Implant Loading Protocols for the Partially Edentulous Posterior Mandible

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Purpose: *To evaluate the predictability of early and immediate loading protocols of implants in the posterior mandible and to investigate whether there is a difference in success rates, survival rates, and peri-implant parameters, including marginal bone level changes, between loading protocols.* ***Materials and Methods****: A comprehensive systematic review of the literature was conducted. The selection of publications reporting on human clinical studies was based on predetermined inclusion criteria and was agreed upon by two reviewers.* ***Results:*** *A total of 19 papers were selected: 8 on early loading, 9 addressing immediate loading, and 2 comparing immediate and early loading. Of the 19 studies, 5 were randomized clinical trials and 14 were prospective studies.* ***Conclusions:*** *Existing literature supports the early loading of microroughened dental implants in the partially edentulous posterior mandible at 6 to 8 weeks in the absence of modifying factors. Therefore, loading within this time frame can be considered routine for the majority of clinical situations in the posterior mandible, either with single crowns or fixed dental prostheses. Immediate loading of microroughened dental implants in the partially edentulous posterior mandible proved to be a viable treatment alternative. Caution is necessary when interpreting published outcomes for immediate loading, as the inclusion exclusion criteria are inconsistent and many subjective confounding factors are evident. Additional studies with longer follow-ups, specifically randomized clinical trials, are needed to consolidate the data for immediate loading. Priority should be given to trials testing immediate loading.* INT J ORAL MAXILLOFAC IMPLANTS 2009;24(SUPPL):158–168

Key words: *dental implants, fixed dental prostheses, loading protocol, partial edentulism, posterior mandible, single crown, systematic review*

There are several factors that may influence the process of successful osseointegration of oral implants. Bone quality, implant surface characteristics, and the amount of micromovement during healing are involved in this complex phenomenon. Functional and anatomical factors vary between the different sectors of the jaws. It has been demonstrated that the chewing load on teeth is maximal on the second molars and progressively decreases in the anterior region of the jaws.[1] This situation is maintained when teeth are replaced with implants.[2] It has also been shown that bone density varies between different regions of the jaws. Various attempts have been made to classify the various bone types with regard to bone density. The first widely used classification, by Lekholm and Zarb,[3] was questioned by Trisi and Rao[4] because of its subjective nature and the absence of a direct correlation to the anatomy and histology of the site.

More recently, different approaches, less dependent on the subjective examination of the clinician, have been used to determine bone density. Computed tomography may be used, and measurements can be performed using the Hounsfield Scale. A recent study demonstrated that the anterior mandible is the site with the highest bone density (927 ± 237 HU), followed by the posterior mandible (721 ± 291), the anterior maxilla (708 ± 277), and the posterior maxilla (505 ± 274 HU).[5] These data confirmed a previous study that found mandibular posterior bone density to be greater than posterior maxilla density.[6]

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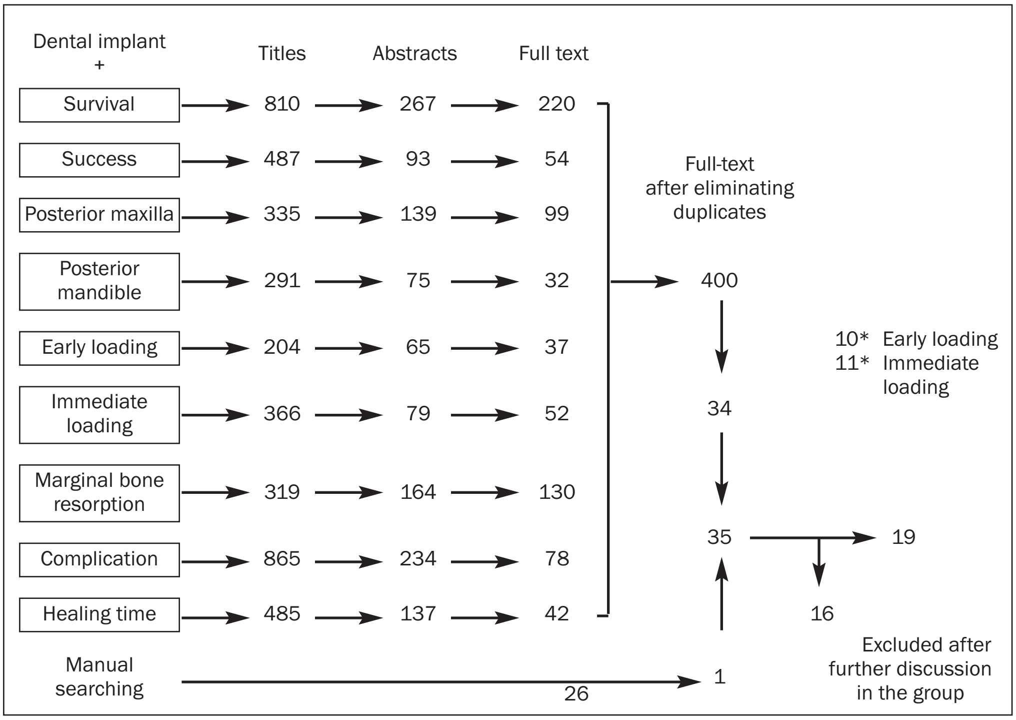

Fig 1 Search strategy and procedures. Two papers (*) deal with immediate and early loading in the posterior mandible.

Other means are used to measure implant stability, such as insertion torque values or resonance frequency analysis (RFA), and are partly correlated to bone density.[7] Usually, better outcomes are found in the posterior mandible than in the posterior maxilla. However, it should be noted that primary implant stability is largely dependent not only on bone density but also on implant design and surface, as well as on the technique and accuracy of the osteotomy preparation.

Usually, the posterior mandible presents with sufficient bone density but faces a very demanding loading situation. This contrasts with the posterior maxilla, in which the loading conditions are similar to the posterior mandible, but the bone is usually of lower density.

Shortening the interval between implant insertion and prosthetic loading may lead to improved patient comfort. Several systematic reviews on immediate and early loading protocols have been published.[8–12] All of these aimed to compare conventional and early/immediate loading by compiling the outcomes of selected clinical studies. Each systematic review, however, was based on the selection and inclusion of a number of articles with a great variety in baseline parameters, such as local oral condition, implant system used, prosthesis type, jaw location, or other factors that could affect loading mechanics and potentially result in misleading interpretation of outcomes. This suggests that it is clinically not useful to evaluate the performance of early or immediate loading per se. The evaluation has to be performed for different clinical indications to provide the practitioner with the appropriate evidence that is related to those indications.

The aim of this systematic review was to evaluate the predictability of early and immediate loading protocols for implants in the posterior mandible and to investigate whether there is a difference in success rates, survival rates, and peri-implant parameters, including marginal bone level changes, between the respective protocols. The loading definitions established by the 2003 ITI Consensus Conference were used for the purpose of this review.[13]

MATERIALS AND METHODS

Search Strategy and Procedures

A comprehensive review of the literature was conducted to select pertinent full-length articles published in English. The most recent electronic search was undertaken on May 1, 2008.

Searching was performed using the electronic databases MEDLINE (PubMed) and Specialist Register of the Cochrane OHG. Key words used in the search included: *dental implants, early loading, healing time, immediate loading, posterior mandible, marginal bone resorption, complications, success rate,* and *survival rate* (Fig 1).

To expand this, a hand search of the following journals was undertaken, covering the years 1991 to present: *Clinical Oral Implants Research, International Journal of Periodontics & Restorative Dentistry, Journal of Periodontology, Journal of Clinical Periodontology,* and *International Journal of Oral & Maxillofacial Implants*.

Bibliographies from selected articles, the proceedings of the second (1997) and third (2003) ITI Consensus Conference, the position papers of the American Academy of Periodontology, and the Proceedings of the Third European Workshop on Periodontology (1999) were also screened. Every attempt was made to obtain recent studies that had been accepted but not yet published, through personal contacts of the authors.

All levels of the hierarchy of evidence except for expert opinions were included. For case reports, only studies with 10 or more cases specifically in the posterior mandible were accepted. For prospective data, only studies reporting outcomes after 12 or more months were included.

The search was limited to human subject studies published in English that evaluated various healing times between surgery and loading. Outcome measures were survival rate, success rate, and marginal bone loss.

Data Collection and Analysis

Titles and abstracts obtained through the described search were screened by two independent reviewers (Marco Aglietta, Ferruccio Torsello). The screening was performed on a printout of the titles and abstracts, and included studies meeting the following criteria:

- Human trials
- Loading time
- Longitudinal studies
- Clinical outcomes

Studies including implants in extraction sockets, guided bone regeneration (GBR), or full-arch reconstructions were excluded. Moreover, articles that reported combined data from the posterior and anterior mandible, and/or from the maxilla and mandible, without the possibility to extract the results for the area of interest were not included.

Full-text copies of studies with possible relevance were evaluated by two reviewers (Mario Roccuzzo and Luca Cordaro). Any disagreement was discussed and resolved. Authors were contacted to provide missing information when possible. Two email attempts were made to contact each author.

The methodological quality of the studies was assessed to appraise:

- Method of randomization. This was classified as *adequate* when a random number table, a coin toss, or shuffled cards were used; as *inadequate* when other methods of randomization such as alternate assignment, hospital number, or odd/even birth date were applied; and as *unclear* when the method of randomization was not reported or explained.
- Allocation concealment. This was classified as *adequate* when examiners were kept unaware of the randomization sequence; as *inadequate* when other methods of allocation concealment were used, such as alternate assignment, hospital number, or odd/even birth date; and as *unclear* when the method of allocation concealment was not reported or explained.
- Completeness of follow-up was considered present if the number of patients was reported both at baseline and at completion of the follow-up, and if the analysis took into account the dropouts.

Significant data from the selected articles were recorded for the following two categories:

1. Early loading of implants placed in the posterior mandible (Table 1)
2. Immediate loading of implants placed in the posterior mandible (Table 2)

RESULTS

A total of 19 papers[14–32] were included in the present review: 8 on early loading, 9 addressing immediate loading, and 2 comparing immediate and early loading. Of the 19 studies, 5 were randomized controlled clinical trials (RCTs) and 14 were prospective studies.

A number of valuable articles had to be excluded because they did not meet the inclusion criteria. Some papers could not be considered because in some of the treated subjects the early or immediate loading protocols were associated with implant placement in fresh extraction sockets, and results could not be separated from implants placed in native bone,[33–37] or in other instances because simultaneous bone augmentation was performed.[38] In other studies it was not possible to determine the exact number of implants placed in the posterior mandible and their specific survival rate in this anatomical region.[39–41] A further study had to be excluded because different loading protocols were used for different sites, and it was not possible to separate out the number of early loaded implants in the posterior mandible.[42]

Table 1 Selected Articles on Early Loading in the Partially Edentulous Posterior Mandible

Study	Study type	Implant surface	No. of patients included	Sites	Smallest implant	No. of implants placed	No of implants loaded	Time of loading	Follow-up	Occlusal contacts	Type of prostheses	Splinted	Survival rate	Failures	Other results
Cochran et al (2002)[14]	Pros	SLA	80	Posterior mandible	ø 4.1 × 8 mm	198	198	6 wk; 12 wk if bone quality = 4	2 y	Yes	FDP	Yes	99% 1 y (n =166) 99% 2 y (n = 94)‡	1	Success rate: 99%
Nordin et al (2004)[15]	Pros	SLA	15	Posterior mandible	NR	41	41	9 d (range 4–22 d)	12 mo	NR	FDP	Yes	100%	0	NR
Salvi et al (2004)[16]	RCT	SLA	27	No third molars	ø 4.1 × 8 mm	31	29	2 wk	12 mo	Yes	SC	No	100%	0	BL 0.57 mm
Salvi et al (2004) [16]	RCT	SLA	27	No third molars	ø 4.1 × 8 mm	36	35	6 wk	12 mo	Yes	SC	No	100%	0	BL 0.72 mm
Vanden Bogaerde et al (2003)[17]*	Pros	TiUnite	> 10†	Posterior mandible	8.5 mm	42	42	4–16 d (mean 9 d)	18 mo	Light	FDP	Yes	100%	0	NR
Vanden Bogaerde et al (2004)[18]	Pros	Machined	> 10†	Posterior mandible	8.5 mm	56	55	< 20 d (average 11 d)	18 mo	Light	FDP	Yes	98%	1	NR
Bornstein et al (2005)[19]	Pros	SLA	45	No third molars	ø 4.1 × 4.8 mm	89	88	6 wk	5 y	NR	SC-FDP only	FDP	99%	1	Success rate: 99% bone resorption: 0.15 mm
Sullivan et al (2005)[20]	Pros	Osseotite	> 10†	Posterior mandible	NR	262	257	2 mo	5 y	NR	SC-FDP	FPD only	98.8% of loaded implants; 96.9% of inserted implants	5 early failures; 3 after loading	NR
Achilli et al (2007)[21]	Pros	TiUnite	15	No third molars	ø 3.5 × 10 mm	32	32	6 wk	12 mo	Light	FPD	Yes	100%	0	NR
Roccuzzo et al (2008)[22]	RCT	SLA	14	No third molars	ø 4.1 × 8 mm	33	32	6 wk	5 y	Yes	SC-FDP	No	100%§	0	NR
Ganeles et al (2008)[23]	RCT	SLActive	> 10†	No second and third molars	ø 4.1 × 8 mm	134	134	28–34 d	12 mo	No	SC-FDP	NR	96%‖	4 early failures; 1 after loading	NR

Pros = prospective; RCT = randomized controlled clinical trial; FDP = fixed dental prosthesis; SC = single crown; NR = not reported; BL = bone loss.
* Additional specific data provided by the authors on request.
† Data deduced from analysis of the text.
‡ One lost implant. Two spinners at the time of abutment connection: loading was postponed and implants successfully healed.
§ One spinner; successfully loaded with definitive crown after 6 additional weeks of healing.
‖ Data extrapolated from Zollner et al (2008)[44] on the same patient population.

Table 2 Selected Articles on Immediate Loading in the Partially Edentulous Posterior Mandible

Study	Study type	Implant surface	No. of patients included	Sites	Bone quality/ primary stability	Smallest implant	No. of implants placed	Restoration time limit	Follow-up	Occlusal contacts	Type of prostheses	Splinted	Survival rate	Other results
Buchs et al (2001)[24]	Pros	Altiva NTR	> 10†	No third molars	NR	NR	82	< 24 h	10–29 mo	Light	SC-FDP	NR	92.7%	—
Calandriello et al (2003)[25]	Pros	Machined	> 10†	Premolars and molars	Torque > 45 Ncm	ø 5 × 10 or ø 3.75 × 13 mm	21	< 24 h	12–24 mo	Light	SC-FDP	NR	100%	—
Calandriello et al (2003)[26]	Pros	TiUnite	> 10†	First or second molars	Torque > 35 Ncm	ø 5 × 10 mm	24α	< 24 h	12 mo	Light	SC	No	100%§	1.1 mm without GBR and 1.8 mm with GBR
Rocci et al (2003)[27]	RCT	TiUnite	22	Premolars and molars	Primary stability checked by hand	7 mm	66‡	< 24 h	12 mo	NR	FDP	Yes	95.5 %	Bone resorption: 0.9 (0.7) mm Success rate 95.5%
Rocci et al (2003)[27]	RCT	Machined	22	Premolars and molars	Primary stability checked by hand	7 mm	55‡	< 24 h	12 mo	NR	FDP	Yes	85.5 %	Bone resorption: 1 (0.9) mm Success rate 85.5%
Cornelini et al (2004)[28]	Pros	SLA	30	First molars	ISQ > 62	ø 4.1 × 12 or ø 4.8 × 10 mm	30	< 24 h	12 mo	Yes	SC	No	97%	Bone resorption: 0.22 mm Success rate 96.7%
Abboud et al (2005)[29]	Pros	Sandblasted Ankylos	11	Premolars and first molars	NR	9.5 mm	11	< 24 h	12 mo	Light	SC	No	100%	0.03
Cornelini et al (2006)[30]	Pros	SLA	20	Premolars and molars	ISQ > 62	ø 4.1 × 12 or 4.8 × 10 mm	40	< 24 h	12 mo	Yes	FDP	Yes	98%	Bone resorption: 0.1 mm mesial and 0.5 mm distal Success rate 97.5%
Romanos and Nentwig (2006)[31]	Pros	Sandblasted Ankylos	12	Premolars and molars	No tapping in soft bone	ø 3.5 × 11 or ø 4.5 × 9.5 mm	36	< 24 h	24 mo	Light	FDP	Yes	100%	22.2% minimal horizontal BL (< 2 mm); 19.4% minimal vertical BL (< 2 mm)
Achilli et al (2007)[21]*	Pros	TiUnite	25	No third molars	No type 4 bone torque > 30 Ncm	ø 3.5 × 10 mm	56	< 24 h	12 mo	Light	FDP	Yes	100%	NR
Schincaglia et al (2007)[32]	RCT	TiUnite	10	No third molars	ISQ > 60 and torque > 30 Ncm	8.5 mm	20	< 24 h	12 mo	Light	FDP	Yes	100%	1.06 mm
Schincaglia et al (2007)[32]	RCT	Machined	10	No third molars	ISQ > 60 and torque > 30 Ncm	10 mm	22	< 24 h	12 mo	Light	FDP	Yes	91%	0.92 mm
Ganeles et al (2009)[23]*	RCT	SLActive	> 10†	No second or third molars	Sufficient primary stability checked by hand	ø 4.1 × 8 mm	127	< 24 h	12 mo	No	SC-FDP	NR	98%‖	NR

Pros = prospective; RCT = randomized controlled clinical trial; FDP = fixed dental prosthesis; SC = single crown; NR = not reported; ISQ= Implant Stability Quotient (measured with resonance frequency analysis); BL = bone loss.
* Additional specific data provided by the authors upon request.
† Data deduced from analysis of the text.
‡ Flapless surgery.
§ Only implants with at least 12 months of follow-up were considered.
‖ Data extrapolated from Zollner et al (2008)[44] on the same patient population.

Early Loading

Ten papers fulfilled the inclusion criteria and were evaluated with regard to outcome of implants restored with an early loading protocol. Of these, three were RCTs and seven were prospective clinical trials. The three RCTs contained an adequate method of randomization and complete follow-up, but the allocation concealment was unclear.[16,22,23] Some of these studies did not solely include implants placed in the posterior mandible. But it was possible to extrapolate the requested data from each of these publications. If there was any remaining uncertainty, the respective authors were contacted by email and asked to provide the missing data.

In one of those publications, a multicenter prospective clinical trial by Cochran and coworkers, implants with a sandblasted and acid-etched (SLA) surface were inserted in different zones of the jaws and divided in groups.[14] A total of 198 implants were inserted in the posterior mandible and loaded with fixed dental prostheses (FDP) after 6 weeks when bone type 1, 2, or 3 was found at the time of surgery. In the case of type 4 bone, loading was postponed to 12 weeks postinsertion. Implants had completed the 12-month (n = 166) or 24-month (n = 61) follow-up. Only one implant was lost, resulting in a success rate of 99% at both intervals.

In another study, early loading of SLA implants was studied by Nordin and coworkers in a prospective three-arm trial.[15] Posterior partially edentulous mandibles and maxillae were included in one group. A total of 41 implants were placed in mandibular posterior sites and restored with fixed dental prostheses (FDPs), with a mean loading interval of 9 days (range 4 to 22 days). In this paper a 100% survival rate was seen after 1 year.

In one RCT that fulfilled the inclusion criteria for this review, Salvi and collaborators compared SLA implants inserted in the posterior mandible and restored with single crowns in occlusal contact after 2 or 6 weeks. A total of 67 implants were inserted in the two groups, with a 100% survival rate after 1 year of loading. No statistically significant difference could be found between the two groups.[16]

In two separate papers, Vanden Bogaerde and coworkers reported the 18-month outcome of early loaded, splinted implants either with a machined or oxidized titanium surface in the maxilla and posterior mandible.[17,18] In the group with an oxidized titanium surface, 42 implants were inserted, then loaded an average of 9 days after surgery. The authors reported a 100% implant survival rate after 18 months. For implants with a machined surface, 31 consecutive patients with 56 implants in the posterior mandible were included in the study. One implant failed before loading, which was performed earlier than 20 days after insertion (average 11 days). The overall survival rate for this group (including the early failure) was 99%.

Five-year results after early loading in the posterior mandible were reported in two different studies involving two different types of implants.[19,20] In a prospective study performed by Bornstein and coworkers in 51 patients,[19] 104 SLA implants were inserted, 89 of which were in the posterior mandible. Implants were loaded after 6 weeks with either single crowns or FDPs. One early failure occurred, and a 99% survival rate resulted after 5 years. The mean marginal bone resorption was 0.15 mm. In a second prospective multicenter study, Sullivan et al evaluated 262 implants with a microtextured acid-etched surface that were inserted in the posterior mandible with a transmucosal technique and loaded 2 months after insertion.[20] Five early failures were reported, and three further failures occurred after loading, resulting in a 97% implant survival rate. In both studies implants were restored either with single crowns or FDPs.

In a prospective study comparing early and immediate loading, Achilli et al evaluated 32 oxidized titanium tapered implants that were inserted in mandibular molar and premolar sites and loaded after 6 weeks with FDPs. A 100% success rate was reported after 1 year.[21]

Implants with a titanium plasma-sprayed surface that were loaded at 12 weeks were compared to SLA implants loaded at 6 weeks by Roccuzzo and coworkers in an RCT with a 5-year follow-up.[22] This split-mouth study compared similar edentulous areas, and implants were loaded with either single crowns or FDPs. After 5 years of observation, a 100% survival rate was seen with both protocols.

In a recently published RCT, Ganeles and coauthors compared early and immediate loading of implants placed in posterior sites of both jaws. A total of 134 implants with a chemically modified SLA surface were placed in the posterior mandible and loaded after an interval of 28 to 34 days with either single crowns or FDPs. Four early failures and one failure after loading were reported, leading to a 96% implant survival rate.[23]

Immediate Loading

According to the inclusion criteria, 11 papers on immediate loading could be included in this review: 8 were prospective clinical studies and 3 were RCTs. Of the 3 RCTs, 2 compared machined versus oxidized titanium surfaces[27,32] and one compared early versus immediate loading.[23] From the latter study,[23] only data concerning immediate loading in the posterior mandible were included in the present section, while data concerning early loading were addressed in the previous part regarding early loading in the posterior mandible. Data on posterior maxilla were discussed in the review paper on implant loading in the partially edentulous posterior maxilla.

In one RCT, both the methods of randomization and allocation concealment were not clearly described, but complete follow-up of patients and implants was included.[28] Two of the RCTs described an adequate method of randomization and complete follow-up, but the allocation concealment was unclear.[24,33]

In a case series study, Buchs and coworkers reported a 92.7% success rate 1 year after immediate loading of titanium oxide–blasted implants in the posterior mandible either with single crowns or FDPs.[24]

Calandriello and coworkers performed two studies on immediate loading.[25,26] One of these focused on immediate loading with single crowns and FDPs. Fifty machined, immediately restored implants with occlusal contacts in centric relation were studied in the maxilla and mandible. For the purposes of this review, only the 21 implants placed in partially edentulous posterior mandibles were considered. After a 12- to 24-month follow-up, the implant survival rate was 100%. It was not possible to determine the mean bone resorption for the mandibular implants, but the authors stated that a mean bone loss of 1.2 mm was found for all implants in the study and that no statistically significant differences were found between maxillary and mandibular implants.[25]

In a second study on immediate loading of wide-platform implants with an oxidized titanium surface, 50 implants were placed and immediately loaded in first and second molar areas. All restorations were single crowns with occlusal contacts in centric relation, but with no contacts during mandibular excursions. In 7 cases a simultaneous GBR procedure was performed. The 6-month results demonstrated a 100% survival rate and a crestal bone resorption of 0.9 mm for implants without GBR (43 implants), and 1.1 mm of crestal bone loss for the 7 implants with GBR. Only 24 implants could be examined at the 24-month follow-up. They demonstrated a 100% survival rate, 1.3 mm of bone resorption in sites without GBR, and 1.8 mm of bone resorption for the implants that received GBR.[26]

Another RCT was designed by Rocci and coworkers to compare immediate loading of oxidized titanium versus machined implants in the posterior mandible.[27] In the test group, 22 patients received 66 implants with an oxidized surface supporting 24 restorations, while 22 control group patients received 55 machined-surface implants supporting 22 restorations. Neither cantilever nor pontic units were allowed. After 12 months, there was a significant difference in survival rates: 85.5% (8 failures) in the machined-surface implant group versus 95.5% (3 failures) in the oxidized-surface implant test group. The results of this study suggested that immediate loading with rough-surfaced implants seemed to be safer than the same procedure with machined implants. A more detailed analysis showed that the main differences were found when implants were placed in soft bone (type 4). In such cases, the success rate for machined implants was 56% versus 92% for rough-surfaced implants. Thus it may be speculated that the use of a modified surface becomes more important in jaw locations with "soft" bone.

Cornellini et al published two studies on immediate loading in posterior sites.[28,30] In both papers an implant stability quotient (ISQ) value of 62 or more was required as an inclusion criterion for immediate loading. In the first study the authors analyzed the performance of 30 SLA implants placed in first molar areas and immediately restored in occlusion with the opposing dentition. At the 12-month reevaluation, only 1 implant was lost, giving a survival rate of 97%. A mean bone loss of 0.2 mm was recorded.[28]

In the second paper, the authors evaluated 40 SLA implants that were immediately functionally loaded with 20 three-unit FDPs in mandibular premolar and molar areas. Only one implant was lost, resulting in a survival rate of 97.5%. A mean crestal bone resorption of 0.1 mm mesially and 0.5 mm distally was measured.[30] Thus, the authors concluded that immediate loading of SLA implants supporting single crowns or fixed partial dentures showed encouraging results, provided that good primary stability could be achieved during surgery.[30]

Abboud and coworkers investigated 20 immediately loaded sandblasted implants for single-tooth replacement in premolar or first molar areas.[29] Of these, 11 were mandibular implants that showed a 100% survival rate at the 12-month follow-up and a mean crestal bone loss of 0.03 mm.

In another study, Romanos and Nentwig evaluated the same implant design and sandblasted surface immediately loaded with FDPs in mandibular molar and premolar areas.[31] In 12 patients a total of 36 implants were placed to support 12 three-unit restorations. This study was designed as a split-mouth RCT, so that 36 implants were placed on the contralateral side of the mandible with similar local conditions. These implants were restored after 12 weeks (conventional loading). A survival rate of 100% was found in both groups. Concerning bone resorption after 24 months, 19% of test implants showed minimal vertical bone loss (< 2 mm), compared to 25% of controls. Moreover, in one control implant, bone loss > 2 mm was present. Since no statistical comparison of bone loss distribution was performed, it cannot be stated that the better outcome found in the immediately loaded group is statistically significant. However, the authors concluded that the 2-year prognosis of immediately restored implants in partially edentulous mandibular areas was similar to the prognosis with conventional loading.[31]

Achilli and coworkers conducted a study on early and immediate loading of oxidized titanium implants in the maxilla and mandible. A total of 56 implants placed in the mandible with an immediate-loading protocol could be included in the present review. The immediately loaded implants supporting FDPs in contact with the opposing dentition showed a survival rate of 100% after 12 months.[21]

A recent split-mouth RCT compared immediate loading of oxidized titanium versus machined implants in posterior mandibular sites.[32] Ten patients were included in the study and bilaterally treated, with 20 implants in the test group and 22 in the control group. All implants had to exhibit good primary stability (insertion torque > 20 Ncm and ISQ > 60) at the time of surgery and were loaded within 24 hours with light occlusal contacts in centric occlusion. The results showed no implant loss among the oxidized titanium implants (100% survival rate) and two implant losses for the machined group (91% survival rate). The mean bone loss recorded was 1.06 mm in the test group and 0.92 mm in the control group. The authors' conclusion was that when implant primary stability was achieved, immediate loading seems to be a safe procedure, especially with rough surfaces.

A recent RCT compared early and immediate loading of SLA implants with chemically modified–surface implants.[24] There were 134 implants randomized to the early loading group in the posterior mandible and 127 implants immediately loaded in the same region. All implants supported single crowns or fixed partial dentures. After a 12-month follow-up, a 98% survival rate was recorded for immediately loaded implants. Fifteen implants were placed in type 4 bone (8 in the early loading group and 7 in the immediate loading group), but none of these failed. This study, providing a large sample compared with previous papers, confirms the positive outcome of immediately loaded implants in the posterior mandible.

DISCUSSION

Early Loading

In this review, "early loading" included various loading intervals and surgical protocols. More aggressive protocols consisted of loading at a time earlier than 3 weeks after implant placement with either FDPs or single crowns.[15–18] It should be noted that only 170 implants could be followed for at least 1 year after loading with this protocol. However, the results seem encouraging, since no failures after loading were registered and only one early failure of a machined-surface implant was found.

The results of loading between 3 and 6 weeks after surgery were studied in a greater number of implants (n = 522). Six early failures and one failure after loading were reported. Implants in the posterior mandible loaded at the 2-month interval were studied in one prospective study including a large number of implants (n = 262), and the 3- and 5-year results were reported in two different publications. Five early failures and three failures after loading were reported, demonstrating a survival rate of 98.8% for loaded implants and 96.9% for inserted implants.

Five-year results were also reported for a 6-week healing interval in one multicenter study and one prospective study. A total of 122 implants loaded with either single crowns or FDPs demonstrated a survival rate of 99% to 100%.[19,20]

More recently, a multicenter RCT including implants with a chemically modified surface[23] demonstrated that loading between 4 and 5 weeks after implant placement leads to an acceptable survival rate regardless of the available type of bone.

In the earlier studies, great emphasis was placed on the necessity of having excellent primary stability in order to apply early loading.[14] In these studies great care was taken to include only implants placed in type 1, 2, or 3 bone, or sites that demonstrated high values of insertion torque. More recently, authors have applied the early loading protocol to all implants regardless of type of bone, and similar results were achieved (see Table 1).

A recent review discussed conventional, early, and immediate loading in partially edentulous patients.[43] It was clearly stated that the evolution of implant surfaces (from machined to microrough to chemically active) has allowed the healing periods to be reduced. The author differentiated between single-tooth-gap and multiple-tooth-gap situations in anterior and posterior areas of both jaws. It was suggested that single-tooth situations are more demanding when compared with cross-arch stabilization of implants because the unsplinted implant may be less protected against deleterious micromovements generated by functional forces. Thus, the necessity to achieve good primary stability has been stressed. In the same paper it was argued that single implants can share the loading forces with the rest of the adjacent teeth, while this is less likely to happen in multiple-tooth gaps in the posterior areas. In such cases the masticatory forces may be concentrated on the implant-supported restorations, thus creating an even more demanding situation.

Two of the papers selected for the present review involved single-tooth gaps, five involved multiple-tooth gaps, and three did not differentiate between the two situations. No differences could be identified on the basis of this parameter. The studies included in this review, with approximately 1,000 implants followed for periods varying from 1 to 5 years, demonstrated a minimal survival rate of 96% for inserted implants (including early failures) and 99% for loaded implants. Therefore, on the basis of the evidence available to date, early loading of implants with rough surfaces in posterior mandibular sites may be considered a routine procedure, regardless of the type of restoration used (single crown or FDP).

It must also be noted that whereas earlier studies mostly compared early loading and conventional loading, more recently early-loading protocols have been compared with immediate loading, which is considered the most demanding procedure from a biomechanical point of view. This suggests that, at least in the hands of experienced clinicians, early loading may be considered the "benchmark" to which more aggressive loading protocols are to be compared. Another consideration is that in the context of early or immediate loading, the submerged surgical placement of implants is rarely indicated.

Immediate Loading

The articles selected for the present review provided data on a total of 580 implants that were placed and immediately loaded in partially edentulous areas of the posterior mandible. Almost all authors consider immediate loading to be a more demanding procedure than early or conventional loading. It presents additional risks, and added precautions are usually taken to obtain survival rates comparable to those of the more conservative loading protocols. Some studies documented that the implant surface is critical to maximize the survival rate, especially in soft bone.[28,31]

The necessity of obtaining satisfactory primary stability has also been stressed by several authors. Many studies used the attainment of satisfactory primary stability as an inclusion criteria, either verified by hand or by measuring the ISQ, or by recording the insertion torque.[20,23,25–29,31] Since almost all studies considered only implants with good primary stability, the resulting equivalence of survival rates of immediately and conventionally loaded implants cannot be extended to all the cases. Thus, even if the results are quite promising, it is recommended to limit the immediate-loading procedure to selected cases that demonstrate satisfactory implant stability at the moment of placement. When this is not the case, the immediate-loading procedure should be aborted and implants should be left unloaded during healing.

The reviewed studies reported information on single-tooth replacement and on FDPs placed in the partially edentulous posterior mandible. Six papers considered only implant-supported FDPs, three studied only single crown indications (with only 65 implants included), and two included both single crowns and FDPs (see Table 2). The results did not show significant differences between prosthetic designs. Almost all papers described the type of occlusion provided to the immediately delivered restoration. Some authors preferred to leave the implants without functional load, while others chose to design restorations with light contacts in maximum intercuspation (see Table 2). Almost all authors emphasized the necessity of avoiding any occlusal contact during excursive movements.

Finally, some consideration should be given to the follow-up periods in the selected studies. Since immediate loading in posterior areas has only rarely been documented in the past, its use has been limited to rehabilitation of edentulous patients with several implants splinted together via a full-arch prosthesis, or to restorations of small edentulous gaps in the esthetic area with limited functional needs. Studies on immediate loading for partial edentulism in the posterior arches have been conducted only in recent years. Thus, only papers with short follow-up periods are available. Among the 10 studies that were selected for this review, 8 articles reported on 12-month follow-ups, and only 2 had observational periods of up to 24 months. It is evident that further studies with longer follow-up are required.

Moreover, there is some concern regarding the immediate loading of implants in the posterior jaws. In particular, the pretreatment analysis should evaluate whether the patient will indeed benefit from this faster procedure. While it is clear that immediate loading in the esthetic area can substantially add to patients' comfort and satisfaction, it is not clear in posterior zones with limited esthetic involvement if this is of equal benefit to the patient.[43]

A recent systematic review concluded that a high degree of primary stability at implant insertion is a key prerequisite for a successful immediate or early loading procedure.[12] A recent RCT[23] suggested that the use of modern implant surfaces may permit the achievement of high survival rates even when bone of poor quality is present. This assumption has to be confirmed by other studies.

In the present review only the results related to the partially edentulous posterior mandible have been analyzed. Thus, the information presented in this review paper may be used when planning a rehabilitation in similar clinical situations.

The use of different methods to assess bone density has not yet been related to the treatment outcome, even in situations that the clinician would consider highly demanding from a clinical point of view.

Since many of the reviewed studies applied restrictive inclusion criteria, the results reported with this technique involve multiple confounding factors, including bone quality and quantity, primary stability, and implant dimension. There is no consistency in the literature regarding the threshold values related to these confounding factors.

CONCLUSIONS

The existing literature supports loading of microroughened dental implants in the partial edentulous posterior mandible at 6 to 8 weeks in the absence of modifying factors such as fresh extraction sockets, GBR, and short implants. Therefore, loading within this time frame should be considered routine for the majority of clinical situations in the posterior mandible, either with single crowns or FDPs. Immediate loading of microroughened dental implants in the partially edentulous posterior mandible is a viable treatment alternative.

Caution is recommended in interpreting published outcomes for the immediate-loading group, as the inclusion and exclusion criteria are inconsistent and many subjective confounding factors are evident. Additional studies and longer follow-ups are needed to consolidate the data for immediate loading.

Well-designed RCTs are needed, and priority should be given to trials testing immediate loading.

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