Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment (Review)

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[Intervention review]

Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

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ABSTRACT

Background

Dental implants require sufficient bone to be adequately stabilised. For some patients implant treatment would not be an option without bone augmentation. A variety of materials and surgical techniques are available for bone augmentation.

Objectives

General objectives: To test the null hypothesis of no difference in the success, function, morbidity and patient satisfaction between different bone augmentation techniques for dental implant treatment. Specific objectives: (A) to test whether and when augmentation procedures are necessary; (B) to test which is the most effective augmentation technique for specific clinical indications. Trials were divided into three broad categories according to different indications for the bone augmentation techniques: (1) major vertical or horizontal bone augmentation or both; (2) implants placed in extraction sockets; (3) fenestrated implants.

Search strategy

The Cochrane Oral Health Group's Trials Register, the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE and EMBASE were searched. Several dental journals were handsearched. The bibliographies of review articles were checked, and personal references were searched. More than 55 implant manufacturing companies were also contacted. Last electronic search was conducted on 9th January 2008.

Selection criteria

Randomised controlled trials (RCTs) of different techniques and materials for augmenting bone for implant treatment reporting the outcome of implant therapy at least to abutment connection.

Data collection and analysis

Screening of eligible studies, assessment of the methodological quality of the trials and data extraction were conducted independently and in duplicate. Authors were contacted for any missing information. Results were expressed as random-effects models using mean

differences for continuous outcomes and odd ratios for dichotomous outcomes with 95% confidence intervals. The statistical unit of the analysis was the patient.

Main results

Seventeen RCTs out of 40 potentially eligible trials reporting the outcome of 455 patients were suitable for inclusion. Since different techniques were evaluated in different trials, no meta-analysis could be performed. Ten trials evaluated different techniques for vertical or horizontal bone augmentation or both. Four trials evaluated different techniques of bone grafting for implants placed in extraction sockets and three trials evaluated different techniques to treat bone dehiscence or fenestrations around implants.

Authors' conclusions

Major bone grafting procedures of resorbed mandibles may not be justified. Bone substitutes (Bio-Oss or Cerasorb) may replace autogenous bone for sinus lift procedures of atrophic maxillary sinuses. Various techniques can augment bone horizontally and vertically, but it is unclear which is the most efficient. It is unclear whether augmentation procedures at immediate single implants placed in fresh extraction sockets are needed, and which is the most effective augmentation procedure, however, sites treated with barrier plus Bio-Oss showed a higher position of the gingival margin when compared to sites treated with barriers alone. Non-resorbable barriers at fenestrated implants regenerated more bone than no barriers, however it remains unclear whether such bone is of benefit to the patient. It is unclear which is the most effective technique for augmenting bone around fenestrated implants. Bone morphogenetic proteins may enhance bone formation around implants grafted with Bio-Oss. Titanium may be preferable to resorbable screws to fixate onlay bone grafts. The use of particulate autogenous bone from intraoral locations, also taken with dedicated aspirators, might be associated with an increased risk of infective complications. These findings are based on few trials including few patients, sometimes having short follow up, and often being judged to be at high risk of bias.

PLAIN LANGUAGE SUMMARY

Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Some patients have insufficient bone to place dental implants but there are many surgical techniques to increase the bone volume making implant treatment possible.

Short implants are more effective and cause less complications than conventional implants placed in thin lower jaws (mandibles) augmented with bone from the hip. Bone substitutes (Bio-Oss or Cerasorb) might be used instead of self generated (autogenous) bone graft to fill large upper jaw (maxillary) sinuses. Bone can be regenerated in a vertical direction using various techniques, but it is unclear which technique is preferable. There is not enough evidence supporting or refusing the need of augmentation procedures when single extracted teeth are immediately replaced with dental implants, nor is it known whether any augmentation procedure is better than the others. There is not enough evidence to demonstrate superiority of any particular technique for regenerating bone around exposed implants, however the use of bone morphogenetic proteins may enhance bone formation.

BACKGROUND

Missing teeth and supporting oral tissues have traditionally been replaced with dentures or bridges permitting restoration of chewing function, speech, and aesthetics. Dental implants offer an alternative. These implants are inserted into the jawbones to support a dental prosthesis and are retained because of the intimacy of bone growth on to their surface. This direct structural and functional connection between living bone and implant surface, termed osseointegration, was first described by Brånemark 1977 and has undoubtedly been one of the most significant scientific breakthroughs in dentistry over the past 30 years.

Teeth may have been lost through dental disease or trauma or they may be congenitally absent. In addition, teeth may be lost as part of a surgical procedure to resect part of a jaw because of pathology such as cancer. Sometimes, there is a lack of supporting bone in addition to the absent teeth due to atrophy, trauma, failure to develop or surgical resection. Dental implants can only be placed if there is sufficient bone to adequately stabilize them, and bone augmentation permits implant treatment that would otherwise not be an option for some of these patients. Bone augmentation procedures may be carried out some time prior to implant placement (two-stage procedure), or at the same time as implant placement (one-stage procedure), using various materials and techniques. When carried out prior to placement, this necessitates an additional surgical episode and then the area is left to heal for a period of time before the implants are placed.

There are different indications, numerous alternative techniques, and various 'biologically active' agents and biomaterials currently used to augment bone. Some materials used to augment the bone volume may be described as follows.

- Autogenous bone grafts

These are bone grafts taken from an adjacent or remote site in the same patient and used to build up the deficient area and are considered to be the material of choice (Palmer 2000) i.e. the 'gold standard'. They are biologically compatible as they are from the same patient and provide a scaffold into which new bone may grow. Sites from within the mouth may be used for relatively small graft requirements or sites such as the hip bone (iliac crest) for larger bone volumes. All of these require surgery at a second site and therefore the morbidity must be considered. Of the many possible sites, each has its own merits and disadvantages. Sometimes it may be possible to recycle bone taken from the site of implant placement when preparing the hole by using a special filter to collect bone particles that would otherwise be lost and use this to build up a deficient area.

- Allografts

These are bone grafts harvested from cadavers and processed by methods such as freezing or demineralising and freezing. The grafts are then sterilised and supplied by specially licensed tissue banks in several convenient ways such as bone particles or large blocks. They are resorbable. There may be some concern regarding their absolute non-infectivity.

- Xenografts

These are graft materials derived from animals such as cow or coral. Bio-Oss (Geistlich Pharmaceutical, Wolhusen, Switzerland) is bovine bone that is processed to completely remove the organic component. Coral has been advocated because of a pore size suitable for permitting bone ingrowth. There has been concern regarding the absolute non-infectivity of bovine-derived materials although this has been disputed (Wenz 2001).

- Alloplastic graft materials

These synthetic bone substitutes include calcium phosphates and bioactive glasses. Alloplasts provide a physical framework for bone ingrowth. Some surgeons use these materials in combination with

autogenous bone grafts. These materials resorb completely or to some degree or not at all with time.

- Barrier membranes for guided bone regeneration (GBR)

This technique uses special barrier membranes to protect defects from the ingrowth of soft tissue cells so that bone progenitor cells may develop bone uninhibited. Ingrowth of soft tissue may disturb or totally prevent osteogenesis in a defect or wound. Examples of membrane are expanded polytetrafluoroethylene (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA), porcine collagen (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland), and polyglactin (Vicryl, polyglactin 910, Ethicon, Somerville, NJ, USA). Membranes can be resorbable or non-resorbable.

- Bone promoting proteins (BMPs) and platelet rich plasma (PRP)

BMPs are a family of proteins naturally present in bone and responsible for activation of bone development (Valentin-Opran 2002). BMPs may encourage bone formation. They may be incorporated into any of the above graft types. Growth factors and PRP are used to promote bone formation.

Some surgical techniques used to augment bone volume include.

- Onlay grafting

The graft material is laid over the defective area to increase width or height or both of the alveolar jawbone. The host bed is usually perforated with a small bur to encourage the formation of a blood clot between the graft and recipient bed. The graft is immobilised with screws or plates or with dental implants (Kahnberg 1989).

- Inlay grafting

One type of inlay graft is a sinus lift or sinus elevation procedure in which graft material is inserted inside the floor of the maxillary sinus to increase bone volume (Tatum 1986; Tong 1998). Also the floor of the nose may be grafted (Higuchi 1992). In another type of inlay grafting procedure, a section of jawbone is surgically separated and graft material sandwiched between two sections. Le Fort I osteotomy and interpositional bone graft procedure (Obwegeser 1969) has been used for patients requiring implant treatment (Keller 1992).

- Ridge expansion

The alveolar ridge is split longitudinally and parted to widen it and allow placement of an implant or graft material or both in the void. The longitudinal split can be limited by placing transverse cuts in the bone.

- Distraction osteogenesis

The principals of distraction osteogenesis in which a gradual, controlled displacement of a surgically prepared fracture is used to increase bone volume, are not new but have recently been introduced into implant surgery to increase alveolar bone volume (Chin 1999). The gap created during the displacement of the bone segment fills with immature non-calcified bone that matures during a subsequent fixation period. The associated soft tissues are also expanded as the bone segment is transported.

- Zygomatic implants

A long implant may be placed to the upper jaw passing through the sinus into the body of the zygomatic bone (Brånemark 2004). This surgical technique is an alternative to bone augmentation in those patients with insufficient bone for placement of the usual type of dental implant. This comparison is not included in this review as the zygoma implant technique is not a technique for bone augmentation but is evaluated in another Cochrane review (Esposito 2005).

Each type of augmentation material may be used in combination with a variety of different surgical techniques, so many permutations of treatment are possible and the situation is rather complicated. In addition new techniques and 'active agents' are continuously introduced in the clinical practice. Particular treatment options have strong proponents with surgeons claiming that a particular material or technique offers improved implant success. This review aims to compare different bone augmentation techniques against each other. The effect of the timing of the augmentation is also of interest to this review. Since we were aware that the literature for the present systematic review was scarce, we decided to make a comprehensive review having in mind that in the future this review could be divided into clearly focussed reviews dealing with specific aspects, indications or techniques for augmenting bone. For the same reasons we also decided not to formulate any hypotheses to be investigated for subgroup analyses since no meta-analysis was expected. However, this will be done in future updates of this review.

Several reviews have been published on the topic. Among the older ones, two are worth mentioning (Tolman 1995; Esposito 1998), though their findings were not based on the most reliable clinical trials, therefore the information presented has to be interpreted with a great deal of caution. A few other systematic reviews were published thereafter (Fiorellini 2003; Wallace 2003; Del Fabbro 2004; Emmerich 2005), however, these have not been conducted in a systematic way according to the Cochrane criteria.

OBJECTIVES

General objectives

To test the null hypothesis of no difference in the success, function, side effect and patient satisfaction between different bone augmentation techniques or no bone augmentation for dental implant treatment, against the alternative hypothesis of a difference.

Specific objectives

(A) To test whether and when augmentation procedures are necessary.
(B) To test which is the most effective augmentation technique for specific clinical indications.
Augmentation procedures were divided into three broad categories of clinical indication.
(1) Different techniques for vertical or horizontal bone augmentation or both (major augmentation procedures).
(2) Different techniques to treat implants placed in extraction sockets (minor augmentation procedures).
(3) Different techniques to treat bone dehiscences or fenestrations around implants (minor augmentation procedures).

METHODS

Criteria for considering studies for this review

Types of studies

Randomised controlled clinical trials (RCTs) including split-mouth studies and preference RCTs. Preference RCTs are those trials in which patients not having a preference for the tested interventions are randomised, whereas those patients who have a definitive preference are allocated to their preferred intervention group.

Types of participants

Patients with missing teeth who may require alveolar bone augmentation prior to or during dental implant placement procedures. The treatment of perimplant defects caused by perimplantitis is analysed in another Cochrane review (Esposito 2008).

Types of interventions

Any bone augmentation technique, active agent (such as bone morphogenetic proteins, platelet rich plasma) or biomaterials used in relation with osseointegrated, root-formed dental implants. For trials to be considered in this review, implants have to be placed and the outcome of the implant therapy has to be reported at least at the endpoint of the abutment connection procedure. The following time points were considered: abutment connection, 1, 3 and 5 years after loading.

Types of outcome measures

Outcome measures included.

- Prosthesis failure: planned prosthesis which could not be placed due to implant failure(s) and loss of the prosthesis secondary to implant failure(s).
- Implant failure: implant mobility and removal of stable implants dictated by progressive marginal bone loss or infection (biological failures). Biological failures were grouped as early (failure to establish osseointegration) and late failures (failure to maintain the established osseointegration). Failures that occurred before prosthesis placement were considered early failures. Implant mobility could be assessed manually or with instruments such as Periotest (Siemens AG, Benshein, Germany) or resonance frequency (Osstell, Integration Diagnostics, Göteborg, Sweden).
- Augmentation procedure failure: failure of the augmentation procedure (i.e. of the bone graft or the guided bone regeneration (GBR) procedure, etc.) not affecting the success of the implant.
- Major complications at treated/augmented sites (e.g. infection, nerve injury, haemorrhage, etc.).
- Major complications at bone donor sites (e.g. nerve injury, gait disturbance, infection, etc.).
- Patient satisfaction including aesthetics.
- Patient preference including aesthetics (only in split-mouth trials).
- Bone gain vertically or horizontally or both expressed in mm or percentage, including bone level changes over time.
- Aesthetics evaluated by dentist.
- Duration of the treatment time starting from the first intervention to the functional loading of the implants.
- Treatment costs.

Trials evaluating only histological outcomes were not considered in this review.

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 (OVID) but revised appropriately for each database. The search strategy used a combination of controlled vocabulary and free text terms and was run with phases 1 and 2 of the Cochrane Sensitive Search Strategy for Randomised Controlled Trials (RCTs) as published in Appendix 5b.2 of the *Cochrane Handbook for Systematic Reviews of Interventions* 4.2.6 (updated September 2006) (Higgins 2006) and amended by the Cochrane Oral Health Group. Details are provided in Appendix 1 and Appendix 2.

Searched databases

The Cochrane Oral Health Group's Trials Register (9th January 2008).
The Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2007, Issue 4).
MEDLINE (1966 to 9th January 2008).
EMBASE (1980 to 9th January 2008).
The most recent electronic search was undertaken on 9th January 2008.

Language

There were no language restrictions.

Unpublished studies

We wrote to all the authors of the identified RCTs, we checked the bibliographies of all identified RCTs and relevant review articles, and we used personal contacts in an attempt to identify unpublished or ongoing RCTs. In the first version of this review we also wrote to more than 55 oral implant manufacturers and we requested information on trials through an Internet discussion group (implantology@yahoogroups.com), however we discontinued this due to poor yield.

Handsearching

Details of the journals being handsearched by the Cochrane Oral Health Group's ongoing programme are given on the website:http://www.ohg.cochrane.org/.
The following journals have been identified as being potentially important to be handsearched for this review: *British Journal of Oral and Maxillofacial Surgery, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, European Journal of Oral Implantology, Implant Dentistry, International Journal of Oral and Maxillofacial Implants, International Journal of Oral and Maxillofacial Surgery, International Journal of Periodontics and Restorative Dentistry, International Journal of Prosthodontics, Journal of Clinical Periodontology, Journal of Dental Research, Journal of Oral Implantology, Journal of Oral and Maxillofacial Surgery, Journal of Periodontology,* and *Journal of Prosthetic Dentistry.* Where these have not already been searched as part of the Cochrane Journal Handsearching Programme, the journals were handsearched by one review author up to the month in which the last electronic search was undertaken.

Data collection and analysis

Study selection

The titles and abstracts (when available) of all reports identified through the electronic searches were scanned independently by two review authors. For studies appearing to meet the inclusion criteria, or for which there were insufficient data in the title and abstract to make a clear decision, the full report was obtained. The full reports obtained from all the electronic and other methods of searching were assessed independently by two review authors to establish whether the studies met the inclusion criteria or not. Disagreements were resolved by discussion. Where resolution was not possible, a third review author was consulted. All studies meeting the inclusion criteria then underwent validity assessment and data extraction. Studies rejected at this or subsequent stages were recorded in the table of excluded studies, and reasons for exclusion recorded.

Quality assessment

The quality assessment of the included trials was undertaken independently and in duplicate by two review authors as part of the data extraction process. In the case that the paper to be assessed had one or more review authors in the authors list, it was independently evaluated only by those review authors not involved in the trials.
Three main quality criteria were examined.
(1) Allocation concealment, recorded as:
(A) Adequate
(B) Unclear
(C) Inadequate as described in the *Cochrane Handbook for Systematic Reviews of Interventions* 4.2.6 (Higgins 2006).
(2) Treatment blind to outcome assessors, recorded as:
(A) Yes
(B) No
(C) Unclear
(D) Not possible.
(3) Completeness of follow up (is there a clear explanation for withdrawals and drop outs in each treatment group?) assessed as:
(A) Yes. In the case that clear explanations for drop outs were given, a further subjective evaluation of the risk of bias assessing the reasons for the drop out was made.
(B) No.
After taking into account the additional information provided by the authors of the trials, studies were grouped into the following categories.
(A) Low risk of bias (plausible bias unlikely to seriously alter the results) if all criteria were met.
(B) High risk of bias (plausible bias that seriously weakens confidence in the results) if one or more criteria were not met as described in the *Cochrane Handbook for Systematic Reviews of Interventions* 4.2.6, section 6.7.
Preference randomised controlled trials were always considered as being at high risk of bias.
Further quality assessment was carried out to assess sample size calculations, definition of exclusion/inclusion criteria, and comparability of control and test groups at entry. The quality assessment criteria were pilot tested using several articles.

Data extraction

Data were extracted independently by two review authors using specially designed data extraction forms. The data extraction forms were piloted on several papers and modified as required before use. Any disagreement was discussed and a third review author consulted where necessary. All authors were contacted for clarification or missing information. Data were excluded until further clarification was available if agreement could not be reached.
For each trial the following data were recorded.

- Year of publication, country of origin and source of study funding.
- Details of the participants including demographic characteristics, source of recruitment and criteria for inclusion.
- Details of the type of intervention.
- Details of the outcomes reported, including method of assessment, and time intervals.

Data synthesis

For dichotomous outcomes, the estimate of effect of an intervention was expressed as odds ratios (OR) together with 95% confidence intervals (CIs). For continuous outcomes, mean differences and standard deviations were used to summarise the data for each group using mean differences and 95% CIs. The statistical unit was the patient and not the augmentation procedure or the implants.
Only if there were studies of similar comparisons reporting the same outcome measures was meta-analysis to be attempted. Odds ratios were to be combined for dichotomous data, and mean differences for continuous data, using random-effects models. Data from split-mouth studies were to be combined with data from parallel group trials with the method outlined by Elbourne (Elbourne 2002), using the generic inverse variance method in RevMan.
The significance of any discrepancies in the estimates of the treatment effects from the different trials was to be assessed by means of Cochran's test for heterogeneity and the I^2 statistic, which describes the percentage total variation across studies that is due to heterogeneity rather than chance. Clinical heterogeneity was to be assessed by examining the types of participants and interventions for all outcomes in each study. It was planned to undertake sensitivity analyses to examine the effect of the study quality assessment on the overall estimates of effect. In addition, the effect of including unpublished literature on the review's findings was also to be examined.
As there were no studies comparing similar interventions, none of the meta-analysis procedures described above were conducted.

RESULTS

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies; Characteristics of ongoing studies.

See Characteristics of included studies table.
See Characteristics of excluded studies table.

Characteristics of the trial setting and investigators

- Of the 40 potentially eligible trials (Dahlin 1991; Gher 1994; Zitzmann 1997; Froum 1998; Schlegel 1998; Majzoub 1999; Carpio 2000; Wannfors 2000; Antoun 2001; Tawil 2001; Friedmann 2002; Hallman 2002; Norton 2002; Jung 2003; Prosper 2003; Stellingsma 2003; Chiapasco 2004; Cornelini 2004; Barone 2005; Bettega 2005; Boyne 2005; Chen 2005a; Chen 2005b; Fiorellini 2005; Kassolis 2005; Raghoebar 2005; Schortinghuis 2005; Steigmann 2005; Szabó 2005; Froum 2006; Raghoebar 2006; Suba 2006; Chen 2007; Chiapasco 2007; Consolo 2007; Mangano 2007; Meijndert 2007; Merli 2007; Roccuzzo 2007; Schaaf 2008), 23 were excluded for various reasons such as: problems with study design (Gher 1994; Zitzmann 1997; Froum 1998; Schlegel 1998; Tawil 2001; Norton 2002); they reported only histological outcomes and did not report any implant related outcomes (Antoun 2001; Friedmann 2002; Barone 2005; Bettega 2005; Fiorellini 2005; Kassolis 2005; Schortinghuis 2005; Steigmann 2005; Froum 2006; Suba 2006; Consolo 2007; Roccuzzo 2007; Schaaf 2008); we were unable to use any of the data presented (Majzoub 1999; Prosper 2003; Boyne 2005); and one study because it was not a randomised controlled trial (RCT) (Mangano 2007).
- Of the 17 included trials, four were conducted in The Netherlands (Stellingsma 2003; Raghoebar 2005; Raghoebar 2006; Meijndert 2007), four in Italy (Chiapasco 2004; Cornelini 2004; Chiapasco 2007; Merli 2007), three in Sweden (Dahlin 1991; Wannfors 2000; Hallman 2002), three in Australia (Chen 2005a; Chen 2005b; Chen 2007), one in the USA (Carpio 2000), one in Switzerland (Jung 2003) and one was a multicentre trial conducted in four European centres (Belgium, Hungary, UK and Italy) (Szabó 2005).
- Eleven trials had a parallel group study design and six had a split-mouth design (Dahlin 1991; Hallman 2002; Jung 2003; Raghoebar 2005; Szabó 2005; Raghoebar 2006). One of the split-mouth trials (Hallman 2002) had a third intervention group composed of those patients who refused to undergo autogenous bone harvesting and were treated with a xenograft (preference trial). Four of the patients of the latter group were treated bilaterally and six monolaterally; in order to be able to analyse the data we randomly selected one site for those patients treated bilaterally. Another split-mouth trial was designed as a placebo-controlled RCT (Jung 2003). Data of two distinct RCTs were presented together as if it was a single RCT in one publication. However the authors clarified this, and we presented the trials as two separate RCTs (Chen 2005a; Chen 2005b).

- For 10 trials it was declared that support was received from industry directly involved in the product being tested also in the form of free material (Dahlin 1991; Carpio 2000; Hallman 2002; Stellingsma 2003; Chen 2005a; Chen 2005b; Raghoebar 2005; Szabó 2005; Raghoebar 2006; Meijndert 2007). One trial received support from the implant manufacturer, however the trial was not designed to test the implants, but the augmentation techniques (Merli 2007). The authors of five trials declared that no support was received from commercial parties whose products were being tested in the trials (Jung 2003; Chiapasco 2004; Cornelini 2004; Chen 2007; Chiapasco 2007). One trial (Jung 2003) tested a product which was internally produced.
- Twelve trials were conducted at university or specialist dental clinics. Five trials were conducted in private practices (Cornelini 2004; Chen 2005a; Chen 2005b; Chen 2007; Merli 2007). One of the centres (Brugge, Belgium) of the multicentre trial was also a private practice (Szabó 2005).
- All studies included only adults.

Characteristics of the interventions

The following interventions were tested.

Different techniques for vertical or horizontal bone augmentation or both (major augmentation procedures)

Is the augmentation procedure necessary? (one trial)

- One trial addressed the issue of which is the best treatment alternative to provide an overdenture to patients with an extremely resorbed mandible, i.e. symphyseal height 6 to 12 mm measured on lateral radiographs (Stellingsma 2003). Three procedures were tested: (1) installation of four short implants (8 or 11 mm) left to heal for 3 months; (2) mandibular augmentation with an autologous bone graft from the iliac crest and (3) transmandibular Bosker implants. We were only interested in the former two procedures. Mandibles were augmented under general anaesthesia using the interpositional technique. In brief, the mandible was sectioned in the interforaminal area, and a bone block taken from the anterior ilium was positioned between the two segments which were stabilized with osteosynthesis wires and left to heal for 3 months. The wires were then removed, and four 13 to 18 mm long implants were placed and left to heal for an additional 3 months. Patients were not allowed to wear their dentures for the entire healing period (about 6 months). The short implants used were Twin Plus IMZ implants (Friatec, Mannheim, Germany), whereas the augmented mandibles were treated with four specially designed IMZ apical screw implants. No explanation was given why two different types of implants were used. Patients were rehabilitated with overdentures supported by an egg-shaped triple bar with a Dolder-clip retention system. The bars did not have cantilever extensions.

Which is the most effective augmentation technique? (eight trials)

- One-stage sinus lift with monocortical iliac bone blocks fixed usually with two implants left to heal for 6 months versus two-stage sinus lift with particulate bone from the iliac crest left to heal for 6 months and then usually two implants were inserted into the healed graft and left to heal for an additional 6 months (Wannfors 2000). All the augmentation procedures were performed under general anaesthesia. All implants were turned titanium self tapping (Nobel Biocare, Göteborg, Sweden) and were rehabilitated with screw-retained cross-arch implant supported prostheses.
- One-stage sinus lift with autogenous particulate bone from the mandibular ramus versus one-stage sinus lift with a mixture of 80% of bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) and 20% of particulate bone from the mandibular ramus, left to heal for 6 months in a split-mouth trial (Hallman 2002). A fibrin glue (Tisseel Duo Quick, Immuno, Wien, Austria) was added to the grafts after thrombin (Thrombin, Immuno, Wien, Austria) for both interventions. A third treatment group was composed of patients who refused to provide autogenous bone but accepted the treatment with a one-stage sinus lift with 100% of bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland). For the latter group a resorbable porcine-derived collagen barrier (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland) was used to cover the defect of sinus and the healing time was prolonged to an average of 8.5 months (range: 8 to 9.5). Procedures were performed under local anaesthesia and oral sedation. All implants were turned titanium self tapping (Nobel Biocare, Göteborg, Sweden): Mark II implant type was used in the former two groups and Mark III in the latter. All patients were rehabilitated with screw-retained metal-ceramic fixed prostheses.
- Two-stage sinus lift with autogenous particulate bone from the iliac crest versus two-stage sinus lift with 1.5 to 2 g beta-tricalcium phosphate (Cerasorb, Curasan AG, Kleinostheim, Germany) left to heal for 6 months (Szabó 2005). In 10 of the 20 patients the alveolar crest was also widened with cortical bone blocks fixed with microscrews. No membranes were used to cover the bone. All the augmentation procedures were performed under general anaesthesia. Patients were instructed not to wear their upper dentures for 30 days. In 16 patients Ankylos (Degussa, Friadent, Germany) implants were used, whereas in four patients Protetim (Hungary) implants were used. The authors did not provide any explana-

tion for using two different implant systems. Two implants were placed in each augmented sinus.

- Two-stage sinus lift with autogenous blocks and particulate bone together with buccal onlays monocortico-cancellous bone grafts, to reconstruct the width of the maxilla, fixed with titanium screws harvested from the iliac crest with or without platelet-rich plasma (PRP) left to heal for 3 months in a split-mouth trial (Raghoebar 2005). Barriers were not used. PRP was made using the Platelet Concentration Collection System kit (PCCS kit, 3i Implant Innovations Inc. Palm Beach Gardens, FL, USA). 54 ml of blood were mixed with 6 ml of anticoagulant (citrate dextrose) and processed with the platelet concentration system. To promote the release of growth factors from the platelets, 10% calcium chloride solution and the patient's serum, as a source of autologous thrombin, were added before actual reconstruction of the defect with the bone graft. The resulting gel was mixed with the bone graft and some gel was applied at the closure of the wound at the side treated with PRP. Three implants were inserted into the healed graft of each side and were left to heal for additional 6 months. All the augmentation procedures were performed under general anaesthesia. Surgical templates were used to optimise implant insertion. All implants were turned titanium self tapping (Nobel Biocare, Göteborg, Sweden) and were rehabilitated with two implant supported prostheses.

- Two-stage buccal onlays monocortico-cancellous bone grafts fixed with two titanium (diameter 1.5 mm, Martin Medizin Technik, Tuttlingen, Germany) or resorbable poly (D,L-lactide) acid (PDLLA, diameter 2.1 mm, Resorb X, Martin Medizin Technik) screws in a split-mouth trial, to reconstruct the width of the maxilla (Raghoebar 2006). Grafts were covered with resorbable barriers (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland). Grafts were harvested from the iliac crest and bilateral sinus lifts were performed at the same time with autogenous blocks and particulate bone. After 3 months, implants were inserted into the healed graft of each side and were left to heal for an additional 6 months. All the augmentation procedures were performed under general anaesthesia. Surgical templates were used to optimise implant insertion. All implants were turned titanium self tapping (Nobel Biocare, Göteborg, Sweden) and were rehabilitated with implant supported overdentures.

- Vertical guided bone regeneration (GBR) with non-resorbable titanium reinforced ePTFE barriers (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) supported by particulate autogenous bone harvested from the mandibular ramus and when the bone was not sufficient also from the chin (two patients) versus vertical distraction osteogenesis (Chiapasco 2004). Two different vertical GBR procedures were used: six patients were treated with a one-stage approach (implants were inserted protruding 2 to 7 mm from the bone level and the augmentation procedure was performed on the same occasion; the abutment connection was performed after 6/7 months) whereas five patients were treated with a two-stage approach (first the bone at site was augmented and after healing of 6/7 months the implants were placed and left submerged for an additional 3 to 5 months). The two-stage approach was used when the risk of insufficient primary implant stability of implants was subjectively expected. With the two-stage approach one or two titanium miniscrews were used as additional support for the titanium reinforced barriers. All barriers were stabilized with titanium fixating pins (Frios, Friadent GmbH, Mannheim, Germany) or miniscrews (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany) or both. The distraction procedure was accomplished by using osteodistractors (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany) fixed to the bone segments with 1.5 mm large titanium screws. The distraction devices were activated after 1 week, twice a day (0.5 mm every 12 h) until the desired amount of distraction was obtained (4 to 9 mm). The bone segments were then left to consolidate for 2 to 3 months, the osteodistractors were then removed and dental implants placed and left submerged for 3 to 6 months. The augmentation procedures were performed under local anaesthesia, local anaesthesia with intravenous sedation and general anaesthesia according to operator and patient preferences. Surgical templates were used to optimise implant insertion. Two implant systems were used: Brånemark Mark III implants (Nobel Biocare, Göteborg, Sweden) in 19 patients and ITI SLA implants (Institut Straumann AG, Waldenburg, Switzerland) in two patients. The choice of two different implant systems was dictated by the system used by the referring dentists. All patients were rehabilitated with screw-retained metal-ceramic fixed prostheses.

- Autogenous onlay bone grafts harvested from the mandibular ramus versus vertical distraction osteogenesis (Chiapasco 2007) to vertically augment deficient mandibles. Patients were grafted with a two-stage approach: first bone blocks were fixed with 1.5 mm diameter miniscrews (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany). Empty spaces were filled with cancellous bone chips. In case of severe vertical resorption, grafts were assembled in a multilayered fashion. No barriers were used. Bone grafts were harvested from the mandibular ramus of the same side of reconstruction in six patients, while in two patients, where larger defects were present, bone was harvested bilaterally. After 4/5 months implants were placed and left submerged for an additional 3/4 months. The distraction procedure was accomplished by using osteodistractors (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany) fixed to the bone segments with 1.5 mm large titanium screws. The distraction devices were activated after 1 week, twice a day (0.5 mm every 12 h) un-

til the desired amount of distraction was obtained (2 to 7 mm). The bone segments were then left to consolidate for 2 to 3 months, the osteodistractors were then removed and dental implants placed and left submerged for 3/4 months. The augmentation procedures were performed under local anaesthesia, local anaesthesia with intravenous sedation and general anaesthesia according to operator and patient preferences. Surgical templates were used to optimise implant insertion. ITI SLA implants (Institut Straumann AG, Waldenburg, Switzerland) were used. All patients were rehabilitated with screw-retained metal-ceramic fixed prostheses.

- One-stage vertical GBR using particulate autogenous bone harvested from intraoral locations covered with non-resorbable titanium reinforced ePTFE barriers (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA), stabilized with miniscrews, versus osteosynthesis plates (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany), appropriately adapted and fixed with miniscrews, supporting resorbable collagen barriers (Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland) (Merli 2007). The augmentation procedures were performed under local anaesthesia or local anaesthesia with intravenous sedation according to operator and patient preferences. XiVES CELLplus (Friadent GmbH, Mannheim, Germany) implants were used. All patients were rehabilitated with provisional resin fixed prostheses. One implant from each patient was used for the statistical calculations.

- Three different techniques to horizontally augment local ridge maxillary defects (from 1st to 1st premolars) for allowing placement of single implants were tested (Meijndert 2007): (1) bone graft from the chin, (2) bone graft from the chin with a resorbable barrier (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland), and (3) 100% bovine anorganic bone (Bio-Oss, spongiosa granules of 0.25 to 1 mm, Geistlich Pharmaceutical, Wolhusen, Switzerland) with a Bio-Gide resorbable barrier. The cortical bone of the recipient sites was perforated to create a bleeding bone surface and to open the cancellous bone. Bone blocks from the chin were fixed with a 1.5 mm diameter titanium screw (Martin Medizin Technik, Tuttlingen, Germany) and particulate bone from the chin was placed around the fixed bone grafts. Implants were placed 3 months after autogenous bone grafting and 6 months after augmenting sites with Bio-Oss. Single ITI-Esthetic^{Plus} implants (Institut Straumann AG, Waldenburg, Switzerland) were placed using templates and left healing submerged for 6 months. On the day of uncovering provisional single crowns were screwed on the implants and were replaced 1 month later by final porcelain crowns with a zirconium oxide core (Procera, Nobel Biocare, Göteborg, Sweden).

Different techniques to treat implants placed in extraction sockets (minor augmentation procedures)

Is the augmentation procedure necessary? (one trial)

- Particulate autogenous bone harvested from the implant site by means of a filter attached to a dedicated suction line (Osseus Coagulum Trap, Quality Aspirators, Duncanville, TX, USA) versus no augmentation procedure for immediate single implants placed in fresh extraction sockets at maxillary anterior or premolar sites (Chen 2005b). Wound closure was achieved by use of a connective tissue graft taken from the palate. Implants were submerged and left to heal for 6 months. All implants were turned surface, screw-type, titanium Brånemark implants (Nobel Biocare, Göteborg, Sweden). All patients were rehabilitated with single implant supported crowns.

Which is the most effective augmentation technique? (three trials)

- Resorbable porcine-derived collagen barrier (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland) versus resorbable barrier (Bio-Gide) plus bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) for immediate single transmucosal implants placed in fresh extraction sockets 2 to 3 mm apical to the cementoenamel junction of the adjacent teeth (Cornelini 2004). Barriers were fixed to the implants by the healing screw. Implants were left to heal for 6 months. All implants were ITI SLA (Institut Straumann AG, Waldenburg, Switzerland). All patients were rehabilitated with single implant supported crowns.

- Non-resorbable ePTFE barrier (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) alone versus resorbable barrier (Resolut, Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) alone versus resorbable barrier (Resolut) supported by particulate autogenous bone harvested from the implant site by means of a filter attached to a dedicated suction line (Osseus Coagulum Trap, Quality Aspirators, Duncanville, TX, USA) for immediate single implants placed in fresh extraction sockets at maxillary anterior or premolar sites (Chen 2005a). All barriers were tucked beneath the flaps. Wound closure was achieved by use of a connective tissue graft taken from the palate. All implants were turned surface, screw-type, titanium Brånemark implants (Nobel Biocare, Göteborg, Sweden). All patients were rehabilitated with single implant supported crowns.

- Bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) versus Bio-Oss plus resorbable porcine-derived collagen barrier (Bio-Gide) for immediate single implants placed in fresh extraction sockets at maxillary

anterior or premolar sites 2 to 3 mm apical to the cementoenamel junction of the adjacent teeth (Chen 2007). Barriers were trimmed as required and fixed to the implants by the healing screw. Implants were not submerged and left to heal for 6 months. All implants were ITI SLA (Institut Straumann AG, Waldenburg, Switzerland). In the original trial a control group that received no graft or barrier was included, but we could not use the data due the subversion of the randomisation procedure. All patients were rehabilitated with single implant supported crowns.

Different techniques to treat bone dehiscences or fenestrations around implants (minor augmentation procedures)

Is the augmentation procedure necessary? (one trial)

- Non-resorbable ePTFE barrier (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) versus no barrier around contralateral implants showing similar fenestrations at implant insertion. A slight space was maintained over the exposed implant surface by manual convex shaping of the barrier which was locked in position by tucking one edge under the periosteum. No bone chips or synthetic material were used as space maintainer as confirmed by the investigators. All implants were turned surface, screw-type, titanium self tapping Brånemark (Nobel Biocare, Göteborg, Sweden). Barriers were allowed to extend 3 to 4 mm around the defect and stabilised by tucking one edge under the periosteum and were kept for 6 to 7 months (Dahlin 1991).

Which is the most effective augmentation technique? (two trials)

- Resorbable porcine-derived collagen barrier (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland) versus non-resorbable ePTFE barrier (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) around implants showing minor dehiscences and fenestrations at placement (Carpio 2000). Both groups had a 1:1 mixture of bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) and autogenous bone derived from the implant osteotomy sites. The barrier was stabilized with either two polylactic acid bioabsorbable pins (Osseofix, Implant Innovations Inc., West Palm Beach, FL, USA or Resor-Pin, Geistlich Pharmaceutical, Wolhusen, Switzerland), or the implant cover screw or the mucogingival flap only and were kept for 6 months. All implants were turned surface, screw-type, titanium (Implant Innovations Inc., West Palm Beach, Florida, USA).
- The effect of recombinant human bone morphogenetic protein-2 (rhBMP-2; 1 ml of 0.5 mg/ml) versus placebo (1 ml of 0.01% trifluoroacetic acid; the solution in which rhBMP-2 is dissolved) on GBR using bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) and resorbable porcine-derived collagen barriers (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland) was evaluated at implants showing bone dehiscences or fenestrations at placement in a placebo-controlled trial (Jung 2003). The barriers were trimmed and adapted in order to overlap the defect border by a minimum 2 mm and were stabilized with polylactic acid bioabsorbable pins (Resor-Pin, Geistlich Pharmaceutical, Wolhusen, Switzerland) and were kept for 6 months. All implants were turned surface, screw-type, titanium Mark II , III or IV Brånemark implants (Nobel Biocare, Göteborg, Sweden).

Characteristics of outcome measures

- Prosthesis failure: Wannfors 2000 ; Hallman 2002 ; Stellingsma 2003; Chiapasco 2004; Cornelini 2004; Chen 2005a ; Chen 2005b ; Raghoebar 2005 ; Szabó 2005 ; Raghoebar 2006; Chen 2007; Chiapasco 2007; Meijndert 2007; Merli 2007.
- Implant failure by individual implant stability assessment with removed prostheses (with the exception for single implants): Dahlin 1991; Carpio 2000; Wannfors 2000; Hallman 2002 ; Jung 2003 ; Stellingsma 2003 ; Chiapasco 2004 ; Cornelini 2004; Chen 2005a; Chen 2005b; Raghoebar 2005; Szabó 2005; Raghoebar 2006; Chen 2007; Chiapasco 2007; Meijndert 2007; Merli 2007.
- Augmentation procedure failure: Dahlin 1991; Carpio 2000; Wannfors 2000; Hallman 2002; Jung 2003; Chiapasco 2004; Raghoebar 2005; Szabó 2005; Raghoebar 2006; Chen 2007; Chiapasco 2007; Merli 2007.
- Major complications at augmented site: perforation of the sinus membrane (though not a major complication): Wannfors 2000 ; various complications: Dahlin 1991 ; Carpio 2000 ; Hallman 2002 ; Jung 2003 ; Stellingsma 2003 ; Chiapasco 2004; Cornelini 2004; Chen 2005a; Chen 2005b; Raghoebar 2005; Szabó 2005; Raghoebar 2006; Chen 2007; Chiapasco 2007; Meijndert 2007; Merli 2007.
- Major complications at bone donor site: Hallman 2002 ; Stellingsma 2003; Chiapasco 2004; Raghoebar 2005; Szabó 2005; Raghoebar 2006; Chiapasco 2007; Meijndert 2007; Merli 2007.
- Patient satisfaction including aesthetics: Stellingsma 2003 ; Chen 2007; Meijndert 2007. We could not use the data of one trial (Meijndert 2007) since they were not presented by study groups.
- Patient preference including aesthetics (only in split-mouth trials): no trials.
- Bone gain vertically or horizontally or both expressed in mm or percentage including bone level changes over time: verti-

cal bone gain was measured in mm by direct measurement in eight studies (Carpio 2000; Jung 2003; Chiapasco 2004; Chen 2005a; Chen 2005b; Chen 2007; Chiapasco 2007; Merli 2007) and in percentage in one trial (Dahlin 1991). Peri-implant marginal bone level changes were assessed in four trials (Chiapasco 2004; Chen 2007; Chiapasco 2007; Meijndert 2007), but data were presented in a way we could not use in three trials (Chiapasco 2004; Chen 2007; Meijndert 2007). The resorption pattern of the mandible after implant insertion was evaluated in one study (Stellingsma 2003) using the oblique lateral radiographic technique, but insufficient data were presented to enable us to evaluate bone height changes.

- Aesthetics assessed by dentist: three trials (Cornelini 2004; Chen 2007; Meijndert 2007). In one trial (Cornelini 2004) the position of the mucosal margin was evaluated in relation to the implant shoulder expressed in mm. In another trial (Chen 2007), the operator assessed whether marginal mucosal recession occurred or not. We could not use the data of one trial (Meijndert 2007) since they were not presented by study groups.
- Duration of the treatment period starting from the first intervention to the functional loading of the implants: all trials.
- Treatment costs: no trials. However, this outcome measure was indirectly extrapolated by us for all trials.

Duration of follow up (including unpublished data kindly provided by the investigators)

- To the abutment connection/implant loading (Dahlin 1991; Carpio 2000; Jung 2003; Cornelini 2004; Szabó 2005; Merli 2007). We were informed that a 5-year follow-up report is expected for two trials (Jung 2003; Merli 2007).
- One-year post-loading (Hallman 2002; Meijndert 2007). We were informed that a 5-year follow-up report is expected for one trial (Hallman 2002).
- Two-year post-loading (Stellingsma 2003; Chen 2005a; Chen 2005b; Raghoebar 2005; Raghoebar 2006). We were informed that a 5-year follow-up report is expected for one trial (Stellingsma 2003).
- Three-year post-loading (Wannfors 2000; Chiapasco 2004; Chen 2007; Chiapasco 2007). We were informed that a 5-year follow-up report is expected for two trials (Wannfors 2000; Chiapasco 2004).

Risk of bias in included studies

The final quality scoring after having incorporated the additional information kindly provided by the authors of the trials is summarized in Additional Table 1. For each trial we assessed whether it was at low or high risk of bias. Eleven studies were judged to be at high risk of bias (code B), and six (Dahlin 1991; Carpio 2000; Jung 2003; Cornelini 2004; Chiapasco 2007; Merli 2007) at low risk of bias (code A).

Table 1. Quality assessment

Study	Allocation concealment	Outcome assessor blind	Withdrawals	Level of bias
Dahlin 1991	Adequate	Yes	Yes	low
Carpio 2000	Adequate	Yes	Yes	low
Wannfors 2000	Unclear	No	Yes	high
Hallman 2002	Adequate in part	No	Yes	high
Jung 2003	Adequate	Yes	Yes	low
Stellingsma 2003	Unclear	No	Yes	high
Chiapasco 2004	Inadequate	No	Yes	high
Cornelini 2004	Adequate	Yes	Yes	low
Chen 2005a	Adeguate	No	Yes	high

Table 1. Quality assessment

(*Continued*)

Chen 2005b	Adequate	No	Yes	high
Raghoebar 2005	Unclear	Yes	Yes	high
Szabó 2005	Unclear	No	Yes	high
Raghoebar 2006	Unclear	No	Yes	high
Chen 2007	Adequate	No	Yes	high
Chiapasco 2007	Adequate	Yes, when possible	Yes	low
Meijndert 2007	Unclear	Yes	Yes	high
Merli 2007	Adequate	Not possible	Yes	low

Allocation concealment

When assessing the information presented in the articles, allocation concealment was scored adequate for two trials (Chiapasco 2004; Merli 2007) and unclear for all other trials. All authors replied to our request for clarification. When evaluating authors' replies, one trial scored as being adequately concealed became not concealed (Chiapasco 2004); 10 trials were judged to be properly concealed (Dahlin 1991; Carpio 2000; Hallman 2002; Jung 2003; Cornelini 2004; Chen 2005a; Chen 2005b; Chen 2007; Chiapasco 2007; Merli 2007) whereas six trials remained unclear (Wannfors 2000; Stellingsma 2003; Raghoebar 2005; Szabó 2005; Raghoebar 2006; Meijndert 2007). One trial was judged to have an adequate allocation concealment only for the randomised groups (Hallman 2002). Since it was a 'preference' trial, one arm of the trial was composed by patients who expressed a definite preference for the interventions to receive and therefore were allocated to their preferred intervention without randomisation. For the latter group, allocation concealment was scored as inadequate.

Blinding

When assessing the information presented in the articles for the outcome measures of interest in the present review which were possible to be masked, blinding of the outcome assessor was scored as unclear for all trials with four exceptions (Jung 2003; Raghoebar 2005; Meijndert 2007; Merli 2007). Three were scored as blinded (Jung 2003; Raghoebar 2005; Meijndert 2007) and the other as blinding not possible (Merli 2007). All authors replied to our request for clarification. When evaluating authors' replies, the outcome assessors of four trials were blinded (Dahlin 1991; Carpio 2000; Cornelini 2004; Chiapasco 2007), and those of nine trials were not blinded (Wannfors 2000; Hallman 2002; Stellingsma 2003; Chiapasco 2004; Chen 2005a; Chen 2005b; Szabó 2005; Raghoebar 2006; Chen 2007).

Completeness of follow up

When assessing the information presented in the articles, information on drop outs was clearly presented in all trials, with one exception (Chiapasco 2004). All authors replied to our request for clarification or provided additional follow-up data or both, including Chiapasco 2004 who confirmed that there were no withdrawals.

Inclusion/exclusion criteria

For more details *see* the Characteristics of included studies table.

Main inclusion criteria

- Severely resorbed maxillae (classes V-VI according to Cawood 1991) with maxillary sinuses having < 5 mm in height of residual alveolar bone with reduced stability and retention of upper dentures (Raghoebar 2005; Raghoebar 2006).
- Severely resorbed mandibles, i.e. symphyseal height 6 to 12 mm as measured on standardised lateral radiographs of patients who have been edentulous for at least 2 years and experienced severe functional problems with their lower dentures (Stellingsma 2003).
- 2 to 7 mm in height of residual alveolar bone in the floor of the edentulous sinus (Wannfors 2000).
- Less than 5 mm in height of residual alveolar bone in the floor of the edentulous sinus (Hallman 2002; Szabó 2005).
- Dehiscences or fenestrations at implant placement (Carpio 2000; Jung 2003). In one trial (Jung 2003) testing the effect of

rhBMP-2 on guided bone regeneration (GBR) the distance between test and control sites had to be of at least 7 mm.
- Edentulous maxillae with buccal fenestrations at implant placement around at least two contralateral implants having a similar size (Dahlin 1991). In all cases a marginal bone buttress was present. The vertical bone should have not been less than 13 mm in height, and there should have been a horizontal resorption of the alveolar crest, with buccal concavities at the mid-portion of the ridge as determined on computer tomography.
- Edentulous ridges requiring vertical regeneration (Chiapasco 2004; Chiapasco 2007; Merli 2007).
- Horizontal bone deficiency in a maxillary site (incisor, cuspid or first bicuspid) requiring a single implant (Meijndert 2007).
- Single post-extractive fresh sockets (Cornelini 2004).
- Single post-extractive fresh sockets at maxillary anterior and premolar sites (Chen 2005a; Chen 2005b; Chen 2007).

Main exclusion criteria

- Heavy smokers (more than two packs of cigarettes per day) (Carpio 2000).
- More than 20 cigarettes per day (Merli 2007).
- More than 15 cigarettes per day (Chiapasco 2004; Chiapasco 2007).
- Smokers (Chen 2005a; Chen 2005b; Meijndert 2007).
- Bone metabolic diseases (Carpio 2000; Wannfors 2000).
- Medication interfering with bone metabolism (i.e. corticosteroids, bisphosphonate, etc.) (Carpio 2000; Wannfors 2000).
- Sinusitis (Carpio 2000; Wannfors 2000).
- Severe knife-edge ridges (Chiapasco 2004; Chiapasco 2007).
- History of reconstructive, pre-prosthetic surgery or previous oral implantology (Raghoebar 2005; Raghoebar 2006; Meijndert 2007).
- Edentulous period of at least 1 year (Raghoebar 2005; Raghoebar 2006).
- Acute infection and suppuration at the fresh extraction socket (Cornelini 2004; Chen 2005a; Chen 2005b; Chen 2007) and $\geq$ 5 mm of attachment loss at buccal aspects (Chen 2007).
- Mucosal disease, such as lichen planus, in the areas to be treated (Chiapasco 2004; Chiapasco 2007).
- None specified (Dahlin 1991; Hallman 2002; Jung 2003; Szabó 2005).

Sample size

A priori calculation for the sample size was undertaken in only one trial (Merli 2007). The calculation was based on the complications that occurred in another similar randomised controlled trial (RCT) (Friedmann 2002). Twenty-one patients were needed in each group to detect a difference between a proportion of complications from 0.27 to 0.80. However the trial included only 22 patients, therefore the sample size requirement was not fulfilled.

Baseline comparability between treatment groups

- No apparent major baseline differences (Carpio 2000; Wannfors 2000; Stellingsma 2003; Chiapasco 2004; Cornelini 2004; Chen 2005a; Chen 2005b; Raghoebar 2005; Raghoebar 2006; Chen 2007; Meijndert 2007; Merli 2007).
- Unclear whether major baseline differences existed (Dahlin 1991; Hallman 2002; Szabó 2005; Chiapasco 2007).
- The following major baseline differences existed: defect depth shallower for control sites (Jung 2003).

Effects of interventions

In total 455 patients were enrolled in the 17 trials. Since different techniques were evaluated in different trials, no meta-analysis could be performed.

Different techniques for vertical or horizontal bone augmentation or both (major augmentation procedures)

Is the augmentation procedure necessary? (one trial)

- One trial (Stellingsma 2003) ('Comparison 1', 'Outcome 1.1') evaluated the need to augment atrophic mandibles (residual bone height between 6 to 12 mm) up to 2 years after loading. Twenty patients received four short implants (8 to 11 mm), whereas 20 patients received interposed iliac bone grafts and four longer implants (13 to 18 mm) to support overdentures. Two patients dropped out, one from each group about 3 months after overdenture delivery due to death and moving. In the short implant group two complications occurred: bleeding during surgery and permanent unilateral hypoaesthesia, and no early implant failure. In the augmented group six complications occurred: one life threatening complication (post-operative sublingual edema which left the patient in intensive care for 3 days); two wound dehiscences; two unilateral dysaesthesiae, one of which completely recovered; and one necrosis of the osteotomized cranial fragment of the mandibles. In the augmented group four patients lost one implant each and a fifth patient lost all implants (possibly for necrosis of the osteotomized cranial fragment of the mandible and had to be re-treated), before or at abutment connection. Although the RevMan P value for the odds ratio (OR) was not statistically significant (P = 0.08), Fisher's exact test (two sided) found a significant difference (P = 0.048), with higher implant failure for the augmented mandibles, confirming the findings of the original article.

Statistically significant differences were also found at 3 weeks after the first surgical intervention: (1) 85% of the patients in the augmentation group reported serious pain for more than 1 week versus 20% of the patients in the short implant group (OR 22.7; 95% confidence interval (CI) 4.4 to 117.5); (2) 30% of the patients in the augmentation group reported no improvement in their facial appearance versus 80% of the patients in the short implant group (in this group, 70% reported no change, and 10% reported a deterioration of their facial appearance) (OR 0.11; 95% CI 0.03 to 0.46). The article also reported a statistically significant difference with 50% of the patients in the augmentation group experienced the operation more negatively than expected versus 25% of the patients in the short implant group, however we did not find this difference significant. With respect to prosthetic aftercare: four unplanned interventions were required in the short implant group versus 10 interventions in the graft group. Numerous aspects of patient satisfaction including aesthetics were investigated using validated questionnaires at 1 year and no statistically significant differences among groups were found. With respect to cost and treatment time, while short implants were placed under local anaesthesia, the graft procedures required general anaesthesia, a mean of 5.9 days of hospitalisation (range 3 to 9; standard deviation (SD) 1.3), and the double healing time (about 3 additional months) and patients could not wear the lower denture for 6 months. The trial was judged to be at high risk of bias and we had no additional clarifications from the authors.

Which is the most effective augmentation technique? (eight trials)

- One trial compared two techniques for augmenting atrophic maxillary sinuses (Wannfors 2000) ('Comparison 2', 'Outcome 2.1'). Only patients having 2 to 7 mm of residual alveolar bone in the floor of the edentulous sinus were included. Twenty patients were treated with a one-stage sinus lift with monocortical iliac bone blocks, and other 20 patients were treated with a two-stage sinus lift with particulate bone from the iliac crest. All patients were followed up to 3 years after loading, therefore there were no drop outs. However, data were presented in a way which could not be used for all the time points we wanted to evaluate. Three patients refused to have their prostheses removed and x-ray examination at the 3-year follow up. The only complications reported were 11 perforations of the sinus membrane in nine patients of the one-stage group versus 11 perforations in 10 patients of the two-stage group. At the time of abutment connection 11 implants in eight patients were found to be not osseointegrated in the one-stage group versus seven implants in six patients of the two-stage group. At 1 year an additional five implants were lost in the one-stage group versus one in the two-stage group. At 3 years one additional implant was lost in the one-stage group versus two in the two-stage group. Two patients of the one-stage group had problems with the fixed prostheses at 1 year. In one patient the prosthesis was lost due to four implant failures whereas in another patient the prosthesis had to be redesigned due to lack of space for the tongue (we did not consider this as a prosthesis failure in the calculations, since it was independent of the bone grafting technique). One prosthesis was lost due to the failure of a strategically positioned implant at 1 year in the two-stage group. There was no statistically significant difference for any of the outcomes considered in this review. With respect to cost and treatment time, all the procedures were performed under general anaesthesia, however the two-stage group required one additional surgical intervention for placing the implants whereas implants were placed simultaneously with the augmentation procedure in the one-stage group. The healing period was 6 months longer in the two-stage group. The trial was judged to be at high risk of bias.

- One trial compared three one-stage techniques for augmenting atrophic maxillary sinuses (Hallman 2002) ('Comparison 2', 'Outcome 2.2'). Only patients with less than 5 mm of alveolar bone height in the sinus floor and fixed dentition on the opposite jaw were included. The trial was designed as a sort of split-mouth/parallel preference trial. Eleven patients willing to provide autogenous bone from the mandibular ramus were treated with a split-mouth approach (autogenous bone versus 80% Bio-Oss and 20% autogenous bone), whereas 10 patients who refused to have their bone harvested from the mandible were treated with 100% Bio-Oss. Since four patients of the last group were treated bilaterally, we randomly selected one sinus in order to have all patients providing one sinus each for statistical evaluation. All patients were followed up to 1 year after loading, therefore there were no drop outs. During the post-operative phase no complications occurred either in the augmented sites or in the donor sites. However a severe resorption of the autogenous bone graft occurred in two patients. At abutment connection six implants failed in five patients in the group treated with autogenous bone only and two implants failed in two patients in the group treated with 80% Bio-Oss. No early implant failures occurred in the randomly selected sinus treated with 100% Bio-Oss, however two implant failures occurred in two of the four randomly excluded sinuses. No implants or prostheses were lost at the 1-year evaluation. The author informed us that additional implants were lost at the 2-year follow up in two patients in the split-mouth group, causing the failure of the fixed prostheses. The complete information should be published in a future 5-year follow-up report. There was no statistically significant difference for any of the outcomes considered in this review. With respect to cost and treatment time, all the procedures were performed under local anaesthesia and the only

difference in cost is due to the use of bone substitutes, and of the collagen barrier in the 100% Bio-Oss group only. The healing period was of 6 months, but it was prolonged to an average of 2.5 months in the 100% Bio-Oss group. The trial was judged to be at high risk of bias.

- One trial compared two techniques for augmenting atrophic maxillary sinuses (Szabó 2005) ('Comparison 2', 'Outcome 2.3'). Only patients with less than 5 mm of alveolar bone height in the sinus floor were included. Twenty patients were treated with a split-mouth approach with a two-stage sinus lift with particulate bone from the iliac crest one side and with a two-stage sinus lift with 100% Cerasorb (a beta-tricalcium phosphate bone substitute) on the contralateral sinus. In 10 patients an additional autogenous onlay bone block was placed to widen the alveolar crest. All patients were followed up to implant loading and there were no drop outs. No serious post-operative complications occurred at the implant sites. Three complications occurred at the bone graft donor sites: one permanent sensory loss of the lateral femoral cutaneous nerve and two had prolonged wound drainage (2 to 3 weeks). At abutment connection two implants failed, one in each group, they both had to be replaced in order to place the prosthesis and this caused a delay of 3 to 6 months (we did not consider these as prosthesis failures in the calculations). There was no statistically significant difference for any of the outcomes considered in this review. With respect to cost and treatment time, due to the nature of split-mouth study design, all the procedures were performed under general anaesthesia and patients were hospitalised for an unspecified number of days. The healing time was about 1 year. The difference in cost was the use of the bone substitutes. The trial was judged to be at high risk of bias.

- One trial compared two techniques for augmenting resorbed maxillae including atrophic maxillary sinuses (Raghoebar 2005) (data not shown). Only patients with less than 5 mm of alveolar bone height in the sinus floor were included. Five patients were treated with a split-mouth approach with two-stage sinus lift with autogenous bone together with buccal onlays grafts, harvested from the iliac crest, one side with platelet-rich plasma (PRP) and the other without. All patients were followed for 2 years after implant loading and there were no drop outs. No serious complications occurred at the grafted sites: one sinus membrane was perforated during surgery but healing was uneventful. A small incision breakdown occurred in the first week at the non-PRP side of one patient. A seroma which healed uneventfully was the only complication that occurred at the donor sites. During the prosthetic phase one implant failed in the PRP side, but no prosthesis failed. There was no statistically significant difference for any of the outcomes considered in this review. The difference in cost and treatment time was the use of PRP. Prostheses were inserted about 10 months after augmentation. The trial was judged to be at high risk of bias.

- One split-mouth trial compared two titanium versus two resorbable screws for fixating two-stage buccal onlay grafts, harvested from the iliac crest, to resorbed maxillae (Raghoebar 2006) (data not shown). Eight patients were followed for 2 years after implant loading and there were no drop outs. No serious complications occurred at the grafted and donor sites. Two resorbable screws broke at insertion (one because of incorrect handling), but they could be removed and replaced. A small incision breakdown occurred in the first week at the titanium screw side of one patient. Another patient developed a slight submucosal swelling with redness of the mucosa above a resorbable implant 3 months after the augmentation procedure, that disappeared after implant placement. No prosthesis or implant failed. There was no statistically significant difference for any of the outcomes considered in this review. The difference in cost and treatment time was the use of different screws. Prostheses were inserted about 10 months after augmentation. The trial was judged to be at high risk of bias.

- One trial compared distraction osteogenesis in 11 patients versus guided bone regeneration (GBR) with non-resorbable barriers and particulate autogenous bone grafts taken from the mandibular ramus (if not sufficient also from the chin) in 10 patients for vertically augmenting edentulous ridges for 3 years after loading (Chiapasco 2004) ('Comparison 2', 'Outcome 2.4'). No patients dropped out. Two complications occurred in two patients of the osteodistraction group: the bone fragment inclined lingually during the distraction phase probably due to the traction on the osteotomized segment by muscle forces of the floor of the mouth. The complications were successfully treated by applying an orthodontic traction until the bone segment consolidated in the desired position. Five complications occurred in four patients of the GBR group: three barrier exposures occurred, one of which was associated with an infection, and two transient paraesthesiae of the chin area lasting 1 and 4 weeks. Both paraesthesiae were associated with the only two procedures for harvesting bone from the chin. All procedures for harvesting bone from the ramus were complication free. No implants or prosthesis failed over the 3-year follow-up period. The mean bone gain after the augmentation procedure was reported for both groups, however without explaining how it was recorded or which were the reference points. Also data on perimplant bone loss were unclear and could not be used. There was no statistically significant difference for any of the outcomes considered in this review. With respect to cost and treatment time, in the GBR group it should be considered the cost of the barriers and the fixing pins, versus the cost of the intraoral distractor and related orthodontic therapy when

needed. In the osteodistraction group the time occurring for exposing the implants ranged between 6 and a half months (mandibles) to 9 and a half months (maxillae) and patients were not allowed to use prostheses for about 3 and a half months. In the GBR group, the time occurring for exposing the implants ranged between 6/7 months, when implants were placed simultaneously with the GBR procedure to 9/12 months, when implants were placed after the ridge had been vertically augmented. Patients were left without removable prostheses for 6/7 months. The trial was judged to be at high risk of bias.

- One trial compared distraction osteogenesis in nine patients versus autogenous onlay bone grafts taken from the mandibular ramus in eight patients for vertically augmenting mandibular edentulous ridges for 3 years after loading (Chiapasco 2007) ('Comparison 2', 'Outcome 2.5' and '2.6'). No patients dropped out. Three complications occurred in three patients of the osteodistraction group: the bone fragment inclined lingually during the distraction phase probably due to the traction on the osteotomized segment by muscle forces of the floor of the mouth. The complications were successfully treated by applying an orthodontic traction until the bone segment consolidated in the desired position. In the third patient, distraction was interrupted before completion, because of the impossibility to move further the distracted segment. This was probably caused by an incorrect design of the vertical osteotomic lines. Shorter implants (6 mm instead of the planned 8 mm) could be placed anyway. Four complications occurred in four patients of the bone graft group: three paraesthesiae of the alveolar inferior nerve, two transient but one permanent. In the last patient the graft became exposed and was partially lost. The treatment could be completed anyway using short implants. No implants or prostheses failed over the 3-year follow-up period. The mean bone gain after the augmentation procedure was 5.3 $\pm$ 1.58 mm for the osteodistracted sites and 5.0 $\pm$ 1.07 mm for the grafted sites. No statistically significant differences were observed regarding marginal perimplant bone loss between groups at 1 and 3 years. Three years after loading implants in osteodistracted sites lost on average 0.9 mm of perimplant bone versus 1.3 mm in grafted sites. There was no statistically significant difference for any of the outcomes considered in this review. With respect to cost and treatment time, in the bone graft group it should be considered only the cost of the fixing pins, versus the cost of the intraoral distractor and related orthodontic therapy when needed, making bone grafting cheaper. In the bone graft group, the time occurring for exposing the implants ranged between 8/9 months. Patients were left without removable prostheses for at least 2 months. In the osteodistraction group the time occurring to expose implants was 7/8 months and patients were not allowed to use prostheses for about 3 months. The trial was judged to be at low risk of bias.

- One trial, compared one-stage particulate autogenous bone grafts from intraoral locations in 11 patients treated with non-resorbable titanium reinforced barriers versus 11 patients treated with resorbable barriers supported by osteosynthesis plates (Merli 2007) ('Comparison 2', 'Outcome 2.7' and '2.8'). One implant per patient was used for the statistical calculations. No patients dropped out. Four complications occurred in each group. In the resorbable group two abscesses determined the failure of the grafting procedures, whereas the other two were minor complications not affecting the outcome of the therapy (barrier exposure without sign of infection, and a swelling suggesting an early infection successfully treated with antibiotics). One infection occurred in the non-resorbable group which determined the failure of the graft. In addition fistulas were noticed in two patients, one occurred just prior to the planned abutment connection, and the other 2 months after the intervention. In the latter case the barrier was removed prematurely and systemic antibiotics were given. The last complication was lymph nodes swelling 1 month after intervention suggesting an infection which was treated with systemic antibiotics. Those three complications did not jeopardize the success of the augmentation procedure. No study implant failed and all planned prostheses could be delivered. Both treatments resulted in statistically significant vertical bone gain, however no statistically significant differences were found among the two procedures. With respect to cost and treatment time, for the resorbable group it should be considered the cost of one or two barriers, the osteosynthesis plates and related fixating pins, versus the cost of a titanium-reinforced barrier and related pins in the non-resorbable group, which could be slightly cheaper. The healing time for both groups was about 4 and a half months; slightly less than originally planned (5 months), due to premature removal of some infected barriers. The trial was judged to be at low risk of bias.

- One trial compared three two-stage techniques to horizontally augment bone at maxillary sites (incisor, cuspid or first bicuspid) to allow placement of single implants (Meijndert 2007). Thirty-one patients were included in each group and were followed up for 1 year after loading. The following procedures were tested: (1) autogenous bone block from the chin; (2) autogenous bone block from the chin plus a resorbable barrier; (3) 100% Bio-Oss plus a resorbable barrier ('Comparison 2', 'Outcome 2.9', '2.10' and '2.11'). No patients dropped out. Not a single complication occurred. Two single implants failed early in the group treated with Bio-Oss plus resorbable barrier, though this difference was not statistically significant. Many other outcome measures (perimplant bone level changes, patient satisfaction, aesthetics judged by patients and by an independent dentist) could not be used

in the present review because data were aggregated and not presented by study groups. With respect to cost and treatment time, the additional costs for the barriers, and Bio-Oss should be considered. Patients had to wait 9 months (bone block groups) or 1 year (Bio-Oss plus barrier group) to be rehabilitated. The trial was judged to be at high risk of bias.

Different techniques to treat implants placed in extraction sockets (minor augmentation procedures)

Is the augmentation procedure necessary? (one trial)

- One trial compared 14 patients receiving particulate autogenous bone harvested from the implant osteotomy site versus 12 patients who were not subjected to any augmentation procedure at immediate single implants placed in fresh extraction sockets at maxillary anterior and premolar sites (Chen 2005b) ('Comparison 3', 'Outcome 3.1' and '3.2') up to 2 years post-loading. The following bone measurements at implant placement and 6 months after at implant exposure were included in the present review: the vertical height of the defect (VDH) measured from the most apical extent of the defect to the coronal aspect of the implant collar, and the horizontal depth of the defect (HDD) measured bucco-lingually from the most buccal extent of the implant collar to the labial bone crest (at dehisced sites, the HDD was estimated by measuring the horizontal distance from the implant collar to a periodontal probe placed against the intact portions of the labial plate at the level of the implant collar). No patients dropped out. Two complications occurred in the group treated with autogenous bone: one abscess that determined the early failure of the implant and one wound dehiscence. In total two implants were lost in the autogenous bone group, whereas no complications or failures occurred in the non-augmented control group. Both treatments resulted in statistically significant bone gain, however no statistically significant differences were found among the two procedures. With respect to cost and treatment time, the difference among groups may not be clinically significant. The trial was judged to be at high risk of bias.

Which is the most effective augmentation technique? (three trials)

- One trial compared 10 patients receiving a resorbable barrier versus 10 patients treated with resorbable barrier plus Bio-Oss at implants placed in fresh extraction sockets (Cornelini 2004) ('Comparison 4', 'Outcome 4.7' and '4.8'). No patients dropped out. No prosthesis or implant failed. No complications occurred. A statistically significant higher position of the soft tissue margins in relation to the implant shoulder was found for barrier plus Bio-Oss at buccal sites (2.1 mm versus 0.9 mm; mean difference = -1.2 mm; 95% CI -2.29 to -0.11). With respect to treatment time, the differences among groups may not be clinically significant. The only difference in cost between the two procedures was the additional cost of the Bio-Oss. The trial was judged to be at low risk of bias.

- One trial compared 12 patients receiving non-resorbable barriers versus 11 patients receiving resorbable barriers versus 13 patients receiving resorbable barriers and particulate autogenous bone harvested from the implant osteotomy site at immediate single implants placed in fresh extraction sockets at maxillary anterior or premolar sites (Chen 2005a) ('Comparison 4', 'Outcomes 4.1 to 4.6') up to 2 years post-loading. The following bone measurements at implant placement and 6 months after implant exposure were included in the present review: the vertical height of the defect (VDH) measured from the most apical extent of the defect to the coronal aspect of the implant collar, and the horizontal depth of the defect (HDD) measured bucco-lingually from the most buccal extent of the implant collar to the labial bone crest (at dehisced sites, the HDD was estimated by measuring the horizontal distance from the implant collar to a periodontal probe placed against the intact portions of the labial plate at the level of the implant collar). No patients dropped out. Four complications occurred, two dehiscences occurred in the resorbable group whereas one abscess (successfully treated with systemic antibiotics) and one dehiscence occurred in the group treated with resorbable barriers and autogenous bone. All treatments resulted in statistically significant bone gain, however no statistically significant differences were found among the three procedures. With respect to cost and treatment time, the differences among groups may not be clinically significant. The trial was judged to be at high risk of bias.

- One trial compared 10 patients receiving Bio-Oss versus 10 patients receiving Bio-Oss plus a resorbable barrier at immediate single implants placed in fresh extraction sockets at maxillary anterior or premolar sites (Chen 2007) ('Comparison 4', 'Outcome 4.9' and '4.10') up to 3 years post-loading. A third control group of 10 patients who received no barrier and no graft could not be evaluated since some patients were systematically excluded from that group and included in the remaining two groups. The following bone measurements at implant placement and 6 months after implant exposure were included in the present review: the vertical height of the defect (VDH) measured from the most apical extent of the defect to the coronal aspect of the implant collar, and the horizontal depth of the defect (HDD) measured bucco-lingually from the most buccal extent of the implant collar to the labial bone crest (at dehisced sites, the HDD was estimated by measuring the horizontal distance from the implant collar to a periodontal probe placed against the intact portions of

the labial plate at the level of the implant collar). After 3 years, three patients dropped out from the Bio-Oss group and five patients from the Bio-Oss plus barrier group. There were no prosthesis or implant failures. Two complications occurred of the Bio-Oss plus barrier group: one abscess developed during the healing period around one implant (the site was re-treated with the same procedure); another implant displayed a chronic inflammation of the perimplant tissues (perimplant mucositis) for the entire study period. All treatments resulted in statistically significant bone gain, however, no statistically significant differences in bone gain were found between the two procedures. After delivery of the prostheses one patient in each group, when asked by the operator, was dissatisfied with aesthetics due to recession of the mucosa on the buccal aspect. Both patients refused a corrective intervention with a soft tissue graft. Aesthetics (position of the soft tissue margin in relation to the adjacent teeth) were also evaluated by the operator after the 6-month healing period, at placement of the final restorations and after 3 years of loading. After healing, 3/10 sites treated with Bio-Oss and 4/10 sites treated with Bio-Oss plus barrier were considered aesthetically unsatisfactory by the operator. The two sites which were judged as unsatisfactory by the patients, were also judged unsatisfactory by the operator. The operator then treated two sites with recession in the Bio-Oss group and one patient with recession and one without recession (marginal mucosa judged to be too thin) of the Bio-Oss plus barrier group with connective tissue grafts. After placement of the final restorations (about 2 months after), the operator judged aesthetics to be poor in 2/10 patients of the Bio-Oss group and in 4/10 of the Bio-Oss plus barrier group. After 3 years of loading, the operator judged aesthetics to be poor in 2/7 patients of the Bio-Oss group and in 2/5 patients of the Bio-Oss plus barrier group. No statistically significant differences were found for any of the aesthetic outcomes. With respect to treatment time, the differences among groups may not be clinically significant. The only difference in cost between the two procedures was the additional cost of the barrier. The trial was judged to be at high risk of bias.

Different techniques to treat bone dehiscences or fenestrations around implants (minor augmentation procedures)

Is the augmentation procedure necessary? (one trial)

- A split-mouth trial evaluated in seven patients with fenestrated implants at implant placement whether a non-resorbable barrier kept for 6 to 7 months was able to regenerate more bone than no barrier (Dahlin 1991) ('Comparison 5', 'Outcome 5.1'). No drop outs, significant complications or implant failures occurred at implant exposure. There was a significant increase in per cent bone gain for the GBR implants when compared to the untreated implants, mean difference = 71 % (95% CI 45 to 98, P = 0.002). However, in 4 out of 7 test implants, the regenerated bone covered only about 55% of the fenestrated implant surface. The only difference in cost between the two procedures was the barrier. The trial was judged to be at low risk of bias.

Which is the most effective augmentation technique? (two trials)

- Another study compared resorbable (23 subjects) versus non-resorbable barriers (25 patients) over a mixture of Bio-Oss and autogenous bone taken from the implant osteotomy sites for 6 months (Carpio 2000) ('Comparison 6', 'Outcome 6.1' and '6.2'). There were no drop outs. There was no significant difference in implant failures (five failures in the resorbable barrier group and four in the non-resorbable group); in various complications (11 in the resorbable group and 11 in the non-resorbable group) and in the reduction in length or width of defect. Cost and treatment times were similar among the two groups. It was also reported that those 34 barriers that were fixed with resorbable pins gave statistically significantly less complications than those 14 barriers secured by the cover screws or adapting the barrier beneath the flap or both. The trial was judged to be at low risk of bias.

- The last study evaluated the effect of a bone morphogenetic protein (rhBMP-2) on Bio-Oss and a resorbable barrier in a split-mouth, placebo-controlled trial study including 11 patients for 6 months (Jung 2003) ('Comparison 6', 'Outcome 6.3'). There were no drop outs. No implant failures occurred. There was one complication (wound dehiscence) in the rhBMP-2 group. No differences in early implant failure and complications were observed, however a borderline statistically significant difference in defect height reduction of 1.5 mm was observed favouring implants treated with rhBMP-2 (mean difference = 1.5 mm; 95% CI 0.06 to 3.03, P = 0.04). The difference in cost was that rhBMP-2, produced in one laboratory of the University of Zurich, was applied to the text group. The trial was judged to be at low risk of bias.

DISCUSSION

This review was conceived as having a broad focus and was aimed to include any randomised controlled trial (RCT) dealing with any aspect of bone augmentation in relation to implant placement. Trials reporting only histological outcomes or which did not report any implant related outcomes were not considered of interest since they would not be able to provide answers to the numerous open clinical questions in this rather disputed area of

implant dentistry. We identified 40 potentially eligible trials, but we were able to use data only from 17 investigations. Twenty-two studies were excluded for various reasons (unclear study designs; the unit of randomisation was the implant rather than the patient, but the analysis failed to reflect this; insufficient data presented; only histological outcome used, etc.). These methodological problems are not uncommon in the dental implant literature (Esposito 2001), and it is recommended that clinicians seek advice from clinical research methodologists and statisticians when designing and analysing studies. Only in one trial was a sample size calculation undertaken (Merli 2007), however the planned sample size was not achieved. Sample sizes of all studies were relatively small. It is therefore likely that many of these studies were underpowered to demonstrate any significant difference in outcome measures between groups. Nevertheless the included trials did provide limited but indeed useful clinical information and indications which should be carefully evaluated by clinicians when deciding whether to perform an augmentation procedure or not, or which augmentation procedure to select. We have spent a great deal of time contacting RCTs' authors, who have kindly provided useful unpublished information on their trials. We feel that these contacts have made the present review more complete and useful for the readers. It is also worth observing that all authors of the included trials replied to our requests of clarifications. It is unusual to have such a high response rate. This might be partly explained by the serious research interests of the investigators conducting RCTs in the area, and may be indicative of a growing consciousness that high quality systematic reviews can be of great benefit to the entire society. We also noticed a considerable increase in the number of RCTs published over the last years. This should be viewed positively since it may indicate that in the near future some currently unanswered clinical questions might finally get an evidence-based answer, going over the traditional 'opinion-biased' approach to clinical decision-making. The priority now is to concentrate research efforts on a few important clinical questions, increasing the sample size, and decreasing the number of treatment variables in the trials. This might be obtained through collaborative efforts among various research groups.

We decided at the protocol stage to divide the trials into three broad groups: (1) trials evaluating different techniques for vertical or horizontal bone augmentation or both (major augmentation procedures); (2) trials evaluating different techniques to treat implants placed in extraction sockets (minor augmentation procedures); and (3) trials evaluating different techniques to treat bone dehiscences or fenestrations around implants (minor augmentation procedures). We are fully aware that there are limitations in this classification, as in many classifications, since the exact borders among the different categories may not always be easily identified. However, in the future, when more information will be available, we might be able to improve this classification, making it more detailed and precise. We also divided trials which evaluated two different aspects of the interventions: (A) whether and when a certain augmentation procedure is necessary; and (B) which is the most effective augmentation technique for a precise clinical indication. This distinction is of great relevance since it is possible that many complicated, painful, discomfortable and even potentially dangerous procedures are widely performed, despite their lack of improvement of the treatment prognosis or the patients' quality of life.

Three trials can be used to evaluate whether and when augmentation procedures are indicated (Dahlin 1991; Stellingsma 2003; Chen 2005b).

- One split-mouth trial (Dahlin 1991), which nowadays can be considered a historical trial, was designed to test as a proof or principle whether it was possible to regenerate new bone around fenestrated implants according to the principles of guided bone regeneration (GBR). While this trial showed that bone can be regenerated at exposed implant surfaces, no proof was given that bone augmentation was actually necessary or provided any kind of benefit to the patients. This is not to say that it is not useful to regenerate bone around exposed implant surfaces, however it should be acknowledged that there is not any available evidence yet proving that it could be useful. It could also be that the real indications for regenerating bone around exposed implant surfaces are more restricted than what is generally believed.

- One parallel design trial (Chen 2005b) evaluated whether autogenous bone grafting was needed at single immediate implants placed in fresh extraction sockets at maxillary anterior and premolar sites. No statistically significant differences could be observed among the groups, which included only few patients. However, all complications and failures (one abscess which determined an early implant failure, one dehiscence and another implant failure) occurred at the augmented sites, whereas no complication or failure occurred at the non-augmented control sites.

- Even more interesting are the findings of the other trial (Stellingsma 2003). The authors, with a well designed and conducted trial, investigated which was the best technique for treating edentulous patients having resorbed mandibles (6 to 12 mm of bone height) and being dissatisfied with their dentures. Three treatment alternatives were tested: (1) iliac crest interposed bone grafting; (2) short implants; and (3) transmandibular implants. We were not interested in the latter option, which performed worse than the short implant alternative. For almost any of the outcome measures considered, the bone graft technique performed statistically and clinically significantly worse than short implants. Therefore, when considering resorbed mandibles, the interposed iliac crest bone grafting technique which, by the way, is generally

considered the best option currently available for this indication, may not be the optimal choice.

It is therefore useful to underline that when evaluating the only three properly designed trials to test whether augmentation procedures are needed, in one case, despite being able to partly achieve its goals, the clinical usefulness of GBR was not assessed (Dahlin 1991); in another trial (Chen 2005b), despite no statistically significant difference being observed (the sample size was small), all complications and failures occurred at the augmented sites and none at the non-augmented control sites; whereas in the case of atrophic mandibles (Stellingsma 2003), the augmentation procedure resulted in more serious complications (including a life threatening sublingual edema), major discomfort and pain, significant costs for society, longer treatment time, and clinically poorer outcomes. These examples should clearly illustrate that a more critical approach should be taken when evaluating the need for bone augmentation procedures for dental implants.

When evaluating which are the most effective augmentation techniques for specific clinical situations we have 11 trials providing some indications for five different clinical conditions: (1) the atrophic posterior maxilla (Wannfors 2000; Hallman 2002; Raghoebar 2005; Szabó 2005; Raghoebar 2006); (2) vertical ridge augmentation (Chiapasco 2004; Chiapasco 2007; Merli 2007); (3) horizontal ridge augmentation for single implants (Meijndert 2007); (4) immediate implants in fresh extraction sockets (Cornelini 2004; Chen 2005a; Chen 2007); and (5) bone dehiscences or fenestrations around implants (Carpio 2000; Jung 2003).

(1) When comparing a one-stage monocortical bone block versus a two-stage technique with particulate bone harvested from the iliac crest for maxillary sinus lifting, no statistically or clinically significant differences were observed (Wannfors 2000). However, the use of autogenous bone blocks from the iliac crest in a one-stage procedure is a technique nowadays seldom used and most of the sinus lifting procedures are now performed under local anaesthesia. The available evidence suggests that with a one-stage approach it is possible to achieve similar results as with a two-stage approach with the advantage of shortening the healing period and avoiding one surgical intervention. Of particular clinical interest are the results of those trials testing the efficacy of bone substitutes in maxillary sinuses having less than 5 mm of residual alveolar bone (Hallman 2002; Szabó 2005). With a relatively simple, rapid and cheap procedure it was possible to achieve similar good results as those obtained with what is considered to be the gold standard procedure: autogenous bone. Another advantage when using bone substitutes is that patient morbidity can be decreased since there is no need to harvest autogenous bone. Therefore, autogenous bone grafting might be replaced by bone substitutes for this indication. We found such results a bit surprising, nevertheless such type of trials deserve some sort of priority in the research agenda in order to see whether similar results can be obtained by other centres with larger patient samples, before the use of bone substitutes could be recommended as a routine treatment for augmenting resorbed maxillary sinuses. Too little evidence (only five patients treated with a split-mouth design) was available to evaluate the clinical efficacy, if any, of platelet-rich plasma (PRP) (Raghoebar 2005). When comparing titanium versus resorbable screws for holding buccal onlay autogenous grafts, despite no significant differences being observed (Raghoebar 2006), although the sample size of eight patients is too small to be able to detect any difference, the observation that two resorbable screws broke at insertion and that a considerable amount of remnants of the resorbable screws were still visible after 9 months and were surrounded by fibrotic tissue rich in giant cells may suggest that titanium screws are still the best choice.

(2) Osteodistraction, various GBR techniques and autogenous block grafting can be successful for augmenting bone vertically (Chiapasco 2004; Chiapasco 2007; Merli 2007). However, there is insufficient evidence to suggest if one technique is preferable. The osteodistraction technique may not be used in all circumstances (for instance in the presence of thin knife-edge bone), it is more expensive than GBR and bone grafting, but may reduce treatment time and allow for more vertical ridge augmentation, if needed. On the other hand GBR and bone grafting techniques also allow for simultaneous bone widening, if needed. Two transient paraesthesiae of the chin area, two transient paraesthesiae of the alveolar inferior nerve as well as a permanent paraesthesia were reported. The use of intraoral donor sites should be carefully evaluated. GBR techniques were also associated with high complication rates (50% in Chiapasco 2004 and 40% in Merli 2007), however only 15% of the interventions resulted in the failure of the GBR procedure (Merli 2007). It is therefore recommended that both clinicians and patients carefully evaluate the pros and cons in relation to the desired outcome before deciding whether to use vertical ridge augmentation techniques.

(3) The largest trial included in this review compared three different two-stage techniques to horizontally augment bone to allow placement of single implants (Meijndert 2007). Thirty-one patients were included in each group and aesthetic outcomes were assessed both by the patients and a blinded experienced evaluator. Unfortunately most of the data were presented aggregated and not by study group, meaning that it was not possible to use them to compare advantages or disadvantages of the individual techniques. For 62 patients a block of bone was retrieved from the chin, whereas in 31 patients the defects were reconstructed with 100% bone substitute (Bio-Oss) and a resorbable barrier. Despite these relatively high numbers, the authors confirmed to us that not a single complication occurred. These are remarkable results not confirmed by other trials included in the present review. Only two implants failed early in the bone substitute group, although they were successfully replaced. The healing period used for the

bone substitute group was 3 months longer, but on the other hand no autogenous bone was needed to complete the procedure. At present it is still difficult to recommend which should be the procedure to be used and additional information is needed to confirm these results.

(4) No differences were observed for various techniques aimed at augmenting single immediate implants in fresh extraction sockets (Cornelini 2004; Chen 2005a; Chen 2007) with the exception of a slightly higher position (1.2 mm) of the gingival margin in relation to the implant head for sites augmented with Bio-Oss plus barrier when compared to barrier alone (Cornelini 2004). Due to the small sample size, there is insufficient evidence to suggest whether one technique could be preferable. Aesthetic parameters are also important for evaluating the efficacy of augmentation procedures at implants placed in fresh extraction sockets. In one trial aesthetics were evaluated by the patients being questioned by the operator (Chen 2007). In a couple of trials the position of the perimplant soft tissue margins (Cornelini 2004; Chen 2007) was evaluated by the dentists, however no independent blind outcome assessors were used in one trial (Chen 2007). There is the need to evaluate aesthetic parameters in an objective way, and, moreover, it is important that the final users, i.e. the patients, and not the providers, evaluate the aesthetic results. In one trial (Chen 2007) it was reported that after delivery of the restorations, 90% of the patients were satisfied with the aesthetic results, whereas the provider was not satisfied in more than 1/3 of the cases and additional interventions (soft tissue grafts) were provided to improve the situation. After 3 years in function, the operator was still unsatisfied with the aesthetic appearance of more that 1/3 of the cases. The potential differences in aesthetics as perceived by patients and dentists should also be properly explored. It might also be worth evaluating the efficacy of 'old-fashioned' alternatives to dental implants such as adhesive bridges and soft tissue corrections, when needed, in long term RCTs.

(5) No differences were observed for two techniques aimed at augmenting bone at implants with dehiscence/fenestration (Carpio 2000). There are two possible options: either there were too few patients included in the trial to detect a statistically significant difference or that no major differences among the different tested techniques exist. Clinical trials with larger patient samples have to be conducted to find out the correct answer. However, a placebo-controlled split-mouth trial testing the effect of a human bone promoting factor (rhBMP-2) (Jung 2003), judged to be at low risk of bias, showed a borderline statistically significant difference in defect height reduction of 1.5 mm favouring implants treated with rhBMP-2. The authors tested the active factor (rhBMP-2) and the placebo at a distance as close as 7 mm (or less) in the same patient. Since we do not know too much about the systemic effects and at which distance 'active' molecules might be effective, the risk of cross-over effects cannot be ruled out.

Another generally accepted 'paradigm', which has not been confirmed in the present systematic review, is that of autogenous bone as being the 'gold standard' for bone augmentation procedures. Actually the majority of the trials included in this review suggested that this may not be always the case. A more cautious approach to autogenous bone collected with 'bone traps' might be needed. Abscesses, fistulas and dehiscences occurred in several trials in which autogenous bone fragments collected with bone traps were used (Carpio 2000; Chiapasco 2004; Chen 2005a; Chen 2005b; Merli 2007), despite antibiotic prophylaxis being generally administered, and dedicated suction devices being used to collect bone. It is in fact known that a considerable amount of bacteria can be found in the particulate bone collected with bone traps also when dedicated suction devices are used (Young 2001). A recent systematic review evaluating studies examining bone debris collected with the use of bone collectors (Graziani 2007) also suggested caution with the use of bone filters. Even for sinus lift procedures, bone substitutes might be able to replace autogenous bone, though such preliminary findings need to be confirmed by larger and more 'robust' trials.

With respect to generalization of the results of the present review to general practice, many of the augmentation procedures evaluated were rather complex, were performed by experienced and skillful clinicians, patients were undergoing strict post-operative control regimens, complications were common, and in few instances serious. Caution is therefore recommended when deciding to use any augmentation procedure. The first clinical question that clinicians should ask themselves is which are the added benefits for the patient by applying such procedures. Then the expected benefits need to be carefully weighted against the risk of complications of the chosen procedure.

AUTHORS' CONCLUSIONS

Implications for practice

- Three trials investigated whether and when augmentation procedures are necessary.

(1) The augmentation of resorbed mandibles of 6 to 12 mm height with an interposed iliac crest graft resulted in more surgical and prosthetic complications, and statistically significantly more implant failures, severe pain, days of hospitalisation, costs, and longer treatment time than using short implants. The current evidence may not justify major bone grafting procedures for resorbed mandibles.
(2) There is evidence that non-resorbable barriers allow statistically significantly more bone regeneration than no barrier at fenestrated implants, however it is not proven that such newly generated bone is of any use or benefit for the patient. While bone regenerative procedures at exposed implants might be useful, there is not yet reliable evidence of which are the proper indications.

(3) There is not enough reliable evidence supporting or refuting the need for augmentation procedures at immediate implants placed in fresh extraction sockets.

- Fourteen trials investigated which are the most effective augmentation techniques for specific clinical indications.

(1) Bone substitutes (Bio-Oss and Cerasorb) might be equally effective as autogenous bone grafts for augmenting atrophic maxillary sinuses, therefore they might be used as a replacement to autogenous bone grafting, though these preliminary findings need to be confirmed by large multicentre trials.
(2) Various augmentation techniques are able to regenerate bone in a vertical direction, however, there is insufficient evidence to indicate which technique could be preferable. Osteodistraction is of little use in the presence of thin ridges, but may allow more vertical regeneration. Complications with guided bone regeneration (GBR) techniques are common, and in some cases determined the failure of the augmentation procedure. Clinicians and patients should carefully evaluate the benefits and risks in relation to the desired outcome when deciding whether to use vertical ridge augmentation techniques.
(3) Various augmentation techniques are able to regenerate bone horizontally, however, there is insufficient evidence to indicate which technique could be preferable. It appears that a bone substitute (Bio-Oss) can be used with a slightly higher risk of having an implant failure.
(4) There is no reliable evidence supporting the superior success of any of the alternative techniques for augmenting bone at fenestrated implants.
(5) There is not enough reliable evidence proving the superior success of any of the alternative techniques for augmenting bone at immediate implants placed in fresh extraction sockets. Sites treated with barrier plus Bio-Oss showed a higher position of the gingival margin, when compared to sites treated with barriers alone.
(6) Bone morphogenetic proteins (rhBMP-2) used in conjunction with Bio-Oss and resorbable barriers may promote bone formation at exposed implants with bone fenestration and dehiscences.
(7) There is insufficient evidence supporting or confuting the efficacy of various active agents such as platelet rich plasma in conjunction with implant treatment.
(8) Titanium screws might be preferable to resorbable poly (D,L-lactide) acid screws to fix onlay bone blocks.
(9) It can be hypothesized that the use of particulate autogenous bone collected from intraoral locations with bone filters attached to suction devices might be associated with an increased risk of infective complications. These findings are based on few trials including few patients, having sometimes short follow up, and being often judged to be at high risk of bias.

Implications for research

In order to understand when bone augmentation procedures are needed and which are the most effective techniques for the specific clinical indications, larger and well designed trials are needed. Such trials should be reported according to the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Moher 2001) (http://www.consort-statement.org/). It is difficult to provide clear indications with respect of which augmentation procedures should be tested first, however, once established in which clinical situations augmentation procedures are actually needed, priority could be given to those interventions which look simpler, less invasive, involve less risk of complications, and reach their goals within the shortest timeframe. The efficacy of bone substitutes for replacing autogenous bone in augmenting severely atrophic maxillary sinuses should be confirmed by large multicentre trials. It would also be worth evaluating further the potential ability of bone morphogenetic proteins (rhBMP-2) to favour bone growth in conjunction with bone substitutes, autogenous bone, and with a combination of the two. It should also be evaluated which donor sites provide the sufficient amount of bone with less risk of complications and patient discomfort. Patient centred outcomes ought to be considered when designing such trials. Trials on augmentation procedures at implants placed in fresh extraction sockets should evaluate first whether such procedures are necessary. 'Objective' aesthetic outcomes assessed by blind outcome assessors and the patient's own perception of aesthetics also need to be properly evaluated.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

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

Carpio 2000

Methods	Randomised, parallel group study (follow up to abutment connection; 6 months). There were no withdrawals.
Participants	Patients with bone dehiscences or fenestrations around implants at implant placement. Adults treated at the University of Buffalo, New York, USA. Patients were excluded if they were heavy smokers, required lateral

Carpio 2000

(*Continued*)	
	ridge or sinus augmentation prior to implant placement, or suffered from diabetes, hyperparathyroidism, osteoporosis, severe liver or kidney condition, active sinusitis, cancer or using immunosupressive or corticosteroids, were or could have been pregnant, or had any addiction to drugs or alcohol. 48 patients enrolled (23 in the collagen group and 25 in the ePTFE group).
Interventions	Resorbable porcine-derived collagen barrier membrane (BioGide, Geistlich Pharmaceutical, Wolhusen, Switzerland) versus non-resorbable ePTFE barrier (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA). Both groups had a 50%:50% mixture of bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) and autogenous bone derived from the osteotomy site placed beneath the barrier. All implants were turned surface, screw-type, titanium (Implant Innovations Inc., West Palm Beach, Florida, USA). The barrier was stabilised with either 2 polylactic acid bioabsorbable pins (Osseofix, Implant Innovations Inc., or Resor-Pin, Geistlich Pharmaceutical, Wolhusen, Switzerland), the implant cover screw or the mucogingival flap.
Outcomes	Implant failure at abutment connection (6 months). Morbidity measures as implant exposure, wound dehiscence, and barrier exposure. These were undertaken at 2, 5, 7, 10, 15, 21, 28 days post-operatively and then monthly up to 6 months. The bone graft size was calculated as the difference in length, width and circumference of the bone defect around the implant measured at implant placement and 6 months later at the implant exposure surgery.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Chen 2005a

Methods	2-year post-loading randomised, parallel group study. There were no withdrawals.
Participants	Patients requiring immediate implant placement in 1 maxillary anterior or premolar tooth site. Adults treated at a private practice in Melbourne, Australia. Patients were excluded if there was an acute infection or suppuration at the planned implant site, if they smoked, and if there were psychological or systemic contraindications. 11 patients enrolled in the resorbable group, 12 in the non-resorbable group and 13 in the resorbable plus autogenous bone group.
Interventions	Non-resorbable ePTFE barrier (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) alone versus resorbable barrier (Resolut, Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) alone versus resorbable barrier (Resolut) supported by particulate autogenous bone harvested from the implant site by means of a filter attached to a dedicated suction line (Osseus Coagulum Trap, Quality Aspirators, Duncanville, TX, USA). All barriers were tucked beneath the flaps. Wound closure was achieved by use of a connective tissue graft taken from the palate. Implants were submerged and left to heal for 6 months. All implants were turned surface, screw-type, titanium Brånemark implants (Nobel Biocare, Göteborg, Sweden). All patients were rehabilitated with single implant supported crowns.
Outcomes	Prosthesis failure, implant failure, post-operative complications at augmented sites. Various bone measurements at the augmentation intervention and at abutment connection.
Notes	Though published as a single RCT, the authors actually conducted 2 different randomised trials in the way we presented the data.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Chen 2005b

Methods	2-year post-loading randomised, parallel group study. There were no withdrawals.
Participants	Patients requiring immediate implant placement in 1 maxillary anterior or premolar tooth site. Adults treated at a private practice in Melbourne, Australia. Patients were excluded if there was an acute infection or suppuration at the planned implant site, if they smoked, and if there were psychological or systemic contraindications. 12 patients enrolled in the control group and 14 in the bone grafted group.
Interventions	Particulate autogenous bone harvested from the implant site by means of a filter attached to a dedicated suction line (Osseus Coagulum Trap, Quality Aspirators, Duncanville, TX, USA) versus no augmentation procedure. Wound closure was achieved by use of a connective tissue graft taken from the palate. Implants were submerged and left to heal for 6 months. All implants were turned surface, screw-type, titanium Brånemark implants (Nobel Biocare, Göteborg, Sweden). All patients were rehabilitated with single implant supported crowns.
Outcomes	Prosthesis failure, implant failure, post-operative complications at augmented sites. Various bone measurements at the augmentation intervention and at abutment connection.
Notes	Though published as a single RCT, the authors actually conducted 2 different randomised trials in the way we presented the data.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Chen 2007

Methods	3-year post-loading randomised, parallel group study. There were 8 drop outs at 3 years. 5 patients dropped out from the Bio-Oss + resorbable group and 3 patients from the Bio-Oss group.
Participants	Patients requiring immediate implant placement in 1 maxillary anterior or premolar tooth site. Adults treated at a private practice in Melbourne, Australia. Patients were excluded if there was an acute infection or suppuration at the planned implant site, clinical attachment loss of 5 mm or more on the buccal aspect, and if there were psychological or systemic contraindications. 10 patients enrolled in each group.
Interventions	Bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) versus Bio-Oss plus resorbable porcine-derived collagen barrier (Bio-Gide). Barriers were trimmed as required and fixed to the implants by the healing screw. Implants were not submerged and left to heal for 6 months. All implants were ITI SLA (Institut Straumann AG, Waldenburg, Switzerland). All patients were rehabilitated with

Chen 2007

(*Continued*)

	single implant supported crowns.
Outcomes	Prosthesis failure, implant failure, post-operative complications at augmented sites. Various bone measurements at the augmentation intervention and at abutment connection. Aesthetics were assessed by patients and by the operator (recession of the mucosal margin).
Notes	The original trial included also a control group that received no graft or barrier, which could not be used in the evaluation due to subversion of the randomisation procedure.

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Chiapasco 2004

Methods	3-year post-loading follow-up randomised, parallel group study. There were no withdrawals.
Participants	Patients subjected to vertical augmentation procedures. Adults treated at the University of Milan, Italy. Patients were excluded if they presented a severe knife-edge ridge, bone defect following tumor resection, smoking more than 15 cigarettes per day, severe renal and liver disease, history of radiotherapy in the head and neck region, chemotherapy at the time of the surgical intervention, non-compensated diabetes, active periodontal disease, mucosal disease, such as lichen planus in the areas to be treated, poor oral hygiene, non-compliant. 21 patients enrolled, 11 in the GBR group and 10 in the osteodistraction group.
Interventions	Non-resorbable titanium-reinforced ePTFE barrier (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) supported by particulated autogenous bone harvested from the mandibular ramus and sometimes from the chin versus vertical distraction osteogenesis. 2 different vertical GBR procedures were used: 6 patients were treated with a 1-stage approach (implants were inserted and the augmentation procedure was performed on the same occasion) whereas 5 patients were treated with a 2-stage approach (first the bone at the site was augmented and left to heal for 6/7 months, and then implants were placed). The 2-stage approach was used when the risk of insufficient primary implant stability of implants was subjectively expected. With the 2-stage approach 1 or 2 titanium miniscrews were used as additional support for the barriers. All barriers were stabilized with titanium fixating pins (Frios, Friadent GmbH, Mannheim, Germany) or miniscrews (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany) or both. The distraction procedure was accomplished by using osteodistractors (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany) fixed to the bone segments with 1.5 mm large titanium screws. The distraction devices were activated after 1 week, twice a day (0.5 mm every 12 h) until the desired amount of distraction was obtained. Surgical templates were used to optimize implant insertion. 2 implant systems were used: Brånemark Mark III implants, (Nobel Biocare, Göteborg, Sweden) and ITI SLA implants, (Institut Straumann AG, Waldenburg, Switzerland). All patients were rehabilitated with screw-retained metal-ceramic fixed prostheses.
Outcomes	Prosthesis failure, implant failure and marginal bone level changes on intraoral radiographs taken with a paralleling technique at abutment connection, 1, 3 and 5 years. Intra- and post-operative complications at both augmentation and at donor sites. Bone gain from the augmentation intervention to the abutment connection.

Chiapasco 2004

(*Continued*)

Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	No	C - Inadequate

Chiapasco 2007

Methods	3-year post-loading follow-up randomised, parallel group study. There were no withdrawals.
Participants	Patients subjected to vertical augmentation procedures. Adults treated at the University of Milan, Italy. Patients were excluded if they presented a severe knife-edge ridge, bone defect following tumor resection, smoking more than 15 cigarettes per day, severe renal and liver disease, history of radiotherapy in the head and neck region, chemotherapy at the time of the surgical intervention, non-compensated diabetes, active periodontal disease, mucosal disease, such as lichen planus in the areas to be treated, poor oral hygiene, non-compliant. 17 patients enrolled, 8 in the bone graft group and 9 in the osteodistraction group.
Interventions	Autogenous onlay bone grafts harvested from the mandibular ramus versus vertical distraction osteogenesis to vertically augment deficient mandibles. Patients were grafted with a 2-stage approach: first bone blocks were fixed with 1.5 mm diameter miniscrews (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany). Empty spaces were filled with cancellous bone chips. In case of severe vertical resorption, grafts were assembled in a multilayered fashion. No barriers were used. Bone grafts were harvested from the mandibular ramus of the same side of reconstruction in 6 patients, while in 2 patients, where larger defects were present, bone was harvested bilaterally. After 4/5 months implants were placed and left submerged for an additional 3/4 months. The distraction procedure was accomplished by using osteodistractors (Gebrüder Martin GmbH & Co., KG, Tuttlingen, Germany) fixed to the bone segments with 1.5 mm large titanium screws. The distraction devices were activated after 1 week, twice a day (0.5 mm every 12 h) until the desired amount of distraction was obtained (2 to 7 mm). The bone segments were then left to consolidate for 2 to 3 months, the osteodistractors were then removed and dental implants placed and left submerged for 3/4 months. The augmentation procedures were performed under local anaesthesia, local anaesthesia with intravenous sedation and general anaesthesia according to operator and patient preferences. Surgical templates were used to optimise implant insertion. ITI SLA implants (Institut Straumann AG, Waldenburg, Switzerland) were used. All patients were rehabilitated with screw-retained metal-ceramic fixed prostheses.
Outcomes	Prosthesis failure, implant failure and marginal bone level changes on intraoral radiographs taken with a paralleling technique at abutment connection, 1, 3 and 5 years. Intra- and post-operative complications at both augmentation and at donor sites. Bone gain from the augmentation intervention to implant placement.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Cornelini 2004

Methods	Randomised, split-mouth study (follow up to implant loading; 6 months). There were no withdrawals.
Participants	Patients requiring immediate implant placement in a fresh extraction socket. Adults treated at a private practice in Rimini, Italy. Patients were excluded if there was an acute infection at the planned implant site, and if there were systemic contraindications (history of diabetes, blood coagulation disorders). 10 patients enrolled in each group.
Interventions	Resorbable porcine-derived collagen barrier (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland) versus resorbable barrier (Bio-Gide) plus bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) for immediate single transmucosal implants placed in fresh extraction sockets 2 to 3 mm apical to the cementoenamel junction of the adjacent teeth. Barriers were fixed to the implants by the healing screw. Implants were left to heal for 6 months. All implants were ITI SLA (Institut Straumann AG, Waldenburg, Switzerland). All patients were rehabilitated with single implant supported crowns.
Outcomes	Prosthesis and implant failure and aesthetics (recession of the mucosal margin).
Notes	

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	B - Unclear

Dahlin 1991

Methods	Randomised, split-mouth study (follow up to implant loading; 6 to 7 months). There were no withdrawals.
Participants	Maxillary edentulous patients with buccal fenestrations around implants at implant placement. Adults treated at the Central Hospital, Västerås, Sweden. Patients were included if they were edentulous and had a vertical height of alveolar bone not less than 13 mm, with horizontal resorption and buccal concavities causing potential risk for fenestration at implant placement on computer tomography scan. 7 patients enrolled.
Interventions	Non-resorbable ePTFE barrier (Gore-Tex, WL Gore and Associates, Inc., Flagstone, USA) versus no barrier. All implants were turned surface, screw-type, titanium self tapping Brånemark (Nobel Biocare, Göteborg, Sweden). A slight space was maintained over the exposed implant surface by manual convex shaping of the barrier which was locked in position by tucking 1 edge under the periosteum. No bone chips or synthetic materials were used as space maintainer. Barriers were allowed to extend 3 to 4 mm around the defect and kept for 6/7 months.
Outcomes	Implant failure at abutment connection (after 6/7 months). Complications. The percentage of new formed bone was calculated as the difference in surface area of exposed implant on digitised photographic images, measured using a computer image analysis software, taken at implant placement and at implant exposure surgery.
Notes	

Risk of bias

Dahlin 1991

(*Continued*)

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Hallman 2002

Methods	1-year post-loading follow-up randomised, split-mouth study wich included a third group formed by patients having a definite preference. There were no withdrawals.
Participants	Patients having less than 5 mm of alveolar bone in the floor of the sinus. Adults treated at the Gävla Hospital, Gävla, Sweden. No specific exclusion criteria were given. 11 patients were treated in the split-mouth study and 10 in the preference trial.
Interventions	1-stage sinus lift with autogenous particulate bone from the mandibular ramus versus 1-stage sinus lift with a mixture of 80% of bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) and 20% of particulate bone from the mandibular ramus left to heal for 6 months. A fibrin glue (Tisseel Duo Quick, Immuno, Wien, Austria) was added to the grafts after thrombin (Thrombin, Immuno, Wien, Austria). A third group was composed by patients who refused to provide autogenous bone but accepted the treatment with a 1-stage sinus lift with 100% of bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland). For the latter group a resorbable porcine-derived collagen barrier (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland) was used to cover the defect of sinus, and the healing time was prolonged to an average of 8.5 months (range: 8 to 9.5). Procedures were performed under local anaesthesia and oral sedation. All implants were turned titanium self tapping (Nobel Biocare, Göteborg, Sweden): Mark II type implants were used in the former 2 groups and Mark III in the latter. All patients were rehabilitated with screw-retained metal-ceramic fixed prostheses.
Outcomes	Prosthesis and implant failure. Complications at the augmented and donor sites. Histomorphometrical evaluation.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Jung 2003

Methods	Randomised, split-mouth, placebo-controlled study (follow up to abutment connection; 6 months). 1 patient in which a complication occurred at the test site was excluded, but author kindly provided the missing data.
Participants	Partially edentulous patients in good general health showing at least 2 bone dehiscences or fenestrations at implant placement. Distance between test and control implants had to be of at least 7 mm. Adults treated

Jung 2003

(*Continued*)	
	at the University Hospital of Zurich, Switzerland. No specific exclusion criteria were given. 11 patients were treated.
Interventions	Recombinant human bone morphogenetic protein-2 (rhBMP-2; 1 ml of 0.5 mg/ml) versus placebo (1 ml of 0.01% triflouroacetic acid) on GBR using bovine anorganic bone (Bio-Oss, Geistlich Pharmaceutical, Wolhusen, Switzerland) and resorbable porcine-derived collagen barrier (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland) at implants showing bone dehiscences or fenestrations at placement. The barriers were trimmed and adapted in order to overlap the defect border by a minimum 2 mm, and were stabilized with polylactic acid bioabsorbable pins (Resor-Pin, Geistlich Pharmaceutical, Wolhusen, Switzerland) and were kept for 6 months. All implants were turned surface, screw-type, titanium Mark II, III or IV Brånemark implants (Nobel Biocare, Göteborg, Sweden).
Outcomes	Implant failure at abutment connection (6 months). Various perimplant bone defect measurements, measured intrasurgically, pre-operatively and at abutment connection. Post-operative complications such as implant exposure, barrier exposure and inflammation during the 6-month period. Histomorphometrical assessment of cylindrical bone biopsies.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Meijndert 2007

Methods	1-year post-loading follow-up randomised, parallel group study including 3 groups. There were no withdrawals.
Participants	Patients with a horizontal bone deficit in the anterior maxilla (incisor, cuspid and first bicuspid) requiring a single implant. Adults treated at the University Hospital Groningen and at Nij Smellinghe Christian Hospital in Drachten. Patients were excluded if smoked, had active periodontitis, diabetes, radiotherapy in the head and neck region, chemotherapy, acute inflammatory oral disease, mental or physical disabilities impairing oral hygiene, and history of reconstructive preprosthetic surgery or previous implant surgery. 31 patients included in each group.
Interventions	3 different techniques to horizontally augment local ridge maxillary defects (from 1st to 1st premolars) for allowing placement of single implants were tested: (1) bone graft from the chin; (2) bone graft from the chin with a resorbable barrier (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland); (3) 100% bovine anorganic bone (Bio-Oss, spongiosa granules of 0.25-1 mm, Geistlich Pharmaceutical, Wolhusen, Switzerland) with a Bio-Gide resorbable barrier. The cortical bone of the recipient sites was perforated to create a bleeding bone surface and to open the cancellous bone. Bone blocks from the chin were fixed with a 1.5 mm diameter titanium screw (Martin Medizin Technik, Tuttlingen, Germany) and particulate bone from the chin was placed around the fixed bone grafts. Implants were placed 3 months after autogenous bone grafting and 6 months after augmenting sites with Bio-Oss. Single ITI-EstheticPlus implants (Institut Straumann AG, Waldenburg, Switzerland) were placed using templates and left healing submerged for 6 months. On the day of uncovering provisional single crowns were screwed on the implants and were

Meijndert 2007

(*Continued*)	
	replaced 1 month after by final porcelain crowns with a zirconium oxide core (Procera, Nobel Biocare, Göteborg, Sweden).
Outcomes	Prosthesis and implant failure, marginal bone level changes on intraoral radiographs taken with a paralleling technique 1 and 12 months after loading, patient satisfaction, aesthetics by patient and aesthetics by dentist at 1 year.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Merli 2007

Methods	Randomised, parallel group study (follow up to implant loading; 5 months). There were no withdrawals.
Participants	Patients subjected to vertical GBR procedures. Adults treated at a private practice in Rimini, Italy. Patients were excluded if they had any general contraindication to implant surgery, history of irradiation in the head and neck area, poor oral hygiene and motivation, uncontrolled diabetes, pregnant or lactating, substance abusers, smoking more than 20 cigarettes per day. 22 patients enrolled, 11 in each group.
Interventions	Autogenous particulate bone harvested from intraoral locations contained under non-resorbable titanium-reinforced ePTFE barrier (Gore-Tex, WL Gore and Associates, Inc.) fixed with miniscrews (Gebrüder Martin GmbH & Co. KG, Tuttlingen, Germany) versus osteosynthesis plates (Gebrüder Martin GmbH & Co. KG, Tuttlingen, Germany), appropriately shaped and fixed with miniscrews, supporting resorbable collagen barriers (Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland). All patients were treated with a 1-stage approach, i.e. implants were inserted and the augmentation procedure was performed on the same occasion with or without intravenous sedation. Surgical templates were used to optimize implant insertion. XiVES CELLplus (Friadent GmbH, Mannheim, Germany) implants were used. All patients were rehabilitated with provisional resin fixed prostheses.
Outcomes	Implant failure at delivery of provisional prostheses (6 months or more). Vertical bone gain, measured intrasurgically pre-operatively and at abutment connection. Any sort of post-operative complications such as infection, implant exposure, barrier exposure and inflammation during the healing period.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

Raghoebar 2005

Methods	2-year post-loading follow-up randomised, split-mouth study. There were no withdrawals.
Participants	Patients with severely resorbed maxilla and reduced stability and retention of the upper denture. Adults treated at the University Hospital Groningen, The Netherlands. Patients were excluded if were edentulous for a period less than 1 year, history of irradiation in the head and neck area, history of reconstructive preprosthetic surgery or previous implant surgery. 5 patients were treated.
Interventions	2-stage sinus lift with autogenous blocks and particulate bone together with buccal onlays monocortico-cancellous bone grafts, to reconstruct the width of the maxilla, fixed with titanium screws harvested from the iliac crest with or without PRP left to heal for 3 months in a split-mouth trial. Barriers were not used. PRP was made using the Platelet Concentration Collection System kit (PCCS kit, 3i Implant Innovations Inc. Palm Beach Gardens, FL, USA). 54 ml of blood were mixed with 6 ml of anticoagulant (citrate dextrose) and processed with the platelet concentration system. To promote the release of growth factors from the platelets, 10% calcium chloride solution and the patient's serum, as a source of autologous thrombin, were added before actual reconstruction of the defect with the bone graft. The resulting gel was mixed with the bone graft and some gel was applied at the closure of the wound at the side treated with PRP. 3 implants were inserted into the healed graft of each side and were left to heal for an additional 6 months. All the augmentation procedures were performed under general anaesthesia. Surgical templates were used to optimise implant insertion. All implants were turned titanium self tapping (Nobel Biocare, Göteborg, Sweden) and were rehabilitated with 2 implant supported prostheses.
Outcomes	Prosthesis and implant failure. Complications at the augmented and donor sites. Histomorphometrical evaluation.
Notes	

Risk of bias

Item	**Authors' judgement**	**Description**
Allocation concealment?	Unclear	B - Unclear

Raghoebar 2006

Methods	2-year post-loading follow-up randomised, split-mouth study. There were no withdrawals.
Participants	Patients with severely resorbed maxilla and reduced stability and retention of the upper denture. Adults treated at the University Hospital Groningen, The Netherlands. Patients were excluded if were edentulous for a period less than 1 year, history of irradiation in the head and neck area, history of reconstructive preprosthetic surgery or previous implant surgery. 8 patients were treated.
Interventions	2-stage buccal onlays monocortico-cancellous bone grafts fixed with 2 titanium (diameter 1.5 mm, Martin Medizin Technik, Tuttlingen, Germany) or resorbable poly (D,L-lactide) acid (PDLLA, diameter 2.1 mm, Resorb X, Martin Medizin Technik) screws in a split-mouth trial, to reconstruct the width of the maxilla. Grafts were covered with resorbable barriers (Bio-Gide, Geistlich Pharmaceutical, Wolhusen, Switzerland). Grafts were harvested from the iliac crest and bilateral sinus lifts were performed at the same time with autogenous blocks and particulate bone. After 3 months, implants were inserted into the healed graft of each side and were left to heal for additional 6 months. All the augmentation procedures were performed

Raghoebar 2006

(*Continued*)	
	under general anaesthesia. Surgical templates were used to optimise implant insertion. All implants were turned titanium self tapping (Nobel Biocare, Göteborg, Sweden) and were rehabilitated with implant supported prostheses.
Outcomes	Prosthesis and implant failure. Complications at the augmented and donor sites. Histomorphometrical evaluation.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Stellingsma 2003

Methods	2-year post-loading follow-up randomised, parallel group study. There were 2 withdrawals, 1 from each evaluated study group due to death and moving.
Participants	Patients with resorbed maxillae (height between 6 and 12 mm) who have been edentulous for at least 2 years and experienced severe functional problems with their lower dentures. Adults treated at the University Hospital of Groningen, The Netherlands. Patients were excluded if they had a history of radiotherapy in the head and neck region, presprosthetic surgery or previous oral implants. 60 patients enrolled, 20 in each group.
Interventions	3 procedures were tested: (1) installation of 4 short implants (8 or 11mm) left to heal for 3 months; (2) mandibular augmentation with an autologous bone graft from the iliac crest and (3) trasmandibular Bosker implants. We were only interested in the former 2 procedures. Mandibles were augmented under general anaesthesia using the interpositional technique. The mandible was sectioned in the interforaminal area, and a bone block taken from the anterior ilium was positioned between the 2 segments which were stabilized with osteosynthesis wires and left to heal for 3 months. The wires were then removed, and 13 to 18 mm long implants were placed and left to heal for an additional 3 months. The short implants used were Twin Plus IMZ implants (Friatec, Mannheim, Germany) whereas the augmented mandibles were treated with 4 specially designed IMZ apical screw implants. Patients were rehabilitated with overdentures supported by an egg-shaped triple bar without cantilever extensions.
Outcomes	Prosthesis failure, implant failure, pocket probing depth, Plaque Index, Gingival Index, bleeding on probing, Periotest and change in mandibular bone height on extra-oral oblique lateral radiographs at overdenture placement, 1 and 2 years. Complications at the augmented sites. Prosthetic complications. Days of hospitalisation. Patient satisfaction was evaluated prior to the intervention and after 1 year of loading. The following aspects were investigated: denture satisfaction, denture complaints, overall denture satisfaction, the impact of denture problems on social activities, psychological well-being and experience of the surgical phase.
Notes	

Risk of bias

Stellingsma 2003

(*Continued*)

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Szabó 2005

Methods	Randomised, split-mouth study (follow up to implant loading; 6 months). There were no widrawals.
Participants	Edentulous patients having less than 5 mm of alveolar bone in the floor of the sinus. Adults treated at university hospitals in Budapest (Hungary), Manchester (UK), Milan (Italy) and in a private practice in Brugge (Belgium). No specific exclusion criteria were given and patients were healthy and had no disease that might influence the treatment outcome. 20 patients enrolled.
Interventions	2-stage sinus lift with autogenous particulate bone from the iliac crest versus 2-stage sinus lift with 1.5 to 2 g beta-tricalcium phosphate (Cerasorb, Curasan AG, Kleinostheim, Germany) left healing for 6 months. In 10 of the 20 patients the alveolar crest was also widened with cortical bone blocks fixed with microscrews. No membranes were used to cover the bone. All the augmentation procedures were performed under general anaesthesia. Patients were instructed not to wear any dentures for 30 days. In 16 patients Ankylos (Degussa, Friadent, Germany) implants were used, whereas in 4 patients Protetim (Hungary) implants were used. The authors did no provide any explanation for using 2 different implant systems. 2 implants were placed in each augmented sinus.
Outcomes	Implant failure at abument connection. Post-operative complications at the grafted site and at the donor site. Panoramic and computer tomographic imagines (CT images in 10 patients only) to provide a qualitative description of the consolidation of the grafts. Histomorphometrical assessment of cylindrical bone biopsies.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

Wannfors 2000

Methods	3-year post-loading follow-up randomised, parallel group design. There were not withdrawals at 3 years though 3 patients in the 1-stage group refused consent to remove the prostheses for testing implant stability. 5-year data not provided.
Participants	Edentulous patients with more than 2 mm but less than 7 mm of residual bone under the maxillary sinuses. Adults treated under general anaesthesia at the Karolinska Hospital, Stockholm, Sweden. Patients were included if they were edentulous in the upper jaw. Patients were excluded if they were older than 80 years, had pathologies in the maxillary sinus, had bone diseases or took medications known to effect bone metabolism (i.e. corticosteroids and biphosphonates). 40 patients enrolled, 20 in each group.

Interventions	1-stage sinus lift with monocortical iliac bone blocks fixed usually with 2 implants left to heal for 6 months versus 2-stage sinus lift with particulate bone from the iliac crest left to heal for 6 months and then usually 2 implants were inserted into the healed graft and were left to heal for an additional 6 months. All implants were titanium self tapping (Brånemark, Nobel Biocare, Goteborg, Sweden).
Outcomes	Prosthesis failure, implant failure and marginal bone level changes on intraoral radiographs taken with a paralleling technique at abutment connection, 1, 3 and 5 years. Intraoperative sinus membrane perforations.
Notes	

Risk of bias

Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

[a] GBR - guided bone regeneration
PRP - platelet-rich plasma
RCT - randomised controlled trial

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

Study	Reason for exclusion
Antoun 2001	Study previously included. Now excluded since it does not contain any outcome measures related to implant treatment.
Barone 2005	No clinical outcome measures related to implant treatment.
Bettega 2005	Protocol of a study with no clinical outcomes related to implant treatment.
Boyne 2005	Described as RCT, unclear number of patients, unequal number of patients in the treatment groups. No reply to letter.
Consolo 2007	No clinical outcome measures related to implant treatment.
Fiorellini 2005	No clinical outcome measures related to implant treatment.
Friedmann 2002	Study previously included. Now excluded since it does not contain any outcome measures related to implant treatment.
Froum 1998	Described as RCT, unclear number of patients and tested interventions which seem to be much more than 8, unequal number of patients in the treatment groups. No reply to letter.
Froum 2006	No clinical outcome measures related to implant treatment.
Gher 1994	Problems with design and analysis. The unit of randomisation was both the patient and the implant and it was not possible to use the data without further information from authors. The authors did not reply to our letter.
Kassolis 2005	No clinical outcome measures related to implant treatment.
Majzoub 1999	Unable to use data as presented on a site not patient basis. Conflicting reporting of infection and dehiscence data.
Mangano 2007	The authors informed us that the trial was not an RCT but a CCT.

Norton 2002	The author kindly informed us that the trial was not an RCT but a CCT with unequal number of patients treated in the intervention groups and with a mixed parallel group/split-mouth design.
Prosper 2003	Unclear how many patients were included in each group. No reply to the letter requesting additional clarification.
Roccuzzo 2007	No clinical outcome measures related to implant treatment.
Schaaf 2008	No clinical outcome measures related to implant treatment.
Schlegel 1998	Inappropriate study design, neither parallel group nor split mouth.
Schortinghuis 2005	Interesting placebo-controlled pilot trial evaluating the efficacy of ultrasound in stimulating bone formation in a distraction gap. Excluded since reporting only histological outcomes, however worth reading.
Steigmann 2005	No clinical outcome measures related to implant treatment.
Suba 2006	No clinical outcome measures related to implant treatment.
Tawil 2001	Inappropriate study design, neither parallel group nor split mouth.
Zitzmann 1997	Unclear study design.

[a] CCT - controlled clinical trial
RCT - randomised controlled clinical trial

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

Cannizzaro

Trial name or title	Early loading of implants in the atrophic posterior maxilla: sinus lift with DBM and Bio-Oss versus short implants. A single-blind, randomised controlled clinical trial.
Methods	
Participants	Any edentulous patient requiring implants in the posterior maxilla. Only patients with a sinus floor having a thickness between 3 to 6 mm and a width equal or more 4 mm as determined on a CT scan will be included.
Interventions	Treatment of posterior atrophic maxilla. Test group: miniature sinus lift with autogenous bone taken directly from the implant site with a trephine bur and 8 mm long implants. Control group: sinus lift with 50% DBM (demineralized bone matrix) putty and 50% Bio-Oss covered with a resorbable barrier and 10 to 16 mm long implants.
Outcomes	Prosthetic failure; implant failure; complications.
Starting date	April 2005.
Contact information	espositomarco@hotmail.com
Notes	

DATA AND ANALYSES

Comparison 1. Augmentation versus no augmentation: vertical/horizontal

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Sandwich bone grafts versus short implants in atrophic mandibles			Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.1 Prosthetic failure (2 years)	1	38	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
1.2 Implant failure (2 years)	1	38	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
1.3 Major complication at augmented site	1	40	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
1.4 Experienced the operation negatively	1	40	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
1.5 Severe pain for > 1 week	1	40	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
1.6 No improvement of facial appearance (3 weeks)	1	40	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable

Comparison 2. Augmentation versus augmentation: vertical/horizontal

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Sinus lift: 1-stage block versus 2-stage particulate bone			Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
1.1 Prosthetic failure (1 year)	1	40	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
1.2 Early implant failure	1	40	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
1.3 Complication (perforation of sinus membrane) at augmented site	1	40	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
2 Sinus lift: bone versus bone + 20% Bio-Oss			OR (Fixed, 95% CI)	Totals not selected
2.1 Implant failure (1 year)	1	22	OR (Fixed, 95% CI)	Not estimable
3 Sinus lift: bone versus 100% Cerasorb			OR (Fixed, 95% CI)	Totals not selected
3.1 Early implant failure	1	40	OR (Fixed, 95% CI)	Not estimable
4 Vertical augmentation: osteodistraction versus GBR (binary)			Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
4.1 Prosthetic failure (3 years)	1	21	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
4.2 Implant failure (3 years)	1	21	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
4.3 Augmentation procedure failure	1	21	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
4.4 Complication at augmentation + donor site	1	21	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable

5 Vertical augmentation: osteodistraction versus bone graft (binary)			Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
5.1 Prosthetic failure (3 years)	1	17	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
5.2 Implant failure (3 years)	1	17	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
5.3 Augmentation procedure (partial) failure	1	17	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
5.4 Complication at augmented + donor site	1	17	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
6 Vertical augmentation: osteodistraction versus bone graft (continuous)			Mean Difference (IV, Fixed, 95% CI)	Totals not selected
6.1 Vertical bone gain	1	17	Mean Difference (IV, Fixed, 95% CI)	Not estimable
6.2 1-year post-loading bone level changes	1	17	Mean Difference (IV, Fixed, 95% CI)	Not estimable
6.3 3-year post-loading bone level changes	1	17	Mean Difference (IV, Fixed, 95% CI)	Not estimable
7 Vertical GBR: non-resorbable versus resorbable barriers (binary)			Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
7.1 Prosthesis not delivered	1	22	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
7.2 Early implant failure	1	22	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
7.3 Augmentation procedure failure	1	22	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
7.4 Complication at augmented site	1	22	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
7.5 Complication at donor site	1	22	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
8 Vertical GBR: non-resorbable versus resorbable barriers (continuous)			Mean Difference (IV, Fixed, 95% CI)	Totals not selected
8.1 Vertical bone gain	1	22	Mean Difference (IV, Fixed, 95% CI)	Not estimable
9 Horizontal augmentation: bone versus bone + barrier			Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
9.1 Prosthesis/implant failure (1 year)	1	62	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
10 Horizontal augmentation: bone versus 100% Bio-Oss + barrier			Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
10.1 Prosthesis/implant failure (1 year)	1	62	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable
11 Horizontal augmentation: bone + barrier versus 100% Bio-Oss + barrier			Odds Ratio (M-H, Fixed, 95% CI)	Totals not selected
11.1 Prosthesis/implant failure (1 year)	1	62	Odds Ratio (M-H, Fixed, 95% CI)	Not estimable

Comparison 3. Augmentation versus no augmentation: immediate implants in extraction sockets

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Autogenous bone graft versus no augmentation (binary)			Odds Ratio (M-H, Random, 95% CI)	Totals not selected
1.1 Prosthetic failure (2 years)	1	26	Odds Ratio (M-H, Random, 95% CI)	Not estimable
1.2 Implant failure (2 years)	1	26	Odds Ratio (M-H, Random, 95% CI)	Not estimable
1.3 Complication	1	26	Odds Ratio (M-H, Random, 95% CI)	Not estimable
2 Autogenous bone graft versus no augmentation (continuous)			Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.1 Bone gain (vertical - VDH)	1	25	Mean Difference (IV, Fixed, 95% CI)	Not estimable
2.2 Bone gain (horizontal - HDD)	1	25	Mean Difference (IV, Fixed, 95% CI)	Not estimable

Comparison 4. Augmentation versus augmentation: immediate implants in extraction sockets

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Resorbable versus non-resorbable barrier (binary)			Odds Ratio (M-H, Random, 95% CI)	Totals not selected
1.1 Prosthetic failure (2 years)	1	23	Odds Ratio (M-H, Random, 95% CI)	Not estimable
1.2 Implant failure (2 years)	1	23	Odds Ratio (M-H, Random, 95% CI)	Not estimable
1.3 Complication	1	23	Odds Ratio (M-H, Random, 95% CI)	Not estimable
2 Resorbable versus non-resorbable (continuous)			Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.1 Bone gain (vertical - VDH)	1	23	Mean Difference (IV, Fixed, 95% CI)	Not estimable
2.2 Bone gain (horizontal - HDD)	1	23	Mean Difference (IV, Fixed, 95% CI)	Not estimable
3 Resorbable versus resorbable + autogenous bone (binary)			Odds Ratio (M-H, Random, 95% CI)	Totals not selected
3.1 Prosthetic failure (2 years)	1	24	Odds Ratio (M-H, Random, 95% CI)	Not estimable
3.2 Implant failure (2 years)	1	24	Odds Ratio (M-H, Random, 95% CI)	Not estimable
3.3 Complication	1	24	Odds Ratio (M-H, Random, 95% CI)	Not estimable
4 Resorbable versus resorbable + autogenous bone (continuous)			Mean Difference (IV, Random, 95% CI)	Totals not selected
4.1 Bone gain (vertical - VDH)	1	24	Mean Difference (IV, Random, 95% CI)	Not estimable
4.2 Bone gain (horizontal - HDD)	1	24	Mean Difference (IV, Random, 95% CI)	Not estimable
5 Non-resorbable versus resorbable + autogenous bone (binary)			Odds Ratio (M-H, Random, 95% CI)	Totals not selected
5.1 Prosthetic failure (2 years)	1	25	Odds Ratio (M-H, Random, 95% CI)	Not estimable
5.2 Implant failure (2 years)	1	25	Odds Ratio (M-H, Random, 95% CI)	Not estimable
5.3 Complication	1	25	Odds Ratio (M-H, Random, 95% CI)	Not estimable
6 Non-resorbable versus resorbable + autogenous bone (continuous)			Mean Difference (IV, Fixed, 95% CI)	Totals not selected

6.1 Bone gain (vertical - VDH)	1	25	Mean Difference (IV, Fixed, 95% CI)	Not estimable
6.2 Bone gain (horizontal - HDD)	1	25	Mean Difference (IV, Fixed, 95% CI)	Not estimable
7 Resorbable versus resorbable + Bio-Oss (binary)			Odds Ratio (M-H, Random, 95% CI)	Totals not selected
7.1 Prosthetic failure at insertion	1	20	Odds Ratio (M-H, Random, 95% CI)	Not estimable
7.2 Implant failure at loading (6 months)	1	20	Odds Ratio (M-H, Random, 95% CI)	Not estimable
7.3 Complication at augmented site	1	20	Odds Ratio (M-H, Random, 95% CI)	Not estimable
8 Resorbable versus resorbable + Bio-Oss (continuous)			Mean Difference (IV, Random, 95% CI)	Totals not selected
8.1 Aesthetics by dentist (mucosal margin from implant head in mm)	1	20	Mean Difference (IV, Random, 95% CI)	Not estimable
9 Bio-Oss versus Bio-Oss + resorbable (binary)			Odds Ratio (M-H, Random, 95% CI)	Totals not selected
9.1 Prosthetic failure (3 years)	1	12	Odds Ratio (M-H, Random, 95% CI)	Not estimable
9.2 Implant failure (3 years)	1	12	Odds Ratio (M-H, Random, 95% CI)	Not estimable
9.3 Augmentation failure	1	20	Odds Ratio (M-H, Random, 95% CI)	Not estimable
9.4 Complication at augmented site	1	20	Odds Ratio (M-H, Random, 95% CI)	Not estimable
9.5 Poor aesthetics measured by patient (after restoration)	1	20	Odds Ratio (M-H, Random, 95% CI)	Not estimable
9.6 Poor aesthetics measured by dentist (after restoration)	1	20	Odds Ratio (M-H, Random, 95% CI)	Not estimable
9.7 Poor aesthetics measured by dentist (3 years)	1	12	Odds Ratio (M-H, Random, 95% CI)	Not estimable
10 Bio-Oss versus Bio-Oss + resorbable (continuous)			Mean Difference (IV, Random, 95% CI)	Totals not selected
10.1 Bone gain (vertical - VDH)	1	20	Mean Difference (IV, Random, 95% CI)	Not estimable
10.2 Bone gain (horizontal - HDD)	1	20	Mean Difference (IV, Random, 95% CI)	Not estimable

Comparison 5. Augmentation versus no augmentation: fenestration

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Non-resorbable barrier versus no barrier (continuous)			mean difference (Fixed, 95% CI)	Totals not selected
1.1 Bone gain (%)	1	14	mean difference (Fixed, 95% CI)	Not estimable

Comparison 6. Augmentation versus augmentation: fenestration

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Resorbable versus non-resorbable barrier (binary)			Odds Ratio (M-H, Random, 95% CI)	Totals not selected
1.1 Early implant failure	1	48	Odds Ratio (M-H, Random, 95% CI)	Not estimable
1.2 Complication at augmented site	1	48	Odds Ratio (M-H, Random, 95% CI)	Not estimable
2 Resorbable versus non-resorbable barrier (continuous)			Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.1 Bone gain (length)	1	48	Mean Difference (IV, Fixed, 95% CI)	Not estimable
2.2 Bone gain (width)	1	48	Mean Difference (IV, Fixed, 95% CI)	Not estimable
3 rhBMP-2 versus no rhBMP-2 (continuous)			mean difference (Random, 95% CI)	Totals not selected
3.1 Bone gain (length)	1	22	mean difference (Random, 95% CI)	Not estimable

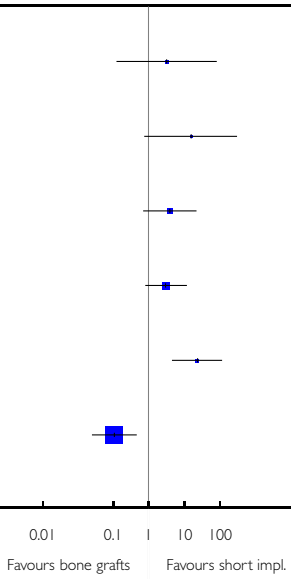
Analysis 1.1. Comparison 1 Augmentation versus no augmentation: vertical/horizontal, Outcome 1 Sandwich bone grafts versus short implants in atrophic mandibles.

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 1 Augmentation versus no augmentation: vertical/horizontal

Outcome: 1 Sandwich bone grafts versus short implants in atrophic mandibles

Study or subgroup	Bone grafts n/N	Short implants n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
1 Prosthetic failure (2 years)				
Stellingsma 2003	1/19	0/19		3.16 [0.12, 82.64]
2 Implant failure (2 years)				
Stellingsma 2003	5/19	0/19		14.79 [0.76, 289.43]
3 Major complication at augmented site				
Stellingsma 2003	6/20	2/20		3.86 [0.67, 22.11]
4 Experienced the operation negatively				
Stellingsma 2003	10/20	5/20		3.00 [0.79, 11.44]
5 Severe pain for > 1 week				
Stellingsma 2003	17/20	4/20		22.67 [4.37, 117.47]
6 No improvement of facial appearance (3 weeks)				
Stellingsma 2003	6/20	16/20		0.11 [0.03, 0.46]

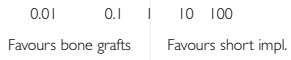


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 1 Augmentation versus no augmentation: vertical/horizontal

Outcome: 1 Sandwich bone grafts versus short implants in atrophic mandibles

Study or subgroup	Bone grafts n/N	Short implants n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
1 Prosthetic failure (2 years)				
Stellingsma 2003	1/19	0/19		3.16 [0.12, 82.64]

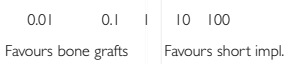


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 1 Augmentation versus no augmentation: vertical/horizontal

Outcome: 1 Sandwich bone grafts versus short implants in atrophic mandibles

Study or subgroup	Bone grafts n/N	Short implants n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
2 Implant failure (2 years)				
Stellingsma 2003	5/19	0/19		14.79 [0.76, 289.43]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 1 Augmentation versus no augmentation: vertical/horizontal

Outcome: 1 Sandwich bone grafts versus short implants in atrophic mandibles

Study or subgroup	Bone grafts n/N	Short implants n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
3 Major complication at augmented site				
Stellingsma 2003	6/20	2/20		3.86 [0.67, 22.11]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 1 Augmentation versus no augmentation: vertical/horizontal

Outcome: 1 Sandwich bone grafts versus short implants in atrophic mandibles

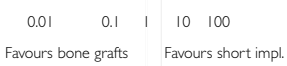
Study or subgroup	Bone grafts n/N	Short implants n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
4 Experienced the operation negatively				
Stellingsma 2003	10/20	5/20		3.00 [0.79, 11.44]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 1 Augmentation versus no augmentation: vertical/horizontal

Outcome: 1 Sandwich bone grafts versus short implants in atrophic mandibles

Study or subgroup	Bone grafts n/N	Short implants n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
5 Severe pain for > 1 week				
Stellingsma 2003	17/20	4/20		22.67 [4.37, 117.47]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 1 Augmentation versus no augmentation: vertical/horizontal

Outcome: 1 Sandwich bone grafts versus short implants in atrophic mandibles

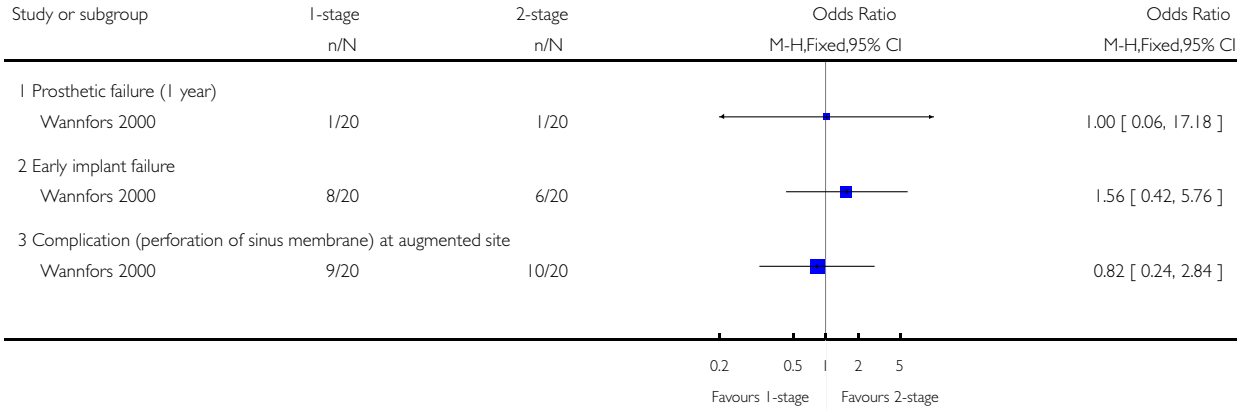
Study or subgroup	Bone grafts n/N	Short implants n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
6 No improvement of facial appearance (3 weeks)				
Stellingsma 2003	6/20	16/20		0.11 [0.03, 0.46]

Analysis 2.1. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 1 Sinus lift: 1-stage block versus 2-stage particulate bone.

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

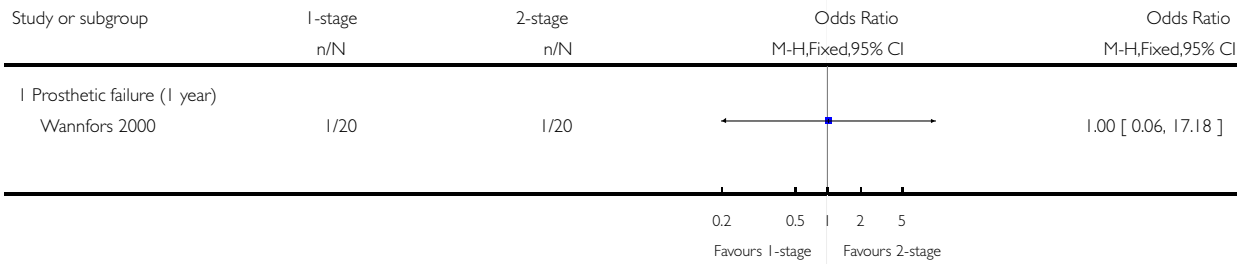
Outcome: 1 Sinus lift: 1-stage block versus 2-stage particulate bone



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

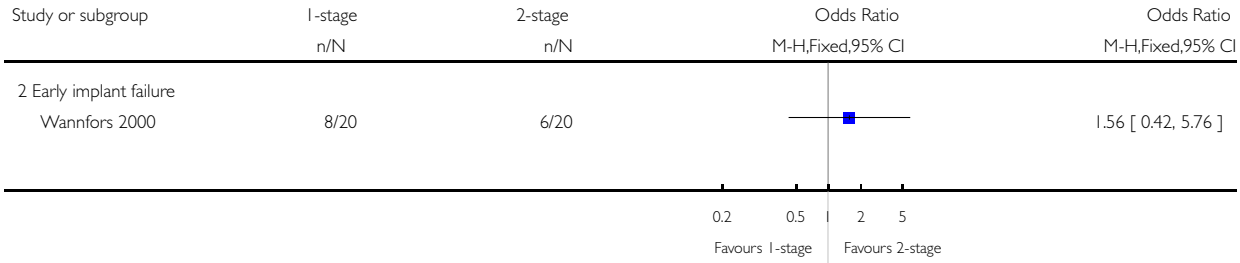
Outcome: 1 Sinus lift: 1-stage block versus 2-stage particulate bone



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

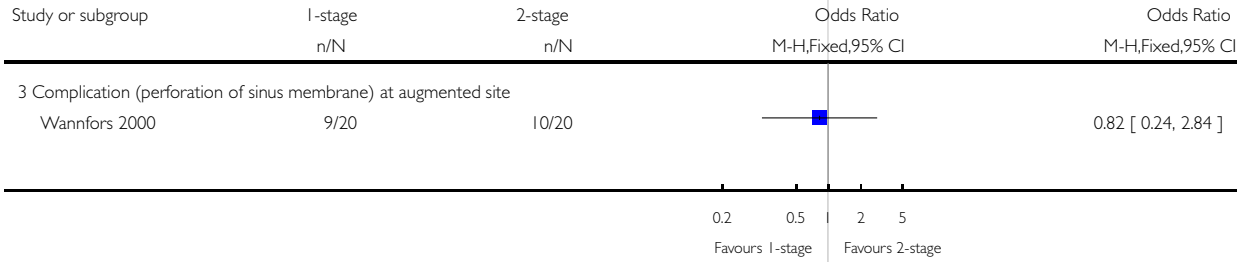
Outcome: 1 Sinus lift: 1-stage block versus 2-stage particulate bone



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 1 Sinus lift: 1-stage block versus 2-stage particulate bone

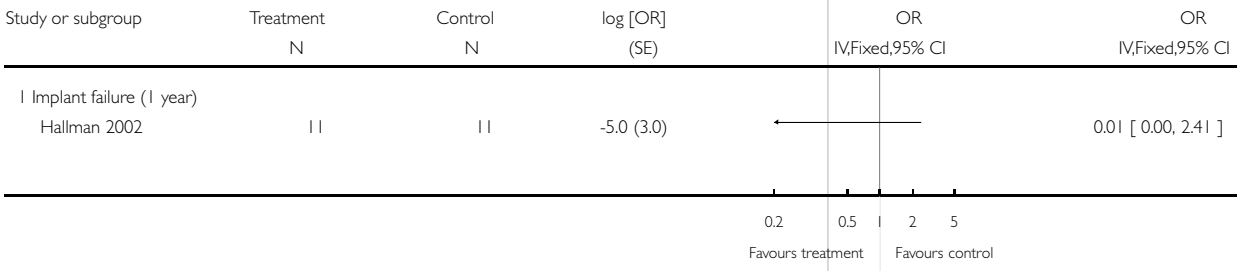


Analysis 2.2. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 2 Sinus lift: bone versus bone + 20% Bio-Oss.

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

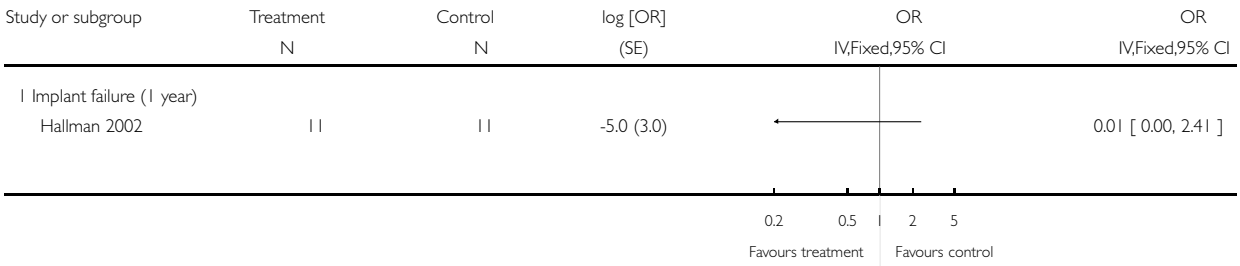
Outcome: 2 Sinus lift: bone versus bone + 20% Bio-Oss



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 2 Sinus lift: bone versus bone + 20% Bio-Oss



Analysis 2.3. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 3 Sinus lift: bone versus 100% Cerasorb.

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 3 Sinus lift: bone versus 100% Cerasorb

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 3 Sinus lift: bone versus 100% Cerasorb

Study or subgroup	Bone N	Cerasorb N	log [OR] (SE)	OR IV,Fixed,95% CI	OR IV,Fixed,95% CI
1 Early implant failure					
Szab 2005	20	20	0.0 (2.2)		1.00 [0.01, 74.58]

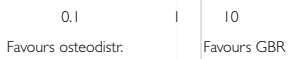
Analysis 2.4. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 4 Vertical augmentation: osteodistraction versus GBR (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 4 Vertical augmentation: osteodistraction versus GBR (binary)

Study or subgroup	Osteodistraction n/N	GBR n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
1 Prosthetic failure (3 years)				
Chiapasco 2004	0/10	0/11		Not estimable
2 Implant failure (3 years)				
Chiapasco 2004	0/10	0/11		Not estimable
3 Augmentation procedure failure				
Chiapasco 2004	0/10	0/11		Not estimable
4 Complication at augmentation + donor site				
Chiapasco 2004	2/10	5/11		0.30 [0.04, 2.11]

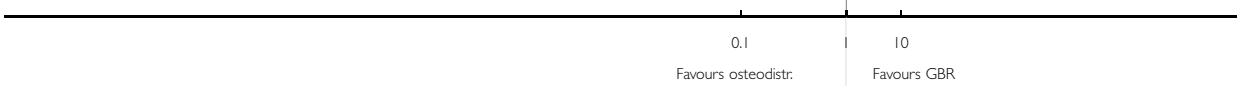


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 4 Vertical augmentation: osteodistraction versus GBR (binary)

Study or subgroup	Osteodistraction n/N	GBR n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
1 Prosthetic failure (3 years)				
Chiapasco 2004	0/10	0/11		Not estimable



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 4 Vertical augmentation: osteodistraction versus GBR (binary)

Study or subgroup	Osteodistraction n/N	GBR n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
2 Implant failure (3 years)				
Chiapasco 2004	0/10	0/11		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 4 Vertical augmentation: osteodistraction versus GBR (binary)

Study or subgroup	Osteodistraction n/N	GBR n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
3 Augmentation procedure failure				
Chiapasco 2004	0/10	0/11		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

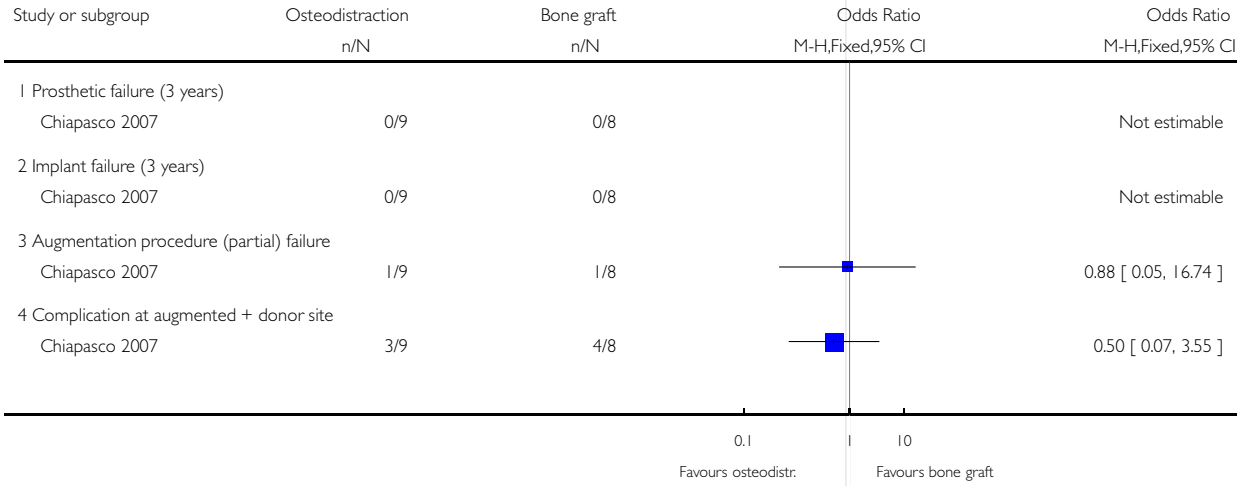
Outcome: 4 Vertical augmentation: osteodistraction versus GBR (binary)

Analysis 2.5. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 5 Vertical augmentation: osteodistraction versus bone graft (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 5 Vertical augmentation: osteodistraction versus bone graft (binary)

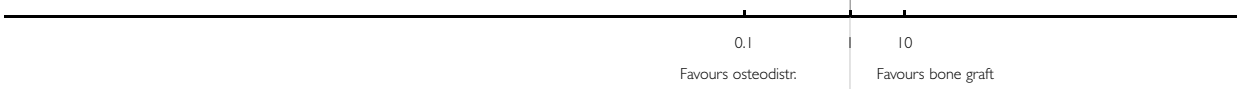


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 5 Vertical augmentation: osteodistraction versus bone graft (binary)

Study or subgroup	Osteodistraction n/N	Bone graft n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
1 Prosthetic failure (3 years)				
Chiapasco 2007	0/9	0/8		Not estimable



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 5 Vertical augmentation: osteodistraction versus bone graft (binary)

Study or subgroup	Osteodistraction n/N	Bone graft n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
2 Implant failure (3 years)				
Chiapasco 2007	0/9	0/8		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

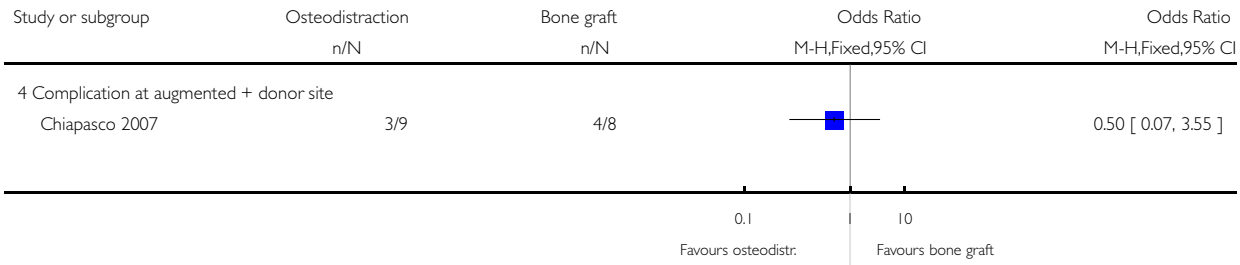
Outcome: 5 Vertical augmentation: osteodistraction versus bone graft (binary)

Study or subgroup	Osteodistraction n/N	Bone graft n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
3 Augmentation procedure (partial) failure				
Chiapasco 2007	1/9	1/8		0.88 [0.05, 16.74]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 5 Vertical augmentation: osteodistraction versus bone graft (binary)

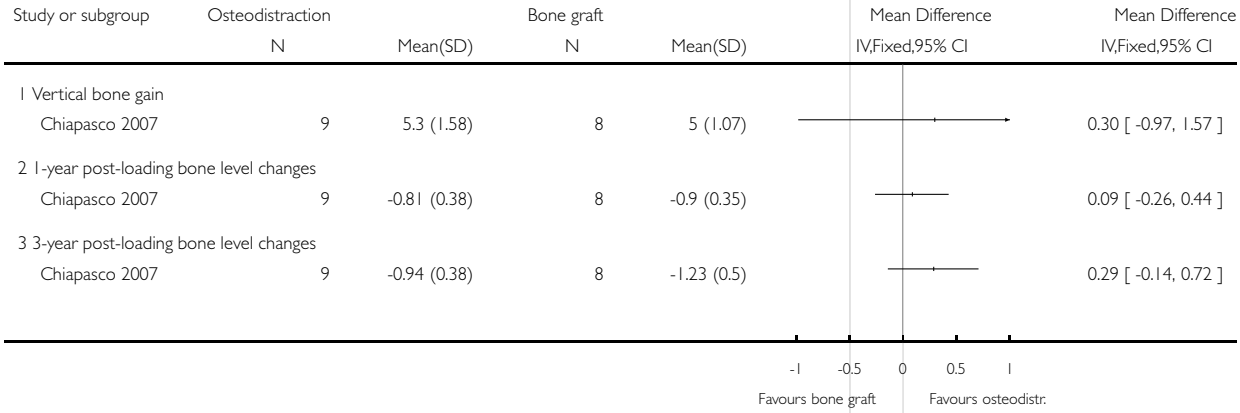


Analysis 2.6. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 6 Vertical augmentation: osteodistraction versus bone graft (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 6 Vertical augmentation: osteodistraction versus bone graft (continuous)

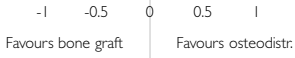


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 6 Vertical augmentation: osteodistraction versus bone graft (continuous)

Study or subgroup	Osteodistraction N	Mean(SD)	Bone graft N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
1 Vertical bone gain						
Chiapasco 2007	9	5.3 (1.58)	8	5 (1.07)		0.30 [-0.97, 1.57]

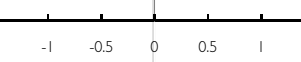


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 6 Vertical augmentation: osteodistraction versus bone graft (continuous)

Study or subgroup	Osteodistraction N	Mean(SD)	Bone graft N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
2 1-year post-loading bone level changes						
Chiapasco 2007	9	-0.81 (0.38)	8	-0.9 (0.35)		0.09 [-0.26, 0.44]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 6 Vertical augmentation: osteodistraction versus bone graft (continuous)

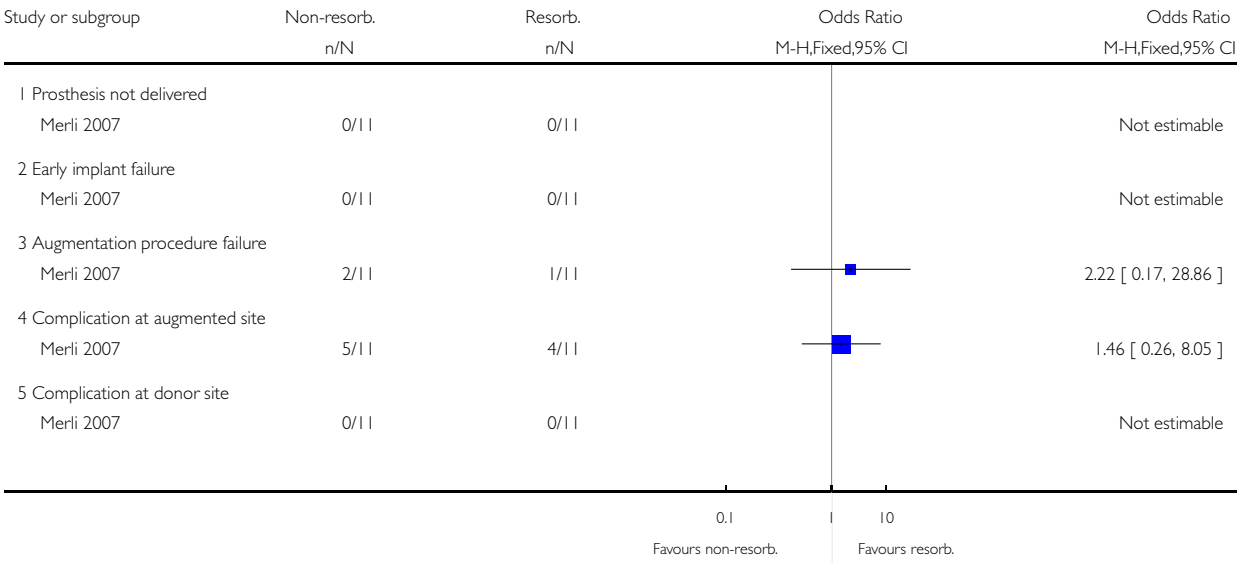
Study or subgroup	Osteodistraction N	Mean(SD)	Bone graft N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
3 3-year post-loading bone level changes						
Chiapasco 2007	9	-0.94 (0.38)	8	-1.23 (0.5)		0.29 [-0.14, 0.72]

Analysis 2.7. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 7 Vertical GBR: non-resorbable versus resorbable barriers (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 7 Vertical GBR: non-resorbable versus resorbable barriers (binary)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

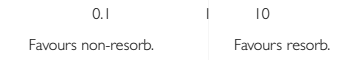
Outcome: 7 Vertical GBR: non-resorbable versus resorbable barriers (binary)

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 7 Vertical GBR: non-resorbable versus resorbable barriers (binary)

Study or subgroup	Non-resorb. n/N	Resorb. n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
2 Early implant failure				
Merli 2007	0/11	0/11		Not estimable

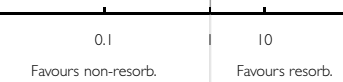


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 7 Vertical GBR: non-resorbable versus resorbable barriers (binary)

Study or subgroup	Non-resorb. n/N	Resorb. n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
3 Augmentation procedure failure				
Merli 2007	2/11	1/11		2.22 [0.17, 28.86]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 7 Vertical GBR: non-resorbable versus resorbable barriers (binary)

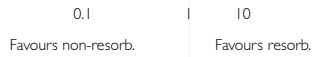
Study or subgroup	Non-resorb. n/N	Resorb. n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
4 Complication at augmented site				
Merli 2007	5/11	4/11		1.46 [0.26, 8.05]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 7 Vertical GBR: non-resorbable versus resorbable barriers (binary)

Study or subgroup	Non-resorb. n/N	Resorb. n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
5 Complication at donor site				
Merli 2007	0/11	0/11		Not estimable



Analysis 2.8. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 8 Vertical GBR: non-resorbable versus resorbable barriers (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 8 Vertical GBR: non-resorbable versus resorbable barriers (continuous)

Study or subgroup	Non-resorb. N	Mean(SD)	Resorb. N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
1 Vertical bone gain						
Merli 2007	11	2.48 (1.13)	11	2.16 (1.51)		0.32 [-0.79, 1.43]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 8 Vertical GBR: non-resorbable versus resorbable barriers (continuous)

Study or subgroup	Non-resorb. N	Mean(SD)	Resorb. N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
1 Vertical bone gain						
Merli 2007	11	2.48 (1.13)	11	2.16 (1.51)		0.32 [-0.79, 1.43]

Analysis 2.9. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 9 Horizontal augmentation: bone versus bone + barrier.

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 9 Horizontal augmentation: bone versus bone + barrier

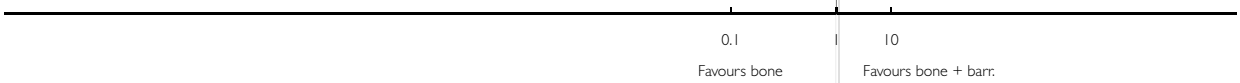
Study or subgroup	Bone n/N	Bone + barrier n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
1 Prosthesis/implant failure (1 year)				
Meijndert 2007	0/31	0/31		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 9 Horizontal augmentation: bone versus bone + barrier

Study or subgroup	Bone n/N	Bone + barrier n/N	Odds Ratio M-H,Fixed,95% CI	Odds Ratio M-H,Fixed,95% CI
1 Prosthesis/implant failure (1 year)				
Meijndert 2007	0/31	0/31		Not estimable

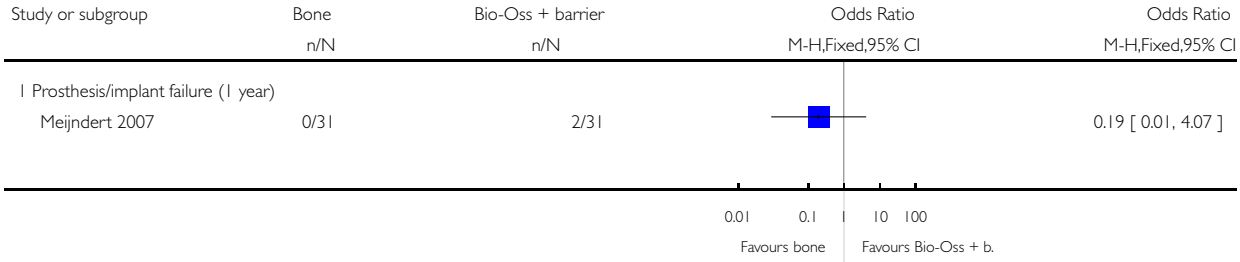


Analysis 2.10. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 10 Horizontal augmentation: bone versus 100% Bio-Oss + barrier.

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

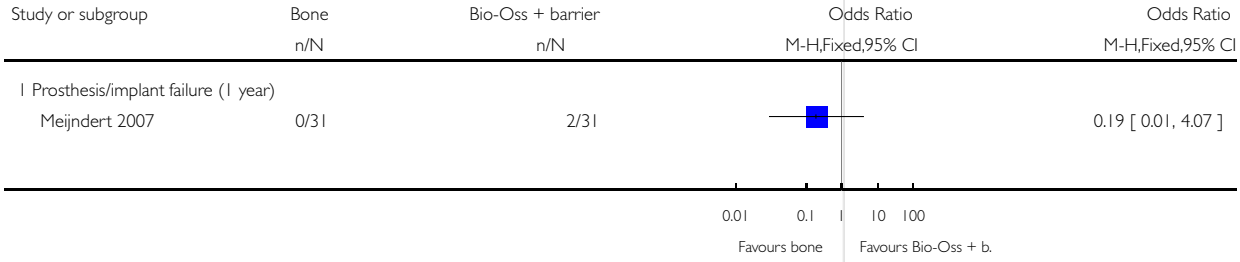
Outcome: 10 Horizontal augmentation: bone versus 100% Bio-Oss + barrier



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 10 Horizontal augmentation: bone versus 100% Bio-Oss + barrier

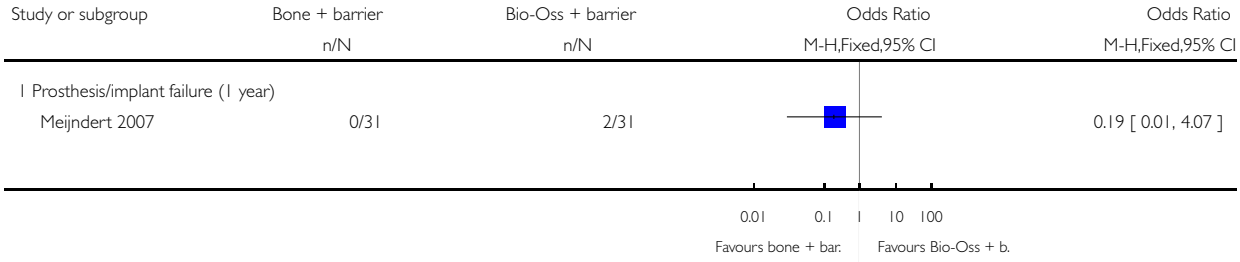


Analysis 2.11. Comparison 2 Augmentation versus augmentation: vertical/horizontal, Outcome 11 Horizontal augmentation: bone + barrier versus 100% Bio-Oss + barrier.

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

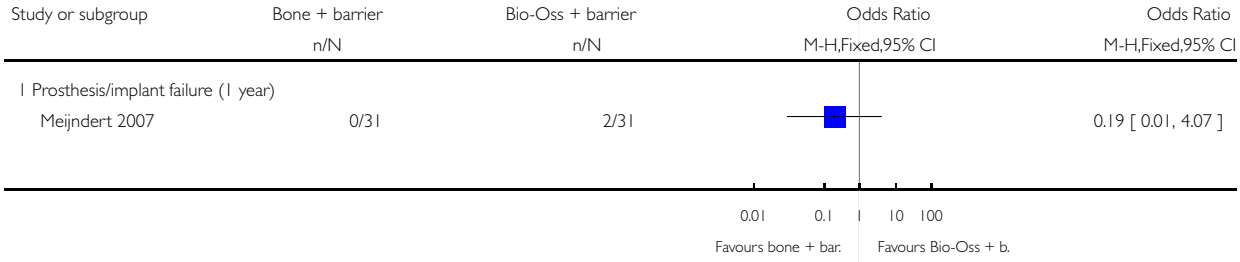
Outcome: 11 Horizontal augmentation: bone + barrier versus 100% Bio-Oss + barrier



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 2 Augmentation versus augmentation: vertical/horizontal

Outcome: 11 Horizontal augmentation: bone + barrier versus 100% Bio-Oss + barrier



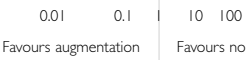
Analysis 3.1. Comparison 3 Augmentation versus no augmentation: immediate implants in extraction sockets, Outcome 1 Autogenous bone graft versus no augmentation (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 3 Augmentation versus no augmentation: immediate implants in extraction sockets

Outcome: 1 Autogenous bone graft versus no augmentation (binary)

Study or subgroup	Augmentation n/N	No augmentation n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure (2 years)				
Chen 2005b	2/14	0/12		5.00 [0.22, 115.05]
2 Implant failure (2 years)				
Chen 2005b	2/14	0/12		5.00 [0.22, 115.05]
3 Complication				
Chen 2005b	2/14	0/12		5.00 [0.22, 115.05]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 3 Augmentation versus no augmentation: immediate implants in extraction sockets

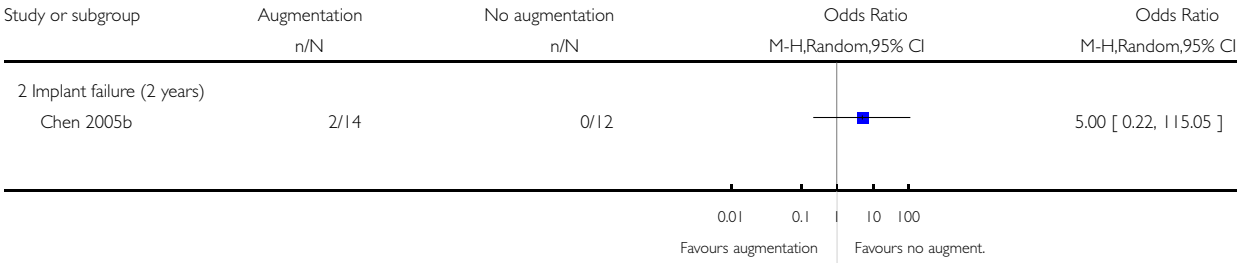
Outcome: 1 Autogenous bone graft versus no augmentation (binary)

Study or subgroup	Augmentation n/N	No augmentation n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure (2 years)				
Chen 2005b	2/14	0/12		5.00 [0.22, 115.05]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 3 Augmentation versus no augmentation: immediate implants in extraction sockets

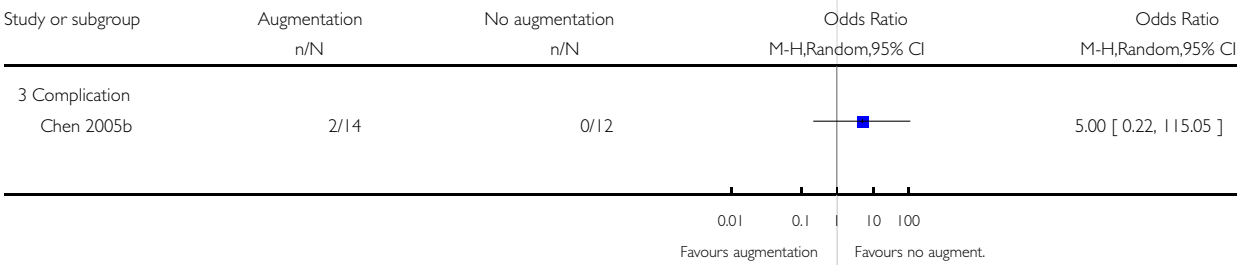
Outcome: 1 Autogenous bone graft versus no augmentation (binary)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 3 Augmentation versus no augmentation: immediate implants in extraction sockets

Outcome: 1 Autogenous bone graft versus no augmentation (binary)



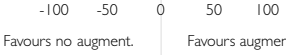
Analysis 3.2. Comparison 3 Augmentation versus no augmentation: immediate implants in extraction sockets, Outcome 2 Autogenous bone graft versus no augmentation (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 3 Augmentation versus no augmentation: immediate implants in extraction sockets

Outcome: 2 Autogenous bone graft versus no augmentation (continuous)

Study or subgroup	Augmentation N	Mean(SD)	No augmentation N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
1 Bone gain (vertical - VDH)						
Chen 2005b	13	75.3 (20.9)	12	73.6 (24.2)		1.70 [-16.09, 19.49]
2 Bone gain (horizontal - HDD)						
Chen 2005b	13	75.6 (26)	12	69.2 (12.8)		6.40 [-9.48, 22.28]

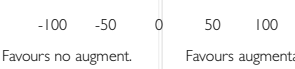


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 3 Augmentation versus no augmentation: immediate implants in extraction sockets

Outcome: 2 Autogenous bone graft versus no augmentation (continuous)

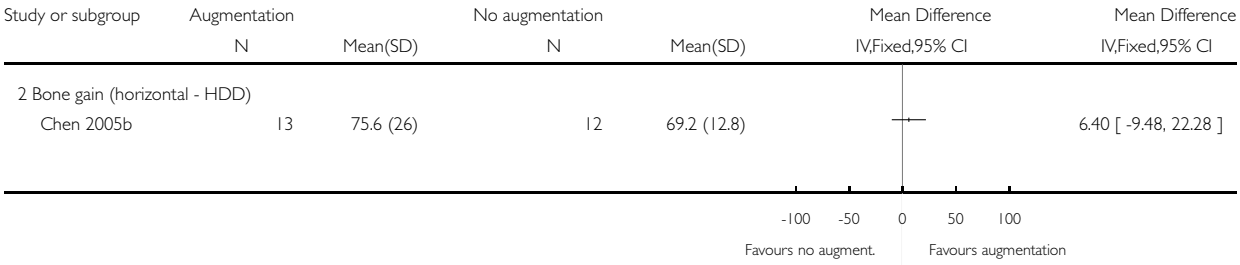
Study or subgroup	Augmentation N	Mean(SD)	No augmentation N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
1 Bone gain (vertical - VDH)						
Chen 2005b	13	75.3 (20.9)	12	73.6 (24.2)		1.70 [-16.09, 19.49]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 3 Augmentation versus no augmentation: immediate implants in extraction sockets

Outcome: 2 Autogenous bone graft versus no augmentation (continuous)

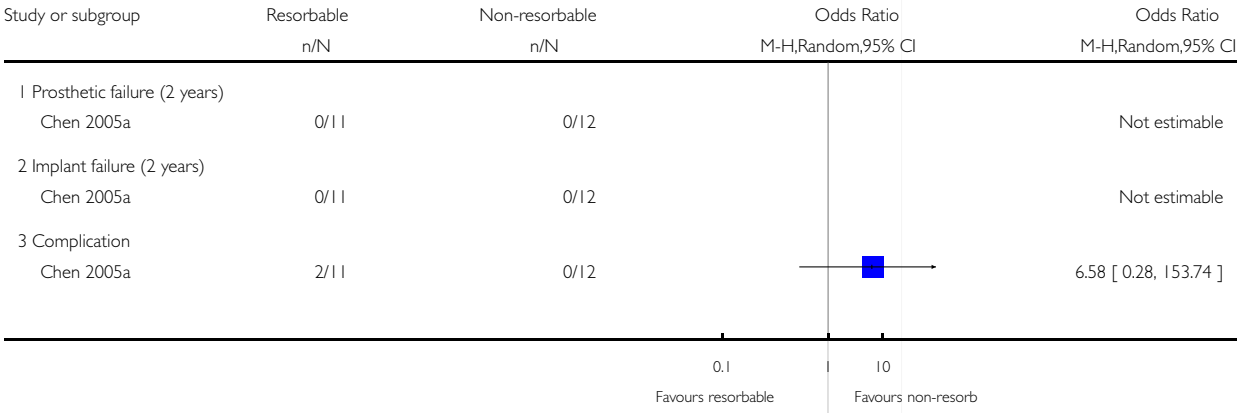


Analysis 4.1. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 1 Resorbable versus non-resorbable barrier (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 1 Resorbable versus non-resorbable barrier (binary)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 1 Resorbable versus non-resorbable barrier (binary)

Study or subgroup	Resorbable n/N	Non-resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure (2 years)				
Chen 2005a	0/11	0/12		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 1 Resorbable versus non-resorbable barrier (binary)

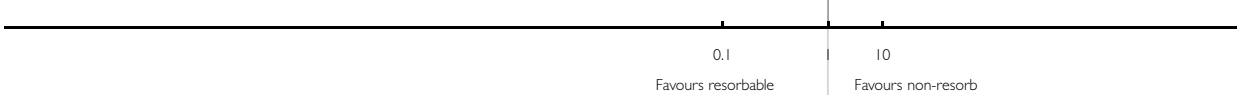
Study or subgroup	Resorbable n/N	Non-resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
2 Implant failure (2 years)				
Chen 2005a	0/11	0/12		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 1 Resorbable versus non-resorbable barrier (binary)

Study or subgroup	Resorbable n/N	Non-resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
3 Complication				
Chen 2005a	2/11	0/12		6.58 [0.28, 153.74]

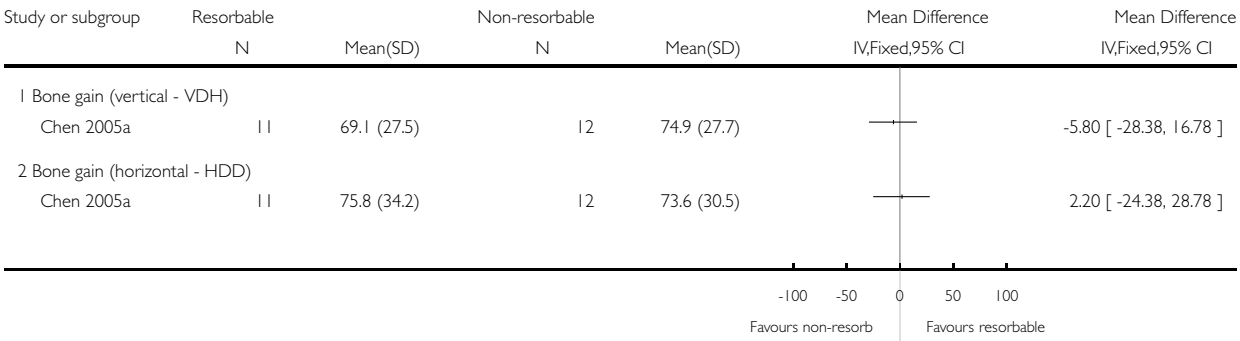


Analysis 4.2. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 2 Resorbable versus non-resorbable (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

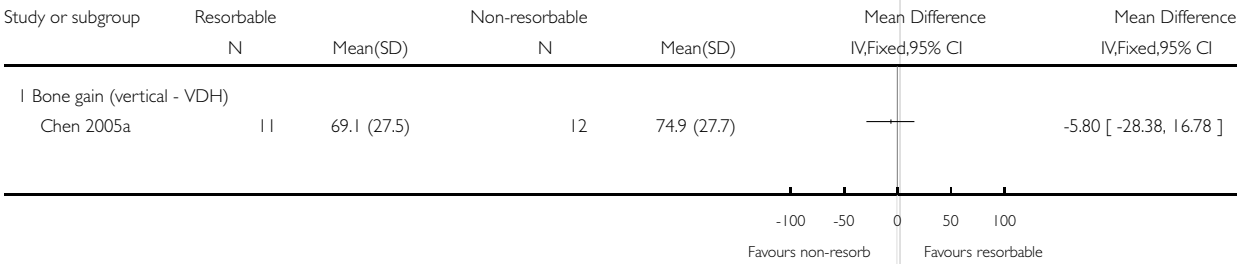
Outcome: 2 Resorbable versus non-resorbable (continuous)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

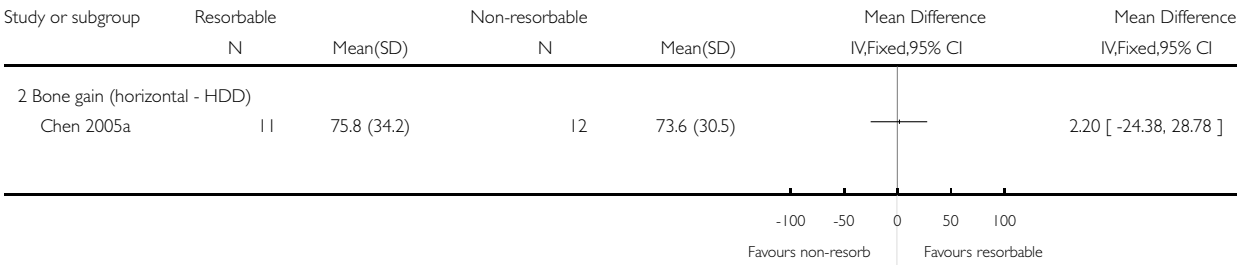
Outcome: 2 Resorbable versus non-resorbable (continuous)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 2 Resorbable versus non-resorbable (continuous)

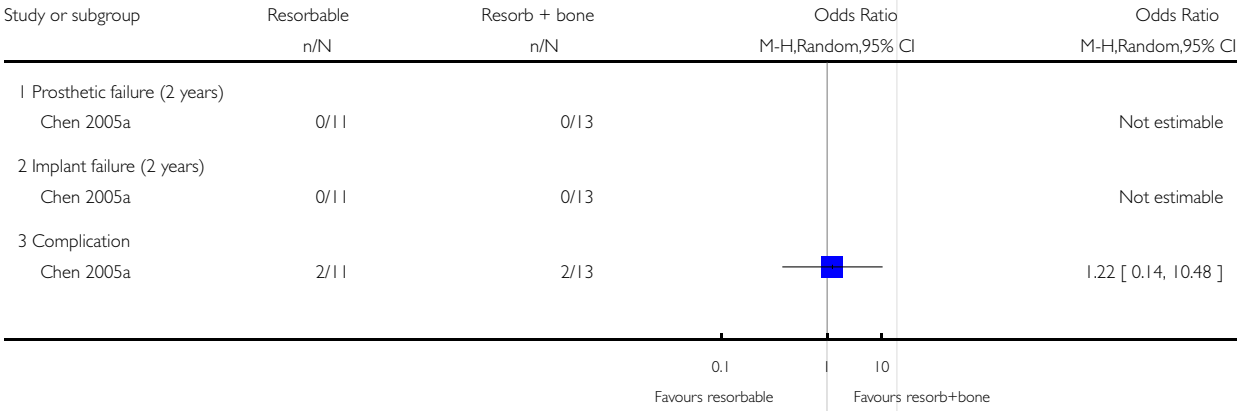


Analysis 4.3. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 3 Resorbable versus resorbable + autogenous bone (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 3 Resorbable versus resorbable + autogenous bone (binary)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 3 Resorbable versus resorbable + autogenous bone (binary)

Study or subgroup	Resorbable n/N	Resorb + bone n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure (2 years)				
Chen 2005a	0/11	0/13		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 3 Resorbable versus resorbable + autogenous bone (binary)

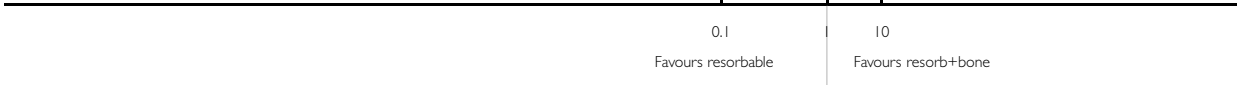
Study or subgroup	Resorbable n/N	Resorb + bone n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
2 Implant failure (2 years)				
Chen 2005a	0/11	0/13		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 3 Resorbable versus resorbable + autogenous bone (binary)

Study or subgroup	Resorbable n/N	Resorb + bone n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
3 Complication				
Chen 2005a	2/11	2/13		1.22 [0.14, 10.48]



Analysis 4.4. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 4 Resorbable versus resorbable + autogenous bone (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 4 Resorbable versus resorbable + autogenous bone (continuous)

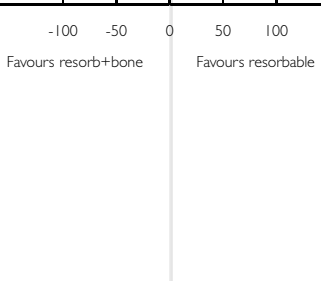
Study or subgroup	Resorbable N	Mean(SD)	Resorb + bone N	Mean(SD)	Mean Difference IV,Random,95% CI	Mean Difference IV,Random,95% CI
1 Bone gain (vertical - VDH)						
Chen 2005a	11	69.1 (27.5)	13	83.1 (23.8)		-14.00 [-34.77, 6.77]
2 Bone gain (horizontal - HDD)						
Chen 2005a	11	75.8 (34.2)	13	89.7 (19.8)		-13.90 [-36.80, 9.00]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 4 Resorbable versus resorbable + autogenous bone (continuous)

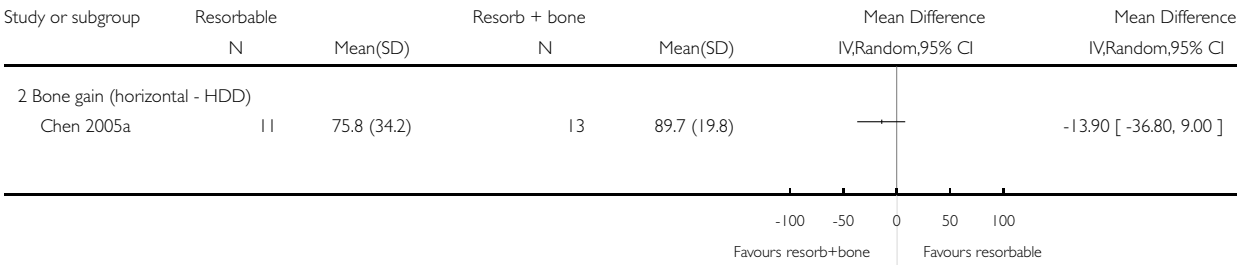
Study or subgroup	Resorbable N	Mean(SD)	Resorb + bone N	Mean(SD)	Mean Difference IV,Random,95% CI	Mean Difference IV,Random,95% CI
1 Bone gain (vertical - VDH)						
Chen 2005a	11	69.1 (27.5)	13	83.1 (23.8)		-14.00 [-34.77, 6.77]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 4 Resorbable versus resorbable + autogenous bone (continuous)

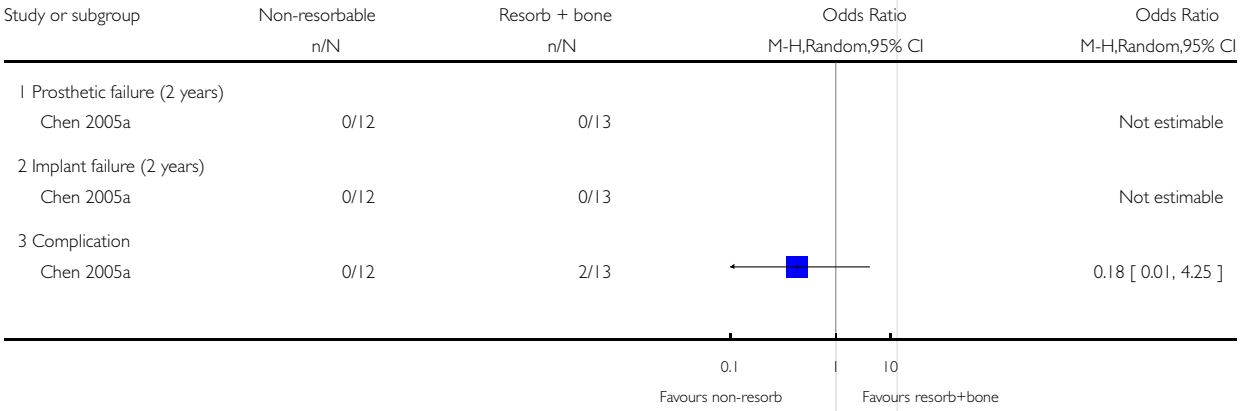


Analysis 4.5. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 5 Non-resorbable versus resorbable + autogenous bone (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 5 Non-resorbable versus resorbable + autogenous bone (binary)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 5 Non-resorbable versus resorbable + autogenous bone (binary)

Study or subgroup	Non-resorbable n/N	Resorb + bone n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure (2 years)				
Chen 2005a	0/12	0/13		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 5 Non-resorbable versus resorbable + autogenous bone (binary)

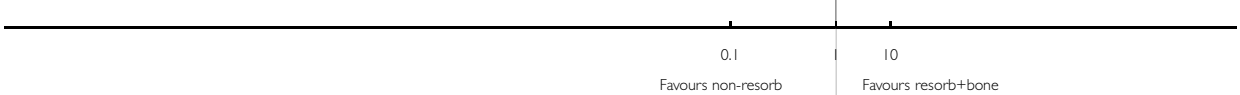
Study or subgroup	Non-resorbable n/N	Resorb + bone n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
2 Implant failure (2 years)				
Chen 2005a	0/12	0/13		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 5 Non-resorbable versus resorbable + autogenous bone (binary)

Study or subgroup	Non-resorbable n/N	Resorb + bone n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
3 Complication				
Chen 2005a	0/12	2/13		0.18 [0.01, 4.25]



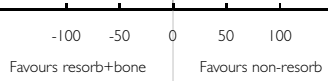
Analysis 4.6. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 6 Non-resorbable versus resorbable + autogenous bone (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 6 Non-resorbable versus resorbable + autogenous bone (continuous)

Study or subgroup	Non-resorb N	Mean(SD)	Resorb + bone N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
1 Bone gain (vertical - VDH)						
Chen 2005a	12	74.9 (27.7)	13	83.1 (23.8)		-8.20 [-28.52, 12.12]
2 Bone gain (horizontal - HDD)						
Chen 2005a	12	73.6 (30.5)	13	89.7 (19.8)		-16.10 [-36.44, 4.24]

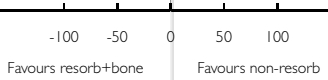


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 6 Non-resorbable versus resorbable + autogenous bone (continuous)

Study or subgroup	Non-resorb N	Mean(SD)	Resorb + bone N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
1 Bone gain (vertical - VDH)						
Chen 2005a	12	74.9 (27.7)	13	83.1 (23.8)		-8.20 [-28.52, 12.12]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 6 Non-resorbable versus resorbable + autogenous bone (continuous)

Study or subgroup	Non-resorb N	Mean(SD)	Resorb + bone N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
2 Bone gain (horizontal - HDD)						
Chen 2005a	12	73.6 (30.5)	13	89.7 (19.8)		-16.10 [-36.44, 4.24]

Analysis 4.7. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 7 Resorbable versus resorbable + Bio-Oss (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 7 Resorbable versus resorbable + Bio-Oss (binary)

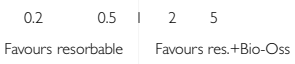
Study or subgroup	Resorbable n/N	Resorb. + Bio-Oss n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure at insertion				
Cornelini 2004	0/10	0/10		Not estimable
2 Implant failure at loading (6 months)				
Cornelini 2004	0/10	0/10		Not estimable
3 Complication at augmented site				
Cornelini 2004	0/10	0/10		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 7 Resorbable versus resorbable + Bio-Oss (binary)

Study or subgroup	Resorbable n/N	Resorb. + Bio-Oss n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure at insertion				
Cornelini 2004	0/10	0/10		Not estimable

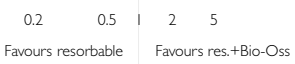


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 7 Resorbable versus resorbable + Bio-Oss (binary)

Study or subgroup	Resorbable n/N	Resorb. + Bio-Oss n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
2 Implant failure at loading (6 months)				
Cornelini 2004	0/10	0/10		Not estimable

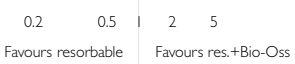


Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 7 Resorbable versus resorbable + Bio-Oss (binary)

Study or subgroup	Resorbable n/N	Resorb. + Bio-Oss n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
3 Complication at augmented site				
Cornelini 2004	0/10	0/10		Not estimable



Analysis 4.8. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 8 Resorbable versus resorbable + Bio-Oss (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 8 Resorbable versus resorbable + Bio-Oss (continuous)

Study or subgroup	Resorbable		Resorb. + Bio-Oss		Mean Difference	Mean Difference
	N	Mean(SD)	N	Mean(SD)	IV,Random,95% CI	IV,Random,95% CI
1 Aesthetics by dentist (mucosal margin from implant head in mm)						
Cornelini 2004	10	0.9 (1.2)	10	2.1 (1.29)		-1.20 [-2.29, -0.11]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 8 Resorbable versus resorbable + Bio-Oss (continuous)

Study or subgroup	Resorbable		Resorb. + Bio-Oss		Mean Difference	Mean Difference
	N	Mean(SD)	N	Mean(SD)	IV,Random,95% CI	IV,Random,95% CI
1 Aesthetics by dentist (mucosal margin from implant head in mm)						
Cornelini 2004	10	0.9 (1.2)	10	2.1 (1.29)		-1.20 [-2.29, -0.11]

Analysis 4.9. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 9 Bio-Oss versus Bio-Oss + resorbable (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 9 Bio-Oss versus Bio-Oss + resorbable (binary)

Study or subgroup	Bio-Oss n/N	Bio-Oss + resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure (3 years)				
Chen 2007	0/7	0/5		Not estimable
2 Implant failure (3 years)				
Chen 2007	0/7	0/5		Not estimable
3 Augmentation failure				
Chen 2007	0/10	1/10		0.30 [0.01, 8.33]
4 Complication at augmented site				
Chen 2007	0/10	2/10		0.16 [0.01, 3.85]
5 Poor aesthetics measured by patient (after restoration)				
Chen 2007	1/10	1/10		1.00 [0.05, 18.57]
6 Poor aesthetics measured by dentist (after restoration)				
Chen 2007	2/10	4/10		0.38 [0.05, 2.77]
7 Poor aesthetics measured by dentist (3 years)				
Chen 2007	2/7	2/5		0.60 [0.05, 6.79]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 9 Bio-Oss versus Bio-Oss + resorbable (binary)

Study or subgroup	Bio-Oss n/N	Bio-Oss + resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
1 Prosthetic failure (3 years)				
Chen 2007	0/7	0/5		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 9 Bio-Oss versus Bio-Oss + resorbable (binary)

Study or subgroup	Bio-Oss n/N	Bio-Oss + resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
2 Implant failure (3 years)				
Chen 2007	0/7	0/5		Not estimable

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 9 Bio-Oss versus Bio-Oss + resorbable (binary)

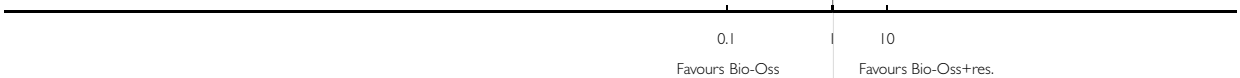
Study or subgroup	Bio-Oss n/N	Bio-Oss + resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
3 Augmentation failure				
Chen 2007	0/10	1/10		0.30 [0.01, 8.33]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 9 Bio-Oss versus Bio-Oss + resorbable (binary)

Study or subgroup	Bio-Oss n/N	Bio-Oss + resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
4 Complication at augmented site				
Chen 2007	0/10	2/10		0.16 [0.01, 3.85]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 9 Bio-Oss versus Bio-Oss + resorbable (binary)

Study or subgroup	Bio-Oss n/N	Bio-Oss + resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
5 Poor aesthetics measured by patient (after restoration)				
Chen 2007	1/10	1/10		1.00 [0.05, 18.57]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 9 Bio-Oss versus Bio-Oss + resorbable (binary)

Study or subgroup	Bio-Oss n/N	Bio-Oss + resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
6 Poor aesthetics measured by dentist (after restoration)				
Chen 2007	2/10	4/10		0.38 [0.05, 2.77]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 9 Bio-Oss versus Bio-Oss + resorbable (binary)

Study or subgroup	Bio-Oss n/N	Bio-Oss + resorbable n/N	Odds Ratio M-H,Random,95% CI	Odds Ratio M-H,Random,95% CI
7 Poor aesthetics measured by dentist (3 years)				
Chen 2007	2/7	2/5		0.60 [0.05, 6.79]

Analysis 4.10. Comparison 4 Augmentation versus augmentation: immediate implants in extraction sockets, Outcome 10 Bio-Oss versus Bio-Oss + resorbable (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 10 Bio-Oss versus Bio-Oss + resorbable (continuous)

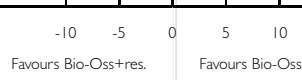
Study or subgroup	Bio-Oss N	Mean(SD)	Bio-Oss + resorbable N	Mean(SD)	Mean Difference IV,Random,95% CI	Mean Difference IV,Random,95% CI
1 Bone gain (vertical - VDH)						
Chen 2007	10	8.2 (1.46)	10	7.2 (2.93)		1.00 [-1.03, 3.03]
2 Bone gain (horizontal - HDD)						
Chen 2007	10	1.5 (1.01)	10	1.5 (0.9)		0.0 [-0.84, 0.84]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 10 Bio-Oss versus Bio-Oss + resorbable (continuous)

Study or subgroup	Bio-Oss N	Mean(SD)	Bio-Oss + resorbable N	Mean(SD)	Mean Difference IV,Random,95% CI	Mean Difference IV,Random,95% CI
1 Bone gain (vertical - VDH)						
Chen 2007	10	8.2 (1.46)	10	7.2 (2.93)		1.00 [-1.03, 3.03]



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 4 Augmentation versus augmentation: immediate implants in extraction sockets

Outcome: 10 Bio-Oss versus Bio-Oss + resorbable (continuous)

Study or subgroup	Bio-Oss N	Mean(SD)	Bio-Oss + resorbable N	Mean(SD)	Mean Difference IV,Random,95% CI	Mean Difference IV,Random,95% CI
2 Bone gain (horizontal - HDD)						
Chen 2007	10	1.5 (1.01)	10	1.5 (0.9)		0.0 [-0.84, 0.84]

Analysis 5.1. Comparison 5 Augmentation versus no augmentation: fenestration, Outcome 1 Non-resorbable barrier versus no barrier (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 5 Augmentation versus no augmentation: fenestration

Outcome: 1 Non-resorbable barrier versus no barrier (continuous)

Study or subgroup	Barrier N	No barrier N	mean difference (SE)	mean difference IV,Fixed,95% CI	mean difference IV,Fixed,95% CI
1 Bone gain (%)					
Dahlin 1991	7	7	71.429 (13.446)		71.43 [45.08, 97.78]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 5 Augmentation versus no augmentation: fenestration

Outcome: 1 Non-resorbable barrier versus no barrier (continuous)

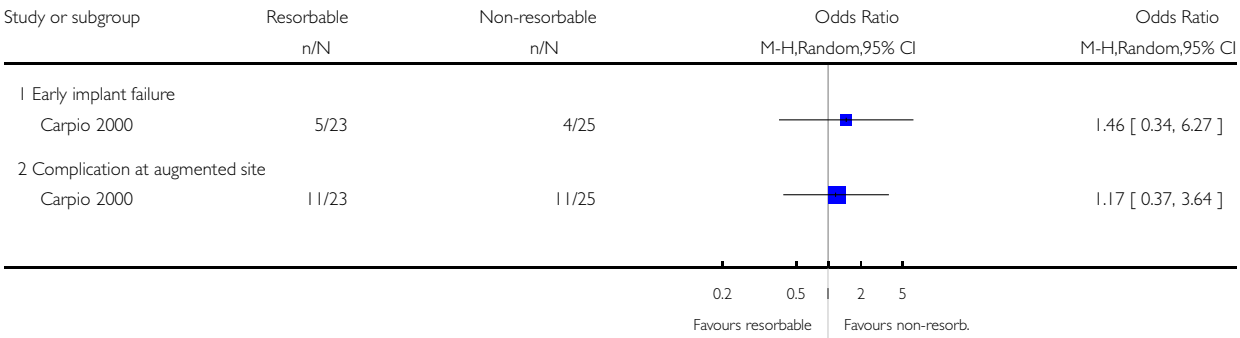
Study or subgroup	Barrier N	No barrier N	mean difference (SE)	mean difference IV,Fixed,95% CI	mean difference IV,Fixed,95% CI
1 Bone gain (%)					
Dahlin 1991	7	7	71.429 (13.446)		71.43 [45.08, 97.78]

Analysis 6.1. Comparison 6 Augmentation versus augmentation: fenestration, Outcome 1 Resorbable versus non-resorbable barrier (binary).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 6 Augmentation versus augmentation: fenestration

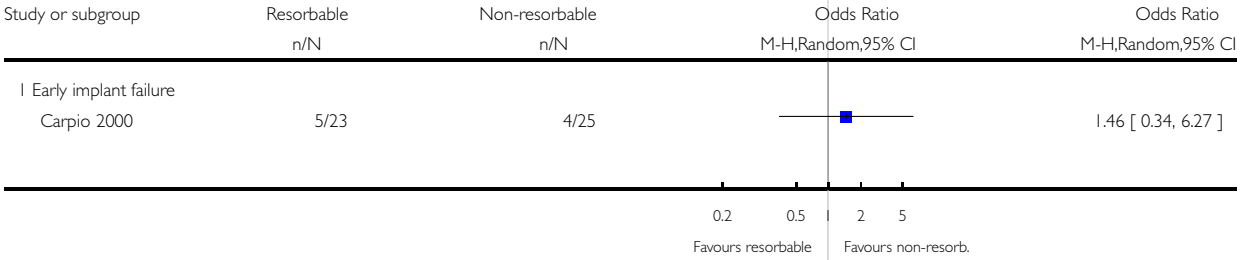
Outcome: 1 Resorbable versus non-resorbable barrier (binary)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 6 Augmentation versus augmentation: fenestration

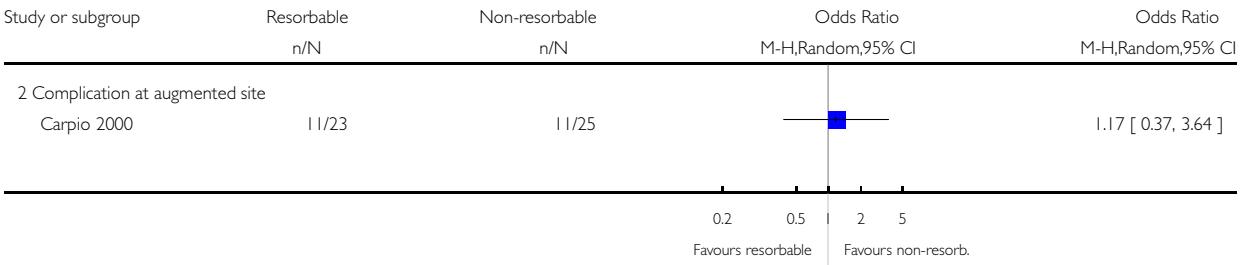
Outcome: 1 Resorbable versus non-resorbable barrier (binary)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 6 Augmentation versus augmentation: fenestration

Outcome: 1 Resorbable versus non-resorbable barrier (binary)

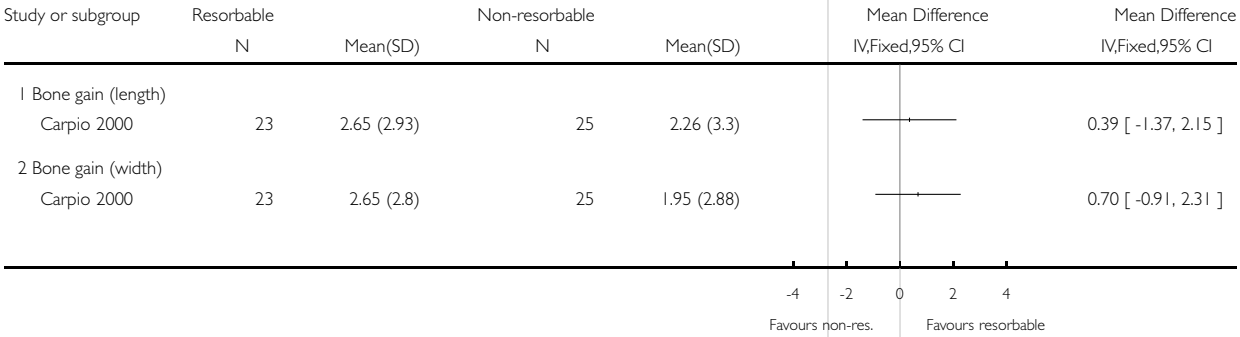


Analysis 6.2. Comparison 6 Augmentation versus augmentation: fenestration, Outcome 2 Resorbable versus non-resorbable barrier (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 6 Augmentation versus augmentation: fenestration

Outcome: 2 Resorbable versus non-resorbable barrier (continuous)



Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 6 Augmentation versus augmentation: fenestration

Outcome: 2 Resorbable versus non-resorbable barrier (continuous)

Study or subgroup	Resorbable N	Mean(SD)	Non-resorbable N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
1 Bone gain (length)						
Carpio 2000	23	2.65 (2.93)	25	2.26 (3.3)		0.39 [-1.37, 2.15]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 6 Augmentation versus augmentation: fenestration

Outcome: 2 Resorbable versus non-resorbable barrier (continuous)

Study or subgroup	Resorbable N	Mean(SD)	Non-resorbable N	Mean(SD)	Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
2 Bone gain (width)						
Carpio 2000	23	2.65 (2.8)	25	1.95 (2.88)		0.70 [-0.91, 2.31]

Analysis 6.3. Comparison 6 Augmentation versus augmentation: fenestration, Outcome 3 rhBMP-2 versus no rhBMP-2 (continuous).

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 6 Augmentation versus augmentation: fenestration

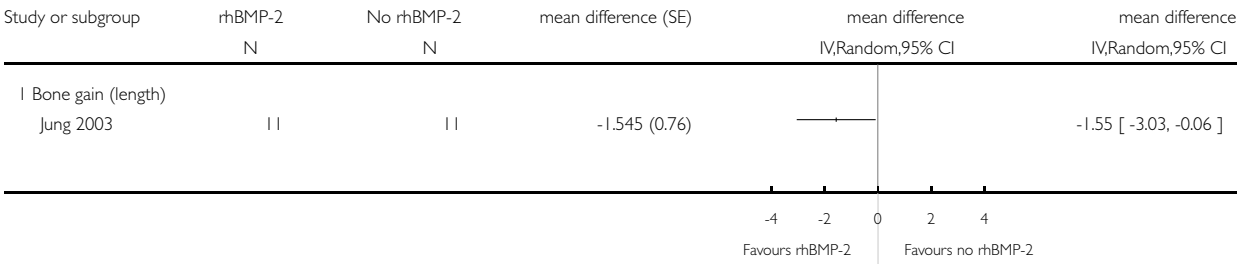
Outcome: 3 rhBMP-2 versus no rhBMP-2 (continuous)

Study or subgroup	rhBMP-2 N	No rhBMP-2 N	mean difference (SE)	mean difference IV,Random,95% CI	mean difference IV,Random,95% CI
1 Bone gain (length)					
Jung 2003	11	11	-1.545 (0.76)		-1.55 [-3.03, -0.06]

Review: Interventions for replacing missing teeth: bone augmentation techniques for dental implant treatment

Comparison: 6 Augmentation versus augmentation: fenestration

Outcome: 3 rhBMP-2 versus no rhBMP-2 (continuous)



APPENDICES

Appendix 1. MEDLINE (OVID) search strategy

1. exp Dental Implants/
2. exp Dental Implantation/ or dental implantation
3. exp Dental Prosthesis, Implant-Supported/
4. ((osseointegrated adj implant$) and (dental or oral))
5. dental implant$
6. (implant$ adj5 dent$)
7. (((overdenture$ or crown$ or bridge$ or prosthesis or restoration$) adj5 (Dental or oral)) and implant$)
8. "implant supported dental prosthesis"
9. ("blade implant$" and (dental or oral))
10. ((endosseous adj5 implant$) and (dental or oral))
11. ((dental or oral) adj5 implant$)
12. OR/1-11

Appendix 2. Phases 1 and 2 of the CSSS for RCTs amended by Cochrane Oral Health Group

1. RANDOMIZED CONTROLLED TRIAL.pt.
2. CONTROLLED CLINICAL TRIAL.pt.
3. RANDOMIZED CONTROLLED TRIALS.sh.
4. RANDOM ALLOCATION.sh.
5. DOUBLE BLIND METHOD.sh.
6. SINGLE BLIND METHOD.sh.
7. CROSS-OVER STUDIES.sh.
8. MULTICENTER STUDIES.sh.
9. ("multicentre stud$" or "multicentre trial$" or "multicenter stud$" or "multicenter trial$" or "multi-centre stud$" or "multi-centre trial$" or "multi-center stud$" or "multi-center trial$" or "multi-site trial$" or "multi-site stud$").ti,ab.
10. MULTICENTER STUDY.pt.
11. latin square.ti,ab.
12. (crossover or cross-over).ti,ab.
13. (split adj (mouth or plot)).ti,ab.
14. or/1-13

15. (ANIMALS not HUMANS).sh.
16. 14 not 15
17. CLINICAL TRIAL.pt.
18. exp CLINICAL TRIALS/
19. (clin$ adj25 trial$).ti,ab.
20. ((singl$ or doubl$ or trebl$ or tripl$) adj25 (blind$ or mask$)).ti,ab.
21. PLACEBOS.sh.
22. placebo$.ti,ab.
23. random$.ti,ab.
24. RESEARCH DESIGN.sh.
25. or/17-24
26. 25 not 15
27. 26 not 16
28. 16 or 27

WHAT'S NEW

Last assessed as up-to-date: 5 May 2008

Date	Event	Description
19 June 2008	Amended	Minor edit.

HISTORY

Protocol first published: Issue 2, 2002

Review first published: Issue 3, 2003

Date	Event	Description
6 May 2008	Amended	Converted to new review format.
6 May 2008	New citation required and conclusions have changed	The review has been updated in the following way: 4 additional new trials were included and 6 were excluded. Slight changes were made to the conclusions.
6 May 2008	New search has been performed	Search updated to January 2008.

CONTRIBUTIONS OF AUTHORS

Conceiving, designing and co-ordinating the review (Marco Esposito (ME), Paul Coulthard (PC)).

Developing search strategy and undertaking searches (ME, PC).

Screening search results and retrieved papers against inclusion criteria (ME, PC, Maria Gabriella Grusovin (GG), Stella Kwan (SK)).

Writing to authors for additional information (ME, Helen Worthington (HW), PC).

Appraising quality (ME, PC, GG, SK).

Data extraction (HW, ME, PC, GG).

Analysis and interpretation of the data (ME, HW, PC).

Writing the review (ME, PC).

Performing previous work that was the foundation of the current study (PC, HW, ME).

DECLARATIONS OF INTEREST

Marco Esposito and Paul Coulthard are among the authors of two of the included trials, however, they were not involved in the quality assessment of these trials.

SOURCES OF SUPPORT

Internal sources

- School of Dentistry, The University of Manchester, UK.

External sources

- The Health Foundation, UK.
- Swedish Medical Research Council (9495), Sweden.

INDEX TERMS

Medical Subject Headings (MeSH)

Dental Implantation [methods]; Oral Surgical Procedures, Preprosthetic [*methods]; Randomized Controlled Trials as Topic

MeSH check words

Animals; Humans