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Review Article

Osseodensification: An Inventive Approach in Implant Osteotomy Preparation Technique to Increase Bone Density

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Abstract

Since the early days of dental implantology, osteotomies have been prepared using standard drills designed for use in industrial applications. These drill designs have proven to be functional for dental applications; implant success rates have been satisfactory over time but osteotomy preparation techniques have still been lacking for various reasons. Standard drill designs used in dental implantology are made to excavate bone to create room for the implant to be placed. Unlike these standard traditional dental drilling techniques, a new technique is introduced which does not excavate bone tissue. Rather, bone tissue is simultaneously compacted and auto-grafted in outwardly expanding directions from the osteotomy. This novel approach to hardware implantation, termed osseodensification, is introduced for the placement of endosteal implants to preserve bulk bone, increase primary stability through densification of the osteotomy walls. This review focuses on the new bone drilling concept, namely osseodensification and its advantages over the standard drilling and extraction drilling techniques.

Keywords: *Implant; Osteotomy; Biomechanics; Osseodensification; Primary Stability; Bone Mineral Density*

Introduction

Dental implants are the milestones in dentistry, and numerous alternative oral therapies that could not be possible with conventional techniques have become possible. The prognosis of any implant procedure relates to the patient-related factors including the bone volume and quality and procedure-dependent parameters which include type of implant, type of surgical procedure. The stability of the implant can be defined either as the mechanical stability between the implant and the bone, or the biological stability that is achieved by osseointegration. Primary stability is achieved upon insertion of implant. It is based on the physical interactions between the bone and the implant [1].

The original protocol for the installation of dental implants advocated that the implants remained submerged (under oral soft tissues) with no functional loading during healing periods of 3–6 months in order to achieve osseointegration predictably [2].

Osseointegration is defined as a direct structural and functional connection between living bone and an implant surface and is considered a prerequisite for implant loading and long-term clinical success. Two frequently cited factors affecting osseointegration are the direct bone to implant contact at the microscopic level and the quality and quantity of the histologic structure of bone at the implant interface, which is strongly correlated with bone mineral density [3]. Increased primary stability and maintaining the bulk of bone mineral and collagen material has been shown to accelerate the healing process after surgery [4,5]. Therefore, it is necessary to preserve bone bulk during the preparation of an osteotomy site.

Drilling is a widespread osteotomy preparation technique that involves the cutting and extraction of bone tissue to create a cylindrical osteotomy that will receive an implant fixture [6]. However, the removal of bone during drilling compromises the implant fixation stability and pullout strength.

Several techniques have been introduced to prevent bone tissue from being sacrificed during the osteotomy preparation process and increase primary implant stability and percentage of bone-implant contact in poor density bone [7].

- The undersized drilling preparation technique was brought in use but even that technique failed to show any improvement in bone volume or healing process.
- Bone compaction utilizing the osteotome technique [8], introduced by Summers increases the primary stability of dental implants without removing bone tissue and is also believed to improve final bone healing [4,9]. On the other hand, Buchter., *et al.* reported the osteotome technique led to decreased implant stability and related this effect to microfractures that were created in the peri-implant bone [10]. *Stavropoulos., et al.* also reported that the osteotome method had a deleterious effect on osseointegration [11].
- Ridge expansion and utilizing screw-type expanders are other reported techniques to expand bone but buccal plate fracture during this procedure may affect implant insertion stability [12].

A new osteotomy preparation technique, osseous densification, has recently been introduced.

Osseodensification (OD), a nonextraction technique, developed by Huwais in 2013 made it possible with specially designed burs to increase bone density as they expand an osteotomy [13]. 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 remodelling time and delayed secondary implant stability. The new burs allow bone preservation and condensation through compaction autografting during osteotomy preparation, increasing the peri-implant bone density, and the implant mechanical stability.

Osseodensification is performed in an attempt to develop a condensed autograft surrounding the implant, making it valuable in clinical settings where there is an anatomic paucity of bone [14]. Unlike traditional drilling protocols (which we refer to as subtractive drilling), osseodensification increases primary stability due to densification of the drilled osteotomy site walls centrifugally by means of non-subtractive drilling [13].

The rationale is that compacted, autologous bone immediately in contact with an endosteal device will not only have higher degrees of primary stability due to physical interlocking between the bone and the device, but also facilitate osseointegration due to osteoblasts nucleating on instrumented bone in close proximity to the implant [14].

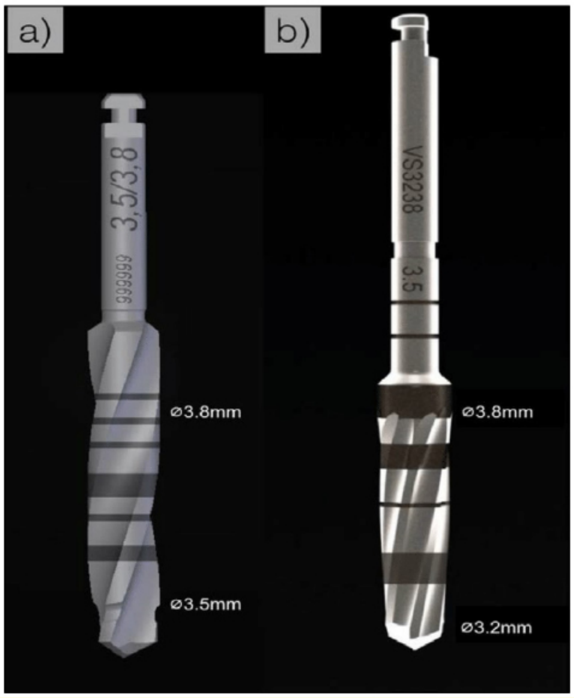


Figure 1: *Geometric design of a) standard burs and b) Osseodensification multi fluted tapered burs.*

Characteristics of osseodensification burs

This specially designed bur which enables the bone preservation.

- It has many lands with a large negative rake angle, which work as noncutting edges to increase the density of the bone as they expand an osteotomy in which the displaced bone is compacted and compressed circumferentially. Therefore, increase in biomechanical stability is likely due to the increased amount of interfacial bone for the osseodensification sites.
- These densifying burs have regular twist drills or straight fluted drills with four or more lands to guide them through the osteotomy and smoothly compact the bone. More lands means less potential chatter.
- Densifying burs are novel surgical devices as they are designed to have a cutting chisel edge and a tapered shank, so as they enter deeper into the osteotomy they have a progressively increasing diameter that controls the expansion process [15].

These burs are used with a standard surgical engine and can densify bone by rotating in the noncutting direction (counter clockwise at 800 - 1,200 rotations per minute) or drill bone by rotating in the cutting direction (clockwise at 800 - 1,200 rotations per minute). This new technique's proposed method of bone compaction is through the application of controlled deformation due to rolling and sliding contact along the inner surface of the osteotomy with the rotating lands of the densifying bur [16].

Mechanism of the densifying burs

During osseodensification, the densifying burs produce a controlled bone plastic deformation, which allows the expansion of a cylindrical osteotomy without excavating any bone tissue.

The spring-back effect has been documented as a response of compacted bone that reduces the osteotomy to a smaller diameter when the osteotome is removed. While much of the compaction of cancellous bone is permanent deformation that occurs due to its plastic behavior when loaded beyond the yield point, the spring-back is due to the viscoelastic portion of the deformation. Viscoelasticity is a time-dependent process, so in order to achieve bone compaction of this nature, it is necessary to apply stress in a time controlled manner [17].

Osseous densification occurs in a slow, incremental process that is carefully controlled by the surgeon, in contrast to the impaction process of Summer's osteotome. The viscoelastic recovery of the osteotomy demonstrates that there are residual strains created in the bone's surface during this preparation technique. The residual strain in the bone creates compressive forces against the implant, therefore increasing the bone-to-implant contact and primary stability, which have been shown to promote osteogenic activity through a mechano-biologic healing process [18]. This reverse compression applied to the implant by the bone is also likely responsible for the much higher removal torques that were generated with osseous densification compared to drilling. High insertion torque is an indication of good primary stability and is necessary to achieve early or immediate loading.

The bone deformation occurs through viscoelastic and plastic mechanisms when the load is controlled beneath the ultimate strength of bone. Copious amounts of irrigation fluid during this procedure provide lubrication between the bur and bone surfaces and eliminate overheating.

A recommended technique is for the surgeon to utilize a bouncing motion of the bur in and out of the osteotomy, which will induce a pressure wave ahead of the point of contact. The irrigation fluid that is then forced into the osteotomy may also facilitate autografting of bone particles along the inner surface of the osteotomy along the walls and at the bottom [19].

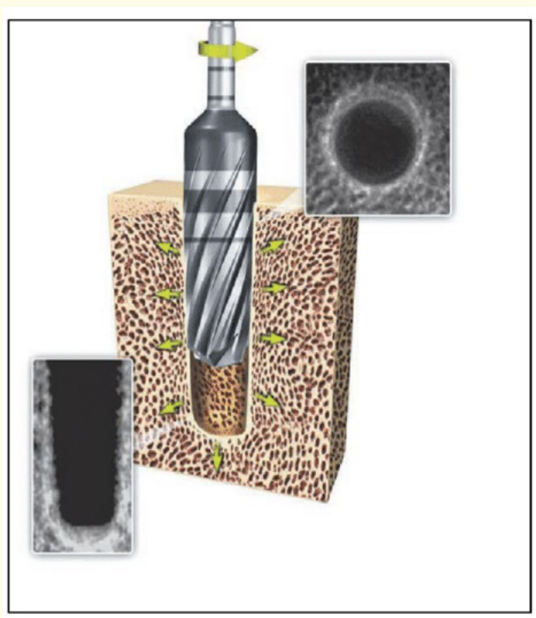


Figure 2: *a) Densifying Crust in Osseodensification Mode due to Compaction Autografting.*
b) Compaction Autografting in the Apex of the Osteotomy Facilitates Sinus Grafting.

The autografting supplements the plastic bone compaction to further densify the inner walls of the osteotome. The surgeon can safely control the osseous densification process because the bur-to-bone contact applies an opposing axial reaction force that is proportional to the intensity of the force applied by the surgeon. This facilitates the strain-rate controlled plastic deformation that compacts the bone and expands the osteotomy.

Hence, the osseous densification preparation technique preserves bone bulk in two ways: compaction of cancellous bone due to visco-elastic and plastic deformation, and compaction autografting of bone particles along the length and at the apex of the osteotomy.

Osseous densification is essentially a burnishing process that redistributes material on a surface through plastic deformation [20]. The bur's counter clockwise rotation causes the lands to slide across the surface of the bone with a compressive force less than the ultimate strength of the bone. Since fresh, hydrated trabecular bone is a ductile material, it has a good capacity for plastic deformation. The irrigation fluid and fluid content of the bone help this process by creating a lubrication film between the two surfaces to reduce friction and more evenly distribute the compressive forces.

Implant stability depends on direct contact between the implant surface and the surrounding bone so that micromotions at this interface are reduced [21]. The amount of micromotion is determined by the bone density around the implant. In low-density bone, drilling procedures that remove bone inevitably lead to low insertion torques and further reductions in bone mineral density. In these cases, early loading of the implant will cause micromotion and may lead to a failed bone healing response. Cancellous bone stiffness and strength are proportional to bone mineral density. With reduced bone mineral density there is a higher risk that the remaining bone will reach or exceed the bone's microdamage threshold. If microdamage does occur, the bone remodeling unit may require 3 or more months to repair the damaged bone area [22].

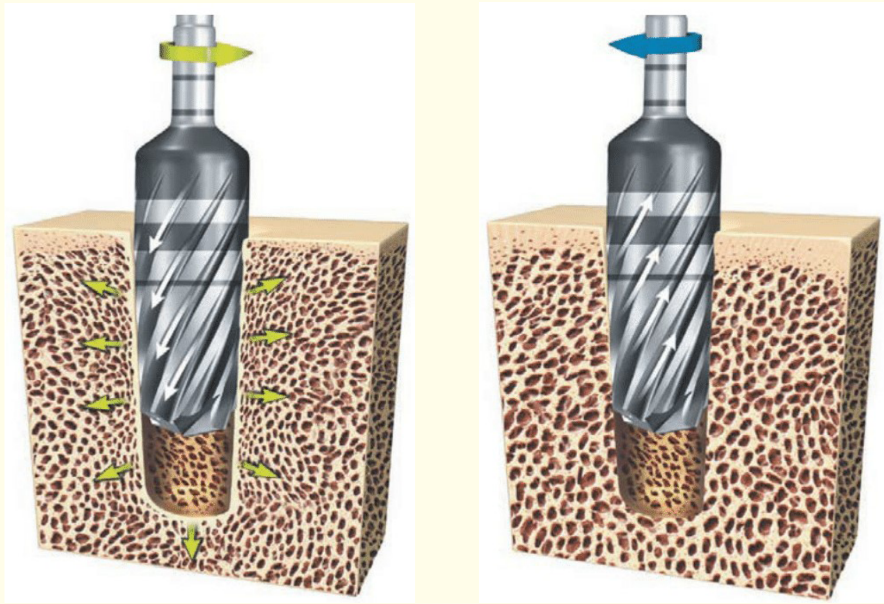
On the other hand, bone compaction techniques have been shown to increase insertion torque and bone density and therefore reduce micromotion [23]. While there is an inverse correlation between insertion torque and micromotion [24], in soft bone Trisi., *et al*. were not able to achieve more than 35 Ncm of peak insertion torque [23]. It is observed that osseous densification increased the insertion torque up from approximately 25 Ncm with the standard drilling technique. The percentage increase in insertion torque was even greater with osseous densification versus drilling. High insertion torque is particularly important in achieving a good clinical outcome with early or immediate loading.

Osteotomy Procedure

Osseodensifying burs progressively increase in diameter throughout the surgical procedure and are to be used with standard surgical engines, to preserve and condense bone (800 - 1500 rpm) in a counter clockwise direction (Densifying Mode), and to precisely cut bone if needed (800 - 1500 rpm) in a clockwise direction (Cutting Mode).

Recommended drill speed is 800 - 1500 rpm with torque range from 5 - 50 Ncm for both modes.

Cutting and Densifying must be done under constant water irrigation. A pumping motion is required to prevent over-heating. Surgical drills and burs should be replaced every 12 - 20 osteotomies or sooner when they are dulled, worn, or corroded.



a) Densifying mode b) Cutting mode.

Figure 3

Indications of osseodensification [13]:

- In cases with less than 3 mm of ridge width- It facilitates lateral ridge expansion.
- In maxillary sinus autografting- It facilitates vertical ridge expansion.

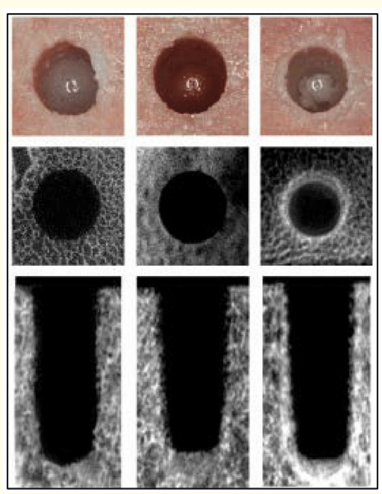


Figure 4: *(a) Surface view of 5.8-mm standard drilling (SD), extraction drilling (ED), and osseous densification (OD) osteotomies. (b) Microcomputed tomography midsection and (c) cross section.*

Comparison of osseous densification technique with standard drilling and extraction drilling techniques:

- The osseous densification technique increases the required penetration force and torque compared to standard drilling and extraction drilling [24].
- The maximum osseous densification insertion torque is approximately double the insertion torques of the standard drilling and extraction drilling techniques. High insertion torque is particularly important in achieving a good clinical outcome with early or immediate loading [23].
- The maximum osseous densification removal torques are also more than double the removal torques of the standard drilling and extraction drilling techniques.
- There is no significant difference in implant stability quotient between osseodensification and standard drilling and extraction drilling techniques.
- Although osseous densification produced higher maximum temperatures than drilling, the maximum temperature increase is limited at approximately 6°C. There is relatively small increases in temperature when irrigation and a bouncing surgical method is used, demonstrating that this technique is safe [25].
- During standard drilling and extraction drilling there were substantial bone particulates that were washed out of the osteotomies by the irrigation fluid and bone material that remained in the flutes of the drills when they were removed from the osteotomy. On the other hand, little bone material was excavated from the osteotomy by either of these mechanisms during the osseous densification technique.
- Although the osseodensifying burs have larger diameters than the standard bur, the diameters of the osseous densification osteotomies were approximately 0.5 mm smaller than standard drilling osteotomies. The smaller osteotomy diameters of the osseous densification technique demonstrates that elastic strain recovery occurs after this osteotomy preparation technique when the bur is removed from the osteotomy.
- There was a crust of compacted bone with increased bone mineral density around the periphery of osseous densification osteotomies, but relatively constant bone mineral density around osteotomies created through drilling.
- After insertion of the implant or a spacer, there is higher amount of increase in bone mineral density around the periphery of osteotomies created by osseous densification osteotomy preparation technique as compared to standard techniques.

Healing of the osteotomy by osseodensification technique

The most peculiar feature of the healing pattern is observed at the level of the more coronal cortical walls where the bone presented an unusual granular aspect. In these areas, osteoid tissue bands, osteons, and newly formed bone become visible. In these zones, the bone trabeculae shows the specific granular aspect also in the inner part, whereas the outer side shows lamellar bone layers.

These bone trabeculae are thickened because of incorporation of autogenous bone fragments during the healing process. The granules observed in the trabeculae appear like mineralization nuclei. Close to these granules, woven bone areas mixed with lamellar bone are observed. The percentage of bone surface lined by osteoid bands in the coronal area is much higher than that found in other areas of the implants. The increase of bone density is particularly evident in the most coronal implant region. Bone chips and resorption of newly formed trabeculae are observed. Active bone remodeling is found to be directed more toward bone apposition and bone density increase than toward bone resorption [26].

This suggests that, in the long run, the bone could still increase its density. The special geometry design of the burs tested allows pulverizing the bone, creating higher mineralization nuclei number.

Conclusions

The osseous densification technique increases primary stability, bone mineral density, and the percentage of bone at the implant surface. Osseous densification is shown to increase the insertion and removal torques of the implants compared to standard drilling and extraction drilling. This demonstrates increased implant primary biomechanical stability. This new technique was also shown to have similar clinical safety to drilling when proper rotary speed, penetration speed, and irrigation are used. Trabecular bone compaction produced during the osseous densification technique created a smaller osteotomy than drilling due to spring-back recovery of viscoelastic deformation when the bur was removed from the osteotomy. The bone mineral density of the osseous densification sites were increased by both compaction and autografting bone along the periphery and at the apex of the osteotomies. The percentage of bone at the implant surface was similarly increased in the osseous densification sites compared with standard drilling and extraction drilling. By preserving the bone bulk with the osseous densification technique, it is hypothesized that the healing process will be enhanced due to the autografted bone matrix, cells, and biochemicals along the osteotomy site.

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