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Socket Preservation: A Review

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Abstract

The process of tooth extraction leads to significant changes in the surrounding alveolar bone, which is crucial for the success of future dental procedures such as implant placement. Following the removal of a tooth, both the tooth socket and the adjacent alveolar bone undergo a series of physiological changes. These alterations are a natural part of the healing process, but they can impact the success of subsequent dental treatments. When a tooth is extracted, the bone in the extraction site begins to undergo remodeling and resorption. This process is not confined to the immediate area of the socket but also affects the surrounding alveolar bone. One of the key factors influencing the extent of these changes is the initial size of the socket. Wider sockets typically require a longer period to heal fully compared to narrower sockets. This healing process involves both vertical and horizontal dimensional changes in the bone. Research indicates that after a tooth extraction, there is an average reduction of 1.67 to 2.03 mm in vertical height and approximately 3.87 mm in horizontal width of the bone ridge. Notably, the most significant changes occur during the first year following the extraction, with both hard and soft tissues undergoing considerable remodeling during this period. In the contemporary field of dentistry, dental implants have become the preferred solution for replacing missing teeth, as they offer an effective means to restore comfort, function, and aesthetics. However, for dental implants to be successfully placed, the preservation of the alveolar ridge is essential. The preservation of this bone structure is critical to ensure that there is enough bone volume and density to support the implant, which ultimately affects the long-term success of the implant procedure. Therefore, understanding the dynamics of bone resorption and remodeling following tooth extraction is vital for dental professionals. Strategies aimed at minimizing bone loss and preserving the alveolar ridge are crucial for achieving optimal outcomes in dental implant procedures. Techniques such as bone grafting and ridge preservation methods are often employed to maintain bone structure and facilitate successful implant placement. The removal of a tooth results in remodeling and absorption not only within the socket but also in the surrounding alveolar bone. Alterations in the bone ridge following extraction are unavoidable, influenced by the initial size of the socket, with wider sockets requiring more time to heal completely. Both the height and width of the bone undergo dimensional changes after tooth extraction. The volumetric bone reduction changes that occur after tooth extraction are 1.67–2.03 mm vertically and 3.87 mm in horizontal direction along with hard and soft tissue remodeling which is higher during the first year. In today's world of modern dentistry, where implant placement is the most favored option for the replacement of missing teeth to achieve optimal comfort, function, and aesthetics, preservation of the alveolar ridge is of vital importance.

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INTRODUCTION

The extraction of a tooth causes remodeling and resorption not only within the socket itself but also in the surrounding alveolar bone. Changes to the alveolar bone ridge can result from a variety of factors, including chronic periodontal disease,

trauma (such as tooth extraction), developmental abnormalities such as alveolar clefts, long-term absence of teeth in the alveolar ridge, mechanical stress on the jaw bones (upper or lower), and tooth morphology [1]. These factors contribute to resorption and are categorized as anatomical, prosthetic, functional, and metabolic effects. Changes in the alveolar bone ridge following tooth extraction are unavoidable. In contemporary dental practice, tooth extraction plays a crucial role in complex treatment. Three-dimensional measurements of the bone and soft tissue significantly influence treatment planning, outcomes, and long-term prognosis. Tooth extraction affects bone resorption and alters gum contours, thus complicating subsequent treatments involving dental implants and prosthetics. Protecting the marginal alveolar bone ridge is crucial for achieving optimal functional and aesthetic results in prosthetic and orthodontic treatments [2]. There is a growing emphasis on minimizing damage to the surrounding soft and hard tissues during tooth extraction. Atraumatic extraction techniques and careful preservation of the alveolus are essential for maintaining these critical parameters [3].

In modern dentistry, implant placement is the most favored option for replacing missing teeth to achieve optimal comfort, function, and aesthetics, and preservation of the alveolar ridge is of vital importance [4].

Following tooth extraction, dimensional changes in the residual alveolar ridge resorption are inevitable. The extraction of teeth is followed by alveolar ridge resorption, which is referred to as bone remodeling, leading to the narrowing and shortening of the residual [5].

Bone resorption persists over time, with the most substantial loss of tissue contour typically occurring within the initial month following tooth extraction, resulting in an average width reduction of 3–5 mm over 12 months. The concept of "socket grafting" was developed to mitigate extensive bone remodeling by filling the extraction site with biomaterials, thereby preparing it for future implant placement. Various terms have been used in the literature, including ridge, socket, and occasional site preservation. Ridge preservation was defined in a consensus statement from 2009 as "a procedure to minimize vertical and horizontal ridge alterations in post-extraction sites" [6].

Several options exist for regenerating both hard and soft tissues to preserve and correct ridge defects, including socket preservation techniques. The materials used for ridge preservation, such as socket grafting, are also employed in other grafting procedures, including guided bone regeneration (GBR) and guided tissue regeneration (GTR) [7]. Bone substitutes are commonly used to prevent soft tissue collapse into extraction sockets, offering osteoconductive and/or osteoinductive properties to enhance new bone formation. These techniques aim to minimize ridge resorption and soft tissue recession while promoting optimal bone formation. Socket preservation, which involves the use of graft materials, helps maintain space and prevents tissue collapse, ensuring a favorable architecture for future restorative options. Examples of bone substitutes include Autografts, Allografts, Xenografts, Alloplasts, Bioactive glass, and Composite ceramics [8].

Barrier membranes may be used independently or in combination to cover graft materials within sockets, prevent epithelial cell penetration, and promote bone formation. Resorbable collagen or polylactic/polyglycolic acid sponges are commonly used to protect graft materials from the oral environment and can serve as carriers for regenerative substances such as recombinant human bone morphogenic protein 2 (rhBMP-2) [9].

Although these methods effectively preserve the blood clot and introduce osteoinductive substances, successful outcomes can be hindered by factors such as infected granulation tissue, chronic inflammation, or infection following grafting procedures. Appropriate socket curettage, adequate bleeding from the socket walls, and preservation of the blood clot are essential for optimal results. Additionally, osteoactive agents such as transforming growth factor β and bioactive polypeptides (e.g., P-15, OSA-117MV) stimulate bone deposition and are considered another category of beneficial

materials for regenerative therapies that can function as osteo-inducers or osteo-enhancers. These materials and their effects are currently being studied for their potential widespread application in bone regeneration. Laser treatment to accelerate wound healing and maintain blood clot stability in extraction sockets has been reported to reduce alveolar bone resorption in clinical settings [10].

Various techniques have been employed to preserve bone volume, which is crucial for achieving favorable aesthetic outcomes. After tooth extraction, the integrity of the buccal plate is often evaluated, and defects are frequently observed due to progressive pathological conditions or anatomical factors. Atraumatic tooth extraction is essential for preserving both soft and hard tissues at the extraction site. Augmentation of tooth sockets following extraction is increasingly common in modern practice and has proven effective for addressing limited defects in bone and soft tissue post-extraction. Surgical procedures in this area continue to evolve with the introduction of new techniques.

RIDGE PRESERVATION

Facial bone anatomy deficiencies significantly affect aesthetics and are key contributors to complications and failures in aesthetic dental implants. However, the dimensions of both hard and soft tissues can be compromised owing to the physiological and structural changes that occur after tooth loss [11].

Experimental and clinical research provides important information about related biological events and the extent of dimensional alterations following tooth extraction, as well as how they can be minimized to maintain the natural soft and bone tissue architecture of the dentition over time. The clinical relevance of bone and soft tissue alterations in tooth extraction sites of the maxilla and mandible is to identify associated modulating factors to assist the clinician in the selection of the most appropriate treatment protocols to facilitate pleasing aesthetic treatment outcomes [12].

Hard Tissue Alterations Following Tooth Extraction

In humans, it has been observed that after tooth loss in the premolar and molar sites, there can be a reduction in ridge width of up to 50% within the first year, with most of this change occurring within the first 3 months following extraction. The healing events of extraction sockets have also been examined in human biopsies obtained at various time points after extraction [9]. It was shown that the density of vascular structures and macrophages slowly decreased from 2 to 4 weeks, the level of osteoclastic activity slowly decreased over 4 weeks, and the presence of osteoblasts peaked at 6–8 weeks and remained almost stable thereafter.

Immediately after tooth extraction, the mean width of the alveolar ridge was 12.0 mm (range 8.6 - 16.5 mm).

Initially, the most occlusal-buccal point was positioned approximately 1.3 mm lower than the occlusal-oral point on average. After 12 months of healing, this difference decreased to 0.2 mm due to a tissue gain of 0.3 mm on the buccal side and a loss of 0.8 mm on the oral side. The majority of this 1 mm reduction in difference was achieved during this period [13].

Hereafter, the pocket depths remain almost unchanged. Mean gingival recession (0.7 mm) occurred gradually during the 1-month healing period. The mean attachment gain of 0.3 mm at the tooth surfaces adjacent to the extraction site was found. Regarding the ridge's width, it was observed to decrease by around 50%, specifically from 12.0 mm to 5.9 mm (a reduction of 6.1 mm, within a range of 2.7 to 12.2 mm). Two-thirds of this reduction occurred within the first month of healing. The percentage reduction was larger in the molar regions than in the premolar regions and the mandible than in the maxilla.

The degree of bone loss after extraction appears to be influenced by factors such as the thickness of the facial bone wall, tooth angulation, and other anatomical variations at different tooth sites. The width

of the facial socket wall was either evaluated intraoperatively, 1 mm below the alveolar crest or measured using Cone Beam Computed Tomography (CBCT) at various levels. Studies have shown that in the anterior maxilla, the facial bone wall thickness is less than 1 mm in 90% of cases and less than 0.5 mm in nearly 50% of cases. Consequently, these thin facial bone walls, mainly composed of bundle bones, are likely to undergo resorption after tooth extraction [14].

Soft Tissue Dimensions Prior To Tooth Extraction

Before extraction, the facial soft tissue in the anterior maxilla is naturally thin in most patients, typically ranging from 0.5 to 1 mm. There was no significant correlation between the thickness of the soft tissue and underlying facial bone wall thickness. Several surgical techniques have been developed to effectively increase the soft tissue volume and are routinely used by clinicians.

Soft Tissue Dimension Post-Extraction

The oral mucosa heals favorably, showing quicker inflammation resolution and better control of myofibroblast activity than skin wounds. Consequently, it is important to recognize that ridge reduction can occur after tooth extraction. Subsequent clinical steps should be planned to address these changes when replacing the extracted tooth with an implant-supported restoration.

SOCKET ALVEOLUS HEALING

Healing is a complex process involving the coordinated interaction of various biological systems and numerous molecules and cells through different phases. The presence or absence of teeth affects alveolar socket remodeling. Following tooth extraction, a sequence of organized biological events occurs in the alveolus, leading to socket healing. This healing process includes vascular changes, inflammatory responses, migration, proliferation, differentiation of various cell populations, ECM production and maturation, bone formation, modeling, and remodeling, ultimately restoring the lost tissue.

Hemostasis and Coagulation

Immediately after tooth extraction, the socket fills with blood owing to the hemorrhagic process, leading to the formation of a stable blood clot within the fibrin network.

Inflammatory Phase

A temporary and moderate inflammatory process is crucial for proper bone healing and regeneration, as described by the concept of constructive inflammation, which involves the activation of both humoral and cellular inflammatory responses.

Proliferative Phase

The proliferative phase can be divided into two stages, fibroplasia, and woven bone formation, both marked by intense and rapid tissue development. During fibroplasia, a provisional matrix was quickly deposited. This matrix is then penetrated by numerous blood vessels and bone-forming cells, leading to the formation of finger-like projections of the woven bone around the vessels.

Bone Tissue Modeling and Remodeling

The final phase of socket healing involves changes in the bone tissue structure, which may include modifications in architecture and shape (modeling) or may occur without altering these parameters (remodeling).

DIFFERENT BIOMATERIALS FOR SOCKET GRAFTING

Immediate implant placement at the time of extraction is often recommended to maintain the extraction socket architecture and expedite the timeline for final implant restoration. Studies have shown that immediate implant placement has a failure rate of less than 5%, which is comparable to that of delayed placement.

Bone Grafts

A bone graft refers to the tissue or material used to address a contour, volume deficiency, or defect. There are varied opinions regarding the selection of particulate materials for common clinical applications, the reasoning behind their selection, the justification for combining materials, and the proportions of each material used in combination. Bone grafts can be categorized into four groups.

- *Autograft:* Tissue that is transferred from one position to another within the same individual.
- *Isograft:* Tissue taken from an individual of the same species that is genetically related to the recipient.
- *Homograft*: Tissue transferred between genetically dissimilar individuals of the same species.

Allograft: Tissue transferred between genetically similar individuals of the same species.

Heterograft: Tissue taken from a donor of a different species, also known as a xenograft.

Barrier Membrane

The concept of GBR was initially described in 1959, using cell-occlusive membranes for spinal fusion. GBR and GTR are often used interchangeably but incorrectly. GTR specifically aims to regenerate the supporting periodontal structures, including the cementum, periodontal ligament (PDL), and alveolar bone, whereas GBR focuses solely on promoting bone formation. Both GBR and GTR are grounded in similar principles, utilizing barrier membranes to maintain space over a defect, facilitating the ingrowth of osteogenic cells, and preventing the migration of undesired cells from overlying soft tissues into the wound.

RECENT ADVANCES IN SOCKET PRESERVATION

Growth Factors

The use of local growth factors (GF) to improve the healing and regeneration capabilities of periodontal surgery has been investigated. GF-enhanced grafts are created using recombinant DNA technology and typically include human growth factors or morphogens (such as BMPs) combined with a carrier medium such as collagen.

Platelet-rich Plasma

Platelet-rich plasma (PRP) is a modified form of autologous fibrin glue obtained through techniques that concentrate a patient's platelets. It has been widely described and utilized in various applications with notable clinical effectiveness. PRP serves as a readily accessible source of growth factors that aid in the healing of both bone and soft tissues.

Platelet-rich Fibrin

Platelet-rich fibrin (PRF) in the form of a platelet gel can be utilized alongside bone grafts, offering several benefits, such as enhancing wound healing, promoting bone growth and maturation, aiding in wound healing and hemostasis, and improving the handling characteristics of graft materials. PRF can also function as a membrane. Numerous clinical studies have indicated that combining bone grafts with PRF effectively enhances bone density.

CONCLUSION

Many socket grafting materials and techniques have been shown to increase the alveolar ridge volume available during surgical implant placement. Nevertheless, failure to preserve ridge dimensions is not infrequent, and ridge volume may appear similar to that of a non-grafted socket. The rate of failure and factors contributing to failure are yet to be elucidated, but the chance of failure should be communicated to the patient.

Socket grafting procedures are recommended when extended treatment times between tooth extraction and implant placement are required. Therefore, the application of grafting materials for

socket preservation may influence vital bone formation. Future research should investigate whether alterations in histological healing affect implant outcomes. Therefore, more efforts should be directed toward developing new techniques to enhance histological healing in extraction sockets.

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