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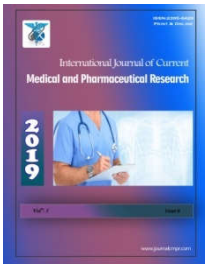

Research Article

ENHANCING IMPLANT STABILITY WITH OSSEODENSIFICATION- A REVIEW

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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.

INTRODUCTION

Dental implants are the milestones in dentistry andthe stability of the implant can be defined either as the mechanical stability between the implant and the bone,or the biological stability achieved by osseointegration.(1),(2)Increased primary stability and maintaining the bone bulk has been shown to accelerate the healing process after surgery.Therefore, it is necessary to preserve bone bulk during the preparation of an osteotomy site..(3,4)A new osteotomy preparation technique, osseous densification, has recently been introduced to develop a condensed autograft surrounding the implant, thus enhancing primary stability.

Advanced Osteotomy Procedures

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.(5)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.(6)

- ✓ 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 osteotometechnique(7), introduced by *Summers* increases the primary stability of dental implants without removing bone tissue and is also believed to improve final bone healing.(3,8)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.(9),(10)
- ✓ 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.(11)

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

Osseodensification (OD), a nonextractiontechnique, developed by *Huwais in 2013* made it 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 remodelling time and delayed secondary implant stability. The new burs allow bone preservation and condensation through compaction autografting during osteotomy preparation, increasing the periimplantbone density, and the implant mechanical stability.

Osseodensification

Time dependent low plastic deformation of bone tissue.

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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.(13) 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.(12)

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.(13)

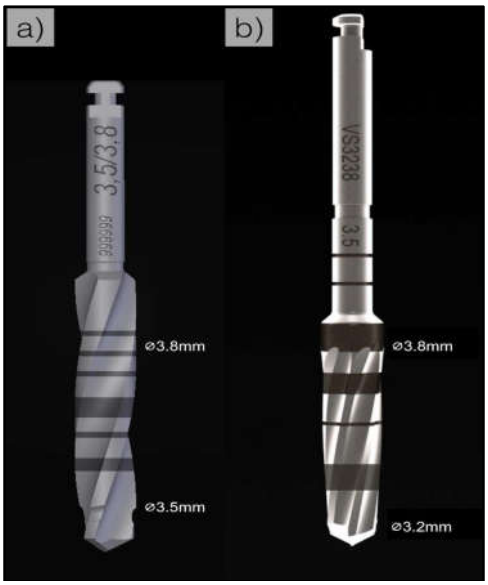

Fig 1 Geometric design of a) standard burs and b)Osseodensificationmulti fluted tapered burs

Characteristics of Osseodensification burs: (Fig. 1)

This specially designed burwhich 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 morelands 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 osteotomythey have a progressively increasing diameter that controls the expansion process.(14)

These burs areused with a standard surgical engine and can densifybone by rotating in the noncutting direction (counterclockwiseat 800–1,200 rotations per minute) or drillbone by rotating in the cutting direction (clockwise at800–1,200 rotations per minute).This new technique's proposed method of bonecompaction is through the application of controlleddeformation due to rolling and sliding contact alongthe inner surface of the osteotomy with the rotatinglands of the densifying bur.(15)

Mechanism of the Densifying burs

During osseodensification, thedensifying 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.(16)

Osseous densification occurs in a slow, incremental process that is carefully controlled by the surgeon, in contrast to the impaction process of Summer'sosteotome. 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 mechanobiologic healing process.(17) This reverse compression applied to the implant by the bone is also likely responsible for the much higher removal torques that was 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 mechanismswhen the load is controlled beneath the ultimatestrength of bone. Copious amounts of irrigation fluidduring this procedure provide lubrication betweenthe bur and bone surfaces and eliminate overheating.

A recommended technique is for the surgeon to utilizea bouncing motion of the bur in and out of the osteotomy,which will induce a pressure wave ahead of thepoint of contact. The irrigation fluid that is then forcedinto the osteotomy may also facilitate autografting ofbone particles along the inner surface of the osteotomy along the walls and at the bottom.(18)

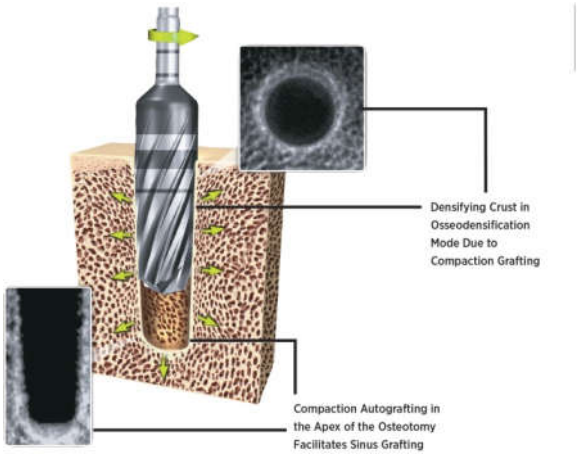

Fig 2: a) Densifying Crust in Osseodensification Mode due to Compaction Autografting

Compaction Autografting in the Apex of the Osteotomy Facilitates Sinus Grafting

The autografting supplements the plastic bonecompaction to further densify the inner walls of the osteotome. The surgeon can safely control the osseousdensification process because the bur-to-bonecontact applies an opposing axial reaction force thatis proportional to the intensity of the force applied bythe surgeon. This facilitates the strain-rate controlledplastic deformation that compacts the bone and expandsthe osteotomy.

Hence, the osseous densification preparation technique preserves bone bulk in two ways:

- Compaction of cancellous bone due to viscoelastic and plastic deformation (Fig 2a), and
- Compaction autografting of bone particles along the length and at the apex of the osteotomy(Fig 2b).

Osseous densification is essentially a burnishing process that redistributes material on a surface through plastic deformation.(19) The bur's counterclockwise 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.(20)(21)Bone compaction techniques have been shown to increase insertion torque and bone density and therefore reduce micromotion.(22) While there is an inverse correlation between insertion torque and micromotion,(23) In soft bone *Trisi et al* were not able to achieve more than 35 Ncm of peak insertion torque.(22) 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 counterclockwise direction (Densifying Mode)(Fig 3a), and to precisely cut bone if needed (800-1500 rpm) in a clockwise direction (Cutting Mode)(Fig 3b). 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 overheating. Surgical drills and burs should be replaced every 12-20 osteotomies or sooner when they are dulled, worn, or corroded.

Fig 3: a) Densifying mode

Fig 3 b) Cutting mode

Indications of Osseodensification(12)

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

Use veneer graft when expanded buccal plate thickness is <2mm

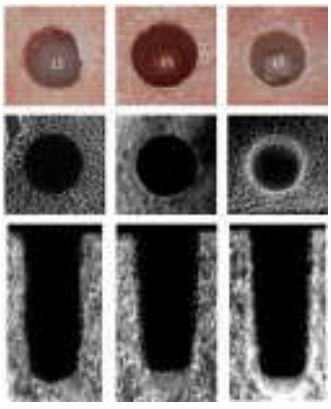

Fig 4 *(a)* Surface view of 5.8-mm standard drilling (SD), extractiondrilling (ED), and osseous densification (OD) osteotomies.*(b)* Microcomputed tomography midsection and *(c)* cross section.

Comparison of osseous densification technique withstandard drilling and extraction drilling techniques (Fig 4)

- The osseous densification technique increases the required penetration force and torquecompared to standard drilling and extraction drilling.(23)
- The maximum osseous densification insertiontorque is approximately double the insertion torques of thestandard drilling and extraction drilling techniques. High insertion torque is particularly important in achieving a good clinical outcome with early or immediate loading.(22)
- The maximum osseous densification removal torquesare also morethan double the removal torques of the standard drillingand extraction drilling techniques.
- There is no significant difference in implant stability quotientbetween osseodensification and standard drilling and extraction drilling techniques.
- Although osseous densificationproduced higher maximum temperatures thandrilling, 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.(24)
- During standard drilling and extraction drillingthere were substantial bone particulates that werewashed out of the osteotomies by the irrigation fluidand bone material that remained in the flutes of thedrills when they were removed from the osteotomy.On the other hand, little bone material was excavatedfrom the osteotomy by either of these mechanismsduring the osseous densification technique.
- Although the osseodensifying burs have larger diameters than thestandard bur, the diameters of the osseousdensification osteotomies were approximately 0.5mm smaller than standard drilling osteotomies.The smaller osteotomydiameters of the osseous densification techniquedemonstrates that elastic strain recovery occurs afterthis osteotomy preparation technique when the bur isremoved from the osteotomy.
- There was a crust of compacted bone with increased bone mineral density around the peripheryof osseous densification osteotomies, but relativelyconstant bone mineral density around osteotomiescreated through drilling.
- After insertion of the implantor 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.

Shortcomings of Osseodensification Technique

- Osseodensification does not work with cortical bone as cortical bone is a non dynamic tissue which lacks plasticity.
- Avoid densifyingxenografts because they behave biomechanically different than the bone tissue, as they have only inorganic content and they just provide the bulk without any viscoelasticity.
- Do not downsize the osteotomy.

Maxilla- 0.5-0.7 of implant diameter
Mandible- 0.2-0.3mm of implant diameter

- Oversize if needed only in expansion cases.

Healing of the Osteotomy by Osseodensification Technique

The most peculiar feature of the healingpattern 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 becomevisible. 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 trabeculaeare thickened because of incorporation of autogenous bone fragments during the healing process. The granules observed in the trabeculaeappear 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 trabeculaeare observed. Active bone remodelingis found to be directed more toward bone apposition and bone density increase than toward bone resorption.(25)

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 osseousdensification technique increases primarystability, bone mineral density, and the percentageof bone at the implant surface. Osseous densification is shown toincrease the insertion and removal torques of the implantscompared to standard drilling and extractiondrilling. This demonstrates increased implant primarybiomechanical stability. This new technique was alsoshown to have similar clinical safety to drilling whenproper rotary speed, penetration speed, and irrigationare used. Trabecular bone compaction producedduring the osseous densification technique created asmaller osteotomy than drilling due to spring-back recoveryof viscoelastic deformation when the bur wasremoved from the osteotomy. The bone mineral densityof the osseous densification sites were increasedby both compaction and autografting bone along theperiphery and at the apex of the osteotomies. The percentageof bone at the implant surface was similarly increased in the osseous densification sites comparedwith standard drilling and extraction drilling. By preservingthe bone bulk with the osseous densificationtechnique, it is hypothesized that the healing processwill be enhanced due to the autografted bone matrix,cells, and biochemicals along the osteotomy site.

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