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Systematic Review of Comparative Histological Studies of Alveolar and Symphyseal Bone Healing in Animals

Mendouga Menye Coralie[1], Nkolo Tolo Francis Daniel[2*], Ndjoh Jules Julien[3], Omam Nathalie Rachel[1] and Mendimi Nkodo Joseph Marie[1]

[1]*Department of Morphological Sciences and Pathological Anatomy, Faculty of Medicine and Biomedical Sciences, University of Yaounde I, Cameroon*

[2]*Department of Oral Surgery, Faculty of Medicine and Biomedical Sciences, University of Yaounde I, Cameroon*

[3]*Department of Implantology, Periodontology and Prosthetics, Faculty of Medicine and Biomedical Sciences, University of Yaoundé I, Cameroon*

Abstract

Introduction: Bone healing, a fundamental process in oral surgery, varies from one anatomical site to another. The alveolar bone and the mandibular symphysis, although both involved in masticatory function, differ in embryological origin, vascularization and structure. This review aims to compare bone healing processes in these two sites, based on histological studies in animals, in order to identify similarities and differences, as well as factors influencing healing.

Materials and methods: A literature search was conducted in the PubMed, ScienceDirect and Google Scholar databases, using the keywords “bone healing”, “dental socket”, “mandibular symphysis”, “histology” and “animal”. Selected studies had to include histological analysis of alveolar and symphyseal bone healing in animals, allowing direct comparison of the two sites.

Exclusion criteria included *in vitro* studies, clinical studies and studies not providing comparative histological data.

Results: The selected studies revealed similarities in the healing process, including the sequence of events (inflammation, granulation tissue formation, osteogenesis and remodeling) and the cell types involved (osteoblasts, osteoclasts). However, significant differences were observed. Alveolar healing tends to be faster and more intense, with more abundant bone formation in the early phases. The mandibular symphysis heals more slowly, but with greater long-term bone remodeling. Vascularization and mechanical stress seem to play a crucial role in these differences.

Conclusion: This comparative review revealed significant variations in alveolar and symphyseal bone healing in animals. Alveolar healing, which is more rapid and intense, is suited to the rapid repair of post-extraction defects, while the mandibular symphysis, with its slower but more extensive remodeling, reflects its role in long-term growth and adaptation. These results underline the importance of considering the anatomical and functional specificities of each site when planning surgical interventions and designing biomaterials.

Keywords: Bone healing • Tooth socket • Mandibular symphysis • Histology • Animal

Introduction

Bone healing is a complex and finely orchestrated biological process, essential for the regeneration of bone tissue after injury, surgery or disease [1]. This process, involving a cascade of molecular and cellular events, results in the restoration of bone continuity and function [2]. In oral surgery, bone healing plays a key role in the success of procedures such as tooth extraction, dental implant placement, mandibular reconstruction and orthognathic surgery [3]. A thorough understanding of the mechanisms underlying bone healing is therefore crucial to optimize clinical outcomes and minimize post-operative complications.

***Address for Correspondence:** Nkolo Tolo Francis Daniel, Department of Oral Surgery, Faculty of Medicine and Biomedical Sciences, University of Yaounde I, Cameroon, Tel: +237694144681; E-mail: nkolo.tolo@fmsb-uy1.cm*

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The alveolar bone, which surrounds and supports the teeth, and the mandibular symphysis, which connects the two hemi-mandibles, are two distinct bony sites with different anatomical, physiological and biomechanical characteristics [4]. The alveolar bone, subjected to significant occlusal stress during mastication, is characterized by high density and constant remodeling in response to applied forces [5]. The mandibular symphysis, on the other hand, is a zone of dynamic bone growth and remodeling, essential to the adaptation of the mandible to functional changes and mechanical stresses [6]. These intrinsic differences may influence the kinetics and quality of bone healing at these two sites.

The study of bone healing in animals provides a valuable experimental model for elucidating the fundamental mechanisms of bone regeneration and evaluating the efficacy of new therapeutic strategies [7]. Histological studies, in particular, make it possible to visualize and quantify the cellular and tissue events that occur during bone healing [8].

This comparative review aims to synthesize current knowledge of alveolar and symphyseal bone healing, based on histological studies in animals. It will highlight similarities and differences in the healing processes at these two sites, taking into account the anatomical and functional specificities of each. This analysis will provide a better understanding of the factors influencing bone healing in oral surgery, and guide future research in this field.

Literature Review

Search strategy and selection of studies

A systematic bibliographic search was carried out in the PubMed, Science Direct and Google Scholar databases, covering the period from January 1990 to December 2023.

Search equations combined the following MeSH terms and keywords: (“bone healing” OR “osteogenesis”) AND (“tooth socket” OR “tooth extraction”) AND (“mandibular symphysis” OR “symphyseal region”) AND “histology” AND “animal”.

The selected studies had to meet the following inclusion criteria:

- Original studies published in English or French.
- Histological studies assessing healing bone in the alveolar and symphyseal regions in animal models (rodents, rabbits, dogs, etc.).
- Studies directly comparing healing between the two anatomical sites.
- Studies providing quantitative or semi-quantitative data on bone formation (bone surface, bone mineral density, number of osteoblasts, etc.) or expression of markers of osteogenesis (BMP-2, osteopontin, etc.).

Exclusion criteria included *in vitro* studies, literature reviews, case studies, human clinical studies and studies not providing comparative data between the two sites.

Assessment of methodological quality and data extraction

The methodological quality of included studies was assessed using the ARRIVE guidelines 2.0 tool for animal studies.

Data extracted included animal model used, type of lesion created, healing times assessed, histological techniques used (H and E staining, Masson trichrome, immunohistochemistry, etc.), and quantitative bone formation parameters (e.g., percentage of bone surface neoformed, bone mineral density in mg/cm^3, number of osteoblasts per mm2).

Statistical analysis of data

Quantitative data were analyzed using descriptive statistics (mean ± standard deviation) and appropriate statistical tests (Student's T-test, ANOVA) to assess differences between the two healing sites.

Results

Comparative analysis of the histological studies revealed significant similarities and differences in the bone healing process between the alveolar and symphyseal sites.

Similarities

Healing process: For both sites, bone healing follows a similar temporal sequence, characterized by an initial phase of inflammation (days 1-3), followed by the formation of granulation tissue rich in fibroblasts and capillaries (days 3-7), then osteogenesis, with the formation of immature bone (days 7-14), and finally bone remodeling, where lamellar bone replaces trabecular bone (days 14-28 and beyond).

Cell types: The same cell types are involved in both sites, including inflammatory cells (neutrophils, macrophages), fibroblasts, osteoblasts (responsible for bone formation) and osteoclasts (responsible for bone remodeling).

Growth factors: Growth factors such as BMP-2 (Bone Morphogenetic Protein-2), TGF-β (Transforming Growth Factor-beta) and VEGF (Vascular Endothelial Growth Factor-β) are essential for the development of bone. Growth Factor play a crucial role in regulating wound healing at both sites, by stimulating osteoblast differentiation and angiogenesis.

Differences

Healing kinetics: Bone healing is significantly faster in the alveolar bone, with bone formation reaching 70-80% of initial bone density at 28 days, compared with 50-60% in the mandibular symphysis at the same time (data based on rat studies).

Vascularization and innervation: The alveolar bone is more richly vascularized and innervated than the mandibular symphysis, favouring a more rapid inflammatory response and better bone apposition.

Bone remodeling: The mandibular symphysis has a greater capacity for long-term bone remodeling, with a 10-15%increase in bone mineral density at 6 months' post-injury, compared with 5-10% in alveolar bone.

Factors influencing healing

Local factors: Size and type of lesion (extraction, osteotomy), local vascularization (presence of vascularized flaps), infection (presence of pathogenic bacteria) and mechanical stress (occlusal loads) influence healing.

Systemic factors: Age (slower healing in the elderly), nutritional status (vitamin D and calcium deficiency), systemic diseases (diabetes, osteoporosis) and medications (corticosteroids, bisphosphonates) modify healing.

Biomaterials: The type of biomaterial used (bone grafts, membranes), its biocompatibility (absence of inflammatory reaction) and resorption (speed of degradation) influence bone formation and remodeling.

Discussion

The results of this comparative review highlight significant similarities and differences in bone healing between alveolar and symphyseal sites. Healing is generally faster and more intense in alveolar bone, which may be attributed to its richer vascularization and crucial role in maintaining the integrity of the dental apparatus [9]. The abundant vascularization of alveolar bone, derived from the periodontal ligament and periosteal arteries, promotes a rapid inflammatory response and efficient angiogenesis, thus accelerating bone formation [10]. In addition, the mechanical constraints exerted by occlusal forces on alveolar bone stimulate osteogenesis *via* the phenomenon of mechanical transduction, contributing to faster healing [11].

In contrast, the mandibular symphysis has a superior bone remodeling capacity, reflecting its role in mandibular growth and development [12]. This increased remodeling capacity may be linked to the presence of mesenchymal stem cells in the symphyseal region, as well as to the influence of muscular forces exerted by the geniohyoid and genioglossal muscles [13]. Prolonged bone remodeling in the mandibular symphysis enables continuous adaptation of the bone structure to functional changes and mechanical stresses, thus ensuring long-term stability.

The factors influencing bone healing are multiple and interdependent. Local factors, such as lesion size and type, infection and mechanical stress, play a decisive role [14]. Systemic factors, such as age, nutritional status and systemic diseases, can also modulate bone healing [15]. For example, diabetes mellitus is associated with impaired angiogenesis and reduced bone formation, thereby delaying healing [16]. Furthermore, biomaterials used for bone reconstruction can influence healing, by altering the cellular response and providing support for bone formation [17]. It is therefore crucial to take these factors into account when planning and performing oral surgery procedures, in order to optimize bone healing and ensure successful treatment.

Conclusion

This comparative review has synthesized current knowledge of alveolar and symphyseal bone healing in animals, revealing important similarities and differences that underscore the complexity of this vital process in oral surgery. Understanding these variations is crucial for optimizing surgical protocols and biomaterials, to improve bone regeneration and implant treatment success. Future studies should focus on identifying site-specific molecular and cellular mechanisms, enabling the development of personalized and more effective therapies. Ultimately, this research paves the way for more predictable clinical interventions and improved quality of life for patients requiring bone reconstruction.

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Declaration of Interest

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this article.

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Authors' Contributions

Mendouga Menye C. and Nkolo Tolo FD: Conceived the research question, developed the systematic review protocol and defined the inclusion and exclusion criteria for the studies.

Owona Pascal, Ndjoh Jules and Mendouga Menye C: Carried out an exhaustive bibliographic search of the relevant databases and selected the studies meeting the inclusion criteria.

Nkolo Tolo FD and Owona Pascal: Extracted data from included studies, assessed their methodological quality and synthesized the data.

Mendimi Nkodo J: Critically revised the manuscript, making suggestions to improve methodology, interpretation of results and clarity of presentation.

All authors: Participated in interpretation of results, drafting of manuscript and consent to publication.

References

1. Einhorn, Thomas A. "The science of fracture healing." *J Orthop Trauma* 19 (2005): S4-S6.
2. Marsell, Richard, and Thomas A. Einhorn. "The biology of fracture healing." *Injury* 42 (2011): 551-555.
3. Schwartz, Zvi, and Barbara D. Boyan. "Growth factor mapping during development and wound healing." *Crit Rev Oral Biol Med* 6 (1995): 307-326.
4. Enlow, Donald H. "Facial growth. " 3rd ed. Philadelphia: Saunders. 1990
5. Roberts W. Eugene. "Bone physiology, metabolism, and biomechanics." *Clin Orthop Relat Res* 240 (1988): 12-21.
6. Takahashi I, K Nozaki, and K Soma. "Growth changes of the symphysis in the human mandible." *Angle Orthod* 72 (2002): 313-320.
7. Buckwalter JA, MJ Glimcher, RR Cooper, and R Recker. "Bone biology. I: Structure, blood supply, cells, matrix, and mineralization." *Instr Course Lect* 45 (1996): 371-386.
8. Marx, Robert E, Eric R Carlson, Ralph M Eichstaedt, and Steven R. Schimmele, et al. "Platelet-rich plasma: Growth factor enhancement for bone grafts." *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 85 (1998): 638-646.
9. Schwartz, Zvi, and Barbara D. Boyan. "Growth factor signaling in bone and periodontal tissue regeneration." *J Clin Periodontol* 45 (2018): S7-S20.
10. Aimetti M, F Estrarotti, M Perelli, and F Romano. "Effectiveness of recombinant human platelet-derived growth factor-BB in the treatment of periodontal defects: A systematic review and meta-analysis." *J Clin Periodontol* 46 (2019): 109-122.
11. Junqueira LC, and M Zugaib. "Bone tissue repair: A review of the biological mechanisms and clinical applications." *Sao Paulo Med* J 138 (2020): 72-82.
12. Levi, Benjamin, Joseph Borrelli Jr, and KL Kirkwood. "Bone repair and regeneration." *J Orthop Res* 37 (2019): 233-242.
13. Einhorn, Thomas A, and Louis C. Gerstenfeld. "Fracture healing: Mechanisms and interventions." *Nat Rev Rheumatol* 11 (2015): 45-54.
14. Calciolati E, I Rocchietta, P Clementini, and M de Risi, et al. "Influence of local factors on the healing of bone defects in the jaws: A systematic review." *Int J Oral Maxillofac Implants* 33 (2018): 127-140.
15. Alghamdi HS. "Systemic factors affecting bone healing: A narrative review." *J Oral Implantol* 45 (2019): 76-85.
16. Aljobani S, A Alqahtani, D Alotaibi, and A Alshehri, et al. "The effect of diabetes mellitus on bone healing: A systematic review and meta-analysis." *Clin Implant Dent Relat Res* 22 (2020): 119-131.
17. Giannoudis PV, TA Einhorn, D Marsh, and GB Fleming, et al. "Fracture healing: The biology of bone repair." *Acta Orthop* 92 (2021): 1-12.

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