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Review Article

Outcomes of Osseodensification: A Comprehensive Review of Current Literature

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Abstract

Osseodensification is a distinctive technique of implant osteotomy preparation that compacts the bone into open marrow spaces with sequential drilling due to its specific bur design. The current literature on osseodensification is constantly evolving with numerous studies citing the success of this novel technique. This comprehensive review encapsulates the effect of outcomes on different variables: primary stability based on drilling protocols, anatomic variables, implant configuration and histomorphometric analysis.

Keywords: Osseodensify; Dental Implant; Primary Stability; Implant Stability Quotient; Resonance Frequency Analysis; Insertion Torque

Abbreviations

OD: Osseodensification; BIC: Bone to Implant Contact; BAFO: Bone Area Fraction Occupancy; UD: Under Drilling; ISQ: Implant Stability Quotient; CW: Clock Wise; CCW: Counter-clock Wise; SD: Standard Drilling

Introduction

The success and prognosis of an implant restoration is multifactorial, governed by the treatment planning, surgical technique, biomechanical considerations such as implant geometry and osseointegration, prosthetic design, patient related systemic factors and maintenance [1]. Amongst the enlisted factors; the role of osseointegration has been repeatedly emphasized in literature. It mirrors the establishment of a structural and functional interface between bone and implant, independent of an inter-positional soft tissue. A peri-implant stress/strain is induced due to placement of a foreign body, thus challenging bone metabolism and triggering a highly integrated cascade of inflammatory reactions resulting in osteogenesis [2,3]. This process is majorly governed by direct microscopic bone- to- implant contact (BIC), the density and quantity of the newly formed bone at the implant interface along with its histologic nature [4].

Amongst the crucial factors of implant success enlisted by Albrektsson., *et al.* in 1981, primary stability of the implant is the most critical factor governing the success of osseointegration [1,5]. Primary stability is a mechanical interlocking of bone to implant that occurs mainly due to successful engagement of an implant thereby preventing excessive micromovement of the implant (<150 μm) [6-8]. This process is followed by secondary stability characterized by new bone formation, apposition and remodeling [9]. Over the years, numerous techniques have been developed to measure primary stability of implants. The most routinely employed methods of measuring primary stability are implant insertion torque (IT) and resonance frequency analysis (RFA) measurements [10,11]. Implant insertion torque is the measurement of the resistance encountered by the implant as it progresses apically in the prepared osteotomy whereas RFA measurements depend the natural frequency of vibration of the implant within the bone. It is determined by the rigidity of the connection of the implant with the bone and represents its degree of micromovement [11]. The noteworthy difference between these two factors is that implant insertion torque can be recorded only at the time of implant placement while RFA enables a long-term assessment of implant stability [11-13].

Bone-to-implant contact (BIC) percentage, is the measure of a dynamic functional response of the bone tissue to implant, which is constantly associated with the remodeling processes under functional loading [14,15]. It is the percentage of the amount of bone in intimate contact with the implant surface along the entire length of the implant. Similarly, bone area fraction occupancy (BAFO) is the percentage of the area within the implant threads occupied by visibly distinct bone. Both these histomorphometric assessments provide a reliable picture of primary implant stability [16].

Over the past few decades, constant attempts have been undertaken to increase the implant primary stability especially in low density bone. These include under sizing the osteotomy preparation, bi-cortical fixation, stepped osteotomy technique and bone condensation [17]. Although these techniques have shown fruitful results, they have their individual drawbacks. To overcome the problems with earlier cited techniques, a new method to increase the density of osteotomy site was introduced by Salah Huwais known as osseodensification. This technique employs specially designed burs to increase bone density by expansion during osteotomy [18].

Osseodensification [OD], as the name suggests, focuses on densifying bone and is a non-subtractive instrumentation method which has shown to remarkably increase the biomechanical engagement at the bone-implant interface [19]. This innovative osteotomy preparatory technique involves a multi-stepped drilling model using distinctively designed burs that promote lateralization and compaction of autogenous bone into the adjacent cancellous structure. Consequently, there is an expansion of the adjacent osseous environment by a rolling and sliding contact with regulated bone deformation [18]. The governing principle of this concept is that bone is a specialized tissue with elastic and plastic properties which facilitate preservation and compaction of bone bulk. This results in densification of the osteotomy due to autografting into the trabecular space [18]. The recommended technique for implant bed preparation is a jumping motion, that is; in and out movement of the bur in the osteotomy, which will induce a pressure wave ahead of the point of contact under copious irrigation [18,20]. The autografting characteristic is further enhanced by the irrigation fluid that is forced into the inner surface of the osteotomy [20]. This autografting enhances the plastic bone compaction to further densify the inner walls of the osteotomy. Owing to the haptic feedback achieved because of bur-to-bone contact, the operator can control the process more efficiently. This facilitates a strain-rate controlled plastic deformation yielding in compacted and expanded osteotomy [18].

The current literature on osseodensification is constantly evolving with numerous studies citing the success of this novel technique. This comprehensive review encapsulates the effect of outcomes on different variables: primary stability based on drilling protocols, anatomic variables, implant configuration and histomorphometric analysis.

1. Primary stability

1.1 Drilling protocol

1.1.1 Drilling techniques

Drilling is an extensive osteotomy preparation method of cutting and extraction of osseous tissue to create an osteotomy to receive an implant [21]. However, this process may result in extensive removal of bone during drilling and can compromise the implant fixation stability and its pull-out strength [22]. Bone drilling may also lead to other clinical complications, such as heat generation–induced necrosis due to insufficient cooling and irrigation, drill-tip slipping along the bone surface, or vibrations created as a result of cutting resistance vector that changes constantly due to heterogenous bone properties, ultimately leading to a compromise in the geometric precision of the osteotomy [23,24]. However, compared to standard drilling and extraction drilling, osseodensification has shown to increase the required penetration force and torque [18].

Summers introduced the bone compaction technique that involves preparation of implant bed without removing bone tissue. The idea behind this technique was to increase the primary stability of dental implants and enhance the ultimate bone healing [25,26]. On the contrary, Buchter., *et al.* and Stavropoulos., *et al.* reported that the osteotome technique caused microfractures in peri-implant bone, thereby decreasing implant stability [27,28]. Other conservative approach for osteotomy preparation involves ridge expansion using screw type expanders that function by displacing and expanding bone rather than removing it [29]. However, complications such as fracture of the buccal cortical plate which is likely to occur during this procedure, may affect implant insertion stability [30].

Recent in vivo studies on humans have explored the association between drilling techniques and primary stability in low-density bones. Most of these studies have shown better primary stability with bone compaction and densification as compared to conventional drilling techniques [11,14,21]. In a recent study by Barbera-Millian., *et al.* (2021) the results showed that implants placed using the under-drilling (UD) technique, had lower primary stability than those placed using the OD technique. They reported a mean insertion torque of 8.87 ± 6.17 Ncm by UD and 21.72 ± 17.14 Ncm by OD and mean RFA value was 65.16 ± 7.45 ISQ in UD group and 69.75 ± 6.79 ISQ in OD group [11]. In a multicenteric clinical trial in 56 patients (150 implants) by Bergamo., *et al.* (2021), similar results were noted. The IT achieved by OD drilling (60 ± 3.4 Ncm) was nearly 41% greater than IT by standard drilling protocol (SD) (35 ± 3.4 Ncm) [19].

1.1.2 Clockwise (CW) vs counter-clockwise drilling (CCW)

Oliviera and coworkers in their study on sheep reported higher insertion torque values for CW drilling (~53 Ncm) as compared to CCW drilling (~78 N·cm) irrespective of implant surface [31].

Moreover, in comparison to conventional drilling in D4 bone; CW and CCW osseodensification of implant osteotomies resulted in higher insertion torque values and %BIC and %BAFO [31]. The results can be attributed to the fact that osseous densification is fundamentally a burnishing process based on redistribution of material on a surface through plastic deformation [32]. 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 relatively ductile in nature, it has a great ability for plastic deformation. The synergistic effect of irrigation fluid and fluid content of the bone aid in creating a lubrication film between the two surfaces to reduce friction and more evenly distribute the compressive forces [18].

1.2 Anatomic variables

The clinical trial by Bergamo., *et al.* also investigated the influence of the different osteotomy techniques in various clinical scenarios of different bone mineral densities, using SD and OD drillings techniques in anterior and posterior maxilla (bone density 2, 3, and 4 -D2/D3/D4 bone) and mandible (predominantly D2 bone in the posterior region) [19]. The results of their study showed no significant difference in the insertion torque and ISQ values for implants placed in the maxilla and mandible using SD. Moreover, higher IT and ISQ values were noted for implants placed in the mandible than in the maxilla using OD [19]. The absence of significant difference in the SD for both arches can be attributed to the subtractive nature of the conventional drilling, which tend to undersize the osteotomy in maxillary bone to deliver comparable frictional forces during implant placement, without major variations in the biomechanical interlocking and strain in the prepared osteotomy [19,33-35].

The major advantage of OD is associated with the enhanced bone mineral density achieved due to the spring back effect and therefore, it may be principally useful in sites with adequate trabecular bone volume in both the maxilla and the mandible, particularly in the maxilla due to the relatively higher amount of trabecular bone [17-19]. Although, OD technique has also shown encouraging outcomes in the mandible in the current literature, caution should be exercised in denser bone sites in mandible, since necrosis and extensive remodeling may result due to downsizing osteotomy technique. However, the use of OD in the mandible is reported to be a favorable technique for alveolar ridge expansion [19,36-37].

1.3 Implant configuration

Implant designs and surfaces have significantly advanced over the years, which has reshaped the spectrum of their clinical indications. It has decreased the difficulty of the treatment and chair side time, costs and morbidity by avoiding the need for additional grafting procedures [19,38]. Previous studies have shown an increase in the primary stability with an increase in diameter and length of the implant [39,40].

Historically, standard drilling provides a wider osteotomy, that creates an increased strain level generated by the interaction between osteotomy-implant dimensions resulting in a more pronounced bone remodeling healing phenomenon [35,41]. Therefore, in comparison to SD, OD provides an equilibrium between preserving bone quantity and producing higher implant stability without creating severely downsized "misfit" osteotomies [19].

According to Bergamo., *et al.*the ISQ values for the OD technique started and remained constantly high for all implant configurations with respect to their diameter and length [with less significance in shorter implants], irrespective of their planned anatomical locations [19]. These results can be attributed to the lowered contact area available for the benefits provided by the OD drilling in increasing the bone mineral density and the biomechanical anchorage to reach a clinically significant effect on the clinical parameters [39,42]. Furthermore, analogous IT and ISQ values for implants of different diameters placed using conventional SD have been reported. Wide implants placed using OD showed greater insertion torque as compared to regular and narrow diameter implants [19].

Huwais and Meyer compared the primary stability of 4.1-mm and 6.0-mm implants of same length by measuring the insertion and removal torques using RFA system [18]. They concluded that osseodensification improved the IT with a 4.1-mm implant to approximately 49 Ncm, as compared to SD (25 Ncm). The percentage increase in insertion torque of the 6.0-mm implant was noted to be even greater with osseous densification against standard drilling [18].

According to Oliveira., *et al.* the surface treatment of the implants did not influence insertion torque values. This is noteworthy, as it demonstrates that the association between improved implant thread design and osseodensification can overcome lower insertion torque values of machined implant surfaces in areas of low bone density when placed by conventional subtractive drilling techniques [31]. Hence, machined implants placed by osseodensification may show at least similar osseointegration success rates of textured implants in low bone density [31]. Almutairi., *et al.* used implants with different thread designs in their study and reported no statistically significant differences in primary stability by OD and conventional drilling [43,44].

2. Histomorphometric analysis

The osteogenic factors surrounding the surface of the implants can be computed by determining the bone to implant contact (BIC) and the bone growth within the implant threads as a percentage, that is, bone area fraction occupancy (BAFO) [45-47]. There is a direct proportionality between the degree of osseointegration to the BIC and BAFO due to the osteoblasts nucleating on instrumented bone that is in close juxtaposition with the implant [1,48]. Due to the presence of this autografted bone around the implants in an osseodensified site, there is a rapid rate of osseointegration achieved. However, since these are histologic assessments of the mechanical relationship between bone and implant, they do not provide an explicit amount of the functionality of the connection [17].

Huwais., *et al.* in their study on porcine tibia assessed the bone morphology at the bone-implant interface by staining histologic sections with toluidine blue and with the use of microradiographs. These images showed that the percentage of bone at the implant surface was remarkably increased with OD (64-72%) as compared to SD (22-26%). They concluded that osseous densification technique reduced the diameter of the prepared osteotomy as observed on microcomputed tomographic imaging due to the autografting of bone particles into the trabecular pores along the osteotomy walls and base. Histologic analysis of these sites exhibited a significant osteogenic activity through a biomechanical healing process without the excessive strain thereby leading to extensive remodeling and subsequently a considerable stability dip [18].

Alifarag., *et al.* evaluated the relationship between drilling technique and two different implant macrogeometry designs, indicating higher BIC and BAFO values in the osseodensification technique compared with conventional drilling at 3 weeks regardless of the implant system used [49]. Oliveira., *et al.* on the other hand, evaluated drilling technique and implant surface treatment, concluding that the combination of osseodensification with machined implants resulted in similar BIC and BAFO values obtained with rougher implant microgeometry placed using the conventional technique. They concluded that the drilling technique greatly improves the early osseointegration of machined devices to degrees comparable to rough-surfaced devices at 3 and 6 weeks [31]. Moreover, Mullings., *et al.* in their recent study on low density ovine bone yielded higher osseointegration rates, BIC and BAFO indicating an increased osteogenic potential in osteotomies prepared using osseodensification technique [50]. All three studies agreed on attributing the improved bone-to-implant contact and bone-area-fraction occupancy to the compacted bone chips acting as nucleating surfaces that bridged the implant and surrounding bone [31].

Conclusion

Ossseodensification is gradually gaining popularity amongst clinicians since the time of its inception, owing to the predictable outcomes achieved from animal models and in vivo cross over trials in patients. The primary stability of implant is the most striking advantage of this technique particularly in low density bone, verified with various histomorphometric analyses. However, the long-term success and complications of this technique are still anticipated. Moreover, this review encompasses only conventional implant placement with OD and does not elaborate on its applications in sinus lift or ridge expansion procedures.

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Conflict of Interest

None.

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