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Meta-Analysis
Dental Implants

Short implants versus bone augmentation in combination with standard-length implants in posterior atrophic partially edentulous mandibles: systematic review and meta-analysis with the Bayesian approach☆

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Abstract. The use of short implants as an alternative to bone reconstruction techniques for the placement of standard-length dental implants is a debated topic. The aim of this study was to perform a systematic review and meta-analysis in order to assist in the clinical decision making about the most appropriate approach for the fixed rehabilitation of the posterior atrophic partially edentulous lower jaws. Only randomized trials with at least 1-year follow-up were included. Of the 1024 studies initially retrieved, 14 articles were selected and independently evaluated by two reviewers. Finally, four studies were included, and underwent data extraction and meta-analysis with the Bayesian approach. Both treatment approaches provide high implant survival rate after 1year of function. However, the probability of survival rate of short implants being greater than standard length implants is 84%, and the probability of complications using short implants being greater than standard-length

☆ Key findings: Short implants have similar survival rates, fewer complications, lower morbidity, cost, needed time for rehabilitation and greater comfort for patients, when compared with the bone reconstruction techniques for placement of dental implants of conventional size.

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implants is 15.7%. In spite of similar survival rates when the residual bone is sufficient for placement of short implants, the latter should be preferred to augmentation techniques and standard-length implants due to fewer complications, lower morbidity and greater comfort for patients.

Key words: alveolar bone grafting; alveolar bone loss; dental implants; mandible; short implants; vertical bone augmentation.

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Osseointegrated dental implants have represented a breakthrough in clinical practice for replacing missing teeth and supporting prosthetic reconstructions in edentulous areas. One of the main requirements for achieving successful implant therapy is the availability of a sufficient bone dimension for the dental implants placement, both in height and thickness.[1] Physiologically, the function of the alveolar bone is to support the tooth, and this function expires after tooth loss/extraction, which triggers a bone resorption process. Since alveolar bone is a tooth-dependent tissue, resorption is a chronic process that starts soon after extraction. This may compromise the future placement of dental implants.[2]

Alveolar bone augmentation techniques have been successfully used with the purpose of creating the required bone volume for the placement of standard-size implants. However, such techniques have generally a high morbidity, can be difficult to perform for the average clinician and may bring some discomfort to the patient. Furthermore, they increase the cost and the duration of the treatment. It is therefore important to evaluate the clinical performance of any therapeutic approach aimed at the rehabilitation of atrophic edentulous sites by avoiding demanding bone augmentation procedures, while keeping the success rate high.[3] Various types of surgical techniques are used currently, either associated or not associated with biomaterials, with the purpose of increasing bone density in height and/or thickness in regions intended for placing dental implants.[4–6] These surgical techniques vary in morbidity, predictability, cost and adverse effects.[7] In addition, complications may arise such as infection, soft tissue dehiscence, exposure of graft, fracture of bone fixation materials, among others, that significantly increase the morbidity of the procedure and may hamper the placing of dental implants.[8] A relatively recent alternative for placing implant-supported fixed rehabilitations in regions with scarce residual bone is represented by implants of reduced length ('short implants'). This type of implant, initially defined as a fixture having an 8-mm or less portion embedded in bone, is indicated in situations of reduced bone height[9,10] for which the conventional alternative is the surgical procedure for bone augmentation. This evidence-based systematic review of the literature aimed at evaluating the efficacy and safety of short implants as compared to surgical procedures for vertical bone augmentation associated with placement of standard-size dental implants.

Materials and methods

This systematic review with meta-analysis was based on the Prisma Statement guidelines[11].

Question to be answered P-Patient, Population or Problem, I-Intervention or exposure, C-Comparison, O-Outcome (PICO)

In patients with posterior atrophic partially edentulous mandible, is the use of short implants superior to augmentation procedures combined with standard-length implants, in terms of implant survival and complication rates after at least 1year of function?

Criteria for study inclusion

Only randomized clinical studies with at least 1-year follow-up after the final rehabilitation were included. The studies had to compare one group treated with short implants (8-mm long or less)[9,12] and one group treated by any augmentation technique in combination with standard-length implants (longer than 8 mm),[13] for the rehabilitation of posterior atrophic partially edentulous mandible. The rehabilitation with short implants in augmented bone was not considered.

Outcome variables

The variables of interest in this study were: implant survival after 1year of loading; biological and mechanical complications associated with the two types of treatment, such as paresthesia, prosthetic connection (abutment type) exposure, bone loss, bone fracture, graft resorption, flap dehiscence and graft exposure.

Search strategy of randomized clinical trials

The electronic search was undertaken on the following databases: MEDLINE (online MEDLARS), LILACS/BIREME (Latin American and Caribbean Sciences of Health) and the Cochrane Register of Controlled Trials (The Cochrane Central Register of Controlled Trials). Only randomized controlled trials (RCTs) published in the English language were considered. The following search terms combined through the Boolean operators AND, OR were used: (short[All Fields] AND (''dental implants''[MeSH Terms] OR (''dental''[All Fields] AND ''implants''[All Fields]) OR ''dental implants''[All Fields] OR (''dental''[All Fields] AND ''implant''[All Fields]) OR ''dental implant''[All Fields])) AND Clinical Trial[ptyp], and (vertical[All Fields] AND (''bone and bones''[MeSH Terms] OR (''bone''[All Fields] AND ''bones''[All Fields]) OR ''bone and bones''[All Fields] OR ''bone''[All Fields]) AND augmentation[All Fields]) AND Clinical Trial[ptyp].

The selection of articles and data extraction was performed by three reviewers: F.J. N.D., V.G.A.P. and M.Z.C. The initial search was conducted by two reviewers independently, who selected the articles through the abstracts retrieved from the databases. In case of disagreement, the two reviewers reached consensus for the inclusion of the selected articles. Any doubt about the possible inclusion of a study in the systematic review was discussed together with the third reviewer until consensus was achieved. The excluded studies were tabulated together with the reasons for rejection.

All included studies underwent risk of bias assessment, considering four domains: random sequence generation, allocation concealment, blinding of participant and personnel, blinding of outcome assessment. The risk of bias for each item was considered as high, low or unclear. If a study had at least one item at high risk, it was considered at high risk, and if at least one item was unclear, the study was considered at medium risk.

Statistical analysis

If at least three studies with similar comparisons, reporting data on implant survival and postsurgical complications were found, a meta-analysis was undertaken using the Bayesian perspective.[14] We were interested in comparing the proportion of the survival of short and conventional implants and their complications. In Bayesian analysis the posterior distribution of the parameter of interest represents a more complete inference. Thus, the methodology used was based on the mixture of the posterior distributions of the proportions of each study belonging to the meta-analysis.[15–17]

The statistical model used was Bernoulli with parameter p (population success proportion). That is, the random variable X represents the survival of an implant; $X = 1$, if there was survival with probability p of $X = 0$, if there not was survival with probability $1 - p$. Then, $X|p \sim Bernoulli(p)$. For each study $j(j = 1, 2, 3, 4)$, after observation $\boldsymbol{x}_j$ from $\boldsymbol{X}_j$, we obtained the respective likelihood function. And, if the prior distribution of p was *Uniform* (0,1), the posterior distribution of p given the data is Beta with parameters $y_j + 1$ and $n_j - y_j + 1$, y_j were the successes of the study j and n_j the sample size. Therefore, the result of this Bayesian meta-analysis was the mixture of the posterior distributions of p, called meta-analytic distributions[16]. We used the sample size observed in each study as weight.

In Bayesian inference, the short and standard-length implant survival rates (p) were unknown quantities from which it was possible to calculate their probability distributions. The same approach held for the proportion of patients with postsurgery complications.

The data were analysed using the software R version 3.1.3.

Results

Search strategy

The search strategy results and study selection steps are shown in Fig. 1.

Papers included

Four papers were included in this systematic review. Their features are listed in Table 1. In these studies, the bone reconstruction procedure consisted of xenogenic grafts fixed by mini-plates with mini-screws and guided tissue regeneration using resorbable collagen membranes.

Papers excluded

The studies excluded after review of the full text and consensus meetings between reviewers are listed along with the reasons for exclusion in Table 2. Based on the risk-of-bias assessment, all studies were judged at a medium risk of bias (Table 3).

Meta-Analysis

The data relating to the studies included are reported in Table 1. Patients treated with short implants displayed fewer complications compared to patients treated with procedures for vertical bone augmentation and standard-length implants.

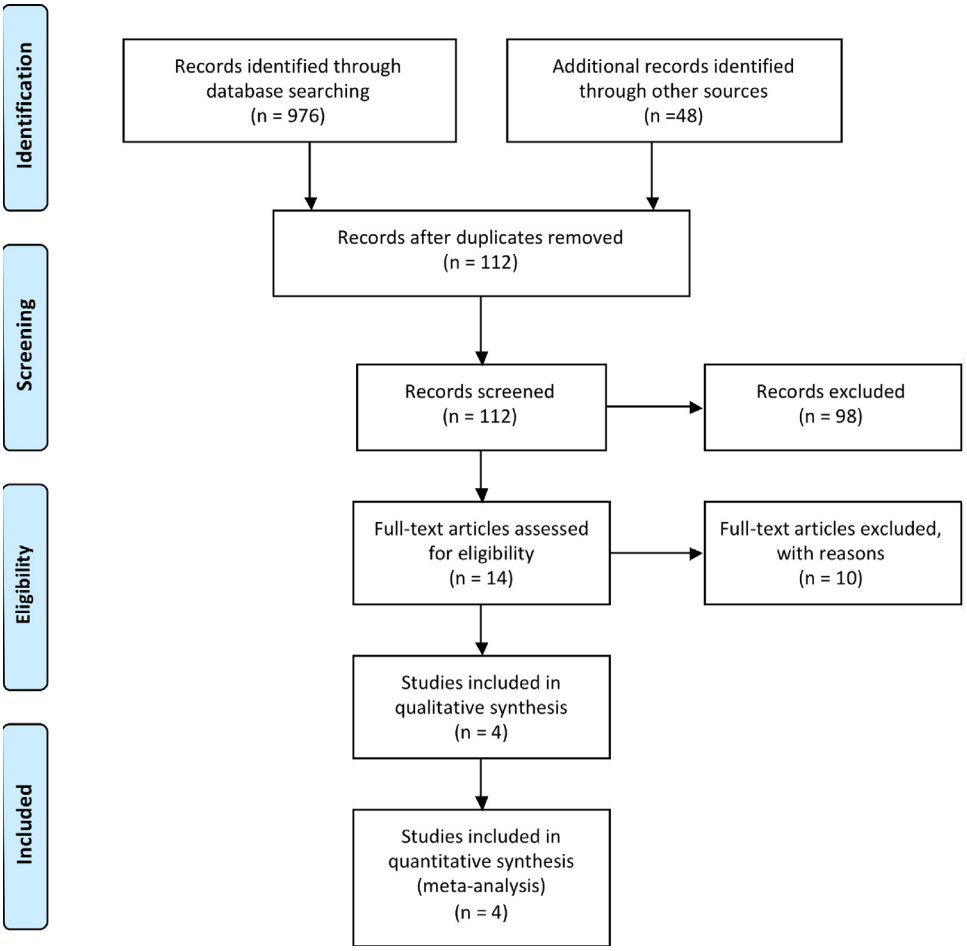

Fig. 1. Prisma flowchart of the study selection procedure.

Table 1. Main data extracted from the included studies.

	Short implant				Bone augmentation + conventional-size			
	Felice et al. (2010)[18]	Esposito et al. (2011)[19]	Pistilli et al. (2013)[20]	Pistilli et al. (2013)[21]	Felice et al. (2010)[18]	Esposito et al. (2011)[29]	Pistilli et al. (2013)[20]	Pistilli et al. (2013)[21]
No. of patients treated	30	15*	20*	20	30	15*	20*	20
Males/females	7/23	4/11*	10/10*	3/17	15/15	4/11*	10/10*	7/13
Mean age (range) at surgery (years)	56 (40–83)	56 (37–69)*	54.1 (42–70)*	58.6 (39–80)	55 (43–67)	56 (37–69)*	54.1 (42–70)*	52.8 (42–70)
Total no. of inserted implants	60	26	41	32	61	30	47	31
Implant survival (12 months)	98.3%	100%	100%	100%	95.1%	96.7%	93.6%	93.5%
Complications before the implant (e.g. graft resorption per patient)	0	0	0	0	4	5	2	1
Number of patients with complications after implant	0	1	0	8	0	1	7	17
Short period paresthesia – few days	0	0	0	8	0	0	7	14
Abutment exposure	0	0	0	0	0	0	0	0
Peri-implant bone loss	0	1	0	0	0	0	0	0
Bone fracture	0	0	0	0	0	0	0	1
Bleeding	0	0	0	0	0	0	0	1
Graft resorption	0	0	0	0	0	5	2	1
Dehiscence	0	0	0	0	4	1	0	1

* Split-mouth design: data on patients' age and gender coincide in the two treatment groups.

The mean survival proportion after 1year of loading for short implants was equal to 97% (95% credibility interval: 90%; 100%), and for vertical bone augmentation and conventional-size implants, it was 92.6% (95% credibility interval: 83.0%; 98.5%). Figure 2A shows the meta-analytic density of the implant survival proportion in the two groups. It can be said, from this analysis, that the probability of survival proportion considering short implants being greater than the vertical bone augmentation and standard length implants was high ($\Pr(p_{short} \geq p_{conventional}|Data) = 0.84$).

The proportion of patients with complications was lower in the groups using short implants than in groups using standard-length implants. The median proportion of patients with complications when using short implants was equal to 6% and the 95% credibility interval for this proportion was [0%; 50%]. For standard-length implants, the median was 39% and 95% credibility interval was [7%; 94%]. Figure 2B shows the meta-analytic density of the proportion of patients with complications when using short and standard-length implants. The probability of the proportion of patients with complications using short implants being greater than the standard-length implants was 15.7% ($\Pr(p_{short} \geq p_{conventional}|Data) = 0,157$). When we calculated the predictive distributions of both types of implant, we found that the probability of a new patient with short implants having complications was 14%, and that for a patient with standard-length implants was 44%.

The results obtained by Bayesian analysis suggested that the probability of survival of short implants was greater, and that the probability of the proportion of patients with complications was lower when compared to standard-length implants.

Table 2. Studies excluded and reasons for exclusion.

Study	Reason for exclusion
Merli et al. (2010)[22]	All implants placed with graft
Felice et al. (2009)[23]	Compared two grafting techniques
Fontana et al. (2008)[24]	Compared two grafting techniques
Felice et al. (2008)[7]	Compared two grafting techniques
Bianchi et al. (2008)[25]	Did not use short implants
Merli et al. (2007)[26]	All implants placed with graft
Chiapasco et al. (2007)[27]	Did not use short implants
Felice et al. (2009)[28]	4 months follow-up
Esposito et al. (2011)[29]	Multiple publication
Esposito et al. (2012)[30]	5 months follow-up after load

Table 3. Risk of bias table.

Trial	Design	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment
Esposito et al. (2011)[19]	RCT	+	+	?	+
Felice et al. (2010)[18]	RCT	+	+	?	?
Pistilli et al. (2013)[20]	RCT	+	+	?	?
Pistilli et al. (2013)[21]	RCT	+	+	?	+

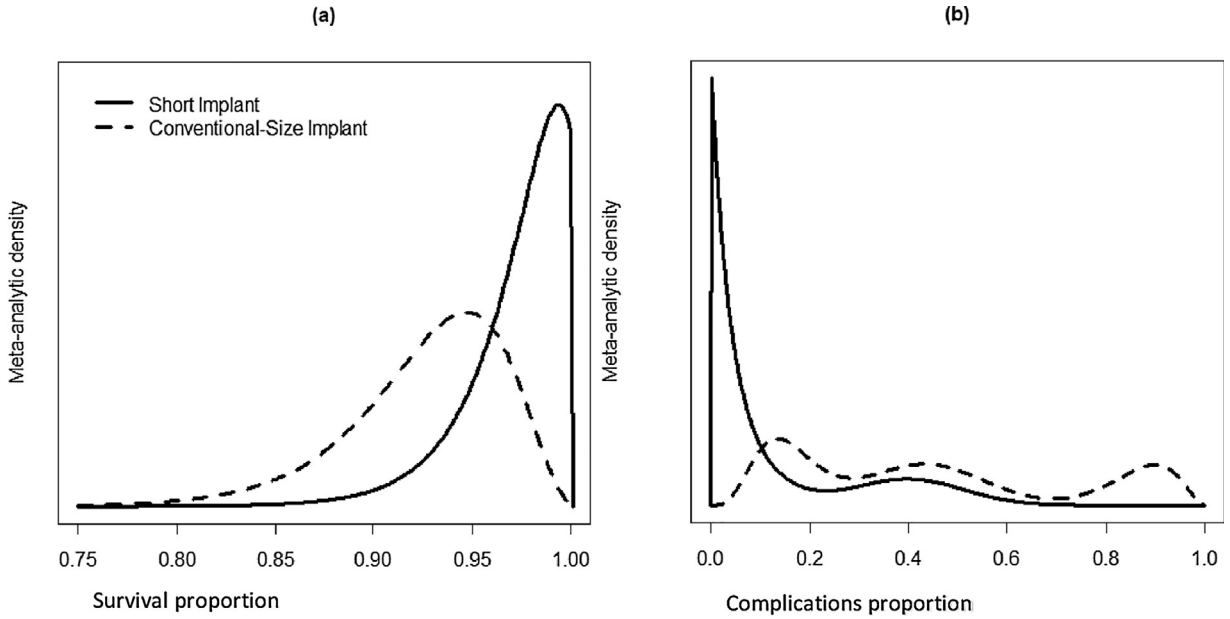

Fig. 2. (A) Meta-analysis for survival proportion. (B) Meta-analysis for proportion of patients with post-surgery complications.

Discussion

This systematic review allowed the comparison of two rehabilitation procedures using osseointegrated dental implants in situations of limited available alveolar bone. The use of short implants has been increasing in recent years, and its promising results support credibility of the technique among professionals in the field of implantology. In 2008 Fugazzotto[31] reported that although the use of short implants is a tempting alternative, proper evaluation of the scientific evidence to ensure that the result is at least equal to that obtained with the use of conventional-size implants would be of utmost importance. In order to draw reliable information about the efficacy and safety of the two approaches, only evidence-based comparative studies need to be considered, as was done in the present review.

The four studies included in this systematic review showed that the survival of the implants after a minimum of 1year of functional loading is 97% for short implants and 92.6% for standard-length implants associated with a vertical bone augmentation procedure. This finding is in line with the results obtained by Sánchez-Garcés et al.[32], who reported a survival rate of 92.5% with minimum follow-up of 18 months after the load of short implants and by Romeo et al.[33], which reported cumulative survival rate in 5years of 95.5% for short implants placed in severely resorbed edentulous mandibles.

These results are justified, possibly as a result of improved techniques and implant systems such as, for example, new surface treatments, diverging from results obtained in the past, in which the short implants achieved results inferior when compared to the conventional-size implants, as in Steenberghe et al.[34] and Naert et al.[35]. In this last study, the authors reported that implants with a length of less than 10mm may achieve a survival rate as low as 81.5% and that for each 1mm of reduction in the length of the implant, the risk of failure increases 0.16 times (with 95% confidence interval of 0.07; 0.26). The gap has been reduced, however, with the use of special macro- and microgeometry adopted by the various companies producing short implants. Today the short implants design is different from standard-length implants: the former are not simply longer implants with a resected apex but their design is adapted to their length: the diameter is often wider than standard implants, and the surface is enhanced to compensate for the reduced overall area.

The use of meta-analysis with the Bayesian approach was justified by the possibility of quantifying the probabilities of upcoming events, according to the results obtained in the studies included in the systematic review, which ensured a high survival rate of implants. Although this study was carried out with the data published in the included studies and not with the original databases, in which it could be possible to know, for example, whether the same patient had more than one complication, an increased tendency of the presence of complications was observed with the use of bone augmentation techniques, associated with the placement of conventional-size implants. Hence, short implants may represent a valuable alternative for the rehabilitation of atrophic mandibles. This consideration may be strengthened by the lack of a need for a prior vertical bone augmentation procedure when the residual bone dimension is sufficient for the safe placement of short implants.

This result is relevant to clinical practice because with a minimally invasive intervention like the placement of short implants the patient will be subject to a less discomfort in addition to a lower probability of failure and complications. In line with the present study, another literature review[36] concluded that the improvement of short implant systems, combined with the correct prosthetic rehabilitation, ensure good clinical outcomes by reducing the number of complications, patient discomfort and cost of rehabilitation. However, one must acknowledge that the use of short implants may imply some technical difficulty. For example, it is less easy to handle small-size implants than standard-size ones. Furthermore, a greater precision is required in placing implants when the available bone is reduced, especially to avoid any lesion to neurovascular structures. Finally, in case of higher than average marginal bone loss over time, the risk of losing stability is greater for short implants than for standard-length ones.

Albrektsson et al.[37] in 1986 enunciated some factors that are considered as implant success indicators such as: absence of pain or paresthesia, lack of mobility of the implant and absence of peri-implant radiolucency upon radiographic examination. The studies included in this systematic review, however, did not evaluate the success rates, but only the survival of the implants, which may represent a limitation of these studies. The most frequent complications in the augmentation group were tissue dehiscence and bone graft resorption that are clearly technique-related events. No randomized clinical trials were found that compared other vertical bone augmentation techniques (e.g. osteogenic distraction, interpositional grafting with autogenous bone and onlay grafts of autogenous or xenogenic bone) with the use of short implants. In the studies included, the most common complication associated with the use of short implants was paresthesia, which is usually temporary, and has also been reported in cases treated with conventional-size implants, as evidenced by the study of Kawakami et al.[38].

In 2006, Ormianer and Palti[39] included the short implants among the risk factors described in the literature as a possible cause of failures or complications in implant treatment, jointly with systemic comorbidities, implants placed in the maxilla, immediate loading, immediate implants in post-extraction sockets and partial edentulism. Over recent years, the use of short implants has increasingly spread worldwide producing a growing amount of scientific evidence in support of their use in implant-based rehabilitations.[27] Short implants represent a reliable alternative option for the treatment of edentulous posterior mandible, displaying excellent clinical outcomes, with reduced complications, cost and morbidity as compared to demanding grafting procedures for the placement of standard-length implants.

In conclusion, this systematic review concluded that both rehabilitation techniques considered may achieve a similarly high implant survival rate after 1year of load. Nevertheless, among other advantages, due to the lower risk of postsurgical complications, the use of short implants should be preferred when the available bone is sufficient for their placement. However, further comparative studies with a wide sample size and a long-term follow-up are necessary to confirm the present results.

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Competing interests

The authors have no competing interests to declare.

Ethical approval

Not required.

Patient consent

Not required.

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