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Surgical techniques used in the rehabilitation of partially edentulous patients with atrophic posterior mandibles: A systematic review and meta-analysis of randomized controlled clinical trials

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SUMMARY

Purpose: Given the lack of general consensus in the literature regarding the best method to rehabilitate partially edentulous patients with extended atrophic edentulous sites in the posterior zone of the mandible, and with a residual ridge height less than 8 mm (with or without bone augmentation procedures), the aim of this systematic review was to analyze all the relevant randomized clinical trials (RCT), and, by means of a meta-analysis of the collected data, draw some conclusions regarding the best available treatments for the rehabilitation of posterior edentulism in partially dentate mandible.

Materials and Methods: An electronic search was conducted in the MEDLINE and Cochrane Oral Health Group databases for studies published between January 2000 and September 2015 with the use of relevant keywords and hand-searching. All identified publications were screened by the authors according to the Cochrane Data Collection Form for Intervention Reviews. Collected outcomes such as biological complications, vertical ridge changes, implant and prosthetic failure were studied by subgroups analyses.

Results: An initial search yielded 81 potential articles, of which 12 studies were chosen for inclusion. Short implants seemed to be effective in limiting incidence of the biological complications (RR: 2.822; 95% CI: 1.809-4.403; $p < 0.0001$) and degree of ridge height reduction (difference in means of 0.052 mm; 95% CI: 0.026-0.079 mm; $p < 0.0001$) when

compared with long implants placed in augmented bone. Implants placed in augmented areas with the use of onlay block grafts seemed to behave worse than implants placed in the augmented sites regardless of the augmentation procedures. However, this difference did not reach statistical significance.

Conclusion: Findings from subgroup analyses revealed that *(1)* short implants placed in the posterior atrophic areas of partially edentulous mandibles were associated with superior outcomes compared with long implants in augmented bone, such as lower rate of biological complications and of peri-implant bone loss; whereas *(2)*, there was no evidence that onlay augmentation was inferior to any of the other augmentation techniques employed.

KEYWORDS

Partially dentate mandible, posterior mandible, atrophic area, dental implant, vertical augmentation

Running Title

Rehabilitation of atrophic posterior mandibles

INTRODUCTION

This paper sets out the results of a systematic review of the literature on the best treatment to rehabilitate posterior edentulism in the partially edentulous mandibles. Treatment with endosseous standard implants (also known as "long implants") has been widely accepted as a reliable and suitable method for oral rehabilitation of edentulous patients. Generally, the placement of a standard length implant without bone augmentation requires a minimum residual bone height of 8 mm. However, a successful implant treatment in the mandible can be limited in posterior regions due to insufficient bone height, which substantially increases the risk of damaging the inferior alveolar nerve (*Barone et al.*, 2012).

To overcome the issue of bone loss in long-term edentulous subjects many rehabilitation strategies have been developed, from non-standard implants placed in pristine bone to replacement with long implants after bone augmentation procedures (*Calvo-Guirado et al.*, 2015; *Esposito et al.*, 2015). When the residual bone height above the mandibular canal ranged between 6 and 8 mm, standard implants could not be placed and the use of non-standard implants (shorts or blades) might be considered clinically appropriate without bone augmentation (*das Neve et al.*, 2006; *Romeo et al.*, 2014). Short implants were considered effective in rehabilitation of patients with an atrophic posterior mandible; they were well-tolerated by patients, inasmuch as they were fast, cheap, and less prone to morbidities, even if several authors did not agree upon the long-term positive outcomes which were associated with short implants. In fact some studies reported that short implants, when they were placed in posterior jaws, achieved favorable outcomes in terms of survival rate (*Omran et al.*, 2015; *Schincaglia et al.*, 2015; *Thoma et al.*, 2015); however, other authors reported that short implants exhibited a lower survival rate compared to standard implants (Queiroz et al. 2015). Unfortunately, the available information

was too weak to draw conclusions regarding the long-term prognosis for short implants (*Esposito et al.*, 2014).

On the other hand, in patients whose residual ridge height was less than 6 mm, bone augmentation procedures became mandatory (*Amorfini et al.*, 2014) even though it was unclear which rehabilitation strategy was the best. Therefore, as far as bone augmentation techniques are concerned, this clinical scenario proved the situation was more intricate. In fact, bone loss could be corrected with different methods, ranging from grafting techniques (*Barone et al.*, 2016; *Sbordone et al.*, 2015; *Martuscelli et al.*, 2014) to distraction osteogenesis (*Chiapasco et al.*, 2007). For example, Esposito and co-workers compared the outcome of prostheses supported either by short implants placed in pristine sites or by long implants placed in augmented bone, in severely atrophic alveolar ridges in patients with a residual height ranging between 5 and 8 mm; that is, the amount of bone required to place short implants but not enough for the standard implants. They concluded that there were no significant differences either in failure or in complication rates (*Esposito et al.*, 2014); however, in the selected patients, they confirmed that mandibular implants exhibited a significant difference in marginal bone loss between short (1.30 mm) and long implants (1.48 mm) one year after loading (*Esposito et al.*, 2014). Furthermore, other authors investigated the effectiveness of short implants placed in pristine bone and of long implants placed in grafted bone, highlighting favorable results in terms of postoperative complications but not in terms of survival rate for short implants placed in the posterior mandibular areas (*Felice et al.*, 2012).

When bone volume augmentation procedures were described, numerous studies have compared different grafting materials; the comparison between the autogenous and xenogeneic bone grafts did not show any difference in terms of vertical bone gain as well as marginal bone

loss of implants placed in the augmented bone (*Cordaro et al.*, 2011; *Felice et al.*, 2009).

A viable alternative to bone grafting in the treatment of the severely resorbed maxillae was alveolar distraction osteogenesis. This method achieved good results in correcting vertically deficient edentulous ridges, maintaining the obtained bone gain over time, and guaranteeing high rates of survival and success of implants placed in the distracted areas (*Chiapasco et al.*, 2004).

Nevertheless, bone augmentation techniques presented several drawbacks that should be considered: *(1)* vertical ridge augmentation was more time consuming; *(2)* the healing phase was longer; *(3)* it was more expensive; and *(4)* it exhibited more complications compared with short implants (*Chiapasco et al.*, 2007; *Felice et al.*, 2010). In addition, augmentation surgery needed an experienced surgeon, due to the anatomical difficulties inherent in rehabilitating the posterior atrophic mandible.

As previously mentioned, the literature does not agree on the best rehabilitation strategy for posterior atrophic mandibles with a residual ridge height of between 5 and 8 mm, and shows even less consensus on what the best bone augmentation technique is for posterior mandibular areas.

The main objective of the present systematic review was to evaluate, in partially edentulous mandibles, (in terms of success rate, predictability and bone loss around implants) which is the best treatment option to replace posterior missing teeth between standard implants placed in augmented bone vs. short implants placed in pristine bone in the rehabilitation of atrophic posterior mandibles. The secondary aim was to compare standard implants placed in augmented bone with autogenous onlay blocks vs. standard implants placed in augmented bone with any of the other augmentation procedures that did not involve onlay blocks.

MATERIALS AND METHODS

Search Strategy

The data for this systematic review and meta-analysis were processed following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) principles (*Moher et al.*, 2010); the introductory set of studies related to the topic "surgical strategies for rehabilitation on the posterior mandible " was obtained through an electronic search of the MEDLINE (Pubmed via the search engine Entrez <http://www.ncbi.nlm.nih.gov/sites/gquery>) and Cochrane Oral Health Group databases.

Relevant articles published between January 1st, 2000 and July 30th, 2016 were searched using the relevant keywords and respective Boolean logic operators (AND, OR, NOT) used in the above-mentioned databases:

(1) *human AND mandible AND posterior*

(2) *bone AND graft*

(3) *inlay OR onlay OR interpositional OR autogenous OR xenogeneic*

(4) *allogeneic AND material*

(5) *augmentation*

(6) *vertical OR horizontal*

(7) *guided AND bone AND regeneration*

(8) *distraction AND osteogenesis*

(9) *nerve*

(10) *transposition OR lateralization OR tunneling*

(11) *short AND implant*

(12) *2 AND 3*

(13) *5 AND 6*

(14) *9 AND 10*

(15) *4 OR 7 OR 8 OR 11 OR 12 OR 13 OR 14*

(16) *1 AND 15*

An additional manual search was performed directly from the websites of the following scientific journals:

Clinical Implant Dentistry and Related Research

Clinical Oral Investigations

Clinical Oral Implants Research

European Journal of Oral Implantology

European Journal of Prosthodontics and Restorative Dentistry

Journal of Clinical Periodontology

Journal of Cranio-Maxillo-Facial Surgery

Journal of Dental Research

Journal of Oral Implantology

Journal of Oral Maxillofacial Surgery

Journal of Oral Rehabilitation

Journal of Periodontology

Implant Dentistry

International Journal of Oral & Maxillofacial Surgery

International Journal of Oral Surgery

International Journal of Periodontics & Restorative Dentistry

The International Journal of Oral & Maxillofacial Implants

Two independent reviewers (A.B, S.M) screened all of the titles, abstracts and then the full text of the studies according to the inclusion and exclusion criteria.

Selection Criteria

Studies were included if they fulfilled the following *a priori* criteria: *(1)* randomized clinical studies that included clinical or radiological outcomes of the surgical strategies for rehabilitation

of atrophic posterior mandibles in partially edentulous patients, including any dimensional change, survival rate and adverse event; *(2)* containing a follow-up from 12 to 24 months; and (3) written in English.

Exclusion criteria were animal experiments and repeated reports of the same study/author (a single reference among multiple references of the same authors describing the same set of subjects should be included in the analysis). Studies could be excluded if enrolled patients were all heavy smokers or drinkers, or showed a poor oral hygiene.

PICO Criteria Definitions

Participants: Partially edentulous patients suffering from atrophy of the posterior mandible with insufficient bone to place standard dental implants.

Intervention: All the surgical interventions and treatments performed to rehabilitate patients suffering from atrophy of the posterior mandible by means of a fixed prosthesis, and supported by either osseointegrated titanium standard dental implants placed in augmented bone or osseointegrated titanium short dental implants placed in pristine bone.

Comparison: Outcomes of standard implants placed in augmented bone vs. outcomes of short implants placed in pristine bone; and outcomes of standard implants placed in bone augmented with onlay blocks vs. outcomes of standard implants placed in bone augmented using the others augmentation procedures that did not involve onlay blocks.

Outcome: Biological complication, bone remodeling around dental implant, implant and

prosthesis survival rate.

Quality Assessment

Each of the authors independently assessed the studies in terms of the inclusion, relevance, eligibility, and risk of bias, in a standard and not-blinded way, following the Cochrane Collaboration tool (*Higgins et al.*, 2011); any disagreement was resolved by consensus of reviewers and statistics researcher (P.T.).

Data Extraction and Collection Process

The authors read the full text of all the studies enrolled in this search process and the data were extracted independently, and any conflict was resolved between the authors and confirmed by the statistician. Information was extracted from each enrolled trial on the *(1)* number of patients, *(2)* number of treated sites, *(3)* position of placed implants, *(4)* type of intervention, and *(5)* mean observation period.

The primary (implant failure and marginal bone loss) and secondary outcomes (biological complications and prosthesis failure) were classified as follows:

Implant failure: classified as failing if the published results indicated that the implants were not in function at the time of evaluation.

Marginal bone loss: (MBL) peri-implant bone loss measured after implant insertion.

Biological complications: insufficient bone gain for implant placement, abscess, pus, transient postoperative paresthesia, pain, swelling and other adverse events.

Prosthetic failure: fixed prosthetic device detachment, loosening of abutment screw or healing cap, and fracture (screw, framework or esthetic material).

Variables such as smoking, alcohol intake, or hygiene were considered confounding factors for endosseous dental implant treatment, they were deemed too complex in these final outcomes and so were not extracted.

Statistical Analysis

Implant and prosthesis failure including biological complications were the dichotomous outcomes evaluated; whereas the marginal bone loss represented a continuous outcome. The statistical unit used for analysis of "implant failure" and "marginal bone loss" was the implant, while for analysis of "prosthesis failure" and 'biological complications' the statistical unit was the patient.

To assess heterogeneity of the study-specific event outcomes, Cochran's Q and I^2 statistics were performed and the *P*-value was also calculated. The data were analyzed using the statistical software METAN command in the STATA statistical computing environment (Stata Statistical Software, Version 11.2, Stata Corp), with a level of statistical significance set at $\alpha = 0.05$.

RESULTS

Search

The selection process of publications, which is reported in the PRISMA flow diagram (Figure 1), yielded 81 articles in MEDLINE. The initial screening of articles was carried out using keywords and abstracts; in the event that both were not clear, the full-text articles were evaluated. The screening yielded 28 eligible studies and only 12 studies of these fulfilled the inclusion and exclusion criteria.

Once a consensus had been achieved, the characteristic, quality and heterogeneity of the enrolled studies were assessed by the Cochrane Collaboration tool and reported in Table 1. In addition, a comprehensive overview of the randomized controlled trials on the rehabilitation strategies of an atrophic posterior area of the partially edentulous mandible are reported in Table 2.A small number of trials compared the effects of different rehabilitation interventions. As a result of the relatively small number of studies, only two meta-analytic processes could be carried out.

Trials enrolled in the present review were ranked into three categories:

Group A: Studies which compared outcomes of standard implants placed in augmented bone (long implants group: *li*) vs. outcomes of short implants placed in pristine bone (short implants group: *si*).

Group B: Studies which compared outcomes of standard implants placed in bone augmented with onlay block (onlay blocks group: *ob*) vs. outcomes of standard implants placed in augmented bone with any of the other augmentation procedures that did not involve onlay blocks (non-onlay blocks group: *nob*).

Group C: Studies not included in category a) or b).

Meta-analyses were performed to compare the results obtained from the studies reviewed in A and B groups.

Population Epidemiology

In the 5 studies of group A (*Felice et al.*, 2010; *Esposito et al.*, 2011; 2014; *Pistilli et al.*, 2013a; 2013b) a total of 223 patients with 386 dental implants were included. Regarding dichotomous outcomes variables, the long implant group had 10 implant failures out of the 197 implants (5.1%) in a 2-year period of follow-up. On the other hand, the short implant group had 5 implant failures out of 189 implants (2.7%) within the same follow-up period. Fifty biological complications (50% [95% CI, 40.2% to 59.8%]) and 10 prosthesis failures (10% [95% CI, 4.1% to 15.8%]) were observed in 100 patients who belonged to the long implant group; whereas 14 biological complications (12.4% [95% CI, 6.3% to 18.5%]) and 6 prosthesis failures (5.3% [95% CI, 1.2% to 9.4%]) were found in 113 patients who belonged to the short implant group. The range of the marginal bone loss (MBL) registered for studies of the group *li* was 0.25÷0.56 mm at loading and 1÷1.16 mm within 2-year of follow-up, whereas in studies on short implant, MBLs ranged between 0.23 mm and 0.59 mm at the time of loading, and between 0.94 mm and 1.05 mm within 2-year follow-up.

In the 3 studies of group B (*Amorfini et al.*, 2014; *Chiapasco et al.*, 2007; *Felice et al.*, 2009) a total of 53 patients with 81 dental implants were included. In the group of the onlay grafting procedure, 5 implants failed (11.9%) out of the 42 implants placed within 2-year of follow-up;

by comparison, in non-onlay augmentation strategies, 2 implants failed (5.2%) out of 39 implants within the same follow-up period. The occurrences of prosthesis failure and biological complications were not reported, therefore, the reviewers were unable to perform data extraction and meta-analysis calculations or comparisons. Only one out of the studies, which belonged to the group of onlay grafting procedure (*on*), reported a mean value of marginal bone loss after 2 years of loading (0.78 mm), whereas the studies which belonged to the list of non-onlay augmentation techniques, had a mean marginal bone loss ranging from 0.62 to 0.9 mm within the same follow-up period.

Four randomized control trials were classified as non-relevant to the study of outcomes comparisons and meta-analysis.

Bianchi & co-workers in their study described clinical outcomes of patients who underwent distraction osteogenesis (*do*) or inlay bone grafting (*in*), reporting 100% of implant survival rates for both groups and differing complication rates (60% for *do* group and 14.3% for *in* group) (*Bianchi et al.*, 2008).

Two additional studies evaluated outcomes of bone grafting when comparing different bone substitute materials. Cordaro & co-workers (2011), in case of onlay grafting procedure, evaluated results of bone augmentation using either autogenous bone block (AB) alone or AB plus xenograft and a collagen membrane covering the graft. Out of the 17 treated patients, 3 complications were observed in the bone mixture group vs. one complication in the group grafted with autogenous blocks (control) (*Cordaro et al.*, 2011).

Felice and co-workers, in the case of sandwich osteotomy procedures, evaluated results of augmentation using either a bone block harvested from the iliac crest or a xenogenic bone block.

The authors recorded one implant failure in the autogenous bone group and non-significant differences on the peri-implant marginal bone loss when two groups were compared (0.82 mm and 0.59 mm in the autogenous and Bio-Oss group, respectively) (*Felice et al.*, 2009).

Finally, Merli and co-workers compared the efficacy of two different techniques for vertical bone regeneration at implant placement with particulate autogenous bone: resorbable collagen barriers supported by osteosynthesis plates vs. non-resorbable titanium-reinforced expanded polytetrafluoroethylene barriers. No prosthesis or implant failures occurred within loading; patients treated with resorbable barriers had lost a mean of 0.51 mm of bone, whilst patients receiving non-resorbable barriers had lost a mean of 0.59 mm of bone (*Merli et al.*, 2010).

Meta-analysis of Studies in Group A

The study report stated that the pooled risk ratio (RR) for the effect of the intervention on biological complications was 2.822 (95% CI, 1.809 to 4.403) (Figure 2a) when group of short implant placed in pristine sites (*si*) and group of long implants placed in augmented areas (*li*) have been compared ($P < 0.0001$); this signified that the magnitude of risk of complications in the *li* groups is approximately 282% of the magnitude of risk of complication in the *si* group.

Moreover, pooled results on marginal bone loss within 2-year of follow-up found a significant effect in favor of the short implant with difference in means of 0.052 mm (95% CI, 0.026 to 0.079 mm, with *P*-value < 0.0001), as illustrated in Figure 2d.

Even if data could encourage net benefit results on the survival outcomes in favor of short implants, it should be considered that the pooled risk ratio of 1.594 (95% CI, 0.542 to 4.690, and

P-value = 0.397) for implant failure, and 1.488 (95% CI, 0.559 to 3.963, with *P*-value = 0.426) for prosthesis failure (Figure 2c) showed no significant increases on the risk of implant/prosthesis failure between *li*-group and *si*-group within a 2-year period.

Meta-analysis of Studies in Group B

No significant difference was found on the risk of marginal bone loss or implant failure between the *on*-group and the group related to non-onlay augmentation strategies (non-onlay blocks, *nob*). The meta-analysis revealed that implants placed in bone augmented with onlay blocks showed similar outcomes to implants placed in augmented bone irrespective of the augmentation procedure used. In fact, differences between the *ob*- and *nob*-group were a non-significant pooled risk ratio of 1.809 in favor of *nob*-group (95% CI, 0.417 to 7.839, and *P*-value = 0.428) for implant failure, and a non-significant difference in means of 0.006 mm (95% CI, -0.190 to 0.177 mm, and *P*-value = 0.946) for marginal bone loss in favor of *nob*-group.

DISCUSSION

The main aim of the current systematic review and meta-analysis was to clarify the best rehabilitation strategy and surgical treatment to rehabilitate partially edentulous patients with atrophic posterior mandibles. The present data were obtained from randomized controlled clinical trials describing rehabilitation of atrophic posterior mandibular areas with a residual ridge height of less than 8 mm.

The articles embraced a wide variety of approaches resulting from differences in study design, terms and definitions, surgical technique, implant system, outcomes' measurement, reported data and follow-up period. This heterogeneous nature of the publications made it very difficult to find proper answers to the queries stated in the focus question of the present systematic review. This was perhaps due to the misleading evaluations of the recorded data, which were copied out from enrolled studies.

The 12 overviewed randomized controlled clinical trials (RCTs) were analyzed for the risk of bias according to the Cochrane Collaboration tool for assessing risk of bias. None of the selected papers could be judged at "Low Risk" of bias because of the presence of two or more domains at "High" or "Unclear" risk of bias. In brief, the main reasons for uncertainty of the results resided in the allocation concealment and blinding processes. In fact, when very different surgical procedures were compared, it was impossible to conceal the allocation group and to blind both the patients and the outcome assessors. In order to perform the meta-analytic processes, the authors examined very carefully the 12 enrolled papers, identified rehabilitation surgery and strategy, and ranked each trial among those with similar design. With this in mind, trials were split up into three groups: 5 trials (group A) compared outcomes of standard implants (placed in augmented bone) vs. outcomes of short implants (placed without augmentation); 3 trials (group B) compared outcomes of standard implants placed in bone augmented with onlay blocks vs. outcome of standard implants placed in bone augmented with others augmentation procedures not involving onlay blocks; and 4 trials (group C) which matched the inclusion and exclusion criteria but the meta-analysis could not be performed due to the intra-study surgical intervention homogeneity.

Rehabilitation Strategies

Some interesting information about rehabilitation strategies was obtained by comparing studies in group A: longer implants placed in augmented bone showed that 17 out of 239 (6.1%) implants failed within 2 years of the survey, while only 5 out of 189 (2.7%) short implants placed in native bone exhibited failure in the same observation period. This difference was not statistically significant. Results on implant failure were in line with the data collected by Esposito and co-workers in their systematic review (*Esposito et al.*, 2009) in which a meta-analysis of two trials resulted in more implant failures (OR = 5.74, $P = 0.06$) for those implants placed in the vertically augmented bone. A very recent systematic review on four RCTs, which compared short implants placed in native bone with longer implants placed in vertically augmented sites, tended to demonstrate similar implant survival rates (96.24% vs. 95.09%, respectively, for short and long implants (*Nisand et al.*, 2015). In a former systematic review, Atieh and co-workers focused their attention on the survival of short dental implants for the treatment of posterior edentulism, and obtained results similar to the present review. Atieh and co-workers, irrespective of treated sites, suggested that there was no significant difference in the reported survival of short (98.5%) versus long implants (97.7%) at the 2-year follow-up. Even if they reported an average follow-up period of 3.9 years (range, 1 to 7 years) with at least 6,000 implants studied, it was apparent that many short implants were not followed for the duration of the investigation. Moreover, the authors defined an implant as "short" when it was ≤ 8.5 mm. In this review, even though there was no common agreement on the definition of "short" implant, if implant length was less than 10 mm, the implant was ranked into the short implant group (*si*) (*Atieh et al.*, 2012).

Few authors reported middle-term results in an RCT. Felice and co-workers found a major

implant failure rate in the short implants group as compared with implants in augmented bone group, even though the results were not statistically significant (P=1). Although the present results seemed to be dissimilar from those of Felice and co-workers, the lack of significance did not allow any conclusions to be drawn other than the fact that short implants could suffer from loss of loading resistance, thereby producing negative results in a longer period (*Felice et al.*, 2014).

Data emerging from the present review about the treatment of posterior edentulism in the mandible attested that the long implants placed in augmented bone showed a higher rate of biological complications (50%) than that registered in the group of short implants placed in pristine bone (12.4%). The difference appeared to be significant: the pooled risk ratio (RR) for the effect of the intervention on biological complications was 2.822 (95% CI, 1.809 to 4.403) (Figure 2a). This indicated that short implants were significantly more favorable ($P < 0.0001$) to standard implants placed in augmented bone. This high rate of complications registered in the group of long implants was confirmed by the reviews of Esposito and co-workers (Esposito et al. 2009), in which short implants appeared more advantageous than long implants in augmented bone in terms of complications (OR of 4.97 in favor of short implants), and of Nisand and co-workers, in which 56 patients out of 85 experienced complications in the augmented groups (65.9%), whilst 18 patients out of 85 had complications in the short implants group (21.2%). When paresthesia was considered, rates of complications lowered, respectively, to 56.2% and 16.7% (*Nisand et al.*, 2015). Even when major complications were considered, longer implants in augmented bone appeared again to be an unfavorable approach due to the appreciable rate of surgical failure of the first surgery (11 grafting procedures failed).

In the present review, when the rates of prosthesis failure within the 2-year follow-up were

analyzed, no significant difference were found between long implant group (10%) and short implant group (5.3%). This was confirmed by data of other review papers which attested that in terms of prosthetic survival rates, there were no differences between the two treatments (*Nisand et al.*, 2015).

Assessment of marginal bone loss (MBL) around implants placed in augmented bone or in pristine bone was very important in the evaluation of the success of dental implants. In the present review, long implants placed in augmented ridges showed a marginal bone loss ranging from 1 mm to 1.16 mm within the 2-year follow-up, while short implants in pristine bone had a marginal bone loss ranging between 0.94 mm to 1.05 mm within the same follow-up period, with a difference in means attesting that short implants were significantly more favorable ($P < 0.0001$). Results of the meta-analysis have been confirmed only by a few RCTs in which short implants experienced statistically significantly less bone loss (from 0.18 to 0.82 mm, Ps < 0.014) than long implants (*Esposito et al.*, 2011; *Felice et al.*, 2014).

Bone augmentation techniques

Since the evaluation of longer implants in augmented bone depends greatly on the surgical technique, a meta-analysis of the collected data was conducted among the RCTs describing different surgical techniques. The present data describing bone augmentations suggested that implants placed in bone augmented with onlay grafts showed similar outcomes to implants placed in augmented bone, irrespective of the augmentation procedure used. When the onlay-graft technique was concerned, mean bone loss ranged from 0.78 mm to 0.89 mm within 2 years of survey, while non-onlay augmentation techniques produced a bone loss ranging from 0.62 mm

to 0.9 mm in the same period of follow-up. These findings agree with Peñarrocha-Diago and co-workers who obtained a peri-implant marginal bone loss of 0.7±1.1 mm in onlay-augmented ridges (*Peñarrocha-Oltra et al.*, 2014).

Moreover, in the present study, the pooled risk ratio between the two groups for implant failure (1.809), and the difference in means between the two groups for marginal bone loss (0.006 mm) did not reach statistical significance. Our results have been confirmed by the review of Esposito and co-workers (*Esposito et al.*, 2009) which compared various horizontal and vertical augmentation techniques and observed no statistically significant differences between procedures. Even if some authors seemed to suggest that onlay bone grafts could exhibit minor implant survival rate when compared to other surgical techniques (*Aghaloo et al.*, 2007), trials in the literature reported results on only a low number of patients and treatments (*Rocchietta et al.*, 2008). An extension of the meta-analytic process to other atrophic sites was very limited at the present time due to several confounding factors: type of intervention, bone morphology, defect size, augmented volume and regenerative capacity of the defects. These were not well described in the respective literature and could heavily impact on the results. In addition, when the implant-supported prosthesis bears occlusal loading, the masticatory forces were exerted mainly on the graft, thus producing a variable and unpredictable resorption rate. Some authors tried to compare autogenous bone graft alone or associated with titanium mesh for vertical ridge augmentation, and stated that the protection of the mesh could cause significantly less bone resorption (*Roccuzzo et al.*, 2007). The most likely hypothesis lay in its protective effect from mechanical pressure during the healing period.

Finally, the trials in the Group C were rather heterogeneous and this made comparison between them impossible. In addition, since these studies did not generally compare two

different techniques within the same study; no data on statistically significant differences were given and no specific *P* values were available for the comparison.

The main limitation encountered in this literature review was the lack of studies with a strict comparative design protocol. Future research should include control groups and standardized criteria for defining the best treatment to rehabilitate edentulous atrophic posterior mandibles of partially edentulous patients, in order to obtain rigorous evidence-based results. As a result, further controlled randomized clinical trials adhering to strict protocols are needed in the future.

CONCLUSION

Even within the limitations of this literature review about the treatment of posterior edentulism in the mandible, one can conclude that short implants placed in atrophic posterior mandibles had fewer biological complications and presented a better marginal bone level when compared to longer implants placed in augmented bone, thereby offering a good choice for prosthetic rehabilitation. However, the large heterogeneity of the analyzed studies relating to procedures and employed bone substitute materials did not allow for a conclusive answer to the second point of the focus question: based on the current literature, there was no evidence that standard implants placed in bone augmented with onlay blocks were inferior to those placed in bone augmented using other augmentation procedures not involving onlay blocks.

CONFLICT OF INTEREST

All authors certify that no financial relationships, current or within the past 5 years, exist regarding any of the products involved in this study.

REFERENCES

Aghaloo TL, Moy K. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Implants 22: 49 70, 2007

Atieh MA, Zadeh H, Stanford CM, Cooper LF. Survival of short dental implants for treatment of posterior partial edentulism: a systematic review. Int J Oral Maxillofac Implants 27: 1323 1331, 2012

Amorfini L, Migliorati M, Signori A, Silvestrini-Biavati A, Benedicenti S. Block allograft technique versus standard guided bone regeneration: a randomized clinical trial. Clin Implant Dent Relat Res 16: 655 667, 2014

Barone A, Orlando B, Cingano L, Marconcini S, Derchi G, Covani U. A randomized clinical trial to evaluate and compare implants placed in augmented versus non-augmented extraction sockets: 3-year results. J Periodontol 83: 836 846, 2012

Barone A, Toti P, Felice P, Marchionni S, Covani U. Early volumetric changes after vertical augmentation of the atrophic posterior mandible with interpositional block graft versus onlay bone graft: a retrospective radiological study. Journal of Cranio-Maxillofacial Surgery 2016 in press

Bianchi A, Felice P, Lizio G, Marchetti C. Alveolar distraction osteogenesis versus inlay bone grafting in posterior mandibular atrophy: a prospective study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 105: 282 292, 2008

Calvo-Guirado JL, Lòpez Torres JA., Dard M, Jved F, Pérez-Albacete Martìnez C, Maté

Sànchez de Val JE. Evaluation of extrashort 4-mm implants in mandibular edentulous patients with reduced bone height in comparison with standard implants: a 12-month results. Clin Oral Implants Res (2015). doi:10.111/clr.12704

Chiapasco M, Consolo U, Bianchi A, Ronchi P. Alveolar distraction osteogenesis for the correction of vertically deficient edentulous ridges: a multicenter prospective study on humans. Int J Oral Maxillofac Implants 19: 399 407, 2004

Chiapasco M, Zaniboni M, Rimondini L. Autogenous onlay bone grafts vs. alveolar distraction osteogenesis for the correction of vertically deficient edentulous ridges: a 2-4 year prospective study on humans. Clin Oral Implants Res 18: 432 440, 2007

Cordaro L, Torsello F, Morcavallo S, di Torresanto VM. Effect of bovine bone and collagen membranes on healing of mandibular bone blocks: a prospective randomized controlled study. Clin Oral Implants Res 22: 1145 1150, 2011

Esposito M, Barausse C, Pistilli R, Sammartino G, Grandi G, Felice P. Short implants versus bone augmentation for placing longer implants in atrophic maxillae: One-year post-loading results of a pilot randomized controlled trial. Eur J Oral Implantol 8: 257 268, 2015

Esposito M, Cannizzaro G, Soardi E, Pellegrino G, Pistilli R, Felice P. A 3-year post-loading report of a randomized controlled trial on the rehabilitation of posterior atrophic mandibles: short implants or longer implants in vertically augmented bone? Eur J Oral Implantol 4: 301 311, 2011

Esposito M, Grusovin MG, Felice P, Karatzopoulos G, Worthington HV, Coulthard P. The efficacy of horizontal and vertical bone augmentation procedures for dental implants - a Cochrane systematic review. Eur J Oral Implantol 2: 167 184, 2009

Esposito M, Pellegrino G, Pistilli R, Felice P. Rehabilitation of posterior atrophic edentulous jaws: prostheses supported by 5mm short implants o by longer implants in augmented bone? One-year results from a pilot randomized clinical trial. Eur J Oral Implantol 4: 21 30, 2014

das Neves FD, Fones D, Bernardes SR, do Prado CJ, Neto AJ. Short implants: an analysis of longitudinal studies. Int J Oral Maxillofac Implants 21: 86 93, 2006

Felice P, Cannizzaro G, Barausse C, Pistilli R, Esposito M. Short implants versus longer implants in vertically augmented posterior mandibles: a randomized controlled trial with 5-year after loading follow-up. Eur J Oral Implantol 7: 359 369, 2014

Felice P, Marchetti C, Iezzi G, Piattelli A, Worthington H, Pellegrino G, Esposito M. Vertical ridge augmentation of the atrophic posterior mandible with interpositional bloc grafts: bone from the iliac crest vs. bovine anorganic bone. Clinical and histological results up to one year after loading from a randomized controlled clinical trial. Clin Oral Implants Res 20: 1386 1393, 2009

Felice P, Pellegrino G, Checchi L, Pistilli R, Esposito M. Vertical augmentation with interpositional blocks of anorganic bovine bone vs. 7-mm-long implants in posterior mandibles: 1-year results of a randomized clinical trial. Clin Oral Implants Res 21: 1394 1403, 2010

Felice P, Pistilli R, Lizio G, Pellegrino G, Nisii A, Marchetti C. Inlay versus Onlay Iliac Bone Grafting in Atrophic Posterior Mandible: A Prospective Controlled Clinical Trial for the Comparison of Two Techniques. Clin Implant Dent Relat Res 11: e69 e82, 2009

Felice P, Pistilli R, Piattelli M, Soardi E, Corvino V, Esposito M. Posterior atrophic jaws rehabilitated with prostheses supported by 5x5 mm implants with a novel nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. Preliminary

results from a randomized controlled trial. Eur J Oral Implantol 5: 149 161, 2012

Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, Savovic J, Schulz KF, Weeks L, Sterne JA; Cochrane Bias Methods Group; Cochrane Statistical Methods Group. The Cochrane collaboration's tool for assessing risk of bias in randomized trials. BMJ 343: d5928, 2011

Martuscelli R, Toti P, Sbordone L, Guidetti F, Ramaglia L, Sbordone C. Five-year outcome of bone remodelling around implants in the maxillary sinus: assessment of differences between implants placed in autogenous inlay bone blocks and in ungrafted maxilla. Int J Oral Maxillofac Surg 43: 1117 1126, 2014

Merli M, Lombardini F, Esposito M. Vertical ridge augmentation with autogenous bone grafts 3 years after loading: resorbable barriers versus titanium-reinforced barriers. A randomized controlled clinical trial. Int J Oral Maxillofac Implants 25: 801 807, 2010

Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Int J Surg 8: 336 341, 2010

Nisand D, Picard N, Rocchietta I. Short implants compared to implants in vertically augmented bone: a systematic review (EAO). Clin Oral Implants Res 26(Suppl.11): 170 179, 2015

Omran MT, Miley DD, McLeod DE, Garcia MN. Retrospective assessment of survival rate for short endosseous dental implants. Implant Dent 24: 185 191, 2015

Peñarrocha-Oltra D, Aloy-Prosper A, Cervera-Ballester J, Peñarrocha-Diago M, Canullo L, Peñarrocha-Diago M. Implant treatment in atrophic posterior mandibles: vertical regeneration

with block bone grafts versus implants with 5.5 mm intrabony length. Int J Oral Maxillofac Implants 29: 659 666, 2014

Pistilli R, Felice P, Cannizzaro G, Piattelli M, Corvino V, Barausse C, Buti J, Soardi E, Esposito M. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long 4 mm wide implants or by longer implants in augmented bone. One-year post-loading results from a pilot randomised controlled trial. Eur J Oral Implantol 6: 359 372, 2013a

Pistilli R, Felice P, Piattelli M, Gessaroli M, Soardi E, Barausse C, Buti J, Corvino V, Esposito M. Posterior atrophic jaws rehabilitated with prostheses supported by 5 × 5 mm implants with a novel nanostructured calcium-incorporated titanium surface or by longer implants in augmented bone. One-year results from a randomised controlled trial. Eur J Oral Implantol 6: 343 357, 2013b

Queiroz TP, Aguiar SC, Margonar R, de Souza Faloni AP, Gruber R, Luvizuto ER. Clinical study on survival rate of short implants placed in the posterior mandibular region: resonance frequency analysis. Clin Oral Implants Res 26: 1036 1042, 2015

Rocchietta I, Fontana F, Simion M. Clinical outcomes of vertical bone augmentation to enable dental implant placement: a systematic review. J Clin Periodontol 35(Suppl.8): 203 215, 2008

Roccuzzo M, Ramieri G, Bunino M, Berrone S. Autogenous bone graft alone or associated with titanium mesh for vertical alveolar ridge augmentation: a controlled clinical trial. Clin Oral Implants Res 18: 286 294, 2007

Romeo E, Storelli S, Casano G, Scanferla M, Botticelli D. Six- mm versus 10-mm long implants in the rehabilitation of posterior edentulous jaws: a 5-year follow-up of randomized controlled

trial. Eur J Oral Implantol 7: 371 381, 2014

Sbordone C, Toti P, Martuscelli R, Guidetti F, Sbordone L, Ramaglia L. A 5-year Implant Follow-up in Maxillary and Mandibular Horizontal Osseous Onlay Grafts and Native Bone. J Oral Implantol 41: 570 578, 2015

Schincaglia GP, Thoma DS, Haas R, Tutak M, Garcia A, Taylor TD, Hammerle CH. Randomized controlled multicenter study comparing short dental implants (6 mm) versus longer dental implants (11-15 mm) in combination with sinus floor elevation procedures. Part 2: clinical and radiographic outcomes at 1 year of loading. J Clin Periodontol 2015. doi: 10.1111/jcpe.12465

Thoma DS, Zeltner M, Husler J, Hammerle CH, Jung RE. EAO supplement working group 4-EAO CC 2015 Short implants versus sinus lifting with longer implants to restore the posterior maxilla: a systematic review. Clin Oral Implants Res 26: 154 169, 2015

LEDENDS TO FIGURES

Figure 1. PRISMA flow diagram of the study selection process.

Figure 2. Forest plot of comparison of long implants in augmented bone (*li*) versus short implant in pristine bone (*si*): a) postoperative biologic complications; b) implant failure; c) prosthetic failure; d) marginal bone loss (MBL).

Figure 3. Forest plot of comparison of onlay blocks (*ob*) vs. rest of augmentation techniques (non- onlay blocks, *nob*): a) implant failure; b) marginal bone loss (MBL).

CAPTIONS TO TABLES

Table 1. Risk of bias assessment of the selected studies. N/A: not reported or unable to be extracted.

Table 2. Comparison of outcomes considering RCTs with an observation period between 12 and 24 months following prosthetic loading. N/A: not reported or unable to be extracted. Protocols: *gbr*: gain bone regeneration; on: onlay grafting; *in*: inlay grafting; *do*: distraction osteogenesis; *si*: short implants without bone-augmented. *P*-values of dichotomous variables were obtained by Fisher exact test.

Table 1. Risk of bias assessment of the selected studies. N/A: not reported or unable to be extracted.

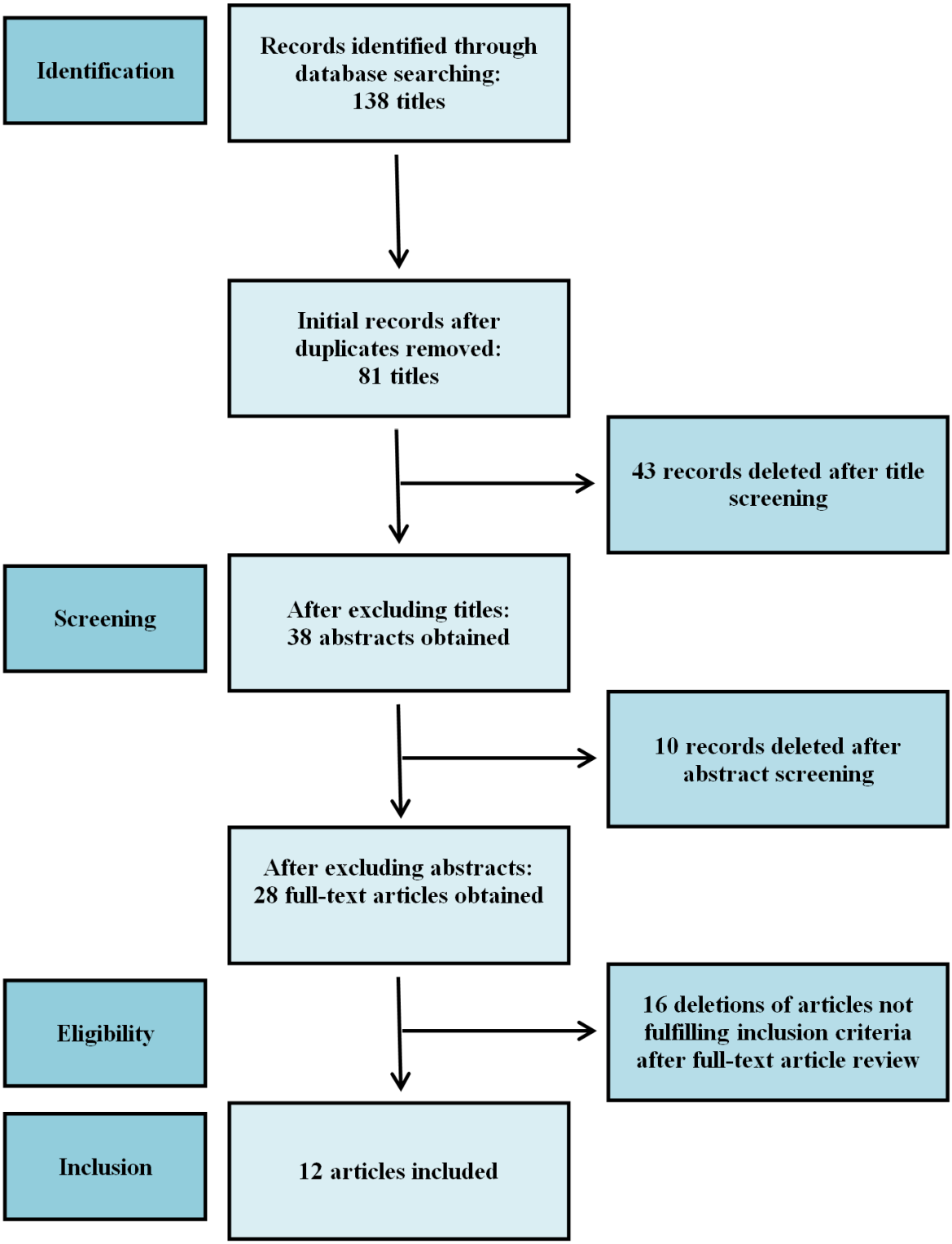
	Risk of bias						Risk of bias (other sources)			
Study reference	**Random sequence generation**	**Allocation concealment**	**Blinding of patients and surgeons**	**Blinding of outcome assessment**	**Incomplete outcome data**	**Selective reporting**	**Group imbalance**	**Sample size**	**Conflict of interest**	**Radiographic outcome**
Amorfini, 2014 cidrr 16:655	low	low	low	low	N/A	N/A	low	high	N/A	low
Bianchi, 2008 oooo 105:282	N/A	N/A	high	N/A	low	low	low	low	N/A	high
Chiapasco, 2007 coir 18:432	N/A	high	N/A	N/A	low	N/A	low	low	N/A	low
Cordaro, 2011 coir 22:1145	low	low	low	N/A	low	N/A	low	low	N/A	high
Esposito, 2011 ejoi 4:21	low	low	high	high	high	N/A	low	low	N/A	high
Esposito, 2011 ejoi 4:301	low	low	N/A	low	N/A	N/A	low	low	N/A	low
Felice, 2009 cidrr 11S1:e69	N/A	N/A	low	high	low	low	low	low	N/A	low
Felice, 2009 coir 20:1386	low	N/A	high	high	low	low	low	high	N/A	low
Felice, 2010 coir 21:1394	low	low	low	high	low	N/A	low	low	N/A	low
Merli, 2010 ijomi 25:801	low	low	low	low	N/A	N/A	low	low	N/A	low
Pistilli, 2013 ejoi 6:343	N/A	low	high	low	low	low	low	low	N/A	low
Pistilli, 2013 ejoi 6:359	low	low	high	low	low	N/A	low	low	N/A	low

Table 2. Comparison of outcomes considering RCTs with an observation period between 12 and 24 months following prosthetic loading. N/A: not reported or unable to be extracted. Protocols: *gbr*: gain bone regeneration; *on*: onlay grafting; *in*: inlay grafting; *do*: distraction osteogenesis; *si*: short implants without bone-augmented. *P*-values of dichotomous variables were obtained by Fisher exact test.

	Study information									**Outcomes**				
	Groups in the study	**Total of subjects**	**Total of implants**	**Protocols**	**Materials**	**Loading between 1 and 2 yrs**	**Folow-up (yrs)**	**Drop-outs patients(implant)**	**Subgroup for analysis**	**Implant failure**	**Prosthesis failure**	**Complication**	**Mean marginal bone loss (mm) at prosthesis insertion**	**Mean marginal bone loss (mm) between 1 and 2 yrs**
Amorfini, 2014	gbr	8	8	*gbr*	xenogeneic	yes	1	0(0)		N/A	N/A	N/A	0.46 ±0.23	0.62±0.40
cidrr16:655	allograft	8	8	*on*	allogeneic	yes	1	0(0)	B	N/A	N/A	N/A	0.43±0.33	0.78±0.52
Level of significance												-	0.72	0.03
Bianchi, 2008	A	6	21	*do*	autogenous	yes	1.9÷2.5	0(0)		0	0	1	N/A	N/A
oooo105:282	B	5	16	*in*	autogenous	yes	1.9÷2.5	0(0)	C	0	0	3	N/A	N/A
Level of significance										1	1	0.2222	-	-
Chiapasco, 2007	1	8	19	*on*	autogenous	yes	2÷4	0(0)		2	N/A	N/A	0.3±0.3	0.9±0.4
coir18:432	2	9	19	*do*	autogenous	yes	2÷4	0(0)	B	0	N/A	N/A	0.2±0.3	0.9±0.4

Level of significance									0.4864	-	-	-	-	
Cordaro, 2011	test	8	28	*on*	autogenous + xenogeneic	yes	2	N/A		0	N/A	3	N/A	N/A
coir22:1145	control	9	27	*on*	autogenous	yes	2	N/A	C	0	N/A	1	N/A	N/A
Level of significance										1	-	0.6109	-	-
Esposito, 2011	long	15	30	*in*	xenogeneic	yes	1	0(5)		1	1	1	0.23±0.21	1.16±0.46
ejoi 4:21	short	15	26	*si*	autogenous	yes	1	0(0)	A	0	0	1	0.25±0.08	0.97±0.56
Level of significance										1	1	1	-	-
Esposito, 2011	augmented	30	61	*in*	xenogeneic	yes	3	1(N/A)		3	4	20	0.56±0.29	1.00±0.31
ejoi 4:301	short	30	60	*si*	autogenous	yes	3	0(N/A)	A	2	3	5	0.58±0.30	1.00±0.36
Level of significance										1	1	0.0001	-	0.90
Felice, 2009	inlay	10	20	*in*	autogenous	yes	1.5	N/A		0	N/A	3	N/A	0.9(0.3-1.8)
cidrr11S1:e69	onlay	10	23	*on*	autogenous	yes	1.5	N/A	B	0	N/A	3	N/A	0.85(0.2-2.8)
Level of significance										-	-	1	-	0.971
Felice, 2009	autogenous	10	10	*in*	autogenous	yes	1.5	1(N/A)		1	1	2	N/A	0.82±0.59
coir 20:1386	xenogeneic	10	10	*in*	xenogeneic	yes	1.5	0(N/A)	C	1	1	1	N/A	0.59±0.4
Level of significance										1	1	1	-	0.41
Felice, 2010	augmented	30	30	*in*	xenogeneic	yes	1	1(N/A)		3	3	4	0.56±0.29	1.00±0.31

coir 21:1394	short	30	30	*si*	autogenous	yes	1	0(N/A)	A	1	1	0	0.58±0.30	1.00±0.36
Level of significance										0.9478	0.9478	0.0521	-	0.90
Merli, 2010	resorbable	11	34	*gbr*	autogenous	yes	3	0(0)	C	0	0	0	N/A	0.51±0.34
ijomi 25:801	non-resorbable	11	43	*gbr*	autogenous	yes	3	0(0)		0	0	0	N/A	0.59±0.58
Level of significance										1	1	1	-	-
Pistilli, 2013	long	20	31	*in*	xenogeneic	yes	1	1(1)		2	2	17	0.46±0.05	1.03±0.07
ejoi 6:343	short	20	32	*si*	autogenous	yes	1	0(N/A)	A	0	0	8	0.45±0.04	0.94±0.05
Level of significance										0.23	0.2307	0,0022	0.876	0.295
Pistilli, 2013	augmented	20	47	*in*	xenogeneic	yes	1	1(N/A)		2	3	8	0.55±0.05	1.07±0.06
ejoi 6:359	short	20	41	*si*	autogenous	yes	1	0(N/A)	A	0	0	0	0.59±0.05	1.05±0.06
Level of significance										0.4966	0.2307	0.0012	0.5108	0.7384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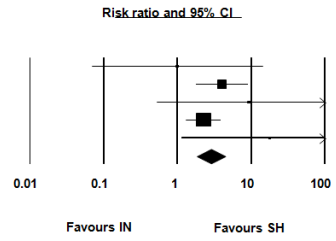
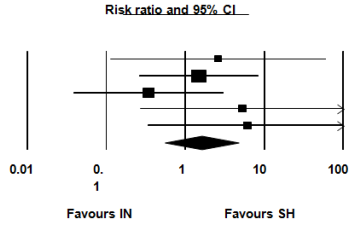
Initial records after duplicates removed: 81 titles
43 records deleted after title screening
Screening
After excluding titles: 38 abstracts obtained
10 records deleted after abstract screening
After excluding abstracts: 28 full-text articles obtained
Eligibility
16 deletions of articles not fulfilling inclusion criteria after full-text article review
Inclusion
12 articles included

posterior_mandible	Risk ratio	Outcome	Lower limit	Z-Value	Upper limit	p-Value	Weight(Fixed) Relative weight	Relative weight
Esposito, 2011_ejoi_4_21	1.000	complication	0.069	0.000	14.553	1.000	2.76	
Esposito, 2011_ejoi_4_301	4.000	complication	1.747	3.281	9.157	0.001	28.85	
Felice, 2010_coir_21_1394	9.300	complication	0.523	1.519	165.391	0.129	2.39	
Pistilli, 2013_ejoi_6_343	2.237	complication	1.280	2.825	3.910	0.005	63.45	
Pistilli, 2013_ejoi_6_359	17.850	complication	1.101	2.028	289.355	0.043	2.55	
	2.822		1.809	4.571	4.403	0.000		



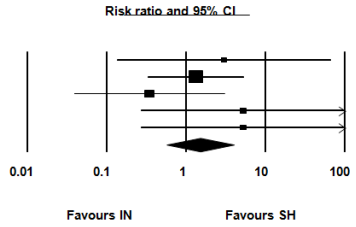
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau-squared Tau Squared	Standard Error	Variance	Tau
Fixed	5	10,201	4,261	24,424	5,214	0,000	3,144	4	0,534	0,000	0,000	0,820	0,672	0,000
Random	5	10,201	4,261	24,424	5,214	0,000								

posterior_mandible	Risk ratio	Outcome	Lowe r limi t	Z-Value	Upper limit	p-Value	Weight(Fixed) Relative weight	Relative weight
Esposito, 2011_ejoi_4_21	2.613	impl_failure_1yr	0.111	0.596	61.511	0.551	11.67	
Esposito, 2011_ejoi_4_301	1.475	impl_failure_1yr	0.256	0.435	8.519	0.664	37.88	
Felice, 2010_coir_21_1394	0.345	impl_failure_1yr	0.038	-0.946	3.127	0.344	23.95	
Pistilli, 2013_ejoi_6_343	5.323	impl_failure_1yr	0.266	1.094	106.536	0.274	12.97	
Pistilli, 2013_ejoi_6_359	6.125	impl_failure_1yr	0.326	1.211	115.179	0.226	13.53	
	1.594		0.542	0.847	4.690	0.397		



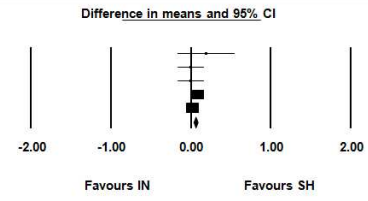
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau-squared Tau Squared	Standard Error	Variance	Tau
Fixed	5	1,649	0,538	5,054	0,876	0,381	3,436	4	0,488	0,000	0,000	1,226	1,503	0,000
Random	5	1,649	0,538	5,054	0,876	0,381								

posterior_mandible	Risk ratio	Outcome	Lower limit	Z-Value	Upper limit	p-Value	Weight(Fixed) Relative weight	Relative weight
Esposito, 2011_ejoi_4_21	3.000	prosth_failure	0.132	0.689	68.259	0.491	9.82	
Esposito, 2011_ejoi_4_301	1.333	prosth_failure	0.328	0.402	5.419	0.688	48.77	
Felice, 2010_coir_21_1394	0.345	prosth_failure	0.038	-0.946	3.127	0.344	19.73	
Pistilli, 2013_ejoi_6_343	5.250	prosth_failure	0.268	1.093	102.740	0.274	10.84	
Pistilli, 2013_ejoi_6_359	5.250	prosth_failure	0.268	1.093	102.740	0.274	10.84	
	1.488		0.559	0.796	3.963	0.426		



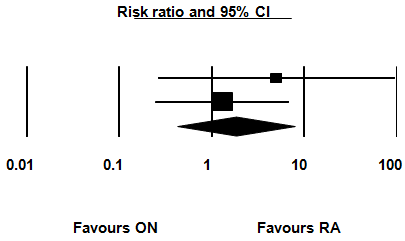
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau-squared Tau Squared	Standard Error	Variance	Tau
Fixed	5	1,567	0,539	4,558	0,825	0,410	3,377	4	0,497	0,000	0,000	1,170	1,370	0,000
Random	5	1,567	0,539	4,558	0,825	0,410								

posterior_mandible	Difference in means	Standard error	Variance	Outcome	Lower limit	Z-Value	Upper limit	p-Value	Weight(Fixed) Relative weight	Relative weight
Esposito, 2011_ejoi_4_21	0.190	0.187	0.035	mbl_1yr	-0.177	1.015	0.557	0.310	0.51	
Esposito, 2011_ejoi_4_301	0.000	0.087	0.008	mbl_1yr	-0.171	0.000	0.171	1.000	2.34	
Felice, 2010_coir_21_1394	0.000	0.087	0.008	mbl_1yr	-0.171	0.000	0.171	1.000	2.34	
Pistilli, 2013_ejoi_6_343	0.090	0.020	0.000	mbl_1yr	0.052	4.596	0.128	0.000	46.52	
Pistilli, 2013_ejoi_6_359	0.020	0.019	0.000	mbl_1yr	-0.018	1.040	0.058	0.298	48.29	
	0.052	0.013	0.000		0.026	3.930	0.079	0.000		



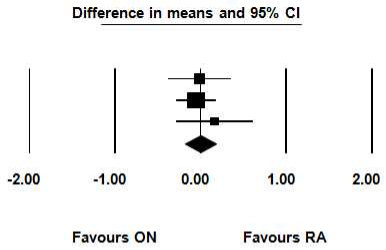
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau-squared Tau Squared	Standard Error	Variance	Tau
Fixed	5	1,773	1,092	2,877	2,317	0,021	13,242	4	0,010	69,793	0,723	0,745	0,555	0,850
Random	5	2,069	0,843	5,076	1,587	0,113								

posterior_mandible		Outcome	Statistics for each study				Weight (Fixed)	
	Risk ratio		Lower limit	Z-Value	Upper limit	p-Value	Relative weight	Relative weight
Chiapasco, 2007_coir_18_432	5.000	impl_failure_1yr	0.256	1.061	97.697	0.289	24.34	
Felice, 2009_cidrr_11S1_e69	1.304	impl_failure_1yr	0.242	0.309	7.040	0.757	75.66	
	1.809		0.417	0.792	7.839	0.428		



Model	Effect size and 95% interval				Test of null (2-Tail)		Heterogeneity				Tau-squared			
Model	Number Studies	Point estimate	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau Squared	Standard Error	Variance	Tau
Fixed	2	1,809	0,417	7,839	0,792	0,428	0,594	1	0,441	0,000	0,000	2,150	4,620	0,000
Random	2	1,809	0,417	7,839	0,792	0,428								

posterior_mandible	Statistics for each study			Outcome	Statistics for each study			Weight (Fixed)	
	Difference in means	Standard error	Variance		Lower limit	Z-Value	Upper limit	p-Value	Relative weight	Relative weight
Chiapasco, 2007_coir_18_432	-0.010	0.192	0.037	mbl_1yr	-0.387	-0.052	0.367	0.958	23.69	
Chiapasco, 2007_coir_18_432	-0.050	0.121	0.015	mbl_1yr	-0.287	-0.414	0.187	0.679	60.05	
Amorfini, 2014_cidrr_16_655	0.160	0.232	0.054	mbl_1yr	-0.295	0.690	0.615	0.490	16.25	
	-0.006	0.094	0.009		-0.190	-0.068	0.177	0.946		



Model	Effect size and 95% confidence interval						Test of null (2-Tail)		Heterogeneity				Tau-squared		
Model	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau Squared	Standard Error	Variance
Fixed	3	-0,006	0,094	0,009	-0,190	0,177	-0,068	0,946	0,646	2	0,724	0,000	0,000	0,031	0,001
Random	3	-0,006	0,094	0,009	-0,190	0,177	-0,068	0,946							

TITLE PAGE

Title of the article

Surgical techniques used in the rehabilitation of partially edentulous patients with atrophic posterior mandibles: A systematic review and meta-analysis of randomized controlled clinical trials

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