

A Systematic Review on Immediate Loading of Implants Used to Support Overdentures Opposed by Conventional Prostheses: Factors That Might Influence Clinical Outcomes

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Purpose: Different treatment protocols in terms of number, diameter, and suprastructure design have been proposed for immediately loaded implants that are used to support mandibular overdentures opposed by maxillary conventional dentures. The aim of this study was to investigate the influence of these protocols on survival rates as well as clinical and prosthodontic outcomes. **Materials and Methods:** Several electronic databases were searched for all relevant articles published from 1966 to June 2014. Only randomized controlled trials and prospective studies with a minimum follow-up of 12 months were selected. The primary outcomes of interest were the success and survival rates of the implants. Prosthodontic complications were also evaluated. **Results:** Fourteen studies fulfilled the inclusion criteria. Of the studies identified, nine were randomized controlled trials and five were prospective studies. The mean follow-up period was 3 years or less for the vast majority of the studies. The reported survival and success rates were comparable to that of conventional loading for most of the included studies. No specific immediate loading protocol seemed to perform better in terms of clinical and prosthodontic outcomes. **Conclusion:** Immediate loading protocols of mandibular overdentures seem to be a viable alternative to conventional loading. It was not possible to recommend a specific treatment protocol related to the number, diameter of the implants, and attachment system used. Long-term, well-designed studies comparing different immediate loading modalities could help to establish a protocol that delivers the most clinically predictable, efficient, and cost-effective outcome for edentulous patients in need of implant overdentures. *INT J ORAL MAXILLOFAC IMPLANTS* 2016;31:63–72. doi: 10.11607/jomi.4028

Keywords: dental implants, implant supported/retained overdentures, immediate loading, mandible, systematic review

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Since their introduction, mandibular overdentures have been a reliable treatment modality for the management of completely edentulous patients.^{1,2} In the early days of oral implantology, up until around 1990, a 3-to-6-month healing period was a prerequisite for optimal osseointegration.³ The objective was to prevent micromovement and to keep the implants load-free during the healing period.⁴

However, in order to reduce the number of surgical interventions, shorten the overall treatment period, and improve patient satisfaction, early and immediate loading protocols were suggested. This became particularly relevant with the introduction of surface-modified implants. A micromotion threshold within the range of 50 to 150 µm has been recommended.⁵

Although the concept of immediate loading of dental implants with overdentures was introduced as early as 1979,⁶ it was not until the 1990s that the

first publication with a relevant sample size and well-defined evaluation criteria appeared in the literature.⁷ With immediate loading protocols, the number, diameter of the implants, and attachment system selected are important factors for the ultimate treatment outcome. Initially, the use of four splinted implants was considered mandatory to obtain long-term favorable results.⁸ The assumption was that rigid splinting of the inserted implants would counteract the bending effects of lateral forces on the implant attachments and thus optimize the treatment outcome.⁹ In an attempt to reduce the costs and complexity of treatment, a reduction in the number of implants was investigated with promising results.^{10–12} Even immediate loading of one single implant has been suggested.¹³

In anatomically compromised cases, to avoid the otherwise necessary augmentation procedures, implants with a reduced diameter (narrow- or mini-diameter dental implants) might be an alternative treatment modality.

Although initially mini dental implants (MDIs) were used for temporary prosthetic stabilization during the healing phase of standard implants,^{14,15} their success has expanded their use.¹⁶ The treatment protocol in edentulous patients often involves the use of four, unsplinted, one-piece MDIs to support mandibular overdentures. There is, however, limited scientific evidence about the long-term survival of MDIs, as well as a lack of scientific guidelines for their application. If further research proves MDIs to be a possible alternative for standard-diameter implants, the scope of implant overdenture indications can be increased. Medically compromised patients who would otherwise be excluded as a result of health problems that preclude extensive surgical procedures can then benefit from implant treatment.

Therefore, the aim of this systematic review was to assess whether there is a combination of number, diameter of implants, and attachment system selected that results in an optimal clinical outcome of immediately loaded implants used to support/retain mandibular overdentures opposed by a maxillary complete denture.

Materials and Methods

The focused PICO question was formulated as follows: In edentulous patients wearing a maxillary conventional prosthesis (P), what is the optimal implant number, diameter, and attachment system used to rehabilitate the mandibular arch with an overdenture retained by immediately loaded implants (I) that will increase the success/survival rate and lower the incidence of biologic as well as technical complications (O) in comparison to conventionally loaded implant overdentures (C)?

Specific inclusion and exclusion criteria were used during the literature search. Inclusion criteria consisted of randomized controlled trials (RCTs), comparative studies, and prospective studies with at least 12 months follow-up on completely edentulous patients rehabilitated with immediately loaded mandibular implant overdentures opposed by conventional maxillary dentures, studies reporting on success and/or survival rates of immediately loaded mandibular implants, and studies in the English language only. Exclusion criteria consisted of any studies where the implants were loaded later than 1 week after insertion or if the loading time was not clearly defined, studies with a sample size smaller than 10 patients ($n < 10$), studies where participants required additional surgical procedures (eg, grafting), and studies reporting on the success and/or survival rates of combined fixed and removable prostheses. In addition, studies reporting on mandibular implants that were not meant for permanent use were also excluded, ie, articles that described the use of implants solely for the purpose of interim/provisional/transitional and temporary prosthodontic treatment. Of the included studies, marginal bone level (MBL) changes were evaluated only when the measurements were made with intraoral radiographs.

For the purpose of this study, the following definitions were adopted. Immediate loading was defined as a situation where the suprastructure was connected to the implants and was in occlusion with the opposing dentition within 1 week.¹⁷ Narrow-diameter implants were defined as implants fabricated from the same biocompatible materials as other dental implants with a diameter smaller than 3.3 mm. MDIs have the same definition as narrow-diameter implants but are manufactured as one piece to include an abutment designed for support and/or retention of a provisional or definitive prosthesis.¹⁸ In the literature, there is no consensus on which diameter constitutes a standard-diameter implant and which constitutes a narrow- or mini-diameter implant, at least when it refers to rehabilitation of the edentulous mandible with implant overdentures.¹⁹ Therefore, for the purpose of this study and based on the methodology of some of the included papers,^{20,21} 3.3 mm or higher was considered a standard-diameter implant, and less than 3.3 mm was defined as a narrow or mini implant.

Search Strategy

MEDLINE (1969 to June 2014), EMBASE (1998 to June 2014), The Cochrane Central Register of Controlled Trials, and The Cochrane Database of Systematic Reviews were searched using the following key words: “mandible ± implant ± overdenture(s),” “oral ± dental ± implant(s),” “loading protocol(s),” and “early ± immediate ± loading,” with the restriction of

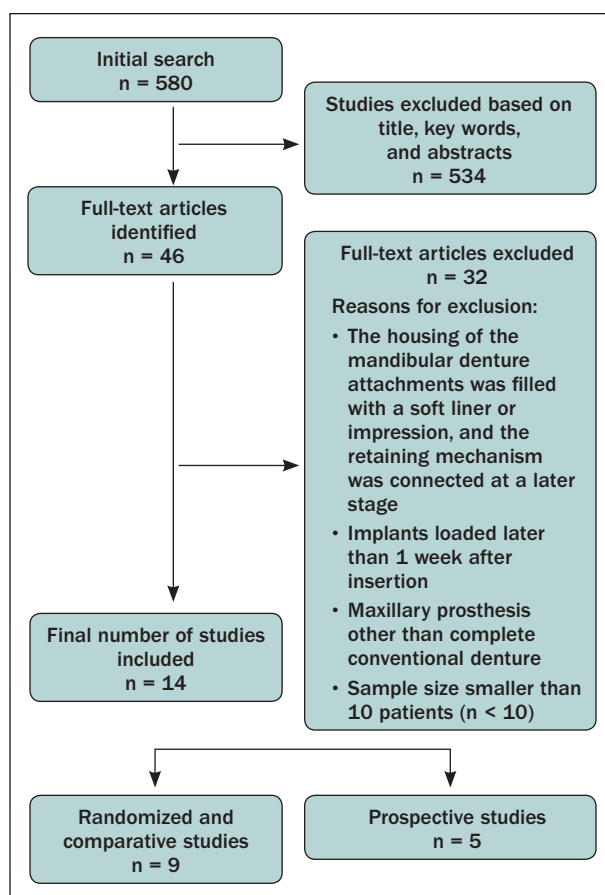


Fig 1 Flowchart of articles selected through the screening process.

articles in English only. Other articles were identified from the reference lists of articles found using the aforementioned databases, supplemented by manual hand-searching for the years 2000 to 2014 of peer-reviewed publications related to the topic. Two of the authors (K.Z. and D.W.) then independently scanned the titles and abstracts of all articles identified to establish whether they met the inclusion criteria. For studies appearing to meet the inclusion criteria or for which there were insufficient data in the title and abstract to make a clear decision, the full text was obtained. If the treatment protocol was not clear, more information was gained by contacting the corresponding author. Unanimous agreement between the reviewers regarding the included studies was achieved.

RESULTS

On initial screening, 580 articles were identified, of which 534 studies were excluded based on title and key words (Fig 1). Of the remaining 46 articles, 14 studies fulfilled the inclusion criteria, while 32 were excluded.

Only the most recent publication for a given study population was analyzed. The included articles consisted of nine RCTs/comparative studies^{20,22–29} and five prospective studies (Tables 1 and 2).^{21,30–33} The follow-up period for most of the studies was 1 to 3 years except for one study that presented long-term 7-year follow-up data.²⁹ With the exception of one study,²⁶ the majority of the studies reported a survival rate of more than 95% for immediately loaded implants used to retain mandibular overdentures opposed by conventional maxillary dentures. Furthermore, MBL changes around the immediately loaded implants were similar to the published data for the conventionally loaded implants. The average bone loss for most of the included studies was less than 1.5 mm, which lies within acceptable criteria for successful osseointegration.³⁴ In only one study, when two unsplinted implants were immediately loaded, a higher rate of bone resorption was observed compared to the conventional loading. However, the mean MBL observed was within the normal range for both groups.²³

A total of 962 implants were immediately loaded. In three studies,^{25,30,32} MDIs were utilized, whereas in the remaining studies standard-diameter implants were used (range, 3.3 to 5.5 mm). The length of the implants used ranged from 8.5 to 15 mm.

The type of suprastructure varied among the studies. In some studies, bar attachments were utilized,^{20–22,27} while in others solitary ball attachments were employed.^{23,24,26,28,29,31} The number of implants used to support the suprastructure also varied from four^{20,22,30,32,33} to only one.²⁶ The prosthodontic outcomes were reported in a limited number of studies.^{20,22–29} The criteria of prosthesis success were not predefined in these studies. A meta-analysis was not possible due to the heterogeneity of the included studies, and therefore, only overall conclusions were drawn.

Number of Implants

In most of the studies, two standard-sized implants were used to support mandibular implant overdentures.^{21,23–25,28,29,31} Three studies published data on the use of four standard-sized implants,^{20,22,33} whereas another two studies used four MDIs.^{30,32} With the exception of one study,²⁶ the number of immediately loaded implants did not influence the survival/success rate or the clinical outcome of immediately loaded implants. Stephan et al reported a 100% survival rate for three immediately loaded splinted implants supporting a mandibular overdenture.²⁷ Stoker and Wismeijer presented a high survival rate of 98.8% for two immediately loaded and interconnected implants, where only three out of 248 implants placed were lost over a follow-up period of 12 to 40 months. However, no

Table 1 Overview of Included Prospective Studies

Study	Abutment/No. of implants	Total no. of patients	No. of implants per patient	Intervention	Range of diameter/Range of length (mm)	Insertion torque
Wittwer et al ³³	Syncone/ 4 implants	22	4	Individual implants supporting an MOD	3.5–5.5/11–17	Periotest range from –7 to –1
Elsyad et al ³⁰	MDIs	28	4	mini implant supporting a ball attachment retained MOD	1.8/12–18	Not mentioned
Scepanovic et al ³²	MDIs	30	4	mini implant supporting a ball attachment retained MOD	1.8/13	At least 35 Ncm
Stoker and Wismeijer ²¹	Bar/ 2 implants	124	2	bar attachment retained MOD	3.3, 4.1/10–14	At least 35 Ncm ISQ values
Marzola et al ³¹	Ball/ 2 implants	17	2	ball attachment retained MOD	3.75–4.0/8.5–15	At least 20 Ncm (vast majority of implants had an insertion torque of 40 Ncm or more)

MOD = mandibular overdenture.

Table 2 Overview of Included RCTs and Comparative Studies

Study	Total no. of patients	No. of implants per patient	Interventions	Range of diameter/Range of length	Type of attachment system used	Insertion torque
Kronstrom et al ²⁶	36	Test group: 1 Control group: 2	Test group: 1 Implant immediate loading (within 24 h) Control group: 2 implants immediate loading (within 24 h)	3.75/At least 10 mm (majority of implants were 15 mm)	O-ring ball attachments	Minimum 30 Ncm
Assad et al ²²	10	4	Test group: immediate loading (within 4 days after surgery) Control group: delayed loading	3.7/13	Bar-retained overdentures	Not mentioned
Elsyad et al ²³	36	2	Test group: immediate loading (same day) Control group: conventional loading	3.7, 4.7, 5.7/10–16	Unsplinted ball attachments	Not mentioned
Gadallah et al ²⁴	12	2	Group 1: Immediate loading (within 1 week) Group 2: Early loading (6 weeks)	3.7/14	Unsplinted ball attachments	Not mentioned
Jofre et al ²⁵	45	2	Group 1: Immediate loading (bar overdenture) Group 2: Immediate loading (ball attachments)	1.8/15	Group 1: bar overdenture Group 2: individual ball attachments (O-rings)	Not mentioned
Romeo et al ²⁰	20	4	Test group: immediate loading (2 days after surgery) Control group: delayed loading	3.3–4.1/At least 10 mm	Bar-retained overdenture	Not mentioned
Tözüm et al ²⁸	17	2	Test group: immediate loading (5 days) Control group: delayed loading	3.75/15	Unsplinted ball attachments	Not mentioned
Turkylmaz et al ²⁹	26	2	Test group: immediate loading (within 1 week) Control group: delayed loading	3.75/15	Unsplinted ball attachments	Not mentioned
Stephan et al ²⁷	26	3	Test group (n = 17): immediate loading (within 2 days) Control group: (n = 9) delayed loading	3.75/10, 13	Bar-retained overdenture	At least 30 Ncm

Mean follow-up	Survival rate (%)	Success rate (%)	MBL (mean \pm SD)	Report of prosthetic maintenance
2 y	97.7	–	–	No
3 y	96.4	92.9	MBL after 36 months: 1.26 \pm 0.64 (vertical MBL) HBLO: -0.74 \pm 0.57 (horizontal MBL)	No
1 y	–	98.3	–	Yes
12–40 mo (mean 2 y)	98.8	–	–	Yes
1 y	100	–	0.7 \pm 0.5	Yes

Average follow-up	Survival rate (%)	MBL (mean \pm SD)	Report of prosthetic maintenance
3 y	81.8 (at 12 mo follow-up)	0.86 mm (0.6–4.2) after 3 y of function	Yes
2 y	100	The decrease in the mesial and distal alveolar bone height measurements around implants did not exceed a mean of 0.854	No
3 y	100 for both groups	Test group: 0.98 \pm 0.64 Control group: 0.62 \pm 0.44	No
1 y	100 for both groups	Group 1: 0.24 mm (mesial) 0.29 mm (distal)	No
2 y	Group 1: 97.8 Group 2: 90.8	Group 1: 0.92 \pm 0.75 Group 2: 1.43 \pm 1.26	No
2 y	–	–	No
2 y	100 for both groups	MBL : Group 1 = 0.146 Group 2 = 0.226	No
7 y	100 for both groups	Test group: 1.29 \pm 0.2 mm Control group: 1.33 \pm 0.2 mm	Only at 2-year follow-up
6 to 40 mo (mean period: 19 mo)	100 for both groups	Not mentioned	No

information was provided with regards to peri-implant soft and hard tissue parameters.²¹ In the same context, a comparable clinical outcome was found when only one immediately loaded implant was used to retain a mandibular overdenture compared with two individual implants in an RCT, although the survival rate of both groups was quite low, around 80%.²⁶

Diameter of Implants

The diameter of the standard-sized implants in the included studies ranged from 3.3 to 5.5 mm. The survival rate for the vast majority of the studies ranged from 97.7% to 100%. The only exception was the aforementioned study by Kronstrom et al, where the comparison between one and two standard-diameter immediately loaded implants demonstrated a low survival rate.²⁶

When MDIs were immediately loaded, the survival rates varied from 90.8% to 98.3%. A prospective study by Elsyad et al³⁰ showed a favorable soft and hard tissue response of immediately loaded MDIs supporting mandibular overdentures after 3 years. The cumulative survival and success rates of MDIs were 96.4% and 92.9%, respectively. Sceanovic et al³² also reported a high 1-year implant survival rate of 98.3% for immediately loaded MDIs.

Type of Attachment System

The attachment system may be another confounding factor that influences the surgical, clinical, and prosthodontic outcomes of immediately loaded implants. For implants with standard diameters, the most common study design involved the use of four or two unsplinted implants.^{23–26,28,29,31,33} Controversial results have been reported for this design. Some authors have reported a survival rate of 100%^{23,24,28,29,31} and no statistically significant differences in the MBL between immediate and conventional loading protocols.^{24,28,29} In a prospective study, Wittwer et al reported a cumulative 2-year survival rate of 97.7% for four immediately loaded non-splinted implants used for mandibular overdenture support.³³ In another prospective study, Marzola et al evaluated the performance of two nonsplinted immediately loaded implants used to support an implant overdenture. Standardized periapical radiographs were used to monitor peri-implant bone loss over a 1-year follow-up period. The average bone loss was 0.7 \pm 0.5 mm after 1 year of function, and no implants were lost. Minimal prosthetic interventions were necessary during this period.³¹ Turkyilmaz et al presented 7-year, long-term data on the outcome of immediately loaded implants and showed that the average annual bone loss did not exceed 0.2 mm after the first year of function and annually thereafter.³⁵ On the contrary, some authors recommended caution with this design due to the increased marginal bone resorption and probing

depth with individual immediately loaded implants.²⁶ In accordance, Elsyad et al demonstrated more marginal bone resorption (0.98 mm) and increased probing depths around two individual, immediately loaded implants, compared to conventionally loaded implants (0.62 mm).²³

On the other hand, a splinted bar design with varying number of implants (two to four implants) was shown to have a survival rate similar to that of delayed loading.^{20–22,27}

In the only study where marginal bone levels were reported with immediately loaded splinted implants, Assad et al revealed peri-implant marginal bone loss of 0.85 mm during the 2-year follow-up period.²²

Primary Stability

Although a high value of initial insertion torque (greater than 30 Ncm) seems to be one of the prerequisites for a successful immediate loading protocol,³⁶ only a few studies reported on the initial insertion torque of the immediately loaded implants.^{21,26,27,31,32} Most of these studies had a prerequisite of 30 Ncm^{21,27,32} as the minimum insertion torque. Resonance frequency analysis (RFA), expressed in implant stability quotient (ISQ) values,^{21,26–29,31,32} and periotest values were used to monitor the implant stability over time.^{20,23,30,33} In most of the included studies, there was no statistically significant difference in ISQ values between the immediate and the delayed loading protocol.^{27–29}

Prosthodontic Maintenance

Prosthodontic maintenance requirements were reported in a limited number of the included studies.^{21,26,31,32} In cases of solitary ball attachments, the most common reported complication was the need for the replacement of resilient O-rings, fractured O-rings, and the need for relining of the prosthesis.^{26,31}

For bar constructions, Stoker and Wismeijer observed no major technical complications, only minor interventions, namely, the need for overdenture relines.²¹ In the same context, immediately loaded MDIs were associated with several incidents of prosthodontic complications, mainly involving overdenture fracture, need of overdenture relines, and minor occlusal adjustments.³²

DISCUSSION

Critique of Methodology

This review was an attempt to answer the question of whether there is an optimal number, diameter, and suprastructure design that might be more favorable in treating patients with mandibular overdentures supported by immediately loaded implants. During the screening process, the authors identified and included

only randomized controlled trials, comparative studies, and prospective studies. Retrospective studies might be subjected to inclusion bias, underestimating implant failures or other adverse events and thus were excluded from this systematic review.³⁷ In this review, the status of the opposing jaw in all of the included studies was restricted to a conventional maxillary prosthesis. To the authors' knowledge, this is the first literature review on immediately loaded implants used to support mandibular overdentures that considers the status of the maxillary arch.

Studies that used panoramic radiographs to measure peri-implant bone loss were used solely to evaluate the survival rates and various clinical outcome parameters, but no MBL data were extracted out of them. The distortion in the interforaminal area of the mental symphysis results in reduced accuracy, which compromises the validity of this method for calculating MBL changes.

With regard to the quality assessment of the included studies, selection bias cannot be excluded since allocation concealment was not used or was uncertain in several studies. Another common finding was the lack of blinding of the examiners of the clinical parameters. Only one study provided details about interexaminer reliability of clinical and radiographic measurements.²³ In addition, there was not always a clear explanation for withdrawals and dropouts of patients during the follow-up period.

In general, because of differences in the experimental design and in endpoints for comparison of outcomes, the results of most studies in edentulous patients are not fully comparable with each other, and only general tendencies can be derived.³⁸

By including studies in which the mandibular overdenture was opposed exclusively by conventional maxillary prostheses, the influence of one potential confounding factor was reduced. The potential negative impact of higher magnitude stresses transferred to the implants and the mandibular overdentures by opposing natural dentition or by a fixed prosthesis was eliminated. It should also be noted that even though all the studies included in this review utilized complete maxillary prostheses, only a few studies provided adequate and detailed information about the maxillary conventional denture and the type of occlusion selected.^{23–26,30} This is an important consideration because control and optimal distribution may be achieved by the careful selection of the occlusal scheme and proper functional adaptation of the prosthesis.³¹

Solid conclusions were difficult to draw because of the short-term follow-up periods. The methodology applied varied among studies. Different inclusion and exclusion criteria, a vague definition of success and survival, and a lack of standardized criteria to define

biologic and technical complications were common. Furthermore, there were hardly any study designs present where two different immediate loading protocols were compared directly to each other. That means it is difficult to conclude whether a specific immediate loading protocol is more favorable compared to another.

The number of patients recruited in some of the included studies was rather small.^{20,22,24,28,31} The small sample size can cause type I error, which means there is the possibility of not detecting an actual difference between groups when it may exist. In the same context, a sample size calculation to provide an 80% power was only performed in two studies.^{23,30}

Interpretation of the Results

The debate regarding the minimum number of implants required to retain a mandibular overdenture is not recent. When the immediate loading protocol was introduced to support implant overdentures in the edentulous mandible, four implants were considered necessary to achieve stability and optimize the biomechanical load distribution.³⁹ There were, however, no long-term data to substantiate this assumption.⁴⁰ Indeed, studies published later demonstrated that immediate loading of only two implants does not lead to early implant loss due to overloading.^{21,31} Even the use of a single implant to retain a mandibular overdenture can be a positive treatment modality for the rehabilitation of the edentulous mandible in selected patients.⁴¹ In an RCT on the immediate loading of mandibular overdentures supported by one or two unsplinted implants, there was no significant difference in the implant failure rates in the two groups, indicating that the number of implants supporting the overdenture had no impact on the outcome. It should be mentioned, though, that in this study, a higher than expected implant failure rate was observed.²⁶

From the results of the current review, it was not feasible to make a conclusion on the minimum number of implants needed for the optimal clinical, surgical, and prosthodontic outcomes. It appears that two standard-diameter, immediately loaded implants may be used to retain a mandibular overdenture with a successful clinical outcome in the edentulous mandible. This is provided that the proper design of the prosthesis and occlusal adjustments are ensured. On the contrary, MDIs are usually combined in most cases with an increased number of implants (usually four) in order to compensate for the reduced diameter and surface area and may be a feasible treatment alternative.^{30,32} However, well-designed, randomized controlled trials are still advised before this design can be recommended for routine clinical use.

Until recently, a prerequisite for the immediate loading protocol was the use of standard-sized implants in order to ensure a favorable distribution of the occlusal forces at the bone-implant interface.

However, unfavorable anatomical conditions such as narrow crestal ridges would require additional surgical procedures or extensive bone reshaping so that the implants are surrounded by at least 1 mm of bone. An alternative treatment may be the insertion of four immediately loaded MDIs, especially in medically compromised patients. Two of the included studies used four immediately loaded single-piece MDIs with favorable short-term results.^{30,32} However, these results should be considered cautiously since long-term clinical and radiographic outcomes of immediately loaded MDIs are rare in the literature.

The type of attachment system may have an influence on the retentive strength, the (over) loading of the implants, the plaque control, the prosthodontic complications, and the eventual marginal bone loss. Two of the included studies used four implants to support a U-shaped Dolder bar-retained overdenture.^{20,22} Several other authors have used a similar prosthetic design based on the idea that this treatment modality could in theory guarantee stability, leading to less detrimental effects of overloading at the bone-implant interface.^{7,40,42} This concept, though, was based on empirical evidence with no reported data to support or refute it.

In subsequent studies, the number of immediately loaded splinted implants was gradually reduced. Stephan et al proposed an immediate loading protocol using three splinted implants. The implants were placed in a tripodal configuration to reduce the anticipated overdenture micromovement. No significant difference was found between the immediate and delayed loading protocols with regards to the health of peri-implant soft and hard tissues. Further, no implant failure was recorded. Although the clinical performance of the implants was promising, the small number of patients and the short-term follow-up limit the extrapolation of the results.²⁷ Stoker and Wismeijer suggested that two immediately loaded interconnected implants used to support mandibular overdentures could be a successful treatment modality.²¹

An alternative attachment mechanism is individual unsplinted ball attachments. The use of two unsplinted implants was the most common design in most of the included studies with contradicting results. Despite the high survival and/or success rate that was reported, data showing an increased rate of implant failure and bone loss were also revealed.

Marzola et al reported an average marginal bone loss of 0.7 mm for two immediately loaded unsplinted

implants that was similar to that of conventionally loaded implants at a 1-year follow-up period.³¹

On the contrary, different authors demonstrated more marginal bone resorption and increased probing depth around two individual, immediately loaded implants compared to conventionally loaded implants. Therefore, a recommendation was made that the immediate loading of two unsplinted implants may be premature and should be performed with caution.^{23,26} Drawing conclusions based on the findings of the previously described studies was not possible due to the small number of patients, short-term follow-up, and the different designs between various studies.

Two individual implants placed in the canine region have the potential to create bending moments about the implants by acting as a fulcrum.⁴¹ The biomechanical behavior may be improved by a bar construction, which may improve the overdenture stability and decrease the bone loss under functional loading.²⁵ Nonetheless, immediate loading of four unsplinted implants may be feasible provided that adequate primary stability and minimal denture movement are guaranteed. Wittwer et al demonstrated a high survival rate of implant overdentures supported by four individual loaded implants.³³ However, the authors emphasized the importance of using implants at least 14 mm long and a minimum of 4.5 mm in diameter to ensure primary stability.

It could be argued, therefore, that splinting implants is not an absolute requirement with immediate loading protocols in the anterior mandible. In the study by Tözüm et al, the use of two individual implants did not seem to cause excessive bone loss compared to conventional loading (0.14 and 0.22 mm of bone loss was observed for immediately and delayed loaded implants, respectively, at 24 weeks of follow-up).²⁸

A direct comparison between ball and bar attachments in case of immediately loaded MDIs showed that the splinting of two MDIs with a rigid superstructure results in less marginal bone loss compared to nonsplinted mini-implants. The difference in the outcome can be attributed to the pattern of load distribution between the two designs.²⁵ Splinting of the one-piece implant with ball abutments was a rather unusual prosthodontic design in the aforementioned study. Accordingly, immediate loading of MDIs in the anterior mandible may be a feasible treatment alternative; however, well-designed, randomized controlled trials are lacking.

A treatment protocol should not only be investigated in terms of its biologic success but for its clinical effectiveness as well.⁴³ In this review, only a few studies reported on prosthodontic maintenance.^{21,26,32} Even in these studies, however, there was a lack of predetermined criteria related to a successful prosthodontic outcome. The results of an 8-year follow-up study, in which three different loading protocols (2, 6, and 12 weeks)

were applied, showed that the long-term prosthodontic maintenance of a mandibular two-implant overdenture is influenced not by the loading protocol but by the attachment system, particularly the type of matrices used.⁴⁴

Marzola et al attributed the low frequency of major complications of implant overdentures supported by two unsplinted implants to minimal adjustments needed due to limited space requirements of ball attachments. The result was to maintain the bulk of the prostheses, preventing the weakening of the denture and any subsequent fracture.³¹ Turkyilmaz and Tumer reported a higher need for prosthodontic maintenance in the immediate loading group compared to the delayed loading group. The authors contributed the previous finding to the fact that secondary healing of the soft tissue around immediately loaded implants may require relining of the prostheses. The events of prosthodontic maintenance encountered were higher in the first year compared to that in the second year.⁴⁵

Primary stability is another important factor that should be considered when an immediate loading protocol is selected.⁴⁶ Different methods exist to evaluate primary stability, among which insertion torque, periotest, and RFA are frequently applied. A high value of insertion torque indicates a high degree of primary stability and therefore less chance of excessive micro-movement that can lead to microgap formation and loss of osseointegration. Kronstrom et al demonstrated a significant correlation between implant failure and ISQ measurements, indicating a higher risk of failure with decreased values, and an increase in mean ISQ values over time among successful implants.²⁶ These results are in contrast with the study of Tözüm et al, which showed a slight decrease in ISQ values of successful implants after 2 years of function.²⁸ Moreover, Turkyilmaz et al found no significant differences in RFA measurements between immediate and delayed loading protocols over a period of 2 years.³⁵ Thus, it remains highly questionable as to whether baseline RFA measurements can be used to predict the risk of implant failure regardless of the loading protocol.⁴⁷

Based on the findings of this review, the results of most studies indicated that the amount of bone loss in the immediate loading protocol was not statistically significantly different compared to that of the delayed loading protocol. However, in a systematic review by Ma and Payne, it was determined that the reported implant success rates could not be compared fairly due to the presence of several limitations when analyzing the validity of MBL changes.⁴⁸

Therefore, it is the authors' recommendation that when an immediate loading protocol is adopted, sound clinical judgments should be followed; initial primary stability of implants should be ensured; and biomechanical

load distribution should be optimized via appropriate prosthodontic design and proper occlusal adjustment.

CONCLUSIONS

Most of the studies included in this systematic review demonstrated comparable outcomes between conventional and immediate loading protocols in case of mandibular implant overdentures. However, this data should be interpreted cautiously due to the differences in study designs, end point outcomes, and small sample sizes. A recommendation on a certain number, diameter of implants, and attachment system selected with immediate loading protocol was not possible. Only general tendencies can be shown. More RCTs are needed to provide a better insight for the optimal management of fully edentulous mandibular cases with removable overdentures supported by immediately loaded implants.

ACKNOWLEDGMENTS

The authors wish to thank librarian R. de Vries for his significant contribution during the literature searching process. The authors reported no conflicts of interest related to this study.

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