CLINICAL ORAL IMPLANTS RESEARCH

J. M. A. G. Ten Heggeler
D. E. Slot
G. A. Van der Weijden

Review

Effect of socket preservation therapies following tooth extraction in non-molar regions in humans: a systematic review

Authors' affiliations:
J. M. A. G. Ten Heggeler, G. A. Van der Weijden, Clinic for Periodontology Utrecht, Utrecht, The Netherlands
J. M. A. G. Ten Heggeler, Clinic for Periodontology Alkmaar, Alkmaar, The Netherlands
D. E. Slot, G. A. Van der Weijden, Department of Periodontology, Academic Center for Dentistry (ACTA), University of Amsterdam and VU University Amsterdam, Amsterdam, The Netherlands

Corresponding author:
Anne Marie ten Heggeler
Clinic for Periodontology Utrecht
Livingstonelaan 466
3526 JB Utrecht
The Netherlands
Tel.: +0031 30 287 0560
Fax: +0031 30 267 2215
e-mail: A.ten.Heggeler@planet.nl

Key words: bone loss, bone resorption, dimensional height and width changes, post-extraction socket, socket augmentation, socket preservation, systematic review, tooth extraction

Abstract

Objective: To assess, based on the existing literature, the benefit of socket preservation therapies in patients with a tooth extraction in the anterior or premolar region as compared with no additional treatment with respect to bone level.

Material and methods: MEDLINE-PubMed and the Cochrane Central Register of controlled trials (CENTRAL) were searched till June 2010 for appropriate studies, which reported data concerning the dimensional changes in alveolar height and width after tooth extraction with or without additional treatment like bonefillers, collagen, growth factors or membranes.

Results: Independent screening of the titles and abstracts of 1918 MEDLINE-PubMed and 163 Cochrane papers resulted in nine publications that met the eligibility criteria. In natural healing after extraction, a reduction in width ranging between 2.6 and 4.6 mm and in height between 0.4 and 3.9 mm was observed. With respect to socket preservation, the freeze-dried bone allograft group performed best with a gain in height, however, concurrent with a loss in width of 1.2 mm.

Conclusion: Data concerning socket preservation therapies in humans are scarce, which does not allow any firm conclusions. Socket preservation may aid in reducing the bone dimensional changes following tooth extraction. However, they do not prevent bone resorption because, depending on the technique, on the basis of the included papers one may still expect a loss in width and in height.

Extraction of teeth will be followed undoubtfully by loss in height and width of the alveolar process. It results in a narrowing and shortening of the residual ridge (Pinho et al. 2006). In the past, partial dentures or fixed partial dentures could camouflage the alveolar defects and the resorption process could be counterattacked by repair of the partial dentures. However, there is a paradigm shift from partial (fixed) dentures to implant-supported structures (Gotfredsen et al. 2008). Implants are an aid for prosthetic devices and therefore need to be placed in a three dimensionally perfect location (Buser et al. 2004). Especially in the esthetic zone, it is important to simulate the natural contours even if there is no tooth or root in the alveolar process.

Bone resorption continues over time, but the most statistically significant loss of tissue contour occurs during the first month after tooth extraction, averaging 3–5 mm in width at 6 months (Amler 1969; Nevins et al. 2006). The mandible will resorb more than the maxilla and the buccal side will lose more volume than the lingual (Smukler et al. 1999). Many studies have shown that resorption of the buccal plate may have devastating esthetical consequences for (implant-supported) crowns and bridges (Bartee 2001; Cardaropoli et al. 2003; Araújo & Lindhe 2005). Regeneration or other surgical procedures appear to restore the alveolar process and prepare the surroundings for esthetic-pleasing prosthetics or implant-supported prosthetics (Adriaens 1999). Osseous augmentation procedures for creating bone volume for dental implants often involve the use of grafting materials with or without barrier membranes to foster selective cell and tissue repopulation (Becker et al. 1994; Lekovic et al. 1997, 1998; Yilmaz et al. 1998; Laurencin & Lane 1999; Froum et al. 2002; Sy 2002; Carmagnola et al. 2003; Fiorellini et al. 2005).

Following extraction it would be of interest to arrest the bone resorptive process or at least minimize it. In other words to provide treatment that will aim at the preservation of the natural tissue contours in preparation for the proposed implant prosthesis (Tarnow et al. 1996). So far, little is known and most controlled studies have been performed in animals (Araújo et al. 2008).

The aim of this paper was to systematically review the literature for data that provide information with respect to the effect of socket

Date:
Accepted 10 August 2010

To cite this article:
Ten Heggeler JMAG, Slot DE, Van der Weijden GA. Effect of socket preservation therapies following tooth extraction in non-molar regions in humans: a systematic review. *Clin. Oral Impl. Res.* **22**, 2011; 779–788.
doi: 10.1111/j.1600-0501.2010.02064.x

preservation following tooth extraction in humans as compared with natural healing (NH).

Materials and methods

Focused question

What is the effect of socket preservation therapies in patient with a tooth extraction in the anterior and premolar region in comparison with no additional treatment following extraction (NH) with respect to bone height and width.

Search strategy

Two internet sources were used to search for appropriate papers that satisfied the study purpose. These included the National Library of Medicine, Washington, D.C. (MEDLINE-PubMed) and the Cochrane Central Register of Controlled Trials. Both databases were searched for studies conducted in the period till June 2010. The search was designed to include any published paper that evaluated the effects of socket preservation compared with NH after tooth extraction. All reference lists of the selected studies were hand screened for additional published work that could possibly meet the eligibility criteria of this study. The databases were searched using the following search terms:

PubMed & Cochrane CENTRAL search

[patient AND intervention]

Patient:

{(〈[text words] Tooth〉
OR
〈[MeSH terms/all subheadings] ''Tooth''〉)
AND
([text words] Extraction)
OR
(〈[text words] Tooth Extraction OR Extraction socket OR Alveolar socket OR dental Extraction OR tooth removal OR tooth pulling〉
OR
〈[MeSH terms/all subheadings] ''Tooth Extraction'' OR ''Tooth socket''〉)}

AND

Intervention:

{[text words] Bone filler OR Autogenous bone OR Socket seal OR Bone substitute OR Allograft OR freeze dried bone allograft OR Demineralized freeze dried bone allograft OR DFDBA OR FDBA OR Xenograft OR Bio-oss OR bio-oss collagen OR Alloplast OR tricalciumphosphate OR cerasorb OR polymeric OR Collagen sponge OR Collagen OR collagen fleece OR collagen plugs OR collagen plug OR Membrane OR Biogide OR Ossix OR Connective Tissue Graft OR biogide OR regeneform OR Biomend OR Osseoguard OR Socket preservation OR growth factor OR BMP OR rhBMP OR bone morphogenetic proteins OR Bone block OR Chin block OR Ramus block OR Bio glass}

The PubMed search was limited to humans and the English language.

The eligibility criteria were:

- Randomized controlled clinical trials (RCTs) or

  Controlled Clinical Trials (CCTs) or prospective cohort studies or
  case-serie(s)

- Conducted in human subjects

  - ≥ 18 years
  - Good general health (no systemic disorders)
  - Tooth extraction in the esthetic zone (anterior-premolar region)

- Intervention: socket preservation therapies
- Control group: NH
- Outcome: bone level changes
- Evaluation parameters: alveolar bone dimension (height and/or width)

Screening and selection

Case reports, letters and narrative or historical reviews were excluded. Of the papers without abstracts but whose titles suggested that they could be related to the objectives of this review, the full text was screened for eligibility.

Initially, the papers were screened independently by two reviewers (G.A.W. and J.M.A.G.), first by title and abstract. Then, as a second step, full-text papers were read in detail by two reviewers (D.E.S. and J.M.A.G.). Those papers that fulfilled all selection criteria were processed for data extraction. Disagreements were resolved by discussion. If disagreement persisted, the judgement of a third reviewer (G.A.W.) was decisive. The two reviewers (D.E.S. and J.M.A.G.) hand searched the reference lists of all included studies for additional articles.

Assessment of heterogeneity

Factors that were recorded in order to evaluate the heterogeneity of the primary outcome across studies were as follows:

- Study design and evaluation period
- Number, age of subjects and sites
- Extraction and intervention type and reason
- Evaluation method
- Adverse effects
- Appropriateness of statistical analysis and publication bias

Quality assessment

Two reviewers (D.E.S., G.A.W.) scored the methodological quality of the included studies. Assessment of methodological study quality was performed combining the proposed criteria of the RCT-checklist of the Dutch Cochrane Center (2009), the CONSORT-statement (Schulz et al. 2010), MOOSE-statement (Stroup et al. 2000), STROBE-statement (Von Elm et al. 2007) and Esposito et al. (2001) and Needleman et al. (2000). This combination resulted in the quality criteria as mentioned in Table 6. When random allocation, defined inclusion/exclusion, blinding to patient and examiner, representative population group, an identical treatment between groups except for intervention and report of follow-up were described, the study was classed as at a low risk of bias. When missing one of these six criteria, the study was classed as having a moderate potential risk of bias. Missing two or more of these criteria resulted in a high potential risk of bias (as adapted from van der Weijden et al. 2009).

Statistical analyses

Data extraction

From the selection of papers that met the criteria, data were processed for analysis. Data were extracted with regard to dimensional changes (height and width) of the alveolar bone after tooth extraction with or without socket preservation therapy, reported clinically or radiographically. Means and standard deviations (SD) were extracted (D.E.S., G.A.W. and J.M.A.G.). Some of the studies provided standard errors (SEs) of the mean. Where possible, the authors calculated SD based on the sample size ($SE = SD/N$).

Data analysis

After a preliminary evaluation of the selected papers, it was found that considerable heterogeneity was present in the study designs, characteristics, outcome variables and results. It was therefore not possible to perform a valid quantitative analysis of the data and subsequent meta-analysis. Instead, a descriptive manner of data presentation was used.

Results

Search results

The PubMed search resulted in 1918 papers (Table 1). The Cochrane search resulted in 163 papers, which provided 44 additional papers to the PubMed search (Table 1). The first screening of titles and abstracts resulted in 18 full text papers. After full reading, nine studies were excluded. The reasons for exclusion are explained in Table 2. Searching of the reference lists of the selected papers did not result in additional papers.

Assessment of heterogeneity

After a preliminary evaluation of the selected papers, considerable heterogeneity was observed

Table 1. **Search and selection results**

Selection	Pub Med	Cochrane	Identical
Search	1918	163	119
Titles and abstracts	1962		
Excluded by title and abstract	1944		
All selected for full text reading	18		
Excluded after full reading	9		
Included after full reading	9		
Final selection for data extraction	9		

Table 2. **Overview of the studies that were excluded**

Reason for rejection	Author(s) (year)
No control group	Pinho et al. (2006) Molly et al. (2008) Neiva et al. (2008)
Only histological outcome measures	Carmagnola et al. (2003) Guarnieri et al. (2004) Froum et al. (2002) Smukler et al. (1999)
No data on bone dimensional changes	Nevins et al. (2006)
Artificial socket	Yilmaz et al. (1998)

in the study design, characteristics, intervention therapies and outcome variables. The number and age of participants varied in the studies. Other differences were found concerning reason for extraction, tooth type, socket preservation therapy and the method to evaluate the dimension of height and width of the alveolar ridge (clinical, radiographic). Information regarding the study characteristics is displayed in Table 3.

Study design and evaluation period

Of the selected studies, six were RCTs (#2, #4, #5, #6, #7, #9) and three used a CCT design (#1, #3, #7). In four studies, a split-mouth design was used (#1, #2, #3, #8) and in others a parallel design was used (#4, #5, #6, #7, #9). All studies had an evaluation period of at least 3 months.

Number, age of subjects and sites

The number of subjects participating in the studies varied between 10 (#1) and 80 (#6) subjects. In most papers, age was given as mean age or as a range of age, which varied between 26 (#7) and 76 years (#4). Overall, mean age was 49.2 years (#1, #2, #3, #4, #6, #8, #9). In most studies, more than one site was evaluated in each subject. Most papers described subject, site and test-site selection. Study #1 exited three patients at 3 months due to exposed membranes. Therefore, the measurements at 3 months for all 10 patients were used.

Extraction and intervention type and reason

In most studies, extractions were surgically performed with full-thickness mucoperiosteal flap elevation. Only in studies #8 and #9, the teeth were extracted without raising a flap. In all studies, sockets were carefully debrided to remove all soft tissue before closing it or before placing graft materials. Four out of nine of the studies used primary closure (#1, #2, #6, #7). Study #3 sutured the flaps in their original positions. In the other studies, it was not specifically described. Two studies reported periodontitis as the reason for extraction (#2, #5). One study (#6) selected subjects with >50% buccal bone loss of the extraction socket. Study #1, #3, #8 and #9 just mentioned that their subjects needed extractions. Studies #4, #7 and #9 state that subjects needed non-molar extractions. Study #8 mentioned for each patient individually, which teeth were extracted.

The selected studies provided data, which could be subdivided into: (A) bone fillers (#3, #4, #7, #8, #9), (B) collagen sponge (#5, #6), (C) growth factors (#6) and (D) membranes (#1, #2). Different bonefillers were used such as bioactive glass with calcium sulfate (BG/CS) (#3), freeze-dried bone allograft (FDBA) (#4), CS (#8, #9) and magnesium-enriched hydroxyl apatite (MHA) (#8) and corticocancellous porcine bone (CPB) with collagen membranes (#7). Study #6 tested a growth factor in two different concentrations (0.75 rhBMP and 1.5 rhBMP). Study #2 used resorbable and study #1 used non-resorbable membranes. All studies but one (#5), prescribe antibiotics following extractions for at least 1 week.

Evaluation method

The data as extracted for the present review are derived from clinical and radiographic observations. Three studies (#1, #2 and #3) used titanium pins on the outer surface of the buccal plate of extraction socket as fixed reference point. Other studies used individually prefabricated acrylic stents and measured with a periodontal probe, or a depth gauge with a digital caliper (#4, #5, #6, #7, #9). The papers that evaluated radiographic images used different X-ray methods, computer tomography scan (#6), and standardized peri-apical radiographs (#8).

Adverse events

Apart from membrane exposure in Study #1 none of the nine studies reported on any adverse or harmful event.

Statistical analysis and publication bias

Apart from study #5, the statistical analysis performed appeared to be appropriate. In study #5, some subjects contributed only with one tooth for which a paired analysis is the wrong choice. Although publication bias is an important issue it was not possible due to the limited number of studies and the heterogeneity to assess this aspect.

Assessment of quality

Quality assessment is presented in Table 6. The estimated risk of bias is considered to be low for four studies, for two moderate and for three high. Study #2, #4, #6 and #9 are considered to have the highest level of evidence with an estimated low risk of bias.

Loss to follow-up

From study #4, in total nine of the original 45 subjects dropped out of the study for reasons unrelated to the treatment provided. However, the paper did not provide information to which group these nine subjects belonged. In study #1 at the 3-month re-evaluation visit, three out of the 10 subjects presented with exposed membranes (test teeth). Therefore, these subjects were prematurely exited from this split-mouth study, which had an effect on the number of sites in the study.

Study outcome

Differences between baseline and end

In Table 4a, the differences in *height* between baseline and post-extraction with or without socket preservation therapy are presented. In the control groups of most studies, the height of the alveolar process was statistically significantly lower after extraction ranging from −0.55 to −3.3 mm (#1, #2, #5, #7, #9). Study #4 and #7, divided the measurements in midbuccal and midlingual. Study #7 showed a statistically significant reduction for both buccal and lingual. In study #4, the lingual measurement showed no statistically significant change, whereas the buccal height was statistically significantly reduced. In study #1 and #2, the test groups with membranes showed no statistically significant differences in height within the group before and after extraction with preservation therapy. The same was observed with bio-absorbable sponge (#5). Study #4 found a statistically significant reduction on the buccal side but not at the lingual side after therapy with FDBA. Study #3 showed no statistically significant change from baseline. However, in this particular study a large SD was observed (2.25–3.18). Study #6 and #8 did not report on the statistical significance of differences in time.

Table 3. **Overview of the study characteristics processed for data extraction**

#	Author (years) Title	Design and evaluation (months)	#subjects (sites), gender, mean age (SD) diagnosis	Comparison # sites	Conclusion
#1	Lekovic et al. (1997) A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases	CCT Split mouth Not blinded 3 months	*N* = 10 (32) 4♂ 6♀ Mean age 49.8 Diagnosis unknown	ES + NAM (10) NH (10)	Results from this study suggested that the technique offers a predictable alveolar ridge maintenance enhancing the bone quality for dental implant procedures and esthetic restorative dentistry.
#2	Lekovic et al. (1998) Preservation of alveolar bone in extraction sockets using bio-absorbable membranes	RCT Split mouth Double-blind 6 months	*N* = 16 (32) 10♂ 6♀ Age 52.6 (11.8) Periodontitis patients	ES + BAM (16) NH (16)	This study suggests that treatment of extraction sockets with membranes made of glycolide and lactide polymers is valuable in preserving alveolar bone in extraction sockets and preventing alveolar ridge defects
#3	Camargo et al. (2000) Influence of bioactive glass on changes in alveolar process dimensions after exodontia	CCT Split mouth Not blind 6 months	*N* = 16 (32) 8♂ 8♀ Mean age 44 ± 15.9 Diagnosis unknown	ES + BG/CS (16) NH (16)	This study suggests that treatment of extraction sockets with a combination of bioactive glass and calcium sulfate is of some benefit in preserving alveolar ridge dimensions after tooth extraction.
#4	Iasella et al. (2003) Ridge preservation with freeze-dried bone allograft and a collagen membrane compared with extraction alone for implant site development: a clinical and histologic study in humans	RCT Parallel Double blind 4–6 months	*N* = 24 10♂ 14♀ Mean age 51.5 (13.6) Diagnosis unknown	ES + FDBA (12) NH (12)	Ridge preservation using FDBA and a collagen membrane improved ridge height and width dimensions when compared to extraction alone.
#5	Serino et al. (2003) Ridge preservation following tooth extraction using a polylactide and polyglycolide sponge as space filler: a clinical and histological study in humans	RCT Parallel Not blind 6 months	*N* = 36 (39) 14♂ 31♀ Age range 35–64 Periodontitis patients	ES + BAS (26) NH (13)	The results of this study indicate that alveolar bone resorption following tooth extraction may be prevented or reduced by the use of a bioabsorbable synthetic sponge of polylactide-polyglycolide acid.
#6	Fiorellini et al. (2005) Randomized study evaluating recombinant human bone morphogenetic protein-2 for extraction socket augmentation	RCT Parallel Double-blind 4 months	*N* = 80 (95) 43♂ 37♀ Mean age 47.4 Diagnosis unknown	ES + ACS (18) ES + 0.75BMP (21) ES + 1.5BMP (20) NH (19)	The data from this randomized. masked. placebo-controlled multicenter clinical study demonstrated that the novel combination of rhBMP-2 and a commonly utilized collagen sponge had a striking effect on de novo osseous formation for the placement of dental implants.
#7	Barone et al. (2008) Xenograft vs. extraction alone for ridge preservation after tooth removal: a clinical and histomorphometric study	RCT Parallel Blind 7 months	*N* = 40 16♂ 24♀ Age range 26–69 Diagnosis unknown	ES (20) ES + CPB (20)	The ridge-preservation approach using porcine bone in combination with collagen membrane statistically significantly limited the resorption of hard tissue ridge after tooth extraction compared to extraction alone.
#8	Crespi et al. (2009) Magnesium-enriched hydroxyapatite compared with calcium sulfate in the healing of human extraction sockets: radiographic and histomorphometric evaluation at 3 months.	CCT Split mouth Single-blind 3 months	*N* = 15 (23) 8♂ 7♀ Mean age 51.3 Diagnosis unknown	CS (7) MHA (8) NH (8)	Radiographs revealed a greater reduction of alveolar ridge in the CS group than in the MHA group.
#9	Aimetti et al. (2009) Clinical and histologic healing of human extraction sockets filled with calcium sulfate	RCT Parallel Double-blind 3 months	*N* = 40 22♂ 18♀ Mean age 51 (8.4) Diagnosis fractures, caries	CS (22) NH (18)	MGCSH seems to be effective in accelerating the bone healing process and minimizing alveolar ridge resorption in intact fresh extraction sockets.

Abbreviations of the interventions: NH, natural healing; ES, extraction site; DMFDB, demineralised freeze-dried bone; rhBMP, recombinant human bone morphogenetic protein; ACS, bio-absorbable collagen sponge; RP + FDBA, ridge preservation + freeze-dried bone allograft; ePFTE, expanded polytetrafluoroethylene; 0.75 BMP, 0.75 mg/ml rhBMPon ACS; 1.5 BMP, 1.5 mg/ml rhBMP on ACS; BAS, bio-absorbable polyactide-polyglycolide acid sponge; BG/CS, bio-active glass combined with calcium sulfate; BAM, bio-absorbable membrane; NAM, not absorbable ePFTE Membrane; CS, calcium sulfate; MHA, magnesium-enriched hydroxyl apatite (Ca_{10-x} $Mg_x[PO_4]_6[OH]_2$); CPB, corticocancellous porcine bone and a collagen membrane.

***Table 4a*. Clinical outcomes with respect to height in millimeters (standard deviation in parentheses)**

#	Authors	Measurement	Intervention/groups	Baseline	End	Change in height (mm)	*P*-value
#1	Lekovic et al. (1997)	Clinical assessment from stent to alveolar ridge	ES + NAM	2.6 (0.7)*	2.1 (0.73)*	− 0.5 (0.7)*	NS
			NH	2.3 (0.82)*	1.1 (0.73)*	− 1.2 (0.41)*	0.0001
#2	Lekovic et al. (1998)	Clinical assessment from stent to alveolar ridge	ES + BAM	3.19 (0.84)*	2.81 (0.76)*	− 0.38 (0.88)*	NS
			NH	3.31 (0.92)*	1.81 (0.76)*	− 1.5 (1.04)*	≤ 0.00005
#3	Camargo et al. (2000)	Clinical assessment from pin to alveolar ridge	ES + BG/CS	3.68 (1.64)*	3.31 (2.2)*	− 0.38 (12.7)*	NS
			NH	3.81 (1.64)*	2.81 (2.2)*	− 1 (9)*	NS
#4	Iasella et al. (2003)	Clinical with stent and caliper at a re-entry operation	ES + FDBA	?	?	Mb + 1.3 (2) Ml 0 (1.3) *Average: + 0.65**	NS
			NH	?	?	Mb − 0.9 (1.6) Ml − 0.4 (1) *Average: − 0.65**	NS
#5	Serino et al. (2003)	Clinical assessment from stent to alveolar ridge	ES + BAS	?	?	+ 0.2 (1.5)	< 0.01
			NH	?	?	− 0.7 (1.2)	< 0.01
#6	Fiorellini et al. (2005)	CT	ES + ACS	?	?	− 1 (1.4)	?
			ES + 0.75BMP	?	?	− 0.62 (1.39)	?
			ES + 1.5BMP	?	?	− 0.02 (1.2)	?
			NH	?	?	− 1.17 (1.23)	?
#7	Barone et al. (2008)	Clinical assessment from stent to alveolar ridge	ES + CPB	?	?	Mb − 0.7 (1.4)	< 0.05
				?	?	Ml − 0.4 (1.3)	< 0.05
				?	?	*Average: − 0.55**	
			NH	?	?	Mb − 3.6 (1.5)	< 0.05
						Ml − 3 (1.6)	< 0.05
						*Average: − 3.3**	
#8	Crespi et al. (2009)	Radiographs	CS	?	?	− 2.64 (0.72)*	?
			MHA	?	?	− 0.52 (0.2)*	?
			NH	?	?	− 3.9 (0.62)*	?
#9	Aimetti et al. (2009)	Clinical	CS	9.2 (1.6)	9.7 (1.7)	− 0.5 (1.1)	0.03
			NH	9.9 (2)	11.1 (2.2)	− 1.2 (0.6)	< 0.0001

P-values of the statistical analysis of the changes between baseline and end.
*Calculated by the authors.
For abbreviations of interventions see Table 3.
NS, not statistically significant; ?, not specified/unclear; Mb, Midbuccal; Ml, midlingual.

***Table 4b*. Clinical outcomes with respect to width in millimeters (standard deviation in parentheses)**

	Author/year	Index	Intervention/groups	Baseline	End	Change in width (mm)	*P*-value
#1	Lekovic et al. (1997)	Clinical assessment (with pins) from stent to alveolar ridge	ES + NAM	7.3 (0.55)	5.5 (0.45)	− 1.8 (0.51)	NS
			NH	7 (0.51)	2.6 (0.37)	− 4.4 (0.61)	0.0002
#2	Lekovic et al. (1998)	Clinical assessment (with pins) from stent to alveolar ridge	ES + BAM	7.38 (0.24)	6.06 (0.17)	− 1.31 (0.24)	≤ 0.0005
			NH	7.5 (0.26)	2.94 (0.19)	− 4.56 (0.33)	≤ 0.00001
#3	Camargo et al. (2000)	Clinical assessment from pin to alveolar ridge	ES + BG/CS	7.86 (0.68)	4.38 (0.43)	− 3.48 (2.68)	0.0001
			NH	7.5 (0.74)	4.44 (0.27)	− 3.06 (2.41)	0.0001
#4	Iasella et al. (2003)	Clinical assessment from stent to alveolar ridge	ES + FDBA	9.2 (1.2)	8 (1.4)	− 1.2 (0.9)	< 0.05
			NH	9.1 (1)	6.4 (2.2)	− 2.6 (2.3)	< 0.05
#7	Barone et al. (2008)	Clinical assessment from stent to alveolar ridge	ES + CPB	10.6 (1)	8.1 (1.4)	− 2.5 (1.2)	< 0.05
			NH	10.8 (0.8)	6.3 (0.8)	− 4.5 (0.8)	< 0.05
#9	Aimetti et al. (2009)	Clinical assessment from stent to alveolar ridge	ES + CS	9.4 (2.2)	7.4 (2)	− 2 (1.1)	< 0.0001
			NH	10 (0.7)	6.8 (1.3)	− 3.2 (1.8)	< 0.0001

P-values of the statistical analysis of changes between baseline and end.
For abbreviations of interventions see Table 3.
NS, not statistically significant.

In Table 4b, the differences in *width*, between baseline and post-extraction with or without socket preservation therapy are presented. All studies measuring width in the control groups, found a statistically significant reduction in width after extraction alone ranging from 2.6 to 4.56 mm (#1, #2, #3, #4, #7, #9).

After preservation therapy with a bio-absorbable membrane (#2), with BG/CS (#3), with FDBA (#4), with CPB (#7) and with CS (#9), a statistically significant reduction in width was still observed.

Differences between treatment and control

In Table 5, a summary of the comparisons between test and control group is shown. The table is divided in bone fillers, collagen sponge, growth factor and membranes. Study #5 did not provide comparisons between groups. Studies #6 and #8 with test sites treated with 0.75 mg rhBMP and CS did not report about width and found no statistically significant difference in bone height as compared with control sites. In contrast, study #6, #8, with, respectively, 1.50 rhBMP-2 and MHA, did find statistically significant differences in height.

Table 5. **Summary of comparison between the various interventions and natural healing after extraction**

Methods	#	Authors	Intervention	Difference in height between test/control (mm)	*P*-value	Difference in width between test/control (mm)	*P*-value	Summary of statistics	
								Height	Width
Filler	#4	Iasella et al. (2003)	FDBA	Mb 2.2 Ml 0.4	<0.05 >0.05	1.4	$=0.05$	+	+
	#8	Crespi et al. (2009)	CS	1.26*	?	?	?	**0**	□
			MHA	3.38*	?	?	?	+	□
	#7	Barone et al. (2008)	CPB	Mb 2.9 Ml 2.6	<0.05 <0.05	2.0	<0.05	+	+
	#3	Camargo et al. (2000)	BG/CS	0.62	0.3	0.42	0.9	**0**	**0**
	#9	Aimetti et al. (2009)	CS	Mb 0.7	0.03	1.2	0.001	+	+
Sponge	#5	Serino et al. (2003)	BAS	0.9	?	□	□	**?**	**?**
	#6	Fiorellini et al. (2005)	ACS	0.17	>0.05	□	□	**0**	□
Growth factor	#6	Fiorellini et al. (2005)	0.75 BMP	0.55	NS	□	□	**0**	□
			1.50 BMP	1.15	0.007	□	□	+	□
Membrane	#2	Lekovic et al. (1998)	BAM	1.12	≤ 0.0005	3.25	≤ 0.00001	+	+
	#1	Lekovic et al. (1997)	NAM	0.7	0.001	2.6	0.002	+	+

P-values of the statistical analysis of the difference. A descriptive summary of these statistics is provided in the two last columns. (0 = no difference, ? = not specified/unclear, □ = no data available, + = positive statistically significant difference in favor of the intervention, − = negative statistically significant difference which indicates a change in favor for the control).

*Calculated by the authors.

For abbreviations of interventions see Table 3.

Mb, Midbuccal; Ml, Midlingual.

Studies #1, #2, #4, #7 and #9 show a statistically significant effect of the socket preservation technique on both height and width. However, even in these test groups a reduction of the width was observed, which ranged between 1.2 and 3.48 mm. With respect to height (#1, #2, #7, #9), a reduction of height was still present ranging between 0.38 and 0.7 mm. Only study #4 using FDBA showed an increase in buccal height of 1.3 mm and no height reduction on the lingual aspect.

Discussion

A recent systematic review evaluating alveolar bone dimensional changes of extraction sockets in humans showed that on average the reduction in width of the alveolar ridge was 3.87 mm (van der Weijden et al. 2009). The present study included some of the studies selected for this previous review and showed a range of width reduction of 2.6–4.6 mm. In contrast to the van der Weijden et al. (2009) review, the present study addressed not only the NH aspect but also the various attempts to preserve the alveolar ridge.

The application of regenerative bio-materials, such as bone autografts, allografts, guided tissue regeneration procedures, xenografts and most recently growth factors has been pursued with varying degrees of success to maintain the anatomic dimensions (Wang et al. 2004).

Allografts, xenografts and alloplasts come in many forms, and data support their safety, clinical applicability and low antigenicity (Buck & Malinin 1994). The present study provided data concerning bone allografts (FDBA), alloplasts (CS and MHA) and xenografts (CPB) (Table 3). Of these, the most promising materials were FDBA (Iasella et al. 2003) and CPB (Barone et al. 2008) which showed a positive effect on both height and width as compared with NH. However, with CPB still some loss in height (average 0.55 mm) and width (2.5 mm) was observed as opposed to a buccal height increase with FDBA (+1.3 mm). Both these products can be categorized as osteoconductive materials. CPB is an an organic porcine bone that has been chemically treated to remove its organic components. After the material is sterilized, it can be used as a xenograft without causing an immune response. It increases the mineral content in the grafted area necessary for bone formation. Its density provides stability of the graft and persists long-term because the xenografts do not completely reabsorb (Garg 2004). Bone allografts are obtained from cadavers, usually available through tissue banks which process and store the allografts under complete sterility. FDBA is the most commonly used allograft. It may form bone or participate in new bone formation by osteoinduction or osteoconduction. The freezing and freeze-drying process essentially lowers the antigenicity (Garg 2004).

Another promising approach is presented by Fiorellini et al. (2005). These authors showed with their higher concentration of growth factor (rhBMP-2) that alveolar height can be preserved, showing almost no height change (−0.02 mm) from baseline to 4 months. While bone morphogenetic proteins (BMPs) are often referred to as a category of growth factors, they are actually a distinct group of proteins. Bone-related growth factors exist primarily in bone matrix and are released during remodeling or in response to trauma. BMPs are osteoinductive factors that can stimulate mesenchymal cells to differentiate into cartilage and bone-forming cells. Unlike true growth factors, however, they are not mitogenic for many cells and cell types (Salata et al. 2002). Although it has been decades since BMPs were isolated, progress on their clinical usefulness has proceeded fairly slowly as researchers continue to grapple with long-standing problems, including identifying adequate carriers to immobilize BMPs for a sufficient duration, determining optimal dosages. One of the drawbacks of this technique for daily practice is at present the very high price. It will take more time and development to come up with a product that is reasonably well priced and in a practical form.

Augmentation of bone volume has been assisted through guided bone regeneration (GBR). GBR is based on the principle that barrier membrane is used for space maintenance over a defect, promoting the ingrowth of osteogenic cells and preventing migration of undesired cells from the overlying soft tissues into the wound (Gottlow et al. 1986). Protection of a blood clot in the defect and exclusion of gingival connective tissue and provision of a secluded space into which osteogenic cell from the bone can migrate are essential for a successful outcome (Lang et al. 1994). Both non-resorbable and bio-absorbable barrier membranes have been used in studies (Lekovic et al. 1997, 1998). These two studies show that the membrane technique has a beneficial effect on

the reduction of width and height. But still a resorption of height ranging between 0.38 and 0.5 mm and width reduction ranging between 1.3 and 1.8 mm was observed. In addition study Lekovic et al. 1997 showed a complication of membrane exposure in three patients using non-absorbable ePTFE membranes. This was anticipated by the authors. In case of exposure, a deleterious effect of ridge dimensions and socket healing was observed most likely due to bacterial contamination. Simion et al. 1994 showed that mean bone regeneration rates were strongly reduced in cases of early exposure of the membrane. Therefore, early exposure should be considered an actual complication that can hinder the effectiveness of guided tissue regeneration. Bioabsorbable membranes are an attractive alternative to overcome the problem mentioned above. Findings of the study by Lekovic et al. 1998 showed that none of the 16 bio-absorbable membranes became exposed. Besides this exposure of membranes (Lekovic et al. 1997), none of the nine selected studies reported any adverse or harmful event.

Many clinicians would prefer to completely preserve the original ridge contours. This was not the case for any of the socket preservation techniques used and presented in this review. Therefore, instead of socket preservation therapy, maybe alternative therapies should be explored, like early implant placement with simultaneous contour augmentation with GBR. The early placement technique is characterized by careful extraction of the tooth without flap elevation, debridement of the socket, followed by a 4–8 week soft tissue healing period, implant placement in a correct three-dimensional position, simultaneous contour augmentation on the facial aspect with GBR using a bio-absorbable collagen membrane combined with autogenous chips and a low substitution bone filler and tension-free primary wound closure (Buser et al. 2008). Although not the purpose of this study, this technique would appear to be more cost effective because the implant placement and bone augmentation therapy are combined in one single procedure. From the data as collected for the present study, socket preservation when followed, at a later stage, by implant placement would most likely still need additional augmentation because none of the therapies completely prevented bone resorption.

In all, a large variation in healing patterns was observed between the different studies. One explanation for this variation may be the absence or presence of teeth adjacent to the experimental site. Furthermore, variations of the level of the bone at the adjacent teeth may be responsible for the observed difference (Barone et al. 2008).

The present review focused solely on bone dimensional changes. However, loss of soft tissue thickness is additive with the loss of hard tissue, and the combined effect of both tissues on total ridge width must be considered, especially because the greatest loss has been described to occur at the expense of the buccal surface. This has the greatest significance in the esthetic zone, where loss of both hard and soft tissue thickness can have a statistically significant visual impact, as occurs with the loss of root prominence convexity (Iasella et al. 2003).

A key component to quality assessment is the statistical analytical method used in each paper because the conclusions are based on these, rather than a meta-analysis. Without this appraisal, the validity of the conclusion is compromised. The appropriate unit of analysis (i.e. site vs. patient) is important to understand the risk of type I error as inflation of 'n' is likely with site-based analysis. Studies I, II, III and VIII used a split mouth design where each treatment (test and control) was assigned to a single tooth. Therefore the unit of analysis is a 'site'as well as a 'patient.' In the studies IV, VI, VII using a parallel design the patient and the site were also synonymous. Only in study #5, one out of 45 patients contributed with more teeth to the study outcome, which consequently resulted in an analysis with the site as 'unit.' The impact of this one patient on the statistical analysis is probably negligible. However, this study did use a paired *t*-test in the comparison of test and control, which appear to be inappropriate because two patients contributed with only one tooth in the outcome data. For the remaining seven studies, the appropriate statistical method for split-mouth studies as well as parallel studies has been used.

Evaluation methods should be validated, because the outcome data depend on this, especially with methods varying from clinical to radiographic, including CT. In Table 6, a summary is provided with respect to the validation of the measurement, which appears to be lacking in all studies. One of the problems with the clinical analysis is that the buccal resorption is masked by a resorption in width. The final buccal measurement is therefore performed more to the lingual aspect for the simple reason that its original position is no longer there. What appears necessary in future studies (in humans) that

Table 6. **Quality and potential risk of bias assessment of the included studies**

Validity	Study #	#1	#2	#3	#4	#5	#6	#7	#8	#9
	Quality criteria	Leckovic et al. (1997)	Leckovic et al. (1998)	Camargo et al. (2000)	Iasella et al. (2003)	Serino et al. (2003)	Fiorellini et al. (2005)	Barone et al. (2008)	Crespi et al. (2009)	Aimetti et al. (2009)
External	Representive population group	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Eligibility criteria defined	?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Internal	Random allocation	? –	Yes Adequate	? –	Yes Adequate	? –	Yes Unclear	Yes Adequate	No NA	Yes Unclear
	Allocation concealment	?	?	?	?	?	?	?	?	?
	Blinded to the patient	NA	NA	NA	NA	?	Yes	NA	?	Yes
	Blinded to the examiner	?	Yes	?	Yes	?	Yes	?	Yes	Yes
	Blinding during statistical analysis	?	?	?	?	?	?	?	?	?
	Reported loss to follow-up	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	#(%) of drop-outs	3 (30%)	0	0	0	9 (20%)	0	0	0	0
	Treatment identical, except for intervention	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 6. **Continued.**

Validity	Study #	#1	#2	#3	#4	#5	#6	#7	#8	#9
	Quality criteria	Leckovic et al. (1997)	Leckovic et al. (1998)	Camargo et al. (2000)	Iasella et al. (2003)	Serino et al. (2003)	Fiorellini et al. (2005)	Barone et al. (2008)	Crespi et al. (2009)	Aimetti et al. (2009)
Statistical	Sample size and power calculation	?	?	?	Yes	?	Yes	?	?	Yes
	Point estimates presented for primary outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Measures of variability for primary outcome	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Intention to treat analysis	No	?	?	?	?	Yes	?	?	Yes
	Statistical test	Paired student *t*-test	Paired student *t*-test	Paired student *t*-test	2 way ANOVA and student *t*-test	Paired student *t*-test	Fisher's, Shapiro-Wilk, Wilcoxon rank sum	Two-tailed paired *t*-test	Two-tailed student *t*-test	Student *t*-test Bonferroni
Clinical validity	Study design	Split mouth	Split mouth	Split mouth	Parallel	Parallel and split mouth	Parallel	Parallel	Split mouth	Parallel
	Evaluation method	Clinical	Clinical	Clinical	Clinical	Clinical	CT	Clinical	Radio-graphical	Clinical
	Reason for extraction	Requiring extraction	Requiring extraction	Requiring extraction	Requiring extraction	Compromized teeth	Requiring extraction	Requiring extraction	Requiring extraction	Requiring extraction
	Calibration examiner	?	?	?	?	?	?	?	?	?
	Reproducibility data shown	No	No	No	No	No	95% CI	No	No	No
	Validated measurement	?	?	?	?	?	?	?	?	?
Estimated potential risk of bias		High	Low	High	Low	High	Low	Moderate	Moderate	Low

NA, not applicable/not feasible; ?, not specified/unclear.

follow post-extraction healing is that both the changes in height and width are assessed. This could be performed by using CT scans, another method that still needs validation. This would, however, impose a high level of radiation on the patient for a treatment as simple as an extraction.

For comparative studies, but especially non-randomized studies, it is important to assess whether test and control sites were similar before treatment. The risk of bias here is considerable. Studies I, III and V did not provide information about randomization. And study VIII was non-randomized. These four studies do not describe in detail whether the teeth in both groups were comparable. Most state that teeth were included in need of extraction. Only study VIII more specifically looked at extraction sockets with three bony walls remaining. Table 6 shows that only for two studies (IV and VI) a sample size calculation was presented. The number of subjects that completed the studies and provided evaluation data were sufficient with respect to the '*a priori*' sample size calculation. The other studies did not provide information in this respect. If not, the risk of a type II error could be substantial. This is true especially for those studies not providing a statistically significant difference.

Allocation concealment is the one aspect of bias protection shown to have a great impact on bias (Pildal et al. 2007). Where a trial has unclear methods, e.g. for allocation concealment, it should be at best of moderate risk of bias. Therefore, looking at the included studies from this perspective there are no low risk studies, only high and moderate risk. For the appraisal of study quality (Table 6), allocation concealment was not considered as an item to estimate the risk of bias. Although the authors recognize that this is an important issue they also are aware that reporting on allocation concealment in the dental literature has not been a critical item up until the recent past. Therefore, including this item would result in an overestimation of the risk of bias. It is, however, emphasized that for future studies researchers should provide information on this aspect which is also an item on the CONSORT-statement (Schulz et al. 2010).

During the last decade, systematic reviews have emerged as an important and useful decision making tool, for health care professionals. Because these systematic reviews are based on previously published evidence, their conclusions depend on the effect of the preferential acceptance of articles reporting significant results on research. Bias in favor of studies showing significant results alters the reliability of systematic reviews by reducing the number of articles with opposing results. Because the validity of this type of publications depends on the representativeness and soundness of the source material, underrepresented evidence will have disproportionally less influence on the outcome (Koletsi et al. 2009). Elimination of bias in clinical research is a shared responsibility. As professionals, we are called upon to be both supportive of new product development and critical of claim validity (Cugini 2009).

Conclusion

Osseous augmentation procedures for creating bone volume for dental implants often involve the use of grafting materials with or without barrier membranes to foster selective cell and tissue repopulation (Fiorellini et al. 2005) to restore the alveolar process and prepare the sur-

roundings for esthetic pleasing prosthetics or implant-supported prosthetics (Adriaens 1999).

The data concerning socket preservation therapies in humans are scarce. Therefore, firm conclusions about dimensional changes cannot be drawn currently. In NH after extraction, a reduction in width ranging between 2.6 and 4.56 mm and in height between 0.4 and 3.9 mm was observed. Socket preservation techniques may aid in reducing the bone dimensional changes following tooth extraction. However, they do not prevent bone resorption so that a loss in width up to 3.48 mm and in height up to 2.64 mm may be still expected.

Acknowledgements: This paper was prepared as part of the obligation for the first author to fulfill the requirements of the New York University College of Dentistry, Linhart Continuing Dental Education Program, Current Concepts in American Dentistry, Implantology and Periodontics.

References

◆Studies included from the search for this review.

Adriaens, P.A. (1999) Preservation of bony sites. In: Lang, N.P., Karring, T. & Lindhe, J., eds. *Proceedings of the Third European Workshop on Periodontology: Implant Dentistry*, 266–280. Chicago: Quintessence Publishing Co. Inc.

◆Aimetti, M., Romano, F., Griga, F.B. & Godio, L. (2009) Clinical and histologic healing of human extraction sockets filled with calcium sulfate. *The International Journal of Oral & Maxillofacial Implants* **24**: 902–909.

Amler, M.H. (1969) The time sequence of tissue regeneration in human extraction wounds. *Oral Surgery Oral Medical Oral Pathology* **27**: 309–318.

Araújo, M., Linder, E., Wennström, J. & Lindhe, J. (2008) The influence of bio-oss collagen on healing of an extraction socket: an experimental study in the dog. *The International Journal of Periodontics & Restorative Dentistry* **28**: 123–135.

Araújo, M.G. & Lindhe, J. (2005) Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *Journal of Clinical Periodontology* **32**: 212–218.

◆Barone, A., Aldini, N.N., Fini, M., Giardino, R., Calvo Guirado, J.L. & Covani, U. (2008) Xenograft versus extraction alone for ridge preservation after tooth removal: a clinical and histomorphometric study. *Journal of Periodontology* **79**: 1370–1377.

Bartee, B.K. (2001) Extraction site reconstruction for alveolar ridge preservation. Part 1: rationale and materials selection. *Journal of Oral Implantology* **27**: 187–193.

Buck, B.E. & Malinin, T.I. (1994) Human bone and tissue allografts. Preparation and safety. *Clinical Orthopaedics and Related Research* **303**: 8–17.

Becker, W., Becker, B.E. & Caffesse, R. (1994) A comparison of demineralized freeze-dried bone and autologous bone to induce bone formation in human extraction sockets. *Journal of Periodontology* **65**: 1128–1133.

Buser, D., Chen, S.T., Weber, H.P. & Belser, U.C. (2008) Early implant placement following single-tooth extraction in the esthetic zone: biological rationale and surgical procedures. *International Journal of Periodontics and Restorative Dentistry* **28**: 441–451.

Buser, D., Martin, W. & Belser, U.C. (2004) Optimizing esthetics for implant restorations in the anterior maxilla: anatomicand surgical considerations. *The International Journal of Oral & Maxillofacial Implants* **19** (Suppl.): 3–61.

◆Camargo, P.M., Lekovic, V., Weinlaender, M., Klokkevold, P.R., Kenney, E.B., Dimitrijevic, B., Nedic, M., Jancovic, S. & Orsini, M. (2000) Influence of bioactive glass on changes in alveolar process dimensions after exodontia. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **90**: 581–586.

Cardaropoli, G., Araújo, M. & Lindhe, J. (2003) Dynamics of bone tissue formation in tooth extraction sites. An experimental study in dogs. *Journal of Clinical Periodontology* **30**: 809–818.

Carmagnola, D., Adriaens, P. & Berglundh, T. (2003) Healing of human extraction sockets filled with Bio-Oss. *Clinical Oral Implants Research* **14**: 137–143.

◆Crespi, R., Capparè, P. & Gherlone, E. (2009) Magnesium-enriched hydroxyapatite compared to calcium sulfate in the healing of human extraction sockets: radiographic and histomorphometric evaluation at 3 months. *Journal of Periodontology* **80**: 210–218.

Cugini, M. (2009) The academic/industry relationship: common misconceptions about bias. *Journal of Dental Hygiene* **83**: 208–209.

Esposito, M., Coulthard, P., Worthington, H.V. & Jokstad, A. (2001) Quality assessment of randomized controlled trials of oral implants. *The International Journal of Oral & Maxillofacial Implants* **16**: 783–792.

◆Fiorellini, J.P., Howell, T.H., Cochran, D., Malmquist, J., Lilly, L.C., Spagnoli, D., Toljanic, J., Jones, A. & Nevins, M. (2005) Randomized study evaluating recombinant human bone morphogenetic protein-2 for extraction socket augmentation. *Journal of Periodontology* **76**: 605–613.

Froum, S., Cho, S.C., Rosenberg, E., Rohrer, M. & Tarnow, D. (2002) Histological comparison of healing extraction sockets implanted with bioactive glass or demineralized freeze-dried bone allograft: a pilot study. *Journal of Periodontology* **73**: 94–102.

Garg, A.R. (2004) *Bone – Biology, Harvesting, Grafting for Dental Implants*, 22–57. Carol Stream, IL, USA: Quintessence Publishing Co. Inc.

Gotfredsen, K., Carlsson, G.E., Jokstad, A., Arvidson Fyrberg, K., Berge, M., Bergendal, B., Bergendal, T., Ellingsen, J.E., Gunne, J., Hofgren, M., Holm, B., Isidor, F., Karlsson, S., Klemetti, E., Lang, N.P., Lindh, T., Midtbø, M., Molin, M., Närhi, T., Nilner, K., Owall, B., Pjetursson, B., Saxegaard, E., Schou, S., Stokholm, R., Thilander, B., Tomasi, C. & Wennerberg, A. (2008) Implants and/or teeth: consensus statements and recommendations. *Journal of Oral Rehabilitation* **35** (Suppl. 1): 2–8.

Gottlow, J., Nyman, S., Lindhe, J., Karring, T. & Wennström, J. (1986) New attachment formation in the human periodontium by guided tissue regeneration. Case reports. *Journal of Clinical Periodontology* **13**: 604–616.

Guarnieri, R., Pecora, G., Fini, M., Aldini, N.N., Giardino, R., Orsini, G. & Piattelli, A. (2004) Medical grade calcium sulfate hemihydrate in healing of human extraction sockets: clinical and histological observations at 3 months. *Journal of Periodontology* **75**: 902–908.

◆Iasella, J.M., Greenwell, H., Miller, R.L., Hill, M., Drisko, C., Bohra, A.A. & Scheetz, J.P. (2003) Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: a clinical and histologic study in humans. *Journal of Periodontology* **74**: 990–999.

Koletsi, D., Karagianni, A., Pandis, N., Makou, M., Polychronopoulou, A. & Eliades, T. (2009) Are studies reporting significant results more likely to be published? *American Journal of Orthodontic Dentofacial Orthopedics* **136**: 632–633.

Lang, N.P., Hämmerle, C.H., Brägger, U., Lehmann, B. & Nyman, S.R. (1994) Guided tissue regeneration in jawbone defects prior to implant placement. *Clinical Oral Implants Research* **5**: 92–97.

◆Lekovic, V., Camargo, P.M., Klokkevold, P.R., Weinlaender, M., Kenney, E.B., Dimitrijevic, B. & Nedic, M. (1998) Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. *Journal of Periodontology* **69**: 1044–1049.

◆Lekovic, V., Kenney, E.B., Weinlaender, M., Han, T., Klokkevold, P., Nedic, M. & Orsini, M. (1997) A bone regenerative approach to alveolar ridge maintenance following tooth extraction. Report of 10 cases. *Journal of Periodontology* **68**: 563–570.

Molly, L., Vandromme, H., Quirynen, M., Schepers, E., Adams, J.L. & van Steenberghe, D. (2008) Bone formation following implantation of bone biomaterials into extraction sites. *Journal of Periodontology* **79**: 1108–1115.

Needleman, I., Moles, D.R. & Worthington, H. (2000) Evidence-based periodontology, systematic reviews and research quality. *Journal of Periodontology* **37**: 12–28.

Neiva, R.F., Tsao, Y.P., Eber, R., Shotwell, J., Billy, E. & Wang, H.L. (2008) Effects of a putty-form hydroxyapatite matrix combined with the synthetic cell-binding peptide P-15 on alveolar ridge preservation. *Journal of Periodontology* **79**: 291–299.

Nevins, M., Camelo, M., De Paoli, S., Friedland, B., Schenk, R.K., Parma-Benfenati, S., Simion, M., Tinti, C. & Wagenberg, B. (2006) A study of the fate of the buccal wall of extraction sockets of teeth with prominent roots. *The International Journal of Periodontics & Restorative Dentistry* **26**: 19–29.

Pildal, J., Hróbjartsson, A., Jørgensen, K.J., Hilden, J., Altman, D.G. & Gøtzsche, P.C. (2007) Impact of allocation concealment on conclusions drawn from meta-analyses of randomized trials. *International Journal of Epidemiology* **4**: 847–857.

Pinho, M.N., Roriz, V.L., Novaes, A.B. Jr, Taba, M. Jr, Grisi, M.F., de Souza, S.L. & Palioto, D.B. (2006) Titanium membranes in prevention of alveolar col-

lapse after tooth extraction. *Implant Dentistry* **15**: 53–61.

RCT-Checklist of the Dutch Cochrane Center. (2009). Available at http://dcc.cochrane.org/sites/dcc.cochrane.org/files/uploads/RCT.pdf (accessed 5 September 2010).

Salata, L.A., Franke-Stenport, V. & Rasmusson, L. (2002) Recent outcomes and perspectives of the application of bone morphogenetic proteins in implant dentistry. *Clinical Implant Dentistry and Related Research* **4**: 27–32.

Schulz, K.F., Altman, D.G., Moher, D., CONSORT Group Collaborators. Altman, D.G., Barbour, V., Berlin, J.A., Boutron, I., Devereaux, P.J., Dickersin, K., Elbourne, D., Ellenberg, S., Gebski, V., Goodman, S., Gøtzsche, P.C., Groves, T., Grunberg, S., Haynes, B., Hopewell, S., James, A., Juhn, P., Middleton, P., Minckler, D., Moher, D., Montori, V.M., Mulrow, C., Pocock, S., Rennie, D., Schriger, D.L., Chulz, K.F., Simera, I.,Wager, E., Clarke, M. & Guyatt, G. (2010) CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. *Annals of Internal Medicine* **1**: 726–732.

◆Serino, G., Biancu, S., Iezzi, G. & Piattelli, A. (2003) Ridge preservation following tooth extraction using a polylactide and polyglycolide sponge as space filler: a clinical and histological study in humans. *Clinical Oral Implants Research* **14**: 651–658.

Simion, M., Baldoni, M., Rossi, P. & Zaffe, D. (1994) A comparative study of the effectiveness of e-PTFE membranes with and without early exposure during the healing period. *The International Journal of Periodontics & Restorative Dentistry* **14**: 167–180.

Smukler, H., Landi, L. & Setayesh, R. (1999) Histomorphometric evaluation of extraction sockets and deficient alveolar ridges treated with allograft and barrier membrane: a pilot study. *The International Journal of Oral & Maxillofacial Implants* **14**: 407–416.

Stroup, D.F., Berlin, J.A., Morton, S.C., Olkin, I., Williamson, G.D., Rennie, D., Moher, D., Becker, B.J., Sipe, T.A. & Thacker, S.B. (2000) Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis of observational studies in epidemiology (MOOSE) group. *Journal of the American Medical Association* **283**: 2008–2012.

Sy, I.P. (2002) Alveolar ridge preservation using a bioactive glass particulate graft in extraction site defects. *General Dentistry* **50**: 66–68.

Tarnow, D.P., Eskow, R.N. & Zamzok, J. (1996) Aesthetics and implant dentistry. *Periodontology 2000* **11**: 85–94.

Van der Weijden, F., Dell'acqua, F. & Slot, D.E. (2009) Alveolar bone dimensional changes of post-extraction sockets in humans: a systematic review. *Journal of Clinical Periodontology* **36**: 1048–1058.

von Elm, E., Altman, D.G., Egger, M., Pocock, S.J., Gøtzsche, P.C. & Vandenbroucke, J.P. (2007) STROBE initiative. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* **370**: 1453–1457.

Wang, H.L., Kiyonobu, K. & Neiva, R.F. (2004) Socket augmentation: rationale and technique. *Implant Dentistry* **13**: 286–296.

Yilmaz, S., Efeoğlu, E. & Kiliç, A.R. (1998) Alveolar ridge reconstruction and/or preservation using root form bioglass cones. *Journal of Clinical Periodontology* **25**: 832–839.