Survival of Mini Dental Implants Used to Retain Mandibular Complete Overdentures: Systematic Review

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Purpose: *To evaluate the survival rate of mini implants used to retain mandibular overdentures.* ***Materials and Methods:*** *An electronic search, supplemented by hand searching of the references, was conducted with no time or language restriction in October 2016 and updated in October 2017. The results were reviewed independently by the two authors. All randomized controlled trials, clinical trials, observational studies, and case series were included. The primary outcome measure was implant survival (months).* ***Results:*** *The search retrieved a combined total of 391 articles. Following screening, 17 articles were included. A total of 1,715 mini implants were assessed in 475 patients. Follow-up periods ranged from 6 to 84 months (mean: 28.24 months). There were 75 failures in total. The overall survival rate was 95.63%. The majority of patients received four implants to retain their prostheses. Most studies used a flapless surgical technique, but there were vast differences in loading protocols and retention methods. Formal meta-analysis was not conducted due to the heterogeneity between studies.* ***Conclusion:*** *Based on the findings of this systematic review, mini dental implants exhibit excellent survival rates in the short to medium term. They appear to be a reasonable alternative treatment modality to retain mandibular complete overdentures from the available evidence.* Int J Oral Maxillofac Implants 2019;34:343–356. doi: 10.11607/jomi.6991

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Dental implants exist in a variety of lengths, diameters, and designs depending on their use. Mini implants are implants of a narrower diameter than conventional implants (Fig 1). However, accepted definitions of the dimensions of "conventional", "regular," or "mini" implants are lacking.[1,2] A classification system for the description of width and length of dental implants has been proposed based on frequency of use of terminology pertaining to implant lengths and diameters. It suggests a classification of all implants less than 3.0-mm diameter to be termed "extra-narrow" implants.[2] However, it does not take into account the design features of mini implants, which are often one-piece implants with diameters of 1.8 to 2.4 mm.[3–5] Frequently, mini implants are placed using a flapless technique, and therefore, are often subject to immediate loading protocols, although this may not be functional loading. Most often, mini implants are made of a titanium alloy (eg, Ti 6Al-4V ELI). This makes them an inherently different type of implant compared with other implants of various diameters, as they differ in more than just width. Therefore, despite the proposed classification system, the authors prefer to maintain the term "mini implant" to differentiate this type of implant from others.

Mini implants have been an available treatment modality for more than 20 years.[6] Originally used as transitional implants[7] or for orthodontic anchorage[8] with a plan for subsequent removal, they evolved into more definitive treatment strategies when it transpired that they were very difficult to remove, as they had osseointegrated.[9] They have been increasingly used to restore single missing teeth,[10] multiple-unit fixed prostheses,[11]

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Fig 1 *(left)* Standard-diameter "root form" implant; *(right)* one-piece mini implant with ball abutment (not to scale).

Table 1 PICO Parameters

	Criteria
Population	Human subjects with a completely edentulous mandible; no age or sex limits
Intervention	Mini implants used to retain a mandibular complete overdenture. No limit on number of implants used or location (within the mandible). No restriction on type of mini implant (must have diameter ≤ 2.4 mm), surgical protocol, loading protocol, prosthetic attachment system, or opposing dentition. Prosthesis must be removable and implants placed with a view to definitive treatment.
Comparisons	Not applicable to research question
Outcomes	Survival of mini implant
Study design	Prospective and retrospective case series, case control, cohort studies, clinical trials, randomized controlled trials

removable complete dentures,[12] and intraoral maxillofacial prostheses.[13] They are also now being placed immediately following dental clearance for prosthodontic rehabilitation.[14] Concern regarding possible high levels of fatigue fracture of these implants in high-stress areas has resulted in their use being limited to removable prostheses by many.

Mini implants are becoming more popular in the management of patients with edentulous mandibles because of lower costs and acceptability of the less-invasive procedure among this group of (often more elderly) patients.[14,15] They have been shown to result in high patient satisfaction post-treatment.[15,16] However, there are very few high-quality studies in the literature to highlight their efficacy and establish their survival rates. Limited cohort[5,15] and retrospective[3] clinical studies have shown acceptable survival rates in the short/intermediate term of approximately 91% after an average of 3.5 years.[17]

The aim of this systematic review was to determine the survival rates of mini implants placed in edentulous patients to retain removable mandibular complete overdentures.

MATERIALS AND METHODS

Review Method

Focused Question/Protocol. The search method and write-up followed the "Preferred Reporting Items for Systematic Reviews and Meta-analyses" (PRISMA) guidelines.[18] The research question, "What is the survival rate of a mini implant placed in the edentulous mandible when used to retain a removable complete overdenture?" was applied. Mini implants were defined as one-piece implants of diameter 1.8 to 2.4 mm. Failure was defined as the loss of the implant (either exfoliation or removal). To formulate a meaningful search strategy, the PICO (population, intervention, comparison, outcome) strategy[18,19] was used as a basis to help construct the search terms and inclusion criteria. A comparator was not employed as part of the search strategy, as this was not a component of the research question (Table 1).

A preliminary search was conducted prior to applying strict exclusion criteria, to assess the availability and quality of relevant studies in order to avoid returning a meaningless search result. As such, a formal protocol was designed but not registered a priori. The scoping search confirmed the lack of high-quality evidence in this area, and also portrayed large variation in reported outcomes, outcome measures, and follow-up times. The only factor that united the studies was inclusion of survival of the implant as a reported outcome, and this was used as the primary outcome measure of the review.

Eligibility Criteria

The eligibility criteria for studies were defined by the PICO criteria outlined in Table 1 and modified by the following inclusion criteria:

- Mini implant(s), defined as a one-piece implant of diameter 1.8 to 2.4 mm
- Mini implant(s) were used to retain a lower complete overdenture.
- Minimum follow-up period of 6 months
- Survival data must be reported and identifiable.

The exclusion criteria were:

- Restorations supported by a combination of mini and standard/narrow diameter implants
- There were fewer than three patients in a case series.

- Mean follow-up time was less than 6 months, and data could not be selectively extracted at the implant level to determine those with a longer follow-up duration.
- Cohort data had been previously published (to avoid duplication).
- Insufficient data were presented to allow extraction for survival analysis, and the authors could not be contacted.

No time or language restrictions were placed on the included studies, and where studies reported on a wider population and when sufficient data were available, these were excluded on an individual level (ie, applicable subsections of the population were included for the data analysis).

Literature Search

Information Sources. A specific electronic literature search was conducted of multiple databases from inception up to October 9, 2016. This was then updated on October 16, 2017. Databases searched included MEDLINE (including epub ahead of print and pre-indexed) and Embase via the Ovid interface, Web of Science, EBSCOhost – Dentistry and Oral Sciences Database, Cochrane Central Library, ClinicalTrials.gov, and WHO Clinical Trials Registry Platform. The electronic search was supplemented with hand searching of the reference lists of included studies or any literature reviews found on the topic. For articles written in non-English language, translations were sought.

Search Strategy

The search strategy for each database is presented in Appendix 1 (see online version of this article at quintpub.com).

Study Selection

All citations were initially imported into Endnote citation manager, and subsequently uploaded to the online systematic review software Covidence (www.covidence.org). Following removal of duplicate citations, a two-stage screening process was conducted independently by two reviewers (S.J., P.C.). In the first stage, titles and abstracts were reviewed to exclude any irrelevant titles. Any disagreement was resolved by discussion. If doubt existed, titles were retained for full text review.

In the second stage, full texts were collected and reviewed for inclusion in line with the criteria outlined above; any disagreement was resolved by discussion.

Where a study was excluded because the cohort data had already been reported on, the original reference was used unless a later publication had a longer follow-up time or a larger sample or data presentation was more clearly presented in another study to facilitate data extraction.

Data Collection and Synthesis

All full texts included were subject to a methodologic assessment, following which the data were extracted using a predesigned proforma. Where data were missing or individual patient data could not be extracted from the information presented, the authors were contacted via email. If information could not be obtained within 8 weeks, then the studies were excluded. For all but one study, data were extracted and quality reviewed independently by both reviewers, then compared for consistency. The study by Jawad et al[20] was only assessed by one author (P.C.) to limit potential reporting bias, as they had no association with the original study.

Data Items

The data recorded included: names of author(s), year of publication, study design, number of participants, demographics (age, sex), brand of implant, size of implant (length and diameter [mm]), total number of implants evaluated (patient-level data as well where possible), surgical method, loading protocol, attachment type, follow-up range (months), implant survival time (months), groups/interventions evaluated, and other outcomes reported. Table 2 summarizes the findings of each study.

Quality Assessment/Risk of Bias Assessment

Quality assessment of included studies was conducted using guidance from the Cochrane handbook for systematic reviews.[21] Randomized controlled trials were assessed using the "Cochrane Risk of Bias Tool." For cohort studies, the recently proposed ROBINS-I tool was employed, which has moved to a domains-based approach (similar to the Cochrane Risk of Bias Tool), rather than the traditional Newcastle-Ottawa scale, which focuses on methodologic quality.[22] Finally, all studies were given a quality grade related to the primary outcome of the review (mini-implant survival) in accordance with the GRADE approach.[23,24]

Data Synthesis

The primary outcome measure of interest was the survival time of mini implants. The survival time was defined from first placement to loss of the implant. Intraoperative fractures were also classified as a failure, but were excluded from the survival analysis. Where feasible, any replacements were included in the analysis. Data were standardized and recorded in number of months for analysis. Given the lack of high-quality evidence, limited information presented in some studies, and heterogeneity between methods, it was felt that

Table 2 Summary of Included Studies

Study	Study design	No. of patients (M:F)	Mini implants analyzed (n)	Mean age (y)	Diameter and length (mm)	Implant system	Flapless (Y/N/NK)
Arafa (2016)[35]	RCT	20 (M:10)	80 (4 each)	56	1.8 × 13	Dentium, Slim Line	NK
Brandt et al (2012)[27]	Prospective case series	24 (unknown M:F ratio)	96 (4 each)	NK	2.0 × 10/11.5/13/15/18	MDL (Intra-Lock) Ti grade 23	Y
Catalán et al (2016)[28]	Prospective case series	7 (unknown M:F ratio)	14 (2 each)	NK (62–74)	1.8 × 13 or 15	Sendax MDI; IMTEC	Y
Cho et al (2007)[25]	Retrospective case series	10 (M:3/F:7)	36 (2 × 2 each) (8 × 4 each) [NB: reports n = 34, but numbers per patient add up to 36]	58	2.4 × 7/10/14	Atlas, Dentatus	Y
de Souza et al (2015)[34]	RCT (intention to treat analysis)	80 (unknown M:F ratio) (9 LTFU 4: n = 3 2: n = 6)	236 (38 × 4 each) (42 × 2 each)	59.5	2.0 × 10	MDL (Intra-Lock)	Y (78%–80%) N (20%–22%)
Elsyad (2016)[29]	Prospective case series	28 (M:16/F:12) 4 LTFU	96 (4 each)	62.9	1.8 × 12–18	Sendax MDI; IMTEC	Y
Enkling et al (2017)[30]	Prospective case series	20 (M:5/F:15)	80 (4 each)	65.5	1.8 × 13 or 15	3M ESPE (formerly IMTEC MDI)	N
Jawad et al (2017)[20]	RCT	22 (M:10/F:12) 2 LTFU	40 (2 each)	68.5	2.1 × 10	3M ESPE (formerly IMTEC MDI)	Y
Jofré et al (2010)[33]	RCT (intention to treat analysis)	45 (M:18/F:27) 2 LTFU (2 in group 2)	90 (2 each)	71	1.8 × 15	Sendax MDI; IMTEC	Y
Maryod et al (2014)[36]	RCT	36 (M:20/F:16) 6 LTFU (3 per group)	120 (4 each)	64.1	1.8 × 15	Sendax MDI; IMTEC	Y

RCT = randomized controlled trial; NK= not known; LTFU= lost to follow-up; PROMs = patient-reported outcome measures; QoL= quality of life; OHRQoL= oral health–related QoL; OHIP = Oral Health Impact Profile; VAS = visual analog scale; PPD = pocket probing depths; MBL = marginal bone loss.

Loading protocol	"O"-rings used?	Follow-up time (mo)	Survival rate	Quality of evidence (GRADE rating)	Groups evaluated	Other comments or outcomes
Unclear	NK	24	100%	Low	G1: Angulated abutment G2: Nonangulated abutment	Surgical technique not known. Significant improvement in marginal bone height post-placement in nonangulated group.
Immediate loading	Y	24	93% 6/96 lost	Very low	Mini implants only	PROMs reported overall improvement in patient satisfaction with dentures. All implants lost were placed in smokers.
Post-immediate (15 d)	Y	84	100%	Very low	Mini implants only	Quantitative measure of retention using dynamometer showed maintained improvements of mini implant–retained overdentures at 7 y in all patients.
Immediate with soft reline	N (soft reline used instead)	14–36 (mean 22.8, max 36 months)	94.1% 2/36 lost	Very low	Mini implants only	Despite implant loss 100% prosthesis survival at 36 mo. PROMs improved.
Early (1 wk) chairside soft reline Delayed (3 mo) loading with O-rings	Y	12	86.9% 31/236 lost G1: 16 G2: 15	Moderate	G1: 4× mini implants G2: 2× mini implants G3: 2× conventional implants	OHRQoL (OHIP-EDENT), satisfaction, and survival assessed. Significantly better OHIP-EDENT in mini groups compared to conventional regardless of number. Greater numbers in mini implant group had better masticatory efficiency.
Immediate	Y	60 (6 mo, 12 mo, 36 mo, 60 mo)	96% (3 fractures)	Very low	Mini implants only	High patient satisfaction with denture (increasing over time) using VAS questionnaire. High rate of "O"-ring damage reoccurring at each time interval. Low mucosa complication rates.
Immediate if torque > 35 Ncm 3 implants of torque < 35 Ncm delayed (3 mo)	Y	12	100%	Very low	Mini implants only	Chewing efficiency did not improve following implant placement (underpowered for detection). Quality of life and mean occlusal force improved significantly following implant placement.
1 week no loading Delayed loading (2 mo)	Y	6	95% 1/20 lost	Low	G1: 2× mini implants G2: 2× conventional implants	Trend for improvement in all QoL measures in both groups with no visual difference between mini and conventional implants. Trend present that mini implants cause less postoperative pain and cost less than conventional implants.
Immediate loading	Y: n = 44 N: Bar = 46	24	94% 5 lost	Low	G1: Splinted mini implant (contaminated with stainless steel) G2: Nonsplinted mini implants	Similar survival rates in splinted (contaminated group) and nonsplinted mini implants. Slightly more failures in nonsplinted group but not statistically significant. (Findings from same cohort [different paper][58] showed more marginal bone loss around unsplinted mini implants.)
Immediate (n = 16) Delayed (n = 16) G2 had soft reline at 2 wk, then O-rings at 3 mo	Y	36	94.2% 8/120 all lost before 12 mo	Moderate	G1: Immediate loading G2: Delayed loading	No significant difference in marginal bone levels at 3 y between groups. Relatively stable after 12 mo. Gentle trend for increase in plaque levels over time; not significant.

Table 2 Summary of Included Studies (cont.)

Study	Study design	No. of patients (M:F)	Mini implants analyzed (n)	Mean age (y)	Diameter and length (mm)	Implant system	Flapless (Y/N/NK)
Mundt et al (2015)[26]	Retrospective case series	95 (unknown M:F ratio)	402 (3: n = 1) (4: n = 76) (5: n = 13) (6: n = 5)	68.8	1.8 (82%) 2.1 (18%) length:10–18	Sendax MDI; IMTEC	Y/N (both)
Omran et al (2013)[37]	RCT	7 (M:7)	28 (4 each)	55	1.8 × 15	Sendax MDI; IMTEC	Y
Preoteasa et al (2014)[31]	Prospective case series	16 (unknown ratio M:F)	74 (4–6 each)	NK	1.8/2.1/2.4 × 10/13/15/18	Sendax MDI; IMTEC	NK
Šćepanović et al (2012)[5]	Prospective case series	30 (M:14/F:16)	123 (4 each) (3 replaced after intraoperative fracture)	NK (range 45–63)	1.8 × 13	3M ESPE (formerly IMTEC MDI)	Y
Temizel et al (2017)[38]	Cohort study	22 (M:10/F:12)	99 MDI (4–5 each)	71	1.8–2.4 × 10/13	3M ESPE (formerly IMTEC MDI)	N
Tomasi et al (2013)[15]	Prospective case series	17 (unknown ratio M:F)	72 (3: n = 2) (4: n = 15) (6 replaced after failed integration)	71 y	1.8/ 2.2/2.4 × 14/10/7	Dentatus Atlas	Y
Zygogiannis et al (2016)[32]	Prospective case series	10 (M:6/F:2 2 dropped out)	32 (4 each)	70.6	1.8/ 2.1 × 10–15	3M ESPE (formerly IMTEC MDI)	N

RCT = randomized controlled trial; NK= not known; LTFU= lost to follow-up; PROMs = patient-reported outcome measures; QoL= quality of life; OHRQoL= oral health–related QoL; OHIP = Oral Health Impact Profile; VAS = visual analog scale; PPD = pocket probing depths; MBL = marginal bone loss.

it was not appropriate to pool the data or perform any advanced statistical methods. Therefore, survival data were summarized into a forest plot, grouped by duration of follow-up, rather than formally combined in a meta-analysis. The quality of data was also too limited to perform any statistical bias assessment. Secondary outcomes were reported purely in a narrative manner.

RESULTS

Three hundred sixty-four references were returned from the online electronic search; a further 27 were found from hand searching of relevant articles. Out of these, 78 duplicates were removed, and 236 irrelevant titles were excluded in the first stage. Following full-text analysis, a further 60 studies were excluded having not fulfilled the inclusion criteria. A total of 17 studies were finally included for data extraction and analysis. The PRISMA flowchart is presented in Fig 2, and Table 2 provides a summary of the study characteristics and main findings.

Quality of Evidence

The vast majority of studies (10/17) included were retrospective[25,26] or prospective[5,15,27–32] case series

Loading protocol	"O"-rings used?	Follow-up time (mo)	Survival rate	Quality of evidence (GRADE rating)	Groups evaluated	Other comments or outcomes
Immediate loading if torque > 35 Ncm If < 35 Ncm used soft reline to load for 3–4 mo prior to O-ring loading	Y	29 (avg) (up to 60)	94.3% (48 mo) 11/402 lost 4/402 fractured (2 during placement)	Low	Mini implants only (also examined in maxilla)	OHRQoL (OHIP-G14) demonstrated significant improvements from baseline at 4 y. Further study[59] of same cohort reported majority of subjects lost < 1.0 mm of bone loss of their follow-up period. Former smokers had significantly more bone loss.
Immediate	Y	12	100%	Low	G1 = mini implants G2 = conventional implants (Biohorizon)	No difference between groups on gingival index and probing depths. Statistically increased MBL for mini implants at 12 months ($P = .025$)— questionable as to whether clinically significant.
NK	NK	36	100%	Very low	Mini implants only (also reports on use in maxilla)	Greater bone loss around implants placed in less dense bone, with lower torque values, placed in distal locations, that have inflamed peri-implant tissues and those placed in females. Cluster failures in two patients.
Immediate (within 24 h)	Y	12	95.9% 5/123 (3 intraoperative fracture, 2 delayed failure)	Very low	Mini implants only	Significantly improved QoL measured (OHIP-EDENT) and chewing ability ($P < .001$). 3 fractures of overdentures recorded.
Delayed (4 mo)	Y	24	100%	Very low	G1 =mini implants G2 = conventional implants (10 patients) (TioLogic-ST implants)	No statistical difference in bone height and cortical thickness between groups at 6 mo. At 24 mo, no difference in plaque scores and bleeding score. Shallower PPD in mini implant group at 12 mo but both groups between 2–3 mm. Primary and secondary stability better in conventional group. But not clinically significant – both within grade 0 mobile range.
Immediate soft reline	N	12	85% 11/72 (replacements followed for 9–11 mo)	Low	Mini implants only	QoL measures (function and comfort) indicated marked positive impact of implant-retained mandibular overdentures using VAS scales.
Immediate loading	Y	18	100%	Very low	Mini implants only	Absolute QoL measures indicated high level of satisfaction with prostheses. Marginal bone levels increased from baseline.

providing low to very low quality evidence (GRADE scale), varying predominantly because of their length of follow-up and respective sample sizes. For the remaining studies, six of these were randomized controlled trials,[20,33–37] and one was a quasi-experimental study of a cohort design.[38] All studies suffered from high risk of bias in relation to blinding of the participants, presumably for ethical reasons, and a few showed high risk of bias in other domains. Table 3 depicts the risk of bias assessment for the randomized controlled trials. Using the ROBINS-I tool, the cohort study was assessed to be at "serious risk of bias" overall (Table 4). Again, the quality of evidence that these studies provide on the GRADE scale, in reference to the primary outcome, implant survival, was moderate to low due to methodologic inconsistencies, short follow-ups, and limited sample sizes. Table 5 provides a summary GRADE score of each included study.

Survival

There was marked variation in the follow-up periods of the included articles, ranging from 6 months to 84 months. It was not possible to pool the data and provide a Kaplan-Meier survival curve, as precise failure times were not known. However, the data were pooled according to known follow-up times, and survival

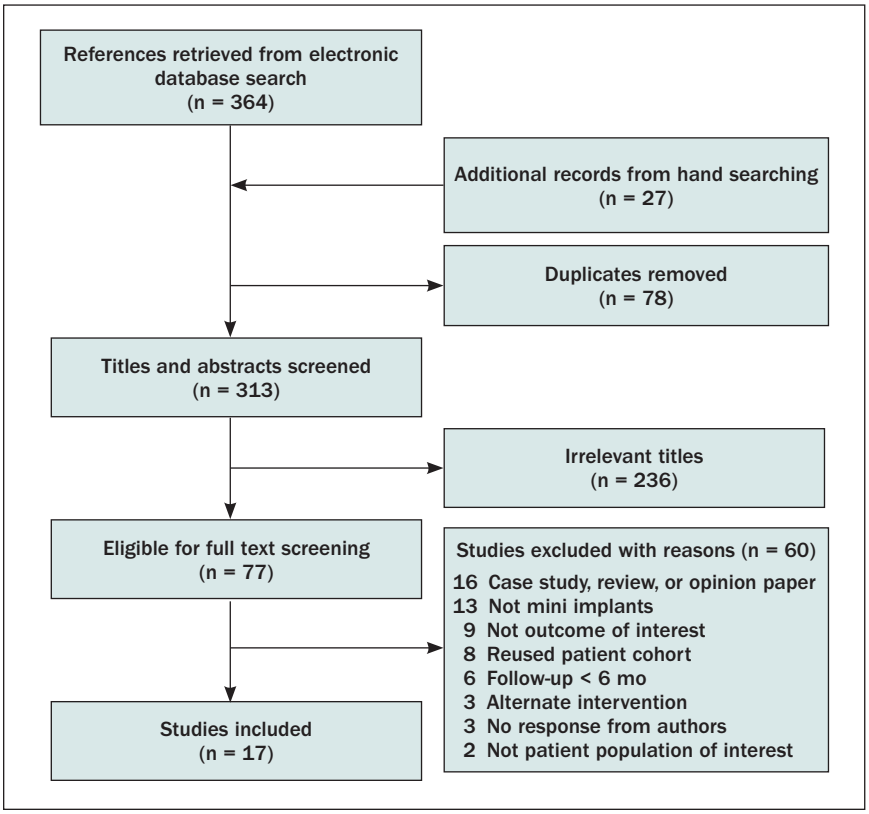

Fig 2 PRISMA flowchart for the study.

Table 3 Cochrane Risk of Bias Assessment

	Selection bias		Performance bias		Detection bias		Attrition bias	Reporting bias	Other biases
Study	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Other potential threats to validity	Blinding of outcome assessment	Other potential threats to validity	Incomplete outcome data	Selective outcome reporting	Additional sources of bias
Arafa (2016)	–	–	–	+	?	–	+	?	+
de Souza et al (2015)	+	+	–	+	+	+	+	+	+
Jawad et al (2017)	+	+	–	+	+	?	+	+	+
Jofré et al (2010)	+	?	–	?	?	–	+	?	+
Maryod et al (2014)	+	?	–	+	–	+	+	+	+
Omran et al (2013)	?	–	–	?	?	–	+	+	+

forest plots of the individual studies are shown in Fig 3. They reveal that within the first year after placement, four out of six studies (66.7%) reported implant failure. Of the 576 implants placed and followed up within this period, 36 failed, giving a 12-month failure rate of 6.25%.

The five studies with 18- to 24-month follow-up revealed 11 failures in 397 mini implants, which equates to 2.77%. The three studies with 3-year follow-up showed that out of 230 mini implants, 10 failed, which equates to 4.35%. The three studies with follow-up of 4 years or greater depicted 18 failures in 597 mini implants, giving a failure rate of 3.01%.

In total, 1,718 mini implants were included as part of the study. Three failed intraoperatively and were replaced immediately; these were excluded from the survival analysis, which was interested in functional survival of the implants. Out of a total of 1,715 mini implants, 75 failed, reflecting an overall failure rate of 4.37%.

Table 4 ROBINS-I Assessment Tool

Study	Pre-intervention		At intervention	Post-intervention				
	Bias due to confounding	Bias in selection of participants	Bias in classification of interventions	Bias due to deviations in intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of reported results	Overall risk of bias judgment
Termizel et al (2017)	Serious risk of bias	No info	Serious risk of bias	Moderate risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Serious risk of bias

Table 5 Quality of Evidence Summary

Study	Study design	Quality level (GRADE rating)	Supporting evidence
Arafa (2016)	RCT	Low	Double downgraded because of small sample size, entirely male cohort, and measurement tool for bone loss (panoramic radiograph) not accurate. Moreover, high risk of bias in majority of domains, even though results imply that there were no failures at 24 months and that bone loss was minimal.
Brandt et al (2012)	Prospective case series	Very low	Simple study design with limited outcome data reported. Demographics and confounders not reported. Grade given due to study design and relatively short follow-up, even though reasonable numbers.
Catalán et al (2016)	Prospective case series	Very low	Although good follow-up and reports on peri-implant mucosal health, grade given because of study design, small sample size, and no objective measure of peri-implant bone health.
Cho et al (2007)	Retrospective case series	Very low	Grade given as small sample size, retrospective nature, with relatively short follow-up period.
de Souza et al (2015)	RCT	Moderate	Well-conducted RCT with no major design flaws and good transparency in reporting of results. Downgraded due to relatively short follow-up leading to imprecision of possible conclusions on generalizability of survival.
Elsyad (2016)	Prospective case series	Low	Simple study design but rating improved for good follow-up time and reasonable numbers of implants followed up.
Enkling et al (2017)	Prospective case series	Very low	Grade given due to simple study design, low sample size, and short follow-up. The study is described as exploratory in nature and is underpowered to detect differences for some of the variables assessed.
Jawad et al (2017)	RCT	Low	Although a well-conducted and reported study, double downgraded RCT due to relatively small sample size and short follow-up, leading to imprecision of determining survival long term.
Jofré et al (2010)	RCT	Low	Significant limitations in design of RCT reducing quality of evidence, particularly in relation to detection and performance bias. Double downgraded due to short follow-up time, limited numbers involved (underpowered), and limited details in reporting of survival outcomes.
Maryod et al (2014)	RCT	Moderate	Although the study design is reasonable, some limitations occurred; namely, the dropout rate caused the cohort to fall below the number required from the sample size calculation. Therefore, downgraded due to low power and relatively limited follow-up period.
Mundt et al (2015)	Retrospective case series	Low	Simple study design with limitations in reporting of some outcomes. Upgraded because although retrospective in nature, large sample size and reasonable follow-up.
Omran et al (2013)	RCT	Low	Double downgraded due to significant limitations in study design and implementation, including low sample and limited follow-up time.
Preoteasa et al (2014)	Prospective case series	Very low	Graded due to study design, limited follow-up, and low sample size (large numbers of implants clustered in individuals).
Šćepanović et al (2012)	Prospective case series	Very low	Graded due to study design, short follow-up period, and limited reporting of all measures (eg, bone levels even though radiographs taken).
Temizel et al (2017)	Cohort study	Very low	Graded due to observational study design, unmatched control and study groups, lack of reporting of potential confounders, limited follow-up, and small sample size.
Tomasi et al (2013)	Prospective case series	Low	Graded due to observational study design, small sample size and limited follow-up duration. Upgraded due to transparency of reporting.
Zygogiannis et al (2016)	Prospective case series	Very low	Graded due to observational study design, very small sample size, and limited follow-up. Moreover, shortcomings in validity of bone level measures (from panoramic radiographs) and risk of bias from selective reporting (no baseline QoL measures).

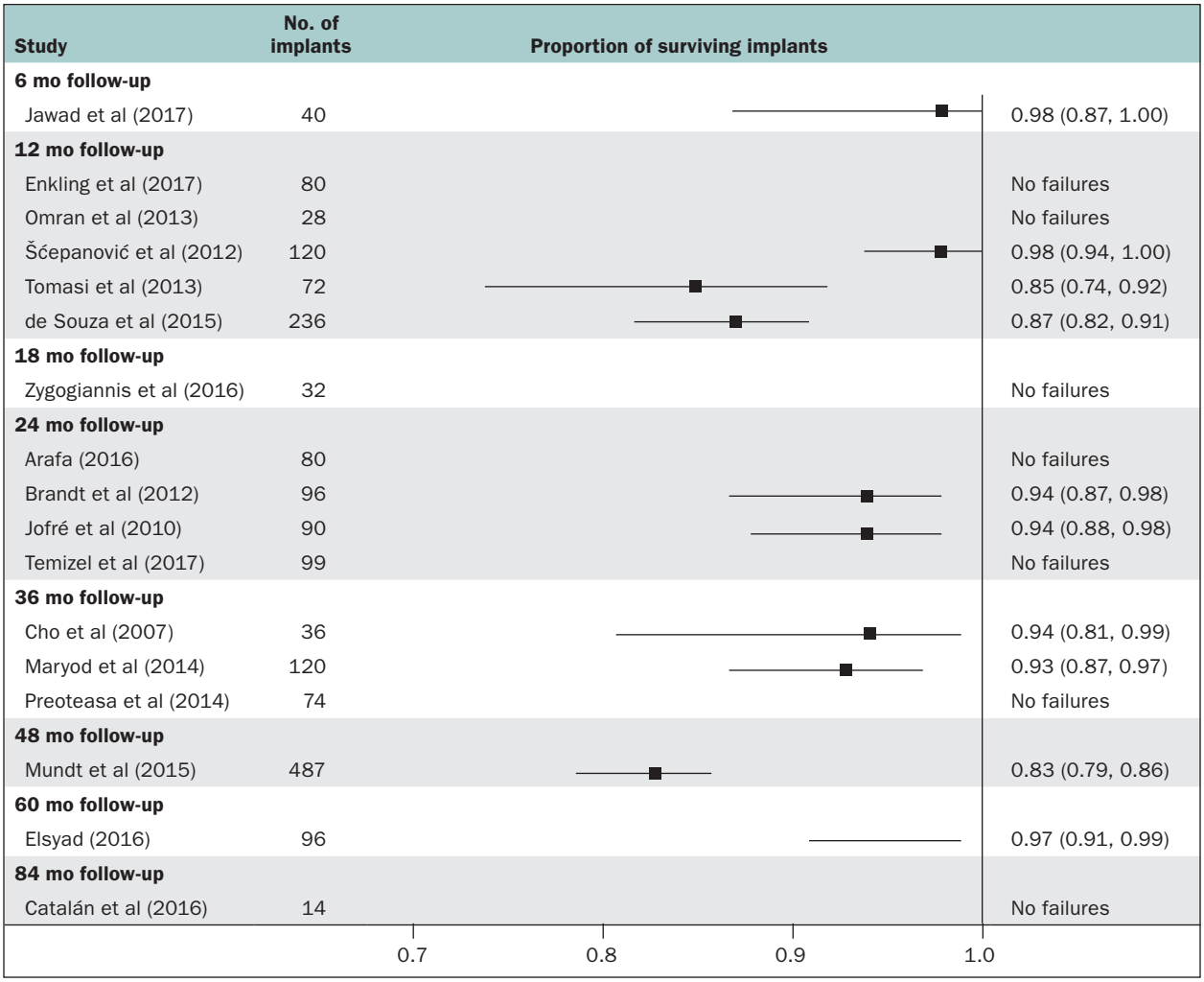

Fig 3 Forest plot of included study implant survival rates.

Table 6 Summary of Frequency of Implant Numbers Per Patient

No. of implants	No. of patients	No. of implants
2	116	232
3	3	11 (+2 replacements)
4	300	1,207 (+7 replacements)
5	13	65
6	5	30
Unspecified	16 (≥ 4 MDI); 22 (4–5 MDI)	173
Total	475	1,718

Implant Number

The majority of studies presented either two or four mini implants in the interforaminal area, or a combination of two or four. Occasionally, three, five, or six mini implants were used. A summary of the frequency of each number of implants is given in Table 6. In total, 1,718 mini implants were placed in 475 patients (mean: 3.6 implants per patient). The most common practice was the use of four mini implants (300 patients).

Implant and Abutment Type

The majority of studies (12/17) used Sendax/3M/IMTEC implants. Two studies used Atlas Dentatus and two MDL intra-lock. One study used Dentium Slim line implants. One study splinted mini implants with a custom-made bar as the retentive element, and compared this with ball abutments. All other studies utilized a ball abutment or dome abutment as the prosthetic component to retain the complete denture. One study used angulated abutments. The majority used the O-ring as the housing design (12/17). One study compared this with a bar, and two studies chose to reline with a soft acrylic only. In two studies, the retentive element was not stated.

Implant Size

The diameters of mini implants used are outlined in Table 7. The lengths were either 7, 10, 11.5, 13, 14, 15, or 18 mm. Little evidence can be drawn from the included studies to advise on the optimal implant length or diameter in terms of implant survival.

Surgical Technique

The majority of studies (10/17) placed the mini implants in a flapless technique. Three used an open-flap technique, and two studies used a combination of both techniques. In three studies, the surgical technique was not reported.

The loading protocols in the studies varied widely. Most of the studies used immediate loading protocols, with O-rings connected immediately postoperatively onto the implants. Some studies chose to utilize a soft reline postoperatively and either accept this as the final retentive technique, or convert to O-rings 1 to 16 weeks later. Some studies chose postimmediate (15 days), early (< 12 weeks), or delayed loading (> 12 weeks).

Comparisons

Four studies compared mini implants with conventional implants, including one study comparing two mini implants with four mini implants and two conventional implants. One study compared straight mini implants with angulated mini implants. One study compared splinted mini implants with nonsplinted mini implants. One study compared immediate loading with delayed loading. Ten studies had no comparison and evaluated mini implants only.

Other Reported Outcome Measures

There was marked variation in the primary and secondary outcome measures reported in the 17 included studies. Bone height was assessed in six studies and showed acceptable levels of bone height, moreso in nonangulated and splinted implants. Greater bone loss was noted around less dense bone, where periimplant inflammation existed, and at the distal-most implant. However, actual numbers to back up these statements are small and underpowered.

Patient-reported outcome measures (PROMs) including quality of life (QoL) analysis were reported in 10 studies. All expressed an improvement in QoL indices and patient satisfaction following mini implant placement. However, due to the heterogeneity of the data, although visually evident, the trend could not be quantified statistically.

Other outcome measures included pain, chewing efficiency, plaque and bleeding scores, gingival indices, pocket probing depths, and primary stability. Although there were positive results, these again could not be pooled due to the variation in study design and outcome measurement tools used.

Table 7 Frequency of Implant Diameters Used in Collected Studies

Implant diameter (mm)	Frequency
1.8	961
2.0	332
2.1	40
2.4	36
Unspecified (≤ 2.4)	349
Total	1,718

In studies that compared mini and conventional implants, those that measured gingival indices showed no statistical differences between groups. QoL measures were either equivalent or better in the mini implant groups compared with the conventional implant groups. Primary and secondary implant stability was found to be marginally better with conventional implants. Mini implant groups tended to report less perioperative and postoperative pain.

DISCUSSION

In the literature, there are considerable overlaps in the definitions of what constitutes a mini implant compared with a narrow, extra-narrow,[2] or small-diameter implant.[39] Often, they are grouped together in reports as one and the same implant.[40] This review has been very specific in looking at mini implants, which are distinctly different from smaller-diameter implants. The diameter chosen was 1.8 to 2.4 mm, as these cutoffs had been previously advocated,[3–5] and the implants had to be one-piece, ie, with abutment connections already on the implant.

This systematic review highlights the paucity of robust evidence that exists in the literature to support the use of mini implants as an alternative treatment modality for the edentulous mandible. Despite a maximum follow-up of 84 months in one study,[28] overall, there was a mean follow-up time of 28.2 months. There is very little data post 3 years to determine the long-term survival rate, and as the studies are so heterogenous (different number of implants, different diameter implants, different sites in the mouth, different patient factors, etc), any conclusions about survival rates of mini implants must be made with caution. A systematic review has tentatively shown that survival rates are in the order of 94.7% at 1 year and 93.4% at 3 years.[1] Further studies quote a survival rate of 86.9% to 100% over 1 to 6 years,[41] and 95.1% over 1 to 7 years.[42] This

study supports these previous findings, with survival rates in the region of 93.7% at 1 year and 95.6% at 3 years. This is only marginally lower than success rates with conventional dental implants.[43]

Modes of failure reported in the present review include fracture (either perioperatively [n = 5] or postintegration [n = 7]) and failure of integration (early [within 12 months] or late [after 12 months]). It is likely that perioperative fracture is a result of the small diameter of the implant itself, as smaller implants have reduced fatigue strength.[44] This is especially pertinent where surgeons have been accustomed to placing conventional implants and handle mini implants in a similar way. Furthermore, no preparation or underpreparation of the osteotomy site, overtorquing of the implant, bone quality, and density[45] may also be contributing factors. Therefore, the use of mini implants represents a slightly different, more fragile handling technique, and this should be noted and taught at the outset. Nevertheless, of the 1,718 mini implants placed, there were only 12 fractures (0.7%). This represents a relatively low risk and is a contextually rare failure modality, not dissimilar to those reported for conventional implants.[46]

Failure of integration is a more common occurrence. In this study, 36 mini implants failed within 12 months, whereas 39 failed later. It is likely that early failures are due to lack of osseointegration, often as a result of a lack of primary stability. This may be due to overpreparation of the osteotomy site, or a reflection of the quality of the underlying bone. Poorer-quality bone may also result in poorer primary stability and subsequent failure,[47] and this is often not evident until the operative procedure has begun. Many of the authors of the included articles recognized the importance of primary stability and therefore proceeded to load the implants only after a stability of 35 Ncm was reached. There is considerable evidence that failure rates are higher in the maxilla than in the mandible,[15,31] despite one included study reporting no difference in failure rates between the maxilla and mandible up to 4 years.[26]

When mini implants fail after loading, it is indicative that the level of osseointegration is not sufficient to withstand loading forces. Interestingly, this does not seem to be related to the number of implants used, as the failure rates in cases with two and four mini implants are similar. It also does not seem to be related to whether mini implants were loaded immediately or delayed.

It is pertinent to consider the question of what happens to the patient/prosthesis if their mini implants fail. In the vast majority of cases where four have been placed, the prosthesis continues to function on three mini implants. However, when two mini implants are placed, the general consensus is that one mini implant is not enough and a new mini implant is placed. This may be the rationale behind support for the four mini implant strategy.[48] Longer-term studies are needed in conjunction with health economics modeling to ascertain which treatment strategy is more cost effective over time. While efficacy trials would assess the failure of the implant, pragmatic trials would be expected to assess the survival of the prostheses. These approaches are subtly different, but both are needed to evaluate the use of mini implants as a treatment modality in patients with an edentulous mandible.

The appeal of mini implants is that they are almost always placed in a flapless (closed) surgical technique, resulting in minimal disruption to underlying tissues[4] and thus less postsurgical pain[3,12] for patients and faster healing.[4] This has been associated with better patient satisfaction.[49] The material costs are also significantly cheaper than both conventional implants and small-diameter implants, although the reason for this is unclear.[1] It may be due to less pure titanium being needed in a mini implant. In some circumstances, mini implants negate the need for complex bone augmentation procedures such as grafting, making them more accessible to patients who would have otherwise been unsuitable or refused such treatment.[31,50] Furthermore, the quicker procedure equates to less workforce and procedural costs.[20]

The potential drawbacks of mini implants have been cited as[1]:

- The need for multiple implants (although this may be unfounded)
- The lack of evidence for long-term survival
- The potential for fracture (although this risk is very low)
- Lack of parallelism is less forgiving due to the one-piece design
- The reduced resistance to occlusal forces
- Complications during flapless placement

However, the scientific basis and clinical relevance of these statements are insufficient to prohibit their use.

Usually, mini implants are secured to lower complete dentures by way of a ball abutment. However, they can also be retained by different-shaped heads[51] or splinted using a bar attachment, a technique that has been shown to offer no advantage or disadvantage to ball attachments.[52] The ball attachments are usually retained using metal housings and stud attachments or O-rings. However, resilient soft liners have also been used.[15] O-rings have been shown to be particularly problematic, as they distort with time,[34] resulting in more postoperative problems.[20,29]

Mini implants are manufactured by a range of different companies, which produce implants of differing diameters, titanium alloy, and abutment style. This further complicates the assessment of the mini implant, as the differing geometry may be a factor in survival rates of the implant system.

Although consensus statements[53,54] have stated that the minimum standard of treatment for patients with an edentulous mandible should be two implants in the interforaminal region of the mandible, when mini implants are used, up to six implants have been placed.[51] Recent clinical guidelines have advocated the use of four.[48] However, studies have shown that four mini implants result in more postoperative pain than two mini implants or two standard-diameter implants,[55] a fact that may make this treatment less accessible to edentulous patients, as fear of pain is a common barrier to proceeding with this therapy.[56] Therefore, the use of two mini implants has been advocated instead due to equivalent clinical results,[34] less postoperative pain,[34,55] and less initial cost.[20] However, the authors do not possess adequate data to enable an assessment of the effect of this approach long term.

An interesting point to note is that while the majority of studies used the same type of implant from the same company (Sendax/IMTEC/3M), at the time of writing this article, this implant is no longer being produced commercially. Therefore, the promising evidence presented in this review must be extrapolated with caution when compared with the performance of different mini implant designs.

The strengths of this review include its thorough, systematic, double-assessor approach. Furthermore, it assesses a vast number of articles through electronic and hand searching to achieve an answer to a topical research question. The search was pragmatic and yields information that would help in both current clinical decision-making and also planning of future research. The limitations are the potential sources of bias from studies that lack robust methodology and sufficient follow-up. The data were too heterogenous for meta-analysis, and therefore, only a descriptive summary was provided.

It is disappointing that there is a distinct lack of high-quality studies in this field of dentistry. Only 2 of the 17 included articles represented moderate quality evidence, while the rest were low or very low. A recent influx of systematic reviews on this subject[41,42,57] reflects that it is considered an important topic in the field of dentistry. A future pertinent research question to answer is how mini implants compare long term to no implant treatment (ie, complete dentures only) or large-diameter conventional implants and whether they would be a more appropriate alternative.

CONCLUSIONS

Based upon this systematic review of the literature, the following conclusions can be made. The placement of two to four mini implants in the edentulous mandible to retain a lower complete overdenture is an acceptable treatment modality. Survival rates are satisfactory for the first 2 to 3 years after placement and loading. Failures are most common within the first year of placement. Flapless surgery, immediate loading, simplicity, and reduced cost make this system attractive to both patients and operators alike.

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APPENDIX

MINI IMPLANT REVIEW SEARCH STRATEGY

RESEARCH QUESTION:

"Survival of mini implants as complete overdenture abutments in the mandible"

SEARCH STRATEGY:

Medline via Ovid (including epub ahead of print, and pre-indexed):

1) Jaw, edentulous/
2) (jaw* and edent*).ab,ti.
3) (mandib* and edent*).ab,ti.
4) (mandib* and resorb*).ab,ti.
5) (total tooth loss or complete tooth loss).mp.
6) 1 or 2 or 3 or 4 or 5
7) Denture, complete/
8) (denture* or overdenture* or over-denture*).ab,ti.
9) dental Prosthesis, implant-supported/
10) denture, Overlay/
11) 7 or 8 or 9 or 10
12) (mini implant* or mini-implant* or narrow implant* or narrow-implant* or small implant* or small-implant*).ab,ti.
13) 6 and 11 and 12

Embase via Ovid:

1) Edentulousness/
2) (jaw* and edent*).ab,ti.
3) (mandib* and edent*).ab,ti.
4) (mandib* and resorb*).ab,ti.
5) (total tooth loss or complete tooth loss).mp.
6) 1 or 2 or 3 or 4 or 5
7) Complete Denture/
8) tooth prosthesis/
9) "implant*".ab,ti.
10) 8 and 9
11) (denture* or overdenture* or over-denture*).ab,ti.
12) denture, Overlay/
13) 7 or 10 or 11 or 12
14) (mini implant* or mini-implant* or narrow implant* or narrow-implant* or small implant* or small-implant*).ab,ti.
15) 6 and 13
16) 14 and 15

Web of Science:

1) WC= (Dentistry, Oral Surgery & Medicine)
2) TS= (edent*)
3) TI=(jaw* AND edent*)
4) TI= (mandib* AND edent*)
5) TI= (mandib* AND resorb*)
6) TS= (total tooth loss OR complete tooth loss)
7) #6 OR #5 OR #4 OR #3 OR #2
8) TS= (Complete denture* or denture*)
9) TS= implant supported*

10) TI= (denture* or over denture* or over-denture* or overdenture*)
11) #10 OR #9 OR #8
12) TS= (mini implant* or mini-implant* or narrow implant* or narrow-implant* or small implant* or small-implant*)
13) TI= (mini implant* or mini-implant* or narrow implant* or narrow-implant* or small implant* or small-implant*)
14) #13 OR #12
15) #14 AND #11 AND #7 AND #1

EBSCOhost – Dentistry and Oral Sciences Database:

1) SU edentulous
2) TI (jaw* AND edent*) OR AB (jaw* AND edent*)
3) TI (mandib* AND edent*)ORAB(mandib* AND edent*)
4) TI (mandib* AND resorb*) OR AB (mandib* AND resorb*)
5) total tooth loss OR complete tooth loss
6) S1 OR S2 OR S3 OR S4 OR S5
7) SU complete denture
8) SU overdenture OR SU overdentures OR SU (overdenture implant retained and supported)
9) TI ((denture* or overdenture* or over denture* or over- denture*)) OR AB ((denture* or overdenture* or over denture* or over- denture*))
10) S7 OR S8 OR S9
11) SU mini implant
12) TI ((mini implant* or mini-implant* or narrow implant* or narrow- implant* or small implant* or small- implant*)) OR AB ((mini implant* or mini- implant* or narrow implant* or narrow- implant* or small implant* or small- implant*))
13) S11 OR S12
14) S6 AND S10 AND S13

Cochrane Central Library

1) MeSH descriptor: [Jaw, Edentulous] explode all trees
2) mouth and edent*
3) jaw* and edent*
4) mandib* and edent*
5) mandib* and resorb*
6) total tooth loss or complete tooth loss
7) {or #1-#6}
8) MeSH descriptor: [Denture, Complete] explode all trees
9) denture* or over denture* or overdenture* or over-denture*
10) MeSH descriptor: [Dental Prosthesis, Implant-Supported] explode all trees
11) MeSH descriptor: [Denture, Overlay] this term only
12) {or #8-#11}
13) {and #7-#12}
14) mini implant* or mini-implant* or narrow implant* or narrow-implant* or small implant* or small-implant*
15) {and #13-#14}

ClinicalTrials.gov

Edentulous AND mandible AND prosthesis

WHO Clinical Trials Registry Platform

Edentulous AND mandible AND prosthesis