Loading Protocols for Mandibular Implant Overdentures: A Systematic Review with Meta-Analysis

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ABSTRACT

Background: Mandibular overdentures are a successful treatment option for the edentulous patients with long-term predictable outcomes, using conventional loading protocols. Currently, both early and immediate loading protocols for mandibular implant overdentures are prevalent in the literature.

Purpose: A systematic review and meta-analysis of the current published literature on comparative studies using conventional versus either early and/or immediate loading protocols for mandibular implant overdentures.

Materials and Methods: The review was carried out in accordance with the QUOROM (Quality of Reporting of Meta-Analyses) guidelines. The PICO (Population, Intervention, Comparisons, Outcomes) format was used in conjunction with predefined inclusion criteria. A literature search of PubMed (1969–October 2008), EMBASE (1998–October 2008), the Cochrane Database of Systematic Reviews, and the Cochrane Controlled Trial Register was conducted. In addition, hand searching through refereed dental journals was also performed for the years 2000 to 2008. The meta-analysis was conducted by using the MIX software v.1.7 (Kitasato Clinical Research Center, Kanagawa, Japan).

Results: A total of 191 studies were identified through the electronic search. After full-text screening and cross-matching with the predefined inclusion criteria, only 10 studies with a minimum follow-up of 2 years were eligible for inclusion in this review. Of the 10 included studies, seven have compared the outcome of conventional versus early loading of implants supporting mandibular overdentures. The remaining three studies, on the other hand, compared the outcome of conventional versus immediate loading. The meta-analysis revealed no significant difference in the outcome between conventional and either early ($p = .72$) or immediate ($p = .08$) loading of implants supporting mandibular implant overdentures.

Conclusions: Short-term outcomes of early or immediate loading protocols for mandibular implant overdentures achieved comparable success to conventional loading ones. No evidence was found of long-term studies to support or refute either early or immediate loading protocols for mandibular implant overdentures.

KEY WORDS: early loading, immediate loading, mandibular implant overdentures, meta-analysis, systematic review

INTRODUCTION

Mandibular overdentures supported by two, three, or four implants in the anterior mandible opposing complete maxillary dentures have been demonstrated to be a successful and predictable treatment option for the completely edentulous patients. This is as a result of the positive outcomes of long-term clinical studies, specifically using a conventional loading protocol.[1–4] This loading protocol empirically implied that successful osseointegration would only occur when implants placed in the anterior mandible were not loaded for at

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least 3 months (Brånemark System®, Nobel Biocare, Göteborg, Sweden).[5] By contrast, early evidence from other clinical studies using prototypes of a different implant system (Straumann Dental Implant System, Institute Straumann, Basel, Switzerland) demonstrated that successful osseointegration could also occur when implants supporting mandibular overdentures were loaded on the same day as surgical placement[6,7]or even a few days later.[8] With time, outcomes from both retrospective[9] and prospective[10–14] clinical studies have confirmed this success to be independent of the implant system used. Survival rates above 90% have been reported in these studies with implants from different systems loaded with mandibular overdentures at shorter healing periods. As with the historical studies,[6–8] however, a similar prosthodontic design was always used to support the overdentures (rigid bars splinting four interforaminal implants).

In recent years, it is evident that researchers have preferred implants roughened-surface topography for loading with overdentures after shorter healing periods.[13–18] These implants (particularly of moderate surface roughness) have been shown to demonstrate stronger bone contact than smooth-surface implants.[19,20] High survival rates between 96 and 100% were reported in case series and prospective clinical studies using roughened-surface implants supporting mandibular overdentures using modified loading protocols.[13–18,21–25] The necessity for this implant surface topography has also been challenged with other short-term reports (albeit limited number) demonstrating comparable outcomes for smooth-surface implants supporting overdentures.[10,12,26] With these findings, it was evident that the site-specific considerations related to the favorable bone quality of the anterior mandible[27–29] have a more significant impact on the outcome than the surface topography of these implants. More so, convincing evidence has also been found to suggest that reducing the number of supporting implants, whether they are rigidly splinted with bar attachment systems[23,30] or unsplinted with ball attachment systems,[16–18,21,22,24,31–33] seems to be irrelevant in the short term. Immediate loading for mandibular overdentures (with a theme of reduced numbers of implants further) has now been extrapolated to the current emerging alternative approach using only a single midline implant.[34,35]

With current prevalence of modified loading protocols (early and immediate) and their redundant variations (progressive, functional), a perplexity of terms and definitions has also become noticeable in the literature. This is largely a result of the lack of consistency among the multiple definitions usually offered for the same protocol.[36–41] Very often, the precise timing of loading and the manner of load application with each of these protocols are either ambiguous or loosely defined.[37,41] Hence, studies on comparative evaluation of treatment outcomes for mandibular implant overdentures using modified loading protocols are often arduous.

Over the last decade, several systematic reviews describing treatment outcomes with oral implants following early and/or immediate loading protocols have been published.[37,42–48] Of these, three reviews[44,45,47] presented objective evaluation of only immediately loaded implants in partially and completely edentulous jaws. Others have presented comparative outcomes of early and immediate loading protocols either in edentulous jaws only[42] or in partially edentulous and completely edentulous jaws.[37,43,48] Systematic reviews designed to exclusively evaluate treatment outcomes of different loading protocols for mandibular implant overdentures using strict eligibility criteria are still lacking. There is only exception of a single review focusing on this treatment.[46]

The aim of this systematic review and meta-analysis was to critically evaluate the current evidences available from all randomized and nonrandomized controlled trials comparing conventional, early, and immediate loading protocols for mandibular implant overdentures.

MATERIALS AND METHODS

This systematic review was conducted in accordance with the guidelines of the Quality of Reporting of Meta-Analyses (QUOROM) guidelines.[49,50] The population, intervention, comparisons, outcomes (PICO) format was used to define a focused clinical question with clear inclusion criteria:[51]

Population or participants: Patients that need mandibular implant overdentures
Intervention: Early or immediate loading of mandibular implant overdentures
Comparison: Conventional loading of mandibular implant overdentures
Outcome: Implant survival

TABLE 1 Definitions of Loading Protocols Used for This Review (Modified after Cochran et al.[38])

Category	Definition
Conventional loading	The prosthesis (overdenture) is attached in a second procedure after a healing period of 3–6 months.
Early loading	A restoration (overdenture with attachment system) is in contact with the opposing dentition and placed at least 48 hours after implant placement but not later than 3 months afterward.
Immediate loading	A restoration (overdenture with attachment system) placed in occlusion with the opposing dentition within 48 hours of implant placement.

Search Strategy

A literature search of PubMed (1969–October 2008), EMBASE (1998–October 2008), the Cochrane Database of Systematic Reviews, and the Cochrane Controlled Trial Register was conducted. Boolean operators were used to combine the following terms "randomized controlled trial," "controlled clinical trial," "overdenture," "implant supported overdenture," "implant retained overdenture," "immediate loading," "early loading," "dental implant," "oral implant," and "endosseous implant." Bibliographies from retrieved papers were then reviewed. In addition, hand searching of the following dental journals was performed for the years 2000 to 2008: *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *European Journal of Oral Implantology*, *Implant Dentistry*, *International Journal of Oral and Maxillofacial Implants*, *International Journal of Periodontics and Restorative Dentistry*, *International Journal of Prosthodontics*, *Journal of Clinical Periodontology*, *Journal of Dental Research*, *Journal of Oral Rehabilitation*, *Journal of Periodontology*, *Journal of Prosthetic Dentistry*, *Journal of Prosthodontics*, *Journal of Oral Surgery*, *Oral Medicine*, *Oral Pathology*, *Oral Radiology and Endodontology*, and *Quintessence International*. The search was performed by the two reviewers (N.A. and M.A.) with disagreements resolved by the third author (A.P.).

Study Selection Criteria

Each of the two reviewers (N.A. and M.A.) screened independently all the titles and abstracts. To be eligible for inclusion, studies needed to comply with the following predetermined inclusion criteria:

1. Study design: randomized controlled trials (RCTs), controlled clinical trials (CCTs)
2. Mandibular implant-supported or implant-retained overdentures
3. Intervention: conventional loading versus early loading, or conventional loading versus immediate loading
4. Each intervention group having the same type and number of implants
5. Endosseous titanium implants
6. Minimum follow-up period: 24 months

The definitions proposed by Cochran and colleagues[38] for conventional, early, and immediate loading were adopted for the purpose of this review, irrespective of the protocol defined in the original article (Table 1).

Data Collection and Extraction

Data were independently abstracted by the two reviewers using specially designed data extraction form, which was designed to collect information on (1) year of publication, (2) demographic characteristics of the participants, (3) study design, (4) number of implants per patient, (5) loading protocol, (6) attachment system, (7), follow-up period, and (8) implant failure rate.

Quality of Studies

The methodological quality of studies included in the meta-analysis was assessed by the three authors using the standard Cochrane criteria for allocation concealment[52] (Table 2) and a modified Jadad scale.[53] The modification was necessary because of the difficulty in

TABLE 2 Allocation Concealment Used for This Review (Higgins and Green[52])

Category	Description
Grade A	Adequate concealment
Grade B	Uncertain
Grade C	Inadequate concealment
Grade D	Not used

TABLE 3 The Modified Jadad Scale Used for This Review (Jadad et al.[53])

Key Criteria	Score
The study was described as randomized	+1
The assessment of the outcome was blinded	+1
The withdrawals and dropouts were described	+1
The method of randomization was appropriate	+1
The method of blinding was appropriate	+1
The method of randomization was inappropriate	−1
The method of blinding was inappropriate	−1

conducting double-blinded trials for replacing missing teeth. Thus, "double-blind" has been changed to "blind" (Table 3).

Statistical Analysis

The meta-analysis was conducted by using MIX software v.1.7 (Kitasato Clinical Research Center, Kanagawa, Japan).[54,55] This software has been validated and shown to be comparable with other well-established programs such as STATA (Stata Statistical Software, Release 9, StataCorp LP, College Station, TX, USA).[55] In addition, MIX provides a wider range of analytical tests and more than 18 graphic outputs compared than other commercial softwares. A Mantel-Haenszel method has been used to calculate the point estimates of the relative risk to investigate the probability of implant failure at a given time point for conventional versus early or immediate loading. Measures of consistency within and between studies variability have been calculated by using the Cochran's Q and I^2. Because these tests suffer from lack of power, a p value of >.10 was considered as homogenous. I^2 values range between 0 and 100%. Values over 50% indicate large heterogeneity.[56] In case of statistical homogeneity, fixed effects model should be used. This model assumes that treatment effect is similar in every study and that the differences in results are only a result of sampling error. On the other hand, random effects model takes into account both within- and between-study variability and allows for random error and equal weight for all studies. Thus, it is used when statistically significant heterogeneity was present.[57] The publication bias was assessed by using the funnel-plot method.[58]

The funnel plot is a graphical method in which the treatment effects are plotted against their sample size or variance of effect measures. A skewed and asymmetrical funnel plot can be a result of bias in selection, publication, and retrieval of studies. The funnel asymmetry is confirmed by two statistical tests: the Begg and Mazumdar test[59] and the Macaskill and colleagues' regression test.[60] The Begg and Mazumdar test is based on the rank correlation between treatment effect estimates and their sampling variances, while the Macaskill and colleagues' test is a regression test based on the sample size.

RESULTS

The electronic literature search identified 191 studies (Figure 1), of which 19 were selected for full text screening. Nine studies were excluded; five had a follow-up period of less than 24 months,[24,32,61–63] one compared between immediate and early loading,[64] one compared early loading of one-piece with two-piece implants with no control group,[12] one compared early loading of two different implant systems,[22] while, in the last study, the number of implants and the implant systems used were not standardized between the two groups.[65] The hand search did not provide any additional publications. A total of 10 studies met the inclusion criteria and were included in the meta-analysis[10,13,15–18,30,31,66,67] (Tables 4 and 5). Four studies were RCTs,[10,15,16,67] while the rest were CCTs. Of the 10 studies included, seven compared conventional with early loading protocol[15–18,31,66,67] (Figure 2). The remaining three studies compared conventional with immediate loading protocol[10,13,30] (Figure 3). All studies included were on mandibular overdentures supported by two, three, or four implants. Moreover, all studies had similar follow-up periods of 24 months. One of the authors was contacted for further clarification on two studies of a similar design.[18,31]

META-ANALYSIS

Conventional versus Early Loading

The meta-analysis of the seven studies that assessed implant failure showed a higher risk of implant failure in the early loading groups. The difference, however, was not statistically significant (relative risk of 3.0, 95% confidence interval [CI] 0.89–10.1, $p = .08$) (see Figure 2). The χ^2 test for heterogeneity demonstrated that differences between the studies were unlikely to have been caused by chance ($\chi^2 = 1.99$, degrees of freedom [df] = 6, $p = .16$, $I^2 = 48.8\%$). The assessment of the funnel plot, Begg and Mazumdar's rank correlation test ($p = .7$), and

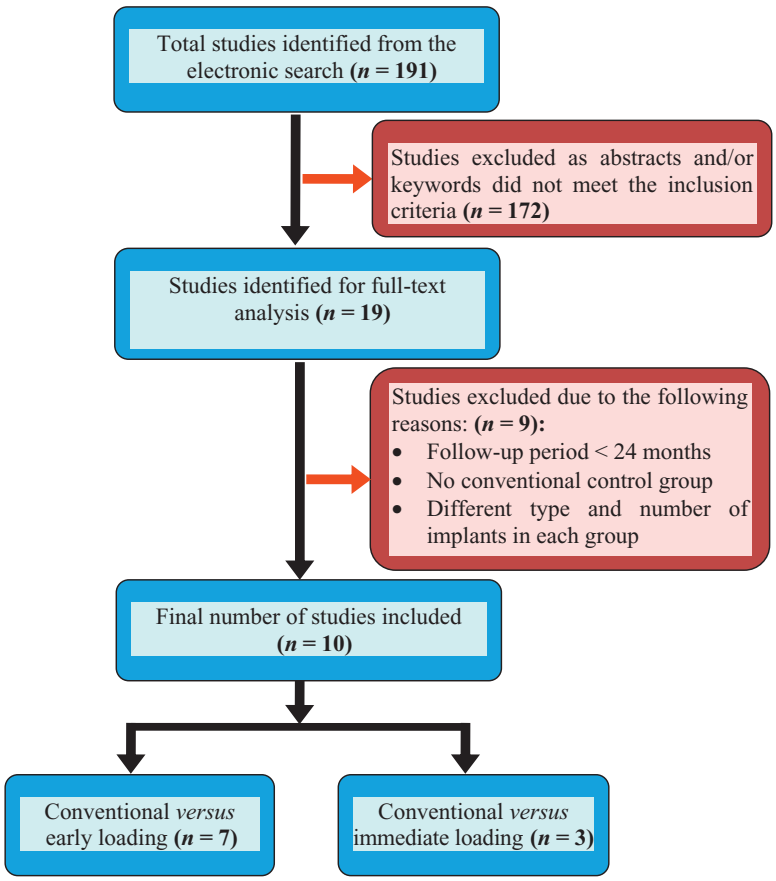

Figure 1 Flow chart for search strategy.

the Macaskill and colleagues' regression test ($p = .59$) excluded the possibility of publication bias.

Conventional versus Immediate Loading

The meta-analysis of the three studies indicated a higher risk in the conventionally loaded groups. Again, the difference between the two protocols was not statistically significant (relative risk of 0.67, 95% CI 0.071–6.25, $p = .72$) (see Figure 3). No significant heterogeneity between the studies was observed, as indicated by the χ^2 test ($\chi^2 = 0.27$, $df = 2$, $p = .61$, $I^2 = 0\%$). The results of Begg and Mazumdar's rank correlation test ($p = 1.0$) and the Macaskill and colleagues' regression test ($p = .29$) in addition to the lack of funnel-plot asymmetry showed no evidence of publication bias.

DISCUSSION

This systematic review and meta-analysis was conducted to investigate the current literature on the outcome of early and immediate loading protocols (compared with conventional ones) for mandibular implant overdentures.

When compared with other systematic reviews, this review is considered different for three reasons. Firstly, a more focused clinical PICO format related to mandibular implant overdentures was followed. This ensured the homogeneity of the studies including a unified follow-up period. Secondly, in the absence of long-term data, only controlled trials with restricted minimum follow-up period of 24 months were identified for inclusion in this review. Our aim with this was to provide reliable and evidence-based conclusions related to overall treatment outcome. Thirdly, our review was supplemented with meta-analysis to increase the validity of our findings while employing a fixed-effects model as no evidence of heterogeneity was detected between the studies. On the other hand, limitations with this review also need to be addressed. The limited number of studies included together with their smaller sample size is acknowledged by the authors. Another limitation was the insufficient data available for comparative analysis of prosthodontic and peri-implant outcomes as other reliable outcome measures. Furthermore, the lack of standardization in the assessment of marginal bone loss

TABLE 4 Characteristics of Studies Included in the Review

Study	Study Design	Implant System and Surface Design	No. of Participants	No. of Implants per Participant	Loading Protocols Compared	Attachment System	Survival Rate (%)	Follow-Up Period (Months)
Chiapasco et al.[10]	RCT	Brånemark (smooth)	10	4	Immediate	Bar (U-shaped)	97.5	24
			10	4	Conventional		97.5	
Roynesdal et al.[17]	Controlled	Straumann (roughened)	11	2	Early	Ball	100	24
			10	2	Conventional		100	
Payne et al.[16]	RCT	Straumann (roughened)	12	2	Early	Ball	100	24
			12	2	Conventional		100	
Romeo et al.[13]	Controlled	Straumann(roughened)	10	4	Immediate	Bar (U-shaped)	100	24
			10	4	Conventional		97.5	
Tawse-Smith et al.[67]	RCT	Sterioss (roughened)	12	2	Early	Ball	70.8	24
			12	2	Conventional		87.5	
		Southern (roughened)	12	2	Early		100	
			12	2	Conventional		83.3	
Turkyilmaz et al.[31]	Controlled	Brånemark (roughened)	13	2	Early	Ball	100	24
			13	2	Conventional		100	
Assad et al.[15]	RCT	Paragon (roughened)	5	4	Early	Bar*	100	24
			5	4	Conventional		100	
De Smet et al.[66]	Controlled	Brånemark (smooth)	10	2	Early	Ball	90	24
			10	2	Conventional		90	
Stephan et al.[30]	Controlled	Brånemark (roughened)	17	3	Immediate	Bar (round)	100	24
			9	3	Conventional		100	
Turkyilmaz and Tumer[18]	Controlled	Brånemark (roughened)	10	2	Early	Ball	100	24
			10	2	Conventional		100	

*Bar design not specified.
RCT = randomized controlled trial.

TABLE 5 Quality Assessment of Allocation Concealment of Included Studies Based on the Cochrane Criteria and the Modified Jadad Score (Jadad et al.[53])

Study	Allocation Concealment	Jadad Score
Chiapasco et al.[10]	B	1
Roynesdal et al.[17]	D	1
Payne et al.[16]	B	3
Romeo et al.[13]	D	1
Tawse-Smith et al.[67]	B	1
Turkyilmaz et al.[31]	D	1
Assad et al.[15]	B	1
De Smet et al.[66]	D	1
Stephan et al.[30]	D	1
Turkyilmaz and Tumer[18]	B	1

B = uncertain; D = not used.

among the studies resulted in implant survival being the selected outcome measure considered in this review. Considering the aforementioned limitations, the results of this review should be interpreted with caution.

The overall treatment effect of the seven studies that compared the outcome of conventional with early loading[15–18,31,66,67] demonstrated no significant difference ($p = .08$). Likewise, the meta-analysis of the three studies that compared conventional with immediate loading of mandibular overdentures[10,13,30] showed no significant differences between the two approaches ($p = .72$).

It is relevant that all studies with immediate loading groups included in this review used a splinted prosthodontic design (round or U-shaped bar attachment systems) on three or four implants. On the other hand, all studies comparing conventional with early loading used an unsplinted prosthodontic design (ball attachment systems on two implants). Therefore, prospective, controlled comparative studies on the outcome between conventionally and immediately loaded implants supporting mandibular overdentures using unsplinted attachment systems are still lacking in the literature.

It has been demonstrated with one study[67] that early loading of two unsplinted implant mandibular overdentures is associated with higher implant failure. This particular study demonstrated the lowest success rate (85.4%) reported among all included studies with seven failed implants in the early loading group. Indeed, it was

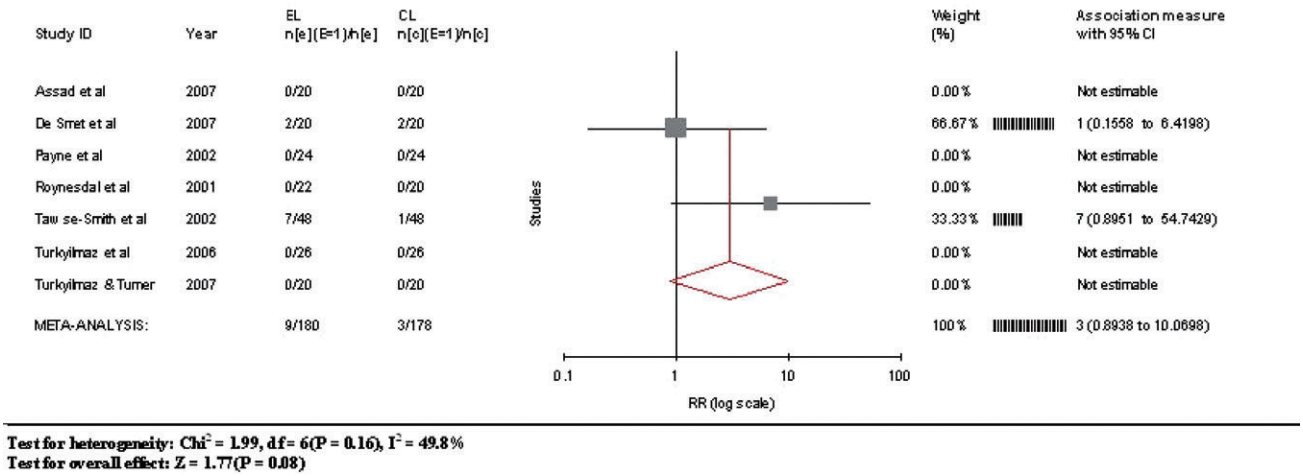

Figure 2 Comparison: conventional versus early loading for mandibular implant overdentures outcome – implant survival. (CI = confidence interval; RR = relative risk).

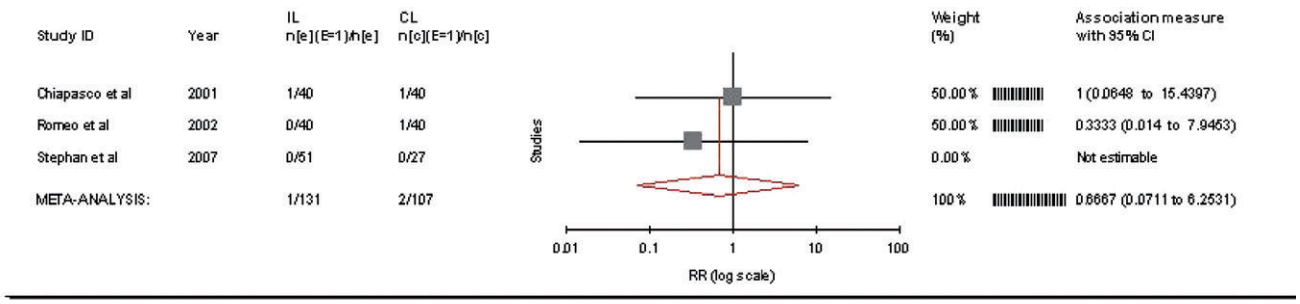

Figure 3 Comparison: conventional versus immediate loading for mandibular implant overdentures outcome – implant survival. (CI = confidence interval; CL = conventional loading; IL = immediate loading; RR = relative risk).

thought that early loading of two unsplinted implants with overdentures using unsplinted prosthodontic designs might compromise successful outcome[13] caused by the uncontrolled rotation of the overdenture. The recommendation, therefore, was that the maximum number of implants rigidly splinted together would promote a better treatment outcome whenever early loading is prescribed.[9] Implant failures observed with early or immediate loading, however, were often attributed to initial learning curve of operator[11,22] or as a cumulative effect with clinical trials of longer follow-up periods.[11]

The present review suggests that both early and immediate loading protocols for mandibular implant overdentures are predictable treatment options that offer comparable short-term outcomes to a conventional protocol. The strength of evidence, therefore, is still weighted in favor of using a conventional loading protocol, which has reported long-term outcomes.[1–4] Furthermore, the review has also revealed no literature with randomized or nonrandomized controlled trials comparing different loading protocols for mandibular single-implant overdentures. This is relevant bearing in mind the emergence of mandibular single-implant overdentures (opposing complete maxillary dentures) as a treatment option for elderly patients with several short-term clinical studies currently available.[34,35,68–70]

CONCLUSIONS

This systematic review and meta-analysis shows that both early and immediate loading protocols using two, three, or four implants supporting/retaining mandibular overdentures can be achieved with comparable success to conventional loading for up to 2 years. Long-term treatment outcomes of well-designed randomized clinical trials using more participants are necessary to further validate these early and immediate loading protocols for mandibular overdentures. Confounding variables such as the number of implants and the prosthodontic design used should be equally evaluated.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare. [Correction added after online publication 24 May 2010: Conflict of Interest Statement added.]

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