

# Extraction Socket Preservation with or without Membranes, Soft Tissue Influence on Post Extraction Alveolar Ridge Preservation: a Systematic Review

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## ABSTRACT

**Objectives:** The purpose of this systematic review was to assess quantitatively and qualitatively the influence of two different factors: membranes and soft tissue graft influence for the extraction socket preservation.

**Material and Methods:** A wide-ranging electronic search was performed in six databases up to 30 of November 2018 in order to identify all the clinical and randomized clinical trials performed in humans published with no data restriction. The inclusion criteria were extraction socket preservation with and without membranes or a soft tissue graft in a intact socket with at least six months of follow-up, have more than 12 patients or treat more than 12 sites per group and evaluated at least one of the primary outcomes measures (radiographic measures histological assessment, clinical measures).

**Results:** From an initial search of 1524 studies only 6 papers fulfil the inclusion and exclusion criterions. All the six selected papers, presented a wide heterogeneity of treatments used, evaluated variables and observation period that made impossible to recommend any specific techniques and/or material to achieve better results. The limited data found suggest that the used of membrane reveals to achieve better results. It wasn't possible to observe in any clinical trial that compares the used of soft tissue graft.

**Conclusions:** New trials need to be performed in order to identify what specific techniques and/or materials are better to decrease the reabsorption of the socket after tooth extraction. Clinical trials designed to understand when/how the soft tissues grafts influence at the socket preservation is needed.

**Keywords:** alveolar bone loss; bone remodeling; tooth socket; systematic review.

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## INTRODUCTION

One of the goals of the periodontal treatment is to maintain the teeth in good conditions to provide health, function and aesthetics to the patients [1]. However, sometimes as a result of caries, periodontal disease, endodontic lesions and others, tooth extraction is inevitable.

There are several options to give to the patients as an alternative to replace the extracted teeth, from removal to fixed dental prosthesis, from implant to adhesive fixed prosthesis, each of them with good results in terms of survival rates with long term follow-ups according to the literature, when well indicated [2,3]. It is clear that all of these options give to the patients an alternative to the teeth lost, but they don't solve the biological and dimensional changes that occur after tooth extraction.

Tooth extraction begins a sequence of biological changes, with intense resorption of the alveolar bone, invagination of the mucosa, just in the first weeks after [4-8]. The quantity and extent of bone process changes are dependent on several factors, which in all of the situations leads to alveolar ridge resorption, in the three-dimensional space [9,10].

In the last years, the goal was not only to solve the existing problem but mainly to avoid the problem or at least to reduce the amount of hard and soft tissue reabsorption over the time. Several different techniques and approaches offer clinicians different possibilities to reach this goal.

From the alveolar ridge preservation [11,12], to immediate implants [13-15] and also to the socket shield technique to immediate implant placement [16-18] the clinician have now several different options with a different type of indications as well as different level of scientific background.

A wide variety of alveolar ridge preservation treatment modalities have been described in the last 20 years, including socket grafting with a biomaterial alone [19], overbuilding of the facial bone wall [20], occluding the access to the socket by interposing a barrier element [12], or a combination of some of them [21], with or without using soft tissue grafts to allow primary intention healing.

There are already in the literature several systematics reviews [22-26] that were designed to give the clinicians the state of art of these techniques to allow them to make the best clinical decision. However, there is limited information based on randomized clinical trials or clinical trials to address the real advantages of alveolar ridge preservation techniques.

Unfortunately, is not clear yet, which technique and materials are the most suitable for socket preservation: autogenous [27], allogenic [19,28] or alloplastic [29]. Furthermore, is still unclear the need of a bone graft, a membrane or only soft tissue graft, as well as the influence of soft tissue impact to socket preservation. Therefore, preservation of alveolar ridge may lead to less reabsorption, but the quantity of regenerated bone, as well as the density, might be variable [30]. Hence, a systematic review of the current literature was conducted in order to analyse the outcome of socket preservation with and without membrane and determine the influence of soft tissues for ridge preservation.

## MATERIAL AND METHODS

This systematic review attempted to assess quantitatively and qualitatively the influence of two different factors i.e. membranes and soft tissue graft influence, for the extraction socket preservation.

### Protocol and registration

The review was registered in an international prospective register for systematic reviews "PROSPERO".

This systematic review was performed according to the guidance of the Cochrane hand book [31] and the writing obeyed to the PRISMA Statement (Preferred Reporting Items for Systematic Review and Meta-Analysis) [32].

### Focus question

The research questions of this systematic review were "Are there radiological, histological, histomorphometric or clinical differences in humans extraction socket preservation when we are performed with and without membranes with a follow-up of at least 6 months?" and "Are there radiological, histological, histomorphometric or clinical differences in humans extraction socket preservation when a soft tissue graft is performed with a follow-up of at least 6 months?"

The focus questions development according to the PICOST criterions for this systematic review is described in Table 1 and 2.

### Information sources

A wide-ranging electronic search for all related articles up to 30 of November 2018 was performed

**Table 1.** Focus question 1 development according to the PICOST

Component	Description
<b>Population (P)</b>	Humans
<b>Intervention (I)</b>	Extraction socket
<b>Comparison (C)</b>	With or without membranes
<b>Outcome (O)</b>	Radiological, histological, histomorphometric or clinical
<b>Study design (S)</b>	Clinical trial; randomized controlled trial
<b>Time (T)</b>	6 months
<b>Focus question</b>	“Are there radiological, histological, histomorphometric or clinical differences in humans extraction socket preservation when we are performed with and without membranes with a follow-up of at least 6 months?”

using the following electronic databases: LILACS; PubMed; SciELO; ScienceDirect; Scopus; Web of Science™.

## Search

Electronic searches for clinical trials and randomized clinical trials published with no data restriction and written in English, Portuguese, Spanish, Italian, German, Lithuanian or French that presented at least one of the keyword combinations: “socket preservation”, “ridge preservation” was performed. In PubMed a MeSH terms explore was performed too “((“Tooth Socket”[MeSH]) AND “Preservation, Biological”[Mesh]) OR “Alveolar Ridge Augmentation”[MeSH]))”.

An additional manual search among periodical journals and the grey literature of relevant papers was also performed.

## Selection of studies

The paper selection based on titles, abstracts and full text was performed by CF and FAR.

In all of this steps attention was paid for the inclusion/exclusion characteristics in order to locate all the paper included in this systematic review.

Disagreements were solved by reviewers discussion prior to final inclusion or exclusion. Kappa test of the agreement was performed and confirmed the high agreement between researches.

## Types of publications

This systematic review included only human clinical trials or randomized clinical trials. Letters, editorials, PhD theses, and abstracts were excluded.

**Table 2.** Focus question 2 development according to the PICOST

Component	Description
<b>Population (P)</b>	Humans
<b>Intervention (I)</b>	Extraction socket
<b>Comparison (C)</b>	Soft tissue graft
<b>Outcome (O)</b>	Radiological, histological, histomorphometric or clinical
<b>Study design (S)</b>	Clinical trial; randomized controlled trial
<b>Time (T)</b>	6 months
<b>Focus question</b>	“Are there radiological, histological, histomorphometric or clinical differences in humans extraction socket preservation when a soft tissue graft is performed with a follow-up of at least 6 months?”

## Types of studies

This systematic review included clinical trials or randomized clinical trials performed in human with at least of six months of follow-up, with more than 12 patients or treat more than 12 sites per group.

## Types of participants/population

Human patients that had been performed an extraction socket preservation with or without membranes or a soft tissue graft in an intact socket.

## Inclusion and exclusion criteria

The studies selection were based on the following inclusion and exclusion criteria:

Inclusion criteria:

- Humans;
- Clinical trial or randomized clinical trial;
- Minimum of 12 patients or 12 sites per group;
- Group with and without membrane;
- Use of membrane or soft tissue graft;
- Report of at least one primary outcome.

Exclusion criteria:

- Animal studies;
- Sockets that weren't intact.

## Sequential search strategy

The duplicated titles were excluded prior to the two investigators (CF and FAR) carefully screened all studies based on titles and abstracts considering the inclusion and exclusion criteria.

For the study eligibility, the full texts were accessed and confirmed that they have the characteristics to be included in this systematic review. The authors of the papers were contacted when data was missing or to clarify ambiguous reports.

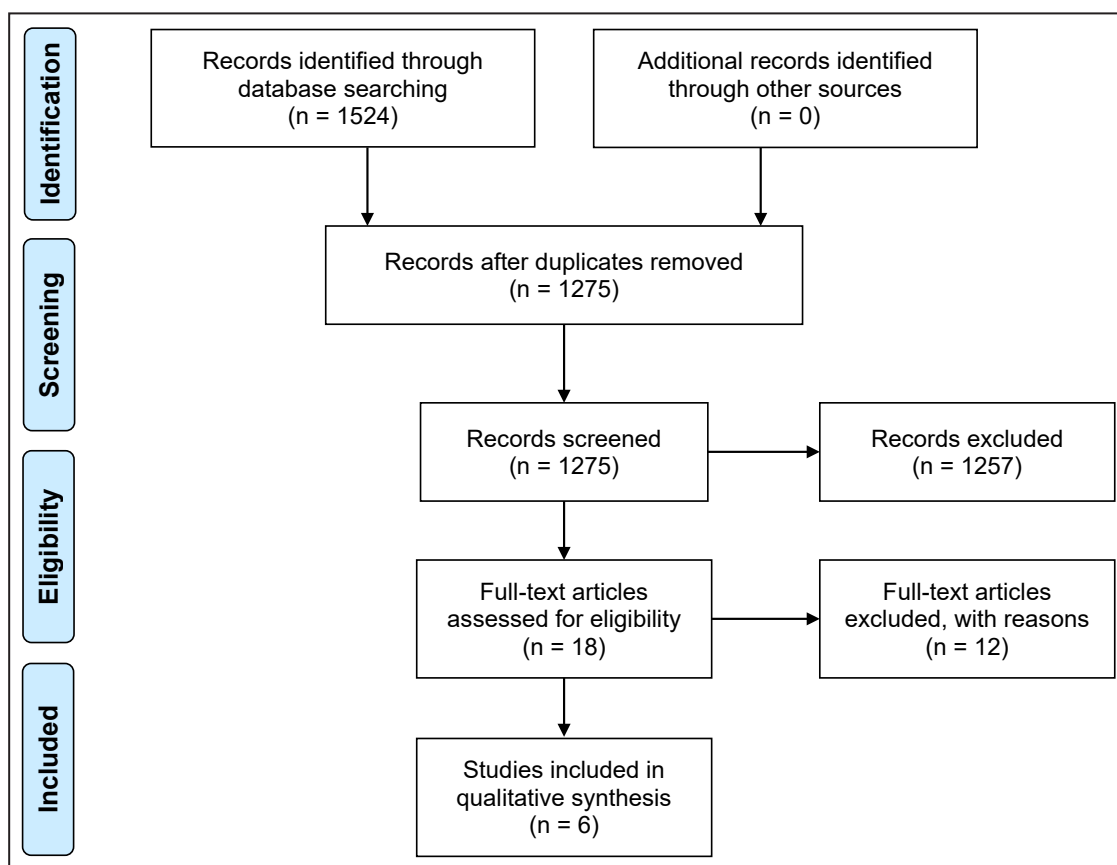


Figure 1. Literature search and procedure for the choice of the papers.

The flow chart representing the literature search is shown in Figure 1.

- Clinical complications: e.g. membrane exposure, graft failure, infections.

### Data extraction

After the selection of the papers to be included data regarding the methods, participants, intervention, outcomes and the risk of bias were extracted.

### Data items

Primary outcome measures:

- Radiographic measures: clinical trials that radiographically evaluated the ridge dimensions previous to the socket preservation and at follow-up.
- Histological/histomorphometric assessment: clinical trials that assess bone quantity and/or quality and/or residual graft material at follow-up.
- Clinical measures: clinical trials that in a clinical way evaluating the ridge dimensions and/or gingival recession and/or keratinized tissue width previous to the socket preservation and at follow-up.

Secondary outcome measures:

- Clinical outcome: clinical findings reported using any biomaterial.

### Risk of bias within studies

The present systematic review was written in accordance with the PRISMA statement guidelines of transparent reporting for systematic review and meta-analyses [32]. The risk of bias assessment was carried out based on the guidance of the Cochrane handbook [31] for systematic review interventions.

The risk of bias was ranked on a three-level scale:

1. Low risk of bias: possible risk of bias which is unlikely to alter report outcomes.
2. Moderated risk of bias: possible risk of bias which may alter report outcomes.
3. High risk of bias: possible risk of bias which seriously weakens the confidence in reported outcomes.

### Statistical analysis

Based on the large variation types of the intervention included, as well as the studies design, a meta-analysis was not possible to be performed.

## RESULTS

### Study selection

The initial search identified a total of 1524 articles, 249 were excluded subsequently because of being duplicate. Following the screening of article titles, 242 potentially relevant articles were identified for abstract reading where the inclusion and exclusion criteria were applied. Independent screening of abstracts resulted in 18 possibly included articles. After read and analysed the 18 full-text articles a total of six articles met the inclusion criteria and were selected for this systematic review.

The  $\kappa$  values for the inter-reviewer agreement of the two researchers (FC and FAR) for potentially relevant articles were  $> 0.9$  (titles and abstracts) and  $> 0.9$  (full-text articles), indicating an “almost perfect agreement” between the 2 reviewers.

Figure 1 displays the search strategy and the screening process leading to the selection of the included six trials.

### Exclusion of studies

The most frequent reasons for excluding the twelve studies after full-text assessment was as follows:

1. Report guided bone regeneration and not socket preservation [33-36].
2. The number of sites per group, less than 12 [37-39].
3. Follow-up, less than 6 months [40-42].
4. Type of study wasn't a clinical trials or randomized clinical trials [43].
5. Doesn't report information about the use of a membrane or a soft tissue graft against a control group [44].

### Quality assessment

The quality assessment (Table 3) revealed that two

articles met a low risk of bias [45,46] and four [12,21,47,48] met a high risk of bias.

### Types of studies

Three [21,45,48] were randomized control trials, one [12] was split-mouth randomized control trial and two [46,47] were designed as a clinical trial.

The studies that compose this systematic review were conducted in seven different countries: two at USA [21,46] and at Italy [45,48]; one at Serbia [12] and Korea [47].

Only one of the included papers of Nam et al. [47] report received funding source from a Ministry of Knowledge and Economy of Seoul, Korea and National Research Foundation of Seoul, Korea.

The studies research were performed at Universities in four of the trials [12,46-48], one of the trials [45] was performed in two private practices private centres and one [21] doesn't report where it was performed.

### Characteristics of outcome measures

The included papers present a wide heterogeneity of treatments used, evaluated variables and observation period.

Related to the clinical variables used, three trials evaluated the dimensional changes based on cone-beam computed tomography (CBCT) analysis [21,45,48] (Table 4), one trial based on periapical X-ray [47] (Table 5); one trial based in clinical variables [12] (Table 6); and four trials gives some information about the histological/ histomorphometric analysis [21,46-48] (Table 7).

### Cone-beam computed tomography analysis

Table 4 shows the selected papers [21,45,48] that present results based on the CBCT analysis.

**Table 3.** Risk of bias at the selected studies

Study	Year of publication	Adequate sequence generation?	Allocation concealment?	Blinding? All outcomes	Incomplete outcome data addressed?	Risk of bias
Lekovic et al. [12]	1998	Low	Low	Low	Low	Low
Iasella et al. [21]	2003	High	Low	Unclear	Unclear	High
Meloni et al. [45]	2015	Low	Low	Low	Unclear	Low
Perelman-Karmon et al. [46]	2012	Low	Low	Unclear	Unclear	Low
Nam et al. [47]	2010	Unclear	Unclear	Unclear	High	High
Barone et al. [48]	2008	High	Low	Low	Unclear	High

Low = low risk of bias; Unclear = unclear risk of bias; High = high risk of bias.

**Table 4.** Study's that reported cone-beam computed tomography analysis

Study	Extraction location	Preservation method	Difference (initial vs follow-up)	Control group	Period observation
Iasella et al. [21]	1, 2, 3, 4, 5, 6	Group A - EXT	Alveolar ridge width: Group A: 17.28 (SD 1.2)/15.68 (SD 1.13) vs Group B: 16.91 (SD 1.34)/15.44 (SD 1.33)	12 patients, 12 sockets	6 months
		Group B: RP with a mineralized freeze-dried bone allograft, 500 to 1,000 µm particle size, and a collagen membrane			
Meloni et al. [45]	Not specified	Socket grafting with deproteinized bovine bone and sealed with epithelial connective tissue graft or porcine collagen matrix	Horizontal bone volume (with collagen vs control): Level A (1 mm below the most coronal aspect of the bone crest): 8.24/7.7 vs 8.39/7.72. Level B (3 mm below the most coronal aspect of the bone crest): 8.18/7.35 vs 8.53/7.62. Level C (5 mm below the most coronal aspect of the bone crest): 8.21/7.99 vs 8.27/7.96	15 patients, 15 sockets	17 months
			Vertical bone volume (with collagen vs control): Level D 17.28/16.58 vs 16.91/15.44		
Barone et al. [48]	Not specified	Group A - EXT	Group RP: 10.6 (SD 1)/8.1 (SD 1.4) vs Group EXT: 10.8 (SD 0.8)/6.3 (SD 0.8)	20 patients, 20 sockets	7 to 9 months
		Group B: preservation procedure with corticocancellous porcine bone (MP3, Osteobio <sup>®</sup> ) and collagen membrane (Evolution, Osteobio <sup>®</sup> )			

EXT = extraction alone; RP = ridge preservation.

**Table 5.** Study's that reported periapical X-ray analysis

References	Extraction location	Preservation method	Difference (initial vs follow-up)	Control group	Period observation
Nam et al. [47]	Various	Group A - bovine bone mineral: OSC-B (Nano - Intelligent Bioengineering, Seoul, Korea)	Vertical buccal: 15.8/16 vs 12.7/11.8	42/15	6 - 8 months
		vs Synthetic oligopeptide - Ossegen-X15 (Nano Intelligent)	Vertical lingual: 13.9/13.8 vs 11.8/12.7		
		vs collagen membrane - Bio-Gide <sup>®</sup>	Width: 9.1/9 vs 7.9/7.7		

**Table 6.** Study's that reported clinical analysis

References	Extraction location	Preservation method	Difference (experimental vs control, mm)	Control group	Period observation
Lekovic et al. [12]	Anterior and premolar teeth	Control group: blood clot	External vertical measurement: 3.19/2.81 vs 3.31/1.81	16	6 months
		Test group: sockets grafted with bovine bone mineral and covered with bioabsorbable membrane made of glycolide and lactide polymers	Internal vertical measurement: 6.88/1.06 vs 6.94/3		
			Horizontal measurement: 7.38/6.06 vs 7.5/2.94		



**Table 7.** Study's that reported histological and histomorphometric analysis

References	% (vital bone)	% (residual graft)	% bone volume (vital bone + residual graft)	% (connective tissue)	Significance
Iasella et al. [21]	Group RP: 28 (SD 14); Group EXT: 54 (SD 12)	Group RP: 37 (SD 18); Group EXT: no data	Group RP: 65 (SD 10); Group EXT: 54 (SD 12)	No data	P < 0.05
Perelman-Karmon et al. [46]	Group A: Bio-Oss® 29.7 (SD 7.21)%; Group B: Bio-Oss® + Bio-Guide® 40.8 (SD 10.61)%	No data	No data	No data	P < 0.05
Nam et al. [47]	10.4 (4.6)	18,7 (SD 7)	20.4 (SD 7.5)	70.8 (SD 8,7)	P < 0.05
Barone et al. [48]	Group RP: 35.5 (SD 10.4); Group EXT: 25.7 (SD 9.5)	Group RP: 29.2 (SD 10.1); Group EXT: no data	No data	Group RP: 36.6 (SD 12.6); Group EXT: 59.1 (SD 10.4)	P < 0.05

EXT = extraction alone; RP = ridge preservation.

Iasella et al. [21] and Barone et al. [48], used a collagen membrane in their test groups comparing to the control group which was for both the extraction alone. In the Iasella et al. [21] study, the filling material was a mineralized freeze-dried bone allograft and in the Barone et al. [48] study, a corticocancellous porcine bone.

After an observation period of 6 months, Iasella et al. [21] concluded that ridge preservation using FDBA and a collagen membrane presented better results in terms of ridge height and width dimensions when compared to extraction alone. In the study of Barone et al. [48], after 7 to 9 months of healing period it was concluded that the ridge-preservation approach using porcine bone in combination with collagen membrane significantly limited the resorption of hard tissue ridge after tooth extraction compared to extraction alone.

Similar outcomes were found in a study of Meloni et al. [45], where after 17 months of the observation period, when two groups were compared, which have been grafting the sockets with deproteinized bovine bone sealed with epithelial connective tissue graft or a porcine collagen matrix. The authors concluded that the use of porcine collagen matrix allowed simplification of treatment because no palatal donor site was involved.

When a CBCT analysis was used comparing different types of treatment for the alveolar preservation, all results are better, independently of the material used, when compared to extraction socket alone. Anyhow there was a great variability of dimension changes between all of the studies analysed.

### Periapical X-ray analysis

Data of Table 5 included only study of Nam et al. [47]

and evaluated the results after 6 - 8 months. Authors used different protocols, with the same purpose, to evaluate the dimensional changes in the alveolar ridge after tooth extraction.

Nam et al. [47], compared Group A - bovine bone mineral (BBM), OSC-B (Nano -Intelligent Bioengineering, Seoul, Korea) vs Group B - synthetic oligopeptide - Ossegen-X15® (Nano Intelligent) and collagen membrane - Bio-Gide® (Geistlich Pharma®, Wolhusen, Switzerland). The ridge preservation was made in 42 patients, and they concluded that the ridge-preservation approach using synthetic oligopeptide coated bone mineral with collagen membrane effectively prevented the resorption of hard tissue with higher bone-to-graft contact, and the oligopeptide-coated bone may be a choice for ridge-preservation procedures while assuring new bone formation.

With limited information in the periapical X-ray analysis, it seems that the use of an alveolar preservation technique reduced the bone changes after tooth extraction.

### Clinical analysis

Table 6 presents the data of Lekovic et al. [12] study, which evaluate the clinical effectiveness of the bioabsorbable membrane made of glycolide and lactide polymers in preserving alveolar ridges following tooth extraction.

Sixteen patients requiring extractions of two anterior teeth or bicuspid participated in the study (split-mouth design). Following the elevation of buccal and lingual full-thickness flaps and extraction of teeth, experimental sites were covered with bioabsorbable membranes; control sites did not receive any membrane.

Flaps were advanced in order to achieve primary closure of the surgical wound.

Three different alveolar bone volume parameters were chosen: external vertical measurement and internal vertical measurements to rate the vertical changes of the post extraction socket and horizontal measurement. The results showed that the higher external vertical volume change from the baseline to the 6 months follow-up was found in the control group (-0.38 [SD 0.22] vs -1.5 [SD 0.26]). However, the internal vertical (-5.81 [SD 0.29] vs -3.94 [SD 0.35] and horizontal measurements (-1.31 [SD 0.24] vs -4.56 [SD 0.33]) presented with significantly less loss of alveolar bone height, more internal socket bone fill, and less horizontal reabsorption of the alveolar bone ridge during the follow-up in the control group.

Like in the previous studies, clinical analysis revealed that the alveolar preservation technique could be an advantage in reducing the alveolar bone dimensions after tooth extraction.

### Histological and histomorphometric analysis

From the six papers included in Table 7, four trials [21,46-48] reported information about the histological variables: percentage of vital bone (four studies [21,46-48]); percentage of residual graft (three studies [21,47,48]), percentage of bone volume (two studies [21,47]), and percentage of connective tissue (two studies [47,48]).

Barone et al. in 2008 [48] presented the histologic analysis showing a significantly higher percentage of trabecular bone and total mineralized tissue in ridge-preservation sites compared to extraction-alone sites 7 months after tooth removal.

Nam et al. [47], presented the results of the histomorphometric analysis: percentage of residual graft, percentage of new bone, percentage of connective tissue and contact between particle and percentage of new bone, comparing the two groups. Results of these two trials [47,48] confirmed advantage of the preservation technique comparing to the control.

In 2012, Perelman-Karmon et al. [46], compared extraction sites augmented with BBM with and without resorbable membrane coverage. BBM particles were grafted in fresh human extraction sockets of 23 patients; in 12 of these patients, a guided tissue regeneration method with collagen membrane was applied. After 9 months cylindric hard tissue sample were obtained for histomorphometric evaluation. Percent bone area fractions of the crestal, middle and apical sections from each

sample were calculated using the point-counting technique. Changes in values were compared. In sites augmented with BBM, the mean BAF ranged from 22.8% (coronal) to 36.3% (apical) compared to sites augmented with BBM and collagen membrane (35.2% [coronal] to 47% [apical]). Comparison between the different depths and the two groups showed a distinct increase in BAF from coronal to apical regions ( $P < 0.001$ ). This pattern was observed in both groups ( $P < 0.001$ ) and was significantly higher in the group augmented with BBM and collagen membrane ( $P < 0.05$ ). In the immediate post extraction phase, BBM as a grafted biomaterial preserved the socket volume and enabled newly formed bone for future implant site preparation. The amount of the osseous fraction increased with collagen membrane.

In a study of Iasella et al. [21], the quantity of bone observed on histomorphometric analysis was slightly greater (statistically significant difference) in preservation sites, although these sites included both vital and non-vital bone but when analysed only the amount of vital bone this parameter was higher in control group. The most predictable maintenance of ridge width, height, and the position was achieved when a ridge preservation procedure was employed.

The two other authors [46,48] showed that vital bone was higher in sockets that were preserved with a membrane. However, in one study [48] the natural healing was chosen as a control group and in the other [46] the grafting with a bovine bone. Therefore, even though the statistically significant differences were achieved in various studies, the results are heterogenic between the studies.

The results presented for the different papers must be analysed with caution because they used different materials in the preservation techniques and different time of analysis. They also included different types of defects, so it is impossible to compare the results between the different studies.

### DISCUSSION

This systematic review was focused on evaluating the effect of different alveolar preservation techniques performed immediately after tooth extraction, in particular, to assess quantitatively and qualitatively the influence of two different factors (membranes and soft tissue graft).

The research questions of this systematic review were "Are there radiological, histological, histomorphometric or clinical differences in humans extraction socket preservation when we are performed



with and without membranes with a follow-up of at least 6 months” and “Are there radiological, histological, histomorphometric or clinical differences in humans extraction socket preservation when a soft tissue graft is performed with a follow-up of at least 6 months”

For this purpose, it was made a wide-ranging electronic search for all related articles up to 30 of November 2018 in the following electronic databases: LILACS, PubMed, SciELO, ScienceDirect, Scopus and Web of Science, with no data restriction.

Based on a clinical purpose, the included papers were only clinical trials and randomized clinical trials, using keywords combinations already presented. It was also made an additional manual search among periodical journals and grey literature of relevant papers.

No animal studies were included. Only intact sockets were included following the same definition propose by Hämmerle et al. [49] “ridge preservation = preserving the ridge volume within the envelope existing at the time of extraction”. The included studies should have at least 12 patients or treated 12 sites per group and when the studies tried to analyse the membrane effect a control group without membrane need to be present.

Based on the inclusion and exclusion criteria there was a lack of information, as reported previously, to take strength conclusions.

There was a great variability of the techniques and materials used, analysed variables, location of the extraction sites and also the time of evaluation.

### Treatment combinations

- A. Control group (blood clot) vs test group (collagen membrane + filling material): two studies (Iasella et al. [21] and Barone et al. [48]).
- B. Control group (blood clot) vs test group (BBM + bioabsorbable membrane made of glycolide and lactide polymers): one study (Lekovic et al. [12]).
- C. Control group (deproteinized bovine bone + epithelial connective tissue graft) vs test group (deproteinized bovine bone + collagen matrix): one study (Meloni et al. [45]).
- D. Control group (Bio-Oss® [Geistlich Pharma®, Wolhusen, Swiss]) vs test group (Bio-Oss® + collagen membrane): one study (Perelman-Karmon et al. [46]).
- E. Control group (deproteinized bovine bone) vs test group (collagen membrane) - one study (Nam et al. [47]).

### Analysed variables

From the six included studies, three evaluated the results based on the CBCT analysis [21,45,48], one on the periapical X-ray [47], one on the clinical variables [12] and four on the histological and histomorphometric analysis [21,46-48].

### Extraction sites

Most of the papers referred that the tooth extractions were made in the anterior zone of the maxilla, but in some of them, there was a lack of information [45,48].

### Time of evaluation

Most of the papers evaluate the results at 6 months after tooth extraction, but there are some that the evaluation period was later, at 9 and 17 months [45].

The risk of bias was high in four of six papers, and it was low in two of them.

As one of the focus questions was related to the advantage or not by using a membrane in alveolar preservation techniques, there were only two studies that compare the use of membrane against blood clot (Iasella et al. [21] and Barone et al. [48]) which presented better results for the test (membrane) group. Both studies made a CBCT and histomorphometric analysis.

There was another study (Perelman-Karmon et al. [46]) which compare the use of BBM (Bio-Oss®) in the control group versus BBM (Bio-Oss®) and collagen membrane in the test group. They made a histological and histomorphometric analysis and confirm the advantages of the use of a membrane. The conclusion was that the BBM, as a grafted biomaterial in fresh extraction sockets, preserved its volume and enabled newly formed bone for future implant site preparation and the application of collagen membrane increased the osseous fraction.

The other focus question was about the advantage of using the soft tissue graft. For this particular question, there was one selected study by Meloni et al. [45] using CBCT analysis as control method. Meloni et al. [45] reported that sealing the socket with a porcine collagen matrix or epithelial connective tissue graft showed similar outcomes if added to the BBM. Anyhow this study does not compare the use of soft tissue graft with control group, which means that this particular conclusion enables to confirm the advantage of using the soft tissue in the alveolar preservation techniques.

All of the other studies could give us an idea about the possible advantages of using the membrane, but they cannot clearly confirm and support this conclusion.

## CONCLUSIONS

1. Based on cone-beam computed tomography, periapical X-ray, clinical and histological and histomorphometric findings it can be concluded that the alveolar preservation techniques, presented in this systematic review, can decrease the dimensional reduction of the alveolar ridge that usually occurs after tooth extraction as compared to tooth extraction alone.
2. After analysis of the selected studies it is impossible to recommend any specific techniques and/or materials to achieve improved results of extraction socket preservation because of the lack of sufficient data.

3. Few studies that compare the use of the alveolar preservation techniques with and without membrane, demonstrated that the application of the membrane allows to achieve superior preservation results.
4. There is lack of information concerning the advantage of soft tissue graft using in the alveolar preservation techniques.

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The authors report no conflicts of interest related to this study.

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