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REVIEW ARTICLE

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Biologic Aspects of Advanced Implant Dentistry

Timur V. Melkumyan[1,2*], Nuritdin Kh. Kamilov[1], Zurab S. Khabadze[2], Maria K. Makeeva[2], Julietta V. Rau[3], Angela D. Dadamova[1]

[1]*Tashkent State Dental Institute, Tashkent, Uzbekistan*
[2]*Peoples' Friendship University of Russia (RUDN University), Moscow, Russia*
[3]*Institute of the "Structure of Matter" of the Italian National Research Council, Rome, Italy*

Abstract

The present review was intended to provide several important biological insights into the practice of implant dentistry. Despite many benefits, it's clear that a dental implant does not share the features of a dentoperiodontal unit, and alveolar bone tolerates an implant, as far as its physiology goes, within the range of adequate response to direct masticatory load. The importance of a gingival tight seal around the transmucosal part of an implant cannot be overestimated from both biological and esthetic aspects. Considering the multifactorial nature of bone augmentation, the successful outcome of this type of surgery is still a matter of chance.**(International Journal of Biomedicine. 2024;14(3):392-397.)**

Keywords: dental implant • dentoperiodontal unit • alveolar bone • gingiva

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Introduction

Successful patient rehabilitation using dental implants depends on a large number of local and systemic factors. The most common problems identified during dental implant planning are insufficient bone volume, thin gum biotype, and a lack of the required amount of keratinized soft tissue. Several studies have revealed that less than half of cases have sufficient native bone to support a dental implant.[1,2]

Gradual atrophy of the alveolar ridge caused by tooth loss is an inevitable process. However, the extent and rate of bone resorption can vary significantly from case to case. It has been found that in a year after tooth extraction, the narrowing of the alveolar ridge width reaches 50%, and the height of the buccal wall decreases by 20%-30%.[2-4] On the other hand, a systematic review performed in the same period revealed that the prevalence of peri-implant mucositis and peri-implantitis ranges from 19% to 65%.[5]

Based on these unbiased data, it can be concluded that complications after dental implantation are primarily associated with insufficient volume of bone and attached gingiva around the neck of a loaded implant. In this regard, preliminary bone plastic surgery is recommended for a significant number of patients wishing to restore their missing teeth with dental implants. A sufficient variety of materials and methods have been developed and used to solve the problem of alveolar bone deficiency. Their widespread popularity in the dental community is due to the fact that an increased amount of bone is needed for the implant to be the necessary size.[6-8]

It is noteworthy that the bone integration of dental implants with native bone has been well studied, and its predictability has been proven over time. However, in accordance with a few data, the quality of the interface between an implant and augmented bone is not high and leaves much to be desired. Also, the outcomes of bone augmentation of an atrophied alveolar process, despite the positive long-term results of many studies, are still the subject of debate in terms of their efficacy, especially in patients with a severely resorbed ridge.[9,10]

In this regard, this review aims to analyze the factors influencing the long-term prognosis of dental implantation and bone augmentation in terms of morphology and physiology of the edentulous alveolar ridge.

***Corresponding author:** Prof. Timur V. Melkumyan, PhD, ScD. Tashkent State Dental Institute, Tashkent, Uzbekistan. Peoples' Friendship University of Russia (RUDN University), Moscow, Russia. E-mail: t.dadamov@gmail.com*

Dental Implants and Alveolar Bone

The alveolar process is an integral part of the periodontium, which develops along with the teeth to support them. It consists of the proper alveolar bone and supporting bone. The alveolar bone is presented by a thin lamina surrounding the tooth root and is the site for attachment of periodontal ligaments. It also has a large number of perforations through which blood vessels, lymphatic vessels, and nerves pass. That is why it is also referred to as a bundle bone or cribriform bone. The supporting bone includes the outer vestibular and oral compact plates with a cancellous or trabecular portion between them and the proper alveolar bone.[11]

The alveolar bone proper and supporting bone adapt themselves to the functional demands of the teeth in a dynamic manner. Bone is resorbed if occlusal demands are reduced, but high masticatory load may cause a denser bone formation. Therefore, the bone of the alveolar process is in a constant state of flux. When teeth are in place, alveolar bone metabolism is mainly orchestrated by local biomechanics and insignificantly by general health. In the case of tooth replacement with dental implants, the influence of systemic factors or medical conditions on the homeostasis of endosseously loaded alveolar bone may be increased.[12,13]

For instance, the survival rate of dental implants in patients with controlled systemic diseases is the same as in healthy individuals. However, several medical conditions are associated with a high risk of implant loss. A bleak prognosis was demonstrated in patients subjected to radiotherapy of the head and neck region. That group of people had lower levels of osseointegration and a high implant failure rate.[14]

Similar bone complications can be seen in patients undergoing a bisphosphonate (BP) treatment. It has been noted that in patients receiving oral or intravenous (BP) therapy, an implant placement must be calculated and planned with caution. Special attention should be paid to posterior regions because most reported cases of BP-associated osteopathology are in the posterior jaw due to impaired remodeling in affected bone and its low ability to adjust to a functional load properly. Also, some studies determined that the implant survival rate was higher in patients using BPs of a second generation than in first and third generations and when there was a preoperative and postoperative drug holiday in terms of BP intake.[15,16]

A patient's medication profile should be considered when planning oral reconstruction involving dental implants in women. The data obtained from 2000 to 2017 revealed a five-fold increase in implant failure among female patients taking oral contraceptives or hormone replacement therapy compared to the similar group not taking those medications. These findings were independent of the presence of smoking habits or diabetes.[17]

Conclusively, the medication regimen of immunosuppressed organ transplant patients must be considered as well because many of them have steroids given in addition to the basic immunosuppressive therapy. Immunosuppressive drugs and glucocorticoids detrimentally affect bone remodeling and turnover rate, promoting osteoblast apoptosis. However, despite the absence of an obvious negative impact on implant survival rate caused by steroid therapy, a cumulative effect of drugs, gender, and medical condition should be calculated individually when mouth rehabilitation with dental implants is to be planned.[18-20]

Therefore, understanding the importance of bone-to-implant contact for the long-term success of dental implants and considering the impact of different therapies on bone metabolism could make it easier to realize the benefits of natural dentition and physiologic occlusion in medically compromised patients.

In comparison to dental implants, teeth are anchored by the periodontal ligament, which serves as a two-step, shock-absorbing system to protect the supporting tissues from possible occlusal trauma. The fluid content of the vasculature provides a hydraulic cushioning effect to address the light masticatory forces. An increase in pressure involves the principal fibers to soften the hit, transmitting it to the walls of the alveoli socket.[12]

Compared to teeth, dental implants are anchored by bone and act much the same as ankylosed teeth. The intensity of bone remodeling around loaded dental implants is very high. However, only 30%-40% of bone-to-implant contact is in the remodeling stage at any point in time and is presented by the resorption site. The remaining implant surface stays rigidly integrated with the supporting bone and prevents it from displacement.[21]

Ankylosed teeth and implants can be characterized by the fusion of the root surface with the surrounding alveolar bone. The phenomenon of tooth ankylosis can be explained by damage to more than 20% of the root surface area, which, after impaired healing, is repopulated by the faster bone-forming cells rather than the slower periodontal ligament fibroblasts or cementoblasts.[22]

Contemporary orthodontic practice demonstrates that ankylosed teeth and implants could provide a reliable anchorage for tooth movement because of their stability and ability to maintain a static equilibrium with the surrounding bone. It has been hypothesized that biomechanics and bone metabolism around ankylosed tooth and dental implants are pretty much the same except for one difference. As soon as the root of an ankylosed tooth is a part of bone, it will be replaced by bone in a progressive manner. However, bone resorption along the implant interface leads to the constant replacement of an old bone with a new one.[23-25]

Therefore, the role of dental implants in maintaining residual bone volume is fraught with uncertainty. Loss of the tooth with the periodontal ligament and adjacent bundle bone leaves the surrounding supporting bone out of natural stimuli. However, the majority of cells constituting the residual bone are osteocytes. According to current knowledge, these cells can respond to mechanical and hormonal stimuli to coordinate bone resorption and bone formation around dental implants. However, this scenario is possible in case of a sufficient amount of viable osteocytes, adequate blood supply, and tolerable occlusal load.[26-29]

Dental Implants and Gingiva

The primary function of the gingiva is to protect the supporting tissues from the oral environment. Junctional epithelium, tooth, cementum, periodontal ligament, and

adjacent part of the alveolar process form a dental-periodontal unit. They are biologically interdependent and, under normal conditions, maintain harmonious relationships throughout life. However, the tooth plays a pivotal role in the unit and assumes greater responsibility for the adaptation and regeneration of the rest. Tooth loss is followed by the inevitable atrophy of surrounding bone and gingiva.[11]

The importance of the keratinized gingival barrier in protecting peri-implant bone from the oral environment should not be underestimated. But what are the common features of gingival epithelium around the transmucosal component of the restored implant and the natural tooth? Normally, gingival epithelium is presented by keratinized or parakeratinized external oral epithelium, partially keratinized or non-keratinized internal sulcular epithelium, and non-keratinized junctional epithelium, which extends apically from the sulcus bottom to form an epithelial collar around the tooth. In its turn, the junctional epithelium consists of external basal lamina, which is continuous with sulcular epithelium and attaches to the connective tissue, and internal basal lamina, which attaches the junctional epithelium to the tooth surface.[12]

Precise evaluation of the quality of soft tissue attachment to the transmucosal part of an implant is associated with preparing informative histological sections for microscopic examination. However, the nature of sample processing poses many difficulties right from the beginning in order to obtain a clear picture of an implant-soft tissue interface. This may be one of the reasons for different conclusions among the studies in this particular field.[30,31]

However, most data indicate the establishment of tight soft tissue apposition to the transmucosal part of an implant without histologic evidence of an absolute biologic attachment, which must be presented by two basal laminas of the junctional epithelium.[32-34]

Apart from the mere mechanical barrier function, gingiva exercises an antibacterial defense activity mediated by the secretion of crevicular fluid into the sulcus. Among the active components of gingival crevicular fluid are inflammatory mediators and antibodies, which are necessary to suppress bacteria invasion and keep the periodontium out of their toxic byproducts.[35,36] The number of split-mouth studies comparing the level of cytokines in the crevicular fluid around healthy teeth and healthy implants is scarce. However, a study by Yaghobee et al.[37] demonstrated that the level of IL-1β around healthy implants is significantly higher than around healthy teeth (P=0.015). Results of another comparative clinical study [38] on healthy peri-implant and periodontal sites revealed a nearly twofold concentration of cytokines around implants, compared to teeth. In a similar study on clinically healthy teeth and dental implants, it was noted that the total volume of crevicular fluid was significantly higher around implants.[39]

Therefore, alterations in the antimicrobial activity of gingiva in the peri-implant zone may be explained by different mechanisms of soft tissue attachment to the transmucosal part of an implant-supported prosthesis. Considering this aspect, it must be noted that tooth loss is associated with the disappearance of dentogingival, dentoperiosteal, and semicircular fiber groups in the gingiva. However, the presence of residual alveologingival, circular, trans gingival, inter gingival, and transeptal groups of collagen fibers may facilitate keeping a tight seal around the artificial supra structure due to their intimate blending.

Dental Implants and Augmented Bone

The form of teeth mainly determines the configuration of the alveolar process. Following tooth removal and socket healing, the alveolar bone undergoes a significant three-dimensional reduction. The disappearance of a cribriform bone is compensated to some extent by a new bone growth into the socket, and the edentulous part of a ridge is mainly presented by changing the amount of supporting bone of the alveolar process. Different measures are being taken to avoid the reduction of alveolar bone caused by the inevitable modeling process. For example, immediate implant placement with a simultaneous grafting of free gaps has become a very popular and regularly performed procedure in recent times, but mostly with disappointing outcomes.[12,40]

The continuous and gradual reduction of the edentulous ridge can be explained by the law of Julius Wolff. In 1892, Julius Wolff postulated that bones change shape to adapt to the stresses they endure. Over 100 years later, his hypothesis remains true, and the formation of a new alveolar bone through orthodontic movement of teeth is a clear example of the bone modeling process caused by stress and strain within bone tissue.[41-43]

Bone remodeling is another distinct process by which healthy bone is renewed to maintain its shape and quality. This process is composed of four subsequent phases: cell activation, old bone resorption, reversal of bone resorption, and bone formation. By the end of this process, a new osteocyte and osteon should be formed.[44]

Nowadays, many techniques augment the bone in horizontal and vertical directions, but guided bone regeneration (GBR) is the most studied. GBR is a guided bone healing technique performed on an edentulous ridge to gain an adequate amount of viable bone to place a fixture in it. This method of bone shape change is based on the biological principles of osteogenesis, osteoinduction, and osteoconduction, except for stress and strain. Bone healing after guided bone augmentation surgery occurs via the following stages: blood coagulation, soft callus or fibrocartilaginous network formation, endochondral ossification, and woven bone deposition. The final stage of augmented bone healing is restructuring a hard callus into a highly organized lamellar bone with the help of osteoclasts and osteoblasts. This stage may last from a month to several years. The presence of loaded implants usually accelerates the reorganization in the augmented part of the bone, but often with the predominance of undesirable bone resorption and gum recession around the fixture.[44-46]

Now is the main question: “How does it happen?” Initially, the quantity and quality of a supporting bone result from functional adaptation to mechanical load. Mechanical signals are interpreted into chemical signals with the help of the tooth and its surrounding periodontal tissues. After tooth extraction and loss of functional stimulation induced by the periodontal ligament, the bone metabolism in the edentulous region of the alveolar ridge is maintained by the autocrine and

paracrine activity of residual cells. Osteocytes comprise 90%-95% of bone cells and play a special role in bone remodeling, forming a network within the mineralized bone matrix. Embedded in the bone matrix, they are responsible for bone homeostasis and adaptation by translating mechanical strain into biochemical signals.[47-49]

This is one of the main reasons for referring to the autologous bone graft as a gold standard. However, several histologic studies with the application of transplanted autologous bone grafts suggest that the majority of osteocytes in monocortical bone do not survive grafting, and neovascularization of non-vital grafted bone is difficult.[50]

Osteocyte lacunae without a histologically visible osteocyte have been termed empty, and the bone regions comprising them defined as non-vital or necrotic per early histologic studies of bone. The reported fraction of necrotic bone found in these studies ranged from under 10% to over 80%.[51,52] Originally, the physiology of osteocytes was adjusted to restricted oxygen supply; however, they can't survive after 3 hours of anoxia. In case of low oxygen tension, osteocytes release apoptotic bodies expressing RANKL to recruit osteoclasts and mediate bone resorption.[53,54]

Therefore, whatever bone augmentation technique is applied, the amount of osteocyte cell population in the augmented part of a bone is important for both regenerated bone stability and implant survival rate.

In conclusion, the present review was intended to provide several important biological insights into the practice of implant dentistry. Despite many benefits, it's clear that a dental implant does not share the features of a dentoperiodontal unit, and alveolar bone tolerates an implant, as far as its physiology goes, within the range of adequate response to direct masticatory load. The importance of a gingival tight seal around the transmucosal part of an implant cannot be overestimated from both biological and esthetic aspects. Considering the multifactorial nature of bone augmentation, the successful outcome of this type of surgery is still a matter of chance.

Competing Interests

The authors declare that they have no competing interests.

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