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Interventions for replacing missing teeth: alveolar ridge preservation techniques for dental implant site development (Review)

Atieh MA, Alsabeeha NHM, Payne AGT, Duncan W, Faggion CM, Esposito M

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[Intervention Review]

Interventions for replacing missing teeth: alveolar ridge preservation techniques for dental implant site development

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ABSTRACT

Background

Alveolar bone changes following tooth extraction can compromise prosthodontic rehabilitation. Alveolar ridge preservation (ARP) has been proposed to limit these changes and improve prosthodontic and aesthetic outcomes when implants are used.

Objectives

To assess the clinical effects of various materials and techniques for ARP after tooth extraction compared with extraction alone or other methods of ARP, or both, in patients requiring dental implant placement following healing of extraction sockets.

Search methods

The following electronic databases were searched: Cochrane Oral Health's Trials Register (to 22 July 2014), the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2014, Issue 6), MEDLINE via Ovid (1946 to 22 July 2014), Embase via OVID (1980 to 22 July 2014), LILACS via BIREME (1982 to 22 July 2014), the metaRegister of Controlled Trials (to 22 July 2014), ClinicalTrials.gov (to 22 July 2014), the World Health Organization International Clinical Trials Registry Platform (to 22 July 2014), Web of Science Conference Proceedings (1990 to 22 July 2014), Scopus (1966 to 22 July 2014), ProQuest Dissertations and Theses (1861 to 22 July 2014) and OpenGrey (to 22 July 2014). A number of journals were also handsearched. Trial authors were contacted to identify unpublished randomised controlled trials. There were no restrictions regarding language and date of publication in the searches of the electronic databases.

Selection criteria

We included all randomised controlled trials (RCTs) on the use of alveolar ridge preservation techniques with at least six months of follow-up. Outcome measures were: changes in the bucco-lingual/palatal width of alveolar ridge, changes in the vertical height of the alveolar ridge, complications, the need for additional augmentation prior to implant placement, aesthetic outcomes, implant failure rates, peri-implant marginal bone level changes, changes in probing depths and clinical attachment levels at teeth adjacent to the extraction site, and complications of future prosthodontic rehabilitation.

Data collection and analysis

Two review authors extracted data independently and assessed risk of bias for each included trial. Corresponding authors were contacted to obtain missing information. Results were combined using random-effects models with mean differences (MD) for continuous outcomes and risk ratios (RR) for dichotomous outcomes, with 95% confidence intervals (95% CI). We constructed 'Summary of findings' tables to present the main findings.

Main results

A total of 50 trials were potentially eligible for inclusion, of which 42 trials were excluded. We included eight RCTs with a total of 233 extraction sites in 184 participants. One trial was judged to be at unclear risk of bias and the remaining trials were at high risk of bias. From two trials comparing xenograft with extraction alone (70 participants, moderate quality evidence), there was some evidence of a reduction in loss of alveolar ridge height (MD -2.60 mm; 95% CI -3.43 to -1.76) and width (MD -1.97 mm; 95% CI -2.48 to -1.46). This was also found in one trial comparing allograft with extraction (24 participants, low quality evidence): ridge height (MD -2.20 mm; 95% CI -0.75 to -3.65) and width (MD -1.40 mm; 95% CI 0.00 to -2.80) and height. From two RCTs comparing alloplast versus xenograft no evidence was found that either ridge preservation technique caused a smaller reduction in loss of ridge height (MD -0.35 mm; 95% CI -0.86 to 0.16) or width (MD -0.44 mm; 95% CI -0.90 to 0.02; two trials (55 participants); moderate quality evidence). There was insufficient evidence to determine whether there are clinically significant differences between different ARP techniques and extraction based on the need for additional augmentation prior to implant placement, complications, implant failure, or changes in peri-implant marginal bone levels and probing depths of neighbouring teeth. We found no trials which evaluated parameters relating to clinical attachment levels, specific aesthetic or prosthodontic outcomes.

Authors' conclusions

There is limited evidence that ARP techniques may minimise the overall changes in residual ridge height and width six months after extraction. There is also lack of evidence of any differences in implant failure, aesthetic outcomes or any other clinical parameters due to the lack of information or long-term data. There is no convincing evidence of any clinically significant difference between different grafting materials and barriers used for ARP. Further long term RCTs that follow CONSORT guidelines (www.consort-statement.org) are necessary.

PLAIN LANGUAGE SUMMARY

Ways of keeping enough jaw bone to allow for dental implants after teeth have been taken out

Review question

The aim of this review is to assess the effectiveness of various materials and techniques for keeping enough bone in the jaw (alveolar ridge preservation) after teeth have been taken out (tooth extraction). These techniques are compared to tooth extraction alone or other methods of preserving the bone, or both, in patients that need dental implants after the tooth socket has healed.

Background

When a tooth has been taken out, the bone around the tooth socket shrinks. Artificial teeth can be used to replace missing teeth following extractions. However, loss of bone width and depth after tooth extraction can affect how successful the implant will be. This is especially the case when artificial teeth (crowns or bridges) need to be held in place by dental implants inserted into the bone of the jaw where the original teeth used to be. If the bone has shrunk too much following the loss of teeth, it makes it difficult or impossible to put dental implants into the jaw. This in turn leads to gum shrinkage.

A procedure known as socket preservation (ARP) may limit the shrinkage of bone following tooth loss although there is a need for evidence of its effectiveness. Several techniques and bone substitute materials can be used to fill the socket after tooth extraction. The socket may then be covered by gums or an artificial membrane and left to heal for several months. The aim is that the bone of the old tooth socket will have kept its shape and size allowing dental implants to be inserted to support crowns or bridges so that the patient's appearance is improved and they can eat, talk and socialise with confidence. It is also hoped that the rate of failure of dental implants will be improved.

Study characteristics

Authors from Cochrane Oral Health carried out this review and the evidence is up to date from 22 July 2014. Eight trials were included with a total of 233 extraction sites (teeth taken out) in 184 participants. Participants were adults aged 18 years or older, in good general health, needing one or more permanent teeth to be taken out and the consideration of the use of ARP (alveolar ridge preservation techniques) with the possibility of using dental implants at a later date.

The review looked at the effects of four techniques and materials used for preserving the tooth extraction socket.

Three studies compared socket preservation to tooth extraction alone, while five studies compared two or more different materials.

Key results

There is limited evidence that socket preservation (ARP) can reduce bone loss compared to tooth extraction alone to allow for dental implant placement.

There is no evidence that socket preservation makes any important differences to the look or lasting quality of crowns or bridges.

There is no convincing evidence of any significant difference between different materials and barriers used for socket preservation.

Quality of the evidence

The quality of the evidence is judged as low due to high risk of bias of the majority of the included studies. Some evidence of reporting bias is suspected, as only two of the included trials did not receive any industry support. Further long-term randomised controlled trials that follow CONSORT guidelines (www.consort-statement.org) are required.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Alveolar ridge preservation: xenograft versus extraction for replacing missing teeth

Alveolar ridge preservation: xenograft versus extraction for replacing missing teeth

Participants or population: people requiring replacement of missing teeth: alveolar ridge preservation techniques for dental implant site development

Settings: dental implantology

Intervention: xenograft versus extraction

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Control	Alveolar ridge preservation (ARP) versus extraction				
Changes in width of alveolar ridge at 6-36 month follow-up (mm) (xenograft versus extraction)	-	The mean changes in width of alveolar ridge (mm) (xenograft versus extraction) in the intervention groups was 1.97 lower (2.48 lower to 1.46 lower)	-	70 (2 studies)	⊕⊕⊕⊖ moderate ¹	-
Changes in height of alveolar ridge at 6-36 month follow-up (mm) (xenograft versus extraction)	-	The mean changes in height of alveolar ridge (mm) (xenograft versus extraction) in the intervention groups was 2.60 lower (3.43 to 1.76 lower)	-	70 (2 studies)	⊕⊕⊕⊖ moderate ¹	-
Complications (e.g. discomfort, pain and swelling)	-	-	-	(0 studies)	-	-
Need for additional augmentation prior to implant placement at 7-36 months (xenograft versus extraction)	500 per 1000 ²	650 per 1000 (375 to 1000)	RR 1.3 (0.75 to 2.24)	40 (1 study)	⊕⊕⊖⊖ low ³	-
Aesthetic outcomes of future prosthodontic rehabilitation	-	-	-	(0 studies)	-	-

Implant failures at 7-36 months (xenograft versus extraction)	50 per 1000²	50 per 1000 (4 to 745)	RR 1 (0.07 to 14.9)	40 (1 study)	⊕⊕○○ low³	-
Peri-implant marginal bone level changes at 7 months (xenograft versus extraction)	-	The mean peri-implant marginal bone level changes in the intervention groups was 0.02 lower (0.18 lower to 0.14 higher)	-	38 (1 study)	⊕⊕○○ low³	-
Changes in probing depth at teeth adjacent to the extraction site	-	-	-	(0 studies)	-	-
Changes in clinical attachment level (CAL) at teeth adjacent to the extraction site	-	-	-	(0 studies)	-	-
Prosthodontic outcomes of rehabilitation	-	-	-	(0 studies)	-	-

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval; **RR:** Risk ratio

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

¹ Quality of evidence has been downgraded because these studies are at unclear or high risk of bias

² Estimated from the events in the control group

³ Quality of evidence has been downgraded twice because the study is at high risk of bias, and lack of precision

Summary of findings 2. Alveolar ridge preservation: allograft versus extraction for replacing missing teeth

Alveolar ridge preservation: allograft versus extraction for replacing missing teeth

Participants or population: people requiring replacement of missing teeth: alveolar ridge preservation techniques for dental implant site development

Settings: dental implantology

Intervention: allograft versus extraction

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Control	Alveolar ridge preservation (ARP) versus extraction				
Changes in width of alveolar ridge at 6 month follow-up (mm) (allograft versus extraction)	-	The mean changes in height of alveolar ridge (mm) (allograft versus extraction) in the intervention groups was 1.40 lower (2.80 to 0.00 lower)	-	24 (1 study)	⊕⊕⊕⊖ low¹	-
Changes in height of alveolar ridge at 6 month follow-up (mm) (allograft versus extraction)	-	The mean changes in height of alveolar ridge (mm) (allograft versus extraction) in the intervention groups was 2.20 lower (3.65 to 0.75 lower)	-	24 (1 study)	⊕⊕⊕⊖ low¹	-
Complications (e.g. discomfort, pain and swelling)	-	-	-	(0 studies)	-	-
Aesthetic outcomes of future prosthodontic rehabilitation	-	-	-	(0 studies)	-	-
Changes in probing depth at teeth adjacent to the extraction site	-	-	-	(0 studies)	-	-
Changes in clinical attachment level (CAL) at teeth adjacent to the extraction site	-	-	-	(0 studies)	-	-
Prosthodontic outcomes of rehabilitation	-	-	-	(0 studies)	-	-

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval; **RR:** Risk ratio

GRADE Working Group grades of evidence

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Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

¹ Quality of evidence has been downgraded twice because the study is at high risk of bias and lack of precision

Summary of findings 3. Different grafting materials for alveolar ridge preservation: alloplast versus xenograft

Different grafting materials for alveolar ridge preservation for replacing missing teeth: alveolar ridge preservation techniques for dental implant site development

Participants or population: people requiring replacement of missing teeth: alveolar ridge preservation techniques for dental implant site development

Settings: dental implantology

Intervention: alloplast versus xenograft

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Control	Different grafting materials for alveolar ridge preservation				
Changes in width of alveolar ridge at 6-12 month follow-up (mm) (alloplast versus xenograft)	-	The mean changes in width of alveolar ridge (mm) (alloplast versus xenograft) in the intervention groups was 0.44 lower (0.90 lower to 0.02 higher)	=	55 (2 studies)	⊕⊕⊕⊖ moderate ¹	-
Changes in height of alveolar ridge at 12 month follow-up (mm) (alloplast versus xenograft)	-	The mean changes in height of alveolar ridge (mm) (alloplast versus xenograft) in the intervention groups was 0.35 lower (0.86 lower to 0.16 higher)	-	49 (1 study)	⊕⊕⊖⊖ low ^{1,2}	-
Complications (e.g. discomfort, pain and swelling)	-	-	-	(0 studies)	-	-
Need for additional augmentation prior to implant placement	-	-	-	(0 studies)	-	-

Aesthetic outcomes of future prosthodontic rehabilitation	-	-	-	(0 studies)	-	-
Implant failures at 12 months (alloplast versus xenograft)	See comment	See comment	Not estimable	25 (1 study)	⊕⊕⊕⊕ low 2,3	-
Peri-implant marginal bone level changes	-	-	-	(0 studies)	-	-
Changes in probing pocket depth at teeth adjacent to the extraction site at 12 months (mm) (alloplast versus xenograft)	-	The mean changes in probing pocket depth at teeth adjacent to the extraction site (mm) (alloplast versus xenograft) in the intervention groups was 0.3 lower (0.61 lower to 0.01 higher)	-	25 (1 study)	⊕⊕⊕⊕ low 1,2	-
Changes in clinical attachment level (CAL) at teeth adjacent to the extraction site	-	-	-	(0 studies)	-	-
Prosthodontic outcomes of rehabilitation	-	-	-	(0 studies)	-	-

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval

GRADE Working Group grades of evidence

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Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

¹ Quality of evidence downgraded because the study is at high risk of bias

² Quality of evidence downgraded due to single study and imprecision (wide confidence interval)

³ No explanation was provided

Summary of findings 4. Different grafting materials for alveolar ridge preservation: alloplast with and without membrane

Different grafting materials for alveolar ridge preservation for replacing missing teeth: alveolar ridge preservation techniques for dental implant site development

Participants or population: people requiring replacement of missing teeth: alveolar ridge preservation techniques for dental implant site development

Settings: dental implantology

Intervention: alloplast with and without membrane

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Control	Different grafting materials for alveolar ridge preservation				
Changes in width of alveolar ridge at 9 month follow-up (mm) (alloplast with and without membrane)	-	The mean changes in width of alveolar ridge (mm) (alloplast with and without membrane) in the intervention groups was 0.43 higher (0.18 to 0.68 higher)	-	20 (1 study)	⊕⊕⊕⊕ low ^{1,2}	-
Changes in height of alveolar ridge at 9 month follow-up (mm) (alloplast with and without membrane)	-	The mean changes in height of alveolar ridge (mm) (alloplast with and without membrane) in the intervention groups was 0.38 higher (0.26 to 0.50 higher)	-	20 (1 study)	⊕⊕⊕⊕ low ^{1,2}	-
Complications (e.g. discomfort, pain and swelling)	-	-	-	(0 studies)	-	-
Need for additional augmentation prior to implant placement	-	-	-	(0 studies)	-	-
Aesthetic outcomes of future prosthodontic rehabilitation	-	-	-	(0 studies)	-	-
Peri-implant marginal bone level changes	-	-	-	(0 studies)	-	-

Changes in clinical attachment level (CAL) at teeth adjacent to the extraction site	-	-	-	(0 studies)	-	-
Prosthodontic outcomes of rehabilitation	-	-	-	(0 studies)	-	-

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

¹ Quality of evidence downgraded because the study is at high risk of bias

² Quality of evidence downgraded due to single study and imprecision (wide confidence interval)

Summary of findings 5. Different grafting materials for alveolar ridge preservation: allograft with and without synthetic cell-binding peptide P-15

Different grafting materials for alveolar ridge preservation for replacing missing teeth: alveolar ridge preservation techniques for dental implant site development

Participants or population: people requiring replacement of missing teeth: alveolar ridge preservation techniques for dental implant site development

Settings: dental implantology

Intervention: allograft with and without synthetic cell-binding peptide P-15

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Control	Different grafting materials for alveolar ridge preservation				
Changes in width of alveolar ridge at 6 month follow-up (mm) (allograft with and without synthet-	-	The mean changes in width of alveolar ridge (mm) (allograft with and without synthetic cell-binding peptide P-15) in the intervention groups was 0.87 lower (1.93 lower to 0.19 higher)	-	36 (1 study)	⊕⊕⊕⊕ low ^{1,2}	-

ic cell-binding peptide P-15)					
Changes in height of alveolar ridge at 6 month follow-up (mm) (allograft with and without synthetic cell-binding peptide P-15)	-	The mean changes in height of alveolar ridge (mm) (allograft with and without synthetic cell-binding peptide P-15) in the intervention groups was 0.30 lower (1.38 lower to 0.78 higher)	-	36 (1 study)	⊕⊕⊕⊕ low 1,2
Complications (e.g. discomfort, pain and swelling)	-	-	-	(0 studies)	-
Need for additional augmentation prior to implant placement	-	-	-	(0 studies)	-
Aesthetic outcomes of future prosthodontic rehabilitation	-	-	-	(0 studies)	-
Peri-implant marginal bone level changes	-	-	-	(0 studies)	-
Changes in clinical attachment level (CAL) at teeth adjacent to the extraction site	-	-	-	(0 studies)	-
Prosthodontic outcomes of rehabilitation	-	-	-	(0 studies)	-

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

- ¹ Quality of evidence downgraded because the study is at high risk of bias
² Quality of evidence downgraded due to single study and imprecision (wide confidence interval)

Summary of findings 6. Different grafting materials for alveolar ridge preservation: DBM single versus multiple particles

Different grafting materials for alveolar ridge preservation for replacing missing teeth: alveolar ridge preservation techniques for dental implant site development

Participants or population: people requiring replacement of missing teeth: alveolar ridge preservation techniques for dental implant site development

Settings: dental implantology

Intervention: DBM single versus multiple particles

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Control	Different grafting materials for alveolar ridge preservation				
Changes in width of alveolar ridge at 6 month follow-up (mm) (DBM single versus multiple particles)	-	The mean changes in width of alveolar ridge (mm) (DBM single versus multiple particles) in the intervention groups was 0.10 higher (0.97 lower to 1.17 higher)	-	30 (1 study)	⊕⊕⊕⊕ low ^{1,2}	-
Changes in height of alveolar ridge at 6 month follow-up (mm) (DBM single versus multiple particles)	-	The mean changes in height of alveolar ridge (mm) (DBM single versus multiple particles) in the intervention groups was 0.10 higher (1.22 lower to 1.42 higher)	-	30 (1 study)	⊕⊕⊕⊕ low ^{1,2}	-
Complications (e.g. discomfort, pain and swelling)	-	-	-	(0 studies)	-	-
Need for additional augmentation prior to implant placement	-	-	-	(0 studies)	-	-
Aesthetic outcomes of future prosthodontic rehabilitation	-	-	-	(0 studies)	-	-



Peri-implant marginal bone level changes	-	-	-	(0 studies)	-	-
Changes in clinical attachment level (CAL) at teeth adjacent to the extraction site	-	-	-	(0 studies)	-	-
Prosthetic outcomes of rehabilitation	-	-	-	(0 studies)	-	-

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

¹ Quality of evidence downgraded because the study is at high risk of bias

² Quality of evidence downgraded due to single study and imprecision (wide confidence interval)

BACKGROUND

Description of the condition

The extraction of teeth is performed for a variety of reasons, often without any consideration for the preservation of the alveolar ridge. Following this, bone remodelling commences and continues for several months, with most changes occurring in the first three months (Schropp 2003). Post-extraction alveolar bone changes have been estimated to cause 50% reduction in the bucco-lingual width of alveolar bone (Camargo 2000; Iasella 2003; Lekovic 1997; Lekovic 1998; Schropp 2003), and a further loss in height has also been reported (Iasella 2003; Lam 1960). A systematic review evaluated the dimensional changes of the alveolar ridge following tooth extraction and showed a mean reduction of 3.8 mm in width and 1.24 mm in height in the first six months (Tan 2012). The predictable order of bone resorption is known, with the buccal aspect resorbing first (Cawood 1988; Soehren 1979), greater resorption in width than height (Johnson 1967), and with the mandibular bone resorbing faster than the maxillary bone (Atwood 1971; Tallgren 1972). Furthermore, a lingual shift of the crest of the bone, in relation to the original position of the tooth, has also been identified (Pietrokovski 1975). Disuse atrophy, inadequate vascularisation and inflammatory response have been implicated as causative factors for alveolar ridge resorption (Ashman 2000).

The overall alveolar changes following tooth extraction may compromise the prosthodontic rehabilitation using tooth-supported fixed or removable prostheses, as well as implant-supported prostheses. The alveolar bone resorption may not allow an optimal positioning of dental implants (John 2007; Mecall 1991). Therefore, the planning for a prosthodontically-driven implant placement may require preservation of the original alveolar ridge dimensions following tooth extraction. Postoperative care of extraction sockets to reduce pain, minimise complications and improve soft and hard tissue healing, has been previously investigated (Khosla 1971). The practice of bone preservation following tooth extraction in an attempt to maintain ridge height and width was first described as 'bone maintenance' (Ashman 1982; Greenstein 1985; Kentros 1985). Different terms were then used to describe the same procedure, such as 'socket preservation', 'socket augmentation', 'socket grafting', 'ridge preservation', 'alveolar bone grafting' and 'alveolar augmentation', which is defined by the Glossary of Prosthodontic Terms as "any surgical procedure employed to alter the contour of the residual alveolar ridge" (Academy of Prosthodontics 2005). To avoid ambiguity, the term 'alveolar ridge preservation' (ARP) will be used throughout this review. ARP is defined as the procedure of arresting or minimising the alveolar ridge resorption following tooth extraction for future prosthodontic treatment including placement of dental implants.

The purpose of ARP is to maintain a favourable alveolar ridge architecture for future dental implant placement. The timing of placement varies and may influence the final functional and aesthetic outcomes. Following ARP, delayed implant placement is considered to allow time for bone formation within the extraction socket. A recent consensus statement has limited the potential benefits of immediate implant placement particularly in the aesthetic zone where a high rate of mucosal recession is expected (Hämmerle 2012). Nevertheless, there remains a lack of evidence regarding the optimal timing for implant placement after ARP.

ARP techniques may include the placement of different grafting materials, with or without the use of membranes, to preserve and minimise ridge resorption for optimising future implant placement. Two systematic reviews (Hämmerle 2012; Vignoletti 2012) were recently published and demonstrated a significantly smaller reduction in the vertical and horizontal dimensions in alveolar ridge following ARP. However, clinicians' choice of ARP technique often relies on personal preference rather than evidence of efficacy. The clinical efficacy of grafting materials and procedures for ARP remains controversial with each claiming superiority in limiting the horizontal and vertical alveolar ridge resorption.

Description of the intervention

ARP techniques include the use of grafting materials of human, animal or synthetic origin, with or without the use of barrier membranes, to further optimise the functional and aesthetic restoration of dental implants. The grafting materials include: particulate autogenous chips (Araujo 2011; Becker 1994), allografts (Iasella 2003), xenografts (Araujo 2010; Carmagnola 2003), and alloplasts (Norton 2002).

In addition, the literature describes a variety of membranes for covering extraction sockets and preserving alveolar ridges. Barrier membranes can be classified into two main categories: the non-resorbable and resorbable membranes. The former is characterised by its larger bone fill and favourable marginal tissue response provided that the membrane is not exposed (e.g. expanded polytetrafluoroethylene (ePTFE)) (Bartee 1998). On the other hand, resorbable membranes do not require a second surgery and are characterised by significant improvement in soft tissue healing, with minimal tissue reaction to membrane exposure (e.g. bovine and porcine collagen matrices) (Iasella 2003).

The additional surgical time involved in ARP is required in anticipation of preserving the alveolar ridge volume and preventing further bone grafting procedure at the time of implant placement. In the early stages of socket healing, a foreign body reaction to the graft particles causes delayed healing response compared with non-preserved sites in which newly formed woven bone occupies most of the ridge volume (Araujo 2009; Luttikhuisen 2006). Nevertheless, new bone formation appears to be similar in both preserved and non-preserved sites at three months and more, with remaining graft particles still occupying part of the ridge volume (Araujo 2009; Becker 1998). Although the residual graft particles may not be fully resorbable, ARP does jeopardise early osseointegration (the firm anchoring of an implant by the growth of bone around it) or primary stability achieved at the time of implant placement (Carmagnola 2003; Molly 2008).

How the intervention might work

Resorbable and non-resorbable membranes are thought to keep the grafting material in place and maintain the space to allow bone regeneration, thus preserving the shape of the alveolar ridge. Bone grafting materials with or without barrier membranes are also used for their osteoconductive and osteoinductive properties. Osteoinduction is the stimulation of bone growth by the use of grafting materials that activate the mesenchymal cells to differentiate into bone forming cells (Reddi 1981; Urist 1965). On the other hand, osteoconduction is the process of encouraging the formation of capillaries and progenitor cells from the recipient site, by using osteoconductive materials that act as a scaffold which

allows the establishment of new bone (Buch 1986; Reddi 1987). A bone graft acts as a space-maintaining device which stabilises the blood clot, and prevents volume reduction and collapse of overlying soft tissue (Friedmann 2002).

Why it is important to do this review

Although several techniques and materials have been introduced to preserve the alveolar ridge, a lack of evidence exists with regard to the efficacy of these techniques and the superiority of one technique over the other. There are at present conflicting views with some authors considering the use of grafting material for ARP an effective technique in limiting alveolar ridge resorption (Barone 2008; Iasella 2003), while others argue that intra-socket grafts may compromise the normal healing process of the extraction socket, or be of no benefit in preserving the alveolar ridge (Becker 1998; Buser 1998). Further controversy is found determining the rate at which grafting material may resorb, with evidence that particles of different grafting material may remain within the extraction socket for more than six months following placement (Artzi 2000; Becker 1994; Carmagnola 2003). The aim of this review was to evaluate whether ARP techniques are effective in minimising post-extraction ridge resorption, and to identify whether any specific material or procedure could provide superior outcomes.

OBJECTIVES

To assess the clinical effects of various materials and techniques for ARP after tooth extraction compared with extraction alone or other methods of ARP, or both, in patients requiring dental implant placement following healing of extraction sockets.

METHODS

Criteria for considering studies for this review

Types of studies

We included all randomised controlled trials (RCTs), including split-mouth trials on the use of ARP techniques, with at least six months of follow-up. The follow-up was regarded as the period from tooth extraction until the final measurements of the alveolar ridge prior to or at the time of implant placement.

Types of participants

Adult participants aged 18 years or older, in good general health (including participants with well-controlled systemic disease), who required extraction of one or more permanent teeth involving the use of ARP techniques, including the use of barrier membrane or bone graft, or both, in mandibular or maxillary, molar or non-molar sites, with consideration of future delayed placement of dental implants.

We excluded participants who had undergone ARP procedures as part of non-implant related prosthodontic treatment.

Types of interventions

We accepted any method of ARP with or without the use of any type of barrier membranes after tooth extraction. ARP was compared to either extraction alone (no ARP was performed), or another type of ARP.

Types of outcome measures

Primary outcomes

- Changes in the bucco-lingual/palatal width of alveolar ridge.
- Changes in the vertical height of the alveolar ridge.
- Complications (e.g. discomfort, pain and swelling).
- Need for additional augmentation prior to implant placement.
- Aesthetic outcomes of future prosthodontic rehabilitation.
- Implant failure rate.

Secondary outcomes

- Peri-implant marginal bone level changes.
- Changes in probing depth (PD) at teeth adjacent to the extraction site.
- Changes in clinical attachment level (CAL) at teeth adjacent to the extraction site.
- Prosthodontic outcomes of rehabilitation.

Search methods for identification of studies

For the identification of studies included or considered for this review, detailed search strategies were developed for each database searched. These were based on the search strategy developed for MEDLINE (Appendix 3) and revised appropriately for each database to take account of differences in controlled vocabulary and syntax rules. The reference lists of all eligible trials were checked for additional studies.

The search strategy combined the subject search with the Cochrane Highly Sensitive Search Strategy for identifying RCTs, as detailed in box 6.4.c of the *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 (updated March 2011) (Higgins 2011).

Electronic searches

The following electronic databases were searched:

- Cochrane Oral Health's Trials Register (to 22 July 2014) (see Appendix 1);
- The Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2014, Issue 6) (see Appendix 2);
- MEDLINE via Ovid (1946 to 22 July 2014) (see Appendix 3);
- Embase via Ovid (1980 to 22 July 2014) (see Appendix 4);
- LILACS via BIREME (1982 to 22 July 2014) (see Appendix 5);
- Web of Science Conference Proceedings (1990 to 22 July 2014) (see Appendix 6);
- Scopus (1966 to 22 July 2014) (Appendix 7);
- ProQuest Dissertations and Abstracts service (1861 to 22 July 2014) (see Appendix 8);
- OpenGrey (<http://www.opengrey.eu/>) (to 22 July 2014) (Appendix 9).

No restrictions on language or date of publication were applied in the electronic searches.

Searching other resources

We searched the following trials registries to identify ongoing or unpublished studies (see Appendix 10 for details of the search strategies):

- metaRegister of Controlled Trials (<http://www.controlled-trials.com/>) (to 22 July 2014);
- ClinicalTrials.gov (www.clinicaltrials.gov) (to 22 July 2014);
- The World Health Organization International Clinical Trials Registry Platform (<http://apps.who.int/trialsearch/>) (to 22 July 2014).

A number of journals have been handsearched as part of the Cochrane worldwide handsearching programme (see the [Masterlist](#) of journals being handsearched for more information). In addition, the following journals were handsearched for the period 2003 to 2014.

- *Clinical Oral Implants Research*
- *European Journal of Oral Implantology*
- *International Journal of Oral and Maxillofacial Implants*
- *Journal of Clinical Periodontology*
- *Journal of Periodontology*

We contacted corresponding authors for further information. We also approached the manufacturers of different grafting materials in an attempt to identify any unpublished or ongoing studies.

Data collection and analysis

Selection of studies

Two review authors independently screened the retrieved citations for relevance. The search results were printed off and checked on the basis of title first, then by abstract and keywords. Irrelevant references were discarded, and those that were screened as relevant were obtained in full and assessed for inclusion in the review by using an eligibility form that was prepared and pilot tested in advance. Any disagreements were resolved by discussion and consultation with a third reviewer. In the presence of more than one publication of the same trial, all the publications were reviewed. We recorded all rejected studies in the table of excluded studies giving reasons for exclusion.

No language restrictions were applied.

Data extraction and management

Two review authors used a piloted data extraction form to independently extract the data, in duplicate, from all the included studies. Any discrepancies were discussed with a third review author. We contacted corresponding authors of studies to request missing data or for clarification. We excluded any studies that had insufficient data. The review authors were not blinded to the study authors' names, institutional affiliations, journal of publication, and the results of the study. The following data were recorded for each included trial according to the Cochrane review guidelines.

1. Study characteristics: title, authors' names, contact address, study location, language of publication, year of publication, published or unpublished data, source of study funding, study design (parallel group or split mouth), method of randomisation, duration of study, allocation concealment, and blinding (participants, investigators, outcome examiners).
2. Participants: demographic characteristics, inclusion/exclusion criteria, number of participants in test and control groups, number of withdrawals and the reasons for dropouts.
3. Interventions: types of ARP techniques and grafting materials.

4. Comparison: extraction alone (no ARP is performed) or another method of ARP.
5. Outcomes: the previously described outcomes in addition to any other outcomes evaluated in the study. The method of assessment, length of the observation period and any adverse events were also recorded.

Assessment of risk of bias in included studies

Two review authors assessed the risk of bias independently, and in duplicate, for the included studies by using a two-part tool that addresses the specific domains set out in Section 8 of the *Cochrane Handbook for Systematic Reviews for Interventions* ([Higgins 2011](#)). The domains include sequence generation, allocation concealment, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and potential sources of bias. In the 'Risk of bias' table, the first part of the tool involves a description for each entry, while the second part determines the risk of bias by assigning a judgment for each entry as 'Low risk' of bias, 'High risk' of bias, and 'Unclear risk' of bias indicating uncertainty or lack of information.

The overall risk of bias was assessed by completing a 'Risk of bias' table for each included study and then studies were grouped in the following categories.

- Low risk of bias - when all key domains are assessed as being at low risk of bias (a possible bias that is unlikely to alter the results).
- High risk of bias - when one or more domains are assessed as being at high risk of bias (a likely bias that seriously indicates less confidence about the results).
- Unclear risk of bias - when one or more key domains are assessed as unclear (a likely bias that raises doubts about the results).

Measures of treatment effect

Continuous data

The mean difference (MD) and 95% confidence interval (CI) were calculated for continuous outcomes such as changes in width and height of alveolar ridge. The reported mean changes from baseline as well as the final mean scores were combined as MD. In the event of combining studies using different scales of measurements, the standardised mean difference (SMD) was used.

Binary data

Risk ratios (RR) and 95% CIs were calculated for dichotomous outcomes such as implant failure rate. The statistical unit was the participant and not the treated site.

Unit of analysis issues

The statistical unit of randomisation for parallel group studies was the participant, and for split-mouth studies it was the site. The following issues were taken into account in data analysis.

- The errors related to the unit of analysis particularly in the presence of multiple treatment sites in split-mouth studies.
- The level of randomisation (i.e. cluster-randomised trials).
- Multiple observations (i.e. repetition of measurements of the same outcome).

Dealing with missing data

In the event of incompletely reported data regarding the study characteristics, methods and results, we contacted the corresponding authors for clarification. We estimated the missing standard deviations of continuous variables using the methods detailed in section 7.3.3 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011).

Assessment of heterogeneity

We used Cochran's test for heterogeneity and the I^2 statistic to statistically determine the percentage variation across the studies. The tests for heterogeneity were interpreted according to the guidelines detailed in section 9.5 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011).

Assessment of reporting biases

A comprehensive search was adopted in an attempt to avoid reporting bias. The search included grey literature, non-English language publications, and contacting different manufacturers to identify ongoing and unpublished clinical trials. We did not use the funnel plot technique (Egger 1997) to assess publication and reporting bias because of the small number of included studies.

Data synthesis

Meta-analyses were conducted for trials of similar comparisons reporting the same outcome measures. The meta-analyses were used to quantitatively summarise the results using RevMan 5.3. Risk ratios and mean differences were combined for dichotomous and continuous data, respectively. Data were combined using a fixed-effect model if no significant statistical heterogeneity was present. Otherwise, a random-effects analysis was planned. The analysis of the split-mouth studies was undertaken using the generic inverse variance method in RevMan, taking into account the clustering of sites within participants. The effect of ARP techniques for bone maintenance was assessed according to different outcomes (alveolar bone width and height, post-surgical complications, need for additional augmentation, and implant failure).

Subgroup analysis and investigation of heterogeneity

Subgroup analysis was performed to investigate the heterogeneity of the results and explore the effects of different methods of ARP. The subgroups included the following.

- Different grafting material versus extraction alone (e.g. xenograft versus extraction and alloplast versus extraction).
- Type of grafting materials (e.g. autogenous versus xenograft and allograft versus xenograft).

Sensitivity analysis

Sensitivity analysis was planned to investigate the influence of methodological quality on the study results.

Presentation of main results

A 'Summary of findings' table was developed for the primary outcomes of this review using GRADEPro software. The quality of the body of evidence was assessed with reference to the overall risk of bias of the included studies, the directness of the evidence, the inconsistency of the results, the precision of the estimates, the risk of publication bias, the magnitude of the effect and whether or not there was evidence of a dose response. The quality of the body of evidence for each of the primary outcomes was categorised as high, moderate, low or very low.

RESULTS

Description of studies

See: [Characteristics of included studies](#); [Characteristics of excluded studies](#)

Characteristics of the trial settings and investigators

A total of 50 trials were potentially eligible for inclusion (Figure 1), of which, 42 trials were excluded. Twenty-one trials had less than six months of follow-up (Aimetti 2009; Cardaropoli 2012; Cardaropoli 2014; Cook 2013; Coomes 2014; Eskow 2014; Fiorellini 2005; Fotek 2009; Hauser 2013; Kim 2014; Kotsakis 2014; Kutkut 2012; Lekovic 1998; Nevins 2006; Oghli 2010; Pinho 2006; Poulas 2013; Sisti 2012; Toloue 2012; Vance 2004; Wood 2012); 10 trials only reported on histologic or histomorphometric analyses (Alkan 2013; Barone 2014; Calasans-Maia 2013; Checchi 2011; Froum 2002; Geurs 2014; Molly 2008; Nevins 2011; Perelman-Karmon 2012; Scheyer 2012), eight trials were not RCTs (Casado 2010; Crespi 2009; Kim 2011; Lekovic 1997; Neiva 2011; Pelegri 2010; Serino 2003; Shakibaie 2013), two trials only reported soft tissue dimensions (Schneider 2014; Thalmair 2013), and for one trial it was unclear whether alveolar ridge preservation (ARP) was used for participants requiring implant-related prosthodontic treatment (Jung 2013).

Figure 1. Study flow diagram.

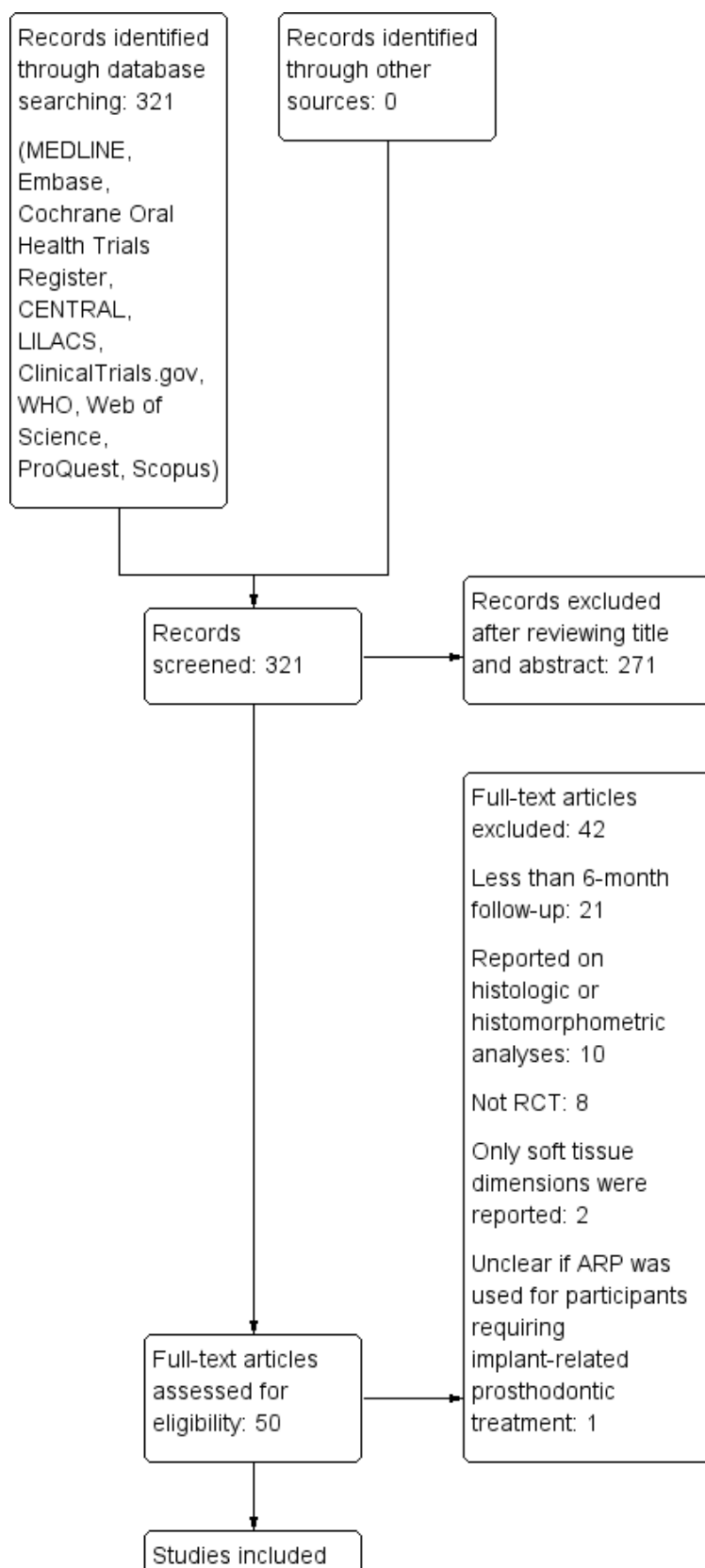


Figure 1. (Continued)

Studies included
in the review: 8

There were no foreign language studies included in this review.

A total of eight trials were included ([Barone 2012](#); [Brkovic 2012](#); [Fernandes 2011](#); [Festa 2013](#); [Gholami 2012](#); [Hoang 2012](#); [Iasella 2003](#); [Patel 2013](#)).

Of the eight included trials, two trials were conducted in the United States ([Hoang 2012](#); [Iasella 2003](#)), two trials in Italy ([Barone 2012](#); [Festa 2013](#)), one trial in Brazil ([Fernandes 2011](#)), one trial in United Kingdom ([Patel 2013](#)), one trial in Serbia ([Brkovic 2012](#)) and one trial in Iran ([Gholami 2012](#)).

The study design was described as parallel group in five trials ([Barone 2012](#); [Brkovic 2012](#); [Hoang 2012](#); [Iasella 2003](#); [Patel 2013](#)), whereas three trials had a split-mouth study design ([Fernandes 2011](#); [Festa 2013](#); [Gholami 2012](#)).

The product used for ARP was supported by the industry in three trials ([Brkovic 2012](#); [Fernandes 2011](#); [Patel 2013](#)). Only two trials ([Gholami 2012](#); [Hoang 2012](#)) did not receive any support, and the funding of the materials used was not reported in three trials ([Barone 2012](#); [Festa 2013](#); [Iasella 2003](#)).

All the trials were conducted at universities, except for one trial ([Barone 2012](#)).

Characteristics of the interventions

1) Bone grafting versus extraction

Three trials ([Barone 2012](#); [Festa 2013](#); [Iasella 2003](#)).

i) Xenografts versus extraction

Two trials ([Barone 2012](#); [Festa 2013](#)) compared porcine derived corticocancellous bone mix and collagen membrane (Osteobiol, Coazze, Italy) with extraction alone.

ii) Allografts versus extraction

One trial ([Iasella 2003](#)) compared tetracycline hydrated freeze-dried bone allograft (FDBA) (American Red Cross, Lorton, VA) and a collagen membrane (Biomend Extend, Centerpulse Dental Division, Carlsbad, CA) with extraction alone.

2) Different grafting materials

Five trials ([Brkovic 2012](#); [Fernandes 2011](#); [Gholami 2012](#); [Hoang 2012](#); [Patel 2013](#)).

i) Alloplast versus xenograft

One trial ([Gholami 2012](#)) compared nanocrystalline hydroxyapatite (NCHA) NanoBone 0.6 mm and Bio-Gide membrane 25 x 25 mm (Geistlich Pharma AG) versus deproteinised bovine bone mineral (DBBM) Bio-Oss spongiosa granules and Bio-Gide membrane 25 x 25 mm (Geistlich Pharma AG). Another trial ([Patel 2013](#)) compared Straumann Bone Ceramic (SBC) (Straumann AG, Basel, Switzerland) and collagen barrier (Bio-Gide, Geistlich, Basel,

Switzerland) versus DBBM (Bio-Oss, Geistlich, Basel, Switzerland) with collagen barrier (Bio-Gide, Geistlich, Basel, Switzerland).

ii) Alloplast with and without membrane

One trial ([Brkovic 2012](#)) compared the use of beta-tricalcium phosphate with type I collagen (β -TCP/C1g) (Septodont, Saint-Maur-des-Fosses, France) with barrier membrane (BioGide, Geistlich AG, Wolhusen, Switzerland) versus β -TCP/C1g alone.

iii) Synthetic cell-binding peptide P-15 as adjunct to other grafting materials

One trial ([Fernandes 2011](#)) compared acellular dermal matrix (ADM) (Alloderm, LifeCell corporation, The Woodlands, TX), anorganic bovine bone matrix (ABM) and synthetic cell-binding peptide P-15 (PepGen P-15, DENTSPLY Friadent CeraMed, Lakewood, CO) versus ADM alone.

iv) Demineralised bone matrix single particle size versus demineralised bone matrix multiple particle size

One trial ([Hoang 2012](#)) compared demineralised bone matrix, single particle size (SPS) between 125 μ m and 710 μ m in a carrier of bovine collagen and sodium alginate versus demineralised bone matrix multiple particle size (MPS) between 125 μ m and 710 μ m in a carrier of bovine collagen and sodium alginate.

Characteristics of the outcome measures

Primary outcomes

- Changes in bucco-lingual/palatal width were reported in eight trials ([Barone 2012](#); [Brkovic 2012](#); [Fernandes 2011](#); [Festa 2013](#); [Gholami 2012](#); [Hoang 2012](#); [Iasella 2003](#); [Patel 2013](#)).
- Changes in vertical height of the alveolar ridge were reported in seven trials ([Barone 2012](#); [Brkovic 2012](#); [Fernandes 2011](#); [Festa 2013](#); [Hoang 2012](#); [Iasella 2003](#); [Patel 2013](#)).
- Complications were reported in three trials ([Brkovic 2012](#); [Festa 2013](#); [Patel 2013](#)). The adverse events ranged from pain and swelling ([Festa 2013](#); [Patel 2013](#)), partial loss of grafting material ([Patel 2013](#)), membrane exposure ([Patel 2013](#)), fibrous adhesion ([Brkovic 2012](#)). Three trials reported that the procedure was uneventful ([Fernandes 2011](#); [Hoang 2012](#); [Iasella 2003](#)).
- Need for additional augmentation prior to implant placement was reported in three trials ([Barone 2012](#); [Gholami 2012](#); [Patel 2013](#)).
- Aesthetic outcomes of future prosthodontic rehabilitation were not assessed in any trial.
- Implant failure rate was reported in two trials ([Barone 2012](#); [Patel 2013](#)).

Secondary outcomes

- Peri-implant marginal bone level changes were measured in one trial ([Barone 2012](#)) using standardised intraoral radiographs.
- Changes in probing depth (PD) at teeth adjacent to the extraction site were presented in one trial ([Patel 2013](#)).

- Changes in clinical attachment level (CAL) at teeth adjacent to the extraction site were not reported in any trial.
- Complications of prosthodontic rehabilitation were not reported in any trial.

Characteristics at baseline

Inclusion criteria

- Age \geq 18 years of age (Barone 2012; Festa 2013; Gholami 2012; lasella 2003; Patel 2013). In one trial, an age range of 20 and 55 was specified (Brkovic 2012).
- \geq 20 teeth in both maxillary and mandibular arches (Fernandes 2011).
- Extraction of non-molars and subsequent single-tooth implant treatment (Barone 2012; Brkovic 2012; Fernandes 2011; Festa 2013; Gholami 2012; lasella 2003; Patel 2013).
- Extraction of one or more maxillary or mandibular molars and subsequent single-tooth implant treatment (Brkovic 2012; Hoang 2012).
- Be in good general health (Brkovic 2012).

Exclusion criteria

- Patients with acute periapical or periodontal infections (Brkovic 2012; Fernandes 2011; Gholami 2012). Acute endodontic lesion in the test tooth or in the neighbouring areas (Patel 2013).
- Teeth with small apical lesions \leq 3 mm were not excluded if it was determined that the lesion could be adequately debrided after extraction (Hoang 2012).
- Inability to maintain adequate oral hygiene (Brkovic 2012). Full mouth plaque level $>$ 30% (Patel 2013).
- Compromised health that could affect the ability of the participants' tissues to heal (Barone 2012; Brkovic 2012; Fernandes 2011; Festa 2013; Gholami 2012; Hoang 2012; Patel 2013). Long-term antibiotic therapy or the need for antibiotic prophylaxis (Fernandes 2011).
- Allergy to medications, grafting materials or membranes used in the study (Barone 2012; Gholami 2012).
- Pregnancy or lactation (Brkovic 2012; Fernandes 2011; Festa 2013; Hoang 2012; Patel 2013).
- Occlusal considerations: lack of opposing occluding dentition in the area intended for extraction (Barone 2012), absence of one or two of the adjacent teeth (Barone 2012; Festa 2013; lasella 2003; Patel 2013), suitable occlusion for the planned prosthodontic treatment (Brkovic 2012), extensive parafunctional habits or bruxism (Patel 2013).
- Smoking habits: smokers (Brkovic 2012; Festa 2013). Smoking more than 10 cigarettes per day (Barone 2012; Patel 2013).

Indications for tooth extraction

Several indications were listed in the selected trials including: inability to restore tooth (Brkovic 2012; Hoang 2012), endodontic reasons (e.g. failed treatment or root fracture) (Brkovic 2012; Hoang 2012) and periodontal disease (Brkovic 2012; Hoang 2012).

Method of assessment

All of the included trials used one or a combination of the methods to record the dimensions of the preserved alveolar ridge: periodontal probe (Barone 2012; Brkovic 2012; Fernandes 2011; Hoang 2012; Patel 2013), caliper (Brkovic 2012; Festa 2013; Gholami 2012; Hoang 2012; lasella 2003), standardised radiograph (Barone 2012; Patel 2013), and template (Barone 2012; Fernandes 2011; Festa 2013; lasella 2003).

Type of socket

Six trials included four-wall socket (Barone 2012; Brkovic 2012; Festa 2013; Gholami 2012; Hoang 2012; Patel 2013). One trial evaluated three-wall socket (Fernandes 2011), while the type of socket was not reported in one trial (lasella 2003).

Surgical technique

Primary closure was not attempted in three trials (Hoang 2012; lasella 2003; Patel 2013), whereas primary closure was achieved in five trials (Barone 2012; Brkovic 2012; Fernandes 2011; Festa 2013; Gholami 2012).

Comparability of control and treatment groups at entry

At entry, the two groups were comparable for the baseline characteristics and outcomes used in all trials.

Timing of implant placement

- Six months (Fernandes 2011; Festa 2013; Hoang 2012; lasella 2003).
- Six to eight months (Gholami 2012).
- Seven months (Barone 2012).
- Eight months (Patel 2013).
- Nine months (Brkovic 2012).

Duration of the studies

- Six months (Fernandes 2011; Festa 2013; Hoang 2012; lasella 2003).
- Six to eight months (Gholami 2012).
- Eight and 12 months (Patel 2013).
- Nine months (Brkovic 2012).
- 36 months (Barone 2012).

Sample size

Only four trials reported a sample size calculation (Fernandes 2011; Hoang 2012; lasella 2003; Patel 2013).

Risk of bias in included studies

The assessment of risk of bias is summarised in Figure 2 and Figure 3. Additional information was provided by most of the authors of the included studies. In summary, only one trial was judged to be at unclear risk of bias (Festa 2013), whereas the remaining trials were judged to be at high risk of bias (Barone 2012; Brkovic 2012; Fernandes 2011; Gholami 2012; Hoang 2012; lasella 2003; Patel 2013).

Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

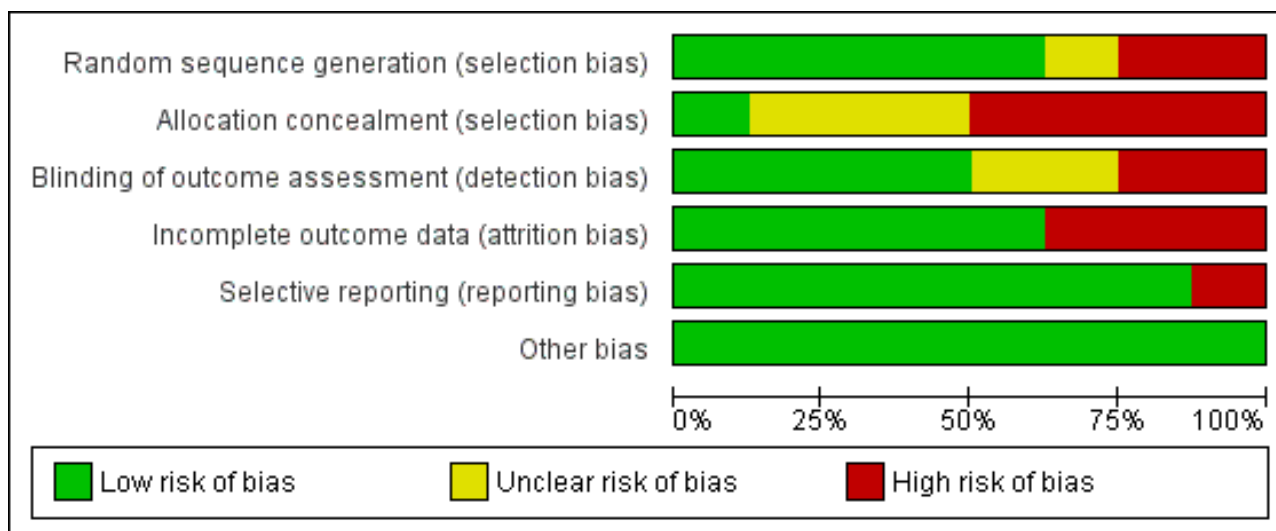


Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Barone 2012	+	+	+	+	-	+
Brkovic 2012	-	?	-	+	+	+
Fernandes 2011	+	-	-	+	+	+
Festa 2013	+	?	?	+	+	+
Gholami 2012	+	-	+	-	+	+
Hoang 2012	?	-	?	-	+	+
Iasella 2003	-	-	+	+	+	+
Patel 2013	+	?	+	-	+	+

Allocation

The random sequence generation was judged as adequate in all but two trials (Brkovic 2012; Iasella 2003). In four trials (Fernandes 2011; Gholami 2012; Hoang 2012; Iasella 2003) allocation was not concealed. It was not clear how the allocation was concealed in three trials (Brkovic 2012; Festa 2013; Patel 2013). Allocation was adequately concealed in one trial (Barone 2012).

Blinding

It is acknowledged that there is a risk of performance bias as it is not possible to blind the surgeon or the participant to the intervention. Therefore, the assessment of blinding was limited to assessing the blinding of outcome evaluation, which is a more practical way to minimise detection bias in these trials.

A blinded outcome assessor recorded the follow-up measurements in four trials (Barone 2012; Gholami 2012; Iasella 2003; Patel 2013).

Blinding of assessors was not clear in two trials (Festa 2013; Hoang 2012). The blinding process was not attempted in two trials (Brkovic 2012; Fernandes 2011).

Incomplete outcome data

Withdrawals and exclusions occurred in three trials (Gholami 2012; Hoang 2012; Patel 2013). One participant in one trial (Gholami 2012) withdrew due to their unwillingness to return to second-stage surgery. In another trial (Hoang 2012), nine participants were noncompliant with the trial protocol and one was excluded from the study at the time of surgery due to large buccal and palatal dehiscence after extracting the tooth. Five withdrawals and exclusions were reported in one trial (Patel 2013), two were excluded due to complete loss of buccal plate during extraction, one withdrew before randomisation, one quit the trial before implant placement, and one did not have the implant due to insufficient primary stability. Another participant did not complete the radiographic part of the trial due to pregnancy.

No withdrawals were reported in five trials (Barone 2012; Brkovic 2012; Fernandes 2011; Festa 2013; Iasella 2003).

Selective reporting

One trial (Barone 2012) was judged at high risk of bias as the figures presented showed one molar site while the inclusion criteria in the text indicated that only non-molar sites were included in the trial. Authors did not reply to our request for clarification.

Other potential sources of bias

All the trials were judged to be at low risk of bias.

Effects of interventions

See: **Summary of findings for the main comparison** Alveolar ridge preservation: xenograft versus extraction for replacing missing teeth; **Summary of findings 2** Alveolar ridge preservation: allograft versus extraction for replacing missing teeth; **Summary of findings 3** Different grafting materials for alveolar ridge preservation: alloplast versus xenograft; **Summary of findings 4** Different grafting materials for alveolar ridge preservation: alloplast with and without membrane; **Summary of findings 5** Different grafting materials for alveolar ridge preservation: allograft with and without synthetic cell-binding peptide P-15; **Summary of findings 6** Different grafting materials for alveolar ridge preservation: DBM single versus multiple particles

In total, 184 participants with 233 extraction sites were included in the analysis.

1) Bone grafting versus extraction

We found three trials in this category: two trials comparing xenografts versus extraction (Barone 2012; Festa 2013) and one trial comparing allografts versus extraction (Iasella 2003).

i) Xenografts versus extraction

Changes in width and height of alveolar ridge

One trial (Barone 2012) of parallel group design compared corticocancellous porcine bone (mp3, Osteobiol, Coazze, Italy) and collagen membrane (Evolution, Osteobiol) with extraction alone. The study evaluated 40 extraction sites in 40 participants at 7 and 36 months. No dropouts were reported. After seven months,

statistically significant differences were detected for ridge width and height in favour of ARP.

One trial (Festa 2013) of split-mouth design compared corticocancellous porcine bone xenograft (OsteoBiol® Gen-Os; Tecnossl srl, Giaveno, Italy) and soft cortical membrane (OsteoBiol® Lamina; Tecnossl srl) versus extraction alone. There were 15 participants with 30 extraction sites. All the participants completed the trial. After six months, there were statistically significant differences for the bucco-lingual/palatal dimensions of the alveolar ridge in favour of the OsteoBiol group rather than extraction alone. There were no statistically significant differences between the control and test groups with regard to vertical height of the alveolar ridge.

Meta-analyses of these two trials showed a significant reduction in the bucco-lingual/palatal width (MD -1.97 mm; 95% CI -2.48 to -1.46; $P < 0.0001$; $I^2 = 0\%$) (Analysis 1.1) and height of the alveolar ridge (MD -2.60 mm; 95% CI -3.43 to -1.76; $P < 0.0001$; $I^2 = 0\%$) (Analysis 1.2). Both meta-analyses indicated a significant benefit for ARP using xenografts.

Need for additional augmentation prior to implant placement

Only one trial (Barone 2012) was included. Additional bone augmentation was required for 13 implants in the test group and 10 in the control group before implant placement. No evidence of difference was shown (RR 1.30; 95% CI 0.75 to 2.24; $P = 0.34$) (Analysis 1.3).

Implant failure

One trial (Barone 2012) found no difference between the use of xenograft and extraction. Two implants failed, one in each group (Analysis 1.4): One implant was not osseointegrated six months post-placement at the time of abutment connection. Another implant failed and was removed as a result of mobility after 24 months of loading.

Peri-implant marginal bone changes

The data in relation to bone dimensional changes were obtained from the results after seven months (Barone 2008). There were no statistically significant differences between the two groups for the marginal bone changes (Analysis 1.5).

ii) Allografts versus extraction

Changes in width and height of alveolar ridge

One trial (Iasella 2003) of parallel group design compared tetracycline hydrated FDBA (American Red Cross, Lorton, VA, USA) and a collagen membrane (Biomend Extend, Centerpulse Dental Division, Carlsbad, CA, USA) versus extraction. Twenty-four participants were enrolled with 12 non-molar extraction sockets in each group. No dropouts were reported. Statistically significant differences were reported for ridge width and height in favour of ARP (Analysis 1.6; Analysis 1.7).

2) Different grafting materials

We found five trials in this category: two trials comparing alloplast versus xenograft (Gholami 2012; Patel 2013); one trial comparing alloplast with and without membrane (Brkovic 2012); one trial comparing allograft with and without synthetic cell-

binding peptide P-15 ([Fernandes 2011](#)); and one trial comparing alloplast with different particle sizes ([Hoang 2012](#)).

i) Alloplast versus xenograft

Changes in width and height of alveolar ridge

One trial ([Gholami 2012](#)) of split-mouth design compared nanocrystalline hydroxyapatite (NCHA) NanoBone 0.6 mm (Artoss GmbH, Rostock-Warnemunde, Germany) versus DBBM Bio-Oss spongiosa granules (small particle size 0.25 mm to 1.0 mm). Both procedures were coupled with the use of Bio-Gide membrane 25 x 25 membrane (Geistlich Pharma AG). Thirteen patients were enrolled in the trial and results were reported for 12 participants with 28 non-molar extraction sockets. One participant withdrew due to unwillingness to return for the second surgery. After 68 months follow-up, there were no statistically significant differences between the two groups for the ridge width.

One trial ([Patel 2013](#)) of parallel group design compared synthetic bone substitute Straumann Bone Ceramic (SBC) (Straumann AG, Basel, Switzerland, granule size 400 µm to 1000 µm) versus DBBM. Collagen barrier (Bio-Gide) was used in both groups. Thirty participants were initially enrolled in this trial, of which, five withdrew from the study and another participant did not complete the radiographic assessment after one year due to pregnancy. At one year after loading there were no statistically significant differences in any of the clinical and radiographic parameters between the two groups.

In one trial ([Patel 2013](#)), the changes in height of the alveolar ridge on mesial and distal sites were included in the meta-analysis. There were no statistically significant differences for changes in width and height of the alveolar ridge, with mean differences of -0.44 mm (95% CI -0.90 to 0.02; $P = 0.06$; $I^2 = 67\%$; [Analysis 2.1](#)) and -0.35 mm (95% CI -0.86 to 0.16; $P = 0.18$; $I^2 = 22\%$; [Analysis 2.2](#)), respectively.

Need for additional augmentation prior to implant placement

The meta-analysis included two trials ([Gholami 2012](#); [Patel 2013](#)) and showed no evidence of difference (RR 1.09; 95% CI 0.65 to 1.83; $P = 0.75$; $I^2 = 0\%$; [Analysis 2.3](#)).

Implant failure

One trial ([Patel 2013](#)) reported that none of the implants failed after 12 months of loading ([Analysis 2.4](#)).

Changes in probing depths (PD)

The meta-analyses of the secondary outcomes showed no differences in PDs at the neighbouring teeth between the test groups. Only one trial ([Patel 2013](#)) reported the changes in PD at teeth adjacent to the extraction sites (MD -0.30 mm; 95% CI -0.61 to 0.01; $P = 0.06$; [Analysis 2.5](#)).

ii) Alloplast with and without membrane

Changes in width and height of alveolar ridge

One trial ([Brkovic 2012](#)) of parallel group design compared β -TCP with type I collagen (β -TCP/C1g) (Septodont, Saint-Maur-des-Fosses, France) versus β -TCP/C1g and barrier membrane (Bio-Gide). Twenty participants enrolled in this study with each participant contributing to either non-molar or molar extraction site. All the sites healed uneventfully with no signs of inflammation. Significant

reductions in the alveolar ridge height and width and height in the non-membrane group were observed ([Analysis 2.6](#); [Analysis 2.7](#)).

iii) Allograft with and without synthetic cell-binding peptide P-15

Changes in width and height of alveolar ridge

One trial ([Fernandes 2011](#)) of split-mouth design compared ADM (Alloderm, LifeCell corporation, The Woodlands, TX, USA), anorganic bovine bone matrix (ABM) with synthetic cell-binding peptide P-15 (PepGen P-15, DENTSPLY Friadent CeraMed, Lakewood, CO, USA) versus ADM only. A total of 18 participants with 36 maxillary anterior extraction sockets completed the study with no postoperative complications. No statistically significant differences were found between the two groups in terms of ridge width and height ([Analysis 2.8](#); [Analysis 2.9](#)).

iv) Alloplast with different particle sizes

Changes in width and height of alveolar ridge

One trial ([Hoang 2012](#)) of parallel group design compared demineralised bone matrix, single particle size (SPS) between 125 µm and 710 µm in a carrier of bovine collagen and sodium alginate versus demineralised bone matrix multiple particle size (MPS) between 125 µm and 710 µm in a carrier of bovine collagen and sodium alginate. No statistically significant differences were found between the two groups in terms of ridge width and height ([Analysis 2.10](#); [Analysis 2.11](#)).

Sensitivity analysis

The planned sensitivity analysis was not performed due to the small number of trials and the fact that none of the trials were of high quality.

DISCUSSION

Summary of main results

See [Summary of findings for the main comparison](#); [Summary of findings 2](#); [Summary of findings 3](#); [Summary of findings 4](#); [Summary of findings 5](#); [Summary of findings 6](#)

The question of whether alveolar ridge preservation does maintain valuable alveolar ridge bone following extractions is relevant to current "state of the art" recommendations for prosthodontically-driven implant placement, with enhanced aesthetic outcomes. This applies whether delayed or immediate placement techniques are followed and regardless of the loading protocol used. The primary outcomes of this review were the changes in alveolar ridge height and width, the need for additional augmentation prior to implant placement, failure of implants placed in preserved sites after loading, and aesthetic outcomes of future prosthodontic rehabilitation. The secondary outcomes included changes in peri-implant marginal bone levels, probing depths, clinical attachment levels, and prosthodontic outcomes. A follow-up period of six months or more was considered suitable to allow for most of the vertical and horizontal resorption of socket walls to occur, in order to provide a better understanding of the role of alveolar ridge preservation in implant site development.

With the limited number of trials, this review finds that there is still insufficient information to draw definitive conclusions. No information is available to evaluate some outcomes, especially

CAL, aesthetic and prosthodontic outcomes. The only statistically significant difference was a reduction in loss of ridge height and width associated with ARP, compared with extraction alone. The subgroup analyses showed that all ARP techniques described in the included trials showed significant reduction in ridge height and width compared with extraction alone. It is worth noting, however, that the differences in ridge height and width became insignificant when different grafting materials were compared. Nevertheless, one trial (Brkovic 2012) at high risk of bias showed that alloplastic materials with membrane resulted in significantly less change in ridge height and width, compared with alloplastic materials alone.

Overall completeness and applicability of evidence

The inclusion of eight trials was insufficient to support definitive conclusions. Despite the fact that the comparison was divided into two main categories, the variety of grafting materials limited the number of participants per subgroup analysis. In addition, the small number of participants increased the risk of overestimation of intervention effects (Thorlund 2011). No sensitivity analysis was attempted due to the small number of included studies. The fact that over 50% of the included trials were published in the last two years indicates that further trials are expected in this growing field of implant research. However, the influence of commercial funding and industry support may result in evaluation of further new materials for ARP, which will likely increase heterogeneity across the included trials in future reviews.

Quality of the evidence

See [Summary of findings for the main comparison](#); [Summary of findings 2](#); [Summary of findings 3](#); [Summary of findings 4](#); [Summary of findings 5](#); [Summary of findings 6](#).

The evidence for ARP interventions, xenograft and allograft, compared with extraction is considered to be low to moderate quality. The evidence comparing different ARP techniques is also low to moderate quality.

Seven out of eight trials were judged to be at high risk of bias, largely due to lack of allocation concealment, and one trial was judged to be at unclear risk of bias. As most of the studies failed to address the method of allocation concealment, one may question whether the participants might have been treated differently if the allocation of the participants was concealed from the operators. Inadequate reporting was another domain of bias. In one case, authors were contacted to clarify inclusion criteria which only included non-molar sites, while the figures showed an ARP of molar site (Barone 2012).

Blinding was not considered as one of the main domains of assessing risk of bias in this review as neither participants nor personnel could be blinded to the intervention. However, we considered the blinded assessment of outcomes because having a blinded examiner to assess the outcomes is possible in these trials, particularly when the assessment is based on radiographic or cast analysis in which the examiner can be unaware of the interventions. Moreover, blinding the outcome assessor may eliminate the detection bias as measurements are made on a very narrow scale of millimetres which may have a significant effect on the results.

In some instances, the information provided by the publications was not sufficient to reliably assess the quality of the trial. Some corresponding authors provided us with additional information

that clarified the trials and allowed us to include them in the present review. This emphasises the importance of clearly reporting the results, including any attempt to conceal the allocation, along with dropouts and the reasons for exclusions, as recommended by the Consolidated Standards of Reporting Trials (CONSORT) guidelines (www.consort-statement.org).

Twenty-two of 50 studies considered potentially eligible were excluded because their follow-up was less than six months and this was deemed insufficient to judge post-extraction ridge resorption. This indicates the need for further trials with long-term follow-up; see [Implications for research](#).

Another important consideration that may affect the quality of the evidence is the confounding variables across the included studies, such as: different tooth sites, anatomical factors, methods of assessment, and keratinised tissue at extraction sites. It is reasonable to assume that it is not possible to standardise all these variables, but one should consider that different determinants may affect the outcome of ARP. Research has suggested that healing time, CAL, and keratinised tissue at extraction site are possible determinants of ridge height preservation, whereas the buccal plate thickness and tooth root length are possible determinants of alveolar ridge width loss (Leblebicioglu 2013).

Potential biases in the review process

In addition to extensive searches of the electronic databases, we approached researchers and manufacturers of grafting materials in an attempt to obtain additional information and details of any unpublished trials. Some corresponding authors did not reply to our requests and their trial data were therefore excluded from the analysis. With more than seven of the included trials either failing to report the source of funding or having commercial support for the ARP product used, publication bias is also suspected on research quality and outcomes.

Agreements and disagreements with other studies or reviews

The present review included all the RCTs available to date. The interaction of many variables and the lack of long-term data mean that it is not possible to determine whether the reduced loss in alveolar ridge height and width achieved by ARP is likely to improve treatment outcomes. Although other published reviews (Avila-Ortiz 2014; Chan 2013; Darby 2009; Horváth 2013; Ten Heggeler 2011; Vignoletti 2012; Vittorini Orgeas 2013) were not based on the most reliable clinical studies, they concluded that ARP may improve bone dimensions compared with extraction alone, but again questioned the long-term effects of ARP on implant success and peri-implant tissues. While there is general agreement that ARP may considerably enhance the site following extraction for future implant placement, it is still premature to conclude which material is superior to others and whether barrier membranes provide any additional benefit.

AUTHORS' CONCLUSIONS

Implications for practice

ARP techniques can minimise the loss of ridge height and width under ideal conditions in non-molar four-wall sockets, following extraction. There is a general agreement that implants can be placed six months after ARP, following a delayed placement

procedure. However, there was no convincing evidence that ARP would improve implant or prosthodontic success. There are more trials to suggest that xenografts (one of the most studied materials) showed successful short-term ARP. However, clinicians should interpret the findings of this review with caution as the quality of evidence remains low with the majority of the studies judged to be at high risk of bias.

It is still not clear which ARP technique provides more predictable results and it is still premature to draw any conclusions with regard to the surgical technique, namely the need for primary closure.

Implications for research

There is a need to conduct further long-term well-designed RCTs, following the CONSORT guidelines (www.consort-statement.org) that not only report changes in ridge height and width, but also the achieved aesthetic/prosthodontic outcomes, the need for any additional augmentation, patient outcomes, and the long-term success rates of implants placed in preserved sites.

The analyses of cost-effectiveness and cost-benefit of ARP techniques are needed to compare the benefits of ARP and

the cost of different grafting materials. As ARP is a relatively new intervention in dental care and the implementation of such procedure generates additional cost, an essential question to be answered resides mainly in the analysis of whether ARP can achieve tangible improvements of the clinical outcomes for the extra financial liability.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Barone 2012

Methods	<p>Trial design: randomised, parallel group trial</p> <p>Location: Lucca, Italy</p> <p>Number of centres: Division of Dentistry, Versilia Hospital, Lido dl Camaiore, Lucca, Italy</p> <p>Recruitment period: 2006 to 2007</p> <p>Funding source: not stated</p>
Participants	<p>Inclusion criteria:</p> <p>Patients 18 years of age and older that required one tooth extraction and requested implant restoration; had extraction sites with adjacent teeth; were able to sign an informed consent form</p> <p>Exclusion criteria:</p> <p>History of systemic diseases; long-term NSAID; required AB prophylaxis; lack of opposite occluding dentition in the area intended for extraction and subsequent implant placement; presence of molar sites that required extraction; absence of adjacent teeth; absence of alveolar bone wall; unwillingness to return for follow-up examination; smoking > 10 cigarettes per day (Participants smoking < 10 cigarettes per day were requested to stop smoking before and after surgery)</p> <p>Age at baseline: range 26 to 69 years</p> <p>Gender: M16/F24</p> <p>Smokers: 12 (six in each group)</p> <p>Teeth extracted: anterior and premolars</p> <p>Number randomised (participants/sites): 40/40</p> <p>Number evaluated (participants/sites): 40/40</p>
Interventions	<p>Comparison: ARP versus extraction alone</p> <p>Test group (n = 20 extraction sockets) xenograft (corticocancellous porcine bone (mp3, Osteobiol, Coazze, Italy)) and collagen membrane (Evolution, Osteobial)</p> <p>Control group: (n = 20 extraction sockets) extraction alone</p> <p>Surgical technique: primary closure</p> <p>Type of the socket: four-wall socket</p> <p>Duration of follow-up: 7 months until implant placement + 36 months</p>
Outcomes	<p>Plaque index, gingival index, bleeding on probing, width and height of alveolar ridge, implant failure, need for additional augmentation prior to implant placement</p>
Notes	<p>Sample size calculation: not reported</p> <p>Data from same study (Barone 2008) were also used</p>

Risk of bias

Barone 2012 (Continued)

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Reported in the article "Extraction sockets were allocated to either a test (graft material) or control (spontaneous healing) group using a computerised random allocation process"
Allocation concealment (selection bias)	Low risk	Reported in the article "Only one of the investigators (BO), not involved in the selection and treatment of the patients, was aware of the randomisation sequence and had access to the randomisation list. The randomised codes were enclosed in sequentially numbered, identical, opaque, and sealed envelopes"
Blinding of outcome assessment (detection bias) All outcomes	Low risk	All radiographic measurement were taken by one masked examiner
Incomplete outcome data (attrition bias) All outcomes	Low risk	All data presented
Selective reporting (reporting bias)	High risk	The inclusion criteria included non-molar sites while the figures in the article showed an ARP of a molar site
Other bias	Low risk	None detected

Brkovic 2012

Methods	<p>Trial design: randomised, parallel group trial</p> <p>Location: Belgrade, Serbia</p> <p>Number of centres: Single centre, Clinic of Oral Surgery, Faculty of Dentistry, University of Belgrade, Belgrade, Serbia</p> <p>Recruitment period: January 2008 to March 2009</p> <p>Funding source: The study was supported by Septodont, France, Grant No. 2207-2006</p>
Participants	<p>Inclusion criteria:</p> <p>Age between 20 and 55 years</p> <p>ASA I status as classified by the American Society of Anesthesiologists</p> <p>Good oral hygiene</p> <p>Indications for tooth extraction such as fracture of the tooth, non-vital tooth without the possibility of endodontic treatment and restoration, chronic periodontitis, endodontic treatment failure, and periodontal disease</p> <p>Extraction socket with four intact walls</p> <p>Occlusion suitable for the planned prosthodontic treatment</p> <p>Non-smokers or had quit smoking for at least 2 months prior to enrolment in study</p> <p>Exclusion criteria:</p> <p>Presence of any chronic systemic disease, allergy, medication given within 48 hours pre-operatively</p>

Brkovic 2012 (Continued)

Presence of purulent periodontal lesions as well as severe periodontal bone loss with a remaining alveolar bone height of less than 6 mm

History of chronic pain

Pregnancy or nursing mothers

Inability to comply with the study protocol

Age at baseline: mean age 49 ± 15 (β -TCP/C1g); 46 ± 13 (β -TCP/C1g + membrane)

Gender: M8/F12

Smokers: 4 (β -TCP/C1g); 5 (β -TCP/C1g + membrane)

Teeth extracted: canine – premolar – molar areas

Number randomised (participants/sites): 20/20

Number evaluated (participants/sites): 20/20

Interventions	Comparison: ARP (grating material) versus ARP (grafting material and membrane)	
	Test group (n = 11 extraction sockets) beta-tricalcium phosphate with type I collagen (β-TCP/C1g) (Septodont, Saint-Maur-des-Fosses, France)	
	Control group: (n = 9 extraction sockets) (β-TCP/C1g) and barrier membrane (BioGide, Geistlich AG, Wolhusen, Switzerland)	
	Surgical technique: flap, primary closure for the (graft and membrane) group	
	Type of the socket: four-wall socket	
	Duration of follow-up: 9 months	
Outcomes	Height and width of alveolar ridge	
Notes	Sample size calculation: not reported but authors replied that sample size was based on practicality. This was the amount of material they had at their disposal, once it ran out the study was finished	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence genera- tion (selection bias)	High risk	Nothing reported in the article The authors replied that cue cards in sealed envelopes drawn from a jar at the time of acceptance of participant into the study
Allocation concealment (selection bias)	Unclear risk	Nothing reported in the article No clarifying reply
Blinding of outcome as- sessment (detection bias) All outcomes	High risk	Nothing reported in the article, but the authors replied that the nature of the appearance of the wound made it impossible to reliably blind the observer
Incomplete outcome data (attrition bias) All outcomes	Low risk	All data presented

Brkovic 2012 (Continued)

Selective reporting (reporting bias)	Low risk	All outcomes appear to be detected
Other bias	Low risk	None detected

Fernandes 2011

Methods	<p>Trial design: randomised, split-mouth trial</p> <p>Location: São Paulo, Brazil</p> <p>Number of centres: Single centre, University of São Paulo, São Paulo, Brazil</p> <p>Recruitment period: February 2009 to March 2010</p> <p>Funding source: BioHorizons, Birmingham, Alabama donated the ADM used in this study</p>
Participants	<p>Inclusion criteria:</p> <p>Systemic health</p> <p>≥ 20 teeth in both maxillary and mandibular arches</p> <p>≥ 2 hopeless, single rooted and non-adjacent teeth in the maxilla</p> <p>Exclusion criteria:</p> <p>Antibiotic therapy in the last 6 months</p> <p>Systemic involvement</p> <p>Smokers</p> <p>Pregnant or lactating patients</p> <p>Age at baseline: mean age 44.0 ± 8.10 years (33 to 58)</p> <p>Gender: M5/F13</p> <p>Smokers: none</p> <p>Teeth extracted: maxillary anterior teeth</p> <p>Number randomised (participants/sites): 18/36</p> <p>Number evaluated (participants/sites): 18/36</p>
Interventions	<p>Comparison: ARP (grafting material) versus ARP (grafting material)</p> <p>Test group (n = 18 extraction sockets) Acellular dermal matrix (ADM) (Alloderm, LifeCell corporation, The Woodlands, TX) + Anorganic bovine bone matrix (ABM) with synthetic cell-binding peptide P-15 (PepGen P-15, DENTSPLY Friadent CeraMed, Lakewood, CO)</p> <p>Control group: (n = 18 extraction sockets) ADM only</p> <p>Surgical technique: flap, primary closure</p> <p>Type of the socket: all alveolar sockets had buccal bone defects after extraction</p> <p>Duration of follow-up: 6 months</p>

Fernandes 2011 (Continued)

Outcomes	Height and width of alveolar ridge	
Notes	Sample size calculation: reported	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Reported in the article “The sites for the test and control groups were randomly selected by a coin toss”
Allocation concealment (selection bias)	High risk	The authors replied that no allocation concealment was attempted
Blinding of outcome assessment (detection bias) All outcomes	High risk	The authors replied that examiners were not blinded
Incomplete outcome data (attrition bias) All outcomes	Low risk	All data presented
Selective reporting (reporting bias)	Low risk	All outcomes appear to be detected
Other bias	Low risk	None detected

Festa 2013

Methods	<p>Trial design: randomised, split-mouth trial</p> <p>Location: Naples, Italy</p> <p>Number of centres: Stomatology Department, Second University of Naples (SUN), Naples, Italy</p> <p>Recruitment period: June 2008 to March 2010</p> <p>Funding source: unclear</p>
Participants	<p>Inclusion criteria:</p> <p>Over 18 years of age</p> <p>Require double extraction of contralateral premolars located in symmetrical quadrants of maxillary or mandibular arches and requested an implant restoration</p> <p>All extraction sites had adjacent teeth</p> <p>Exclusion criteria:</p> <p>Systemic diseases that affect the periodontium or that contraindicate surgical treatment</p> <p>Long-term NSAID therapy</p> <p>Failure to sign an informed consent</p> <p>Smoking</p> <p>Pregnancy or lactating period</p>

Festa 2013 (Continued)

Buccal or palatal/lingual bony wall fractured or completely lost during the extraction procedure

Age at baseline: range 28 to 58 years

Gender: M6/F9

Smokers: none

Teeth extracted: premolars

Number randomised (participants/sites): 15/30

Number evaluated (participants/sites): 15/30

Interventions	<p>Comparison: ARP (grafting material) versus extraction alone</p> <p>Test group (n = 15 extraction sockets). Corticocancellous porcine bone xenograft (Osteobiol Gen-Os) (mixed granules with a diameter ranging from 250 to 1000 µm + soft cortical membrane (OsteoBiol Lamina)</p> <p>Control group: (n = 15 extraction sockets) extraction alone</p> <p>Surgical technique: flap, primary closure</p> <p>Type of the socket: four-wall socket</p> <p>Duration of follow-up: 6 months</p>
Outcomes	Height and width of alveolar ridge
Notes	Sample size calculation

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Reported in the article "The test and control sites were randomly selected using a coin toss"
Allocation concealment (selection bias)	Unclear risk	No information in the article and the authors did not provide further information
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No information in the article and the authors did not provide further information
Incomplete outcome data (attrition bias) All outcomes	Low risk	All data presented
Selective reporting (reporting bias)	Low risk	All outcomes appear to be detected
Other bias	Low risk	None detected

Gholami 2012

Methods	Trial design: randomised, split-mouth trial
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Gholami 2012 (Continued)

Location: Tehran, Iran

Number of centres: Single centre, Department of Periodontics, Dental School, Shaheed Beheshti University of Medical Sciences, Tehran, Iran

Recruitment period: June 2009 to July 2010

Funding source: not supported or sponsored by any external resources

Participants	<p>Inclusion criteria:</p> <p>Over 18 years of age</p> <p>Require one or two pairs of non-molar teeth extraction and desired implant restoration</p> <p>Four-wall sockets of the teeth with hopeless prognosis due to endodontic problems, trauma or prosthetic issues</p> <p>Exclusion criteria:</p> <p>History of systemic diseases that would contraindicate surgical treatment</p> <p>Acute infection in surgical sites</p> <p>Long-term non-steroidal anti-inflammatory drug therapy</p> <p>Periodontal disease with bone loss</p> <p>Known allergy to any of the materials used in the study</p> <p>Molar extraction sites</p> <p>Presence of inter-radicular septum in extraction sockets</p> <p>Failure to sign an informed consent</p> <p>Age at baseline: mean age 44.6 ± 11.4 years (21 to 60)</p> <p>Gender: M4/F8</p> <p>Smokers: none</p> <p>Teeth extracted: non-molar teeth</p> <p>Number randomised (participants/sites): 13/30</p> <p>Number evaluated (participants/sites): 12/28</p>
Interventions	<p>Comparison: ARP (grafting material) versus extraction alone</p> <p>Test group (n = 15 extraction sockets). Deproteinised bovine bone mineral (DBBM) Bio-Oss spongiosa granules (small particle size 0.25 mm to 1.0 mm) + Bio-Gide membrane 25 x 25 mm (Geistlich Pharma AG)</p> <p>Control group: (n = 15 extraction sockets) Nanocrystalline hydroxyapatite (NCHA) NanoBone 0.6 mm + Bio-Gide membrane 25 x 25 mm (Geistlich Pharma AG)</p> <p>Surgical technique: flap, primary closure</p> <p>Type of the socket: four-wall socket</p> <p>Duration of follow-up: 6 to 8 months (mean 6.9 ± 0.8 months)</p>
Outcomes	<p>Height and width of alveolar ridge, need for additional augmentation prior to implant placement</p>

Gholami 2012 (Continued)

Notes Sample size calculation: not reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Reported in the article "Fifteen symmetrical pairs were randomly selected using a random number table"
Allocation concealment (selection bias)	High risk	No information in the article. In their response, the authors did not provide more details to clarify this issue
Blinding of outcome assessment (detection bias) All outcomes	Low risk	The horizontal ridge width was assessed blindly. The operator was blinded to the treatment groups during surgical re-entry, and the serial longitudinal sections were also coded and analysed by an examiner masked to the type of treatment
Incomplete outcome data (attrition bias) All outcomes	High risk	One participant withdrew due to their unwillingness to return to second-stage surgery.
Selective reporting (reporting bias)	Low risk	The study lost one participant, and therefore not all the data were presented. However, the lost data did not affect the results
Other bias	Low risk	None detected

Hoang 2012

Methods	<p>Trial design: randomised, parallel group trial</p> <p>Location: San Antonio, TX, USA</p> <p>Number of centres: University of Texas Health Science Center at San Antonio (UTHSCSA)</p> <p>Recruitment period: November 2008 to May 2010</p> <p>Funding source: no funding was received for this study</p>
Participants	<p>Inclusion criteria:</p> <p>Having one molar tooth requiring extraction, followed by replacement with a dental implant</p> <p>Adequate restorative space and height of alveolar bone</p> <p>Extracted teeth were removed as a result of non-restorability, fracture, periodontal disease, or failed endodontic procedures</p> <p>Teeth with small apical lesions ≤ 3 mm were not excluded if it was determined that the lesion could be adequately debrided after extraction</p> <p>Exclusion criteria:</p> <p>Pregnant or planning to become pregnant within the study period</p> <p>Had any medical contraindications to dental surgery or any medical conditions that may affect wound healing after dental surgery, such as autoimmune disorders and immunosuppressive therapy</p> <p>Molar sites, with a buccal bony dehiscence extending $> 50\%$ of the length of socket, were excluded from the study</p>

Hoang 2012 (Continued)

Age at baseline: mean age 56.1 years; range 29 to 76

Gender: M15/F15

Smokers: all non-smokers

Teeth extracted: molars

Number randomised (participants/sites): 40/40

Number evaluated (participants/sites): 30/30

Interventions	<p>Comparison: ARP (grafting materials) versus ARP (grafting materials)</p> <p>Test group (n = 15 extraction sockets). Demineralised bone matrix, single particle size (SPS) between 125 µm and 710 µm in a carrier of bovine collagen and sodium alginate.</p> <p>Control group: (n = 15 extraction sockets). Demineralised bone matrix, multiple particle size (MPS) between 125 µm and 710 µm in a carrier of bovine collagen and sodium alginate + additional particles measuring approximately 2 to 4 mm in length</p> <p>Surgical technique: flaps were not reflected to obtain primary closure of the wound</p> <p>Type of the socket: 4-wall socket. 4 of the 16 subjects in the SPS group and 3 of the 14 subjects in the MPS group had a small dehiscence in the buccal wall (authors replied)</p> <p>Duration of follow-up: 6 months (time of implant placement)</p>
Outcomes	Height and width of alveolar ridge
Notes	Sample size calculation: reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	<p>Reported in the article "Immediately preceding the start of the surgical procedure, an envelope was drawn from a stack of sealed envelopes with the name of either graft material written inside"</p> <p>It is not clear whether the envelopes were shuffled or the codes were placed in sequence</p>
Allocation concealment (selection bias)	High risk	Reported in the article "The treating providers, residents in periodontology at UTHSCSA, were not masked to group assignment".
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Histologic examination was conducted by masked examiners but not clear whether clinical parameters were recorded by masked examiners
Incomplete outcome data (attrition bias) All outcomes	High risk	The study excluded 10 participants. Of which, nine were noncompliant with the trial protocol and one withdrew from the study at the time of surgery due to large buccal and palatal dehiscence after extracting the tooth
Selective reporting (reporting bias)	Low risk	All outcomes appear to be detected
Other bias	Low risk	None detected

Iasella 2003

Methods	<p>Trial design: randomised, parallel group trial</p> <p>Location: Louisville, KY</p> <p>Number of centres: Graduate Periodontics, School of Dentistry, University of Louisville, Louisville, KY</p> <p>Recruitment period: 2001 to 2002</p> <p>Funding source: the funding was internal</p>
Participants	<p>Inclusion criteria:</p> <p>Patients over 18 years old with one or two non-molar teeth requiring extraction and implant restoration; extraction sites bordered by at least one tooth</p> <p>Exclusion criteria:</p> <p>Systemic diseases (debilitating or affecting the periodontium); long-term NSAID; known allergy to FDDBA or collagen membranes; AB prophylaxis; failure to sign informed consent; molar extraction sites</p> <p>Age at baseline: mean age 51.5 ± 13.6 years (28 to 76)</p> <p>Gender: M10/F14</p> <p>Smokers: 9 (4 in the control group and 5 in the test group)</p> <p>Teeth extracted: non-molar sites</p> <p>Number randomised (participants/sites): 24/24</p> <p>Number evaluated (participants/sites): 24/24</p>
Interventions	<p>Comparison: ARP (grafting material) versus extraction alone</p> <p>Test group (n = 12 participants with a single extraction socket each). Tetracycline hydrated freeze-dried bone allograft (FDDBA) (American Red Cross, Lorton, VA) and a collagen membrane (Biomend Extend, Centerpulse Dental Division, Carlsbad, CA)</p> <p>Control group: (n = 12 participants with a single extraction socket each) extraction alone</p> <p>Surgical technique: flap, no primary closure</p> <p>Type of the socket: intact 4-wall sockets except for two in each group (test and control) that had some loss of the buccal crest following the extraction</p> <p>Duration of follow-up: 4 to 6 months</p>
Outcomes	Plaque index, gingival index, bleeding on probing, height and width of alveolar ridge
Notes	Sample size calculation: reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Coin toss. The toss was done after the flap and extraction but before grafting
Allocation concealment (selection bias)	High risk	The authors replied that only the operator knew the assignment. However, flipping the coin during the procedure may increase the risk of bias
Blinding of outcome assessment (detection bias)	Low risk	All measurements were taken by two masked examiners

Iasella 2003 (Continued)

All outcomes

Incomplete outcome data (attrition bias) All outcomes	Low risk	All data presented
Selective reporting (reporting bias)	Low risk	All outcomes appear to be detected
Other bias	Low risk	None detected

Patel 2013

Methods	<p>Trial design: randomised, parallel group trial</p> <p>Location: London, UK</p> <p>Number of centres: Clinical Investigation Centre, UCL Eastman Dental Institute, London, UK</p> <p>Recruitment period: 2006 to 2008</p> <p>Funding source: the study was supported by a grant from the Institut Straumann AG, Basel, Switzerland</p>
Participants	<p>Inclusion criteria:</p> <p>Age between 18 and 75 years; good general health</p> <p>The presence of a hopeless tooth in the mandibular or the maxillary incisor, canine or premolar region requiring extraction and would be suitable for replacement by a dental implant</p> <p>The tooth to be extracted has at least one neighbouring tooth</p> <p>The subject had voluntarily signed the informed consent</p> <p>Exclusion criteria:</p> <p>Pregnancy or lactating period</p> <p>Chronic treatment with any medication known to affect oral status and bone turnover or contraindicate surgical treatment within 1 month of baseline visit</p> <p>Concomitant anticoagulant therapy</p> <p>Any known diseases (not including controlled diabetes mellitus)</p> <p>Infections or recent surgical procedures within 30 days of study initiation</p> <p>HIV or hepatitis</p> <p>Administration of any other investigational drug within 30 days of study initiation</p> <p>Limited mental capacity or language skills or suffering from a known psychological disorder</p> <p>Heavy smoking (> 10 cigarettes per day)</p> <p>Uncontrolled or untreated periodontal disease</p> <p>Full-mouth plaque level (FMPL) > 30% at the enrolment visit</p> <p>Severe bruxism</p> <p>Acute endodontic lesion in the test tooth or in the neighbouring areas</p>

Patel 2013 (Continued)

Major part of the buccal or palatal osseous wall damaged or lost following tooth extraction

Age at baseline: mean age 37.3 ± 11.4 years (20 to 58)

Gender: M6/F21

Smokers: 3

Teeth extracted: non-molar sites

Number randomised (participants/sites): 30/30

Number evaluated (participants/sites): 25/25 (radiographic evaluation 24/24)

Interventions	Comparison: ARP (grafting material) versus ARP (grafting material) Test group (n = 13 extraction sockets). Synthetic bone substitute-Straumann Bone Ceramic (SBC) (Straumann AG, Basel, Switzerland, granule size 400 µm to 1000 µm) + collagen barrier (Bio-Gide, Geistlich, Basel, Switzerland) Control group: (n = 12 extraction sockets) Bio-Oss deproteinised bovine bone mineral (DBBM) + collagen barrier (Bio-Gide, Geistlich, Basel, Switzerland) Surgical technique: flap, no primary closure Type of the socket: four-wall socket Duration of follow-up: 8 months at implant placement (Mardas 2010) 12 months post-loading (Patel 2013)	
Outcomes	Height and width of alveolar ridge, probing pocket depth, gingival recession, implant survival, need for additional augmentation prior to implant placement	
Notes	Sample size calculation: reported	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Reported in the article: “The subjects were randomly assigned to the test or the control group by a computer-generated table. A balanced randomly permuted block approach was used to prepare the randomisation tables in order to avoid unequal balance between the two treatments. The subjects were randomised according to smoking habits”
Allocation concealment (selection bias)	Unclear risk	No information was provided in the article
Blinding of outcome assessment (detection bias) All outcomes	Low risk	All the periodontal and surgical measurements were made by a single, blinded examiner
Incomplete outcome data (attrition bias) All outcomes	High risk	As three participants were excluded and it is not clear how the authors managed the dropouts
Selective reporting (reporting bias)	Low risk	All outcomes appear to be detected
Other bias	Low risk	None detected

Abbreviations: AB (prophylaxis) - ?antibiotics?; FDBA - freeze-dried bone allograft; NSAID - non-steroidal anti-inflammatory drugs

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Aimetti 2009	The study followed up participants for less than six months
Alkan 2013	A histological study
Barone 2014	A histological and histomorphometrical study
Calasans-Maia 2013	A histological and histomorphometrical study
Cardaropoli 2012	The study followed up participants for less than six months
Cardaropoli 2014	The study followed up participants for less than six months
Casado 2010	The study is not a randomised controlled trial
Checchi 2011	A histological and histomorphometrical study
Cook 2013	The study followed up participants for less than six months
Coomes 2014	The study followed up participants for less than six months
Crespi 2009	The study is not a randomised controlled trial
Eskow 2014	The study followed up participants for less than six months
Fiorellini 2005	The study followed up participants for less than six months
Fotek 2009	The study followed up participants for less than six months
Froum 2002	A histological study
Geurs 2014	A histological and histomorphometrical study
Hauser 2013	The study followed up participants for less than six months
Jung 2013	Unclear whether alveolar ridge preservation was used for participants requiring implant-related prosthodontic treatment. Awaiting clarification from study authors
Kim 2011	The study is not a randomised controlled trial
Kim 2014	The study followed up participants for less than six months
Kotsakis 2014	The study followed up participants for less than six months
Kutkut 2012	The study followed up participants for less than six months
Lekovic 1997	The study is not a randomised controlled trial
Lekovic 1998	The study followed up participants for less than six months
Molly 2008	A histological study

Study	Reason for exclusion
Neiva 2011	The study is not a randomised controlled trial
Nevins 2006	The study followed up participants for less than six months
Nevins 2011	A histological and histomorphometrical study
Oghli 2010	The study followed up participants for less than six months
Pelegriane 2010	There were serious doubts if the study was actually a randomised controlled trial and the authors did not answer back and clarified the doubts
Perelman-Karmon 2012	A histological and histomorphometrical study
Pinho 2006	The study followed up participants for less than six months
Poulas 2013	The study followed up participants for less than six months
Scheyer 2012	A histological study
Schneider 2014	The study only reported the soft tissue volumetric changes
Serino 2003	The study is not a randomised controlled trial
Shakibaie 2013	The study is not a randomised controlled trial
Sisti 2012	The study followed up participants for less than six months
Thalmair 2013	The study only reported the soft tissue volumetric changes
Toloue 2012	The study followed up participants for less than six months
Vance 2004	The study followed up participants for less than six months
Wood 2012	The study followed up participants for less than six months

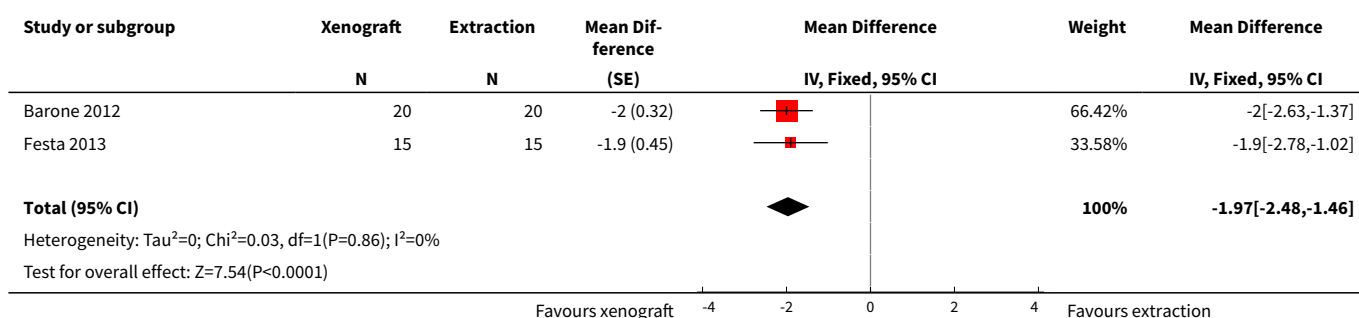
DATA AND ANALYSES

Comparison 1. Alveolar ridge preservation (ARP) versus extraction

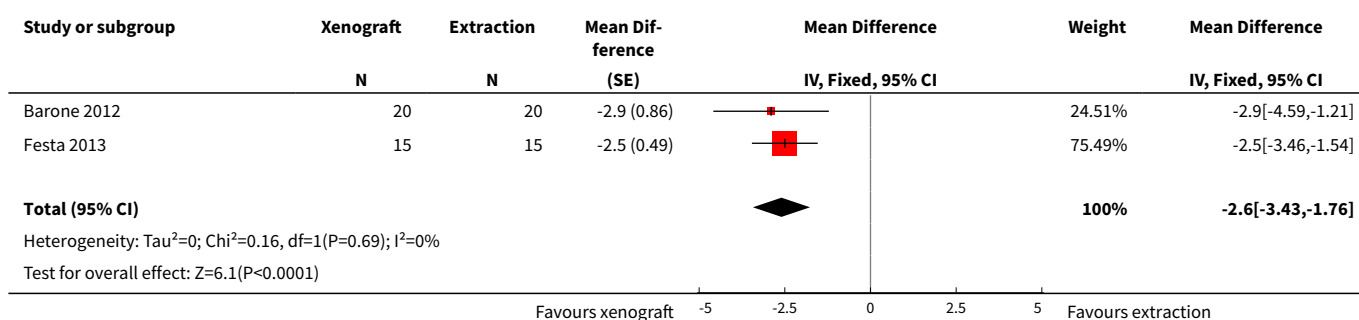
Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Changes in width of alveolar ridge (mm)	2	70	Mean Difference (Fixed, 95% CI)	-1.97 [-2.48, -1.46]
2 Changes in height of alveolar ridge (mm)	2	70	Mean Difference (Fixed, 95% CI)	-2.60 [-3.43, -1.76]
3 Need for additional augmentation prior to implant placement	1	40	Risk Ratio (M-H, Fixed, 95% CI)	1.3 [0.75, 2.24]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
4 Implant failures	1	40	Risk Ratio (M-H, Fixed, 95% CI)	1.0 [0.07, 14.90]
5 Peri-implant marginal bone level changes	1	38	Mean Difference (IV, Fixed, 95% CI)	-0.02 [-0.18, 0.14]
6 Changes in width of alveolar ridge (mm)	1	24	Mean Difference (IV, Fixed, 95% CI)	-1.40 [-2.80, -0.00]
7 Changes in height of alveolar ridge (mm)	1	24	Mean Difference (IV, Fixed, 95% CI)	-2.20 [-3.65, -0.75]

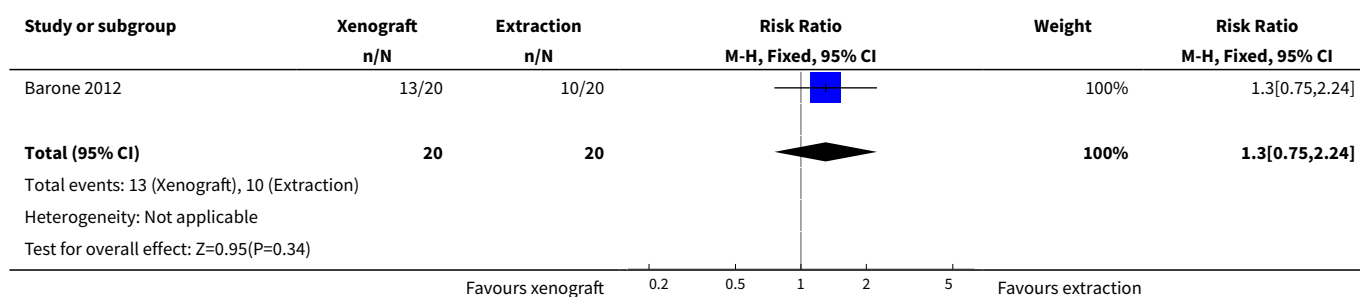
Analysis 1.1. Comparison 1 Alveolar ridge preservation (ARP) versus extraction, Outcome 1 Changes in width of alveolar ridge (mm).



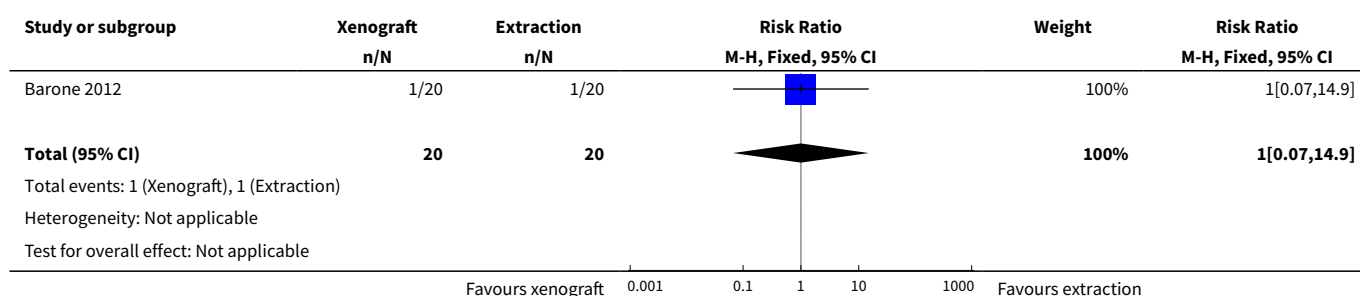
Analysis 1.2. Comparison 1 Alveolar ridge preservation (ARP) versus extraction, Outcome 2 Changes in height of alveolar ridge (mm).



Analysis 1.3. Comparison 1 Alveolar ridge preservation (ARP) versus extraction, Outcome 3 Need for additional augmentation prior to implant placement.



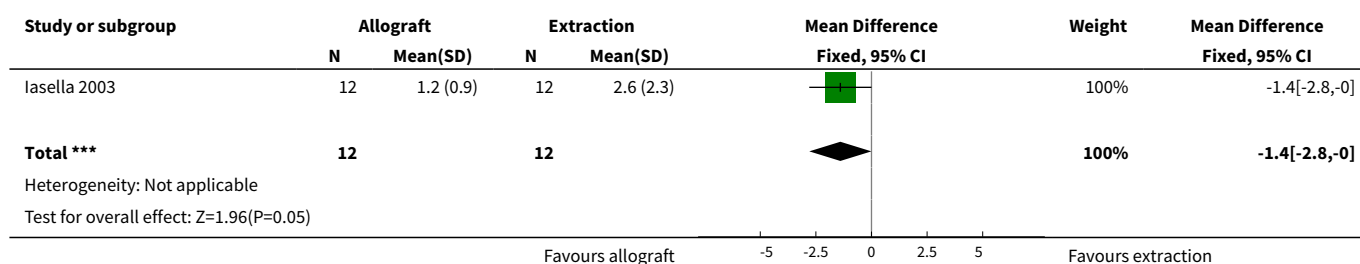
Analysis 1.4. Comparison 1 Alveolar ridge preservation (ARP) versus extraction, Outcome 4 Implant failures.



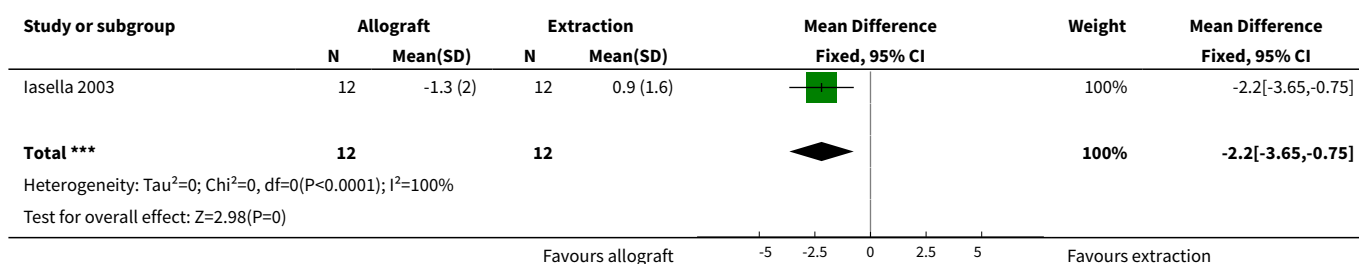
Analysis 1.5. Comparison 1 Alveolar ridge preservation (ARP) versus extraction, Outcome 5 Peri-implant marginal bone level changes.



Analysis 1.6. Comparison 1 Alveolar ridge preservation (ARP) versus extraction, Outcome 6 Changes in width of alveolar ridge (mm).



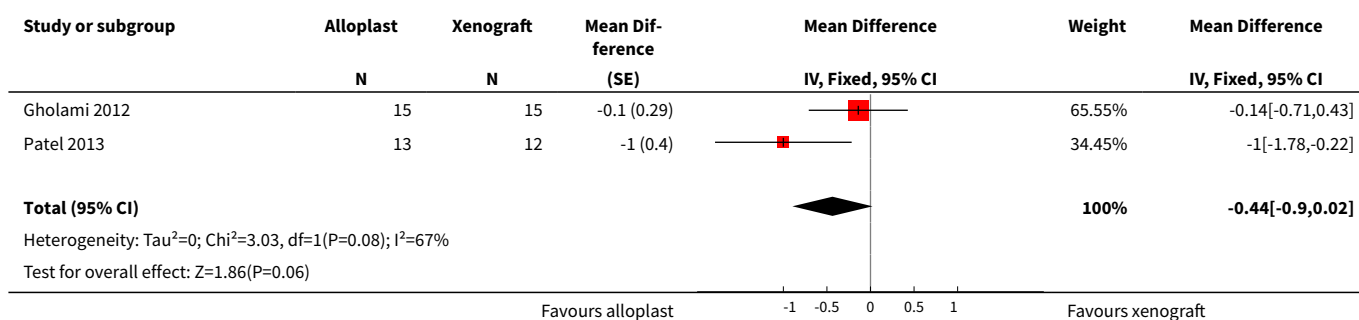
Analysis 1.7. Comparison 1 Alveolar ridge preservation (ARP) versus extraction, Outcome 7 Changes in height of alveolar ridge (mm).



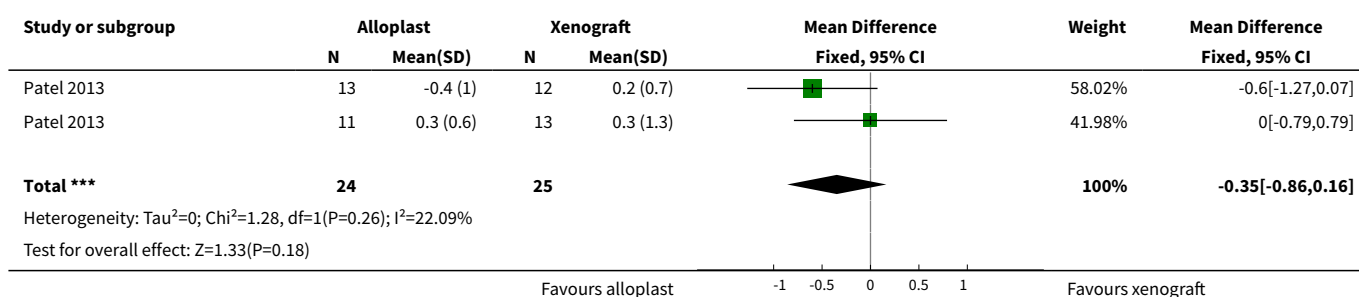
Comparison 2. Different grafting materials for alveolar ridge preservation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Changes in width of alveolar ridge (mm)	2	55	Mean Difference (Fixed, 95% CI)	-0.44 [-0.90, 0.02]
2 Changes in height of alveolar ridge (mm)	1	49	Mean Difference (IV, Fixed, 95% CI)	-0.35 [-0.86, 0.16]
3 Need for additional augmentation prior to implant placement	2	55	Risk Ratio (Fixed, 95% CI)	1.09 [0.65, 1.83]
4 Implant failures	1	25	Risk Ratio (M-H, Fixed, 95% CI)	0.0 [0.0, 0.0]
5 Changes in probing pocket depth at teeth adjacent to the extraction site (mm)	1	25	Mean Difference (IV, Fixed, 95% CI)	-0.3 [-0.61, 0.01]
6 Changes in width of alveolar ridge (mm)	1	20	Mean Difference (IV, Fixed, 95% CI)	0.43 [0.18, 0.68]
7 Changes in height of alveolar ridge (mm)	1	20	Mean Difference (IV, Fixed, 95% CI)	0.38 [0.26, 0.50]
8 Changes in width of alveolar ridge (mm)	1	36	Mean Difference (Fixed, 95% CI)	-0.87 [-1.93, 0.19]
9 Changes in height of alveolar ridge (mm)	1	36	Mean Difference (Fixed, 95% CI)	-0.3 [-1.38, 0.78]
10 Changes in width of alveolar ridge (mm)	1	30	Mean Difference (IV, Fixed, 95% CI)	0.10 [-0.97, 1.17]
11 Changes in height of alveolar ridge (mm)	1	30	Mean Difference (IV, Fixed, 95% CI)	0.1 [-1.22, 1.42]

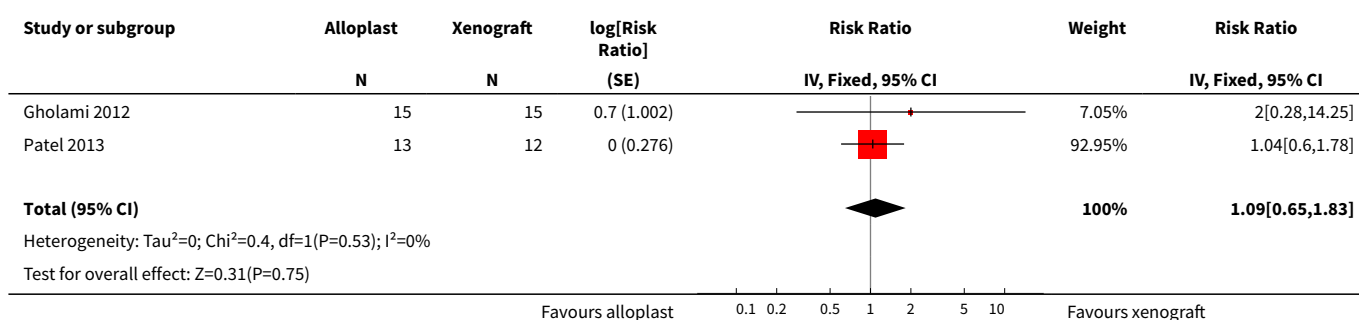
Analysis 2.1. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 1 Changes in width of alveolar ridge (mm).



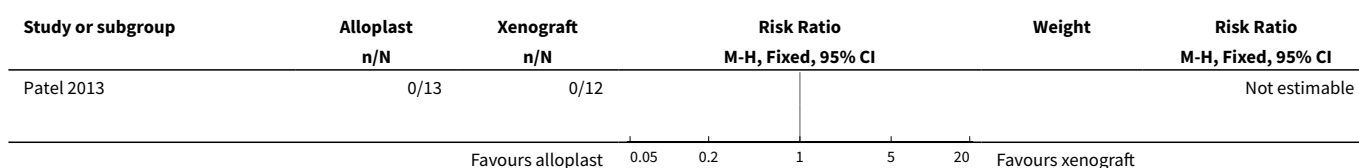
Analysis 2.2. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 2 Changes in height of alveolar ridge (mm).

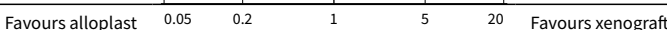


Analysis 2.3. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 3 Need for additional augmentation prior to implant placement.



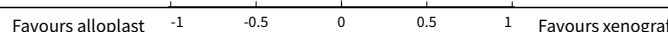


Analysis 2.4. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 4 Implant failures.



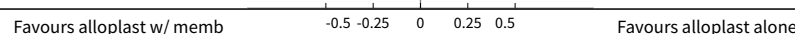


Study or subgroup	Alloplast n/N	Xenograft n/N	Risk Ratio M-H, Fixed, 95% CI	Weight	Risk Ratio M-H, Fixed, 95% CI
Total (95% CI)	13	12			Not estimable
Total events: 0 (Alloplast), 0 (Xenograft)					
Heterogeneity: Not applicable					
Test for overall effect: Not applicable					
					



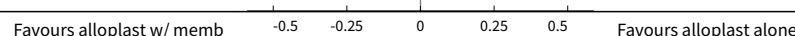
Analysis 2.5. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 5 Changes in probing pocket depth at teeth adjacent to the extraction site (mm).

Study or subgroup	Alloplast		Xenograft		Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
	N	Mean(SD)	N	Mean(SD)			
Patel 2013	13	0 (0.4)	12	0.3 (0.4)		100%	-0.3[-0.61,0.01]
Total ***	13		12			100%	-0.3[-0.61,0.01]
Heterogeneity: Not applicable							
Test for overall effect: Z=1.87(P=0.06)							
							

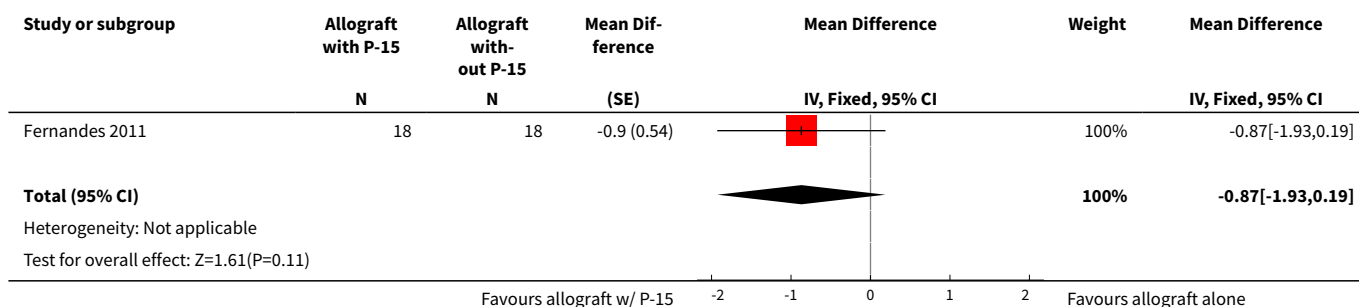
Analysis 2.6. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 6 Changes in width of alveolar ridge (mm).

Study or subgroup	Alloplast w/ membrane		Alloplast w/ o membrane		Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
	N	Mean(SD)	N	Mean(SD)			
Brkovic 2012	11	1.3 (0.3)	9	0.9 (0.3)		100%	0.43[0.18,0.68]
Total ***	11		9			100%	0.43[0.18,0.68]
Heterogeneity: Not applicable							
Test for overall effect: Z=3.32(P=0)							
							

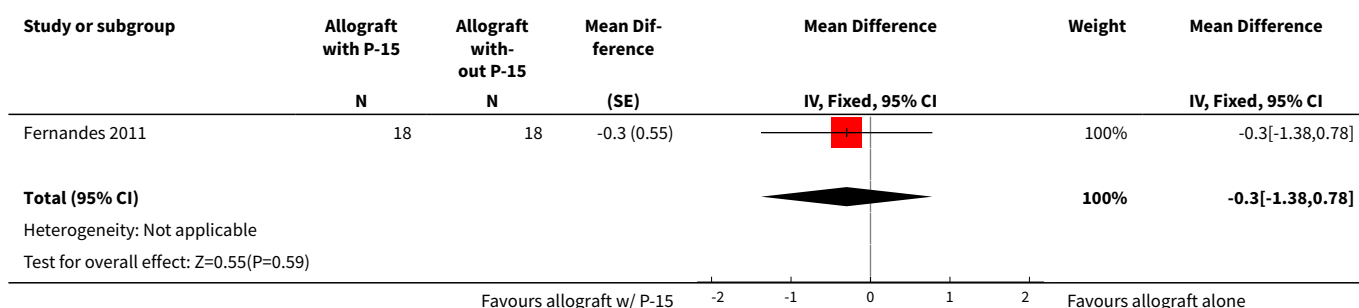
Analysis 2.7. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 7 Changes in height of alveolar ridge (mm).

Study or subgroup	Alloplast w/ membrane		Alloplast w/ o membrane		Mean Difference Fixed, 95% CI	Weight	Mean Difference Fixed, 95% CI
	N	Mean(SD)	N	Mean(SD)			
Brkovic 2012	11	0.5 (0.2)	9	0.1 (0.1)		100%	0.38[0.26,0.5]
Total ***	11		9			100%	0.38[0.26,0.5]
Heterogeneity: Not applicable							
Test for overall effect: Z=5.98(P<0.0001)							
							

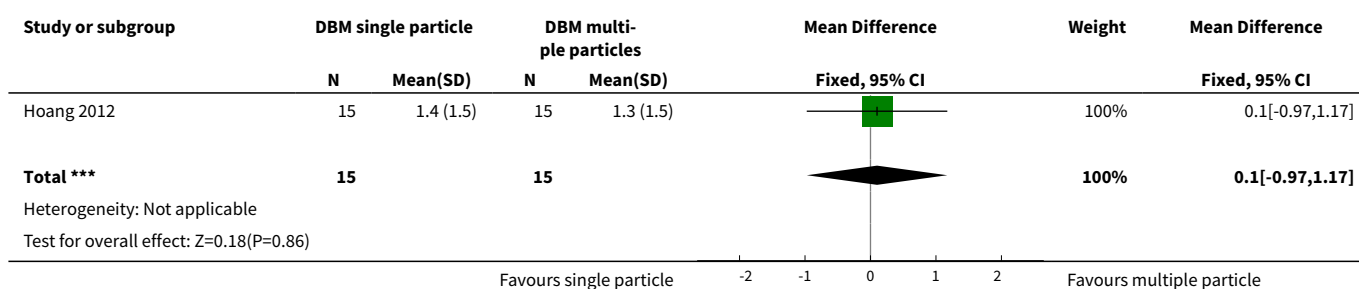
Analysis 2.8. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 8 Changes in width of alveolar ridge (mm).



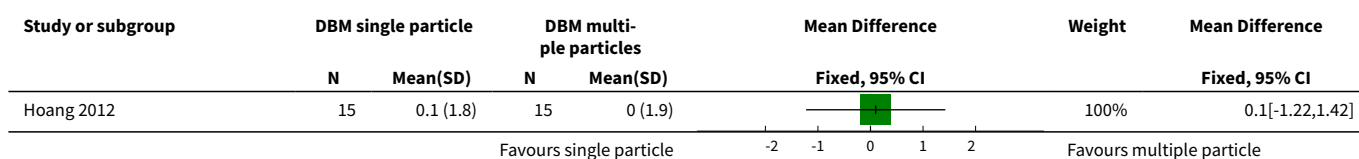
Analysis 2.9. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 9 Changes in height of alveolar ridge (mm).

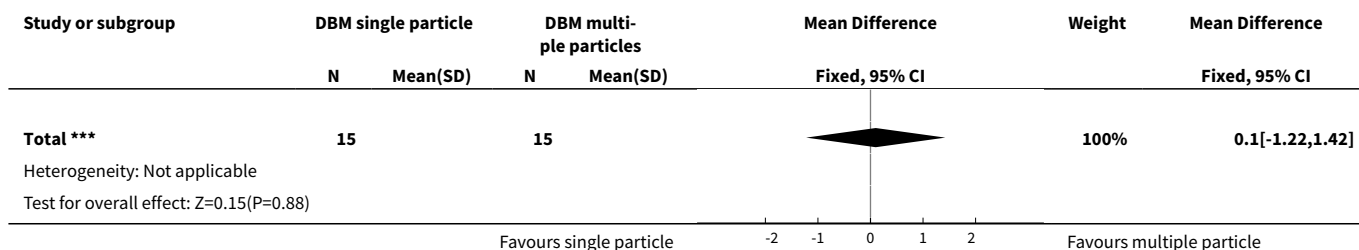


Analysis 2.10. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 10 Changes in width of alveolar ridge (mm).



Analysis 2.11. Comparison 2 Different grafting materials for alveolar ridge preservation, Outcome 11 Changes in height of alveolar ridge (mm).





APPENDICES

Appendix 1. Cochrane Oral Health's Trials Register search strategy

From July 2014, searches of Cochrane Oral Health's Trials Register were conducted using the Cochrane Register of Studies and the search strategy below:

1. (((socket* or ridge* or alveolar) and (preserv* or augment*))) AND (INREGISTER)
2. ((graft* or autograft* or allograft* or "homologous bone" or DFDBA or FDBA or xenograft* or "heterologous bone" or "bovine bone" or "anorganic bone" or alloplast* or hydroxyapatite or ceramic* or polymer* or "calcium sulfate" or "calcium phosphate" or "tricalcium phosphate" or "calcium phosphosilicate" or "bioactive glass" or collagen* or "resorbable membrane*" or "non-resorbale membrane*" or "non resorbable membrane*" or "growth factor*" or "bone morphogenetic protein*" or BMP or rh-BMP)) AND (INREGISTER)
3. (#1 and #2) AND (INREGISTER)

Previous searches of Cochrane Oral Health's Trials Register were undertaken in February 2012 and January 2013 using the Procite software and the search strategy below:

((socket* or ridge* or alveolar) and (preserv* or augment*)) AND (graft* or autograft* or allograft* or "homologous bone" or DFDBA or FDBA or xenograft* or "heterologous bone" or "bovine bone" or "anorganic bone" or alloplast* or hydroxyapatite or ceramic* or polymer* or "calcium sulfate" or "calcium phosphate" or "tricalcium phosphate" or "calcium phosphosilicate" or "bioactive glass" or collagen* or "resorbable membrane*" or "non-resorbale membrane*" or "non resorbable membrane*" or "growth factor*" or "bone morphogenetic protein*" or BMP or rh-BMP))

Appendix 2. Cochrane Central Register of Controlled Trials (CENTRAL) search strategy

- #1 MeSH descriptor ALVEOLAR BONE LOSS this term only
- #2 MeSH descriptor Alveolar Process explode all trees
- #3 ((socket* in All Text or ridge* in All Text or alveolar in All Text) and (preserv* in All Text or augment* in All Text))
- #4 (#1 or #2 or #3)
- #5 MeSH descriptor BONE SUBSTITUTES explode all trees
- #6 ((bone* in All Text near/5 graft* in All Text) or (socket* in All Text near/5 graft* in All Text))
- #7 ("autogenous graft*" in All Text or "autologous graft*" in All Text or autograft* in All Text)
- #8 (allograft* in All Text or "homologous bone" in All Text or DFDBA in All Text or FDBA in All Text)
- #9 (xenograft* in All Text or "heterologous bone" in All Text or "bovine bone" in All Text or "anorganic bovine" in All Text)
- #10 (alloplast* in All Text or hydroxyapatite in All Text or ceramic* in All Text or polymer* in All Text or "calcium sulfate" in All Text or "calcium phosphate" in All Text or "tricalcium phosphate" in All Text or "calcium phosphosilicate" in All Text or "bioactive glass*" in All Text)
- #11 ((resorbable in All Text or non-resorbable in All Text or ("non in All Text and resorbable" in All Text)) and membrane* in All Text)
- #12 (collagen in All Text and (plug* in All Text or fleece* in All Text or barrier* in All Text or seal* in All Text or matri* in All Text)) 639 edit delete
- #13 ("growth factor*" in All Text or "bone morphogenetic protein*" in All Text or BMP in All Text or rh-BMP in All Text)
- #14 (#5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13)
- #15 MeSH descriptor DENTAL IMPLANTS explode all trees
- #16 MeSH descriptor DENTAL IMPLANTATION explode all trees
- #17 (osseointegrated in All Text near/5 implant* in All Text)
- #18 ((implant* in All Text near/5 dent* in All Text) or (implant* in All Text near/5 oral* in All Text))
- #19 ((overdenture* in All Text or crown* in All Text or bridge* in All Text or prosthesis in All Text or restoration* in All Text) and (dental in All Text or oral in All Text) and implant* in All Text)
- #20 "implant supported dental prosthesis" in All Text
- #21 (#15 or #16 or #17 or #18 or #19 or #20)

#22 (#4 and #14 and #21)

Appendix 3. MEDLINE (Ovid) search strategy

1. ALVEOLAR BONE LOSS/
2. exp ALVEOLAR PROCESS/
3. ((socket\$ or ridge\$ or alveolar) and (preserv\$ or augment\$)).mp.
4. or/1-3
5. exp BONE SUBSTITUTES/
6. ((bone\$ adj5 graft\$) or (socket\$ adj5 graft\$)).mp.
7. ("autogenous graft\$" or "autologous graft\$" or autograft\$).mp.
8. (allograft\$ or "homologous bone" or DFDBA or FDBA).mp.
9. (xenograft\$ or "heterologous bone" or "bovine bone" or "anorganic bovine").mp.
10. (alloplast\$ or hydroxyapatite or ceramic\$ or polymer\$ or "calcium sulfate" or "calcium phosphate" or "tricalcium phosphate" or "calcium phosphosilicate" or "bioactive glass\$").mp.
11. ((resorbable or non-resorbable or "non resorbable") and membrane\$).mp.
12. (collagen adj (plug\$ or fleece\$ or barrier\$ or seal\$ or matri\$)).mp.
13. ("growth factor\$" or "bone morphogenetic protein\$" or BMP or rh-BMP).mp.
14. or/5-13
15. exp DENTAL IMPLANTS/
16. exp DENTAL IMPLANTATION/
17. (osseointegrated adj5 implant\$).mp.
18. (implant\$ adj5 (dent\$ or oral\$)).mp.
19. (((overdenture\$ or crown\$ or bridge\$ or prosthesis or restoration\$) adj5 (dental or oral)) and implant\$).mp.
20. ("implant supported dental prosthesis").mp.
21. or/15-20
22. 4 and 14 and 21

The above subject search will be combined with the Cochrane Highly Sensitive Search Strategy (CHSSS) for identifying randomised trials in MEDLINE: sensitivity maximising version (2008 revision) as referenced in Chapter 6.4.11.1 and detailed in box 6.4.c of the *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 (updated March 2011) ([Higgins 2011](#)).

1. randomized controlled trial.pt.
2. controlled clinical trial.pt.
3. randomized.ab.
4. placebo.ab.
5. drug therapy.fs.
6. randomly.ab.
7. trial.ab.
8. groups.ab.
9. or/1-8
10. exp animals/ not humans.sh.
11. 9 not 10

Appendix 4. Embase via Ovid search strategy

1. ALVEOLAR BONE LOSS/
2. ((socket\$ or ridge\$ or alveolar) and (preserv\$ or augment\$)).mp.
3. or/1-2
4. BONE PROSTHESIS/
5. ((bone\$ adj5 graft\$) or (socket\$ adj5 graft\$)).mp.
6. ("autogenous graft\$" or "autologous graft\$" or autograft\$).mp.
7. (allograft\$ or "homologous bone" or DFDBA or FDBA).mp.
8. (xenograft\$ or "heterologous bone" or "bovine bone" or "anorganic bovine").mp.
9. (alloplast\$ or hydroxyapatite or ceramic\$ or polymer\$ or "calcium sulfate" or "calcium phosphate" or "tricalcium phosphate" or "calcium phosphosilicate" or "bioactive glass\$").mp.
10. ((resorbable or non-resorbable or "non resorbable") and membrane\$).mp.
11. (collagen adj (plug\$ or fleece\$ or barrier\$ or seal\$ or matri\$)).mp.
12. ("growth factor\$" or "bone morphogenetic protein\$" or BMP or rh-BMP).mp.
13. or/4-12
14. exp TOOTH IMPLANTATION
15. (osseointegrated adj5 implant\$).mp.
16. (implant\$ adj5 (dent\$ or oral\$)).mp.

17. (((overdenture\$ or crown\$ or bridge\$ or prosthesis or restoration\$) adj5 (dental or oral)) and implant\$).mp.
18. ("implant supported dental prosthesis").mp.
19. or/14-18
20. 3 and 13 and 19

The above subject search was linked to Cochrane Oral Health's filter for identifying RCTs in Embase via Ovid:

1. random\$.ti,ab.
2. factorial\$.ti,ab.
3. (crossover\$ or cross over\$ or cross-over\$).ti,ab.
4. placebo\$.ti,ab.
5. (doubl\$ adj blind\$).ti,ab.
6. (singl\$ adj blind\$).ti,ab.
7. assign\$.ti,ab.
8. allocat\$.ti,ab.
9. volunteer\$.ti,ab.
10. CROSSOVER PROCEDURE.sh.
11. DOUBLE-BLIND PROCEDURE.sh.
12. RANDOMIZED CONTROLLED TRIAL.sh.
13. SINGLE BLIND PROCEDURE.sh.
14. or/1-13
15. ANIMAL/ or NONHUMAN/ or ANIMAL EXPERIMENT/
16. HUMAN/
17. 16 and 15
18. 15 not 17
19. 14 not 18

Appendix 5. LILACS via BIREME Virtual Health Library search strategy

(Mh Alveolar bone loss or Mh Alveolar process or ((socket\$ or ridge\$ or alveolar or alveolo or rebordo or cresta) and (preserv\$ or augment\$ or aument\$))) [Words] and ((Mh Bone substitutes or "bone graft\$" or (socket\$ and graft\$) or (hueso and injerto) or (osso and enxerto) or allograft or aloinjerto or "homologous bone" or DFDBA or FDBA or "autogenous graft\$" or "autologous graft\$" or autograft\$ or xenograft\$ or "bovine bone" or "anorganic bovine" or alloplast\$ or hydroxyapatite or ceramic\$ or polymer\$ or "calcium sulfate" or "calcium phosphate" or "tricalcium phosphate" or "bioactive glass\$" or "resorbable membrane\$" or "non-resorbable membrane\$" or "nonresorbable membrane\$" or collagen\$ or "growth factor" or "bone morphogenetic protein" or BMP) AND (Mh Dental implants or Mh Dental implantation or "osseointegrated implant" or (dent\$ and implant\$) or (oral and implant\$) or overdenture\$ or crown\$ or bridge\$ or prosthesis or restoration)) [Words]

The above subject search was linked to the Brazilian Cochrane Center filter for identifying RCTs in LILACS:

((Pt randomized controlled trial OR Pt controlled clinical trial OR Mh randomized controlled trials OR Mh random allocation OR Mh double-blind method OR Mh single-blind method) AND NOT (Ct animal AND NOT (Ct human and Ct animal)) OR (Pt clinical trial OR Ex E05.318.760.535\$ OR (Tw clin\$ AND (Tw trial\$ OR Tw ensa\$ OR Tw estud\$ OR Tw experim\$ OR Tw investiga\$)) OR ((Tw singl\$ OR Tw simple\$ OR Tw doubl\$ OR Tw doble\$ OR Tw duplo\$ OR Tw trebl\$ OR Tw trip\$) AND (Tw blind\$ OR Tw cego\$ OR Tw ciego\$ OR Tw mask\$ OR Tw mascar\$)) OR Mh placebos OR Tw placebo\$ OR (Tw random\$ OR Tw randon\$ OR Tw casual\$ OR Tw acaso\$ OR Tw azar OR Tw aleator\$) OR Mh research design) AND NOT (Ct animal AND NOT (Ct human and Ct animal)) OR (Ct comparative study OR Ex E05.337\$ OR Mh follow-up studies OR Mh prospective studies OR Tw control\$ OR Tw prospectiv\$ OR Tw volunt\$ OR Tw volunteer\$) AND NOT (Ct animal AND NOT (Ct human and Ct animal))) [Words]

Appendix 6. Web of Science Conference Proceedings search strategy

- # 1 TS=(socket* or ridge* or alveolar)
- # 2 TS=(preserv* or augment*)
- # 3 #1 and #2
- #4 TS=(bone and graft*)
- #5 TS=(socket* and graft*)
- #6 TS=("autogenous graft*" or "autologous graft" or autograft* or allograft* or "homologous bone" or DFDBA or FDBA or xenograft* or "heterologous bone" or "bovine bone" or "anorganic bovine" or alloplast* or hydroxyapatite or ceramic* or polymer* or "calcium sulfate" or "calcium phosphate" or "tricalcium phosphate" or "calcium phosphosilicate" or "bioactive glass")
- #7 TS=((resorbable or non-resorbable or "non resorbable") and membrane*)
- #8 TS=(collagen and (plug* or fleece* or barrier* or seal* or matri*))
- #9 TS=("growth factor*" or "bone morphogenetic protein*" or BMP or rh-BMP)
- #10 #4 or #5 or #6 or #7 or #8 or #9
- #11 TS=((osseointegrated or dent* or oral*) and implant*)

#12 TS=((overdenture* or crown* or bridge* or prosthesis or restoration*) and implant*)

#13 #11 or #12

#14 #3 and #10 and #13

Appendix 7. SCOPUS search strategy

TITLE-ABS-KEY(((socket* OR ridge* OR alveolar) AND (preserv* OR augment*)) AND (graft* OR autograft* OR allograft* OR "homologous bone" OR dfdba OR fdba OR xenograft* OR "heterologous bone" OR "bovine bone" OR "anorganic bone" OR alloplast* OR hydroxyapatite OR ceramic* OR polymer* OR "calcium sulfate" OR "calcium phosphate" OR "tricalcium phosphate" OR "calcium phosphosilicate" OR "bioactive glass" OR collagen* OR "resorbable membrane*" OR "non-resorbale membrane*" OR "non resorbable membrane*" OR "growth factor*" OR "bone morphogenetic protein*" OR bmp OR rh-bmp) AND ("clinical trial" OR random*))

Appendix 8. Proquest Dissertations and Theses search strategy

"alveolar ridge preservation" or "alveolar bone preservation" or "alveolar ridge augmentation" or "alveolar bone augmentation":TI

Appendix 9. OpenGrey search strategy

"alveolar ridge preservation" or "alveolar bone preservation" or "alveolar ridge augmentation" or "alveolar bone augmentation"

Appendix 10. Trials Registry search strategies

metaRegister of Controlled Trials search strategy

"alveolar ridge preservation" or "alveolar bone preservation" or "alveolar ridge augmentation" or "alveolar bone augmentation"

ClinicalTrials.gov search strategy

"alveolar ridge preservation"

"alveolar bone preservation"

"alveolar ridge augmentation"

"alveolar bone augmentation"

WHO International Clinical Trials Registry Platform search strategy

"alveolar ridge preservation"

"alveolar bone preservation"

"alveolar ridge augmentation"

"alveolar bone augmentation"

WHAT'S NEW

Date	Event	Description
9 February 2017	Amended	Minor edits. Reason for exclusion changed for Jung 2013

CONTRIBUTIONS OF AUTHORS

The specific tasks specified for the review authors are as follows:

Task	Who has agreed to undertake the task?
Draft the protocol	Momen A Atieh, Nabeel HM Alsabeeha, Alan GT Payne
Develop a search strategy	Momen A Atieh, Anne Littlewood (Information Specialist, Cochrane Oral Health)
Search for trials	Momen A Atieh, Nabeel HM Alsabeeha, Alan GT Payne
Obtain copies of trials	Momen A Atieh, Nabeel HM Alsabeeha

Select which trials to include	Momen A Atieh, Nabeel HM Alsabeeha, Alan GT Payne
Extract data from trials	Momen A Atieh, Nabeel HM Alsabeeha, Clovis Mariano Faggion Jr
Enter data into RevMan	Momen A Atieh, Nabeel HM Alsabeeha
Carry out the analyses	Momen A Atieh, Nabeel HM Alsabeeha, Clovis Mariano Faggion Jr
Interpret the analysis	Momen A Atieh, Nabeel HM Alsabeeha, Alan GT Payne, Marco Esposito
Draft the final review	Momen A Atieh, Nabeel HM Alsabeeha, Alan GT Payne, Marco Esposito
Update the review	Momen A Atieh, Nabeel HM Alsabeeha, Alan GT Payne, Marco Esposito

DECLARATIONS OF INTEREST

None of the authors has any interests related to this review.

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- Cochrane Oral Health Global Alliance, Other.

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DIFFERENCES BETWEEN PROTOCOL AND REVIEW

In terms of subgroup analysis, the effect of barrier membrane and site of ARP (molar versus non-molar) were omitted in the review due to the lack of adequate number of studies to carry out the subgroup analysis.

Different grafting materials were compared in addition to the type of grafting material versus extraction.

The wording of two outcomes was changed.

- "complications" instead of "post-surgical complications (i.e. discomfort, pain and swelling)" to include both intra- and postoperative complications.

- "Prosthodontic outcomes of rehabilitation" instead of "Prosthodontic outcomes of future prosthodontic rehabilitation".

INDEX TERMS

Medical Subject Headings (MeSH)

*Alveolar Process; *Tooth Socket; Biocompatible Materials [*administration & dosage]; Bone Regeneration; Bone Remodeling; Dental Implantation, Endosseous; Heterografts; Organ Sparing Treatments [*methods]; Randomized Controlled Trials as Topic; Time Factors; Tooth Extraction [*adverse effects] [methods]

MeSH check words

Adult; Humans; Middle Aged