Surgical Techniques for Alveolar Socket Preservation: A Systematic Review

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Purpose: *To evaluate, through a systematic review of the literature, the efficacy of different surgical techniques in maintaining residual bone in the alveolar process following tooth extractions.* ***Materials and Methods:*** *MEDLINE/PubMed was searched through January 2010 and papers were selected according to the CONSORT statement and an independent three-stage screening process. The selected outcome variables were clinical width and height changes of the socket, and means and standard deviations were calculated from the included studies. For those studies that were randomized controlled trials, six meta-analyses were performed by dividing studies into three groups with regard to the use of barriers and grafting (barriers alone, graft alone, or both).* ***Results:*** *Thirteen papers met the eligibility criteria and were included in the analyses. Statistically significant ridge preservation was found for studies that used barriers alone; the pooled weighted mean was 0.909 mm (95% confidence interval, 0.497554 to 1.320732 mm) for bone height, while the mean for bone width was 2.966 mm (95% confidence interval, 2.334770 to 3.598300 mm).* ***Conclusions:*** *Socket preservation procedures are effective in limiting horizontal and vertical ridge alterations in postextraction sites. The meta-analysis indicates that the use of barrier membranes alone might improve normal wound healing in extraction sites.* Int J Oral Maxillofac Implants 2013;28:1049–1061. doi: 10.11607/jomi.2670

Key words: *alveolar socket preservation, ridge preservation, systematic review*

Over the past 15 years, multiple techniques have been proposed to manage alveolar socket healing. Among the multiple causes of tooth loss, a series of pathologic conditions could negatively affect the normal healing pattern of extraction sockets. Severe periodontal and endodontic lesions, as well as iatrogenic or accidental trauma, could impair the wound-healing process, causing defective ridge formation. The extraction of multiple teeth results in an overall decrease in the size of the edentulous ridge, which varies considerably between individuals.[1–8] Following the loss of even a single tooth, severe hard and soft tissue alterations may take place within the affected site of the alveolar ridge.[9,10] The amount of horizontal bone loss is generally the greatest and occurs more frequently on the buccal/facial side than on the lingual/palatal side of the ridge. To a lesser extent, there is a subsequent reduction of vertical ridge height, which has been described to be more pronounced on the buccal.[11–13] This three-dimensional resorption process at extraction sites results in narrower ridges with reduced vertical height[14] and lingual/palatal shifting of their long axes. Clearly, such a defective ridge form will not allow for appropriate prosthetic fabrication or correct placement of endosseous implants. To prevent this clinical situation, different authors have described several surgical procedures, ranging from regenerative techniques for socket preservation[15–19] to immediate implant placement.[20,21] Regenerative techniques have been widely tested in controlled and uncontrolled studies with various materials and clinical approaches: bone grafting alone, including autografts, allografts,[22,23] xenografts,[24,25] and alloplasts[26,27]; membrane alone, whether absorbable[28] or not[29,30]; and membrane in conjunction with grafting.[31,32] The aim of the present paper was to perform a systematic review to clarify the efficacy and effectiveness of various alveolar socket preservation techniques in maintaining edentulous ridge dimensions, and to identify which technique(s) could best prevent horizontal and vertical dimensional changes in the extraction sites.

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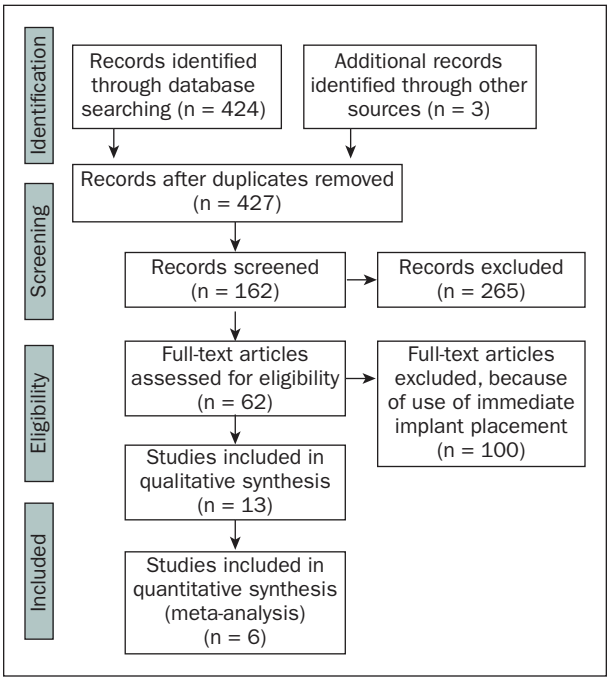


Fig 1 Search results: PRISMA flow diagram.

MATERIALS AND METHODS

Focused Question

What are the dimensional changes of the extraction socket following different surgical techniques for alveolar socket preservation?

Search Strategy

The search strategy included searching MEDLINE/PubMed up to January 2010. This research was supplemented by cross-checking the reference lists of selected studies and review articles to locate additional papers that could meet the eligibility criteria fixed for the study. Also, the so-called "grey literature" was investigated by means of direct contacts with authors and companies. The database was searched using the following terms: (fresh extraction socket OR alveolar socket) AND (socket preservation OR alveolar ridge preservation OR biomaterial OR graft OR membrane OR barrier OR flap OR flapless OR immediate implant placement OR immediate implant). The terms NOT ("trauma" OR "tumor" OR "injuries" OR "cancer" OR "cleft lip and palate")" were then added to exclude any irrelevant studies.

The following types of studies were included:

- Human studies
- Publications in English
- Randomized controlled clinical trials, controlled clinical trials, prospective/retrospective clinical trials, or case series with a minimum of 10 patients
- Studies describing the use of biomaterials and/or barriers
- Clinical evaluation of hard tissues over a minimum of 3 months

Excluded were animal studies, publications reporting the same data of later publications by the same authors, studies describing immediate implant placement in fresh extraction sockets, and letters and narrative or historical reviews.

Screening Process. A three-stage screening process was performed independently by three reviewers (MC, VDR, GVO). Initially, all the titles were screened to eliminate irrelevant publications and reviews. During the second stage of screening, the abstracts of all the selected publications were analyzed, and consequently the full texts of articles that still appeared to fulfill the inclusion criteria were obtained. In the third stage, through analysis of the complete texts of all remaining articles, the included articles were chosen. After this search, all reference lists of selected studies, relevant reviews, and studies from the "grey literature" were screened for additional papers that might have met the eligibility criteria (Fig 1). Any disagreements between the three reviewers were resolved through additional discussion.

Assessment of Heterogeneity. To evaluate the heterogeneity of the primary outcome between the selected studies, the following factors were recorded: study design; setting; duration of follow-up; number, age, and sex of subjects; smoking status; surgical and pharmacologic treatments; and clinical outcomes.

Quality Assessment. The methodologic quality of each study was assessed as proposed by Van der Weijden et al,[13] combining the criteria of PRISMA (Preferred Items for Reporting of Systematic Reviews and Meta-analysis),[32] the CONSORT statement,[33] Moher et al,[34,35] the MOOSE statement,[36] the STROBE statement,[37] Esposito et al,[38] and Needleman et al.[39] A given study was classified as having a low risk of bias when the following were specified: *(1)* random allocation, *(2)* defined inclusion/exclusion criteria, *(3)* blinding of patient and examiner, *(4)* balanced experimental groups, *(5)* an identical treatment between groups except for intervention, and *(6)* report of follow-up. When one of these six criteria was missing, the study was classified as having a moderate potential risk of bias. When two or more of these criteria were missing, this resulted in a high potential risk of bias. In addition, the levels of evidence[40] of the Centre for Evidence-Based Medicine (CEBM) were used to assess the methodologic quality of all included studies. The Jadad score[41] was used to assess the quality of any included randomized controlled trials (RCTs).

Data Extraction and Analysis

Data from the selected studies were processed for analysis. Mean values and standard deviations were extracted with regard to dimensional changes of bone in both width and height after socket preservation was performed. Changes in clinical width and height (at mesial, distal, buccal, and lingual locations and at the center of the socket) were selected as the outcome variables. For all studies, the pooled weighted means were reported and a respective approximation of the 95% confidence interval (CI) was computed. Considering only the RCTs, meta-analysis of means for both bone height and width changes with the given technique was performed using computer software (StatsDirect). A statistical homogeneity test was applied, and the fixed effect or random effect estimate of the pooled mean was reported to evaluate the heterogeneity of the studies. The level of significance was set at $P < .05$.

RESULTS

Search Results

The initial database search resulted in 424 papers (Fig 1). After titles were screened, 190 publications were excluded for incorrect topic or language. Subsequent abstract screening resulted in 162 remaining papers. After full-text analysis, 149 articles were excluded on the basis of the inclusion criteria because they were concerned with socket preservation conducted with immediate implant placement and because they did not provide clinical measurements as outcomes. The remaining 13 papers that fulfilled the inclusion criteria[14,15,24,28,31,42–49] were processed for data extraction. Three additional papers found in the reference lists of the selected studies were analyzed and then excluded because they did not meet the inclusion criteria (Fig 1).

Assessment of Quality

Assessment of the quality of the included articles is presented in Table 1a. The estimated risk of bias was defined as low in five studies,[28,31,42,46,47] moderate in three studies,[24,44,45] and high in five studies.[14,15,43,48,49] Five studies presented a combination of a low potential risk and a 1B level of evidence (CEBM, 2009). Nine studies scored 1B,[14,28,31,42,44–47,49] whereas the other four[15,24,43,48] scored 2B. For RCTs and controlled trials (CTs), a Jadad score[41] was also calculated. Three studies[28,46,47] scored 3, five studies[14,31,43,44] scored 2, and only two studies[15,49] scored 1.

Assessment of Heterogeneity. The selected studies showed considerable heterogeneity. These characteristics are presented in Table 1b.

Study Design and Follow-up. Of the selected studies, seven were RCTs[14,28,31,42,44,46,47] and three were CTs.[15,48,49] Cardaropoli and Cardaropoli[43] was a case series, Hoffmann et al[45] was a retrospective study, and Artzi et al[24] was an individual cohort clinical trial. Five studies had a parallel design[14,31,43,46,48] and four employed a split-mouth design.[15,28,44,48,49] Follow-up periods ranged between 3 and 12 months.

Population Epidemiology, Tooth Types, and Reason(s) for Extraction. The studies included a number of subjects, ranging between 10 and 276. Only two studies did not report the mean age of the patients,[24,44] while five did not report the age range of the subjects.[15,28,46,47,49] Only one study[14] did not report information about sex. Only three studies[14,42,43] clearly reported the reasons for extraction, and one study[28] did not report them at all. Most studies evaluated the effects of socket preservation on anterior or single-rooted teeth, while two studies included molars.[43,45] Two studies did not report this information.[46,48] Nine studies did not report the smoking status of the participants.[15,24,28,31,43,46–49] The studies of Fotek et al[42] and Pinho et al[14] excluded smokers, whereas Barone et al[44] and Hoffman et al[45] included 5 and 124 smokers, respectively.

Intervention and Pharmacologic Treatment. Table 1b details the interventions performed in the included studies, as well as any prescription medications administered before, during, and after treatment.

Evaluation Parameters and Methods. Only data regarding clinical measurements were extracted from selected studies. Among these, 11 studies[14,15,28,31,42–46,48,49] assessed mean changes in bone width. Twelve studies[14,15,24,28,31,42,44–49] evaluated mean bone height changes. Five studies[24,31,44,45,47] evaluated mean changes at the oral/buccal aspect/side of the extraction site, whereas six[14,15,28,42,48,49] considered mean changes at the midbuccal. Only in the study of Fiorellini et al[46] was the evaluation conducted at the center of the extraction site. An acrylic resin stent was used to perform repeatable clinical measurements in four studies[42,44,45,48]; all four measured ridge width, and Fotek et al[42] additionally measured ridge height. Titanium pins were used as reference points for both horizontal and vertical measurements in three studies[14,15,28] and for horizontal measurements alone in one study.[49] In all other studies, the reference points were not clear. Two other kinds of measurements were also performed: socket bone fill was measured in four studies,[14,15,28,49] and soft tissue dimensions were recorded in three studies[31,42,47] (Tables 2a and 2b).

Loss to Follow-up. Four studies[24,43,45,47] did not report any information regarding loss to follow-up. In one study,[42] two subjects dropped out for unreported reasons. Another study[48] reported nine dropouts for reasons unrelated to the therapy. In Lekovic et al,[15] three subjects dropped out because of premature

Table 1a Quality Assessment of Included Studies

Validity/Quality criteria	Fotek et al[42]	Cardaropoli and Cardaropoli[43]	Barone et al[44]	Hoffmann et al[45]
External				
Representative population group	Yes	Yes	Yes	Yes
Eligibility criteria defined	Yes	Yes	Yes	Yes
Internal				
Random allocation	No	?	Yes	Yes
Allocation concealment	No	?	?	No
Blinded to the patient	No	?	?	No
Blinded to the examiner	Yes	?	?	Yes
Blinding during statistical analysis	No	?	?	?
Reported loss to follow-up	Yes	No	Yes	?
No. (%) of dropouts	2 (10%)	?	0	?
Treatment identical, except for intervention	Yes	Yes	Yes	?
Statistical				
Sample size calculation and power	No	?	?	Yes
Point estimates presented for primary outcome	No	?	Yes	Yes
Measures of variability for the primary outcome	No	Yes	Yes	?
Intention-to-treat analysis	No	Yes	?	?
Clinical aspects				
Study design	RCT	CS	RCT (parallel)	Retrospective
Validated measurement	?	?	?	No
Calibration examiner	?	?	?	Yes
Reproducibility data shown	No	No	No	Yes
Reason for extraction	Endodontic failure, tooth fracture	Root fractures, periodontal, endodontic failures, advanced caries lesions	Requiring extraction	Requiring extraction
Estimated potential risk of bias	Low	High	Moderate	Moderate
Level of evidence (CEBM)	1B	2B	1B	1B
Jadad score (for CTs)	2	NA	2	NA

CS = case series; NA = not applicable.

membrane exposure; in this case, earlier measurements were conducted and included in the statistical analysis. In the remaining six studies there were no dropouts.

Study Outcomes. The study outcomes are presented in Tables 3 and 4. Data relative to control groups with no treatment were not considered. With respect to crestal bone width, the mean weighted change was a loss of 0.36 mm (n = 483) (95% CI, –0.42 to –0.29 mm). Meanwhile, the weighted mean change in width related to RCTs alone was –0.16 mm (n = 181) (95% CI, –0.24 to 0.12 mm). At the same time, with respect to crestal bone height, the mean weighted change was –0.58 mm (n = 522) (95% CI, –0.69 to –0.54 mm), whereas the weighted mean change in crestal bone height reported by RCTs alone was –0.35 mm (n = 181) (95% CI, –0.59 to –0.27 mm). Six meta-analyses were performed: three regarding bone height changes created by socket preservation techniques and three regarding bone width changes with the same techniques. Similar modifications regarding untreated sites were used as case controls. Results are shown in Tables 4 to 9. All the pooled weighted mean differences (WMDs) were calculated using random effect estimate. In four

	Pinho et al[14]	Fiorellini et al[46]	Vance et al[47]	Serino et al[48]	Iasella et al[31]	Camargo et al[49]	Artzi et al[24]	Lekovic et al[28]	Lekovic et al[15]
	?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	No	Yes	Yes	Yes	Yes	Yes	Yes	?	?
	Yes	Yes	Yes	Yes	Yes	?	No	Yes	?
	?	?	No	?	?	?	No	?	?
	?	Yes	No	?	?	?	No	?	?
	?	Yes	Yes	?	Yes	?	No	Yes	?
		?	No	?	?	?	No	?	?
	Yes	Yes	?	Yes	Yes	Yes	?	Yes	Yes
	0	0	?	9 (20%)	0	0	?	0	0
	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	?	?	No	?	Yes	?	No	?	?
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	No	Yes	No	?	?	?	No	?	?
	RCT (parallel)	RCT (parallel)	RCT	CT (parallel and split-mouth)	RCT (parallel)	CT (split-mouth)	Individual cohort	RCT (split-mouth)	CT (split-mouth)
	?	?	Yes	?	?	?	Yes	?	?
	No	?	Yes	?	?	?	No	?	?
	No	Yes	Yes	No	No	No	Yes	No	No
	Advanced periodontal disease	Requiring extraction	Requiring extraction	Compromised teeth	Requiring extraction	Requiring extraction	Unclear	Requiring extraction	Requiring extraction
	High	Low	Low	High	Low	High	Moderate	Low	High
	1B	1B	1B	2B	1B	1B	2B	1B	2B
	2	3	3	2	2	1	NA	3	1

groups belonging to two studies,[46,48] a graft was used to preserve bone height. In this case, the pooled WMD is –0.776 mm (95% CI, –2.507968 to 0.95576 mm) and the Z value is –0.878 (P = .3798) (Table 5). A graft was used to preserve alveolar crest width in three groups in the study of Fiorellini et al.[26] The pooled WMD is 1.324 mm (95% CI, –0.018312 to 2.665724 mm) and the Z value is 1.933 (P = .053) (Table 6). A barrier was used to preserve bone height and width in two groups in the studies of Lekovic et al.[15,28] For vertical evaluation, the pooled WMD is 0.909 mm (95% CI, 0.497554 to 1.320732 mm) and the Z value is 4.329 (P < .0001) (Table 7), while for horizontal evaluation the pooled WMD is 2.966 mm (95% CI, 2.334770 to 3.598300 mm) and the Z value is 9.203 (P < .0001) (Table 8). In both cases, the results were statistically significant (the CIs do not include any 0 values). A combined graft/barrier technique was used to preserve bone height and width in three groups within three studies.[31,44,49] Regarding bone height, the pooled WMD is 0.962 mm (95% CI, –1.177765 to 3.101909 mm) and the Z value is 0.881 (P = .3782) (Table 9). For bone width the pooled WMD is 1.199 mm (95% CI, –0.086553 to 2.485404 mm) and the Z value is 1.828 (P = .0675) (Table 10).

Table 1b Main Characteristics of Selected Studies

Study	Study design, setting	Follow-up	No. of patients; age (mean, range); sex	No. of smokers	Groups
Fotek et al[42]	RCT, university	4 mo	20; 59.55 y (29–77); 7 M, 13 F	0	**Test 1:** sockets filled with solved-preserved mineralized cancellous bone (Puros) covered with acellular dermal matrix (AlloDerm) **Test 2:** sockets filled with solved-preserved mineralized cancellous bone (Puros) covered with a d-PTFE membrane (Cytoplast)
Cardaropoli and Cardaropoli[43]	CS, private practice	4 mo	10; 45.9 y (27–63); 6 M, 4 F	Unknown	**Test:** sockets filled with xenograft material (GenOs Osteobiol) covered with a collagen membrane (Evolution Osteobiol)
Barone et al[44]	RCT, hospital	7 mo	40; >18 y (26–29); 16 M, 24 F	5 (3 control group/2 test group)	**Test:** sockets filled with corticocancellous porcine bone (MP3 Osteobiol) covered with a collagen membrane (Evolution Osteobiol) **Control:** no treatment
Hoffmann et al[45]	Retro-spective, private practice	12 mo	276; 50.2 y (24–73); 151 M, 125 F	124	**Test:** sockets covered with a nonresorbable d-PTFE membrane (Cytoplast)
Pinho et al[14]	RCT, university	6 mo	10; 46.3 y (35– 60); unknown	0	**Test:** sockets filled with autogenous bone graft covered with a titanium membrane (Frios Boneshield) **Control:** sockets covered with a titanium membrane (Frios Boneshield)
Fiorellini et al[46]	RCT, multicenter	4 mo	80; 47.4 y; 43 M, 37 F	Unknown	**Test 1:** sockets filled with 0.75 mg/mL of rhBMP-2/ACS (Helistat) **Test 2:** sockets filled with 1.50 mg/mL of rhBMP-2/ACS (Helistat) **Placebo:** sockets filled with ACS alone **Control:** no treatment
Vance et al[47]	RCT, university	4 mo	24; 56.0 ± 11 y; 9 M, 15 F	Unknown	**Test 1:** sockets filled with a putty binder composed of carboxy-methylcellulose and CaS mixed with DFDBA (50:50) covered with a CaS barrier (Capset) **Test 2:** sockets filled with mineralized bovine-derived xenograft (Bio-Oss) covered with a collagen membrane
Serino et al[48]	CT, university	6 mo	45; 45.9 y (35–64); 14 M, 31 F	Unknown	**Test:** sockets filled with a commercially available re-absorb-able sponge of polylactide-polyglycolide acid (Fisiograft) **Control:** no treatment
Iasella et al[31]	RCT, unknown	4–6 mo	24; 51.5 ± 13.6 y (28–76); 10 M, 14 F	Unknown	**Test:** sockets filled with FDBA (American Red Cross) + 50 mg/mL tetracycline solution covered by a collagen mem-brane (Biomend Extend) **Control:** no treatment
Camargo et al[49]	CT split mouth, university	6 mo	16; 44.0 ± 15.9 y; 8 M, 8 F	Unknown	**Test:** sockets filled with a bioactive glass material (Biogran) covered with a layer of surgical-grade calcium sulfate (Capset) **Control:** no treatment
Artzi et al[24]	Individual cohort, university	3 mo	15; 23–64 y; 6 M, 9 F	Unknown	**Test:** sockets filled with cancellous PBBM (Bio-Oss)
Lekovic et al[28]	RCT, university	6 mo	16; 52.6 ± 11.8 y; 10 M, 6 F	Unknown	**Test:** sockets covered with a bioabsorbable polylactide/ polyglycolide membrane (Resolut) **Control:** no treatment
Lekovic et al[15]	CT, university	6 mo	10; 49.8 y; 6 M, 4 F	Unknown	**Test:** sockets covered with an e-PTFE membrane (Gore-Tex) **Control:** no treatment

ACS = absorbable collagen sponge; CaS = calcium sulfate; CEJ = cementoenamel junction; CS = case series; d-PTFE = dense polytetrafluoroethylene; e-PTFE = expanded polytetrafluoroethylene; DFDBA = demineralized freeze-dried bone allograft; FDBA = freeze-dried bone allograft; PBBM = porous bovine bone mineral; rhBMP-2 = recombinant human bone morphogenetic protein-2.

Pharmacologic treatment	Flap raised, releasing incisions, closure	Clinical outcomes (reference point)
Antibiotics for 7 d, anti-inflammatory as needed	No, No, No	Horizontal width (stent to the buccal plate), vertical height (stent to the buccal crest), soft tissue dimensions
Antibiotics for 6 d, chlorhexidine until suture removal	No, No, No	Horizontal ridge width
Antibiotics for 4 d, chlorhexidine for 21 d, anti-inflammatory for 3 d	Yes, Yes, Yes	Horizontal ridge width, vertical distance from the template at four points (template)
Antibiotics for 6 d, chlorhexidine for 35 d, anti-inflammatory for 4 d	Yes, No, No	Horizontal width, vertical height at eight points (resin stent to adjacent CEJ)
Antibiotics for 10 d, chlorhexidine for 15 d	Yes, Yes, Yes	With a periodontal probe to the nearest millimeter: external vertical measurement, internal vertical measurement, horizontal measurement
Antibiotics for 7–10 d, chlorhexidine for ? d, anti-inflammatory for ? days	Yes, Yes, Yes	Alveolar bone height, bone width (at three points along the length of the extraction socket)
Antibiotics for ? d, chlorhexidine for ? d, anti-inflammatory for ? d	Yes, ?, Yes	Horizontal ridge width, vertical height at four sites, soft tissue dimensions
Chlorhexidine for 14 d, anti-inflammatory as needed	Yes, No, No	Bone level change (at three points, from the acrylic stent to the buccal alveolar crest)
Antibiotics for 14 d, chlorhexidine until soft tissue closure, anti-inflammatory for 7 d	Yes, No, No	Horizontal alveolar ridge width, vertical ridge height, soft tissue dimensions
Antibiotics for 7 d, oral antiseptics for 15 d, analgesics as needed	Yes, Yes, No	External vertical measurement, internal vertical measurement, horizontal measurement (titanium pin)
Antibiotics for 7 d, chlorhexidine for 14 d, anti-inflammatory as needed	Yes, No, Yes	Socket wall height (from the neighboring crestal ridge at four points)
Antibiotics for 7 d, chlorhexidine for 15 d, anti-inflammatory as needed	Yes, Yes, Yes	External vertical measurement, internal vertical measurement, horizontal measurement (titanium pin)
Antibiotics for 7 d, chlorhexidine for ? d, anti-inflammatory as needed	Yes, Yes, Yes	External vertical measurement, internal vertical measurement, horizontal measurement (titanium pin)

Table 2a Mean Changes in Soft Tissue Dimensions

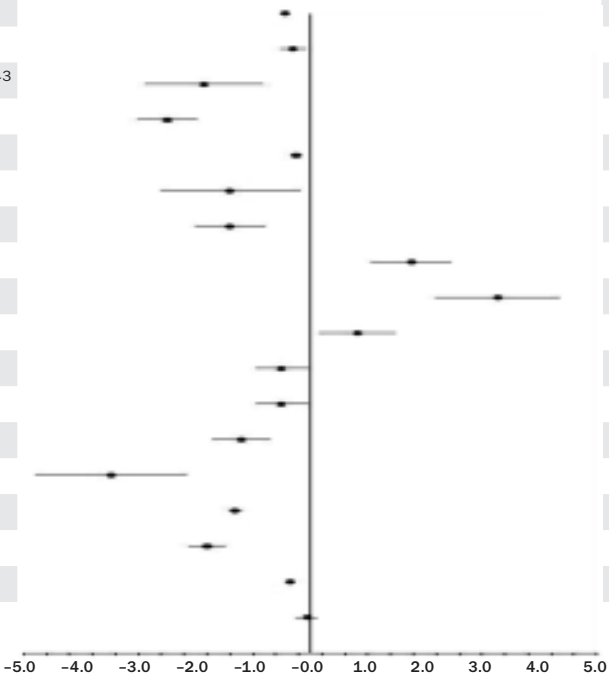
Study	Thickness (mm)	Width (mm)
Fotek et al[42]	Test 1: –0.06 Test 2: –0.17	Test 1: –0.06 Test 2: –0.17
Vance et al[47]	Test 1: +0.1 ± 0.6 buccal, –0.1 ± 0.7 lingual Test 2: –0.2 ± 1.5 buccal, +0.0 ± 0.7 lingual	Not reported
Iasella et al[31]	Test: –0.1 ± 0.5 buccal, –0.6 ± 1.5 lingual Control: +0.4 ± 0.6 buccal, +0.5 ± 1.5 lingual	Not reported

Table 2b Mean Changes in Bone Fill

	Mean clinical change (mm)	Percent fill
Pinho et al[14]	Not reported	Test: 100% Control: 100%
Camargo et al[49]	Test : –6.43 ± 2.78 Control: –4.00 ± 2.33	Not reported
Lekovic et al[28]	Test : –5.81 ± 0.29 Control: –3.94 ± 0.35	Not reported
Lekovic et al[15]	Test : –4.90 ± 0.86 Control: –3.00 ± 0.63	Not reported

Table 3 Bone Width Changes (Means and 95% CIs) After Treatment

Study	Graph of values	No. of patients	Bone width changes (mm) Mean	95% CI
Fotek et al[42]*		9	–0.44	–0.47 to –0.41
Fotek et al[42]*		10	–0.30	–0.51 to –0.09
Cardaropoli and Cardaropoli[43]		10	–1.85	–0.83 to –2.87
Barone et al[44]*		20	–2.50	–1.97 to –3.03
Hoffmann et al[45]		276	–0.25	–0.22 to –0.28
Pinho et al[14]*		10	–1.40	–0.18 to –2.62
Pinho et al[14]*		10	–1.40	–0.79 to –2.01
Fiorellini et al[46]*		22	1.76	2.46 to 1.06
Fiorellini et al[46]*		21	3.27	4.35 to 2.19
Fiorellini et al[46]*		17	0.82	1.49 to 0.15
Vance et al[47]*		12	–0.50	–0.05 to –0.95
Vance et al[47]*		12	–0.50	–0.05 to –0.95
Iasella et al[31]*		12	–1.20	–0.69 to –1.71
Camargo et al[49]		16	–3.48	–2.17 to –4.80
Lekovic et al[28]*		16	–1.31	–1.19 to –1.43
Lekovic et al[15]		10	–1.80	–1.42 to –2.12
Pooled**		483	–0.36	–0.42 to –0.29
Pooled RCTs**		181	–0.16	–0.24 to 0.12



*RCT; **Pooled estimations: weighted means with approximation of 95% CI.

DISCUSSION

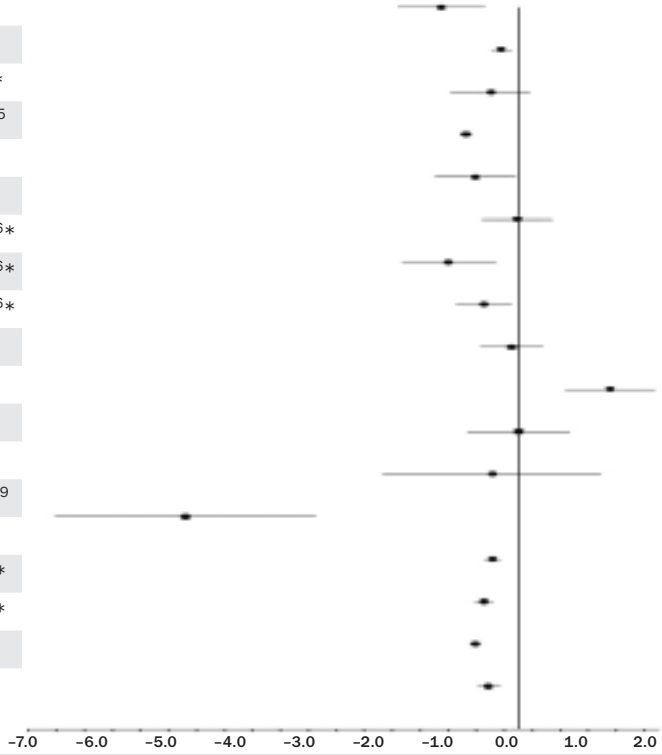
The purpose of this systematic review was to evaluate the efficacy of different surgical techniques in improving the quantity of available bone in the alveolar process following tooth extraction. Because precise inclusion criteria were set, the large number of papers about this topic in the literature produced only 13 eligible studies, which exhibited clear heterogeneity (Table 1b). Thus, a lower level of evidence should be considered for this systematic review, at least in part.

Socket Preservation Techniques Versus No Treatment

The data from weighted means analysis show a slight advantage in favor of socket preservation techniques

Table 4 Bone Height Changes (Means and 95% CIs) After Treatment

Study	Graph of values	No. of patients	Bone height changes (mm) Mean	CI 95%
Fotek et al[42]*		9	–1.11	–1.73 to –0.49
Fotek et al[42]*		10	–0.25	–0.39 to –0.11
Barone et al[44]*		20	–0.40	–0.97 to 0.17
Hoffman et al[45]		276	–0.75	–0.79 to –0.71
Pinho et al[14]*		10	0.40	–1.60 to 2.40
Pinho et al[14]*		10	0.20	–1.90 to 2.30
Fiorellini et al[46]*		22	–0.62	–1.20 to –0.04
Fiorellini et al[46]*		21	–0.02	–0.53 to 0.49
Fiorellini et al[46]*		17	–1.00	–1.67 to –0.33
Vance et al[47]*		12	–0.50	–0.90 to –0.10
Vance et al[47]*		12	–0.10	–0.55 to 0.35
Serino et al[48]		34	1.30	0.66 to 1.94
Iasella et al[31]*		12	0.00	–0.74 to 0.74
Camargo et al[49]		16	–0.38	–1.94 to 1.18
Artzi et al[24]		15	–4.76	–6.63 to –2.89
Lekovic et al[28]*		16	–0.38	–0.49 to –0.27
Lekovic et al[15]*		10	–0.50	–0.64 to –0.36
Pooled**		522	–0.58	–0.69 to –0.54
Pooled RCTs**		151	–0.35	–0.59 to –0.27



*RCT; **Pooled estimations: weighted means with approximation of 95% CI.

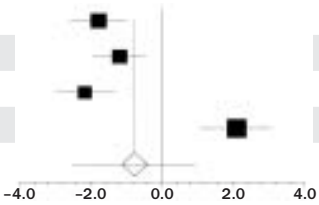
versus no treatment postextraction because of reduced bone loss both horizontally and vertically. This result suggests that a benefit may be obtained from socket preservation procedures, as they can at least limit bone changes of the alveolar process; the use of grafting materials and barriers, both together and alone, might help to interfere in the normal sequence of biologic events leading to resorption in wound healing. It is necessary to bear in mind that these are mean data obtained by pooling the results of a few studies dealing with a variety of surgical procedures and with largely different samples of enrolled populations. Therefore, any conclusions drawn should be hypothetical.

Different Techniques for Alveolar Socket Preservation

In the final meta-analysis, the authors divided the selected studies into three groups according to the different surgical procedures and biomaterials used. The three categories are graft, barrier, and graft+barrier. These categories are intended to isolate different interactions with wound healing. The results showed that a higher level of evidence was obtained with the two meta-analyses of the studies of barriers (Tables 7 and 8); however, their statistical significance gives rise to doubts, because the barriers alone produced better clinical results than grafts+barriers or grafts alone. It could be argued that the protective, space-making effect of the barriers on the blood clot inside the socket and on the remaining bone walls outside the socket is responsible; ie, the barrier, acting as a shield, could enhance the physiologic healing process, minimizing bone loss and maximizing bone repair, with a resulting net effect of improvement versus untreated extraction sockets in terms of bone height and width.

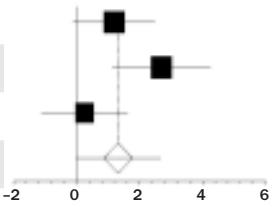
In the selected studies, several surgical approaches were proposed, with different flap designs, in attempts to achieve soft tissue primary closure, to improve barrier adaptation, or even to set reference points. Nevertheless, it could be argued that socket preservation techniques are effective regardless of whether primary flap closure is achieved; it could be speculated that the influence of releasing incisions on wound healing of both soft and hard tissues would at least slightly

Table 5 Meta-analysis of Weighted Mean Differences in Bone Height After Grafting in RCTs

Study	Graph of values	Mean difference (mm)	95% CI (mm)	Test patients	Control patients
Fiorellini et al[46]		1.19	−0.105 to 2.485	22	20
Fiorellini et al[46]		1.14	1.142 to 4.258	21	20
Fiorellini et al[46]		0.25	−1.114 to 1.614	17	20
Serino et al[48]		2.10	1.108 to 3.092	34	20
Pooled*		−0.78	−2.508 to 0.956	94	80

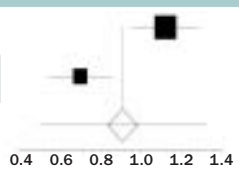
Homogeneity test: Cochran Q = 52.234, $P < .001$.
*Random effects weighted mean difference.

Table 6 Meta-analysis of Weighted Mean Differences in Bone Width After Grafting in RCTs

Study	Graph of values	Mean difference (mm)	95% CI (mm)	Test patients	Control patients
Fiorellini et al[46]		1.19	−0.105 to 2.485	22	20
Fiorellini et al[46]		1.14	1.142 to 4.258	21	20
Fiorellini et al[46]		0.25	−1.114 to 1.614	17	20
Pooled		1.323	−0.018 to 2.665	60	60

Homogeneity test: Cochran Q = 5.588, $P > .001$.
*Random effects weighted mean difference.

Table 7 Meta-analysis of Weighted Mean Differences in Bone Height After Use of a Barrier in RCTs

Study	Graph of values	Mean difference (mm)	95% CI (mm)	Test patients	Control patients
Lekovic et al[28]		1.12	0.953 to 1.287	16	16
Lekovic et al[15]		0.70	0.542 to 0.858	10	10
Pooled*		0.909	0.497 to 1.320	26	26

Homogeneity test: Cochran Q = 12.801, $P < .001$.
*Random effects weighted mean difference.

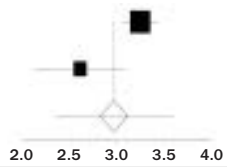
modify the clinical outcome. However, the present study was not designed to test the effect of these variables, and it is impossible to draw any definite conclusion.

Heterogeneity in Clinical Measurements

Another important issue arising from the outcome analyses is the evident heterogeneity in the clinical measurements made among both selected and unselected studies. In fact, the performed Cochran Q calculation often confirmed that this heterogeneity was statistically significant, thus suggesting inconsistent outcomes for ridge preservation techniques versus no treatment; this is the main cause of the authors' inability to advance definitive clinical indications. Nevertheless, it is possible to suppose a trend toward a better performance regarding some socket preservation interventions.

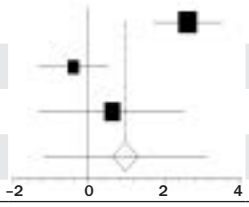
Further research is needed to develop a clearer understanding of the reported variability of clinical outcomes. It is advisable that future studies should focus on selecting a small group of precise and clear surgical techniques, testing a limited amount of graft materials and a few types of barriers, and taking into account the primary role of the biologic principles of wound healing. Furthermore, because clinicians often tend to focus on bone availability and its effect on possible implant placement to achieve optimal esthetics and function for prosthetic therapy, attention must also be paid to changes in the soft tissues. Therefore, future studies should consider both hard and soft tissue changes. In consideration of this, it might also be useful to consider the previous systematic review of Van Der Weijden et al[13] and to compare the present results with theirs. With respect to healing of untreated sockets, the weighted mean

Table 8 Meta-analysis of Weighted Mean Differences in Bone Width After Use of a Barrier in RCTs

Study	Graph of values	Mean difference (mm)	95% CI (mm)	Test patients	Control patients
Lekovic et al[28]		3.25	3.062 to 3.438	16	16
Lekovic et al[15]		2.60	2.107 to 3.093	10	10
Pooled*		2.966	2.334 to 3.598	26	26

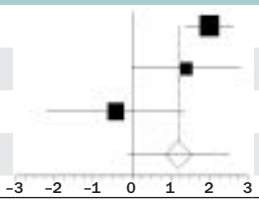
Homogeneity test: Cochran Q = 5.832, $P < .001$.
*Random effects weighted mean difference.

Table 9 Meta-analysis of Weighted Mean Differences in Bone Height After Grafting+Barrier in RCTs

Study	Graph of values	Mean difference (mm)	95% CI (mm)	Test patients	Control patients
Barone et al[44]		2.60	1.696 to 3.503	20	20
Iasella et al[31]		–0.40	–1.328 to 0.528	12	12
Camargo et al[49]		0.62	–1.289 to 2.529	16	16
Pooled*		0.962	–1.177 to 3.101	48	48

Homogeneity test: Cochran Q = 20.866, $P > .001$.
*Random effects weighted mean difference.

Table 10 Meta-analysis of Weighted Mean Differences in Bone Width After Grafting+Barrier in RCTs

Study	Graph of values	Mean difference (mm)	95% CI (mm)	Test patients	Control patients
Barone et al[44]		2.00	1.368 to 2.362	20	20
Iasella et al[31]		1.40	0.002 to 2.797	12	12
Camargo et al[49]		–0.42	–2.186 to 1.346	16	16
Pooled*		1.999	0.086 to 2.485	48	48

Homogeneity test: Cochran Q = 6.570, $P > .001$.
*Random effects weighted mean difference.

changes based on the data derived by Van Der Weijden et al[13] showed that loss of bone width (–3.87 mm) was greater than loss of bone height (–1.67 and –2.03 mm on buccal and lingual sides, respectively), although it must be noted that these are mean values with standard deviations. Comparing the present results (–0.36 mm mean horizontal bone loss and –0.58 mm mean vertical bone loss) to those values, it is evident that, regardless of the surgical procedures and biomaterials used, socket preservation techniques minimized the amount of postextraction bone loss; in the future, more accurate studies are needed to clarify the different roles played by surgical techniques and grafts/barriers in achieving the aforementioned results. In other words, it must be clarified which is most important in limiting physiologic postextraction alveolar ridge alterations: the surgical aspect, the biomaterial, or both.

CONCLUSION

Differences at many levels in study methodologies as well as lack of homogeneity of the data precluded an adequate and complete pooling of results for a more comprehensive analysis. Therefore, only general conclusions and suggestions can be drawn regarding the use of surgical techniques for socket preservation.

Clinical Implications for Practice

- Socket preservation procedures seem to be effective in limiting horizontal and vertical ridge alterations following tooth extraction.
- The best available evidence (meta-analysis) seems to indicate that the use of barrier membranes alone might improve normal wound healing in extraction sites.

- Flap elevation and soft tissue primary closure seem to have little effect on horizontal and vertical bone loss at extraction sites.
- Evaluation of the cost/benefit ratio should be taken into greater account from the biologic and economic points of view. In fact, untreated extraction sites usually show normal healing. Furthermore, the various biomaterials suggested probably have a wide range of costs.

Scientific Implications for Research

- High-quality randomized controlled clinical trials are needed in which authors should adhere to CONSORT statement guidelines in reporting their data. This will facilitate the evaluation of such studies.
- A split-mouth design should be a mandatory prerequisite for a proper study that seeks to test different clinical procedures with particular surgical techniques and biomaterials of various kinds.
- Greater consideration should be given during the study design process to standardize both surgical procedures and outcome measures; this will facilitate validation and replication for study purposes.

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