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Meta-Analysis Dental Implants

Vertical bone augmentation and regular implants versus short implants in the vertically deficient posterior mandible: a systematic review and meta-analysis of randomized studies

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Abstract. The aim of this study was to perform a systematic review and meta-analysis of randomized controlled trials (RCTs) comparing the outcomes of short dental implants (≤ 7 mm) versus vertical bone augmentation followed by regular dental implants (> 7 mm) in the deficient posterior mandible. In total, eight RCTs (six using interpositional sandwich grafting and two using a guided bone regeneration technique) were reported in 17 articles at different time points. In the meta-analysis of the sandwich group, the relative risk (RR) for implant loss at 1 year was in favour of short implants (RR 0.41, $P = 0.02$), while no significant difference was found at 3 years (RR 0.65, $P = 0.43$), 5 years (RR 1.08, $P = 0.86$), or 8 years (RR 1.53, $P = 0.52$). The risk of complications was in favour of short implants (RR 0.34, $P = 0.0002$), as was the mean difference in marginal bone resorption after 1 year (-0.09 mm, $P = 0.17$), 3 years (-0.32 mm, $P < 0.00001$), 5 years (-0.65 mm, $P < 0.00001$), and 8 years (-0.88 , $P < 0.00001$). The mean residual osseointegration length of the implants was between 2.94 mm and 4.44 mm in the short implants group and between 7.97 mm and 8.62 mm in the regular implants group after 5 years. In conclusion, in the deficient atrophic posterior mandible, short implants and regular implants demonstrate comparable outcomes within the first 5 years. Patients who are fit for surgery should be informed about the risks and benefits of both options.

Key words: dental implants; bone transplantation; osteotomy; meta-analysis; mandible; evidence based medicine.

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Bone augmentation is used to increase the bone height above the mandibular nerve in the posterior mandible. It is a predictable method, especially if the sandwich technique is applied¹. With this technique, a bone segment is created by osteotomy, which stays pedicled to the blood perfusion of the lingual soft tissues. To increase the bone height in the posterior mandible, the segment is secured in an elevated position by metal plates and screws. Graft material in the form of a block or particles, of autologous, allogeneic, or xenogeneic origin or alloplastic, is interposed. The method is also referred to as interpositional grafting or an inlay technique, and sometimes as osteodistraction², although the latter term is usually reserved for the concept of distraction osteogenesis. Staged vertical bone augmentation in the posterior mandible is usually a technically sensitive surgery that requires an experienced clinical team, involves costs for a second surgery including graft materials, causes an operative burden, and incurs an additional waiting time of around 4 months for the patient. Other options include the method of guided bone regeneration (GBR), which can either be performed in a staged procedure³ or simultaneously with dental implant placement⁴.

Short implants (≤ 7 mm), introduced recently, have proven to be a safe option, especially in the cortical bone of the mandible⁵. Short implants have become increasingly popular. In the deficient posterior mandible with 6–9 mm height above the nerve, they offer an option for the integration of implant-borne restorations without the need for vertical bone augmentation. Both concepts, augmentation and short implants, are presumed to be feasible. However, there are concerns about the longevity of short implants, because they have less osseointegrated length, especially after marginal bone resorption.

The question of bone augmentation and regular implants versus short dental implants in the vertically deficient posterior mandible has been addressed in four recent systematic reviews. The authors concluded that short implants are equal to regular implants with bone augmentation, the latter causing significantly more complications. However, there was no timewise analysis of the numerous publications of several randomized trials on the comparison of bone augmentation with short implants in the mandible. The systematic review of Starch-Jensen and Nielsen⁶ published in 2018 did not include a numerical analysis. The meta-

analysis of Dias et al.⁷ published in 2019 did not account for the variation in observation time, which ranged from 4 months to 8 years. The study by Palacios et al.⁸ from 2018 did not include recent studies performed after 2015. Esposito et al.⁹ (2019a) only looked at the 5-year time point, but not at the variation over time.

The aim of this study was to systematically review the literature comparing the treatment outcomes of short implants (≤ 7 mm) versus bone augmentation followed by regular implants (> 7 mm) applied in the deficient posterior mandible.

Materials and methods

This study was performed in accordance with the PRISMA checklist for systematic reviews of the literature. In the subsequent meta-analysis, the methodology of the *Cochrane Handbook for Systematic Reviews of Interventions* version 5.1.0. was applied (www.training.cochrane.org).

The PICO framework was as follows: population (P): patients in need of dental implants with a mandibular unilateral or bilateral free end situation and vertical bone atrophy; intervention (I): treatment with short implants ≤ 7 mm and no vertical bone augmentation; comparator (C): vertical bone augmentation followed by placement of dental implants > 7 mm; outcomes (O): differences in implant survival (outcome 1), rate of severe perioperative complications (outcome 2), marginal bone resorption (outcome 3), and residual osseointegrated length of the dental implant (outcome 4).

Literature search and study inclusion criteria

A systematic search of the literature was performed in the PubMed library using the search phrase (atrophic OR augmentation OR sandwich OR distraction OR inlay) AND (short OR longer) AND (dental implant*), with restriction to clinical trials (date of last search September 30, 2019). There was no language restriction. Only randomized controlled trials (RCTs) that compared short implants with regular implants in vertically augmented bone in the posterior mandible were eligible for inclusion. In this analysis, short implants were defined as dental implants with a length of ≤ 7 mm. The minimum follow-up time had to be 1 year. Additionally, a search under the author name 'Esposito M' was performed. A hand search was

performed in the *European Journal of Oral Implantology* (the name changed to *International Journal of Oral Implantology* after January 2019). Systematic reviews addressing a similar topic were cross-checked for additional candidate papers⁹.

Data items and collection

Data for the agreed outcomes were extracted from the papers and recorded in an Excel spreadsheet: (1) implant survival (implant present in the oral cavity) based on the number of inserted implants as the baseline, with follow-up intervals started after prosthetic loading. (2) Number of patients with perioperative complications (A: all reported complications; B: only complications of duration longer than 4 days). (3) Peri-implant marginal bone resorption (MBR, in millimetres) from the loading time point as the baseline, as measured radiographically on standardized peri-apical radiographs or, in the event of missing peri-apical radiographs, on panoramic X-rays. (4) Residual osseointegrated implant length, by subtracting the mean measured radiographic bone levels measured from the implant collar (in millimetres) from the reported technical implant lengths.

Risk of bias assessment

The risk of bias assessment was done using the tool provided in RevMan 5.3 software (Cochrane Community) in six subcategories. This assessment was performed independently by two authors (GM and GR). Differences of opinion were resolved by discussion. The authors of previous systematic reviews had determined some of the included studies to have a low risk of bias according to the Cochrane criteria, although only at the earlier follow-up times^{5,8,9}.

Data synthesis

The meta-analysis was conducted using RevMan 5.3 software (Cochrane Community). The statistical unit was the patient. Data from split-mouth studies were combined with data from parallel group trials. For dichotomous outcomes, the relative risk (RR) was calculated; for continuous data, the mean difference (MD) was calculated. The random-effects model was applied for the meta-analysis.

Results

Included studies

In total, eight RCTs were identified^{2,3,4,10-14} (Fig. 1). Some of these were ongoing studies that had been published at different time points, ranging from 4 months to 1 year, 3 years¹⁵⁻¹⁸, 5 years¹⁹⁻²², and 8 years of follow-up²³. These trials could be differentiated by the brand of implant system used. Overall, the eight RCTs were reported in 17 articles (Table 1).

Six of the RCTs involved vertical sandwich bone augmentation (interpositional grafting) in the posterior mandible^{2,10-14}; five of these studies were published by the Esposito group at different time points¹⁰⁻¹⁴. The first of these six studies was a parallel arm comparison in the mandible using Biomet 3i implants (Zimmer Biomet, Palm Beach Garden, FL, USA)¹⁰. The second study used MegaGen implants (MegaGen, Daegu, South Korea) in a split-mouth study in maxillae and mandibles; the data had been reported thoroughly, so the mandibular results could be extracted separately for this review¹¹. The third study used ExFeel implants with

a calcium incorporated surface (MegaGen, Daegu, South Korea) in a parallel arm study in posterior maxillae and mandibles; the mandibular data could be extracted separately¹². The fourth study applied Southern implants (Southern Implants, Irene, South Africa) in a split-mouth design, in atrophic mandibles and maxillae, and the mandible data were reported separately¹³. In the fifth study, Twinkon 4.0 mm implants (Global D, Brignais, France) were used in a parallel arm study in atrophic maxillae and mandibles; again, the mandible data were accessible¹⁴. The sixth study, published by Bernardi et al.², in which sandwich bone augmentation was used as the control intervention, applied IM-Macon implants (Maco Dental Care, Salerno, Italy) in a split-mouth approach in mandibles.

Two of the included RCTs used GBR as the method for vertical bone augmentation in the posterior mandible. Rogn et al.³ used a staged GBR technique with a healing time of 6 months before Straumann TL implants were placed (Straumann, Basel, Switzerland). Shah et al.⁴ performed GBR simultaneously with the placement of ei-

ther short or regular MIS Seven dental implants (MIS Implant Technologies Ltd, Shlomi, Israel).

Methodological aspects of the studies

A meta-analysis was only performed for the six studies that used sandwich bone augmentation as the control intervention^{2,10-14}. Some heterogeneity was presented by the different xenogenic augmentation materials, of which some were not well scientifically documented. Some heterogeneity occurred with the different bone fixation methods using microplates or miniplates, which may affect the stability of the osteotomized bone segment. Instability would be a major risk factor for graft loss. In this meta-analysis, all implant lengths ≤ 7 mm were pooled in one group. Comparability of the intervention and control groups was given by clear inclusion and exclusion criteria, clear randomization, and the same implant system and geometry used in the control and intervention groups in all studies.

The two studies on GBR as the control intervention were not included in the meta-analysis, for the following reasons: GBR is a surgical procedure different from sandwich bone augmentation^{3,4}. The study of Rogn et al.³ was a zero-event study, because no implant losses occurred, and such studies should not be included in meta-analyses for mathematical reasons (division through zero). The two GBR studies were heterogeneous, because one used a staged GBR approach and the other a simultaneous GBR approach, one used a split-mouth design and the other a parallel arm design, and one study counted implant loss from placement and the other from the loading time point^{3,4}. The study by Shah et al.⁴ was not limited to the mandible and also included data on short implants in the maxilla. Furthermore, a non-specified number of implants in the anterior mandible were included. The authors were contacted by e-mail and did respond; however they were not able to provide the missing data within a reasonable time before 2020.

Risk of bias

In general, the risk of bias was considered to be low (Fig. 2). Blinding of the participants would be impossible. Blinding of the assessors was performed only in one study. Incomplete reporting of the outcome was noted in the studies by Shah et al.⁴ and Bernardi et al.². The authors of the Bernardi 2018 study² were contacted using the published e-mail address, how-

Fig. 1. Flow diagram of the study inclusion process.

Table 1. Study characteristics. All studies were RCTs comparing short implants with regular implants in augmented bone.

First author	Year	RCT design	Follow-up years	Bone height (mm)	Augmentation method	Material	Membrane	Implant brand	Diameter (mm)	Length short (mm)	Length long (mm)	Short, n	Long, n
Studies that used interpositional sandwich grafting in the control group for bone augmentation													
Felice ¹⁰	2010	Parallel	1	7.8	Interpositional sandwich grafting	Bio-Oss block and granules (bovine)	Bio-Gide	Biomet 3i	4	6.6	11.2	29	30
Esposito ¹¹	2011a	Split-mouth Mandibul/maxilla	1	6	Interpositional sandwich grafting	Bio-Oss block and granules (bovine)	Bio-Gide	MegaGen	6	5	10.4	15	15
Pistilli ¹²	2013a	Parallel Mandibul/maxilla	1	6	Interpositional sandwich grafting	Sp-Block (equine) OsteoBiol mp3 (porcine)	Evolution fine	Calcium ExFeel	5	5	10.7	20	19
Pistilli ¹³	2013b	Split-mouth Mandibul/maxilla	1	7	Interpositional sandwich grafting	Tecross block (equine)	No	Southern	4	6	10.8	19	19
Bolle ¹⁴	2018	Parallel Mandibul/maxilla	1	5.5	Interpositional sandwich grafting	Gen-Os (porcine) Sp-Block (equine) OsteoBiol mp3 (porcine)	No	Twinkon	4	4	9.2	20	19
Bernardi ²	2018	Split-mouth Mandible	1	NR	Interpositional sandwich grafting	Sp-Block (equine)	No	IM-Macon	3.9	6	10	36	36
Esposito ¹⁵	2011b	Parallel Mandible	3	7.8	Interpositional sandwich grafting	Bio-Oss block and granules (bovine)	Bio-Gide	Biomet 3i	4	6.6	11.2	28	28
Esposito ¹⁶	2014	Split-mouth Mandible	3	6	Interpositional sandwich grafting	Bio-Oss block and granules (bovine)	Bio-Gide	MegaGen	6	5	10.4	14	14
Gastaldi ¹⁷	2018	Parallel Mandible	3	6	Interpositional sandwich grafting	Sp-Block (equine) OsteoBiol mp3 (porcine)	Evolution fine	Calcium ExFeel	5	5	10.7	18	18
Felice ¹⁸	2018a	Split-mouth Mandible	3	7	Interpositional sandwich grafting	Tecross block (equine)	No	Southern	4	6	10.8	17	17
Felice ¹⁹	2014	Parallel Mandible	5	7.8	Interpositional sandwich grafting	Gen-Os (porcine)	Bio-Gide	Biomet 3i	4	6.6	11.2	27	25
Felice ²⁰	2019a	Split-mouth Mandible	5	6	Interpositional sandwich grafting	Bio-Oss block and granules (bovine)	Bio-Gide	Mega Gen	6	5	10.4	10	10
Esposito ²¹	2019b	Parallel Mandible	5	6	Interpositional sandwich grafting	Sp-Block (equine) OsteoBiol mp3	Evolution fine	Calcium ExFeel	5	5	10.7	17	17
Felice ²²	2019b	Split-mouth Mandible	5	7	Interpositional sandwich grafting	Tecross block (equine)	No	Southern	4	6	10.8	16	16
Felice ²³	2018b	Parallel Mandible	8	7.8	Interpositional sandwich grafting	Gen-Os (porcine) Bio-Oss block and granules (bovine)	Bio-Gide	Biomet 3i	4	6.6	11.2	25	23
Studies that used guided bone regeneration (GBR) in the control group for bone augmentation													
Rokn ⁵	2018	Split-mouth Mandible	1	8.1	GBR Staged	Allograft (not specified, allogeneic) and autologous bone chips	Xenogeneic	Straumann	4.1	4	8	11	11
Shah ⁴	2018	Parallel Mandibul/maxilla	1	6-8.5	GBR Simultaneous	4Bone, Biomatlante (allopastic)	4Bone RCM	MIS Seven	NR	6	10	25	25

NR, not reported; RCT, randomized controlled trial.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Bernardi 2018	+	+	?	+	?	+	?
Bolle 2018	+	+	?	?	+	+	+
Esposito (a) 2011	+	+	?	?	+	+	+
Esposito (b) 2011	+	+	?	?	+	+	+
Esposito 2014	+	+	?	?	+	+	+
Esposito 2019	+	+	?	?	+	+	+
Felice (a) 2018	+	+	?	?	+	+	+
Felice (a) 2019	+	+	?	?	+	+	+
Felice (b) 2018	+	+	?	?	+	+	+
Felice (b) 2019	+	+	?	?	+	+	+
Felice 2010	+	+	?	?	+	+	+
Felice 2014	+	+	?	?	+	+	+
Gastaldi 2018	+	+	?	?	+	+	+
Pistilli (b) 2013	+	+	?	?	+	+	+
Pistilli (a) 2013	+	+	?	?	+	+	+

Fig. 2. Risk of bias summary.

ever they did not respond, which was counted as a risk of other bias.

Implant survival rate

In the meta-analysis of implant survival (Fig. 3), short implants performed significantly better than regular implants in augmented bone after 1 year (RR 0.41, $P = 0.02$). After 3 years, the results were still in favour of short implants, although

this was not significant (RR 0.65, $P = 0.43$). There was a shift towards better results for regular implants after 5 and 8 years, which did not reach significance (5 years RR 1.08, $P = 0.86$; 8 years RR 1.53, $P = 0.52$).

Rate of perioperative complications

Peri-operative complications were extracted from the 1-year follow-up

reports of six studies^{2,10-14} within the meta-analysis that reported on complications (Fig. 4). These complications included mild temporary complications lasting less than 3 days, such as postoperative hypoesthesia of the lips, which had disappeared completely after 3 days.

Within the total number of complication events, some complications reported by the authors lasted longer than 3 days, including one jaw fracture¹⁴ and several graft losses; these occurred in 9% of all augmentation cases and 0% of the short implant cases. According to the reports, all cases finally showed healing without permanent damage, in particular no permanent sensory deficit of the alveolar nerve. Overall, the risk of complications was in favour of short implants (RR 0.34, $P = 0.0002$ (Fig. 4).

Marginal bone resorption (MBR)

For five of the ongoing RCTs, MBR data were reported by the authors at a variety of time points¹⁰⁻¹⁴. The RCT by Bernardi et al.² did not report detailed bone resorption data and was excluded from this analysis.

The meta-analysis of MBR (Fig. 5) showed a significantly lower MBR for short implants. The timewise analysis showed that this difference increased consistently over the years: MBR after 1 year (MD -0.09 mm, $P = 0.17$), 3 years (MD -0.32 mm, $P < 0.00001$), 5 years (MD -0.65 mm, $P < 0.00001$), and 8 years (MD -0.88, $P < 0.00001$).

Residual osseointegrated implant length

Five of the ongoing RCTs by the Esposito group reported the residual osseointegrated implant length at a variety of time points (Table 1)¹⁰⁻¹⁴. The RCT by Bernardi et al.² did not report detailed data on the bone levels at the dental implants and was not included in this analysis.

The residual osseointegrated implant length is responsible for anchorage of the dental implants in the bone. The study by Bolle et al.¹⁴, which used 4 mm short implants, reported the lowest mean residual osseointegration of all included studies at 1 year: the residual osseointegration was 3.49 ± 0.16 mm for the short implants compared to 8.43 ± 0.21 mm for the longer implants¹⁴ (Fig. 6). The mean residual osseointegration length of the implants after 5 years ranged between 2.94 mm and 4.44 mm in the short implants group and between 7.97 mm and 8.62 mm in the regular dental

Fig. 3. Forest plot of the meta-analysis of implant survival for the studies on deficient bone that used sandwich augmentation as the control intervention. After 1 year, the results were slightly in favour of short implants. This changed after 3, 5, and 8 years. A constant shift over time in favour of regular implants in augmented bone was observed, which was not significant ($P = 0.52$).

implants group after 5 years ($P < 0.00001$).

Results of the GBR studies

The implant survival was 100% in the study by Rokn et al.³ after staged GBR. In contrast, in the study by Shah et al.⁴ using simultaneous GBR, four short implants and one control implant were lost, giving a calculated survival rate of 84% for the short implants and 96% for the regular control implants.

In the split-mouth study by Rokn et al.³, complications occurred on the augmentation side in five out of 10 patients, giving a patient-based complication rate of 50%, compared to zero complications on the short implants side. However, these complications were only membrane exposures and transient paresthesia for less than 2 weeks. There was one case of incomplete gain of bone height insufficient to place the planned long implants. Complications were not mentioned in the study by Shah et al.⁴.

MBR amounted to 0.3 ± 0.34 mm for the short implants versus 0.47 ± 0.54 mm for the control implants in the study by Rokn et al.³. In the study by Shah et al.⁴, MBR was 0.6 ± 0.16 mm for short implants versus 0.86 ± 0.2 mm for regular implants.

Residual osseointegration after 1 year was 2.45 ± 0.34 mm for short implants compared to 6.03 ± 0.8 mm for regular implants in the study by Rokn et al. using a staged GBR and 4 mm implants³. Residual osseointegration was 5.03 ± 0.7 mm versus 9.04 ± 1.2 mm in the study by Shah et al., which used a simultaneous GBR procedure⁴.

Discussion

One of the main results of the meta-analysis of studies that used the sandwich technique, was the significantly higher survival of short implants when compared to regular implants in augmented bone over a short observation time of up to 1 year. This higher survival changed grad-

ually with increasing observation time: after 3 years the advantage for short implants showed no statistical significance, and after 5 years and 8 years there was a non-significant shift in favour of regular implants and bone augmentation. The same pattern of shift in favour of regular implants after 5 years of observation has been observed in studies comparing short and regular implants in patients with sufficient bone without augmentation⁵. The two analysed RCTs that used GBR as the bone augmentation technique showed better results for the augmentation group after 1 year of follow-up.

Short implants consistently showed less change in marginal bone level than regular implants. The difference between the two groups reached almost 1 mm on average over the years. The same pattern of lower resorption in the short implants has been observed in studies where there has been sufficient bone without augmentation and also in studies using the GBR technique for bone augmentation⁵. The biological reason for the lower absolute marginal

Fig. 4. Forest plot of the meta-analysis of the observed complications. There was a clear and significant approximately three times (0.34) lower risk of experiencing complications in the short implants group compared to the bone augmentation with long implants group.

Fig. 5. Forest plot of the meta-analysis of marginal bone resorption (MBR) for the studies on deficient bone that involved sandwich bone augmentation as the control intervention. The analysis over time showed that the difference between the groups increased consistently over the years.

bone resorption with short implants is unclear. A possible explanation is that there is a greater functional stimulus to the bone over the smaller osseointegration length for short implants, which may better preserve the compact bone in the lateral mandible. Another explanation could be that alveolar bone loss after tooth extraction is physiological and the speed of such resorption decreases the closer the shape of the mandible comes towards the basal bone²⁴.

The comparison of survival rates over time suggested a trend towards bone augmentation and regular implants possibly having a better long-term survival than short implants. A prospective observation-

al study showed that the osseointegration of short implants failed after longer observation times, even without signs of infection or inflammatory bone loss²⁵. As a percentage of their functional length, short implants had a higher bone resorption than regular implants. The comparison of marginal bone resorption over time showed a consistent and significant advantage for short implants beginning after 3 years, with a constant increase in the difference over time up to 0.88 mm between short and regular implants. If both trends (survival and MBR) are extrapolated over time, regular implants with bone augmentation appear to be the more sustainable concept than short implants, because they

can resist MBR for longer. On the other hand, if the increasing resorption is clinically connected with pocket formation and not with gingival recession, the longer implants may become more prone to peri-implantitis.

Two RCTs were included that used 4 mm short implants, sometimes called ultrashort implants^{3,14}. For both studies, only a 1-year follow-up is reported in the literature. In the study by Bolle et al.¹⁴, in which interpositional sandwich grafting was performed, residual osseointegration after 1 year was 3.49 mm for the short implants compared to 8.43 mm for the regular implants; the lower border of the standard deviation was 3.3 mm versus

Fig. 6. Forest plot of the meta-analysis of residual osseointegration in the studies on deficient bone that involved sandwich bone augmentation as the control intervention. The analysis over time showed a slightly decreasing difference between the regular implants and the short implants. At 1 year, regular implants had 4.85 mm more osseointegrated length than short implants; after 8 years, they had 3.81 mm more osseointegrated length.

8.2 mm. In the study by Rogn et al.³, in which GBR was performed for bone augmentation, the mean osseointegrated length after 1 year was 2.45 mm compared to 6.03 mm for the regular controls, with a lower border of the standard deviation of 2.1 mm versus 5.2 mm. According to these short-term studies, short implants can remain functional in the cortical bone of the posterior mandible even with little more than 2 mm of osseointegrated length. Whether there is a difference within the short implants group between short and ultrashort implants cannot be answered on the basis of the present data.

The implants in the various studies were placed under study conditions with constant supervision of the patients and supportive periodontal care. Under normal clinical conditions inflammatory bone loss may occur, which may quickly result in complete loss of osseointegration of the short implants. In contrast, longer implants with a higher reserve osseointegrated length may remain stable even after some degree of inflammatory bone resorption. In these cases, the treatment of peri-implantitis could be initiated, with the aim of preserving the implants and the prosthesis, which would not be possible with the short implants. Significant progress in

the treatment of peri-implantitis has been made in recent years, although the data on the treatment modalities are still inconclusive²⁶. On the other hand, there is the argument that a short implant is lost before peri-implantitis occurs and that such a situation does not leave behind a large bone defect.

Replacement implants placed at the same sites as previously failed implants show a significantly lower survival rate (73%) than the original ones (94%)²⁷. For this reason, the common technical thinking of quick obsolescence and replacement of a technical device after a planned functional period has strong limitations in biology. If an implant is lost, especially if inflammatory processes are involved, the surgical field for a next implant placement is more difficult, due to scarring of the soft tissues and other influences. The data from the present study suggest that bone augmentation and regular implants could probably avoid such repeated surgery at one site. Consequently, patients who are fit for surgery should be informed about the risks and benefits of bone augmentation. This could also involve the referral of a patient to a specialist for bone augmentation in particular cases.

Vertical bone augmentation has its disadvantages. In this analysis, bone augmentation caused perioperative complications lasting longer than 3 days in nearly 9% of the patients, whereas these complications were totally absent in patients who received short implants. The complications included one jaw fracture among the 138 patients in the control group of this meta-analysis, and several bone graft losses. All complications could be treated without leaving permanent damage, according to the authors of the study¹⁴. In general, there was no permanent damage, in particular no permanent nerve damage reported for the sandwich bone grafting technique analysed here. From the standpoint of the patient, a short implant is attractive since it involves fewer costs, less operative burden, less treatment time, and a lower complication risk, and there is usually less need to involve a surgical specialist, so the patient does not need to contact another practice.

The conclusions presented here are drawn on a relatively high level of evidence, since eight RCTs were included in the review, with data obtained at various time points. There was a low risk of bias in the studies. Two of them were relatively heterogeneous (GBR technique) and were

not included in the meta-analysis, which was limited to the group of sandwich bone augmentations. The two additional GBR studies showed the same pattern of outcomes as the sandwich studies in two respects: higher MBR and higher complications in the regular implants and augmentation group than in the short implants group. However, the results for implant survival differed from those of the sandwich studies, because a higher implant loss was already documented at the 1 year time point for the short implants. The six studies in the meta-analysis of sandwich bone augmentation were relatively homogeneous in terms of clinical methods. The comparisons within the studies were fair, since the same implant systems, only differing in length, were used at the test and control sites.

Nevertheless, there are limitations. In the sandwich studies, paracrestal incisions were used for the bone augmentation, but crestal incisions were used for implant placement. This double incision can cause a hypovascularized marginal gingiva at the implant emergence point. As such, this might have jeopardized the results of the control groups. Further, the limited multicentre foundation of the data should be considered. All but one of the studies included in the meta-analysis were performed by the same author group and were published in the same journal, for which the senior author was also the editor in chief. Another criticism may be that the biomaterials used for bone grafting were heterogeneous, since various xenogeneic equine, porcine, and bovine bone block materials were used for the sandwich bone augmentation technique as the control intervention in all included studies (Table 1). The bovine material used was protein-free. However, the collagenated equine and porcine materials used contained xenogeneic and therefore possibly immunogenic proteins with an unclear contribution to the observed graft rejections, as observed on other occasions. For example, in a recent study on partially processed collagenated equine bone blocks, more than one third of the patients experienced complications such as wound dehiscence and graft rejection²⁸.

In conclusion, in the deficient atrophic posterior mandible, short implants and regular implants demonstrated comparable outcomes within the first 5 years. Patients who are fit for surgery should be informed about the risks and benefits of both options.

Patient consent

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Ethical approval

Ethical approval was not required for this literature review.

Competing interests

The authors declare that there are no relevant conflicts of interest. HT has received speaker honoraria and course fees from Geistlich, Straumann, and Camlog within the last 3 years. GR and GM declare no conflicts of interest.

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