AIN SHAMS UNIVERSITY

Evaluation of Collagen Matrix versus Mineralized Bone Allograft for Alveolar Ridge Preservation: A Clinical, Histomorphometric, Immunohistochemical and Computed Tomography Study

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By

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بسم الله الرحمن الرحيم

قَالُوا سُبْحَانَكَ لاَ عِلْمَ لَنَا
إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ
أَنتَ الْعَلِيمُ الْحَكِيمُ

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REVIEW OF LITERATURE

After tooth extraction, significant dimensional changes of the alveolar ridge always occur. The amount of the horizontal bone loss occurs mainly on the buccal plate as opposed to the lingual/palatal aspect of the ridge, meanwhile a subsequent vertical bone loss is more pronounced on the facial side as well. This double resorption of extraction sites results in thinner ridges with a reduced vertical height and lingual/palatal shifting of their long axis ***(Tan et al., 2012, De Risi et al., 2015).***

Bone resorption occurs in two phases. In the first phase, the bundle bone is rapidly resorbed and replaced with newly formed immature woven bone which then starts to be replaced with mature lamellar bone in about 180 days. In the second phase, the periosteal surface of the alveolar bone remodels through an interaction between osteoclastic resorption and osteoblastic formation, leading to an overall horizontal and vertical tissue contraction ***(Pagni et al., 2012; Wang et al., 2012)***.

Ridge atrophy follows certain patterns. In the maxilla, the labial wall of the alveolar socket tends to resorb more rapidly and the ridge gradually becomes represented by the previous palatal wall. In the mandible, however, the lingual wall tends to resorb before the buccal. This discrepancy in the resorption pattern frequently compromises the sagittal and axial intermaxillary relationship. In both jaws, the thickness of the alveolar bone ridge is compromised before its height ***(Gaggl et al., 2005; Ibrahim et al., 2012).***

The extent of vertical alveolar bone resorption occurs primarily during the first 3–6 months following extraction. The buccal plate of bone is the most affected because its crestal portion is comprised only of bundle bone. It is also usually thinner than the lingual plate, about 0.8 mm at the anterior teeth and 1.1 mm at the premolar teeth ***(Schroop et al., 2003; Tan et al., 2012; Jamjoom et al., 2015).***

The rate and pattern of bone resorption may be altered if pathologic and traumatic processes have damaged one or more of the bony walls of the socket. In these circumstances, fibrous tissue will likely occupy part of the socket, preventing normal healing and osseous regeneration. These morphologic changes may affect the successful placement and osseointegration of dental implants ***(Chen et al., 2004).***

In **1963, Atwood** described six classes of alveolar ridge based on alveolar ridge resorption: (1) Pre-extraction normal bone, (2) Post-extraction normal bone: after extraction and before resorption started, (3) High well rounded adequate in height and width, (4) Knife-edge, adequate height, inadequate width, (5) Low well rounded, inadequate height and width, (6) Depressed ridge.

In ***1991, Jaffin & Berman*** classified alveolar ridge according to its density, alveolar bone has been classified into 4 types:

D-1 bone: *Dense compacta*; almost entirely composed of cortical bone, it is found in the anterior mandible, and this can withstand substantial loads because of its highly mineralized matrix.

D-2 bone: *Porous compacta* and coarse trabecular bone; it is commonly located in the posterior mandible and sometimes in anterior maxilla.

D-3 bone: *Porous compacta* and fine trabecular bone; found primarily in the anterior maxilla, it is more fragile than D1 and D2, and its bearing ability to load is reduced.

D-4 bone: *Fine trabecular bone*; most commonly found in long-term edentulous posterior maxilla, it is characterized by extremely thin cortical bone and reduced density of cancellous bone; it is least suitable for implant placement and has failure rates as high as 35%.

In ***2004, Juodzbalys and Raustia,*** using panoramic x-ray, computerized tomography, and ridge maping caliper with 347 patients, classified alveolar ridge atrophy into three types:

Type I: Alveolar height is ≥ 10 mm and width is ≥ 6 mm and the vertical defect in the anterior region is ≤ 3 mm, which is optimal for implant placement.

Type IIA: The height is ≥ 10 mm and the width is 4-5 mm: narrow edentulous jaw dental segment (narrow eJDS).

Type IIB: The height is 4-9 mm and the width is ≥ 6 mm (shallow eJDS).

Type IIC: The height is 4-9 mm and the width is 4-5 mm (shallow and narrow eJDS).

Type IID: The height is ≥ 10 mm and the width is ≥ 6 mm, the vertical cosmetic defect in an anterior region is > 3 mm from the crest of the alveolar bone to the necks of adjacent teeth.

Type III: The height is < 4 mm and the width is < 4 mm (too shallow and too narrow for implantation).

Dental implants have become a common means of replacing lost teeth. They have proved to be reliable, with good long-term results, provided that some clinical conditions are taken into consideration. One of these is that the implant must be placed in such a way that the bottom and sides are completely covered with bone. Functional loading of osseointegrated implants has been shown to significantly reduce bone loss and even promote bone growth in edentulous jaw segments ***(Shiratori et al., 2012; Ibrahim et al., 2012).***

However, Alveolar ridge resorption may interfere with placement of implant in a prosthetically ideal position. When ridge resorption occurs, bone augmentation is essential to guarantee adequate bone volume, to provide patients with adequate inter-arch dimension and to assure a satisfactory aesthetic result ***(Jensen & Shou, 2011; Milinkovic & Cordaro, 2014).***

Optimal positioning of implants depends on having adequate bone and soft tissue dimensions vertically and horizontally. The minimal bone dimensions required for placement of cylindric root-form implants are 5-8 mm in height and 6 mm in width. Intact alveolar bone with thickness of 1 mm should encircle the full length of the implant after insertion ***(Sanz et al., 2010; Ibrahim et al., 2012; Wallace et al., 2014).***

Salvi et al. in 2004 concluded that the parameters that may be applied for assessing the state of peri-implant health and the severity of peri-implant disease include: plaque accumulation, probing depth, bleeding on probing, keratinized mucosa width and crevicular fluid volume.

Many techniques have been suggested to maintain the three-dimensional topography of the socket. Two common examples are alveolar ridge preservation (ARP) with placement of bone graft material into the socket or immediate implant placement. The outcomes following intra-socket grafting are variable and controversial, especially from the biological point of view, due to the fact that placing a graft into the socket always hinders the self-healing response of the site ***(De Rissi et al., 2015; Caiazzo et al., 2018)***.

Implants can be positioned in conjunction with grafting procedures or after consolidation of the graft has occurred**.**

Moreover, the ideal timing of implant placement after dental extraction: (1) **immediate or type 1**, when the implant is placed during the same surgical intervention as the dental extraction; (2) **early implant placement or type 2**, when implants are placed during the early stages of healing (from 4 to 8 weeks); and (3) **delayed implant placement or type 3**, when implants are placed when the ridge has healed (from 3 to 6 months) ***(Celementini et al., 2013).***

The rationale for immediate implant placement in the aesthetic zone (one stage therapy) was to preserve the original hard and soft tissue architecture especially thin highly scalloped gingival biotype with a suitably fabricated provisional abutment and crown. This approach offers social and psychological (shorter treatment time), functional (correct placement permitting axial loads) and aesthetic (tissue preservation) advantages ***(Canullo et al., 2009; Weigl & Strangio, 2016).***

In **2004 Chen *et al.,*** reported the success rates and clinical outcomes associated with immediate, early and delayed implant placement. They found similar success rates among the different procedures. ***Pellicer-Chover et al., in (2014)*** reported that immediate placement has certain advantages over delayed implant insertion including: the reduction in treatment time and the avoidance of second surgery**.**

Immediate implants have the advantage of no bone resorption at the time of surgery but are associated with an increased risk of mucosal rescession due to continued remodeling of the extraction socket post implant placement ***(Chen &Buser., 2009).***

Although it is challenging to determine a clear indication for immediate or delayed implant placement, the majority of authors suggest immediate implant placement when the residual alveolar bone presents adequate quality and quantity. In fact, the primary stability of dental implants, which is considered to be the essential condition for osseointegration, is closely related to these parameters ***(Chiapasco et al., 2006; Clementini et al., 2013).***

Raghoebar et al. (2003), Lizuka et al. (2004), supported delayed placement since immediate placement of implants exposes the patient to some risks, such as partial or total loss of the graft in the case of wound dehiscence, membrane or onlay graft exposure and/or infection, and non-integration of implants related to the immediate placement into avascular bone.

Table (1): Global Comparison between Immediate, Early, and Delayed Implant Insertion ***(Quirynen et al., 2007)***

	Immediate	**Early**	**Delayed**
Time	Short treatment time	Short treatment time	Long treatment time
Surgery	• Reduced number of surgical procedures • Bone substitute to fill in voids where applicable • Use of membrane may be indicated	• Extra surgical intervention procedures • Bone substitute to fill in voids where applicable • Use of membrane may be indicated	• Extra surgical intervention procedures • Reduced number of cases in need of bone substitute • Membrane less frequently needed
Antibiotics	Recommended	Often recommended	Not always necessary
Implant position	Do not allow socket to dictate implant position	Do not allow socket to dictate implant position	
Bone	• Less resorption of buccal plate of bone • Increased osteoblast activity up to week 8	• Less resorption of buccal plate of bone • Increased osteoblast activity up to week 8	• Obvious resorption buccal plate of bone
Special requirements	• Primary stability is to be achieved via apical/lateral stabilization • Ability to remove all residual infection	• Primary stability is to be achieved via apical/lateral stabilization	
Outcome	• Early implant placement technique preserves periimplant marginal bone level more than immediate and delayed techniques • Delayed implant placement demonstrated greater risks of marginal bone loss ***(Prati et al., 2017)***.		

In fact, when a delayed placement is accomplished, it would be possible to place implants in a re-vascularized graft. Since the regenerative capacity of bone is controlled by the presence of vessels, bone marrow, and vital bone surfaces, a delayed approach would allow a better integration of implants and stability of implants as compared with immediate implant placement ***(Clementini et al., 2013)*.**

Brånemark in ***(1985)*** defined osseointegration as "a direct structural and functional connection between ordered vital bone and the surface of a load carrying implant without intervening soft tissues". Undoubtedly, osseointegration has been one of the most scientific breakthroughs in dentistry. It is a good indication of the clinical success of titanium implants referring to the direct anchorage of such implants to the surrounding host bone with the ability to withstand occlusal forces ***(Sakka & Couthard, 2009).***

Osseointegration is a physiological mechanism similar to direct fracture healing. Initially, mechanisms of cellular and plasmatic hemostasis lead to fibrin polymerization and the formation of a blood clot, New bone generates by (distance osteogenesis) where osteoblasts migrate to the surface of the implant, differentiate, and lead to the formation of new bone. Or (contact osteogenesis) in which, osteogenic cells migrate directly onto the implant surface and generate de novo bone ***(Terheyden et al., 2012; von Wilmowsky et al., 2014; Smeets et al., 2016)*.**

In fact, the success of implant is highly dependent on the chemical, physical, mechanical, and topographic characteristics of its surface. The surface topography influences the differentiation and proliferation of osteoblasts, and the up-regulation of transcription factors that are responsible for the expression of bone matrix formation genes. Thus, shorter healing times from implant placement to restoration can be achieved ***(Ogle, 2015)*****.**

The primary stability of implant is highly influenced by the load transfer at the interface which depends mainly on the length, diameter, and body/thread shape. The optimum length and diameter depend on the quality of the bone support. In type 1 and 2 bone, length and diameter do not seem to be significant factors for implant success. In type 3 and 4 bone, large diameter and long implants are recommended. Therefore, the peak stress values will decrease and stress distributions will be more homogenous ***(Ogle, 2015)*****.**

Petrie and Williams in ***(2005)*** demonstrated that increasing implant diameter resulted in a 3.5-fold reduction in crestal strain compared to a 1.65-fold reduction in crestal strain when implant length was increased. Increasing implant diameter therefore decreases the hazard of peri-implant overloading and allows for better stress distribution. It also allows better engagement of the buccal and lingual cortical plates which promotes increased primary stability and hence osseointegration.

The secondary stability of a dental implant largely depends on the degree of new bone formation at the bone to implant interface. Successive phase of load oriented bone remodeling leads to a replacement of primary woven bone to realigned lamellar bone in order to optimize the absorption of occlusal load and to transmit the mechanical stimuli to the adjacent bone. At the end of the remodeling phase, about 60–70% of the implant surface is covered by bone ***(Terheyden et al., 2012; von Wilmowsky et al., 2014; Smeets et al., 2016).***

To obtain high implant success, modification in implant design should achieve high levels of primary stability, faster and better quality osseointegration, reduced crestal bone loss, and improved stress distribution during functional loading. Research efforts have focused on topographic changes of implant surface in both its macro- and micro-properties to optimize osteoblastic migration, adhesion, proliferation, and differentiation, thus enhancing implant survival rate ***(Lan et al., 2012, Ogle, 2015; Sing, 2016).***

In ***(2007) Huang et al.*** reported that the tapered design decreased the stress in both cortical and trabecular bone compared with straight one. Appropriate macro-geometry combined with adequate implant drill hole preparation is the fundamental basis of clinical success in dental implantology.

Dental implant design can be classified into macro-, micro-, and nano scale. The macro-design of an implant is determined by its visible geometry, which include body shape, threads, anti-rotational features, and thread design (pitch, depth, angle, thickness, thread helix) while micro-design comprise surface topography, material composition, and bioactive coatings ***(Sing, 2016)*.**

Implant body shapes can be classified as threaded, stepped, or tapered. Threaded implants improve the primary stability via mechanical friction with the surrounding bone and it also increase bone-to-implant contact area. However, the stepped implant mimic the natural root form, creating a favorable load distribution, while tapered implants reduce repetitive micro-strains at the crestal margins by directing the axial load away from the dense cortical bone and toward the resilient trabecular bone ***(Nascimento et al., 2012, Sing, 2016).***

Thread shape can be square, v shaped, buttress, reverse buttress, and spiral. Threads reduce shear loads and increases functional surface area. Shear loads exhibited the most detrimental force that affects bone strength, while compressive forces are the most favorable. In square and buttress threads, axial forces are transmitted to the bone mainly by compressive forces, whereas in v-shaped and reverse buttress, load forces are transmitted to the bone by a combination of shear, tensile, and compressive forces ***(Mish, 2008; Abuhussein et al., 2010; Sing, 2016)*.**