Int. J. Oral Maxillofac. Surg. 2019; 48: 239–249
https://doi.org/10.1016/j.ijom.2018.05.010, available online at https://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Systematic Review and Meta-Analysis
Pre-Implant Surgery

Short implants (≤8 mm) compared to standard length implants (>8 mm) in conjunction with maxillary sinus floor augmentation: a systematic review and meta-analysis

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H.B. Nielsen, S. Schou, F. Isidor, A.-E. Christensen, T. Starch-Jensen: Short implants (≤8 mm) compared to standard length implants (>8 mm) in conjunction with maxillary sinus floor augmentation: a systematic review and meta-analysis. Int. J. Oral Maxillofac. Surg. 2019; 48: 239–249.

Abstract. The objective was to test the hypothesis of no difference in the treatment outcome after the installation of short implants (≤8 mm) in the posterior part of the maxilla compared to standard length implants (>8 mm) in conjunction with maxillary sinus floor augmentation (MSFA) using the lateral window technique, after an observation period of ≥3 years. A search of the MEDLINE, Embase, and Cochrane Library databases, in combination with a hand-search of relevant journals, was conducted. The search yielded 1102 titles. Finally, three studies that fulfilled the inclusion criteria were included. All were considered to have a low risk of bias. Meta-analyses revealed no significant differences in implant survival or peri-implant marginal bone loss between the two treatment modalities. However, the use of standard length implants in conjunction with MSFA was characterized by a tendency towards more peri-implant marginal bone loss. There was no statistically significant difference between the two treatment modalities with regard to overall patient satisfaction. Short implants seem to be a suitable alternative to standard length implants in conjunction with MSFA. However, further randomized controlled trials with larger patient samples and an observation period of more than 3 years are needed before one treatment modality might be considered superior to the other.

Key words: alveolar ridge augmentation; dental implants; meta-analysis; sinus floor augmentation; systematic review.

Accepted for publication 8 May 2018
Available online 3 July 2018

0901-5027/020239 + 011

The placement of oral implants is a predictable and highly successful treatment for complete, partial, and single edentulism[1–4]. However, the placement of implants in the posterior part of the maxilla is frequently compromised or impossible due to atrophy of the alveolar process, poor bone quality, and/or maxillary sinus pneumatization. Maxillary sinus floor augmentation (MSFA) using the lateral window technique is the method most commonly applied to increase the alveolar bone height in the posterior part of the maxilla, prior to or in conjunction with implant placement, and high long-term prosthesis and implant survival rates have been reported in several systematic reviews[5–7]. However, MSFA is associated with the risk of donor site morbidity and an increased risk of surgical complications[8–10]. In addition, the technique is more time-consuming and incurs additional costs.

The installation of short implants is a less invasive surgical procedure and has therefore been advocated to avoid the disadvantages described above after the installation of standard implants in conjunction with MSFA[11–13]. Several systematic reviews have documented high short-term survival of suprastructures and implants after the installation of short implants in the posterior part of the maxilla[14–18], but long-term studies on this subject are limited. Long-term implant survival and the stability of the peri-implant marginal bone level around short implants have not yet been clarified[19–22]. However, a well-maintained peri-implant marginal bone level around short implants after 7 years has been described in one study[23].

From a clinical and patient perspective, it would be an advantage if the posterior part of the maxilla could be prosthetically rehabilitated with the use of short implants instead of standard length implants in conjunction with MSFA. However, long-term comparative studies assessing the two treatment modalities appear to be lacking, and standardization and consistency are needed in regard to important outcome measures[24].

Therefore, the objective of this systematic review was to test the hypothesis of no difference in the treatment outcome after the installation of short implants (≤8 mm) in the posterior part of the maxilla compared to standard length implants (>8 mm) in conjunction with MSFA using the lateral window technique, after an observation period of ≥3 years.

Materials and methods

The methods for the analysis and the inclusion criteria were specified in advance and documented in a protocol. The review was registered in the PROSPERO database, an international prospective register of systematic reviews. The protocol can be accessed at https://www.crd.york.ac.uk/PROSPERO with registration number CRD42017064931.

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews[25].

Eligibility criteria and outcome measures

All randomized controlled clinical trials (RCTs) comparing the installation of short implants (≤8 mm) in the posterior part of the maxilla to standard length implants (>8 mm) in conjunction with MSFA using the lateral window technique, with an observation period of ≥3 years, were included.

The primary outcome measures are outlined in Table 1. Secondary outcome measures were also included as surrogate measures in this systematic review.

The inclusion criteria and focused question were developed using the PICOS guidelines, as shown in Table 2.

Inclusion criteria were RCT with an observation period of ≥3 years, assessing the implant treatment outcome after the installation of short implants (≤8 mm) in the posterior part of the maxilla compared to standard length implants (>8 mm) in conjunction with MSFA using the lateral window technique, and addressing the outcome measures described. In addition, at least 10 patients had to be included in each treatment group in the study and the number of implants inserted and the surgical intervention used had to be specified clearly.

The following exclusion criteria were applied: uncontrolled clinical trial, case series, retrospective studies, letters to the editor, editorials, PhD theses, case reports, abstracts, technical reports, conference proceedings, animal or in vitro studies, and review papers. Studies with an insufficient description of the numbers of surgical procedures performed, implants inserted, length of the implants inserted, length of the observation period, and studies involving osteotome-mediated MSFA in conjunction with implant installation were also excluded. Likewise, studies adding growth factors or platelet-rich plasma to the graft material were also excluded.

Table 1. Outcome measures.

Primary outcome measures:
• Survival of suprastructures: loss of the suprastructure was defined as a total loss because of a mechanical and/or biological complication
• Survival of implants: loss of an implant was defined as mobility of a previously clinically osseointegrated implant or removal of a non-mobile implant due to progressive peri-implant marginal bone loss and infection
Secondary outcome measures:
• Peri-implant marginal bone loss: evaluated by radiographic measurements
• Implant stability quotient (ISQ): estimated by resonance frequency analysis
• Patient-reported outcome measures (PROMS)
• Complications

Table 2. PICOS guidelines used for the development of the inclusion criteria.

Patients and population (P)	Healthy patients with atrophy of the posterior part of the maxilla receiving short implants or standard length implants in conjunction with MSFA
Intervention (I)	Short implants
Comparator or control group (C)	Standard length implants in conjunction with MSFA
Outcomes (O)	The primary outcome measures included survival of suprastructures and survival of implants Secondary outcome measures included peri-implant marginal bone loss, implant stability quotient, patient-reported outcome measures, and complications
Study design (S)	Randomized controlled clinical trials with the aim of comparing short implants with standard length implants in conjunction with MSFA, with an observation period of ≥3 years
Focused question	Are there differences in the long-term final implant treatment outcome between the two treatment modalities involving short implants compared to standard length implants in conjunction with MSFA?

MSFA, maxillary sinus floor augmentation.

Search strategy for the identification of studies

The search strategy incorporated electronic databases supplemented by a thorough hand-search of relevant journals (**Supplementary Material**, Table S1). The manual search also included the bibliographies of all articles selected for full-text screening, as well as previously published reviews relevant to the present systematic review. The search was performed by two reviewers (HN, TSJ). If disagreements occurred, another reviewer was consulted (SS).

The search was conducted in the Ovid MEDLINE, Ovid Embase, and Cochrane Library databases and included studies published in English from January 1, 1990 to June 1, 2017. The search was conducted in collaboration with a librarian and utilized a combination of both controlled vocabulary terms and free text terms:

1. (((atrop* or posterior) adj3 maxilla*) or Alveolar Ridge Augmentat* or sinus floor Augmentat*).mp. (6473)
2. Alveolar Ridge Augmentation/ or Sinus Floor Augmentation/ (4174)
3. 1 or 2 (6473)
4. Dental Implants/ or implant*.mp. (458,135)
5. randomized controlled trial/ or (rct or rcts or randomi#ed).mp. (830,184)
6. 3 and 4 and 5 (414)

Study selection

The titles of the identified reports were initially screened (Fig. 1). The abstract was assessed when the title indicated that the study fulfilled the inclusion criteria. Full-text analysis was done when the abstract was unavailable or when the abstract indicated that the inclusion criteria were fulfilled. The references of the identified papers were cross-checked for unidentified articles. The study selection was performed by two reviewers (HN, TSJ). If disagreements occurred, another reviewer was consulted (SS).

Data extraction

Data were extracted by one reviewer (HN) using a pre-prepared data collection form, ensuring systematic recording of the outcome measures. In addition, relevant characteristics of the study were recorded. The corresponding author was contacted by e-mail in the event of missing important information or ambiguities.

The following information was obtained from the articles included: number of patients, number of implants, implant length, residual bone height, prosthetic solution, length of the observation period, survival of suprastructures, survival of implants, implant stability quotient (ISQ), peri-implant marginal bone loss (PIMBL), patient-reported outcome measures (PROMS), intraoperative complications, and postoperative complications.

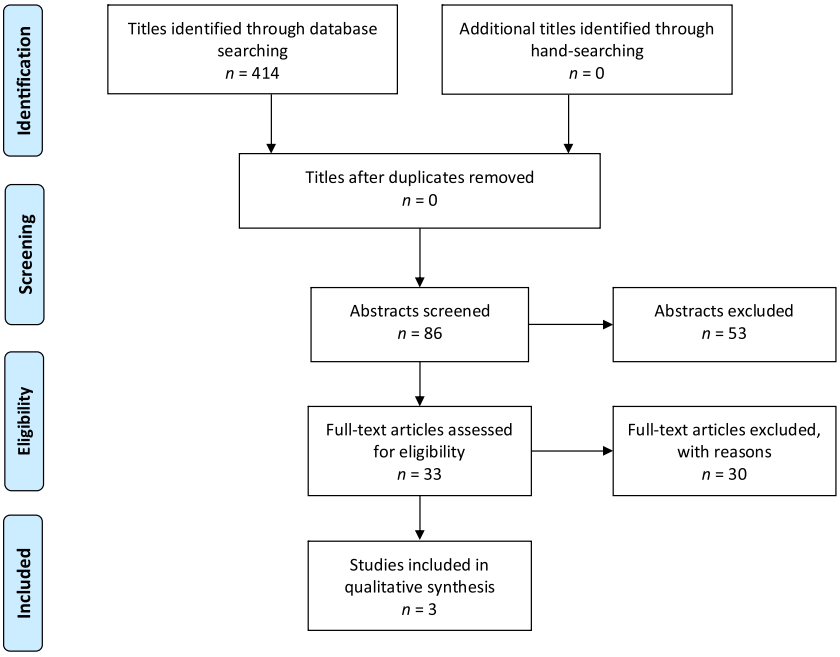

Fig. 1. PRISMA flow diagram demonstrating the results of the systematic literature search.

Quality assessment and assessment of heterogeneity.

The quality assessment of the included studies was undertaken by two reviewers (HN, TSJ) as part of the data extraction process. A methodological quality rating system was used, and the classification of the risk of bias potential for each study was based on five criteria: random selection in the population, definition of inclusion and exclusion criteria, report of losses to follow-up, validated measurements, and statistical analysis (see **Supplementary Material**, Table S2).

The significance of any discrepancies in the estimates of the treatment effects of the different studies was assessed by means of Cochran's test for heterogeneity and the I^2 statistic, which describes the percentage total variation across studies that is due to heterogeneity rather than chance. Heterogeneity was considered statistically significant if $P < 0.1$. A rough guide to the interpretation of I^2 given in the *Cochrane Handbook* is as follows: (1) at 0–40% the heterogeneity might not be important, (2) 30–60% may represent moderate heterogeneity, (3) 50–90% may represent substantial heterogeneity, and (4) 75–100% may represent considerable heterogeneity[26].

Results

Study selection

The article review and data extraction were performed according to the PRISMA flow diagram, as outlined in Fig. 1. A total of 1102 titles were identified and 86 abstracts were reviewed. The full-text analysis included 33 articles. Three studies were finally included[19,20,27]. No articles were included as a result of the hand search.

The reasons for exclusion of studies after full-text assessment were the following: inadequate data reporting[28–34], retrospective study design[35–37], inadequate follow-up period[21,22,38–46], and lack of any augmentation procedure in both treatment groups or use of an augmentation procedure including osteotome-mediated sinus floor augmentation in both treatment groups[13,47,48].

Study characteristics

The studies included in this systematic review were all RCTs[19,20,27].

The multicenter study by Pohl et al. enrolled a total of 101 patients with partial edentulism in the posterior part of the maxilla and a residual alveolar bone height of 5–7 mm[27]. The patients were randomly allocated to the installation of either short implants (Astra Tech 6 mm) or standard length implants (Astra Tech 11–15 mm) in conjunction with MSFA using the lateral window technique. Sixty-seven short implants were inserted in 51 patients and 70 standard length implants were inserted in 50 patients. Six months after implant installation, the implants were restored and loaded with single-tooth, non-splinted crowns. The patients were re-examined annually, and implant survival, PIMBL, technical complications, clinical probing depth, bleeding on probing, and plaque accumulation were assessed up to 3 years after loading[27]. Intraoral radiographs were obtained with the paralleling technique at the time of implant placement (baseline) and after 1, 2, and 3 years. The PIMBL was measured from the implant shoulder to the most coronal bone-to-implant contact on the mesial and distal aspects of the implant[27]. All patients participated in the 3-year follow-up examination.

The study by Bechara et al. enrolled 53 patients with partial edentulism in the posterior part of the maxilla and a residual alveolar bone height of 4 mm or more and a width of 5 mm or more[19]. Patients were randomly allocated to placement of either short implants (MegaGen AnyRidge 6 mm) or standard length implants (MegaGen AnyRidge $\geq$10 mm) in conjunction with MSFA. Forty-five short implants were inserted in 33 patients and 45 standard length implants were inserted in 20 patients. Provisional acrylic resin single crowns or fixed partial dentures were fabricated and loaded 4 months after implant installation. Four months later, definitive restorations were mounted. The patients were re-examined annually, and implant survival, implant stability, PIMBL, complications, patient satisfaction, treatment time, and costs were assessed up to 3 years after loading[19]. Panoramic radiographs were obtained at baseline, at delivery of the final prosthetic restoration, and at 1 year and 3 years after implant placement. PIMBL was measured on the mesial and distal aspects of the implants, and the reference points for the linear measurements were the coronal margin of the implant shoulder and the most coronal level of bone-to-implant contact[19]. All patients participated in the 3-year follow-up examination.

The study by Esposito et al. enrolled 15 patients with partial edentulism in both sides of the posterior part of the maxilla and a residual alveolar bone height of 4–6 mm[20]. This was a split-mouth study. The sides of the maxilla were randomly allocated to the placement of either short implants (MegaGen Rescue 5 mm) or delayed placement of standard length implants (MegaGen EZ Plus $\geq$10 mm) in conjunction with MSFA. Thirty-four short implants were inserted in the 15 patients. Moreover, 38 standard length implants were inserted 4 months after MSFA on the contralateral side. Provisional prostheses were fabricated and loaded 4 months after implant installation. After an additional 4 months, definitive metal–ceramic splinted restorations were delivered[20]. Patients were re-examined every 4 months up to 3 years after loading to assess failure of the suprastructure and implants, PIMBL, and complications[20]. Intraoral radiographs were obtained with the paralleling technique at implant placement, at delivery of the provisional prosthesis, and at 1 year and 3 years after loading. The measurements were taken parallel to the implant axis, and the most coronal margin of the implant collar and the most coronal level of the bone-to-implant contact were used as reference points for the linear measurements[20]. One patient with a non-specified implant type dropped out after 2 years and 3 months.

The main results are described below and summarized in Tables 3 and 4.

Synthesis of results

Meta-analyses were to be conducted only if there were studies of similar comparisons, reporting identical outcome measures. However, there was considerable variation in study design for the studies included, i.e. different implant designs, implant regions, time frame between implant installation and loading, residual bone height, prosthetic solution, and types of outcome measure. Therefore, a well-defined meta-analysis was not applicable. Nevertheless, the odds ratios (OR) in relation to patient-based implant loss were analysed and a forest plot was drawn. One of the studies had an implant loss of 0% for both implant types[27]. Hence, standard methods would exclude this study from the pooled estimate. Therefore, the Peto method for pooling data was used; continuity correction was performed by adding 0.5 to each cell in the contingency table for the study[49]. Moreover, a sensitivity analysis for pooling data was performed involving a fixed-effects model with Mantel–Haenszel method for pooling data.

The difference in PIMBL across the studies was analysed and a forest plot was drawn. A fixed-effects model with inverse variance was used, and the difference in PIMBL was expressed as the mean percentage with a 95% confidence interval (CI).

Primary outcome measures

Survival of suprastructures

The survival of suprastructures was assessed in one study[20]. The 3-year patient-based survival of suprastructures was 87% with short implants and 100% with standard length implants in conjunction with MSFA. Two prostheses were lost in two patients with short implants due to explantation of the implants as a result of peri-implantitis. There was no statistically significant difference between the two treatment modalities[20].

In summary, the survival of suprastructures was described in one study, which revealed a non-significant higher survival rate of suprastructures with standard length implants in conjunction with MSFA compared to short implants after 3 years, at the patient level.

Survival of implants

The survival of implants was assessed in all of the included studies[19,20,27].

Esposito et al. reported a 3-year patient-based implant survival rate of 87% for short implants and 93% for standard length implants in conjunction with MSFA[20]. There was no statistically significant difference between the two treatment modalities. Three short implants were lost in two patients. One implant was explanted at abutment operation due to a lack of osseointegration. This implant was successfully replaced. Two short implants were lost in one patient at 2 years after loading; the patient did not wish to have the implants replaced. A standard length implant was lost in one patient at 6 months after loading due to loss of osseointegration. The implant was removed and not replaced, in accordance with the patient's wishes.

Bechara et al. reported that the 3-year patient-based implant survival was 100% for short implants compared to 95% for standard length implants in conjunction with MSFA. There were no statistically significant differences between the two treatment modalities[19]. Two standard

Table 3. Randomized controlled clinical trials assessing short implants and standard length implants in conjunction with maxillary sinus floor augmentation.

Study	Patients, *n*	Materials and methods					Primary outcome measures		Secondary outcome measures		
		Implants	Implant length (mm)	RBH (mm)	Prosthetic solution	LOP (years)	Survival of: SS	Survival of: Implants	ISQ	PIMBL (mm)	PROM
Esposito et al. 2014[20]	15[a]	SI: 15 patients (34 implants)	5	4–6	Splinted crowns	3	87%	87%	ND	1.02	ND
		SLI + MSFA: 15 patients (38 implants)	≥10				100%	93%		1.54	
Bechara et al. 2016[19]	53	SI: 33 patients (45 implants)	6	ND	Single crowns or FPD	3	ND	100%	71.6	0.20	Significant difference in treatment time and costs[b]
		SLI + MSFA: 20 patients (45 implants)	10–15					95%	72.4	0.27	
Pohl et al. 2017[27]	101	SI: 51 patients (67 implants)	6	5–7	Single crowns	3	ND	100%	ND	P: 0.6 M: 0.4	ND
		SLI + MSFA: 50 patients (70 implants)	11–15					100%		P: 0.4 M: 0.5	

FPD, fixed partial dentures; ISQ, implant stability quotient; LOP, length of observation period; M, molar; MSFA, maxillary sinus floor augmentation; ND, no data; P, premolar; PIMBL, peri-implant marginal bone loss; PROM, patient-reported outcome measures; RBH, residual bone height; SI, short implants; SLI, standard length implant; SS, suprastructures.

[a] Split-mouth study design.

[b] Difference in treatment time, $P < 0.0001$; difference in treatment costs, $P = 0.003$.

Table 4. Biological and technical complications after the installation of short implants compared to standard length implants in conjunction with maxillary sinus floor augmentation.

Study	Intraoperative			Postoperative			Prosthesis	
	Complications	Treatment	Consequence	Complications	Treatment	Consequence	Complications	Treatment
Esposito et al. 2014[20]	SI: SMP ($n = 3$) SLI + MSFA: SMP ($n = 1$)	Collagen barrier Resorbable synthetic barrier	ND	PIM ($n = 1$)	PS	Loss of implants ($n = 2$)	ND	ND
Bechara et al. 2016[19]	SI: None SLI + MSFA: IOB ($n = 3$)	None	ND	Pain and swelling ($n = 1$) Swelling ($n = 14$) CSI ($n = 1$)	ND	Loss of: Graft ($n = 1$) Implants ($n = 2$)	None	None
Pohl et al. 2017[27]	SI: None SLI + MSFA: None	None	None	None	None	None	ASL, AF ($n = 8$) ASL, AF ($n = 2$)	DC ($n = 2$) DC ($n = 1$)

AF, abutment fracture; ASL, abutment screw loosening; CSI, chronic sinus infection; DC, decementation of crown; IOB, intraoperative bleeding; MSFA, maxillary sinus floor augmentation; ND, no data; PIM, peri-implant mucositis; PS, peri-implantitis surgery; SI, short implant; SLI, standard length implant; SMP, sinus membrane perforation.

length implants were lost in one patient before loading due to a chronic sinus infection and lack of osseointegration[19].

Pohl et al. reported a 3-year patient-based implant survival of 100% for both short implants and standard length implants in conjunction with MSFA[27].

In summary, there was no statistically significant difference in 3-year implant survival of implants placed in the posterior part of the maxilla between short implants and standard length implants in conjunction with MSFA.

Secondary outcome measures

Peri-implant marginal bone loss

PIMBL was evaluated in all of the included studies[19,20,27].

Esposito et al. reported a 3-year PIMBL of 1.02 mm after installation of short implants compared to 1.54 mm with standard length implants in conjunction with MSFA[20]. The difference between the two treatment modalities was statistically significant[20].

Bechara et al. reported that the 3-year PIMBL was 0.20 mm after the installation of short implants compared to 0.27 mm with standard length implants in conjunction with MSFA[19]. The difference between the two treatment modalities was statistically significant[19].

Pohl et al. reported that the 3-year PIMBL was 0.6 mm in the premolar region and 0.4 mm in the molar region after the installation of short implants compared to 0.4 mm and 0.5 mm, respectively, with standard length implants in conjunction with MSFA[27]. There were no statistically significant differences in PIMBL between the two treatment modalities[27].

In summary, limited PIMBL was revealed with both treatment modalities after 3 years. However, a significantly higher PIMBL was reported after the installation of standard length implants in conjunction with MSFA compared to short implants.

Implant stability quotient

The ISQ value was assessed in one study[19]. The ISQ value at 3 years reported by Bechara et al. was 71.6 for short implants compared to 72.4 for standard length implants in conjunction with MSFA[19]. The ISQ value at implant installation was 68.2 for short implants compared to 67.8 for standard length implants. The ISQ value increased for both treatment modalities, but standard length implants showed a statistically significant higher ISQ value after 3 years[19].

In summary, both treatment modalities demonstrated high ISQ values at implant installation and at 3 years after loading. However, after 3 years, a significantly higher ISQ value was reported after the installation of standard length implants in conjunction with MSFA compared to short implants.

Patient-reported outcome measures

PROMS were assessed in one study[19]. Patient appreciation of the final implant treatment outcome at 3 years after installation was assessed using a questionnaire assessing perceptions of the therapy received, function, aesthetics, cleaning of the implant-supported restorations, satisfaction, and costs, and comparisons were made between the two treatment groups[19]. The questions were answered on a three-point scale. With respect to overall satisfaction with the treatment, no statistically significant difference was found between the two treatment modalities[19]. However, regarding costs, 84.4% of the patients allocated to short implants were fully satisfied with the costs and 15.6% were sufficiently satisfied, while for patients receiving standard length implants in conjunction with MSFA, 55% were fully satisfied and 45% were sufficiently satisfied. The difference between the two treatment modalities was statistically significant ($P = 0.03$). No patient implied dissatisfaction with the cost of treatment[19]. The overall treatment time was significantly longer for the standard length implants in conjunction with MSFA compared to the short implants ($P < 0.0001$)[19].

In summary, PROMS were assessed in one study, revealing no statistically significant difference between the two treatment modalities for overall patient satisfaction. However, treatment involving standard length implants in conjunction with MSFA was significantly more time-consuming and patients receiving short implants were significantly more fully satisfied with the cost of the treatment.

Complications

Biological complications were reported in two studies[19,20]. Esposito et al. reported perforation of the sinus membrane in three patients after the installation of short implants and in one patient after the installation of standard implants in conjunction with MSFA[20]. In the study by Bechara et al., intraoperative or postoperative bleeding, pain, and swelling were infrequently reported after the installation of standard length implants in conjunction with MSFA, but were not described after the installation of short implants[19]. Peri-implant mucositis was reported in one patient at 2 years after loading of short implants[20]. The loss of graft material occurred in one patient due to a chronic sinus infection after the installation of standard length implants in conjunction with MSFA[19].

Technical complications were reported in one study[27]. Pohl et al. reported that decementation of two crowns and eight cases of abutment screw loosening or fracture of the abutment screw occurred after the installation of short implants after 3 years[27]. Decementation of one crown and two cases of abutment screw loosening or fracture of the abutment screw were reported after the installation of standard length implants in conjunction with MSFA[27]. There was no statistically significant difference in technical complications between the two treatment modalities[27].

In summary, the frequency and severity of biological and technical complications associated with the two treatment modalities were generally low.

Results of the meta-analysis

The meta-analysis for patient-based implant loss using the Peto method with continuity correction of 0.5 demonstrated an OR of 0.90 (95% CI 0.15 to 5.44) for short implants compared to standard implants in conjunction with MSFA (Fig. 2). A test for heterogeneity revealed no important heterogeneity among the studies included, but the result was non-significant ($I^2 = 0.0\%$, $P = 0.369$). The sensitivity analysis showed a similar result, but a different heterogeneity ($I^2 = 24.0\%$, $P = 0.251$).

Meta-analysis using a fixed-effects model with inverse variance demonstrated a mean difference in PIMBL of −0.07 mm (95% CI −0.12 to −0.02) between standard length implants in conjunction with MSFA and short implants (Fig. 3). For studies with confidence intervals, the standard deviation was calculated using the formula $SD = \sqrt{N} \times \frac{ul-ll}{2\times 1.96}$, where 'ul' is the upper limit and 'll' is the lower limit. The test for heterogeneity disclosed substantial heterogeneity among the studies included ($I^2 = 62.1\%$, $P = 0.072$). A sensitivity analysis showed similar but non-significant results.

The analysis was conducted using the metaprop function in Stata 14 (2015) (Stata Corp LP, College Station, TX, USA).

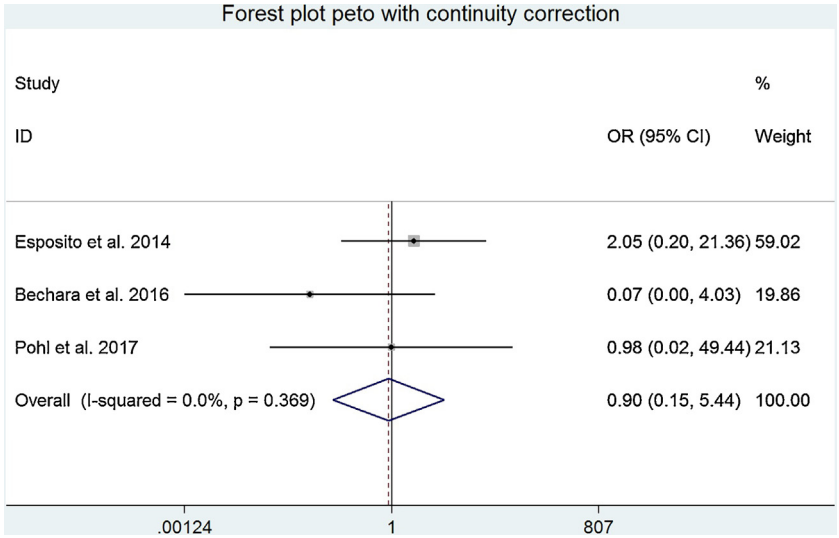

Fig. 2. Overall estimated patient-based implant survival with no implant loss.

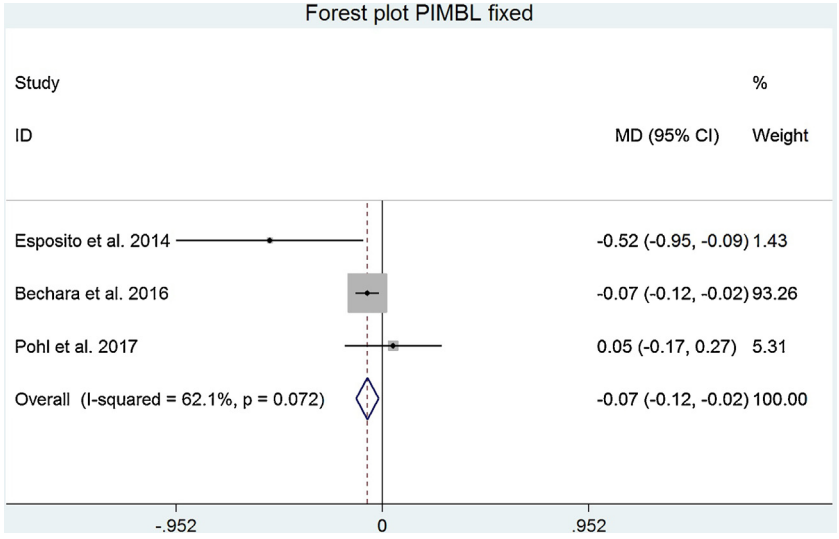

Fig. 3. Meta-analysis using a random-effects model, assessing the peri-implant marginal bone level.

Methodological quality

The quality of the included studies is summarized in Table 5. All studies were considered to present a low risk of bias, since all quality criteria were met[19,20,27]. Moreover, a clear explanation of withdrawals and drop-outs was included, but blinding of the outcome assessment was not performed in any of the included studies.

Discussion

The objective of this systematic review was to test the hypothesis of no difference in implant treatment outcome after the installation of short implants (≤8 mm) in the posterior part of the maxilla compared to standard length implants (>8 mm) in conjunction with MSFA using the lateral window technique, after an observation period of ≥3 years. The survival of suprastructures and survival of implants were included as primary outcome measures. Secondary outcome measures included PIMBL, ISQ, PROMS, and complications. Three RCTs with a low risk of bias fulfilled the inclusion criteria. A high survival of suprastructures and implants was found, regardless of the treatment modality used. Moreover, PIMBL was limited, ISQ values were high, and patient satisfaction was high with both treatment modalities. However, none of the studies involved an observation period of more than 3 years. Hence, the conclusions drawn from the results of this systematic review and meta-analysis should be interpreted with caution.

Survival of the suprastructures was assessed in one of the studies, revealing high survival rates and no statistically significant difference between the two treatment modalities after 3 years[20]. These results are in accordance with previously published systematic reviews, which have revealed that short implants represent a feasible alternative for the rehabilitation of the atrophic posterior maxilla when compared to the installation of standard length implants in conjunction with MSFA[24,50,51]. However, the conclusions in previously published systematic reviews have been based predominantly on non-randomized short-term studies with substantial heterogeneity, involving both single and splinted prosthetic solutions[11,13,20,42,46,52,53]. In contrast, a newly published systematic review reported high long-term survival of suprastructures after the installation of standard length implants in conjunction with MSFA[7]. Thus, non-randomized studies and various systematic reviews have reported high long-term survival of suprastructures after the installation of short implants and standard length implant implants in conjunction

Table 5. Quality assessment.

Study	Random selection in the population	Definition of inclusion and exclusion criteria	Report of losses to follow-up	Validated measurements	Statistical analysis	Risk of bias[a]
Esposito et al. 2014[20]	Yes	Yes	Yes	Yes	Yes	Low
Bechara et al. 2016[19]	Yes	Yes	Yes	Yes	Yes	Low
Pohl et al. 2017[27]	Yes	Yes	Yes	Yes	Yes	Low

[a] Low risk of bias if all the quality criteria were met; moderate risk of bias if one of the criteria was not met; high risk of bias if two or more criteria were not met.

with MSFA in the posterior part of the maxilla. Further RCTs with larger patient samples and longer observation periods are needed before one treatment modality can be considered superior to the other.

Implants inserted in partially or totally edentulous patients without bone augmentation have demonstrated high long-term survival, as documented in previously published reviews[54,55]. High implant survival after the installation of short implants or standard length implants in conjunction with MSFA in the posterior part of the maxilla has been documented previously in long-term non-comparative studies and various systematic reviews[2,6,8,56]. In the present systematic review, no statistically significant difference in implant survival was found between the two treatment modalities after 3 years. In particular, the meta-analysis and OR revealed a non-significant lower odds of losing short implants compared to standard length implants in conjunction with MSFA after 3 years. Moreover, a newly published systematic review assessing the long-term results after MSFA demonstrated a high implant survival rate regardless of the grafting material used[7]. This result is in accordance with the implant survival rate in the studies included in this systematic review. However, an observation period of more than 3 years is necessary before final conclusions can be drawn regarding the long-term implant survival rate with the two treatment modalities.

Several factors may influence PIMBL, including smoking, hygiene deficiency, systemic medical conditions, parafunctional habits, type of connection between the implant and suprastructure, implant neck design, and implant surface[57–59]. The quantity of PIMBL is a concern in the long-term prognosis of short dental implants. In a previous study, it was demonstrated that short implants are in general lost 2.5 years earlier compared to standard implants[60]. Moreover, the installation of short implants creates a higher crown-to-implant ratio compared to standard length implants, which might induce a higher stress at the peri-implant cortical bone during function[61]. However, a previously published systematic review reported a significant negative association between the crown-to-implant ratio and PIMBL[62]. Moreover, another systematic review documented that short implants ($<$10 mm) had similar PIMBL to standard implants ($\geq$10 mm) for implant-supported fixed prostheses[63]. In the present systematic review, a gradual PIMBL was observed for both treatment modalities, and the meta-analysis revealed a non-significant higher PIMBL with standard length implants in conjunction with MSFA compared to short implants. Therefore, further long-term studies assessing the PIMBL with the two treatment modalities are needed before definite conclusions can be drawn regarding the clinical relevance of the progressive PIMBL.

Primary implant stability depends on bone quality, bone quantity, implant design, implant surface roughness, surgical technique, and operator skills[64]. A higher ISQ value can be regarded as an indication of improved implant stability[65]. The ISQ value was assessed in one of the studies included in this systematic review, which revealed high primary ISQ values and a gradual increase in ISQ with both treatment modalities[19]. However, after 3 years, a significantly higher ISQ value was reported after the installation of standard length implants in conjunction with MSFA compared to short implants[19]. An ISQ value of 71.6 was reported for short implants and 72.4 for standard length implants in conjunction with MSFA, after 3 years. Consequently, both treatment modalities appear to facilitate acceptable long-term ISQ values.

PROMS are essentially subjective reports of the patients' perceptions of their oral health status and its impact on their daily life or quality of life. The Oral Health Impact Profile questionnaire, Orofacial Esthetic Scale, and Chewing Function Questionnaire are methods commonly used for the assessment of PROMS. In this systematic review, PROMS were assessed in one of the included studies, demonstrating no statistically significant difference between the two treatment modalities concerning overall patient satisfaction[19]. However, treatment involving standard length implants in conjunction with MSFA was significantly more time-consuming and patients receiving short implants were significantly more fully satisfied with the cost of the treatment. In fact, MSFA almost doubled the treatment time and costs, which has also been documented in previous publications[20,39,41]. Assessments of PROMS using questionnaires after the installation of oral implants have disclosed a high degree of patient satisfaction[66–68], which is in accordance with the results of a non-comparative study[69] and studies comparing short implants with standard length implants in conjunction with MSFA[39,41,46,70]. Consequently, both treatment modalities appear to be associated with a high degree of patient satisfaction.

Intra- and postoperative surgical complications were reported for some patients in all of the included studies, revealing fewer surgical complications with short implants compared to standard length implants in conjunction with MSFA[19,20,27]. Intraoperative complications mainly involved sinus membrane perforation and bleeding, whereas postoperative complications included peri-implant mucositis, pain, swelling, and chronic sinus infection[19,20]. Perforation of the sinus membrane was the most frequent intraoperative complication, but did not seem to influence the final treatment outcome[19,20]. Prosthetic complications were reported in one study, disclosing no significant difference between the two treatment modalities after 3 years[27]. In conclusion, the frequencies of biological and technical complications related to both treatment modalities were generally low and they were not severe, which seems to be in accordance with previous publications[39,41,46,70].

The results of this systematic review and meta-analysis imply no difference in implant survival rates of short implants in comparison to standard length implants in conjunction with MSFA. However, despite the high quality of the studies included and the low risk of bias, there is a potential risk of bias because of the heterogeneity among the studies. Moreover, short implants with PIMBL may be more prone to late implant loss compared to standard length implants. Therefore, an observation period of 3 years appears insufficient.

In conclusion, the hypothesis of no difference in implant treatment outcomes after the installation of short implants ($\leq$8 mm) in the posterior part of the maxilla compared to standard length implants ($>$8 mm) in conjunction with maxillary sinus floor augmentation using the lateral window technique, after an observation period of $\geq$3 years, could neither be confirmed nor rejected due to significant heterogeneity among the included studies. However, all of the studies reported high survival rates of suprastructures and implants, with limited PIMBL. Thus, the insertion of short implants in the posterior part of the maxilla seems to be a suitable alternative to the installation of standard length implants in conjunction with MSFA. Further RCTs with larger patient samples and observation periods of more than 3 years are needed before one treatment modality might be considered superior to the other.

Funding

In 2016, Dr Helle Baungaard Nielsen received Astra Tech implants from Dentsply for a PhD study assessing long-term implant outcomes after the installation of short implants in the posterior part of the maxilla compared to standard length implants in conjunction with MSFA.

Competing interests

None.

Ethical approval

Not required.

Patient consent

Not required.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ijom.2018.05.010.

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