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Review article

OSSEODENSIFICATION AS AN ALTERNATIVE APPROACH IN DENTAL IMPLANTOLOGY FOR IMPLANT SITES WITH INSUFFICIENT AVAILABLE BONE

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ABSTRACT

Considerations for tooth replacement with osseointegrated dental implants include the biologic conditions of soft and hard tissues in the implant site.

The aim of this review is to evaluate osseodensificationas a method for implant site preparation that could enhance bone density, ridge width, and implantprimary and secondary stability. An electronic database search was conducted in PUBMED using appropriate keywords. Osseodensification technique in dental implantology is used to increase the width of available bone and bone-to-implant contactsurface area (BIC)in a low-density bone. Compared to conventional implant drilling techniques, osseodensificationmay increase implant primary stability and reduce micromotion. Osseodensification technique is based on the bone expansion attitude - that widerdiameter implant could be placed in a narrow ridge without creating bone dehiscence or fenestration.

Keywords: bone volume, bone density, implant osteotomy, osseodensification, osseointegration, bone expansion, implant primary stability,

INTRODUCTION

Mechanical stability of the implants at the time of surgery is an essential condition to achieve implant osseointegration.Factors that are associated with implant primary stability are bone density [1, 2], surgical protocol [3], implant thread type, and geometry [4]. The insertion torque peak was demonstrated to be directly related to implant primary stability and host bone density [5]; high insertion torque could significantly increase the initial bone-to-implant contact percentage (BIC) with respect to implant inserted with low insertion torque values [5]. Installation of implants into bone usually is characterized by minimizing the inherent gap between the implant and bone surface.*A basic rule in dental implantology*is thatthe less traumatic the surgical procedure and the smaller the tissue injury (the damage) in the recipient site during implant installation, the more expeditious is the process through which new bone is formed and laid down on the implant surface. The various steps used at implant installation, such as [6] *incision* of the mucosa, often but not always followed by [7] the elevation of *mucosal flaps* and the separation of the periosteum from the cortical plates, [8] the preparation of the *canal* in the cortical andcancellous bone of the recipient site, and [9] the insertion of the titanium device (the implant) into this canal, bring to bear a series of mechanical insults and injury to both the mucosa and the bone tissue. The host responds to this injury with an inflammatory reaction, the main objective of which is to eliminate the damaged portions of the tissues and prepare the site for regeneration or repair. To the above described injury to the hard tissues must be added the effect of the so- called "press fit", which is when the inserted implant is slightly wider than the canal prepared in the host bone. In such situations, [6] the mineralized bone tissue around the implant is compressed and exhibits a series of microfractures, [7] the blood vessels, particularly in the cortical portion, of the canal will collapse, [8] the nutrition to the bone in this portion is compromised, and [9] the affected tissuesmost often become non- vital.

The injury to the soft and hard tissues of the recipient site, however, also initiates the process of wound healing that ultimately ensures that (6) the implant becomes "ankylotic" with the bone, that is osseointegrated, and (7) a delicate mucosal attachment is established and a soft tissue seal forms that protects the bone tissue from substances in the oral cavity. During the 6 weeks of healing that was monitored in this particular study in humans, it was observed that while the amount of old bone, bone debris, and soft tissue that initially occurred in close proximity to the implant gradually decreased, the amount of newly formed bone increased (6, 7).

Historically, the criteria of success have involved one of quantification of pain, mobility, and periimplant radiolucency. These criteria were established by Albrektsson and colleagues and remain one of the standards in long-term evaluation of dental implants (8). Other methods involved the use of Periotest instruments or nanodevices that promote radiofrequency response from the osseointegrated implant to give an indication of mobility (9).

Another challenge in implantology is placement of implants into a recent extraction socket, and it is possible in cases of freedom from infection,sufficient bone amount and reasonable orientation of the existing tooth. Ways of facilitating this technique may incorporate orthodontic extrusion to create a smaller socket in the bone, facilitating extraction, and overcorrecting bone apposition to recreate missing architecture. The extrusion should take place slowly, usually over 3 to 6 months(10)and that's why alternative techniques are proposed.

Osseodensification (OD), a nonextraction technique, was developed by Huwais [11] in 2013and made possible with specially designed burs to increase bone density as they expand an osteotomy [12]. These burs combine advantages of osteotomes with the speed and tactile control of the drilling procedures. Standard drills remove and excavate bone during implant site preparation; while osteotomes preserve bone, they tend to induce fractures of the trabeculae that require long remodeling time and delayed secondary implant stability. The new burs allow bone preservation and condensation through compaction autografting during osteotomy preparation, increasing the periimplant bone density, (%BV), and the implant mechanical stability was reported by *in vitro* testing [13].

According to the manufacturer, these special burs demonstrate the ability to expand narrow bone ridges similarly to split crest techniques. The bur geometry, rotating in reverse mode at a rotating speed of 800rpm to 1500 rpm with profuse saline solution irrigation to prevent bone overheating, allows compacting the bone along the inner surface of the implant osteotomic site without cutting. The bouncing motion (in and out movement) is helpful to create rate-dependent stress to produce a rate-dependent strain and allows saline solution pumping to gently pressurize the bone walls. This combination facilitates increased bone plasticity and bone expansion.

The mechanical friction between the implant surface and bone walls of the osteotomic site gives primary implant stability. The osseointegration process leads to new bone apposition on the implant surface and allows reaching the implant secondary stability that is the functional contact between alive bone and titanium dental implant.

In case of poor bone density, such as the upper human jaw, the insufficient bone amount around the implants could negatively influence the histomorphometric parameters (such as %BIC and bone volume percentage %BV and, consequently, both primary and secondary implant stabilities.

Undersized implant site preparationand the use of osteotomes to condense bone [14] are surgical techniques proposed to increase primary implant stability and %BIC in low density bone. Various healing patterns and periimplant bone remodeling models were also observed [15, 16, 17] between standard site preparation and undersized implant site preparation. Specifically designed implants for low-density bone were also developed[18]testifying the hardness of the challenge to reach sufficient implant stability in poor bone density.

The use of the osteotomes in poor density bone allows fracturing and condensing of bone trabeculae [19,20], but this technique does not improve periimplant bone density (%BV) or implant stability. It is demonstrated that fractured trabeculae in periimplant bone, caused using the osteotome technique, induce delayed secondary stability with respect to conventional drilling procedures during healing [20, 21].

Besides, tooth loss, old age, and removable or unsuitable removable dentures inevitably lead to alveolar bone resorption both in height and width [22]. It was reported that bone reduction in a width of approximately 25% after 1 year of tooth extraction in the mandible showed a bone loss rate 4 times higher than the maxilla [23]. Narrow alveolar bone ridges are common in edentulous patients needing dental implant restoration, and many surgical techniques have been developed, over the years, to perform bone expansion or augmentation. The alveolar ridge splitting/expansion technique in 1 stage was proposed as a valid alternative to the 2-stage Guided Bone Regeneration (GBR) [24]. The predictability of horizontal and vertical augmentation techniques by bone regeneration, using bone substitutes or autogenous bone, is still not clear, and surgical complications are common [25]. However, osteodistractionosteogenesis and ridge splitting technique [26] are considered efficient to increase bone width [27] with lesscomplication incidence.

This method of biomedical bone preparation(OD)is characterized by low plastic deformation of bone that is created by rolling and sliding contact using a densifying bur that is fluted such that it densifies the bone with minimal heat elevation [21].

These burs provide advantages of both osteotomes combining the speed along with improved tactile control of the drills during osteotomy. Standard drills excavate bone during implant osteotomy, while osteotomes tend to induce fractures of the trabeculae requiring long remodeling time and delayed secondary implant stability. The Densah burs allow for bone preservation and condensation through compaction autografting during osteotomy preparation, thereby increasing the bone density in the peri-implant areas and improving the implant mechanical stability [28]. The bone-remodeling unit requires more than 12 weeks to repair the damaged area created by conventional drills that extract a substantial amount of bone to let strains in the walls of osteotomy reach or go beyond the bone microdamage threshold. Hence, OD will help preserve bone bulk and increase density, thereby shortening the healing period [29].

Unlike traditional osteotomy, OD does not excavate bone but simultaneously compacts and autografts the particulate bone in an outward direction to create the osteotomy, thereby preserving vital bone tissue. This is achieved using specialized densifyingburs. When the specialized drill is used at high speed in an anticlockwise direction with steady external irrigation (Densifying Mode), the dense, compact bone tissue is created along the osteotomy walls [30]. The pumping motion (in and out movement) creates rate-dependent stress to produce rate-dependent strain and allows saline solution pumping to gently pressurize the bone walls. This combination facilitates increased bone plasticity and bone expansion. Huwais demonstrated that OD helped ridge expansion while maintaining alveolar ridge integrity, thereby allowing implant placement in autogenous bone, also achieving adequate primary stability. OD helped in preserving bone bulk and shortened the waiting period to the restorative phase [31].

Trisi et al. in *in vivo* study found a statistically significant correlation between peri-implant bone density, insertion torque, and micromotion. A significant increase in insertion torque and a concomitant reduction in micromotionwas noted with an increase in bone density values [32]. Berardini et al. [33] and Li et al. [34] in a review reported no significant difference in crestal bone resorption and failure rate between implants inserted with either high- or low-insertion torque values. They also demonstrated the ability of OD drills to increase the % of BV and % of BIC for dental implants inserted into poor density bone compared to conventional osteotomies, which may help in enhancing osseointegration [8, 35,].

Biomechanical capabilities of implants are affected by various factors, which include implant macro/microgeometry, nanosurface modifications, and osteotomy techniques employed [36, 37]. Standard drills used in implant site osteotomy excavate bone to facilitate implant placement. They produce effective cutting of bone but lack the design capability to create a precise circumferential osteotomy. Osteotomies, therefore, become elongated and elliptical due to the imprecise cutting of the drills. This leads to a reduction of torque during implant insertion, leading to poor primary stability and contributing to the potential for nonintegration of implants. Furthermore, osteotomies prepared in the deficient bone may produce either buccal or lingual dehiscence, which results in a reduction of primary stability and necessitates an additional bone grafting adding to the total cost of treatment and increasing healing time.

Undersizing the implant site preparation [38, 39] and using the osteotomes for bone condensation [40, 41] are some of the surgical methods advised to increase primary stability in implants and % of BIC in poor density bone. Observations were also made on different healing patterns and peri-implant boneremodeling models [42, 43, 44]. The alternative to implant drilling procedures in the posterior maxilla is the osteotome technique [45] that aims to compact the bone with the mechanical action of cylindrical instruments along the osteotomy walls. This procedure created trabecular fractures with debris, which caused an obstruction to the process of osseointegration [46].

OD osteotomy diameters were found to be smaller than conventional osteotomies prepared with the same burs due to the springy nature and elastic strain of bone. This increased the percent of bone available at the implant site by about three times. Histomorphological analysis has demonstrated the presence of autogenous bone fragments in the osseodensified osteotomy sites, especially in the bone of low mineral density relative to regular drills [46]. These fragments acted as nucleating surfaces promoting new bone formation around the implants and providing the greater bone density and better stability. Gil et al. found no statistically significant difference in bone-area-fraction occupancy as a result of drilling technique ($P = 0.22$) [47].

CONCLUSION

The concept of osteodensification(bone preserving technique)with universally compatible drills has been proposed to help in better osteotomy preparation, bone densification, and indirect sinus lift procedure and also achieve bone expansion at different sites of varying bone densities. During this procedurewith autograft bone in the phase of plastic deformation results in an expanded osteotomy with preserved and dense compacted bone tissue that helps maintain ridge integrity and allows implant placement with superior stability. With this technique, the clinician can achieve improvement in primary and secondary stability of implanst. A further study could assess the long-term effectiveness of this technique.

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