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Review Article

A Systematic Review of Alveolar Defect Healing Following Tooth Extraction through Primary and Secondary Intention

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ABSTRACT

Tooth extraction leads to changes in the dimensions of the alveolar ridge, prompting efforts to reduce complications and bone loss. Various strategies have been investigated to preserve bone width, height, and keratinized tissue after extractions. This systematic review analyzes the effect of secondary and primary intention healing on the dimensional changes and histomorphometric properties of the alveolar ridge. In adherence to PRISMA guidelines, a literature search was performed on the Cochrane Library, PubMed, and ScienceDirect databases. This review included randomized controlled trials, retrospective studies, observational studies, split-mouth randomized trials, single-blinded, and controlled clinical trials. Articles published between March 1, 2013, and March 1, 2023, that compared bone changes or histomorphometric data after tooth extraction were included. The risk of bias was assessed using the "Cochrane Collaboration's risk-of-bias (RoB 2) tool." A total of 5 studies, involving 92 patients and 128 extracted teeth, were reviewed. The findings showed no significant difference in the resorption of alveolar height and width between the groups treated with primary or secondary intention. Similarly, there were no significant differences in histomorphometric changes between the two healing methods. Therefore, the healing method choice did not significantly affect the dimensional alterations or new bone formation in post-extraction defects.

Keywords: Socket, Primary intention, Open flap, Secondary intention, Closed flap

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Introduction

After tooth extraction, the alveolar ridge undergoes changes that present challenges for dental specialists in daily clinical practice. The ridge's dimensions, including its shape and size, are influenced by the tooth's structure and the vertical and horizontal alterations that follow tooth loss [1]. Around 60% of the ridge volume decreases within the first 2–3 years post-extraction, with the resorption continuing at a rate of 0.25–0.5% annually throughout life [2]. Most of this bone loss occurs within the first few months after extraction [3], and horizontal bone loss tends to be more significant than vertical loss [4]. Research shows that the outer (buccal) part of the alveolar ridge experiences more resorption than the inner (lingual) side [5]. This is due to the thinner buccal wall, which makes it more susceptible to dehiscence [6]. When there are fewer bony walls, there is less opportunity to retain a blood clot in the socket [7]. Several factors, including the thickness of the alveolar wall, tooth position, surgical trauma, flap elevation, and the size of the original defect, determine the extent of bone resorption following extraction [8]. Studies indicate that about 30% of the alveolar ridge undergoes resorption after tooth extraction, with approximately two-thirds of both soft and hard tissues being affected within the first three months [9]. To minimize bone loss during the healing process, researchers are focused on methods and materials that can help preserve or restore bone width, height, and keratinized tissues.

After tooth extraction, various materials, including autogenous, allogenic, xenogenic, and alloplastic bone granules, are employed to maintain the socket's dimensions and encourage the regeneration of viable bone tissue. The selection of these materials may be influenced by the clinician's preference, as well as financial or cultural factors [7]. To stabilize the bone grafts, different membranes are used, ranging from resorbable options like collagen films to non-resorbable membranes, such as PTFE or titanium, which require an additional surgical procedure for removal. Several techniques are available for closing the post-extraction wound to shield the socket from external threats. In primary intention healing, the wound is sealed using a mucoperiosteal flap, while in secondary intention healing, the flap is not completely sutured, allowing for drainage or sometimes left unsutured [10, 11]. The majority of the scientific literature suggests that to prevent infection, most membranes should be entirely covered with a mobilized mucoperiosteal flap for primary intention healing. Nevertheless, it is also possible to leave certain membranes, like d-PTFE or collagen, without suturing for secondary intention healing [10].

This study aims to evaluate the effects of primary and secondary intention healing on the dimensional changes of the alveolar ridge and histomorphometric bone tissue markers following tooth extraction.

Materials and Methods

In conducting this systematic review, the study adhered to the PRISMA guidelines, which guided the planning, objectives, article selection, and data analysis process [12]. The PICO framework was used to structure the research question, considering the study outcomes: P: population, I: intervention, C: control, and O: outcomes [12]. The primary research question addressed in this study was: Does the dimensional remodeling of post-extraction alveolar defects differ between secondary and primary intention healing?

P (population): Individuals undergoing socket augmentation procedures following tooth extraction.

I (intervention): Socket healing through primary intention following tooth extraction.

C (control): Socket healing through secondary intention following tooth extraction.

O (outcomes): Primary outcomes: changes in socket dimensions during the 3-6 months following tooth extraction. Secondary outcomes: histomorphometric characteristics of bone tissue in sockets healing via primary and secondary intention.

Selection criteria

This systematic review includes randomized controlled trials, observational studies, retrospective analyses, single-blind split-mouth randomized trials, and controlled clinical studies. The primary aim is to evaluate and compare the effects of secondary and primary intention healing on the dimensional changes of the alveolar ridge and the histomorphometric properties of bone tissue following tooth extraction.

Inclusion criteria

- Research articles published within the last decade.
- Full-text studies written in English.
- Human-based research assessing the healing of augmented alveolar defects through secondary and primary intention following tooth extraction.
- Studies analyzing changes in bone dimensions or histomorphometric properties.
- Randomized, prospective, and retrospective research studies.

Exclusion criteria

- Research comparing secondary and primary intention treatments regarding complication rates.
- In vitro and ex vivo studies.
- Studies focusing on only 1 group of sockets with either secondary or primary intention healing.
- Systematic reviews, meta-analyses, case reports, poster and conference presentations, as well as theses.
- Studies involving fewer than 10 patients.

Search strategy

Two independent researchers searched for relevant publications to include in the systematic review. The search was carried out across three databases: Cochrane Library, PubMed, and ScienceDirect. Articles published between March 1, 2013, and March 1, 2023, were considered (Last search date: March 4, 2023). To maintain consistency in keyword combinations across all databases, six Boolean operators ('AND' and 'OR') were used, and keywords were chosen from the MeSH Terms (Medical Subject Headings) thesaurus to ensure the inclusion of commonly used medical terminology. The preliminary search resulted in the following keyword combination: (((primary intention) AND (secondary intention)) OR ((open flap) AND (closed flap))) AND ((socket) OR (extraction)) AND (tooth).

The article selection process occurred in two phases. In the first phase, duplicate entries were removed, and irrelevant publications were excluded based on titles and abstracts. In the second phase, full-text articles were reviewed, analyzed, and either included in the literature review or rejected according to the defined exclusion and inclusion criteria. Moreover, the references in the selected articles were examined for potentially relevant studies to be included.

Quality assessment

The evaluation of bias risk in prospective randomized studies was conducted using the “RoB 2” tool from The Cochrane Collaboration [13]. This tool includes five established criteria, each with a corresponding evaluation algorithm. Based on the assessment, each criterion is assigned a risk level, classified as low (+), medium (-), or high (x).

Results and Discussion

Study selection

In the first phase of the publication search, a total of 996 articles were initially identified using the selected keywords. After filtering out studies older than ten years, excluding systematic reviews and case reports, and removing duplicates (n=153), 350 articles remained. These articles were reviewed based on their titles and abstracts. Following this, 29 articles were selected for further evaluation. In the second phase, these 29 articles were fully analyzed. Several were excluded based on specific rejection criteria: 11 lacked a control group, 2 focused on complications, 8 did not assess alveolar bone height (BH), bone width (BW), or bone histomorphometric parameters, 1 was a duplicate of another article, 1 was written in Chinese, and 1 did not involve socket augmentation in the control group. Ultimately, 24 articles were excluded, leaving 5 studies [7, 14-17] for inclusion in the systematic review. A diagram of the search process is shown in **Figure 1**.

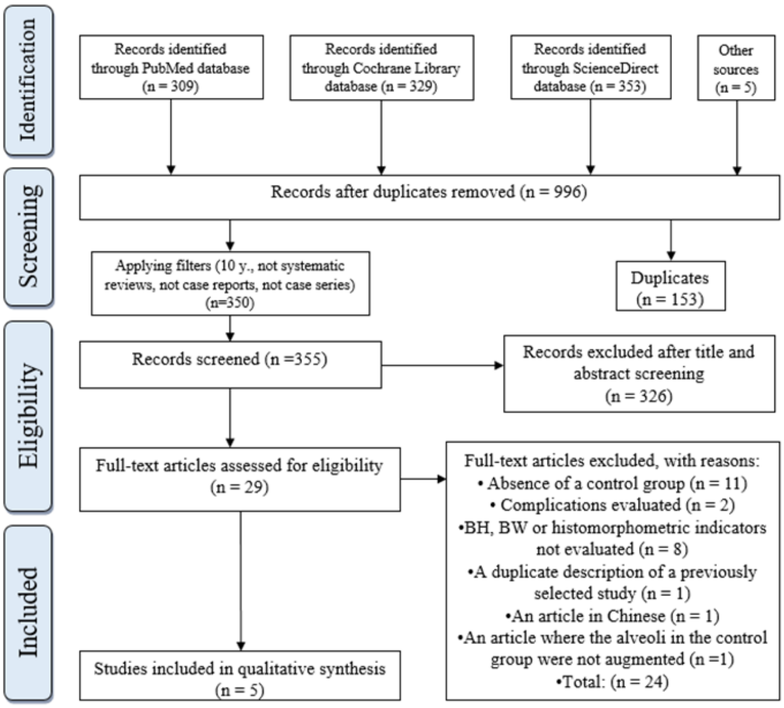

Figure 1. PRISMA flowchart search process diagram; BH: bone height change, and BW: bone width change

Characteristics of included studies

A total of 5 studies [7, 14-17] were included in the systematic review. All of these were prospective randomized controlled trials, each with two groups assigned randomly: a control group and an experimental group. The studies evaluated at least 1 of the predetermined criteria: changes in bone height, changes in bone width, or histological markers of viable bone. One research assessed both alterations in bone height and histological markers [7], three studies focused solely on the histological percentage of new bone formation [14-16], and one research examined changes in bone height, width, and histomorphometric indicators of bone tissue [17]. The results from all the studies are summarized in **Table 1**.

Statistical analysis

The initial plan included conducting both a systematic review and a meta-analysis, incorporating both qualitative and quantitative methods. However, due to significant differences in the data, a meta-analysis could not be completed. In conclusion, the review focused solely on a descriptive analysis of the data, without quantitative evaluation, to identify relevant information for statistical interpretation. The statistical results were presented as mean values along with standard deviations (mean ± SD).

Risk of bias assessment

The risk of bias in the included studies was evaluated using the Cochrane RoB 2 tool. All studies were determined to have a low risk of bias overall. However, three studies [7, 14, 17] showed a moderate risk of selective reporting bias among the randomized controlled trials. This did not affect the overall low risk of bias assessment. A visual depiction of the risk of bias analysis, generated using the 'Robvis' tool [18], is shown in **Figure 2**.

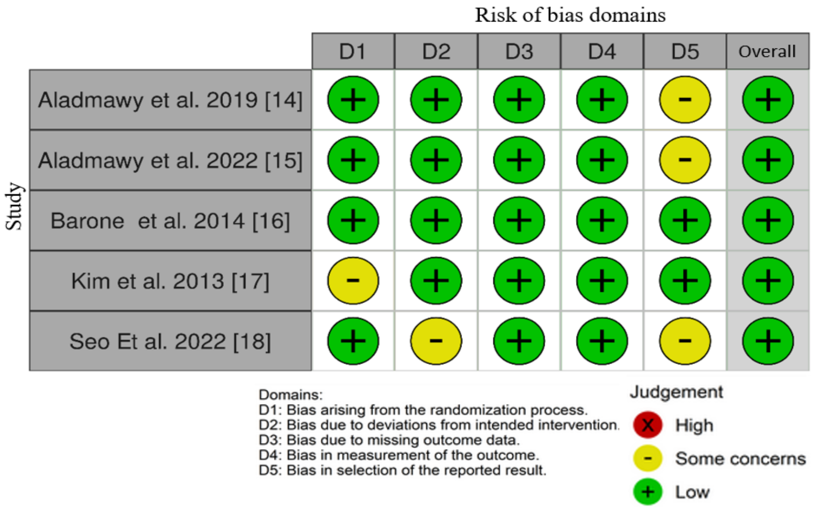

Figure 2. Risk of bias assessment of included studies in the review; risk of bias summary; B risk of bias graph; symbols: (+) = low risk of bias, (?) = unclear risk of bias, and (-) = high risk of bias

Impact of primary and secondary healing intention on alveolar height changes

2 studies [7, 17] investigated modifications in alveolar bone height following tooth extraction with secondary and primary intention healing. These studies involved a total of 48 sockets, examining a range of tooth types, including incisors, premolars, canines, and molars. Both studies provided data on the overall reduction in alveolar height post-extraction [7, 17].

In the 2019 research by Aladmawy *et al.* [7], a significant reduction in alveolar height was observed when healing occurred via primary intention, with an average decrease of -8.1 ± 1.9 millimeters after six months (P = 0.05). For secondary intention healing, the decrease in alveolar height ranged from -7.5 ± 1.8 millimeters (P = 0.05) [7] to -0.9 ± 1.5 millimeters (P < 0.05) [17]. In Seo *et al.*'s study [17], after four months, the modification in alveolar height was -1.4 ± 1.2 millimeters with primary intention healing and -0.9 ± 1.5 millimeters with secondary intention healing, though no statistically significant difference was found between the two healing methods (P = 0.349).

Table 1. Summary of results presented in the studies included in the systematic review

					Primary intention healing			**Secondary intention healing**			
No.	**Study**	**Type of study**	**Study sample/Number of study areas**	**Follow up**	**BH (mm)**	**BW (mm)**	**New bone (%)**	**BH (mm)**	**BW (mm)**	**New bone (%)**	**Conclusions**

1	Aladmawy *et al.* [7]	Randomized prospective study	10/20	6 months	-7.5 ± 1.8 (P = 0.389)	-0.1 ± 0.3 (P = 0.317)		-8.1 ± 1.9 (P = 0.389)	0.1 ± 0.5 (P = 0.564)		There were no significant changes observed in bone height (BH) or bone width (BW) with secondary intention healing. In contrast, the primary intention healing group showed a notable increase in the width of keratinized gingiva and a significant reduction in pain levels compared to the secondary intention group.
2	Aladmawy *et al.* [14]	Randomized prospective study	8/16	6 months			71.1% ± 23.5% (P = 0.066)			50.9 % ± 16.2% (P = 0.066)	The study found no statistically important difference in the formation of new bone between primary and secondary intention healing, based on histomorphometric measures.
3	Barone *et al.* [15]	Randomized prospective study	34/34	6 months			22.5% ± 3.9% (P = 0.917)			22.5% ± 4.3% (P = 0.917)	There was no statistically important difference in histomorphometric parameters between healing via primary intention and secondary intention.
4	Kim *et al.* [16]	Randomized prospective study	12/30	6 months			47.3% ± 11.3% (P > 0.05)			40.3% ± 7.8% (P > 0.05)	Healing of alveolar sockets through secondary intention showed comparable radiological, clinical, and histological results to those observed with primary intention healing.
5	Seo *et al.* [17]	Randomized prospective study	28/28	6 months	-1.4 ± 1.2 (P = 0.349)	-4.9 ± 3.1 (P = 0.529)	26.2 ± 17.7% (P > 0.05)	-0.9 ± 1.5 (P = 0.349)	-4.2 ± 2.5 (P = 0.529)	24.6 ± 18.4% (P > 0.05)	Both secondary and primary intention healing led to the comparable development of new viable bone and similar radiological alterations in alveolar dimensions.

Abbreviations: BH = bone height change, BW = bone width change, B = buccal, and L = lingual.

The impact of primary and secondary healing intention on alveolar width changes

Two studies assessed the modifications in alveolar width following tooth extraction, with a total of 48 sockets included in the analysis [7, 17]. One study focused on anterior teeth, including incisor, canine, and premolar sockets [17], while the other analyzed only posterior teeth, ranging from molars to premolars [7]. In Seo *et al.*'s research [17], after four months, the modification in alveolar width with primary intention healing was -4.9 ± 3.1 millimeters and -4.2 ± 2.5 millimeters with secondary intention healing. However, the difference between these two groups wasn't statistically important (P = 0.529) [17]. In Aladmawy *et al.*'s study [7], which evaluated alveolar width after six months, the change in width was -0.1 ± 0.3 millimeters for primary intention healing (P = 0.317) and 0.1 ± 0.5 millimeters for secondary intention healing [7]. There was no significant statistical difference between the two healing methods regarding alveolar width changes (P = 0.564).

The impact of primary and secondary healing intention on bone histomorphometric indicators

In the systematic review, four studies assessed histomorphometric bone indicators 3-6 months post-tooth extraction, focusing on the percentage of new viable bone formed in the socket during both primary and secondary intention healing [14-17].

Aladmawy *et al.* [14] used an allogeneic freeze-dried mineralized bone substitute (MinerOss, BioHorizons, Birmingham, Alabama, USA) to preserve alveolar dimensions. In the primary intention group, the bone granules were covered with a PTFE membrane and the mucoperiosteal flap was fully sutured. In contrast, the secondary intention group had bone granules left uncovered and no flap suturing. The results displayed that, six months after tooth extraction and alveolar augmentation, new bone formation in the primary intention group was 71.1 ± 23.5%, while the secondary intention group had 50.9 ± 16.2%. The difference was not statistically significant (P = 0.066) [14].

Barone *et al*. [15] used a xenogeneic bone substitute (MP3, Osteobiol, Coazze, Italy) to fill the socket and cover it with a collagen membrane. The results displayed that three months after tooth extraction, the percentage of newly formed viable bone was 22.5 ± 3.9% in the primary intention group and 22.5% ± 4.3% in the secondary intention group, with no significant difference between the groups (P = 0.917) [15].

Kim *et al*. [16] conducted a study using synthetic bone substitutes (Osteon II, Genoss, Suwon, South Korea) in both secondary and primary healing intention groups, with each group having a collagen membrane covering the socket. After 6 months, the primary intention group showed a new bone formation of 47.3 ± 11.3%, while the secondary intention group exhibited 40.3 ± 7.8%. No statistically important difference was observed between the groups (P > 0.05) [16].

In a separate research by Seo *et al.* [17], xenogeneic bone substitutes (InterOss, SigmaGraft, Fullerton, USA) were utilized. In the primary healing group, a buccal coronally displaced mucoperiosteal flap was added on top of the collagen membrane, whereas the secondary healing group had open healing with the membrane left exposed. After four months, the new bone formation was 26.2 ± 17.7% in the primary intention group and 24.6 ± 18.4% in the secondary intention group, with no important difference between the two (P > 0.05) [17].

This systematic review analyzed and included 5 studies [7, 14-17], aiming to assess the impact of primary versus secondary intention healing on changes in alveolar socket dimensions and histomorphometric bone indicators.

After tooth extraction, socket remodeling is part of the healing process. Seo *et al.* used cone-beam computed tomography (CBCT) to assess vertical bone loss and found that secondary intention healing resulted in less bone loss compared to primary intention healing, although the difference wasn't statistically significant [17]. A similar conclusion was drawn in Aladmawy *et al.*'s study [7], which reported no significant differences in socket height or width between the secondary and primary intention healing groups.

Regarding horizontal remodeling of the alveolar ridge, Seo *et al*. [17] observed similar changes in both healing groups, with no significant differences between secondary and primary intention healing. Similarly, Aladmawy *et al*. noted horizontal resorption of the alveolar ridge. While the primary intention healing group showed less resorption than the secondary intention group, the difference wasn't statistically significant [7]. The type of materials used—xenogenic bone substitute and collagen membrane in Seo *et al*.'s research [17], and allogenic bone and a non-resorbable d-PTFE membrane in Aladmawy *et al.*'s study [7]—did not affect the amount of vertical or horizontal resorption in the alveolar ridge. Likewise, Zhao *et al.* [18] reported a tendency for greater horizontal resorption with primary intention healing when using a xenogenic bone substitute and a collagen membrane, but the difference wasn't statistically significant.

Four studies included in this systematic review analyzed histomorphometric bone parameters following tooth extraction [14-17]. These studies used various materials for socket augmentation, including xenogenic, allogenic bone substitutes, and autogenous bone. Additionally, different types of membranes were used to protect the bone granules: 3 studies employed non-resorbable collagen membranes [15-17], while one utilized a non-resorbable PTFE membrane [14]. Across all studies, higher percentages of new bone formation were observed in the healing of the socket by primary intention, though the differences between primary and secondary healing intention groups were not statistically significant.

Recent histomorphometric studies indicate a trend toward increased new viable bone formation in socket healing by primary intention, likely due to better protection of the bone substitute particles. Gabay *et al*. [19] understood that primary intention healing led to greater new bone formation, while secondary intention healing resulted in more connective tissue than viable bone. However, in Ramaglia *et al*.'s case series [20], a higher amount of new bone was observed in secondary intention healing. These findings must be interpreted with caution, as the secondary and primary intention healing groups were assessed at different time points, which may have affected the outcomes.

The evaluation of post-extraction wound healing must extend beyond dimensional and histomorphometric parameters to include clinical indicators such as pain, swelling, and potential complications like alveolitis, dehiscence, infection, or bleeding. Both primary and secondary healing intentions can involve these issues. Jakse *et al.* [21] observed that primary intention healing often offers patients a sense of security and comfort, which can accelerate postoperative recovery and lower the risk of socket clot loss. Kilinc and Ataol [22] further supported this by demonstrating that primary intention healing might help reduce the likelihood of alveolitis. In contrast, secondary intention healing minimizes surgical trauma, reduces the need for suturing, and provides greater flexibility in mucosal healing [23]. This approach avoids the need for flap mobilization, preserves the oral vestibule, and retains more keratinized gingiva [7, 23]. Aggarwal *et al.*'s study [24] reinforced the less traumatic nature of secondary intention healing, reporting that patients in this group experienced less pain and swelling than those in the primary intention group. Rodrigues *et al.* [25] similarly found significantly reduced pain and swelling in the primary healing group when compared to the secondary intention group.

Conclusion

Based on the results, the method of healing, whether through secondary or primary intention, does not have a significant effect on the dimensional changes observed in the alveolar ridge following tooth extraction. In addition, the type of healing, whether secondary or primary intention, does not affect the formation of new viable bone in the post-extraction site.

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