place.

Various loading protocols for the restoration of dental implants are described in the literature. Several terms are important to understand when discussing them. In the case of *direct occlusal contact*, the restoration makes contact with the opposing dentition. With *indirect occlusion*, the implant is restored without directly contacting the opposing dentition, ie, it is out of occlusion. With *progressive loading*, the implant is restored in “light” contact initially and is gradually brought into full contact with the opposing dentition. Unfortunately, it is currently unknown whether the type of occlusion has an influence on the success of the timing of loading of the implant.

Another important aspect of loading protocols is the implant site. The site can range from a well-healed edentulous space to an area where a tooth has just been removed—an immediate extraction site. In the latter case, the size of the defect around the implant varies depending on the size of the tooth being extracted. Another section of this consensus conference addressed the placement of implants in extraction sites; however, it is clear that the nature of the implant site can have a significant impact on the outcome of the implant restoration, regardless of the loading protocol. Thus, for the purpose of these reviews, when discussing implant loading protocols it was assumed that the implant is placed in a well-healed edentulous ridge with native bone surrounding the implant.

CONSENSUS STATEMENTS

An appreciation of the mechanism governing how an implant interacts with bone tissue provides a basis for understanding how immediate and early loading protocols are possible. Stability of the implant is important for the success of any loading protocol. In fact, the outcome most often assessed

and most often associated with procedure success in the literature was implant stability, and in many citations it was the only outcome assessed. Stability of the implant was found to be influenced by factors including, but not limited to, implant surface and geometry, quality and quantity of bone, splinting of implants, control of occlusal load, and absence of detrimental patient habits.

The literature is often characterized by inclusion and exclusion criteria that limit evaluation to a selected patient population. Thus, the results are often obtained under conditions that are considered favorable. With the understanding that the literature base is small, and the strength of evidence is graded as inadequate to fair, the group reached the following conclusions.

Edentulous Mandible

In edentulous mandibles, the immediate loading of 4 implants with an overdenture in the interforaminal area with rigid bar fixation and cross-arch stabilization is a predictable and well-documented procedure. This indication represents the only indication where the literature includes randomized and controlled studies. According to criteria agreed upon by this consensus group, this procedure is supported by 7 studies involving 376 patients and 1,529 implants.

In contrast, the early loading of implants (splinted or unsplinted) in the edentulous mandible with an overdenture is not well documented. Only 6 publications considered by this consensus group support such a procedure. They involved just 85 patients and 230 implants.

Immediate loading of implants supporting fixed restorations in the edentulous mandible is a predictable and well-documented procedure, provided that a relatively large number of implants are placed. The consensus group considered the procedure to be supported by 15 articles involving 387 patients and 2,088 implants, 1,804 of which were immediately loaded.

The consensus group found only 6 publications supporting the early loading of implants in the edentulous mandible with a fixed restoration. The publications involved 51 patients and 272 implants, 234 of which were loaded early.

Edentulous Maxilla

No articles were found supporting immediate or early loading of implants with an overdenture in the edentulous maxilla. Therefore, this procedure would have to be considered experimental at this time.

In the edentulous maxilla, immediate or early loading of implants utilizing a fixed prosthesis is not

well documented. Regarding immediate loading, 7 publications involving 30 patients and 276 implants were found and discussed by the consensus group. For early loading, 4 articles involving 26 patients and 192 implants were reviewed.

Partially Edentulous Mandible or Maxilla

In the partially dentate maxilla and mandible, the immediate restoration or loading of implants supporting fixed prostheses is not well documented. It should be noted that in many of these cases the restoration is not in contact with the opposing dentition. This observation highlights the care that must be expended to plan and successfully complete such a restoration. Factors that have been highlighted include the absence of parafunctional habits, the use of a roughened implant surface, the use of a threaded implant, and primary stability of the implant.

In contrast, the early restoration or loading of titanium implants with a roughened surface supporting fixed prostheses after 6 to 8 weeks of healing is well documented and predictable in the partially dentate maxilla and mandible. Results seem to indicate that the outcome is similar to results obtained with conventional procedures. However, because of the limited number of implants placed (in comparison to the number of conventionally loaded implants) and the short follow-up period, further studies are necessary before these procedures can be proposed as routine.

Interproximal crestal bone levels and soft tissue changes adjacent to immediately restored or loaded implants were found to be similar to those reported for conventional loading protocols.

Other issues that were discussed included the following:

- A conventional loading period of 3 to 6 months is likely to be modified for implants with roughened surfaces. The 3- to 6-month period was originally defined for implants with machined surfaces, and it is well documented that the machined surface is not as successful as the roughened surface in certain indications.
- A question that needs to be addressed is whether the patient benefits from an immediate or early loading protocol. There is an associated risk with immediate and/or early loading, and this risk must be evaluated in terms of patient benefit. Postoperative care must be evaluated in such calculations.
- A related question is whether conventional loading is justified in certain cases. For example, does delaying the restoration of an implant place the patient at a disadvantage?

- The types of occlusal schemes need to be specified in various loading protocols. Occlusal schemes for immediate and early loaded implants that result in successful outcomes need to be determined.

CLINICAL RECOMMENDATIONS

The following types of treatment are recommended, provided that all other aspects of diagnosis and treatment planning have been performed and considered acceptable by the clinician. Immediate restoration and loading procedures are considered to be advanced or complex. As such, it is assumed that the clinician has the required level of skill and experience. The recommendations are based on the literature and the collective experience of the consensus working group.

Immediate Restoration or Loading

Edentulous Mandible. Four implants are suitable for use in 2 protocols: an overdenture retained and/or supported by a bar that rigidly connects the implants, or a fixed restoration on a framework (acrylic resin and/or metal) that rigidly connects the implants. More than 4 implants are suited for a rigid provisional restoration connecting all of the implants, or for a fixed restoration on a framework (acrylic resin and/or metal) that rigidly connects the implants.

Edentulous Maxilla. No routine procedure is recommended.

Partially Dentate Maxilla and Mandible. No routine procedure is recommended.

Early Restoration or Loading

Edentulous Mandible. Two implants may be placed to retain an overdenture, supported by a bar connecting the implants or by free-standing implants, when the implants are characterized by a rough titanium surface and allowed to heal for at least 6 weeks. In a 4-implant scenario, either of 2 options is recommended: an overdenture retained and supported by a bar connecting the implants or by unconnected implants, or a fixed restoration on a framework that rigidly connects the implants. The implants should be characterized by a rough titanium surface and allowed to heal for at least 6 weeks. More than 4 implants may be used for a fixed restoration on a framework that rigidly connects the implants; again, the implants are characterized by a rough titanium surface and allowed to heal for at least 6 weeks.

Edentulous Maxilla. Four different early loading scenarios are possible.

1. Four implants retaining an overdenture, supported by a bar connecting the implants or by unconnected implants, with implants characterized by a rough titanium surface and allowed to heal for at least 6 weeks. The site must be characterized by type 1, 2, or 3 bone.⁴
2. Four implants supporting a fixed restoration on a framework that rigidly connects the implants. As with the above scheme, the implants are characterized by a rough titanium surface and allowed to heal for at least 6 weeks, and the site is characterized by type 1, 2, or 3 bone.
3. More than 4 implants retaining an overdenture, supported by a bar connecting the implants or by unconnected implants, with implants characterized by a rough titanium surface and allowed to heal for at least 6 weeks, in a site characterized by type 1, 2, or 3 bone.
4. More than 4 implants supporting a fixed restoration on a framework that rigidly connects the implants. Again, the implants are characterized by a rough titanium surface and allowed to heal for at least 6 weeks, and the site is characterized by type 1, 2, or 3 bone.

Partially Dentate Maxilla and Mandible. A fixed prosthesis is recommended in these cases.

Implant number and distribution are dependent on patient circumstances, including bone quality and quantity, number of missing teeth, condition of opposing dentition, type of occlusion, and bruxism. Implants must be characterized by a rough titanium surface and are allowed to heal for at least 6 weeks and in type 1, 2, or 3 bone.

CONCLUSION

Consideration should be given to the quality of available evidence for these procedures. It is recognized that many of the clinical recommendations suggested by the consensus group are not yet associated with strong evidence. Readers should note that the experience of the group was used in formulating the recommendations.

Additional outcomes to be evaluated in future studies include:

- Physiologic impact (chewing, phonetics, maintenance of supporting tissues)
- Psychologic impact (patient satisfaction, esthetics, quality of life)
- Cost and effort (initial and recurring)

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Diagnostic Parameters for Monitoring Peri-implant Conditions

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Purpose: To review the literature on clinical, radiographic, and biochemical parameters used for monitoring peri-implant conditions. **Materials and Methods:** A MEDLINE search was conducted that included articles published in English until the end of August 2003. Results from human and experimental animal studies are presented. **Results:** The parameters that may be used to assess the presence of peri-implant health and the severity of peri-implant disease include plaque assessment, mucosal conditions, peri-implant probing depth, width of the peri-implant keratinized mucosa, peri-implant sulcus fluid analysis, suppuration, implant mobility and discomfort, resonance frequency analysis, and radiographic evaluation. **Discussion:** Based on the analysis of the available evidence, it appears reasonable to use a number of clinical and radiographic parameters to discriminate between peri-implant health and disease. **Conclusions:** Systematic and continuous monitoring of peri-implant tissues during maintenance care is recommended for the early diagnosis of peri-implant disease. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):116–127

Key words: clinical parameters, dental implants, dental radiography, diagnosis, long-term evaluation, peri-implant disease

Oral endosseous implant systems with 2 different healing modalities (submerged and nonsubmerged) have been developed and used successfully for the rehabilitation of partially or completely edentulous patients.^{1–20} Knowledge of the biology of osseointegration and peri-implant soft tissue healing has expanded rapidly.^{21–27} A comparative study in the beagle dog²⁸ has provided histologic evidence that the peri-implant hard and soft tissues around 1-stage and 2-stage implant systems do not

significantly differ with respect to morphology and composition. Furthermore, studies have provided clinical and radiographic evidence that 2-part implant systems can successfully osseointegrate in the mandible when a nonsubmerged surgical protocol is applied for implant placement.^{29–32}

At the population level, longitudinal evaluation of oral implant systems is of primary importance for the assessment of long-term survival and complication rates of each system, for the determination of factors affecting the success of therapy, and for the identification of specific problems. At the individual level, clinical peri-implant evaluation is necessary for the detection of early signs of disease and for the planning of therapeutic interventions. An unbiased comparison of different implant systems is only meaningful if the stages of peri-implant disease are defined and if appropriate clinical parameters and indices are available.

As established in 1993 at the First European Workshop on Periodontology in Ittingen, Switzerland, *peri-implant disease* is a collective term for

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Table 1 Indices Used to Assess Plaque Accumulation Around Oral Implants

Score	Mombelli et al ⁴⁰ (mPI)	Lindquist et al ⁴⁷
0	No detection of plaque	No visible plaque
1	Plaque only recognized by running a probe across the smooth marginal surface of the implant	Local plaque accumulation
2	Plaque can be seen by the naked eye	General plaque accumulation greater than 25%
3	Abundance of soft matter	

inflammatory processes in the tissues surrounding an implant.³³ *Peri-implant mucositis* was defined as a reversible inflammatory process in the soft tissues surrounding a functioning implant, whereas *peri-implantitis* is an inflammatory process additionally characterized by loss of peri-implant bone. A subgingival biofilm formation has been shown in animal experiments and clinical studies to be an important etiologic factor for the initiation of peri-implant inflammation and subsequent loss of marginal bone.^{34–37} In contrast to early implant losses, implant loss occurring during function may be the result of biologic processes characterized by clinical signs (eg, implant mobility) that emerge only when an advanced and possibly irreversible state of the disease has been reached. Therefore, the clinical and radiographic parameters routinely used to monitor oral implants during maintenance care should be of high sensitivity and/or specificity, should be easy to measure, and should yield reproducible data. The aim of this review article is to summarize current scientific evidence on the available diagnostic parameters for the longitudinal monitoring of oral implants.

MATERIALS AND METHODS

A search of Medline/PubMed was performed up to and including August 2003. The search was limited to human and experimental animal studies published in English. The following search terms were used: dental implants, peri-implant health, peri-implant disease, peri-implant mucositis, peri-implantitis, probing depth, bleeding on probing, dental plaque, peri-implant sulcus fluid, peri-implant keratinized mucosa, implant mobility, supuration, long-term evaluation, and dental radiography. The journals *Clinical Oral Implants Research*, *Journal of Clinical Periodontology*, *Journal of Periodontology*, and *The International Journal of Oral and Maxillofacial Implants* were searched by hand up to July 2003. The selection criteria included all levels

of available evidence: systematic reviews, randomized controlled clinical trials, controlled clinical trials, prospective and retrospective cohort studies, and case reports of human and experimental animal studies. One reviewer (GES) screened titles and abstracts of the search results. The full text of publications of potential relevance was then obtained.

EVALUATION OF THE ORAL HYGIENE STANDARD

Plaque Assessment

Microbial biofilms have been shown to form on inert biomaterial surfaces in an aqueous environment.³⁸ Implants placed in the oral cavity represent artificial surfaces colonized by bacteria from saliva and ecologic niches such as periodontal pockets, tonsils, and crypts of the tongue. Experimental and human studies have provided evidence that formation and development of a microbial biofilm represents an important etiologic factor in the pathogenesis of peri-implant disease.^{34,37,39–42} Several microbiologic features of the subgingival biofilm around implants have been correlated with the presence of clinically detectable plaque.⁴³ Furthermore, periodontal pathogens from residual pockets of remaining teeth in patients treated for periodontal disease have been documented to colonize oral implants.^{44,45} Mombelli and coworkers⁴⁰ modified the original Plaque Index introduced by Silness and L  e⁴⁶ to assess biofilm formation in the marginal area around ITI implants (mPI) (Institut Straumann, Waldenburg, Switzerland). Lindquist and associates⁴⁷ assessed oral hygiene levels according to a 3-point scale and reported a significant relationship between oral hygiene and peri-implant bone resorption over an observation period of 6 years. Therefore, it appears meaningful to monitor oral hygiene habits by quantifying plaque accumulation. Indices used to assess plaque accumulation around oral implants are presented in Table 1.

Table 2 Indices Used to Assess Marginal Mucosal Conditions Around Oral Implants

Score	Mombelli et al ⁴⁰ (mGI)	Apse et al ⁵⁰
0	No bleeding when a periodontal probe is passed along the mucosal margin adjacent to the implant	Normal mucosa
1	Isolated bleeding spots visible	Minimal inflammation with color change and minor edema
2	Blood forms a confluent red line on mucosal margin	Moderate inflammation with redness, edema, and glazing
3	Heavy or profuse bleeding	Severe inflammation with redness, edema, ulceration, and spontaneous bleeding without probing

EVALUATION OF THE PERI-IMPLANT MARGINAL TISSUES

Mucosal Conditions

In addition to redness and swelling of the marginal tissues, bleeding on probing (BOP), pocket formation, and suppuration have been reported to result from peri-implant infections.^{40,48} Assessment of these clinical signs has been considered important in the diagnosis of periodontal diseases. Therefore, the definition of peri-implant parameters based on periodontal indices such as the Gingival Index System⁴⁹ (GI) seems indicated. The GI⁴⁹ has been modified and adapted (mGI) for application around oral implants,⁴⁰ while a simplified GI has been proposed by Apse and associates.⁵⁰ Indices used to assess marginal mucosal conditions around oral implants are presented in Table 2.

Around implants, however, soft tissue texture and color depend on the normal appearance of the recipient tissues before implant placement, and may be influenced by the material characteristics of the implant surface.⁵¹ Furthermore, difficulties in recording mucosal inflammation have been reported, such as nonkeratinized peri-implant mucosa normally appearing redder than keratinized tissue.⁵² In a longitudinal study, only a weak correlation between GI scores and changes in peri-implant crestal bone level was reported.⁵²

Presence or Absence of Bleeding

BOP (notated in clinical records as BOP+) elicited after the insertion of a probe into the sulcus with light pressure (ie, 0.25 N) has been shown to detect the presence of an inflammatory lesion in the gingiva around teeth with a normal⁵³ and a healthy but reduced periodontium.⁵⁴ On the other hand, absence of bleeding on probing (BOP-) has been reported to represent periodontal health with a negative predictive value of 98.5%.^{55,56} BOP has been

used to assess peri-implant tissue conditions around implants. Lekholm and colleagues⁵⁷ found no correlation between BOP and histologic, microbiologic, or radiographic changes around implants. These authors hypothesized that bleeding could have been caused by inappropriate force transmission from the periodontal probe tip to the peri-implant soft tissues. These preliminary findings were confirmed in an animal study.⁵⁸ Conversely, findings from animal experiments using ITI implants yielded completely different results.⁵⁹ Healthy sites were characterized by absence of bleeding (0%), whereas both peri-implant mucositis and peri-implantitis sites showed substantially increased BOP (67% and 91%, respectively). The reason for these results might be attributed to the different probing forces applied by the various investigators. These findings were confirmed in a prospective study where absence of BOP had a high negative predictive value, thus serving as a predictor for stable peri-implant conditions.⁶⁰ Luterbacher and coworkers⁶¹ evaluated the diagnostic characteristics of different BOP prevalences alone or in combination with a microbiologic test for monitoring periodontal and peri-implant soft tissue conditions during maintenance therapy. The authors reported that BOP alone yielded higher diagnostic accuracy at implant sites compared with tooth sites. Furthermore, when combining positive microbiologic test and BOP of 75% or more, the positive predictive values were greater for implants than for teeth. With predictive values of 100% at BOP frequencies of 50% or more at implant sites, this parameter appears to play a central role in monitoring changes in peri-implant tissue conditions.

Peri-implant Probing Depth

In contrast to natural teeth, for which average periodontal probing depth (PD) has been reported, the physiologic depth of the peri-implant sulcus of successfully osseointegrated implants has been a matter

of debate. Increasing periodontal PD and loss of clinical attachment are pathognomonic for periodontal diseases. Pocket probing is therefore an important diagnostic process for the assessment of periodontal status and for the evaluation of periodontal therapy. The extent of probe penetration is influenced by factors such as probing force and angulation, probe tip diameter, roughness of the implant or root surface, inflammatory state of the periodontium, and firmness of the marginal tissues. Furthermore, it has to be realized that PD measurements may be affected by compromised access. Data demonstrate that the periodontal probe often fails to locate the histologic level of the connective tissue attachment around teeth.^{62,63}

The differences with respect to soft tissue composition, organization, and attachment between the gingiva and the root surface on the one hand and between the peri-implant mucosa and the implant surface on the other make the conditions for PD measurements around teeth and implants not fully comparable.^{37,64,65} One potential explanation influencing the differences in probe penetration is that most collagen fibers in the supracrestal connective tissue compartment have been demonstrated to run mostly in a parallel direction to the implant axis.^{51,66}

Ericsson and Lindhe⁵⁸ used a beagle dog model to compare the extent of probe penetration around teeth and implants under healthy soft tissue conditions. Compared with natural teeth, probe tip penetration around 2-stage submerged implants ended closer to the alveolar crest. The extent of peri-implant probe penetration has also been investigated around 1-stage oral implants in beagle dogs.⁵⁹ It was reported that density of the peri-implant tissues influences probe penetration. In the presence of inflamed peri-implant tissues, periodontal probes penetrate close to the alveolar bone, exceeding the connective tissue level by a mean of 0.52 mm. However, if healthy peri-implant conditions or mucositis are present, the probe tips may identify the histologic level of the supracrestal connective tissue attachment. One potential explanation for the different outcomes between the 2 above-mentioned studies may be attributed to the different probing forces employed (0.5 N versus 0.2 N). A recent experimental study in monkeys⁶⁵ has documented that PD measurements around teeth and implants are different. While no difference was observed with respect to probe penetration under healthy peri-implant/periodontal conditions, mild and severe marginal inflammation around implants was associated with a significantly deeper probe penetration into the supracrestal connective tissue when compared to that around teeth.

The magnitude of probe penetration into a periodontal pocket depends on the force applica-

tion.^{67,68} Furthermore, simultaneous recordings of probing PD and probing force before and after periodontal therapy have revealed that the force range chosen for repeated probing influences the amount of attachment level change determined.^{69,70} The tissue resistance to probing and the accuracy of depth measurement at different force levels (eg, 0.25, 0.5, 0.75, 1.0, and 1.25 N) were compared around nonsubmerged ITI dental implants and teeth in 11 subjects.⁷¹ It was concluded that peri-implant PD measurements are more sensitive to force variation than the corresponding measurements around teeth.

Correlations between bone levels recorded on radiographs and the extent of peri-implant probe penetration have been observed. In the case of screw-type implants, the probe tip appeared to stop 1.4 mm coronally to the bone level.⁷² The mean discrepancy between probe penetration and the location of the bone margin in radiographs was 1.17 mm in 100 nonsubmerged hollow-screw and hollow-cylinder implants measured 1 year after implantation.⁷³ In general, studies have indicated that successful implants allow probe penetration of approximately 3 mm.^{40,50,73-78}

Implant shape and surface texture influence penetration of the probe tip. Peri-implant probing is impossible around some implant systems because of characteristics of the design (eg, concavities, shoulders, suprastructure, or steps). Lack of surface smoothness, as with plasma-coated, sandblasted, acid-etched, or threaded implants, might interfere with probe penetration when bone resorption has reached this level and may lead to underestimation of pocket depth.⁷⁹ Although convincing evidence is lacking, some authors have expressed concerns about the possibility of introducing bacteria into the peri-implant tissues and about damaging the implant surface with a metallic periodontal probe.^{58,65,77,79} Other authors concluded that increased pocket depth could be correlated with a higher degree of inflammation of the peri-implant mucosa^{41,57,72,80} but not necessarily with peri-implant bone loss.^{81,82} However, absolute values of PD have to be interpreted in the context of surgical implant positioning, eg, submucosal implant placement in esthetic anterior sites versus conventional implant placement in posterior non-esthetic sites. Progressive increases in PD may be an alarming sign. Therefore, the establishment of baseline PD values at the time of delivery of the prosthetic suprastructure is of critical importance in allowing comparison with future PD measurements.

Peri-implant probing should also include the location of the soft tissue margin relative to a fixed landmark point on the implant (eg, implant shoulder for

1-stage nonsubmerged implant systems) or its supra-structure. The combined full-mouth PI and the BOP scores, as well as the mean attachment level of all teeth in a group of partially edentulous subjects, were shown to significantly influence mean PD and connective tissue level around implants.⁸³ If peri-implantitis is associated with marginal recession, then PD alone may not accurately reflect peri-implant bone loss, whereas increasing loss of connective tissue level is a definite sign of peri-implant pathology. In a longitudinal study, Bragger and coworkers⁸⁴ found that the connective tissue level in combination with the radiographic parameters obtained 2 years after implant loading were good predictors of the peri-implant tissue condition. Repeated peri-implant PD measurements may be performed with higher reproducibility by means of an automated controlled-force periodontal probe.⁸⁵ Furthermore, animal experiments have shown that, as is the case around teeth,⁸⁶ peri-implant probing disrupts the epithelial attachment but does not cause permanent damage to the transmucosal soft tissue seal. In one study, complete attachment of the junctional epithelium was re-established after 5 days following probing using a conventional periodontal probe.⁸⁷

Width of Peri-implant Keratinized Mucosa

Clinical and experimental studies^{88,89} have failed to support the concept of an "adequate width" of keratinized tissue adjacent to natural teeth for the maintenance of periodontal health. Implant research has also focused on the necessity of the presence of keratinized mucosa around oral implants. No differences in peri-implant soft tissue recession or bone loss have been found between sites with or without keratinized mucosa following plaque-induced breakdown at implants placed in dogs.⁹⁰ On the other hand, ligated titanium or hydroxyapatite-coated implants in monkeys with minimal or no keratinized mucosa demonstrated significantly more recession and connective tissue loss than those surrounded by keratinized tissue.^{91,92} This suggests that the absence of keratinized mucosa around implants seems to increase the susceptibility of plaque-induced peri-implant tissue destruction. These findings have been confirmed in other studies,^{83,93} suggesting that the presence of keratinized mucosa around implants is strongly correlated with optimal soft and hard tissue health. However, longitudinal clinical studies have failed to reveal major differences in the progression of lesions around implants placed in sites with or without keratinized mucosa, or that the lack of an attached portion of masticatory mucosa may jeopardize the maintenance of soft tissue health.^{74,94-97} Furthermore, in

the presence of good oral hygiene, the nature of the mucosa may have little influence on the long-term survival of implants. However, suboptimal oral hygiene may lead to greater tissue damage around implants within alveolar mucosa than around implants within keratinized tissue. Proper oral hygiene procedures may also be facilitated in the presence of an adequate band of keratinized mucosa. Prospective longitudinal controlled clinical trials will have to be performed to further elucidate the potential role of a sealing effect of keratinized mucosa on long-term peri-implant health.

Peri-implant Sulcus Fluid Analysis

Several biochemical mediators in the gingival crevicular fluid (GCF) around natural teeth have been identified as potential host markers for periodontal disease activity and progression.⁹⁸ To date, only a few studies have reported on the association between signs of peri-implant inflammation and increased levels of inflammatory mediators in the peri-implant sulcus fluid (PISF). A pilot study⁹⁹ investigated whether the crevicular fluid volume around osseointegrated implants shows a relationship to peri-implant soft tissue condition. The results indicated a close relationship between PISF volume and plaque accumulation as well as degree of peri-implant soft tissue inflammation. Numerous investigations of potential diagnostic markers of stable and diseased peri-implant conditions have focused on the sulcus fluid analysis of several mediators, including protease activity^{60,100,101}; collagenase, gelatinase, and elastase activity¹⁰²⁻¹⁰⁷; aspartate aminotransferase¹⁰⁸; glycosaminoglycans^{109,110}; and proinflammatory mediators such as interleukin-1beta (IL-1 β) and prostaglandin E₂ (PGE₂).^{80,111} Kao and coworkers¹¹¹ reported that PISF-IL-1 β levels around diseased implants were approximately 3 times higher than those around stable implants, thus providing evidence for the involvement of this catabolic cytokine in peri-implant bone destruction.

In a 3-year longitudinal investigation, Behneke and associates⁸² were able to show a positive correlation between PISF volume and the amount of bone resorption. In a subsequent report of the 5-year data,² the percentage of sites exhibiting elevated PISF rates increased significantly in the second half of the observation period. Using a cross-sectional study design, Salcetti and coworkers⁸⁰ investigated the production of IL-1 β , PGE₂, interleukin-6, platelet-derived growth factor, and transforming growth factor beta in the PISF of patients with 1 or more failing titanium implants. Several of these patients had at least 1 other stable implant that did not present with clinical signs of

inflammation or radiographic evidence of peri-implant bone loss. Significant elevations in PISF levels of IL-1 β , PGE₂, and platelet-derived growth factor in subjects with failing implant sites were detected when compared with patients with healthy control implants. The significant elevations of IL-1 β and PGE₂ at both failing implant sites and at stable implant sites in the same subject indicate that an increased local host response is detectable at the patient level as well as at local sites of peri-implant inflammation.

The finding that enzymes from polymorphonuclear granulocytes (PMN) are detected in high concentrations at sites with peri-implantitis may indicate enhanced PMN cell activity.^{105,107} Hultin and colleagues¹⁰⁵ analyzed the composition of PISF at implants in patients with “stable marginal tissue conditions” and peri-implantitis. Implant sites with peri-implantitis had higher concentrations of lactoferrin and elastase activity than control sites. Similarly, Plagnat and associates¹⁰⁷ collected and analyzed PISF from sites with and without clinical and radiographic signs of peri-implantitis. The authors reported that PISF levels of elastase, alpha2-macroglobulin, and alkaline phosphatase were significantly higher at diseased sites than at healthy sites, and that the levels of these markers correlated with clinical symptoms. On the other hand, similar low levels of the above-mentioned markers were found both at baseline and at the 3-year examination in the sulcus fluid around successful implants placed in esthetic anterior sites, indicating stable biochemical peri-implant conditions.¹⁰⁴ Collectively, these data document an important implication of catabolic inflammatory mediators in peri-implant tissue breakdown and indicate a potential value of biochemical markers for monitoring the host response during the supportive phase of implant therapy.

Suppuration

High numbers of PMN cells have been detected around implants that are associated with severe signs of mucosal inflammation.⁴⁸ Several histopathologic and immunohistochemical analyses of tissues surrounding implants with signs of peri-implantitis, ie, clinical signs of inflammation and advanced bone loss, have revealed the presence of large inflammatory cell infiltrates.^{35,112–115} Sanz and associates¹¹⁵ analyzed soft tissue biopsies from patients with peri-implantitis and reported that a considerable portion of the connective tissue (ie, 65%) was occupied by an inflammatory infiltrate. Esposito and coworkers¹¹² analyzed the characteristics of soft tissues surrounding failing implants

immunohistochemically. They reported that the marginal portion of the specimens was characterized by an “intense inflammatory and immunologic response.” Piattelli and colleagues¹¹⁴ described histopathologic characteristics of 230 retrieved implants. The authors reported that around implants removed because of peri-implantitis, “an inflammatory infiltrate composed of macrophages, lymphocytes, and plasma cells was observed in the connective tissue.” Gualini and Berglundh¹¹³ reported that peri-implantitis lesions contained significantly greater proportions of B-lymphocytes and PMN cells than mucositis lesions. Collectively, the observation that large numbers of inflammatory cells, including PMN cells, occupy the connective tissue infiltrate may explain the presence of suppuration at sites with advanced peri-implant disease.

EVALUATION OF THE BONE-IMPLANT INTERFACE

Implant Mobility and Discomfort

Primary stability at the time of implant placement has been recognized as an important prerequisite for the achievement of osseointegration.^{74,94,116} The establishment and maintenance of direct contact at the bone-implant interface are requirements for long-term implant success. Implant mobility is an indication of lack of osseointegration. Even if peri-implant disease has progressed relatively far, implants may still appear immobile because of some residual direct bone-to-implant contact. The recording of implant mobility may be a very specific—but not at all sensitive—clinical parameter in detecting loss of osseointegration. This parameter more likely detects the final stage of osseo-disintegration and, therefore, represents a late implant loss. Furthermore, pain or discomfort may be associated with increased implant mobility and could be one of the first signs indicating a failing implant.^{117,118} Persistent discomfort may be evident long before any radiographic change is detectable.¹¹⁹

Longitudinal assessment of individual implant mobility may be performed for screw-retained suprastructures. For obvious reasons, this cannot be applied to all cemented and tooth/implant-supported restorations. An electronic device (Periotest; Siemens, Bensheim, Germany), originally designed to measure the damping characteristics of the periodontium around natural teeth,^{120,121} has been recommended to monitor initial degrees of implant mobility or horizontal displacement. However, differences in Periotest values (PTVs) have been reported for implants in the mandible and in the

maxilla,⁷³ with implants in the maxilla showing significantly higher PTVs. In patients treated with Brånemark System implants (Nobel Biocare, Göteborg, Sweden), this procedure was found to be related to the type of jaw treated, implant and abutment length, condition of the peri-implant tissues, and bone density.¹²² Despite some positive claims for this method,^{2,82,123,124} the prognostic accuracy of PTVs for the diagnosis of peri-implantitis and early signs of implant failure has been criticized because of the lack of resolution, poor sensitivity, and susceptibility to operator variables.¹²⁵

Resonance Frequency Analysis

A new, noninvasive device based on the principles of resonance frequency analysis (RFA) has been developed to measure primary implant stability and to monitor implant stability over time.¹²⁶ This method evaluates the stiffness of the bone-implant interface by means of a signal transducer connected to a frequency response analyzer (Osstell; Integration Diagnostics, Göteborg, Sweden). The resonance frequency of the transducer-implant unit is calculated from the peak amplitude of the signal and is graphically illustrated on the Osstell display as the peak of a frequency-amplitude plot. In addition, an implant stability quotient (ISQ) is displayed as a number between 1 and 100. This ISQ value has been introduced to quantify the frequency measurements of oral implants with a range between 3,500 and 8,500 Hz. Several investigations^{127–132} have shown that the ISQ value of a stable osseointegrated implant increases with time, suggesting an increase in the bone-implant contact area. On the other hand, crestal bone loss around implants has been correlated with loss of implant stability.^{124,129} This may allow detection of an increase in implant mobility before clinical signs are recorded.¹³³ However, conclusive data on the bone-implant interface and RFA values are still lacking.¹³⁴

RADIOGRAPHIC EVALUATION

Long-term preservation of crestal bone height around osseointegrated implants is often used as a primary success criterion for different implant systems. Originally, a mean crestal bone loss ≥ 1.5 mm during the first year after loading and ≥ 0.2 mm/year thereafter had been proposed as one of the major success criteria.^{94,135} This success criterion, however, has recently been questioned, because longitudinal studies have provided evidence that crestal bone loss around osseointegrated implants in well-maintained patients may be minimal.^{2,18,136}

Conventional radiography represents a widely accepted technique for the long-term evaluation of marginal bone changes at interproximal sites of osseointegrated implants. In general, the long-cone paralleling technique, supported by positioning devices, is used. It should be noted that conventional radiography yields a high proportion of false negative findings, ie, it has low sensitivity in the detection of early pathologic and/or bone remodeling changes.¹³⁷ Therefore, radiographic methods are confirmatory rather than exploratory and should only be considered in conjunction with assessment of the clinical parameters.¹³⁸ Nevertheless, the distance from a landmark on the implant (eg, implant shoulder for 1-stage transmucosal implant systems or apical termination of the cylindrical portion of the implant for 2-stage submerged implant systems) to the alveolar bone crest represents a reliable parameter for long-term monitoring in clinical practice.

It should be pointed out that radiographic evidence of bone-to-implant contact does not imply osseointegration on a histologic level.¹³⁹ More importantly, if clinical parameters indicate peri-implant disease (eg, increased PD, BOP+, suppuration), additional radiographs should be obtained to evaluate the extent of peri-implant crestal bone loss. For longitudinal clinical research purposes, radiographs should be obtained at baseline and at 1-, 3-, and 5-year intervals. Thereafter, they should be obtained every 5 years if marginal peri-implant bone stability has been demonstrated.¹⁴⁰

Computer-assisted image analysis has been shown to improve the diagnostic accuracy (ie, increased sensitivity) of detecting minimal periodontal tissue changes.^{137,141} Consequently, the use of digital image analysis has expanded into implant dentistry to monitor peri-implant bone healing and gain or loss of alveolar bone density.¹⁴²

CONCLUSION

Evidence from the presented literature indicates that the use of a number of clinical, biochemical, and radiographic parameters is meaningful in the evaluation of peri-implant tissue status. Research efforts are currently under way to relate biologic parameters to morphologic changes in peri-implant structures. However, reliable prognostic indicators for peri-implant hard and soft tissue changes are still lacking. This is not surprising, because the same phenomenon (ie, development of diagnostic tests for the assessment of active periodontal tissue destruction) has challenged periodontal research in recent decades.

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Antimicrobial Treatment of Peri-implant Diseases

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Purpose: To review the literature on the treatment of peri-implant diseases. Specific emphasis was placed on the use of antimicrobial therapy, defined as local or systemic administration of antiseptic and/or antibiotic agents. **Materials and Methods:** A search of MEDLINE, the Cochrane Controlled Trials Register, and The Cochrane Health Group Specialized Register was conducted, and articles published in English until July 31, 2003, were included. The results of experimental animal studies and human research are presented. **Results:** A variety of antimicrobial treatment regimens in combination with nonsurgical or surgical debridement with and without regenerative therapy were reported. Use of antimicrobials varied between studies with respect to type of drug, dosage, delivery system, duration, and commencement of antibiotic administration. Patient compliance and adverse effects related to the antimicrobials were mostly not mentioned. **Discussion:** While the majority of the case reports and studies presented showed positive outcomes following antimicrobial treatment, there were no non-medicated controls included, so the relative effect of the antimicrobial agent(s) cannot be evaluated. **Conclusions:** Although antimicrobials are widely used for the treatment of peri-implant diseases, evidence of their benefit is limited, and randomized, controlled human trials should be initiated where ethically possible. In addition, prospective cohort studies designed to monitor consecutive cases treated using specific treatment protocols are required. INT J ORAL MAXILLOFAC IMPLANTS 2004; 19(SUPPL):128–139

Key words: antimicrobials, dental implants, peri-implant disease, peri-implant infection, peri-implantitis, peri-implant mucositis, treatment

Biologic complications in implant dentistry include peri-implant mucositis and peri-implantitis. At the first European Workshop on Periodontology, *peri-implantitis* was defined as an inflammatory process affecting the tissues around an osseointegrated implant in function, resulting in loss of supporting bone. *Peri-implant mucositis* was defined as reversible inflammatory changes of the peri-implant soft tissues without any bone loss.¹

INCIDENCE OF PERI-IMPLANT DISEASES

There is limited information in the literature regarding the incidence of peri-implant diseases, as data referring to the presence or absence of peri-implantitis are often not reported. Furthermore, because of inconsistencies in peri-implant assessment procedures and definitions of peri-implant mucositis and peri-implantitis, the interpretation of data is difficult. In a systematic review of implant complications from prospective longitudinal follow-up studies of at least 5 years, the incidence of peri-implantitis in the included articles ranged from 0% to 14.4%.² There is recent evidence that the incidence of peri-implantitis may be higher in patients with implants replacing teeth lost because of chronic periodontitis.³ The incidence of peri-implantitis may well be related to the number of years the implant has been in the oral cavity, and thus continuous monitoring of peri-implant conditions, provision of a supportive care program, and the implementation of well-tested protocols for the treatment of peri-implant diseases remain important.

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ETIOLOGY OF PERI-IMPLANT DISEASES

Evidence for the microbial etiology of peri-implant diseases is overwhelming. Bacterial colonization of the implant surface leads to mucositis⁴⁻⁶ and, if the peri-implant bone levels are affected, to peri-implantitis.⁷⁻¹⁰ The microflora associated with peri-implantitis is complex and closely resembles that found in chronic periodontitis, with high levels and proportions of suspected periodontal pathogens including *Actinobacillus actinomycetemcomitans*, *Porphyromonas gingivalis*, *Prevotella intermedia*, *Tannerella forsythensis*, and *Treponema denticola*.¹¹⁻¹⁹

It is therefore not surprising that therapies proposed for the management of peri-implant diseases appear to be based on the evidence available for treatment of periodontitis. Most publications in humans report individual cases treated with combined procedures, aimed at reducing the bacterial load within the peri-implant pocket, decontaminating the implant surface, and in many cases attempting to regenerate bone. Proposed therapies include nonsurgical debridement, antimicrobial therapy, access flap surgery, implant surface decontamination, bone grafts or bone substitute grafts, barrier membranes, combinations of grafts and barrier membranes, and supportive therapy.

Treatment outcomes are most commonly assessed using criteria that include peri-implant probing depth (PD), presence of bleeding on probing (BOP), presence of suppuration, and changes in radiographic bone level or density. In animal studies, evaluation at a histologic level enables assessment of the resolution of the inflammation, and in addition, possible re-osseointegration following regenerative procedures.

The objective of this article was to review antimicrobial therapy, including the use of antiseptic and/or antibiotic agents, administered locally or systemically for the treatment of peri-implant diseases.

MATERIALS AND METHODS

Search Strategy

A search of MEDLINE, the Cochrane Controlled Trials Register, and The Cochrane Health Group Specialized Register was conducted, and articles published in English until July 31, 2003, were included. The following search terms were used: “peri-implantitis,” “periimplantitis,” “peri-implant mucositis,” “periimplant mucositis,” “treatment peri-implant infections,” “treatment periimplant

infections,” “treatment peri-implant mucositis,” “treatment periimplant mucositis,” “treatment peri-implantitis,” “treatment periimplantitis.” Manual searches included bibliographies of previous reviews and the following journals up to July 2003: *Journal of Periodontology*, *Journal of Clinical Periodontology*, *Clinical Oral Implants Research*, and *The International Journal of Oral & Maxillofacial Implants*.

Selection Criteria

1. All levels available in the hierarchy of evidence were included: systematic reviews, randomized controlled clinical trials, controlled clinical trials, prospective cohort studies, case reports in humans, and experimental animal studies.
2. For the treatment of peri-implant mucositis, only publications with a minimum observation period of 6 weeks following treatment, and where implants were clearly defined as having peri-implant mucositis, were included.
3. For the treatment of peri-implantitis in humans, only publications reporting a series of cases with a minimum follow-up period of 6 months, and providing data on treatment outcomes assessed by clinical probing and/or radiographic or re-entry measurements, were included.
4. For the treatment of ligature-induced peri-implantitis, only publications reporting an observation period of at least 4 months were included.

RESULTS

Antimicrobial Treatment of Peri-implant Mucositis: Human Studies

Table 1 summarizes the available evidence evaluating antimicrobial treatment of peri-implant mucositis. Three studies investigated the use of antiseptic cleansing protocols using chlorhexidine^{20,21} or Listerine (Pfizer, Morris Plains, NJ).²² One study evaluated the submucosal placement of tetracycline fibers²³ and another the submucosal application of phosphoric acid gel.²⁴

These studies, which were all of short duration and involved only a small number of subjects, demonstrated that effective plaque removal from the implant crown and abutment surface resulted in resolution of inflammation in the peri-implant mucosa, probing depth reduction, and reduction of bleeding on probing.²⁵⁻²⁷ However, there was no obvious superiority of one treatment over another in achieving these positive outcomes.

Table 1 Antimicrobial Treatment of Peri-implant Mucositis (Human Studies)

Study	Study design	Patients/implants	Treatment procedures	Evaluation period (mo)	Treatment outcomes	Comments
Felo et al 1997 ²⁰	Randomized comparative study, Parallel-group design	24 patients	Self-administered CHX (0.06%) irrigation (100 mL 1×/d); versus full-mouth CHX (0.12%) rinsing (2 mL)	3	Pl: 1.4; marginal bleeding: 0.3; versus Pl: 1.6; marginal bleeding: 0.4	Antiseptic irrigation achieved signif. lower plaque + marginal BI scores.
Porras et al 2002 ²¹	Controlled study, Parallel-group design	16 nonsmoking patients; 24 Ti implants, 4 HA implants	Mechanical cleansing + OHI + CHX (0.12%) irrigation + topical CHX gel (0.12%) + CHX rinsing (0.12%) 2×/d, for 10 d; versus mechanical cleansing + OHI	3	PD: 3.3 to 2.7 mm; versus PD: 3.5 to 2.6 mm	No signif. difference in reduction in mPl, mBI, BOP, or in detection of 8 suspected periodontal pathogens. More PD reduction in control group.
Ciancio et al 1995 ²²	Randomized, double-blind, parallel-group design	20 patients with ≥ 2 Ti root-form implants	Antiseptic mouthrinse (Listerine) (20 mL 2×/d for 30 s); versus placebo mouthrinse (5% hydroalcohol) 2×/d for 30 s	3	Pl: 2.0 to 0.8, BI: 0.6 to 0.3, and PD: 2.12 mm; versus Pl: 1.8 to 1.6, BI: 0.6 to 0.5, and PD: 1.97 mm	Less plaque and bleeding in antiseptic group; however, higher PD scores. No adverse events reported. Compliance 89% in both groups.
Schenk et al 1997 ²³	Controlled study, split-mouth design	8 patients, 24 Ti zircon oxide implants	Mechanical debridement (steel curettes + rubber cup polishing) + local tetracycline HCl fibers + CHX (0.2%) rinsing 2×/d for 10 d; versus mechanical debridement + CHX (0.2%) rinsing 2×/d for 10 d	3	mPl: 0.9 to 1.0 and BOP: 67% to 50%; versus mPl: 0.9 to 0.9 and BOP: 51% to 66%	In both groups, plaque scores were high at 12 weeks. Similar outcome for 2 treatment groups.
Strooker et al 1998 ²⁴	Randomized split-mouth design	16 patients, 64 implants	Monthly phosphoric acid gel (35% (pH 1) for 1 min; versus monthly mechanical debridement (carbon fiber curettes + rubber cup)	5	GI: 0.9 to 0.3, BOP: 31% to 10%, and PD: 3.0 to 2.3 mm; versus GI: 0.8 to 0.6, BOP: 29% to 14%, and PD: 2.8 to 2.5 mm	No signif. difference between treatments in reduction of BOP or PD. No difference in frequency of detection of bacteria. Nine of 16 patients complained of pain after gel.

BI = Ainamo and Bay Bleeding Index²⁵; BOP = bleeding on probing; CHX = chlorhexidine digluconate; GI = Gingival Index²⁶; HA = hydroxyapatite; mBI = modified Bleeding Index¹¹; OHI = oral hygiene instruction; PD = peri-implant probing depth; Pl = Turesky modification of the Quigley-Hein Plaque Index²⁷; Ti = titanium.

Antimicrobial Treatment of Peri-implantitis: Human Studies

Nonsurgical Debridement Combined with Antimicrobial Therapy. Table 2 describes human studies in which treatment of peri-implantitis involved nonsurgical debridement combined with antimicrobial therapy. Two prospective cohort studies evaluated the treatment of peri-implantitis using mechanical and antiseptic cleansing followed by antibiotics. In one study, systemic ornidazole (1,000 mg \times 1) was administered over 10 days,²⁸ and in a subsequent study, tetracycline fibers were placed around the implants for 10 days.²⁹ Two of 30 patients in the study using tetracycline fibers required additional treatment because of persistent peri-implantitis. One of 9 patients in the study using ornidazole showed no improvement. In the remaining patients, probing depth reduction and resolution of inflammation were achieved and maintained over a 1-year observation period. Microbiologic monitoring was performed in both studies, and a significant reduction in the proportion of gram-negative anaerobes²⁸ and in the frequency of detection of several suspected periodontal pathogens was observed.²⁹

In another study, a similar protocol including mechanical debridement, chlorhexidine irrigation, and systemic antibiotics, which were selected on the basis of antimicrobial susceptibility testing, resulted in resolution of inflammation, as demonstrated by reductions in peri-implant probing depth ranging from 1.3 to 1.5 mm at 6 months.³⁰ Patients in this comparative study had initial bone loss greater than 50% of the implant length and following nonsurgical antimicrobial therapy entered a surgical phase aimed at eliminating the peri-implant defect by bone regeneration. In all 3 studies, nonsurgical antimicrobial therapy resulted in only limited radiographic bone fill. The relative importance of mechanical debridement, topical antimicrobials, and systemic or local antibiotics cannot be determined from these studies.

Antimicrobial Therapy Combined with Surgical Debridement. There are no human studies comparing the effect of surgical debridement with or without systemic or local antibiotics.

Antimicrobial Therapy Combined with Regenerative Surgery. Table 3 includes reports that combined regenerative surgical procedures with systemic antibiotics.

Behneke and coworkers³¹ presented results of treatment of 25 implants in 17 patients with initial mechanical and antiseptic therapy for 1 month, followed by surgical access, implant surface decontamination, and autogenous bone grafting. Systemic antibiotics were prescribed postoperatively for 7 days. Considerable probing depth reduction and

radiographic bone gain was reported at 1 and 3 years of follow-up; however, at 3 years only 10 of the original 25 implants were evaluated. Complications included infection and graft removal for 2 implants and flap dehiscence for another 4 implants.

Treatment of peri-implantitis using barrier membranes combined with antimicrobial therapy was described in 2 case series involving 9 patients.^{32,33} Following a short period of antiseptic therapy, both authors used a nonresorbable e-PTFE membrane followed by postoperative systemic antibiotics and achieved resolution of inflammation, probing depth reduction, and radiographic bone gain. Membrane exposure was reported in more than half of the cases.

Table 3 also includes 2 publications reporting the treatment of peri-implantitis using antimicrobial therapy combined with barrier membranes and graft materials. Khoury and Buchmann,³⁰ in a comparative study, initiated systemic antibiotics at 4 weeks preoperatively for 1 week and administered them again for 7 days postoperatively. The antibiotic was chosen based on antimicrobial susceptibility test results. Haas and associates³⁴ investigated regenerative surgery without prior initial therapy, prescribing penicillin (Augmentin, SmithKline Beecham, Mayenne, France) for 5 days postoperatively. Various methods for implant surface decontamination were used, including photosensitizing treatment³⁴ and chlorhexidine + citric acid + hydrogen peroxide + saline irrigation.³⁰ Both studies reported radiographic bone fill and an improvement of the soft tissue conditions in the majority of cases. Two implant losses were reported in the series by Haas and associates,³⁴ and early membrane exposure was a common complication in both studies.

Antimicrobial Treatment of Ligature-Induced Peri-implantitis: Animal Studies

Animal studies investigating antimicrobial treatment of experimental ligature-induced peri-implantitis are described in Table 4.

In a study by Ericsson and colleagues, the effect of antibiotic therapy with or without debridement of the surgical defect was evaluated.³⁵ Systemic antibiotic therapy (amoxicillin 375 mg \times 2 + metronidazole 250 mg \times 3), administered for 3 weeks, starting 1 week prior to flap surgery, was found to successfully reduce the inflammatory lesion when combined with local debridement and decontamination of the implant surface. There was no new bone formation. The control implants, where no local treatment was provided, had persistent infection. These results emphasize the importance of local mechanical debridement to disrupt the biofilm when systemic antibiotics are administered.

Table 2 Treatment of Peri-implantitis with Nonsurgical Antimicrobial Therapy (Human Studies)

Study	Study design	Patients/ implants	Treatment procedures	Antimicrobial	Adverse effects	Evaluation period (mo)	Comments
Mombelli/Lang 1992 ²⁸	ProsC	9 patients, 9 implants; ITI F type/Bonefit	OHI + mechanical cleaning + CHX (0.5%) irrigation + systemic antibiotic for 10 d + daily irrigation CHX (0.2%) for 10 d + supportive therapy	ORN (1,000 mg × 1)	No improvement in PD in 1 patient (1 implant)	12	Sig reductions in BI (1.6 to 0.7), PD (5.9 to 3.4 mm), and proportion gram- negative anaerobes (41% to 19%)
Mombelli et al 2001 ²⁹	ProsC	25 patients, 30 implants; ITI hollow screws/ cylinders, 3 full- body screws	OHI + mechanical cleaning + tetracycline fibers for 10 d; + CHX (0.2%) mouthrinse for 2 wk + supportive therapy	TET HCl fibers	Persistent peri-implantitis in 2 patients (2 implants)	12	Sig reductions in mBI (0.95 to 0.37), PD (4.7 to 3.5 mm), 6% radiographic bone fill, CAL change (2 mm in deepest pockets); decrease in detection of some suspected periodontal pathogens
Khoury/Buchmann 2001 ³⁰	CS, initial therapy prior to surgical therapy	25 patients, 41 implants with bone loss > 50% implant length; IMZ/Friadent	CHX irrigation (0.2%) + mechanical cleaning + susceptibility test + systemic antibiotics for 1 wk + weekly prophylaxis + OHI	AMX, MET, TET, CLIN, CIPRO	Not reported	6	PD reduction: range 1.3 to 1.5 mm; radiographic bone fill: range 0.2 to 0.3 mm

AMX = amoxicillin; BI = Ainamo and Bay Bleeding Index²⁵; CAL = clinical attachment level; CHX = chlorhexidine digluconate; CIPRO = ciprofloxacin; CLIN = clindamycin; CS = case series; mBI = modified Bleeding Index¹¹; MET = metronidazole; OHI = oral hygiene instruction; ORN = ornidazole; PD = peri-implant probing depth; ProsC = prospective cohort study; TET = tetracycline.

Table 3 Treatment of Peri-implantitis with Regenerative Surgery and Systemic Antibiotics (Human Studies)

Study	Study design	Patients/implants	Systemic antibiotic	Treatment procedures	Evaluation period	Treatment outcome	Adverse events
Khoury/ Buchmann 2001 ³⁰	Comp	1. 7 patients/12 implants; 2. 11 patients/20 implants; 3. 7 patients/9 implants; IMZ/Friadent	AMX, MET, TET, CLIN, ERY, CIPRO after susceptibility testing for 2 wk (1 wk at 4 wk preop + 1 wk at 1 wk postop)	Initial therapy + surgical debridement + CHX irrigation + citric acid (pH1) for 1 minute + H ₂ O ₂ + saline (0.9%) + 1. AB, 2. AB + e-PTFE, 3. AB + collagen membrane. Submerged healing, supportive care for 3 to 6 mo	3 y	1. PD: 6.5 to 2.9 mm, PBL: 6.9 to 4.1 mm. 2. PD: 6.7 to 2.8 mm, PBL: 7.4 to 4.3 mm. 3. PD: 6.4 to 5.1 mm, PBL: 7.0 to 5.1 mm. Radiographic bone fill: 1. 2.2 mm, 2. 2.5 mm, 3. 1.7 mm	59% of barrier- treated implants were compromised by early posttherapy complications (membrane exposures, dehiscence, fistula, sequestrum)
Behneke et al 2000 ³¹	CR	17 patients, 25 implants; ITI (TPS surface)	MET (400 mg × 2) for 7 d postop	Initial therapy: mechanical debridement + irrigation iodine (1×/wk for 1 mo); access flap + air-powder abrasive + saline + AB augmentation. Supportive care for 3 mo; nonsubmerged healing	6 mo to 3 y	1 y (18 implants): PD: 5.3 to 2.2 mm. At 3 y (10 implants): PD: 5.3 to 1.6 mm and complete refill of angular bone defects	Flap dehiscence (4 lesions), graft failure (2 lesions)
Jovanovic et al 1992 ³²	CR	7 patients, 10 implants; IMZ/Brånemark/TPS	TET (250 mg × 4) for 7 d postop	Surgical debridement + air powder+ chloramine-T + saline + e-PTFE; nonsubmerged healing	6 mo	PI: 1.7 to 0.6; GI: 2.1 to 0.3; PD: 6.8 to 4.1 mm	Membrane exposure (× 3)
Hämmerle et al 1995 ³³	CR	2 patients, 2 implants; ITI (hollow screw, TPS surface)	MET (250 mg × 3) and AMX (375 mg × 3) for 10 d postop	CHX (0.2%) irrigation, 5 d later surgical debridement + CHX (0.2%) and saline irrigation + e-PTFE; nonsubmerged healing, removal 2×/d until membrane removal + supportive therapy	12 mo after membrane removal	PD: 6.7 to 3.5 mm; PAL gain: 1.8 mm; mean radiographic bone gain: 2.2 mm	Membrane exposures and removal after 4 and 6 mo, respectively
Haas et al 2000 ³⁴	CR	17 patients, 24 implants; IMZ	AUG for 5 d postop	Surgical debridement + toluidine blue (100 µg/mL) + saline rinsing + soft laser light (906 nm) + AB + e-PTFE. Submerged healing, supportive care	Mean 9.5 mo	No clinical parameters assessed. Radiographic mean bone fill: 2.0 mm (range -0.5 to 7.3 mm); 36% defect fill (range -14% to 100%)	All membranes exposed at 3 weeks; 2 implants failed

AB = autogenous bone; AMX = amoxicillin; AUG = augmentin; CHX = chlorhexidine digluconate; CIPRO = ciprofloxacin; CLIN = clindamycin; Comp = comparative study; CR = case reports; e-PTFE = expanded polytetrafluoroethylene membrane; ERY = erythromycin; GI = Gingival Index²⁶; MET = metronidazole; PAL = probing attachment level; PBL = probing bone level; PD = peri-implant probing depth; PI = Turesky modification of the Quigley-Hein Plaque Index²⁷; surgical debridement/curettage = removal of granulation tissue; TET = tetracycline; TPS = titanium plasma sprayed.

The importance of implant surface characteristics³⁶ and implant surface decontamination^{9,37,38} for peri-implantitis treatment outcome has been addressed in animal studies incorporating systemic antimicrobials within the treatment protocol.

In the majority of studies in Table 4, postoperative systemic antibiotics were used in combination with local debridement and regenerative procedures. Barrier membranes were evaluated in 2 studies.^{39,40} Other treatment protocols applied bone augmentation procedures using membranes combined with bone grafts (including demineralized freeze-dried bone allograft,^{41,42} anorganic bovine bone,⁴³⁻⁴⁵ and autogenous bone^{10,46}) or bone substitutes (hydroxyapatite^{41,42}). Hanisch and coworkers⁴⁷ evaluated the use of recombinant human bone morphogenetic protein-2 and systemic antibiotics for treatment of peri-implantitis.

Antimicrobial therapy using lethal photosensitization in conjunction with surgical debridement was investigated by Shibli and associates⁴⁸ for the treatment of ligature-induced peri-implantitis.

All experimental treatments listed in Table 4 resulted in resolution of the inflammatory lesion and new bone formation, while some protocols demonstrated varying degrees of re-osseointegration. The most common choice of systemic antibiotic was a combination of metronidazole and amoxicillin, or metronidazole alone. The various outcomes of the above-mentioned surgical protocols in combination with the administration of antimicrobials are reviewed elsewhere.⁴⁹

Conclusions from the Available Evidence

Antimicrobial Treatment of Peri-implant Mucositis.

From the available evidence it may be concluded that the treatment of peri-implant mucositis should include patient motivation and instruction in oral hygiene procedures, followed by mechanical/chemical plaque removal using a combination of professional and self-performed care.

Antimicrobial Treatment of Peri-implantitis with Nonsurgical or Surgical Therapy: Human Studies.

While the results of the majority of human case reports and studies presented suggest positive clinical and radiographic treatment outcomes, some cases treated were unsuccessful or required additional therapy.

The antibiotic regimens used varied between studies with respect to type of antibiotic, dosage, delivery system, duration, and commencement of antibiotic therapy. Adverse effects related to the antimicrobial agents and patient compliance were not considered. Antimicrobial susceptibility testing was done prior to selection of the antibiotic in only

1 study.³⁰ There were no controls included, and the relative importance of mechanical debridement, topical antimicrobials, and systemic or local antibiotics cannot be determined from these studies. There is insufficient evidence to recommend a particular anti-infective protocol for the treatment of peri-implantitis.

Antimicrobial Treatment of Ligature-Induced Peri-implantitis: Animal Studies. All experimental studies resulted in resolution of the inflammatory lesion and new bone formation, while some protocols demonstrated varying degrees of re-osseointegration. The most common choice of systemic antibiotic was metronidazole and amoxicillin combined, or metronidazole alone. However, there are no animal studies comparing local therapy with or without systemic antibiotics, and hence the value of adjunctive antimicrobial therapy cannot be evaluated.

DISCUSSION AND CLINICAL IMPLICATIONS

Following successful periodontal and implant therapy, patients should be offered an individualized supportive care program. Diagnosis of peri-implant disease requires continuous systematic monitoring of the peri-implant tissue conditions. Parameters recommended to assess the absence, presence, and severity of disease include: presence of plaque or calculus, peri-implant probing depth in relation to baseline measurements obtained at the time of prosthetic reconstruction, presence of bleeding on gentle probing, presence of suppuration, and, if indicated, radiographic evaluation.

Probing depths for conventionally placed 1-stage implants generally range between 2 and 4 mm under healthy conditions.⁵⁰ In sites of esthetic priority, where the implant shoulder has intentionally been placed submucosally, or where mucosal tissues are thick, deeper baseline probing depths may be present. Increases in probing depths above these baseline values should be viewed as a sign of peri-implant disease.

A systematic approach for the prevention and treatment of peri-implant disease was suggested by Lang and coworkers.⁵¹ This protocol, referred to as *cumulative interceptive supportive therapy* (CIST), includes 4 treatment modalities (*A*, mechanical debridement; *B*, antiseptic treatment; *C*, antibiotic treatment; and *D*, regenerative or access/resective surgery), which should be used in sequence in a cumulative fashion, depending on the diagnosis made at each recall.

Although this protocol has not been assessed in its entirety, 2 prospective cohort studies have been

Table 4 Treatment of Ligature-induced Peri-implantitis (Animal Studies)

Study	Animals/implants	Systemic antibiotic	Treatment procedures	Implant surface decontamination	Healing period	Treatment outcomes
Ericsson et al 1996 ³⁵	5 dogs, 10 implants (Brånemark machined surface)	AMX (375 mg X2) and MET (250 mg X3) for 3 wk starting 1 wk prior to surgery	1. Access flap; 2. untreated control	Delmopinol 1%; abutments autoclaved	4 mo	1. Resolution of inflammation, no bone formation; 2. Persistent infection
Persson et al 2001a ³⁶	4 dogs, 8 implants; ITI 1.4 machined surface, 2. 4 SLA surface	AMX (250 mg X2) and MET (250 mg X2) for 17 d starting 3 d prior to surgery	Access flap	Cotton pellet soaked in saline	6 mo	Bone regeneration (% of original defect surface area): 1. 72%, 2. 77%; Re-osseointegration: 1. 22%, 2. 84%; Radiographic bone gain: 1. 0.8 mm, 2. 1.4 mm; "spontaneous exposure" of some implants after 1 month
Persson et al 1999 ³⁷	4 dogs, 24 implants (Brånemark machined surface)	AMX (500 mg/d) and MET (750 mg/d) starting 2 d before surgery for 3 wk	Access flap	1. Rotating brush + pumice; 2. cotton pellet soaked in saline	7 mo	Bone regeneration (% of original defect surface area): 1. 59%, 2. 64%; soft tissue capsule between bone and implant
Persson et al 2001b ³⁸	2 dogs, 16 implants (12 test/4 control) (Brånemark machined surface)	AMX (500 mg X 1) and MET (250 mg X 1) for 3 wk starting 1 wk prior to surgery	1. Access flap + replacement of coronal implant part; 2. access flap	Cotton pellet soaked in saline	4 mo	1. Osseointegration identified on the replaced implant part = 35% osseointegration; 2. defects "filled with new bone separated from the fixture surface by dense connective tissue" 1. Elimination of inflammatory infiltrate and "formation of a dense CT capsule"; 2. persistent infection and "no resolution of peri-implant lesion"
Persson et al 1996 ³⁹	5 dogs, 30 implants (Brånemark machined surface)	AMX (375 mg X 2) and MET (250 mg X 3) for 3 wk postop	1. Access flap + 1% e-PTFE; 2. untreated control	Delmopinol	4 mo	Bone regeneration (% of original defect surface area): 1. 14% to 31%, 2. 62% to 83%; membrane exposures
Wetzel et al 1999 ⁴⁰	7 dogs, 39 implants (ITI TPS surface, SLA surface, machined surface)	MET (20 mg/kg) for 10 d starting 2 wk prior to surgery	1. Access flap; 2. access flap + e-PTFE	CHX irrigation	6 mo	New bone at clinical re-entry: 1. 0.5 mm; 2. 1.8 mm; 3. 2.2 mm; 4. 3.6 mm; 5. 3.2 mm; 6. 3.8 mm
Hürzeler et al 1995 ⁴¹	4 dogs, 24 implants (Brånemark machined surface)	MET (250 mg X 1) for 3 wk starting 2 wk prior to surgery	1. Access flap; 2. access flap + HA; 3. access flap + DFDBA; 4. access flap + e-PTFE; 5. access flap + HA + e-PTFE; 6. access flap + DFDBA + e-PTFE	Air-powder abrasive for 30 s	4 mo	New bone at clinical re-entry: 1. 0.5 mm; 2. 1.8 mm; 3. 2.2 mm; 4. 3.6 mm; 5. 3.2 mm; 6. 3.8 mm
Hürzeler et al 1997 ⁴²	7 dogs, 42 implants (Brånemark machined surface)	MET (250 mg X 1) for 3 wk starting 2 wk prior to surgery	1. Access flap; 2. access flap + HA; 3. access flap + DFDBA; 4. access flap + e-PTFE; 5. access flap + HA + e-PTFE; 6. access flap + DFDBA + e-PTFE	Air-powder abrasive for 30 s	5 mo	Bone regeneration: 1. 0.5 mm; 2. 1.3 mm; 3. 1.6 mm; 4. 2.5 mm; 5. 2.4 mm; 6. 3.0 mm. Re-osseointegration: 1. 0.3 mm; 2. 0.9 mm; 3. 0.9 mm; 4. 1.0 mm; 5. 2.3 mm; 6. 2.2 mm
Machado et al 1999 ⁴³	4 animals, 16 implants (Napio System Ti implants)	MET (250 mg X 1) for 3 wk starting 2 wk prior to surgery	1. Access flap; 2. access flap + e-PTFE; 3. access flap + bovine anorganic bone; 4. access flap + bovine anorganic bone + e-PTFE	Air-powder abrasive for 30 s	5 mo	Bone regeneration at clinical re-entry: 1. 0.9 mm; 2. 1.4 mm; 3. 1.6 mm; 4. 1.6 mm. One membrane exposure at 1 wk

Table 4 Treatment of Ligature-induced Peri-implantitis (Animal Studies) continued

Study	Animals/implants	Systemic antibiotic	Treatment procedures	Implant surface decontamination	Healing period	Treatment outcomes
Machado et al 2000 ⁴⁴	5 dogs, 20 implants (Napio System)	MET (250 mg × 1) for 3 wk starting 2 wk prior to surgery	1. Access flap; 2. access flap + e-PTFE; 3. access flap + bovine anorganic bone; 4. access flap + bovine anorganic bone + e-PTFE	Air-powder abrasive for 30 s	5 mo	Re-osseointegration (reference: 6 most coronal threads): 1. 27%; 2. 31%; 3. 28%; 4. 27%
Nociti et al 2001 ⁴⁵	5 dogs, 30 implants (Napio System)	MET (250 mg/day) for 3 wk starting 2 wk prior to surgery	1. Access flap; 2. access flap + bovine anorganic bone; 3. access flap + e-PTFE; 4. access flap + collagen membrane; 5. access flap + e-PTFE + bovine anorganic bone; 6. access flap + collagen membrane + bovine anorganic bone	Air-powder abrasive for 30 s	4 mo	Bone regeneration (reference: previous vertical defect height): 1. 14%; 2. 21%; 3. 19%; 4. 22%; 5. 20%; 6. 28%. Four membrane exposures
Hanisch et al 1997 ⁴⁷	4 monkeys, 31 implants (HA coated)	CEPH (50 mg/kg × 3) for 1 wk	1. Access flap + rh BMP-2; 2. access flap + vehicle control	Citric acid + air-powder abrasive	4 mo	Bone regeneration/re-osseointegration: 1. 2.6 mm (40% re-osseointegration); 2. 0.8 mm (9% re-osseointegration). Implant exposure through oral mucosa
Schou et al 2003a ⁹	8 monkeys, 57 implants (TPS surface)	AMP (17 mg/kg × 3) and MET (13 mg/kg × 3) 12 d starting 2 d before surgery	Access flap + AB+ e-PTFE	1. Air-powder abrasive unit (5 min) + citric acid (2 min); 2. air-powder abrasive unit (5 min); 3. gauze soaked in saline (5 min) + citric acid (2 min); 4. gauze soaked alternately in CHX + saline (5 min)	6 mo	Total bone regeneration: 39% to 46% re-osseointegration (reference previous defect); no difference between methods; 36% membrane exposure
Schou et al 2003b,c ^{10,46}	8 monkeys, 61 implants (ITI TPS surface)	MET (13 mg/kg × 3) and AMP (17 mg/kg × 3) for 12 d starting 2 d before surgery	1. Access flap + AB + e-PTFE; 2. access flap + AB; 3. access flap + e-PTFE; 4. access flap	Gauze soaked alternately in CHX and saline (5 min)	6 mo	Healthy peri-implant tissues. Radiographic bone fill: 1. 4.7 mm; 2. 4.0 mm; 3. 3.0 mm; 4. 1.9 mm. Re-osseointegration (reference original defect): 1. 45%; 2. 22%; 3. 21%; 4. 14%; 38% membrane exposure
Shibli et al 2003 ⁴⁸	6 dogs; 19 implants (1. cpTi, 2. TPS, 3. HA, 4. AE)	None	Access flap + e-PTFE	Lethal photosensitization w/toluidine blue+ diode laser	5 mo	Bone regeneration (% of original defect): 1. 27%; 2. 40%; 3. 48%; 4. 27%. Re-osseointegration: 1. 25%; 2. 25%; 3. 16%; 4. 17%

AB = autogenous bone; AE = acid etched; AMP = ampicillin; AMX = amoxicillin; CEPH = cephalosporin; CHX = chlorhexidine digluconate; cpTi = commercially pure titanium; CT = computerized tomography; DFDBA = demineralized freeze-dried bone allograft; e-PTFE = expanded tetrafluoroethylene membrane; HA = hydroxyapatite; MET = metronidazole; rhBMP-2 = recombinant human bone morphogenetic protein-2; SLA = sandblasted, large-grit, and acid-etched (Straumann); TPS = titanium plasma spray.

published evaluating the treatment modalities A + B + C.^{28,29} Furthermore, an ongoing prospective cohort study reported significant improvements in clinical and microbiologic parameters at 3 months in the treatment of peri-implantitis using local application of minocycline microspheres as part of the CIST protocol.⁵² In addition, Khoury and Buchmann³⁰ reported on the administration of systemic antibiotics as part of an initial phase of therapy prior to surgery.

Limitations to nonsurgical therapy may necessitate surgical intervention. According to the CIST protocol, peri-implantitis lesions with more than 2 mm of bone loss require initial therapy followed by either access/resective or regenerative surgery. A number of issues associated with surgical treatment of peri-implantitis have been investigated, including methods for implant surface decontamination. Several protocols have been suggested, including air-powder abrasives, citric acid, or antimicrobial agents. In a recent animal study, Schou and colleagues⁹ compared 4 decontamination protocols and concluded that alternating between gauze soaked in chlorhexidine and gauze soaked in saline for cleaning was the preferred method. There is no evidence for the necessity of smoothing mechanical implant surfaces.

It is apparent that pre- and postoperative systemic antibiotics are frequently empirically prescribed in conjunction with regenerative surgical procedures. Evidence for an advantage in using adjunctive systemic antibiotics is lacking. However, the severity and aggressive nature of the inflammatory lesion around implants with peri-implantitis recently documented by Gualini and Berglundh⁵³ suggests that the use of systemic antimicrobials in combination with surgical therapy may be indicated.

While there is insufficient evidence to recommend a specific postoperative antibiotic regimen, the most commonly used antibiotics among published protocols (Tables 3 and 4) are metronidazole and amoxicillin. Systemic metronidazole alone or in combination with amoxicillin has been shown to be effective in suppressing gram-negative anaerobic microorganisms generally associated with peri-implantitis in humans.⁵⁴ There is evidence that in some instances peri-implantitis may be associated with organisms such as *Staphylococcus spp.*,⁵⁵ *Enterobacter spp.*, and yeasts.¹⁸ Based on these findings, microbial diagnosis may be advantageous prior to antibiotic selection.

It should be emphasized that a prerequisite for successful antimicrobial therapy is the establishment and maintenance of proper oral hygiene and supportive care at regular intervals. With regard to maintenance, there is no evidence that the use of powered

or sonic toothbrushes is superior to manual brushing for efficacy in plaque removal around implants.⁵⁶

CONCLUSIONS

The conclusions of this review are similar to those of a recent systematic review by Klinge and associates.⁵⁷ Evidence for antimicrobial treatment of peri-implantitis is limited, and randomized, controlled trials should be initiated where ethically possible. There is a need to determine whether antimicrobials used for periodontal therapy are effective for the treatment of peri-implant diseases. With respect to antimicrobial treatment protocols, there is limited information as to what extent initial improvement is sustained over the long term. There are no studies investigating the influence of defect characteristics or patient-related factors on treatment outcome. Additional prospective cohort studies designed to monitor consecutive cases treated using specific treatment protocols are recommended. Until the results of such trials are available, the most logical and evidence-based protocol for use in clinical practice is cumulative interceptive supportive therapy (see group 4 consensus statement).

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Surgical Treatment of Peri-implantitis

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Surgical treatment of peri-implantitis lesions can be performed in cases with considerable pocket formation (larger than 5 mm) and bone loss after the acute infection has been resolved and proper oral hygiene has been instituted. A literature review was conducted to ascertain current knowledge about surgical treatment options for peri-implantitis around commercially pure titanium implants. Recently reported animal studies involving implants with a rough surface indicate that considerable bone regeneration and re-osseointegration can be obtained by using membrane-covered autogenous bone graft particles. However, comparisons of the treatment outcomes in studies involving humans and animals are difficult because of differences in implant type, graft type, and evaluation protocols. In addition, different treatment procedures, including implant surface decontamination methods, have been used. Therefore, further long-term studies in humans involving sufficient numbers of subjects are needed to provide a solid basis for recommendations regarding the surgical treatment of peri-implantitis. Moreover, the encouraging treatment outcomes of regenerative procedures recently revealed in animal experiments and applied in the treatment of peri-implantitis around implants with sandblasted/acid-etched surfaces have not yet been documented for implants with other surfaces, especially turned surfaces. Numerous implant surface decontamination methods have been suggested as part of the surgical treatment of peri-implantitis. Decontamination of affected implants with titanium plasma-sprayed or sandblasted/acid-etched surfaces may most easily and effectively be achieved by applying gauze soaked alternately in chlorhexidine and saline. INT J ORAL MAXILLOFAC IMPLANTS 2004;19(SUPPL):140–149

Key words: dental implants, pathology, peri-implant infection, peri-implantitis, treatment

Various treatment modalities for plaque-induced inflammatory lesions in the peri-implant tissues have been described.^{1–4} Thus, mechanical debridement, antiseptics, antibiotics, surgical procedures, and explantation were suggested to be used depending on the severity of the clinical and radiographic manifestations of the lesions.^{1,2} The present review will focus on the current knowledge about surgical treatment options for peri-implantitis around commercially pure titanium implants. Single

case reports and studies involving titanium-alloy implants or hydroxyapatite-coated implants were not included in this review.

SURGICAL PROCEDURES

Surgical treatment of peri-implantitis lesions may be performed in cases with considerable pocket formation (larger than 5 mm) and bone loss.^{1,2} As clearly stated in the preceding review by Heitz-Mayfield and Lang,⁵ prior to surgical therapy the acute infection must be resolved and proper oral hygiene instituted. The primary goals of the treatment are to eliminate the inflammatory lesion, stop the disease progression, and maintain the implant in function with healthy peri-implant tissues. Moreover, treatment procedures resulting in regeneration of the lost peri-implant tissues are desired.

Animal Studies

Animal experiments evaluating procedures used for surgical treatment of peri-implantitis are reported in

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Figs 1a to 1d Surgical treatment of experimentally induced peri-implantitis in a monkey model. From Schou et al²⁰; reprinted with permission.

Fig 1a (Left) Elevation of a full mucoperiosteal flap, removal of granulation tissue, and preparation of multiple perforations of the cortical bone.

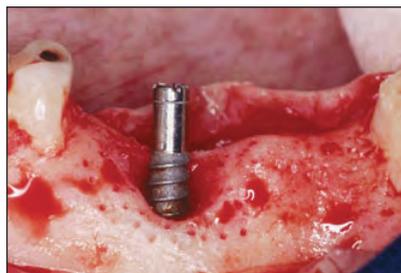


Fig 1b (Right) Affected area, after membrane placement over autogenous bone graft particles.

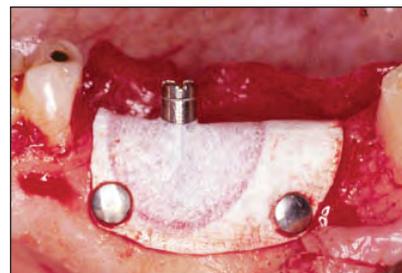


Fig 1c (Left) Subtraction image obtained 6 months after treatment with membrane-covered autogenous bone (white lines indicate the former border of the peri-implant defect).



Fig 1d (Right) Subtraction image 6 months after treatment with a conventional flap procedure.

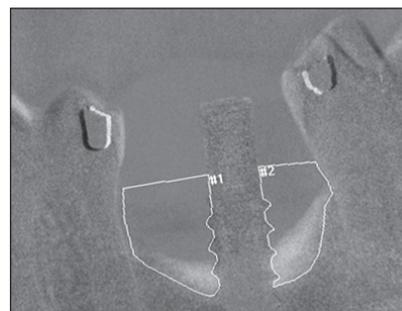


Table 1.⁶⁻²³ Regenerative techniques, including barrier membranes alone and/or in combination with different bone substitutes, together with systemic antibiotic therapy, were evaluated in dogs and non-human primates. Implant type and surface, antibiotic therapy, surgical technique, implant surface decontamination, and healing conditions differed considerably among these studies. The evaluation included treatment modalities using both submerged and nonsubmerged approaches. Although clinically healthy peri-implant tissues were obtained and maintained in most of these studies, the amount of documented bone regeneration and re-osseointegration varied considerably. In many of these studies, the re-establishment of osseointegration has been questioned. It is unclear to what extent an implant surface previously exposed to plaque can obtain new bone-to-implant contact following decontamination. However, encouraging treatment outcomes have been reported from animal studies involving implants with rough surfaces.¹⁹⁻²³

Surgical therapy aiming to regenerate the peri-implant bone using autogenous bone graft particles and expanded polytetrafluoroethylene (e-PTFE) membranes (Gore-Tex, Gore and Associates, Flagstaff, AZ) was recently evaluated.^{20,21} Sixty-four ITI implants (Institut Straumann, Waldenburg, Switzerland) with a titanium plasma-sprayed (TPS) surface were placed in the jaws of 8 cynomolgus monkeys (*Macaca fascicularis*). Three months after implant placement, experimental peri-implantitis was created, resulting in bone loss of 4 to 6 mm.

Plaque control was then implemented and surgical therapy was carried out, including: (1) autogenous bone grafts covered by membranes, (2) autogenous bone grafts alone, (3) membranes alone, or (4) a control access flap procedure (Figs 1a and 1b). As part of the surgical procedure, the implant surface was cleaned alternately with 0.1% aqueous chlorhexidine and physiologic saline-soaked gauze. No attempts were made to cover the implants with oral mucosa as part of the surgical procedure.

The animals were sacrificed 6 months after surgical therapy. In cases where membrane-covered autogenous bone graft particles were used, bone gain was achieved corresponding to the level that existed before the peri-implant defects were established, as assessed by quantitative digital subtraction radiography. In contrast, defects treated with autogenous bone alone, membranes alone, or the control flap procedure yielded minimal bone regeneration (Figs 1c and 1d). Moreover, in defects treated with membrane-covered autogenous bone, stereologic estimates of ground sections demonstrated significantly larger amounts of bone regeneration and re-osseointegration than sections treated with the other 3 procedures (Figs 2a to 2c). When the treatment involved membrane-covered autogenous bone, a mean bone-to-implant contact of 45% was observed in the defect region. The corresponding estimates for autogenous bone grafting, membranes alone, and the control flaps were 22%, 21%, and 14%, respectively.

Other grafting materials, such as anorganic porous bovine bone mineral (Bio-Oss, Geistlich

Table 1 Studies in Animals on Surgical Treatment Modalities for Peri-implantitis

Study	Animals	Implants	Antibiotic	Treatment	Implant surface decontamination	Healing period	Results			Comments
							INF	R-Oss	BR	
Grunder et al 1993 ⁶	10 dogs	40 Screw-Vent (AE)	NI	Flap surgery ± e-PTFE for 1 mo	Air-powder abrasive unit	Sub and NSub	No	≤ 0.3 mm groups	Minimal	Suspension membrane sutures used in the NSub group. High frequency of membrane exposures
Jovanovic et al 1993 ⁷	3 dogs	10 Brånemark (TS), 10 IMZ (TPS surface), and 10 Integral (HA-coated surface)	NI	1. Flap surgery and e-PTFE for 2 or 4.5 mo; 2. Flap surgery alone	Air-powder abrasive unit (30 s) and supersaturated citric acid (30 s)	Sub	NI	1. Limited; 2. Minimal	1. Yes; 2. Minimal	No comments
Ericsson et al 1996 ⁸	5 dogs	10 Brånemark (TS)	Amoxicillin and metronidazole (3 wk)	1. Flap surgery; 2. No flap surgery	1. 1% delmopinol and abutments autoclaved; 2. No decontamination	Nsub	1. No; 2. Yes	1. No; 2. No	1. No; 2. No	No comments
Perisson et al 1996 ⁹	5 dogs	30 Brånemark (TS)	Amoxicillin and metronidazole (3 wk)	1. Flap surgery and e-PTFE for 4 mo; 2. No-flap surgery	1. 1% delmopinol; 2. No decontamination	1. Sub; 2. Nsub	1. No; 2. Yes	1. Minimal; 2. No	1. Minimal; 2. No	Vertical measurements of defect during surgery
Hürzeler et al 1997 ¹⁰	7 dogs	42 Brånemark (TS)	Metronidazole (3 wk)	1. Flap surgery, HA, and e-PTFE for 4 mo; 2. Flap surgery, DFDB, and e-PTFE for 4 mo; 3. Flap surgery and HA; 4. Flap surgery and DFDB; 5. Flap surgery and e-PTFE for 4 mo; 6. Flap surgery alone	Air-powder abrasive unit (30 s)	Sub	No	1. 2.3 mm; 2. 2.2 mm; 3. 0.9 mm; 4. 0.9 mm; 5. 1.0 mm; 6. 0.3 mm	1. 2.4 mm; 2. 3.0 mm; 3. 1.3 mm; 4. 1.6 mm; 5. 2.5 mm; 6. 0.5 mm	No comments
Machado et al 1999 ¹¹	4 dogs	16 Napio (AE)	Metronidazole (3 wk)	1. Flap surgery, Bio-Oss, and PTFE for 4 mo; 2. Flap surgery and Bio-Oss; 3. Flap surgery and PTFE for 4 mo; 4. Flap surgery alone	Air-powder abrasive unit (30 s)	Sub	NI	NI	1. 1.6 mm; 2. 1.6 mm; 3. 1.4 mm; 4. 0.9 mm	Vertical measurements of defect during surgery
Perisson et al 1999 ¹²	4 dogs	24 Brånemark (TS)	Amoxicillin and metronidazole (3 wk)	Flap surgery	1. Rotating brush with pumice; 2. Cotton pellet soaked in saline	Sub	No	1. 0.4 mm; 2. 0.4 mm	Reference: Previous defect: 1. 2.0 mm ² (59%); 2. 1.6 mm ² (64%)	Flourochrome injected 2 weeks after surgery

Table 1 Studies in Animals on Surgical Treatment Modalities for Peri-implantitis continued

Study	Animals	Implants	Antibiotic	Treatment	Healing period	Results			Comments
						INF	R-OSS	BR	
Weitzel et al 1999 ¹³	7 dogs	39 ITI: 1. & 4. SLA surface, 2. & 5. TPS surface, 3. & 6. TS	Metronidazole (10 d)	1., 2., 3., Flap surgery and e-PTFE for 5.5 months; 4., 5., 6., Flap surgery alone	Sub	No	Reference: Previous defect: 1. 20% (0.6 mm); 2. 14% (0.5 mm); 3. 2% (0.1 mm); 4. 11% (0.3 mm); 5. 14% (0.3 mm); 6. 7% (0.2 mm)	Reference: Previous defect: 1. 2.3 mm (83%); 2. 2.6 mm (73%); 3. 2.2 mm (62%); 4. 0.4 mm (15%); 5. 0.3 mm (14%); 6. 0.8 mm (31%)	Flourochrome injected 2 weeks before surgery. Titanium ring placed around implant at defect bottom
Machado et al 2000 ¹⁴	5 dogs	20 Napio (AE)	Metronidazole (3 wk)	1. Flap surgery, Bio-Oss, and PTFE for 4 mo; 2. Flap surgery and Bio-Oss; 3. Flap surgery and PTFE for 4 mo; 4. Flap surgery alone	Sub	NI	Reference: 6 most coronal threads: 1. 27%; 2. 28%; 3. 31%; 4. 27%	Reference: 6 most coronal threads: 1. 52%; 2. 56%; 3. 52%; 4. 50%	No comments
Deppe et al 2001 ¹⁵	6 dogs	60 Frialit-2 (TPS surface)	NI	1., 3., 5., Flap surgery alone; 2., 4., 6., Flap surgery and e-PTFE for 4 mo	Sub	NI	1. 0.8 mm; 2. 1.2 mm; 3. 1.0 mm; 4. 1.2 mm; 5. 0.8 mm; 6. 1.1 mm	Reference: Previous defect: 1. 0.5 mm (29%); 2. 1.6 mm (94%); 3. 0.9 mm (53%); 4. 1.9 mm (112%); 5. 0.8 mm (47%); 6. 1.5 mm (88%)	No signs of thermal damage to surrounding bone after implant surface decontamination with CO ₂ laser
Nociti et al 2001 ^{16,17}	5 dogs	30 Napio (AE)	Metronidazole (3 wk)	Flap surgery alone or combined with Bio-Oss and PTFE for 4 mo; Bio-Oss and Bio-Gide membrane; PTFE for 4 mo; Bio-Oss; or Bio-Gide membrane	Sub	NI	Reference: Previous defect: 26% to 31% irrespective of treatment	Reference: Previous vertical defect height: 14% to 28% irrespective of treatment	Vertical measurements of defect during surgery
Perrsson et al 2001 ¹⁸	2 dogs	16 Brånemark (TS) modified implants versus standard implants	Amoxicillin and metronidazole (3 wk)	Flap surgery Replacement of the coronal contaminated implant part with a non-contaminated part; versus cotton pellet soaked in saline	Sub	No	New osseointegration identified on the replaced implant part; versus minimal	Yes	Flourochrome injected 2 wk after surgery
Perrsson et al 2001 ¹⁹	4 dogs	24 ITI TS versus SLA surface	Amoxicillin and metronidazole (17 d)	Flap surgery Cotton pellet soaked in saline	Sub initially, but all NSub after 1 mo	No	Reference: Previous defect: TS: 22% (0.4 mm); SLA: 84% (1.2 mm)	Reference: Previous defect: TS: 3.8 mm ² (72%); SLA: 3.2 mm ² (77%)	Flourochrome injected 2 wk after surgery

Table 1 Studies in Animals on Surgical Treatment Modalities for Peri-implantitis continued

Study	Animals	Implants	Antibiotic	Treatment	Implant surface decontamination	Healing period	Results			Comments
							INF	R-OSS	BR	
Schou et al 2003 ^{20,21}	8 monkeys	61 ITI (TPS surface)	Ampicillin and metronidazole (12 d)	1. Flap surgery, AB, and e-PTFE for 3 mo; 2. Flap surgery and AB; 3. Flap surgery and e-PTFE for 3 mo; 4. Flap surgery alone	Gauze soaked alternately in CHX and saline (5 min)	Nsub	No	Reference: Previous defect: 1. 45%; 2. 22%; 3. 21%; 4. 14%	Reference: Previous defect: 1. 16.1 mm ² , 4.7 mm (94%); 2. 9.2 mm ² , 4.0 mm (80%); 3. 6.3 mm ² , 3.0 mm (65%); 4. 5.4 mm ² , 1.9 mm (40%)	Transfer of defect border from radiographs to histologic sections. Unbiased stereologic estimates
Schou et al 2003 ²²	8 monkeys	62 ITI (TPS surface)	Ampicillin and metronidazole (12 d)	1. Flap surgery, Bio-Oss, and e-PTFE for 3 mo; 2. Flap surgery and Bio-Oss; 3. Flap surgery and e-PTFE for 3 mo; 4. Flap surgery alone	Gauze soaked alternately in CHX and saline (5 min)	Nsub	No	Reference: Previous defect: 1. 36%; 2. 16%; 3. 23%; 4. 13%	Reference: Previous defect: 1. 11.2 mm ² , 5.0 mm (111%); 2. 8.7 mm ² , 4.6 mm (96%); 3. 7.9 mm ² , 3.7 mm (74%); 4. 5.3 mm ² , 2.1 mm (47%)	Transfer of defect border from radiographs to histologic sections. Unbiased stereologic estimates
Schou et al 2003 ²³	8 monkeys	57 ITI (TPS surface)	Ampicillin and metronidazole (12 d)	Flap surgery, AB, and e-PTFE for 3 mo	1. Air-powder abrasive unit (5 min) and supersaturated citric acid (2 min); 2. Air-powder abrasive unit (5 min); 3. Gauze soaked in saline (5 min) and supersaturated citric acid (2 min); 4. Gauze soaked alternately in CHX and saline (5 min)	Nsub	No	Reference: Previous defect: 1. 46%; 2. 39%; 3. 43%; 4. 40%	Reference: Previous defect: 1. 14.1 mm ² , 4.6 mm (99%); 2. 14.1 mm ² , 4.7 mm (105%); 3. 14.2 mm ² , 4.4 mm (94%); 4. 13.9 mm ² , 4.7 mm (105%)	Transfer of defect border from radiographs to histological sections. Unbiased stereologic estimates

All group values referred to are expressed as mean values.

AB = autogenous bone; AE = AE; BR = bone regeneration; CHX = chlorhexidine; DFDB = demineralized freeze-dried bone; e-PTFE = expanded polytetrafluoroethylene membrane; HA = hydroxyapatite; INF = inflammation; NI = no information; Nsub = Nonsubmerged; PTFE = polytetrafluoroethylene membrane; R-Oss = re-osseointegration; SLA = sandblasted and acid-etched; Sub = submerged; TPS = titanium plasma-sprayed; TS = turned surface.

Figs 2a to 2c Treatment of experimentally created peri-implantitis defects in a monkey model. From Schou et al²¹; reprinted with permission.

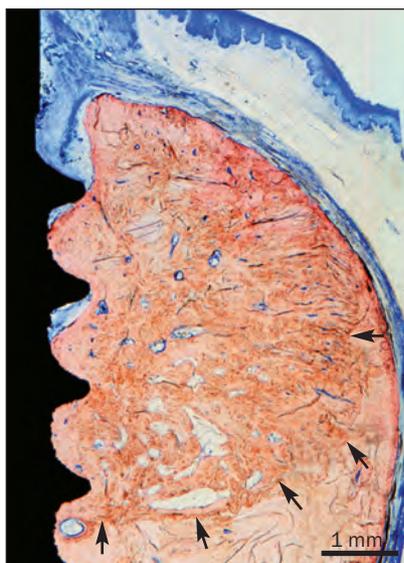


Fig 2a Considerable bone regeneration occurred after surgical treatment involving autogenous bone graft particles and e-PTFE membrane (arrows indicate the former peri-implant defect border) (Stevenel's blue and alizarin red S).

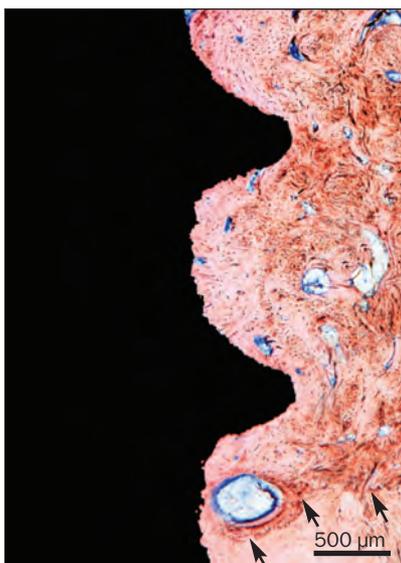


Fig 2b Higher magnification. Considerable re-osseointegration was obtained.

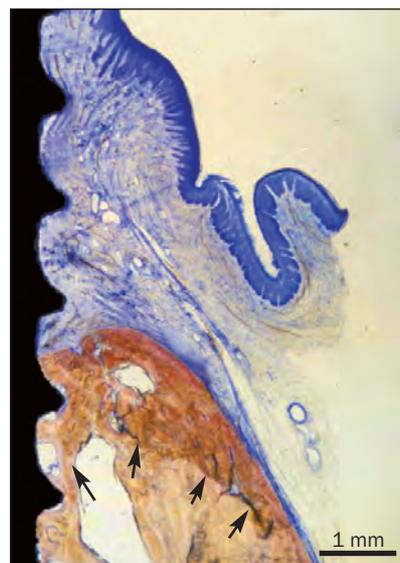


Fig 2c Limited bone regeneration was achieved after treatment with a conventional flap procedure alone (Stevenel's blue and alizarin red S).

Pharma, Wolhusen, Switzerland) used alone or in combination with membranes, have also been evaluated in animal experiments (Table 1).^{11,14,16,17} However, no statistically significant differences in bone regeneration were demonstrated between the evaluated procedures and the control flap procedure. Results from an animal study by Schou and coworkers using an experimental design similar to the one mentioned above^{20,21} showed superior treatment outcomes with the combined use of Bio-Oss and e-PTFE membranes compared to Bio-Oss alone, membranes alone, or a control flap procedure.²²

Considerable amounts of re-osseointegration to rough implant surfaces have also been demonstrated in dogs.¹⁹ Twenty-four ITI implants with a turned or a sandblasted/acid-etched (SLA) surface were placed in 4 beagle dogs. Experimental peri-implantitis was induced over a period of 3 months until 50% of the initial bone support was lost. A surgical procedure, including cleaning of the implant surface with cotton pellets soaked in saline, was carried out following the administration of systemic antibiotics. The implants were initially submerged but became exposed to the oral environment after 1 month of healing. A histologic evaluation performed 6 months after treatment revealed comparable amounts of bone regeneration within the previous defects around implants with turned and SLA surfaces. In contrast, the amount of re-osseointegration was substantially greater on SLA

implant surfaces (84%) than on turned implant surfaces (22%). Therefore, it was suggested that re-osseointegration after treatment of the peri-implantitis defect appeared to be dependent on the surface characteristics of the implant. Similar findings were also evident in a previous animal study.¹³

In a study by Persson and associates¹⁹ with an experimental design comparable to that mentioned above, new osseointegration was observed on experimental 2-part implants with a turned surface.¹⁸ Surgical therapy and replacement of the coronal and previously contaminated part of the implant with a pristine implant unit resulted in new osseointegration. This observation indicated that the pristine turned implant surface exhibited different properties for osseointegration than a previously contaminated surface.

Human Studies

Human studies have also focused on the regenerative potential of membranes, bone substitutes, and autogenous bone grafts in the surgical treatment of peri-implantitis (Table 2).^{24–28} Additional systemic antibiotic therapy was included in most studies. Furthermore, the evaluations have included both submerged implants and implants penetrating the oral mucosa during the healing period. The animal studies mentioned above indicated that membrane-covered autogenous bone graft particles appeared

most effective in the surgical treatment of peri-implantitis around implants with a rough surface.

The use of autogenous bone grafts with or without membrane coverage in humans was also evaluated in 3 studies involving 90 implants (Table 2).²⁶⁻²⁸ A clinically healthy peri-implant mucosa was a consistent finding after treatment, but the amount of bone regeneration varied widely among studies. As an example, 25 ITI implants with a TPS surface were analyzed in one study.²⁶ The surgical treatment involved placement of blocks or particles of autogenous bone without membrane coverage after cleaning of the implant surface with an air-powder abrasive unit. A mean radiographic bone gain of 4.2 mm, corresponding to 100% regeneration, was observed after 3 years. However, in another study that involved 24 IMZ implants (Friadent, Mannheim, Germany) with a TPS surface,²⁷ autogenous bone graft particles covered with an e-PTFE membrane were used after implant surface decontamination using photosensitization by Toluidine blue and soft laser irradiation. The radiographic evaluation performed after an observation period of about 9.5 months demonstrated a mean bone gain of 2 mm, corresponding to only 36% of the previous defect height. In contrast, the third study involved 41 IMZ and Friadent implants,²⁸ and 3 different surgical treatment procedures were performed: (1) autogenous bone covered with an e-PTFE membrane; (2) autogenous bone covered with a porcine-derived bilayered types I and III collagen membrane (Bio-Gide, Geistlich Pharma); or (3) autogenous bone without membrane coverage. The autogenous bone graft was used either as a block or as particles. The implant surface was cleaned with chlorhexidine, citric acid, and hydrogen peroxide. Bone gain varied between 1.9 and 2.8 mm after an observation period of 3 years. It was concluded that additional application of a membrane did not improve the treatment outcome in comparison to the use of autogenous bone alone. However, it should be noted that no randomization was performed, and hence the results of this study should be interpreted with care.

Membranes are applied to stabilize the blood clot and to prevent growth of connective tissue and epithelium into the peri-implant bone defect during surgical therapy.^{29,30} Various grafting materials have been combined with membranes to maintain the space created under the membrane and to serve as an osteoconductive scaffold to promote bone regeneration. Findings from animal studies have indicated that the combination of grafting materials and a membrane is preferable in the surgical treatment of the osseous defects in peri-implantitis.²⁰⁻²² However, membrane exposure is a frequent complication after

such procedures. For example, 13% to 38% of the membranes were exposed in the previously mentioned experimental studies.²⁰⁻²² Exposure of porous e-PTFE membranes may result in bacterial penetration and lead to infection.³¹⁻³³ Although topical application of chlorhexidine seems to reduce plaque formation on the exposed membranes, bacterial penetration cannot be prevented.³³ Satisfactory results may occasionally be obtained despite membrane exposure if plaque control is optimal.^{29,30} However, based upon observations in humans, immediate removal of exposed membranes used as a part of the surgical treatment of peri-implantitis is recommended to avoid impeding bone regeneration.²⁷ Future studies may shed more light on this issue.

Conclusions Regarding Surgical Treatments

Surgical treatment of peri-implantitis seems feasible. Recently performed animal studies involving implants with a rough surface indicate that considerable bone regeneration and re-osseointegration can be obtained by using membrane-covered autogenous bone graft particles. Comparisons of the treatment outcomes in studies involving humans and animals are difficult because of differences in implant type, graft type, and evaluation protocols. In addition, different treatment procedures, including implant surface decontamination methods, have been used. Therefore, further long-term studies in humans involving sufficient numbers of subjects are needed to provide a solid basis for recommendations regarding the surgical treatment of peri-implantitis. It is important to underline that osseous defects of peri-implantitis normally exhibit well-demarcated craters. Peri-implant bone defects with horizontal bone loss or craters with a narrow crestal opening may be more difficult to access for regenerative procedures. Finally, the encouraging treatment outcomes of regenerative procedures recently revealed in animal experiments and applied in the treatment of peri-implantitis around implants with a SLA surface have not yet been documented for implants with other surfaces, especially turned surfaces.

IMPLANT SURFACE DECONTAMINATION

It has been suggested that the establishment of an implant surface conducive to bone formation is a prerequisite for successful regenerative treatment of peri-implantitis.³⁴ Contaminants such as bacteria and their products, calculus, and soft tissue cells should be removed without modifying the implant surface. However, it is still unknown to what extent these contaminants have to be removed to achieve a successful treatment outcome.³⁵

Table 2 Studies in Humans on Surgical Treatment Modalities for Peri-implantitis

Study	No. of patients	Implants and time since placement	Antibiotic	Treatment	Implant surface decontamination	Healing period	Observation period	Results		
								Inflammation	"Bone" regeneration	Comments
Hämmerle et al 1995 ²⁴	2	2 ITI (TPS surface); 4 y	1. Metronidazole and amoxicillin (10 d); 2. Amoxicillin (10 d)	Flap surgery and e-PTFE	Irrigation alternately with CHX and saline	NSub	1 y	1. No, PD: 3.3 mm; 2. No, PD: 3.7 mm	1. 2.7 mm; 2. 1.9 mm	1. Membrane removal after 4.5 mo; 2. Membrane removal after 6.5 mo
Mellonig et al 1995 ²⁵	3	3 titanium hollow cylinders (TPS surface); 1.5 to 2.5 y	NI	Flap surgery; HA or DFDB soaked in tetracycline, and e-PTFE	Tetracycline irrigation	NSub	8 to 12 mo	No	Yes	Membrane removal after 6 to 9 wk
Behneke et al 2000 ²⁶	17	25 ITI (TPS surface); 8 implants within 2 y of function, 17 implants after 2 y of function	Metronidazole (7 d)	Flap surgery and AB (block or particulate) fixated with screws or fibrin glue	Air-powder abrasive unit (30 s)	NSub	6 to 36 mo	No, PD after 3 y: 1.6 mm	After 3 y: 4.2 mm (100%)	Yes
Haas et al 2000 ²⁷	17	24 IMZ (TPS surface)	Penicillin (5 d)	Flap surgery, AB, and e-PTFE	Photosensitization by Toluidine blue and soft laser irradiation	Sub	9.5 mo	No	2.0 mm (36%)	All membranes exposed
Khoury et al 2001 ²⁸	25	41 IMZ and Friadent; 5.8 y of function	According to antimicrobial susceptibility test (2 wk)	1. Flap surgery, AB (block or particulate), and e-PTFE; 2. Flap surgery, AB (block or particulate), and Bio-Gide membrane; 3. Flap surgery and AB (block or particulate)	CHX irrigation, citric acid, and H ₂ O ₂	Sub	3 y	1. PD 2.8 mm; 2. PD 5.1 mm; 3. PD 2.9 mm	1. 2.8 mm; 2. 1.9 mm; 3. 2.4 mm	Membrane removal after 6 mo. 1. 45% of membranes exposed; 2. 33% of membranes exposed; 3. No complications

All group values referred to are expressed as mean values.

AB = autogenous bone; BR = "bone" regeneration; CHX = chlorhexidine; DFDB = demineralized freeze-dried bone; e-PTFE = expanded polytetrafluoroethylene membrane; HA = hydroxyapatite; INF = inflammation; NI = no information; NSub = nonsubmerged; OP = observation period; PD = probing depth; Sub = submerged; TPS = titanium plasma-sprayed.

Numerous implant surface decontamination methods have been suggested, either alone or in various combinations, as part of the surgical treatment of peri-implantitis both in animals and in humans (Tables 1 and 2).⁴ In vitro studies focusing on various methods to clean the implant surface have recently been reviewed and discussed in detail.²³ It was concluded that several methods are inappropriate for implant surface cleaning, especially metal curettes for hand scaling, conventional sonic/ultrasonic scalers, and some types of lasers, which may severely damage the implant surface. Although implant surface damage can almost be prevented by using either ultrasonic scalers with a nonmetallic tip or resin/carbon fiber curettes, presence of implant threads and/or implant surface roughness may compromise the access for cleaning.

Animal models of experimental peri-implantitis have been useful for evaluation of various implant surface decontamination methods in the surgical treatment of peri-implantitis (Table 1).^{12,15,23} No difference could be demonstrated regarding the degree of osseointegration with implants that were cleaned either with cotton pellets soaked in saline or with a rotating brush with pumice during regenerative surgery.¹² Furthermore, no difference could be detected when decontamination by a carbon dioxide laser and/or an air-powder abrasive unit was done during flap surgery with or without coverage of the defect by an e-PTFE membrane.¹⁵

Air-powder abrasive units are often recommended for the surgical treatment of peri-implantitis (Tables 1 and 2). The influence of various air-powder abrasive systems on the titanium surface has been evaluated in vitro and was previously reviewed.²³ Although increased implant surface roughness and retained powder particles have been observed as a result of such application, no or only minor surface changes were identified in most studies. The mixture of water and abrasive powder is driven by compressed air. Therefore, the pressure applied may cause complications. However, the number of reported emphysema and pneumoparotitis cases induced by air-powder abrasive units appears to be low.³⁶⁻³⁸

Recently, 4 implant surface decontamination methods were compared in a monkey model: (1) air-powder abrasive technique followed by citric acid application, (2) air-powder abrasive technique, (3) gauze soaked in saline followed by citric acid application, and (4) gauze soaked alternately in 0.1% chlorhexidine and saline.²³ Experimental peri-implant defects, created over a period of 9 to 17 months around implants with a TPS surface, were surgically exposed. Each implant surface was subjected to one of the previously mentioned treatment

procedures. All defects were filled with autogenous bone graft particles and covered by an e-PTFE membrane. Clinical parameters, radiography (including quantitative digital subtraction radiography), histology, and stereology did not reveal significant differences between any of the methods used. Almost complete bone fill and considerable reosseointegration were obtained irrespective of the method applied. Hence, it was concluded that for implants with a rough surface, the simplest method, ie, gauze soaked alternately in chlorhexidine and saline, should be the preferred implant surface decontamination method when combined with membrane-covered autogenous bone graft particles.

Findings from an in vitro study combining photosensitization by Toluidine blue solution and soft laser irradiation have indicated that elimination of bacteria from different titanium surfaces without modification of the implant surface was possible.³⁹ A clinical and microbiologic study confirmed that this technique also significantly reduced the number of bacteria on a TPS surface.⁴⁰ The method was applied to 24 implants with a TPS surface in humans in combination with membrane-covered autogenous bone grafts.²⁷ Bone regeneration was obtained, but the procedure was not compared to other methods or controls.

Conclusions Regarding Implant Decontamination

Decontamination of peri-implantitis-affected implants may be achieved most easily and effectively by applying gauze soaked alternately in chlorhexidine and saline, especially with implants with TPS or SLA surfaces that are undergoing surgical treatment.

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Consensus Statements and Recommended Clinical Procedures Regarding Implant Survival and Complications

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INTRODUCTORY REMARKS

The working group based its discussion on 2 systematic reviews published in 2002, 2 systematic reviews published in 2004 on related topics, and 3 traditional reviews prepared specifically for this consensus workshop (see reference list).

After extensive discussion, the previously unpublished reviews were amended where indicated, and consensus was reached that the reviews were both comprehensive and complete in covering the available published literature up to August of 2003. Hence, the papers were accepted and formed the basis for the consensus report on implant survival and complications. Subsequent to the consensus meeting, the quoted literature was updated up to December 2003.

For the purpose of clarification and understanding of the evaluated literature, the working group adopted a glossary of terms.

GLOSSARY OF TERMS

- *Survival*: The element (implant or reconstruction) is present at the follow-up examination but its condition is not specified.
- *Success*: The element (implant or reconstruction) is present at the follow-up examination, and complications are absent.
- *Loss*: The element (implant or reconstruction) is no longer present at the time of the follow-up examination.
- *Complications*: Chair time is required after incorporation of the prosthesis.
- *Failure*: Either the element (implant or reconstruction) is lost or a complication is present at

the follow-up examination. Hence, this term will generally be avoided and replaced by the above-mentioned terms.

- *FPD*: Fixed partial denture

Terms related to biologic complications/peri-implant disease:

- *Mucositis*: Localized lesion without bone loss around an osseointegrated implant
- *Peri-implantitis*: Localized lesion including bone loss around an osseointegrated implant
- *Soft tissue complications*: Fistula, excessive swelling, hyperplasia, etc

Terms related to technical complications:

- *Implant-related*: Fracture
- *Connection-related*: Loosening, fractures
- *Suprastructure-related*: Framework, veneer, loss of retention (fracture of the cement seal)

CONSENSUS STATEMENTS

Single Crowns and Overdentures

A recently published systematic review addressed the incidence of implant loss and complications of oral implants supporting single crowns over at least 5 years.¹ The analysis was based on 8 studies and yielded an early loss of 0.8% before prosthetic placement and an incidence of 2% to 2.5% loss during 5 years of function. The same systematic review reported 2.5% implant loss prior to the placement of overdentures and nearly 6% implant loss during 5 years of function.

Fixed Partial Dentures

The systematic reviews prepared for this consensus workshop reported exclusively on complication and survival rates of fixed partial dentures (FPDs), either implant-supported or implant/ tooth-supported.

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For implant-supported FPDs² the following conclusions were drawn:

- The cumulative survival rate of oral implants supporting FPDs was 95.4% after 5 years of function and 92.8% after 10 years of function. This evidence is derived from 10 prospective and 5 retrospective cohort studies with a mean of 5 years of follow-up and 6 prospective cohort studies with a mean 10-year follow-up.
- With regard to the ITI Dental Implant System, on the basis of 2 prospective cohort studies with 5 years of follow-up and 1 study with 10 years of follow-up, the survival rates were 97.2% and 98.6%, respectively.
- The cumulative survival rate of FPDs supported by oral implants was 95.0% after 5 years of function and 86.7% after 10 years of function. This evidence is derived from 14 studies including 1,289 FPDs after 5 years and 3 studies including 219 FPDs after 10 years.
- With regard to the ITI Dental Implant System, on the basis of 2 prospective cohort studies with 5 years of follow-up (n = 108) and 1 study with 10 years of follow-up (n = 33), the cumulative survival rates for FPDs were 98.3% at 5 years and 93.9% at 10 years, respectively.
- FPDs without any biologic or technical complications were encountered in 61.3% of patients after 5 years. Data on the absence of complications were available from only 4 of the 21 cohort studies. It should be noted that the implant types and components reported in the literature have been modified, and some of them are no longer available.
- Reports of biologic complications were variable in nature. Based on 8 cohort studies, peri-implantitis and soft tissue complications occurred in 8.6% of patients after 5 years.
- Reports on technical complications included implant fracture and connection-related and suprastructure-related complications. Based on 7 cohort studies with 5 years of follow-up and 4 studies with 10 years of follow-up, the incidence of implant fracture was 0.4% after 5 years and 1.8% after 10 years. The incidence of connection-related complications (screw loosening or fracture) was 7.3% (5 years). The incidence of suprastructure-related complications (veneer and framework fracture) was 14.0% after 5 years. Of the 7% of the restorations that were cemented, loss of retention of the restoration occurred in 2.9% within 5 years and 16.2% within 10 years.
- The cumulative survival rate of oral implants used in implant/tooth-supported FPDs was 90.1% after 5 years of function and 82.1% after 10 years of function. This evidence is derived from 8 cohort studies with a mean follow-up of 5.7 years and 4 cohort studies with a mean 10-year follow-up period.
- With regard to the ITI Dental Implant System, on the basis of 1 prospective cohort study of 5 years of follow-up and 1 study with a 10-year follow-up, the corresponding survival rates were 94.8% and 77.3%, respectively.
- The cumulative survival rate of FPDs supported by oral implants and teeth was 94.1% after 5 years of function and 77.8% after 10 years of function. This evidence is derived from 5 studies including 114 FPDs after 5 years and 3 studies including 60 FPDs after 10 years.
- With regard to the ITI Dental Implant System, on the basis of 1 prospective cohort study of 5 years of follow-up (n = 18) and 1 study of 10 years of follow-up (n = 22), the cumulative survival rates for FPDs were 94.5% and 79.3%, respectively.
- Combined tooth/implant FPDs with no biologic or technical complications were seen in 50% of patients after 10 years. However, data on the absence of complications were only available from 1 of the 13 cohort studies.
- Biologic complications adjacent to implants were reported in 2 studies. Based on these studies, peri-implantitis and soft tissue complications occurred in 11.7% of implants after 5 years.
- Reports on technical complications included implant fracture and connection-related and suprastructure-related complications. Based on 4 cohort studies with 5 years of follow-up and 2 studies with 10 years of follow-up, the incidence of implant fracture was 0.9% after 5 years. The incidence of connection-related complications (screw loosening or fracture) was 4.3% after 5 years and 26.4% after 10 years. The incidence of suprastructure-related complications (veneer and framework fracture) was 9.8% after 5 years. Of the 9% of restorations that were cemented, loss of retention of the restoration occurred in 6.2% (2 studies) within 5 years and 24.9% (1 study) within 10 years.
- The incidence of abutment tooth loss was 3.2% after 5 years and 10.6% after 10 years. Implants were lost in 3.4% and 15.4%, respectively. These observations are based on six 5-year cohort studies and two 10-year cohort studies, respectively. Information about the association between biologic complications around teeth (caries, tooth

For the combined tooth/implant-supported FPDs³ the following conclusions were drawn:

fractures, endodontic complications, and periodontitis) and the loss of the abutment teeth could not be determined from these studies.

- The reported incidence of complications encountered, especially over the 10-year observation period, should be interpreted cautiously because of the limited number of studies ($n = 2$) available and the small sample sizes ($n = 20$ and 22).

CLINICAL IMPLICATIONS

Implant-supported and implant/tooth-supported FPDs present with high implant and restoration survival rates. However, biologic and technical complications occurred in about half the cases after 5 years of function.

The combined implant/tooth-supported FPDs showed slightly elevated rates of technical complications after 5 years of function. In addition to the expected complications encountered with oral implants or components, abutment teeth may develop additional biologic complications (endodontic, caries, fracture) leading to abutment loss. Therefore, implant-supported FPDs appear to be preferable to combined tooth/implant-supported FPDs.

Because of the limited availability of long-term documentation (10 years) for combined implant/tooth-supported FPDs, no clinical estimates can be made with regard to longevity or complication rates.

Diagnostic Parameters

For the review of diagnostic parameters⁴ the following conclusions and clinical recommendations are presented.

Systematic and continuous monitoring of peri-implant tissues is recommended for the early diagnosis of peri-implant disease. The parameters that may be used to assess the presence and severity of disease include assessment of plaque accumulation, scrutiny of mucosal conditions, peri-implant probing depth (PD), width of peri-implant keratinized mucosa, analysis of peri-implant sulcus fluid, monitoring for suppuration, and evaluation of aspects of the bone-implant interface such as implant mobility, radiographic interpretation and—maybe—resonance frequency analysis.

Plaque Assessment. Like tooth surfaces, implant surfaces are subjected to biofilm formation. Hence, patients should be instructed and motivated to regularly perform an adequate level of plaque control around both teeth and implants. To assess the level of oral hygiene during maintenance care, plaque

deposits may be visualized with staining solutions and, if indicated, the patient re-instructed in the correct use of cleansing devices.

Mucosal Conditions. As a result of biofilm formation, an inflammatory host response develops in the peri-implant soft tissue compartment. Although a modification of the Gingival Index has been used to assess peri-implant mucosal health or marginal inflammation (ie, peri-implant mucositis), the bleeding on probing (BOP) parameter may be preferred for longitudinal clinical documentation.

Absence of BOP may represent stable peri-implant soft tissue status, similar to the way that absence of BOP indicates periodontal health. Therefore, periodic recording of this parameter in conjunction with light probing force (ie, 0.2 to 0.25 N) can be recommended to monitor peri-implant soft tissue conditions.

Peri-implant PD. As a result of inflammation, the peri-implant sulcus may develop into a pocket. Therefore, peri-implant probing should be performed with a light force (ie, 0.2 to 0.25 N) to avoid tissue trauma. It should be viewed as an important and reliable diagnostic parameter in the longitudinal monitoring of peri-implant soft tissue conditions. No adverse effects on the integrity of the peri-implant soft tissue seal should occur from repeated probing.

PDs for conventionally placed implants generally range between 2 and 4 mm under healthy conditions. In sites of esthetic priority, where the implant shoulder has intentionally been placed submucosally, or where mucosal tissues are thick, deeper baseline PDs may be present. Increases in PD above these baseline values should be viewed as a sign of peri-implant disease.

Width of Peri-implant Keratinized Mucosa. No definite recommendation can be made on the need for keratinized mucosa around implants in humans. Nevertheless, preservation of the peri-implant keratinized mucosa is advocated. In the absence of keratinized mucosa around implants, the indications for soft tissue grafting are unclear.

Peri-implant Sulcus Fluid Analysis. Although biochemical markers reflecting the host-parasite interaction in the peri-implant sulcus may be useful for the study of the pathogenesis of peri-implant disease, no specific marker has been identified for routine diagnostic use.

Suppuration. Suppuration has been associated with peri-implantitis in case reports. However, sensitivity and specificity of suppuration as a marker for the detection of initial peri-implantitis or its progression are lacking.

Evaluation of the Bone-Implant Interface

Implant Mobility. Implant mobility is indicative of the absence of osseointegration. However, it is not a sensitive parameter for the detection of peri-implant disease. Therefore, routine assessment of implant mobility is not essential. When it is used, it should always be performed in conjunction with evaluation of the clinical and radiographic parameters. Because of its poor diagnostic accuracy, the Periotest cannot be recommended.

Radiographic Interpretation. It is appropriate to establish baseline bone levels at the time of prosthesis placement. However, justification for repeated exposure to radiation during maintenance care should not be based on predetermined protocols. The indication for radiographic examination should be made following individual clinical assessment. The imaging method should be selected to minimize radiation exposure and may be influenced by the number of implants to be imaged and their distribution in the jaws.

Resonance Frequency Analysis. This recently developed diagnostic instrument is intended to assess implant stability. However, studies validating its diagnostic utility are still lacking.

Treatment of Peri-implant Diseases

For the review of antimicrobial treatment of peri-implant diseases⁵ and surgical treatment of peri-implantitis,⁶ the following conclusions are presented:

- Evidence for antimicrobial treatment of peri-implant diseases is limited. There is a need to determine whether antimicrobials are effective in the treatment of peri-implant diseases.
- A variety of antimicrobial treatment regimens, in combination with nonsurgical or surgical debridement and with and without regenerative therapy, have been reported. Use of antimicrobials varied between studies with respect to type of drug, dosage, delivery system, time of initial administration, and duration. Patient compliance and adverse effects related to the antimicrobials were mostly not mentioned. While the majority of the case reports and studies available showed positive outcomes following antimicrobial treatment, no nonmedicated controls were included; therefore the relative effect of the antimicrobial agent(s) cannot be evaluated.
- Surgical procedures have been assessed in case report series and animal experiments. Clinically healthy peri-implant tissues have been reported following treatment. However, the amount of bone regeneration and re-osseointegration varied substantially. Recently performed animal experiments including implants with a titanium plasma-sprayed or sandblasted/acid-etched surface indicate that considerable bone regeneration and re-osseointegration can be obtained with and without membrane-covered bone grafts. However, these results should be confirmed in prospective cohort studies before specific recommendations on surgical treatment procedures in humans are made.
- Numerous methods to decontaminate implant surfaces have been used as a part of the surgical procedure. Comparisons of decontamination methods did not reveal any statistically significant differences in treatment outcomes.

RECOMMENDATIONS

- Following successful implant therapy, patients should be offered an individualized supportive care program.
- Systematic and continuous monitoring of peri-implant tissue conditions is recommended for the diagnosis of peri-implant health and disease. The parameters that are recommended to assess the presence and severity of disease include: presence of plaque and calculus, peri-implant PD, presence of BOP, presence of suppuration, and, if indicated, radiographic evaluation.
- Based on periodic diagnosis, and in agreement with the previous ITI consensus report,⁷ the Cumulative Interceptive Supportive Therapy (CIST) protocol (Fig 1) is recommended. This protocol includes 4 treatment modalities: A = mechanical debridement; B = antiseptic treatment; C = antibiotic treatment; and D = regenerative or resective surgery. Although this protocol has not been assessed in its entirety, 2 prospective cohort studies have evaluated the treatment modalities A + B + C. The benefits of adding surgical therapy (D) to the CIST protocol are documented in case series, single case reports, and a series of animal experiments.

The CIST protocol is also in agreement with the systematic review⁸ presented at the 4th European Workshop on Periodontology in Ittingen, Switzerland, which suggested a combination of various anti-infective therapies (mechanical, antiseptic, and antibiotic) to prior surgical intervention.

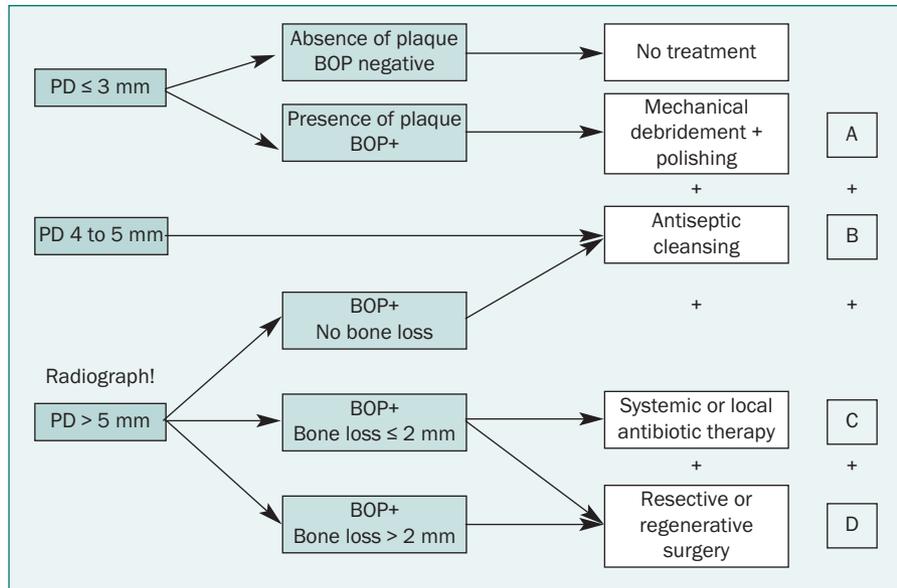


Fig 1 Cumulative Interceptive Supportive Therapy (CIST) protocol. Note that PDs may exceed the normal range stated here, so that PDs used to determine the protocol may have to be adjusted for these differences. In part A of the CIST protocol, typically initiated when plaque and BOP are present but PDs are 3 mm or less, patients are re-instructed in oral hygiene and motivated to initiate and continue maintenance; mechanical debridement is performed using nonmetallic curettes; and polishing takes place using a rubber cup and nonabrasive polishing paste. Part B, when PDs of 4 to 5 mm are found, consists of antiseptic treatment. Here, chemical plaque control is performed using chlorhexidine digluconate, typically as mouthrinses with 0.1% to 0.2% chlorhexidine for 30 seconds using approximately 10 mL, application of local chlorhexidine gel (0.2%), and/or local irrigation with chlorhexidine (0.2%), 2 times a day for 3 to 4 weeks. Protocol C, systemic or local antibiotic treatment, is initiated when PDs are greater than 5 mm. In addition, radiography should be used to supplement clinical findings. Typical systemic treatment is with ornidazole (1,000 mg × 1) or metronidazole (250 mg × 3) for 10 days, or a combination of amoxicillin (375 mg × 3) and metronidazole (250 mg × 3) for 10 days. Local treatment might include local application of antibiotics using a controlled-release device for 10 days, eg, tetracycline fibers and minocycline microspheres. Once treatment modalities A, B, and C have been completed, a surgical approach (D) may be considered. Surgical therapy for peri-implantitis should be performed in conjunction with systemic antibiotics and implant surface decontamination. If regenerative treatment is chosen, a barrier membrane technique alone or in combination with autogenous grafts and/or bone substitutes (deproteinized bovine bone mineral) may be considered. Resective surgery may be considered when the peri-implant defect is not suitable for regenerative techniques.

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