

# Application of Immediate Loaded Mini Dental Implants for Retaining Mandibular Overdenture Prosthesis in Edentulous Patients: A Systematic Review

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**Abstract:** The aim was to systematically review the efficacy of immediate loaded mini dental implants (MDIs) to retain mandibular overdentures in regards to survival rates of MDIs, peri-implant clinical and radiographic tissue response and associated factors. A literature search of English literature was performed using Google Scholar, Scopus, Web of Science, MEDLINE (OVID), EMBASE, and PubMed using predetermined inclusion criteria. Specific terms were utilized in searching from the inception of the respective databases up to April 2021. The focused question was: Do immediate loaded MDIs supporting mandibular overdentures present favorable treatment options for prosthetic rehabilitation? The 11 articles included in the present review examined 349 patients (198 males + 171 females [66.65 ± 6.28 years]) in which 1190 MDIs were placed to retain mandibular overdentures. The mean follow-up duration was 24.5 months. The cumulative survival rate of MDIs was 97.3%. The mean scores of plaque index, gingival index, probing depth, and bleeding on probing ranged between 0–3, 0–3, and 1.203–1.76 respectively, whereas the mean marginal bone loss values ranged from 0.42 ± 0.56 mm to 1.26 ± 0.64 mm. The results identified that the application of immediate loaded MDIs to retain mandibular overdentures are a potential treatment modality for edentulous patients.



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**Keywords:** mini implants; overdenture; prosthodontic rehabilitation; survival rate

## 1. Introduction

For years, edentulous patients have had no other option than conventional dentures for re-establishing their oral function [1]. Loose and unstable dentures with a compromised function is a common complaint in complete denture patients. [2]. During the previous decades, there has been a revolution regarding rehabilitation treatments for edentulous patients. The progress in dental implants and osseointegration formulated a new set of possibilities other than the conventional treatment with complete dentures, even for individuals presenting parafunctional activities [3]. A conference group, after much debate, established that the ideal rehabilitation model for an edentulous patient should be a complete maxillary denture and a two-implant retained mandibular overdenture as an antagonist [4].

A major limitation to the procedure of implant placement is the deficiency of bone tissue to support and sustain the dental implant. As per Atwood classification, alveolar ridge atrophy and resorption take place in two dimensions: horizontal and vertical. The alternative in such scenarios is to carry out bone graft surgery for increasing bone height and volume. Mini dental implants (MDIs) are indicated in horizontally atrophied alveolar ridges having inadequate bone width and adequate bone height. Usually, elderly patients are not willing to undergo so many surgical procedures and may refuse dental implant-retained rehabilitation [5–12].

MDIs (1.8–2.9 mm in diameter) have been indicated to be a surgical alternative to conventional dental implants for patients with narrow alveolar ridges [13–18]. The Glossary of Oral and Maxillofacial Implants (GOMI) has defined MDIs as “dental implants fabricated

of similar biocompatible materials as other dental implants but of smaller dimensions” [19]. They present a single body system with a ball-type attachment incorporated and usually are placed in a one-stage surgical procedure [20]. Originally, they were fabricated as transitional implants [21] or for orthodontic anchorage [22], however, their osseointegration outcomes, because of a rough surface, have exhibited to be comparable to conventional dental implants and were then considered as a permanent alternative [17,23–25]. Additional benefits of MDIs include low-cost, less denture bulk, ease of technique, and simple surgical procedures without bone augmentation [26]. A few drawbacks are also associated with MDIs since their mechanical features favor deformation of the ball attachment, implant fracture, and the lack of an anti-rotational notch [6]. A greater incidence of implant fracture has been associated with the use of MDIs as compared to conventional dental implants and has been reported to be sensitive to high-insertion torque [6]. Hence, concern related to possible high fatigue fracture levels associated with MDIs in high-stress regions has resulted in their application is restricted to removable prostheses by many [26].

The previous reports that assessed the MDIs with prosthetic purpose evaluated their viability for retaining single provisional prosthesis in anterior areas, as attachment systems in partial removable dentures, and as support for retaining mandibular overdentures [27–29]. Promising outcomes have been reported so far; however, there is an absence of consensus regarding the utilization of immediate loaded MDIs for retaining mandibular overdentures in the published literature. Some reports have shown high survival rates for MDIs to support mandibular overdentures [15,30] while other reports have demonstrated low survival rates as compared to SDDIs [31]. Hence, this systematic review aimed to verify the feasibility of utilizing immediate loaded MDIs to support mandibular overdentures for permanent prosthetic rehabilitation. The null hypotheses of the present systematic review are stated as follows: (a) the survival rates of immediate loaded MDIs to retain mandibular overdentures are not different compared to SDDIs retaining mandibular overdentures; (b) MDIs retaining mandibular overdentures do not show a compromise in peri-implant clinical and radiographic parameters, quality of life, or patient satisfaction.

## 2. Materials and Methods

The Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines were followed to carry out the present systematic review [32].

### 2.1. Focused Question

The PICO (Population, Intervention, Comparisons, Outcomes) question formulated was as follow: “Do immediate loaded MDIs supporting mandibular overdentures present favorable treatment option for prosthetic rehabilitation?”. The population (P) was subjects rehabilitated using immediate loaded dental implants to retain mandibular overdentures; the intervention (I) was edentulous subjects rehabilitated using mandibular overdentures retained by MDIs; the comparison (C) was edentulous subjects rehabilitated using overdentures retained by SDDIs; the primary outcome (O) was the survival rates of MDIs, while the secondary outcomes were peri-implant clinical (plaque index [PI], gingival index [GI], probing depth [PD], and bleeding on probing [BOP]) as well as radiographic parameters (marginal bone loss [MBL]), along with the quality of life and satisfaction with MDIs where they were utilized to retain mandibular overdentures.

### 2.2. Eligibility Criteria

The inclusion criteria were: (1) randomized controlled/clinical trials, retrospective, case-control, cross-sectional, or cohort studies conducted on adult human subjects involving immediate loaded MDIs for mandibular overdentures; (2) studies published in the English language; and (3) articles published in a peer-reviewed scientific journal.

The exclusion criteria were: (1) studies that did not mention MDIs description as per the definition of GOMI; [19] (2) studies that stated dental implants >3 mm in diameter; (3) studies that did not describe the utilization of immediate loaded MDIs for mandibular

overdentures; (4) studies that did not permit extraction of quantitative data; (5) subjects or clinical information that were redundantly reported in other included studies; (6) case reports/series comprising less than three study participants; and (7) literature review articles.

### 2.3. Data Sources, Search Strategy, and Article Selection

Single investigator performed an independent electronic search of the English literature utilizing Google Scholar, Elsevier's Scopus, Clarivate Analytics' Web of Science, MEDLINE (OVID), EMBASE, and PubMed (National Library of Medicine). The search period ranged from inception up to April 2021. The exact search words were "mini dental implant\*" OR "mini implant\*" OR "mini dental implant\*" AND "overdenture" OR "mini dental implant\*" AND "prosthodontic\*" OR "mini implant\*" AND "overdenture" OR "mini implant\*" AND "prosthodontic\*".

Manual searching for the studies was conducted by the same investigator until April 2012 in the following journals: Journal of Prosthetic Dentistry, International Journal of Prosthodontics, Journal of Prosthodontics, Journal of Oral Rehabilitation, Journal of Dentistry, Journal of Dental Research, International Journal of Prosthodontics, International Journal of Oral and Maxillofacial Surgery, International Journal of Oral and Maxillofacial Implants, Clinical Oral Implants Research, and Clinical Implant Dentistry and Related Research.

The screening of the abstracts and titles of the articles identified using the abovementioned strategy was conducted by single investigator. A full-text reading of the relevant articles was performed. Manual searching of the bibliography of the pertinent literature reviews and research articles was also carried out for identifying articles that may have been missed in the previous step. Discrepancies were solved via discussion.

### 2.4. Data Extraction

The extraction of data from the included studies was carried out independently by single investigator. The data extracted from the included articles are as follow: (1) author, journal, year, and country of article publication; (2) study design; (3) surgical procedure performed; (4) implant company; (5) length and diameter of dental implants; (6) implant design; (7) number, mean age, and gender of the study participant; (8) total number of dental implants (MDIs and SDDIs) placed; (9) mean scores of clinical and radiographic peri-implant parameters; follow-up period; (11) number of implants failed; (12) survival rate; and (13) study outcome. All the extracted data were cross-checked by the reviewers and any discrepancies were again solved via discussion.

### 2.5. Risk of Bias Assessment

The risk of bias of randomized controlled/clinical trials was evaluated on the basis of the revised guidelines of the Consolidated Standards of Reporting Trials statement. [33] For individual included RCT, the risk of bias was recorded on the basis of the Cochrane Handbook of Systematic Reviews of Interventions [34]. In summary, the following sections were taken into consideration: (a) selection bias (i.e., allocation concealment and randomization); (b) performance bias (i.e., blinding of the research investigator); (c) detection bias (i.e., blinding of outcome assessors); (d) attrition bias (i.e., completeness of follow-up duration); and few other biases. Articles were categorized as "low" (i.e., low risk of bias), "medium" (i.e., medium risk of bias), or "high" (i.e., high risk of bias) for individual sections. Overall, articles were regarded as: (a) "low risk of bias" if all criteria were met; (b) "high risk of bias" if  $\geq 1$  criteria were not met; and (c) "medium risk of bias" if  $\geq 1$  criteria were partly met.

### 2.6. Additional Analysis

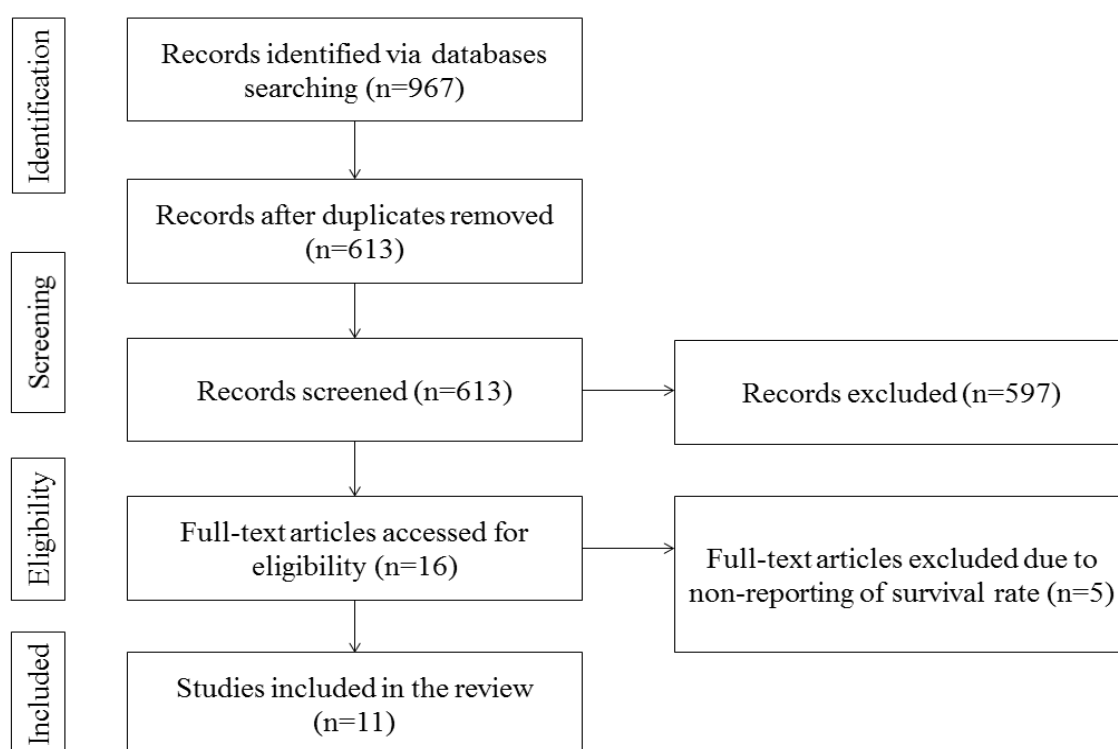
The Kappa statistics was recorded to identify the intra-reader agreement in the article selection method for articles published in all databases as well as for the quality assessment scores of the included studies. The level of inter-reader agreement is almost perfect if the value of kappa is 0.81–1.00; substantial if kappa is 0.61–0.80; moderate if kappa is 0.41–0.60; fair if kappa is 0.21–0.40; and poor if kappa is  $< 0.20$ . The calculation of

Kappa was performed by assessing the selected abstracts and titles, and later obtaining a score for selected studies on Google Scholar (kappa = 0.91), Scopus (kappa = 1.00), Web of Science (kappa = 1.00), MEDLINE (kappa = 0.95), EMBASE (kappa = 0.89), and PubMed (kappa = 0.93), indicating a high level of intra-reviewer agreement as per Kappa criteria [35].

### 3. Results

#### 3.1. Literature Search

A total of 967 titles were obtained as a result of the search from all electronic databases, out of which only 57 abstracts were suitable for this review. Overall, 16 studies were further considered for full-text review based on the applicability of the exclusion criteria. Further scrutiny led to exclusion of 5 full-text studies, which resulted in an overall 11 articles from which quantitative and qualitative data were gathered for final analysis. The study identification flowchart as per PRISMA is depicted in Figure 1.



**Figure 1.** Prisma flow diagram for study methodology.

#### 3.2. General Description of the Studies

Of the 11 included articles, 9 were prospective studies [8,17,36–42], while 2 were randomized clinical trials [43,44]. For the placement of MDIs, the majority of the articles used full-thickness flaps (n = 5) [8,39,40,43,44], followed by flapless technique (n = 4) [17,36,41,42] and minimal thickness flap procedure (n = 2) [37,38]. In the included studies, the length and the diameter of MDIs used ranged between 8–18 mm and 1.8–3 mm, respectively. Five studies utilized 1-piece implants [17,36,39,40,44], one study used 2-piece implants [43], while 5 studies did not mention the design of implants used (Table 1) [8,37,38,41,42].

In the included studies, 1190 MDIs and 170 SDDIs were placed in 349 patients [198 males + 171 females (range: 8–62 patients)]. The age of participants ranged between 45 and 86 years ( $66.65 \pm 6.28$  years). A wide variation was noticed regarding the implant follow-up durations, with the lowest being 12 months and the highest being 60 months after implant surgery (Table 2).

**Table 1.** Summary of qualitative data of the 11 included articles on immediately loaded mini dental implants to retain mandibular overdentures.

Study	Study Type	Surgical Procedure	Implant Company	Implant Length (mm)	Implant Diameter (mm)	Implant Design
Elsyad et al., (2011); J Oral Rehabilitation; Egypt	Prospective	Flapless	Vitapan™; Vita Zahnfabrik, Bad Sackingen, Germany	12–18	1.8	One-piece
Scepanovic et al., (2014); Annals of Anatomy; Serbia	Prospective	Flapless	3M ESPE, St. Paul, MN, USA	13	1.8	One-piece
Mangano et al., (2014); J Periodontol; Italy	Prospective	Full thickness flap	Tixos Nano, Leader Implants, Milan, Italy.	10.0, 11.5, and 13.0	2.7	One-piece
Maryod et al., (2014); Int J Prosthodont; Egypt	Prospective	Flapless	3M™ ESPE	15	1.8	-
Aunmeungtong et al., (2016); Clin Implant Dent Relat Res; Thailand	Randomized clinical trial	Full thickness flap	PW plusV™, Nakhon Pathom, Thailand	12	3	Two-piece
Zygogiannis et al., (2016); Int J Oral Maxillofac Implant; Netherlands	Prospective	Full thickness flap	3M™ ESPE	10–15	1.8 and 2.1	-
Zygogiannis et al., (2017); Int J Oral Maxillofac Implant; Netherlands	Randomized clinical trial	Full thickness flap	3M, ESPE	10–18	1.8, 2.1, and 2.4	One-piece
Park et al., (2018); Int J Prosthodont; South Korea	Prospective	Flapless	3M™ ESPE	10–15	2.1 and 2.4	-
Enkling et al., (2019); Clin Oral Implant Res; CH	Prospective	Full thickness flap	MDI™ system 3M ESPE, now distributed by Condent GmbH	13 and 15	1.8	One-piece
Mifsud et al., (2020); Clin Implant Dent Relat Res; Malta	Prospective	Minimal flap reflection	ZEST LOCATOR Overdenture Implant [LODI] system, distributed by Biomet 3i, Palm Beach Gardens, Florida, USA	8–14	2.4 and 2.9	-
Mifsud et al., (2020); Clin Implant Dent Relat Res; Malta	Prospective	Minimal flap reflection	ZEST LOCATOR Overdenture Implant [LODI] system, distributed by Biomet 3i, Palm Beach Gardens, Florida, USA	8–14	2.4 and 2.9	-

**Table 2.** Summary of quantitative data of the 11 included articles on immediately loaded mini dental implants to retain mandibular overdentures.

Study	Participants (n); (Male + Female); Age	No. of MDIs (n)	Follow-Up (Months)	Peri-Implant Clinical Parameters	Peri-Implant Radiographic Parameters (MBL)	Implants Failed (n)	Survival Rate	Key Outcome
Elsyad et al., (2011)	28 (16 + 12); 49–75 years (62.9 mean)	112	36	PI: 2 (0–3) GI: 1 (0–3) PD: $1.39 \pm 0.39$ mm	$1.26 \pm 0.64$ mm	4	96.4%	Clinical and radiographic peri-implant tissue responses of immediately loaded MDIs supporting a mandibular overdenture were favourable after 3 years.
Scepanovic et al., (2014)	30 (14 + 16); 45 to 63 years	MDIs: 120	12	-	-	2	98.3%	MDIs placed into the interforaminal region could achieve a favorable primary stability for immediate loading. The 1-year bone resorption around immediately loaded MDIs is within the clinically acceptable range for standard implants.
Mangano et al., (2014)	62 (38 + 24); 62–86 years (71.1 mean)	231	48	-	$0.62 \pm 0.20$ mm	6	96.9%	Immediate loading one 1-piece, unsplinted, titanium MDIs by means of ball-attachment supported mandibular overdentures is a successful treatment procedure.
Maryod et al., (2014)	36 (20 + 16); 63.4 years (mean)	120	36	PI: 1.688 PD: 1.203 BOP: 1.313	$1.17 \pm 0.65$ mm	7	94.2%	Immediate and early loading protocols demonstrated good clinical outcomes with favourable peri-implant tissue response 3 years after implant placement. Early loading of MDIs supporting a mandibular overdenture seemed to be preferable to immediate loading.
Aunmeungtong et al., (2016);	60 (34 + 26); $69.2 \pm 11.2$ years	60 (2-MDIs: 20+ 4-MDIs: 20+ SDDIs: 20)	12	-	-	0	100%	Two and four MDIs can be immediately used successfully for retaining lower complete dentures, as shown after a 1-year follow up.
Zygiogiannis et al., (2016)	8 (6 + 2); 70.6 years (mean)	110	18	-	$1.05 \pm 0.81$ mm	0	100%	The short-term radiographic peri-implant bone level changes of MDIs immediately loaded with overdentures in the edentulous mandible were within physiological limits. The patients expressed a high level of satisfaction and OHRQoL with this treatment modality.

Table 2. Cont.

Study	Participants (n); (Male + Female); Age	No. of MDIs (n)	Follow-Up (Months)	Peri-Implant Clinical Parameters	Peri-Implant Radiographic Parameters (MBL)	Implants Failed (n)	Survival Rate	Key Outcome
Zygogiannis et al., (2017)	50 (24 + 26); 67.9 ± 7.7 years	150 (MDIs: 100 + SDDIs: 50)	12	PI: 0.43 ± 0.71 PD: 1.76 ± 0.43 BOP: 0.32 ± 0.38	0.42 ± 0.56 mm	2	98%	Immediate loading of four unsplinted MDIs or two splinted SDDIs to retain mandibular overdentures appeared to be a feasible treatment option The marginal bone level changes around the MDIs were well within clinically acceptable range.
Park et al., (2018)	45 (24 + 21); 69.9 ± 7.8 years	177	12	-	0.50 ± 0.75 mm	5	97.2%	There were no significant differences in treatment outcomes between patients treated with MDI or SlimeLine implants. MDIs with wider diameters showed higher initial stability than those with narrow diameters, which may influence implant survival.
Enkling et al., (2019)	25 (5 + 15); 41–87 years (65.5 median)	80	60	-	-	0	100%	MDIs seem to be a successful treatment option for edentulous elderly patients with very high survival and success rates, and serve to improve long-term oral function.
Mifsud et al., (2020)	50 (25 + 25); 66.8 ± 8.1 years	100 (MDIs: 50 + SDDIs: 50)	12	-	0.53 ± 0.67 mm	3	94%	Implant diameter does not affect number of prosthetic maintenance and complications, and that abutment loosening is a risk factor for overdenture fractures, regardless of the implant diameter used.
Mifsud et al., (2020)	50 (25 + 25); 66.8 ± 8.1 years	100 (MDIs: 50 + SDDIs: 50)	12	-	-	SDDIs: 1 MDIs: 3	94%	Mandibular overdentures retained by two SDDIs or MDIs lead to a significant and comparable improvements in OHRQoL and satisfaction over a 1-year follow-up.

Abbreviations: MDIs: mini dental implants; MBL: marginal bone loss; SDDIs: standard diameter dental implants; OHRQoL: oral health-related quality of life; PI: plaque index; GI: gingival index; PD: probing depth.

The groups of investigated participants varied as per the study type; seven studies were conducted using MDIs only [8,17,36,39,40,42,44]; three studies compared the utilization of MDIs with SDDIs [37,38,43]; and one study compared the outcomes of immediate with early loaded MDIs to retain mandibular overdentures [41].

### 3.3. Primary and Secondary Outcome Analysis

A total of 32/1190 MDIs (2.7%) failed with a cumulative survival rate of 97.3% (survival rate range: 94–100%). The peri-implant clinical (plaque index [PI], gingival index [GI], probing depth [PD], and bleeding on probing [BOP]) and radiographic (marginal bone loss [MBL]) parameters were reported by 3 and 6 studies, respectively. Regarding MBL, 5 out of the 6 included studies reported the utilization of different indexing techniques to attach the film-holder for obtaining reproducible images of marginal bone levels on subsequent follow-ups including self-cure acrylic resin [17], polyvinyl siloxane [40,41], distance (mm) from the polished transgingival collar of the implant to the first crestal bone-to-implant contact [8], and light-cure acrylic resin [44]. The mean scores of PI, GI, PD, and BOP ranged between 0–3, 0–3, 1.203–1.76 respectively, whereas the mean MBL values ranged from  $0.42 \pm 0.56$  mm to  $1.26 \pm 0.64$  mm (Table 2).

### 3.4. Key Outcomes

The majority of the studies reported that the immediate loading of MDIs to retain mandibular overdentures seemed to be a feasible treatment option for edentulous patients with a high survival rate. Additionally, studies reported that peri-implant clinical and radiographic tissue responses of immediate loaded MDIs for retaining mandibular overdentures were well within clinically physiological limits at the subsequent follow-ups. According to a study, the number of prosthetic complications is not affected by the diameter of the dental implant, and the loosening of the abutment is a predisposing factor for overdenture fractures, irrespective of the dental implant diameter utilized. One study reported that the application of MDIs having wider diameters demonstrated higher initial stability as compared to those having narrow diameters, which might affect implant survival. Another study concluded that early loading of MDIs supporting a mandibular overdenture appeared to be a preferable option to immediate loading.

### 3.5. Impact of MDIs on Quality of Life and Satisfaction

Out of 11 included articles, only 3 studies assessed the quality of life/degree of satisfaction of patients post prosthetic therapy with MDIs [8,38,43]. The indices described by these studies are as follow (1) Oral Health Impact Profile (OHIP-14); (2) Denture Satisfaction Questionnaire (DSQ); (3) Visual Analogue Scale Satisfaction (VAS); and (4) Oral Health-Related Quality of Life (OHRQoL). The chewing efficacy was reportedly unchanged using immediate loaded MDIs to retain mandibular overdentures at 1-year follow-up, however, it was enhanced at 5-year follow-up. Moreover, a constant increase in the maximum voluntary bite force (MBF) was observed over time. Additionally, a high level of OHRQoL and satisfaction was expressed by the patients receiving this treatment modality.

### 3.6. Risk of Bias/Quality Assessment

In the qualitative analysis, quality assessment exhibited a wide variety across the included articles (Table 3). Four studies demonstrated a low risk of bias [8,41,42,44], two studies showed medium risk of bias [39,43], and five studies exhibited high risk of bias [17,36–38,40]. Therefore, a high risk of bias was observed for the included studies.



**Table 3.** Quality assessment of studies included in the systematic review.

Study	R	B	Clear and Appropriate Focused Study Question	Identical Treatment Except for Intervention	Defined Eligibility Criteria	Sufficient Number of Implants	Follow-Ups Completed/ Dropouts/Reason for Dropout (Yes/No)	Conflict of Interest Stated	Funding Source	Risk of Bias
Elsyad et al., (2011)	No	No	Yes	Yes	Yes	Yes	Yes	No	No	High
Scepanovic et al., (2014)	No	No	Yes	Yes	Yes	Yes	Yes	No	No	High
Mangano et al., (2014)	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	High
Maryod et al., (2014)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Low
Aunmeungtong et al., (2016)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Medium
Zygogiannis et al., (2016)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Zygogiannis et al., (2017)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Park et al., (2018)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Enkling et al., (2019)	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Medium
Mifsud et al., (2020)	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	High
Mifsud et al., (2020)	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	High

Abbreviations: B: blinding; R: randomization.

#### 4. Discussion

The present systematic review aimed to investigate the survival rate of immediate loaded MDIs to retain mandibular overdentures in edentulous patients. Although MDIs were introduced around 15 years ago, however, there is a dearth of published studies regarding implant/prosthetic literature [13]. Moreover, only four articles reported a follow-up duration of  $\geq 3$  years. Additionally, relatively low sample size was observed in the majority of the included studies. Furthermore, no study compared the MDIs with narrow diameter dental implants, while only four studies compared the MDIs with SDDIs for fixed prosthetic therapy. In addition, no study described the application of immediate loaded MDIs to retain maxillary overdentures. Contrarily, a few reports on the application of MDIs for orthodontic therapy were observed [45–47]. This might be due to the short duration that MDIs are utilized in orthodontic treatment; this aids in designing the study.

In the current review, NDDIs were not considered to be included in order to perform a more targeted search. This explicit differentiation between MDIs and NDDIs was made to resolve all possible ambiguities. The GOMI definition of MDIs and threshold of  $>3$  mm implant diameter was applied [48]. As no previous consensus reports or clinical studies have differentiated between these two kinds of dental implants, we selected the GOMI definition of MDIs in combination with a threshold of  $>3$  mm implant diameter. According to the authors of the present review, a dental implant having a diameter of  $\leq 3$  mm is best considered to be an MDI, which is considerably different from NDDI. This adoption of the GOMI definition and 3 mm implant diameter threshold is recommended for future studies on MDIs.

The hypothesis has been accepted since this systematic review reported a high survival rate (97.3%) for immediate loaded MDIs for retaining mandibular overdentures, and this survival outcome was comparable to those using SDDIs to retain overdenture prostheses [49,50]. These outcomes suggest that MDIs for mandibular overdentures might become a feasible therapeutic technique, particularly for patients having limitations including financial constraints because SDDIs need a particular retention system for retaining prostheses (i.e., bar-clip, ERA<sup>TM</sup>, O'ring), while MDIs are mostly single-body dental implants including the ball system. Furthermore, postoperative morbidity is decreased by using MDIs in patients who are unable to be subjected to extensive surgical procedures; in the majority of instances, the installation of MDIs is carried out without the utilization of surgical flaps [30,51].

Generally, the overall survival rate of immediate loaded MDIs for retaining mandibular overdentures is favorable as reported by the outcomes of the present review. Of the included studies, four studies compared the utilization of MDIs with SDDIs. According to two reports conducted by Mifsud et al. [37], lower survival rates were exhibited by MDIs in comparison with SDDIs, i.e., one SDDI failed (98%), while three MDIs failed (94%). Similarly, according to Zygiogiannis et al. [8], MDIs showed lower survival rates as compared to SDDIs, i.e., two MDIs failed (98%), while no SDDI failed (100%). In the present study, a higher survival rate ( $>96\%$ ) was observed by utilizing longer MDIs (10–18 mm) as compared to shorter MDIs (8–14 mm) ( $<95\%$ ). Similar outcomes were noticed in a study reported by Tomasi et al. [52], according to which MDIs having a short length (7–10 mm) exhibited a higher failure rate as compared to longer MDIs (14 mm). Hence, the longevity of MDIs might be affected by their length, and longer MDIs should be chosen for better treatment outcomes.

Of the 11 included articles, nine were prospective studies, while two were clinical trials. A variable reporting method on MDIs' follow-up was observed in several studies, which led to a challenging quantitative data extraction as follow: (a) most studies reported a wide follow-up duration (i.e., between 12 months and 60 months); (b) the majority of studies failed to report the number of implants followed during a particular interval of time and did not mention the timing of implant failure; (c) the majority of studies reported follow-up durations of  $<3$  years; (d) most of the studies ( $n = 6$ ) described a follow-up duration of 12 months only, indicating that the long-term survival rate of MDIs is unknown;

and (3) only one study described the life table survival analysis with an interval survival rate and cumulative survival rate of 94.7% each. It is essential to note that the 1st year interval survival rate of 94.7% does not indicate the one-year true survival rate of MDIs, since not all MDIs had a minimum follow-up duration of 12 months.

McGill consensus suggests the utilization of two SDDIs for retaining mandibular overdentures [53]. With regards to the application of MDIs, most of the articles included in the present review utilized four MDIs for retaining mandibular overdentures, whereas two articles utilized two MDIs, and only one study utilized both two and four MDIs. On assessing the effect of the number of MDIs in the same article [43], higher prosthetic complications were observed for the utilization of two MDIs ( $n = 64$ ) as compared to four MDIs ( $n = 52$ ). Moreover, the findings of the present review suggest that four MDIs are linked with higher rates of patient satisfaction and quality of life. Hence, the use of four MDIs might be recommended to retain mandibular overdentures for prosthetic rehabilitation.

The findings of the included studies in the present review report that the MBL was well within clinically physiological limits [54], and no study reported an MBL of  $\geq 1.5$  mm. It is imperative to notice that this review examined bone loss scores in the mandibular arch, and this might have affected this variation. Hence, further studies following subjects over longer durations to assess MBL in both the maxillary and mandibular arch should be carried out to compare the bone loss of MDIs with SDDIs.

Regarding the surgical technique, most of the studies used the full-thickness flap technique for the placement of MDIs (45.45%), followed by the flapless technique (36.36%). Some authors recommend the use of a flapless procedure since it might decrease discomfort, postoperative pain, and resultantly reducing the morbidity of patients [13,17,29]. However, Ribeiro and colleagues [51] compared the flap technique with the flapless technique for installing SDDIs and observed no difference with regards to postoperative morbidity and/or pain.

One of the limitations of this systematic review is the inclusion of the studies published in English language only. Although, there has been a remarkable increase in the number of studies that have examined the behavior of immediate loaded MDIs to retain mandibular overdentures, however, there are a very limited amount of randomized controlled/clinical trials. Moreover, the challenge of blinding the research investigators, participants, and outcome assessors might be regarded as a bias of this review. Therefore, caution should be taken while interpreting the outcomes of this study because of lower number of randomized controlled/clinical trials, and further clinical trials should be conducted to better answer in regards to rehabilitation therapy using mandibular overdentures retained by MDIs. Despite this, the utilization of immediate loaded MDIs for retaining mandibular overdentures exhibits viability, high patient satisfaction and quality of life, adequate survival rates, and clinically acceptable peri-implant clinical and radiographic parameters.

## 5. Conclusions

Within the boundaries of the present systematic review, the utilization of immediate loaded MDIs to retain mandibular overdentures is an alternative treatment modality as it demonstrates high survival rates of MDIs, favorable peri-implant clinical and radiographic tissue response, and enhancements in parameters associated with quality of life and satisfaction of patients.

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