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Biomechanical Parameters of Implants Placed with Osseodensification Versus Implants Placed with Under-drilling Osteotomy Techniques in Posterior Maxilla: A Comparative Clinical Study

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Abstract

BACKGROUND: To facilitate better implant survival rates in areas with clinically low bone density, osteotomy techniques that provide higher implant stability and improve bone quality are often recommended. The most widely used are under-drilling (UD) and osseodensification (OD). In the UD technique, the diameter of the final osteotomy drill is narrower that the diameter of the placed implant, whereas in the OD technique, special drills that rotate counter-clockwise to condense and densify the bone are used.

AIM: The aim of this study was to evaluate the effect of two different implant osteotomy methods – UD versus osseodensification (OD) in terms of implant stability during the period of osseointegration in the posterior maxillary region.

MATERIAL AND METHODS: This prospective randomized clinical study included 22 patients who received a total of 37 implants in the posterior maxillary region. They were divided into two groups: In 11 patients, 18 implants were placed using the under-drilling method (UD), while the other 11 patients received 19 implants using the osseodensification method (OD). Within the OD group, 10 implants were placed in areas with the initial height that was insufficient to accommodate implants with a minimal length of 8 mm. In these areas, crestal sinus elevation without bone graft use was performed simultaneously with implant placement, according to the osseodensification protocol proposed by the manufacturer. All implants were placed in a dual-stage manner – completely covered with soft tissue and uncovered 4 months later, at the time of second-stage surgery. The implant stability was determined by measurement of implant stability quotient (ISQ) with instrument that utilizes the method of resonance frequency analysis (RFA) to discover implant stability. The ISQ represents a value on a scale between 0 and 100, with values above 65 indicating high implant stability. ISQ values were measured at two timepoints: At the time of implant placement and at the time of their uncovery. Statistical analysis was performed with Prism 9 statistical program for Mac. The data were analyzed using one-sample t-test, Wilcoxon, and paired two-way ANOVA test. The significance level was set at $p \leq 0.05$.

RESULTS: The differences between the primary implant stability ISQ values in the UD and osseodensification (OD) groups were not statistically significant. The secondary implant stability was statistically significantly higher in the osseodensification group ($p < 0.001$) There were no statistically significant differences between secondary implant stability values in implants placed with and without crestal sinus floor lift within the osseodensification group.

CONCLUSION: Within the limitations of the study, the conclusion is that osseodensification method of implant osteotomy (OD) results in higher secondary implant stability values that the under-drilling method (UD), which has clinical relevance regarding long-term implant survival. It should be a preferred method of choice for osteotomy in areas with clinically low density of bone due to its predictability and effectiveness.

Introduction

The implant stability is a prerequisite for long-term success of dental implants. The stability achieved at the time of implant placement is referred to as primary implant stability and has a mechanical nature. The stability achieved during the functional life of the dental implant – secondary implant stability is of a biological nature since it is achieved through osseointegration and bone remodeling. The primary implant stability prevents the implant micromotions that may disrupt the process of osseointegration and results in non-mineralized bone-implant contact and early implant failure. It is dependent on many factors: Local (implant design, bone quantity and quality, surgical technique) and systemic (diseases affecting bone metabolism, smoking).

The early implant failure is a common clinical problem in the posterior maxilla due to the specific bone structure represented with wide trabecular spaces and thin cortical bone plates. This results in inadequate bone-to-implant contact (BIC) for implant survival, micromovements, and fibrous incapsulation of

the placed implant. Therefore, achieving the sufficient primary implant stability (especially for immediate loading – insertion torque above 35 Ncm) is a challenge. The standard implant bed preparation technique ends with an implant drill which diameter corresponds with the implant diameter. This standard technique has been clinically modified in several ways to achieve better stability.

One of them is the under-drilling technique (UD) whereas another one is the osseodensification technique (OD). With the UD technique, the final osteotomy is smaller than the diameter of the implant to be placed. This underpreparing of the implant site results in better bone-implant contact, better primary stability, and chance for immediate loading. However, the UD method brings certain risk for implant survival. The pressure to the bone may compromise blood supply and lead to the phenomenon known as pressure necrosis. This causes delayed healing of the peri-implant bone and consecutive early implant failure.

In 2017, Huwais S. proposed a unique osteotomy preparation technique for increasing the biomechanical implant stability, bone density, and bone-implant contact, known as osseodensification (OD) [1]. OD achieves this using the viscoelastic characteristics of the alveolar bone to create its plastic deformation. This osteotomy technique utilizes especially designed tapered universal drills that preserve and condense the bone when rotating in counterclockwise direction or cut the bone when rotating in a clockwise direction – Densah® drills (Versah, Jackson, MI, USA). The counter-clockwise rotation is at a speed of 800–1500 rpm [2]. This technique is especially useful for osteotomies in the posterior maxilla, crestal sinus elevations, expansion of narrow bone crests, and immediate implants [3], [4]. The literature suggests that both techniques are equally beneficial for increasing primary implant stability with UD being riskier and less predictable due to the possibility of pressure necrosis. However, it is still not clear which technique results in higher secondary implant stability, which is a biomechanical parameter clinically relevant for long-term implant success due to its biological nature.

Material and Methods

Study design

The authors of this study have no conflicts of interests to declare.

The study was approved by the Ethical Committee for Medical and Dental Research at the Faculty of Dentistry, Ss. Cyril and Methodius University in Skopje, Macedonia.

This study was designed as a prospective randomized comparative clinical study. The previous clinical studies treating this subject had representative samples of at least 20 patients. Therefore, our study included 22 patients randomly allocated to received a total of 37 implants in the posterior maxillary region. Randomization was carried out by a statistician using predefined randomization tables. A balanced random permuted block approach was used to prepare the randomization tables to avoid unequal balance between the two groups taking into account the variables of age, sex, and bone density. Allocation was done by an examiner not involved in the initial patient assessment or to the surgical procedure, who received a concealed envelope for each patient for assignment to either one of the two study groups. The envelope would be opened at the time of surgery.

The patients had to meet certain inclusion criteria: At least 18 years of age, absence of systemic diseases, not smoking more than 10 cigarettes/day, minimal bucco-palatal bone width of 6 mm, minimal vertical soft-tissue thickness of 2 mm, not <5 mm of bone height and implant sites with healed bone (at least 3 months post-extraction) to avoid bone augmentation procedures. The exclusion criteria were alcoholism, heavy smoking, drug abuse, systemic diseases, previous bone regenerative or augmentation procedures, bleeding disorders, compromised immune system, irradiation treatments, and previous or active treatment with steroids or bisphosphonates. The patients underwent radiographic evaluation by use of cone-beam computerized tomography before implant placement for surgical planning.

Before the surgical procedure, the patients signed informed consent for implant placement and the benefits and risk of the surgical procedure were verbally explained to them. All patients were evaluated for their medical and dental history, and oral hygiene habits and were clinically examined. The patients were divided into two groups: In 11 patients, 18 implants were placed using the under-drilling method (UD), while the other eleven patients received nineteen implants using the osseodensification method (OD). Within the OD group, 10 implants in four patients were placed with simultaneous crestal sinus floor elevation, due to inadequate bone height to accommodate implants with at least 8 mm of length. The crestal sinus elevation was not exceeding five millimeters and therefore it was done without bone graft use, according to the protocol proposed by the manufacturer (Versah, Jackson, IL, USA). The implants used for the study were implantswiss bone level (Novodent, Yverdon-les-Bains, Swiss). Each placed implant was with conical connection with hexagonal index, hybrid microgeometry (conical apical and cylindrical coronal shape) and sandblasted, acid-etched surface, without a polished implant neck ring. The shortest implant was with dimension 4.3 mm width and 8 mm length and the longest implant was with 3.7 mm width and 11.5 mm length. Two implants were dropped out of the study due to a lack of osseointegration. Only the participants involved in the study were blinded as whether they will be in the UD or OD group.

The patients were scheduled for monthly post-operative follow-up examinations until the time for the implant uncovery procedure. The primary outcome measure of the study was implant stability determined with the ISQ values, while secondary outcome measures were patient-reported outcome measures (pain, discomfort, and level of difficulty of the surgical procedure) and clinical outcome measures (bleeding on probing, lack of peri-implant infection, and implant mobility). The set null hypothesis was that there is no significant difference in both primary and secondary ISQ measures since both protocols (UD and OD) are effective in achieving implant stability.

Surgical technique

The patients were asked to preoperatively rinse with 0.2% chlorhexidine solution for 1 min. The implant placement procedure was done under infiltrative local anesthesia (articaine with epinephrine 1:100 000). The implants were placed after making midcrestal incision using 15 type blade (Swann Morton, Sheffield, England) blade. Full-thickness surgical flaps were raised and implant osteotomies were done with copious saline irrigation and raising a full–thickness flap. The implants were placed by an experienced surgeon (D.V) utilizing KaVo Intrasurg 300 surgical motor (KaVo, Biberach an der Riss, Germany). The osteotomies were performed at 800 rpm with the use of final drills with one step smaller diameter that the planned implants' diameter (UD group) or with OD drilling burs (OD group) (Figure 1). The insertion of the implants started with the motor handpiece, without irrigation at 50 rpm, and insertion was completed with a manual torque wrench indicator. A total of 10 implants were placed after crestal sinus floor elevation utilizing the OD technique (Figure 2).

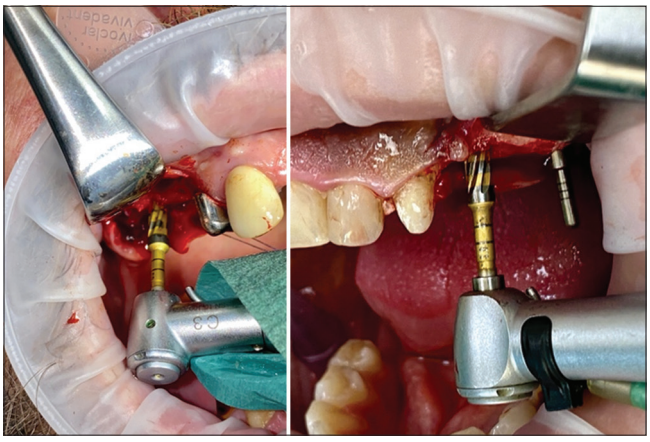

Figure 1: Implant osteotomy

All implants were placed in a dual-stage manner, regardless of their primary implant stability. After the final seating of the implant, a transducer (multipeg) specific for the implant system was utilized for each implant and a resonance frequency analysis (RFA) was performed using a Penguin ISQ device (Integration Diagnostics, Gothenburg, Sweden). The

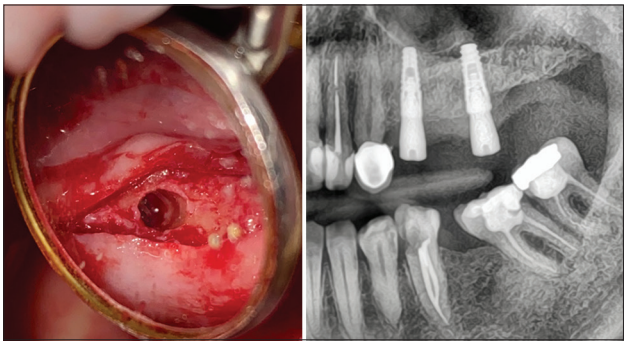

Figure 2: Crestal sinus lift

implant stability measurement was done at two-time points: At the time of surgery and at the time of their uncovery (4 months later). At the time of the second stage surgery, the threshold for connection of healing abutments to the implants was RFA reading of 65 (Figure 3). The surgical field was closed utilizing 5-0 PGLA sutures (Boz Medical, Ankara, Turkey). The sutures were removed 7–10 days postoperatively.

Figure 3: Primary and secondary stability

The patients were instructed to follow a soft diet in the first few post-surgical days after surgery and given complete instructions for oral hygiene. An antibiotic was prescribed (amoxicillin with clavulanic acid 1 – Amoxiclav, Lek, Ljubljana, Slovenia) 2 times daily for 5 days. Additional prescriptions included anti-inflammatory and analgesic drugs. Following the second stage surgery, the implants were restored with fixed partial dentures (Figure 4).

Statistical analysis

The mean and standard deviation values were calculated for each group in each test. The one-sample t-test was used to compare the mean values with hypothetical mean. The Wilcoxon test and two-way ANOVA test were used to compare between the median values of the analyzed groups with hypothetical median. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with Prism 9 statistical program for Mac.

Results

Among all patients examined from May 2023 until October 2023, a total of 37 implants were placed by the same experienced surgeon in 22 patients that

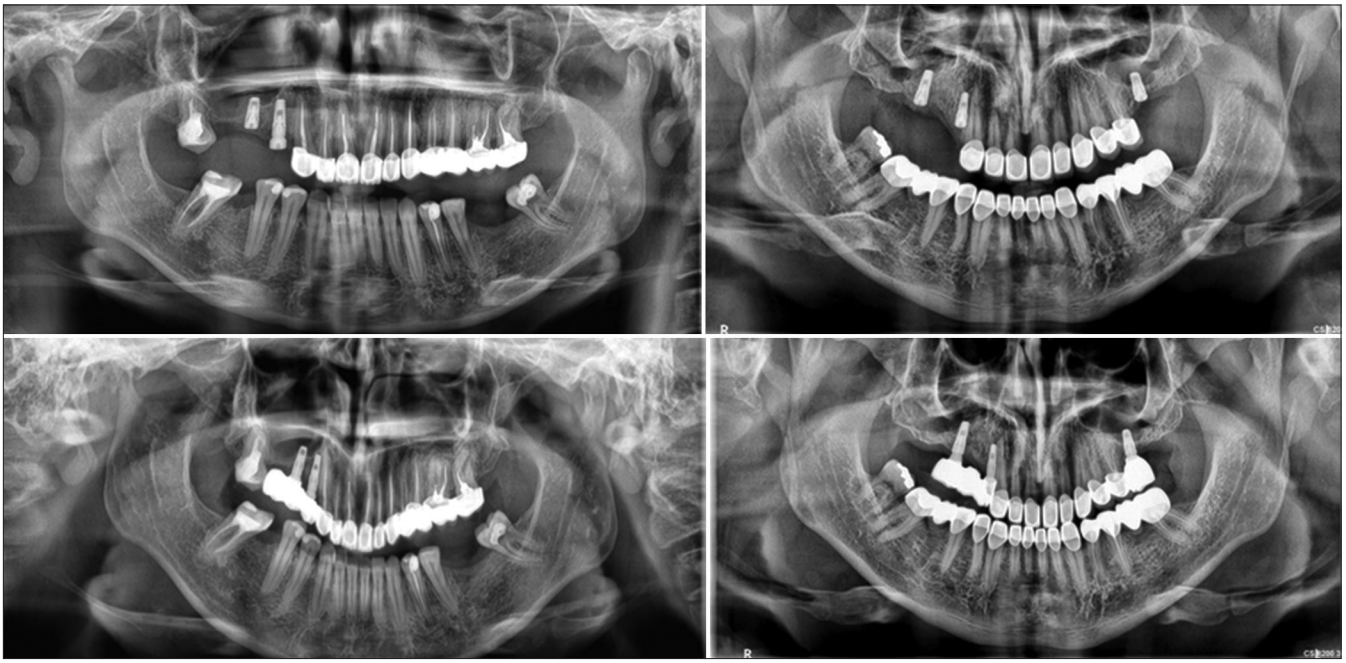

Figure 4: OPG Images

were divided randomly into two groups. Within the study population, 13 (59.1%) were female and 9 (40.9%) were male with mean age of 51 years 51 (±3.5 years – 95% CI). A total of 37 implants were placed by the same experienced surgeon following two different implant placement protocols.

The early implant survival rate was 94,6% since 35 implants were osseointegrated. Except for the two failed implants, the clinical findings demonstrated a successful implant healing process, without signs and symptoms of peri-implant tissue inflammation and/or infection at the time of the second stage – implant reopening phase.

The mean value for primary implant stability and secondary implant stability in UD group was 74,11 (SD 5.72,) and 74.86 (SD 4.87), respectively, whereas the same values in OD group were 73.11(SD 6.23) and 84.00 (SD 2.65).

The differences between the primary implant stability ISQ values in the UD and OD group were not statistically significant (Figure 5). The values of secondary implant stability were significantly higher in the OD group ($p < 0.0001$) (Figure 6). Within the OD group, there were no statistically significant differences in the primary stability values between the implants placed with and without crestal sinus floor elevation (Figure 7). There were no statistically significant differences in the secondary stability values within the OD crestal sinus elevation group (Figure 8).

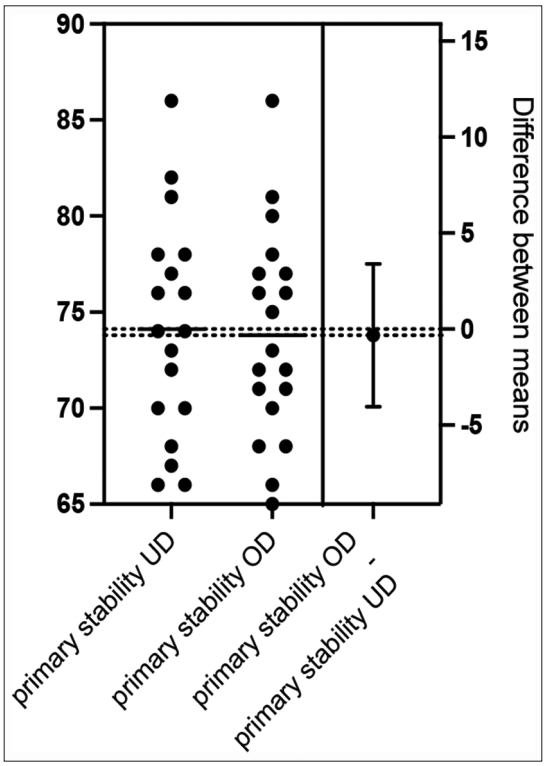

Figure 5: Differences between the primary implant stability ISQ values in the under-drilling and osseodensification group (p = 0.8617)

Discussion

The proper surgical technique for implant placement is crucial for achieving implant stability as an important factor for implant osseointegration, especially in cases with sub-optimal bone quality and quantity [5], [6], [7], [8]. The scientific data suggest that at 2–4 weeks after implantation, a stability dip is generally present [9]. The potential limitations of conventional SD, mostly in terms of inadequate stability, may be avoided by OD drilling protocol an alternative approach. The present data indicates higher biomechanical and histomorphometric parameters

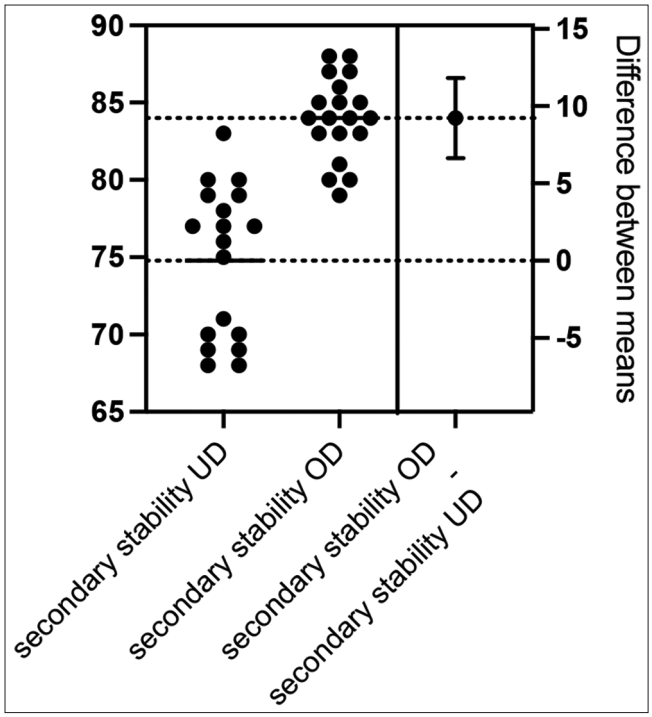

Figure 6: Differences between the secondary implant stability ISQ values in the under-drilling and osseodensification group (p < 0.0001)

for OD versus conventional standard drilling protocols [1], [2], [10], [11], [12], [13].

This clinical study investigated the effect of underling (UD) and osseodensification (OD) on ISQ values at different time points in implants placed in the posterior maxilla. Implant insertion torque (IT) and Implant stability quotient (ISQ) are two clinically accepted parameters to determine implant primary stability. Higher primary IT and ISQ provide stable conversion to the biological secondary implant stability since absence of micromotion enhances osseointegration [14], [15], [16], [17].

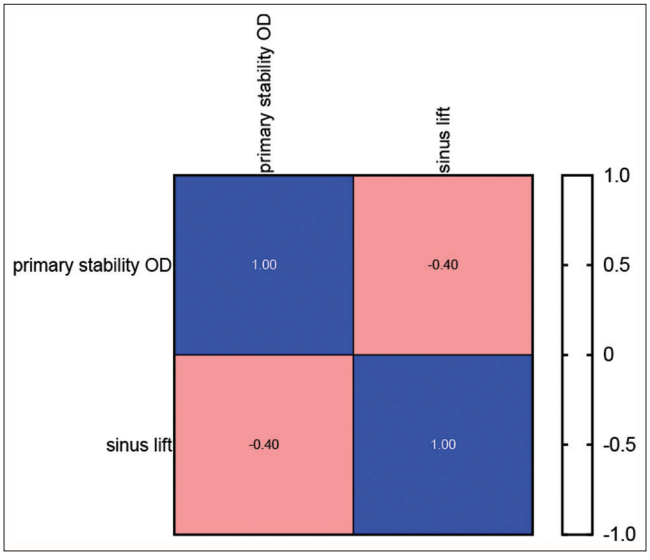

Figure 7: Differences between primary implant stability values in implants placed with and without crestal sinus floor lift with osseodensification (p = 0.93) (p = 0.868)

ISQ is an objective indicator that compares measurements in different time points data analyses demonstrated significantly higher ISQ values at the time of the implant uncovery phase in the OD group. Contrary to this, at the time of implant placement, there was no significant difference in the ISQ values between the UD and OD group. Therefore, the null hypothesis that the implant placement method has no impact on both primary and secondary implant stability was rejected.

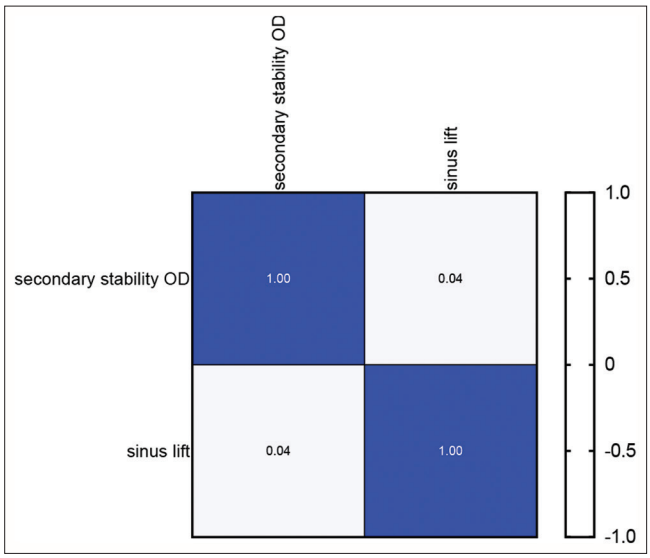

Figure 8: Differences between secondary implant stability values in implants placed with and without crestal sinus floor lift with osseodensification (p = 0.868)

The successful implant site osteotomy bed preparation means implant placement in a correct restoratively-driven 3D position with adequate biomechanical stability by means of progressive series of drills, avoiding overheating and bone tissue necrosis [8]. Under-drilling (UD) of the implant site means omitting of at least the final drill matching the implant width to achieve better stability in bone types with low density [18], [19]. On the other hand, OD drilling not only increases bone-implant contact (BIC) but also improves bone quality through plastic deformation of the bone. Histomorphometric analyses of OD sites in animal models have exhibited bone mineral density increase. The zone of bone density increase was 1 mm circumferentially and apically to the osteotomy wall and resulted from compaction of autograft particles that act as new bone formation nucleating sites and improve osseointegration [1], [2], [10], [11], [12], [13]. This has been enabled by utilizing osteotomy burs which use the elastic and plastic properties of the bone and move bone particles within the osteotomy site instead of removing them [1], [20].

Moreover, this osteotomy method has demonstrated superior sealing of the implant intra-thread spaces due to the reversed compression exerted by the bone spring-back effect. This technique excludes the excessive strain that leads to extensive

bone remodeling and stability dip of under-drilled preparations [1], [2], [10], [11], [12], [13], [21]. The stability dip phenomenon seems to be the reason for lower secondary stability ISQ values in under-drilled implant sites when compared the osseodensified sites. When the implant is inserted in the bone, peri-implant tissue strain occurs as a result of friction between the bone and the external implant surface. This enables the mechanical interlocking needed for primary stability [5], [6], [7], [8]. This tissue strain is even greater in implant sites prepared with the UD method. Bone tissue tolerates certain levels of compressive strain. However, excessive strain, plastic deformation, and the presence of microcracks trigger an extensive interfacial bone remodeling, decrease the initial stability, and negatively affect the osseointegration within the period from primary to secondary stability [5], [6], [7], [8], [22].

The reduction of the ISQ values was significant in the UD group at 4 months postoperatively, whereas within the OD group, ISQ values started high and remained relatively unchanged, above 70, throughout the follow-up period at the same time point. Therefore, it can be concluded that the strain generated for both UD and OD drilling methods may induce different interfacial bone remodeling. The OD technique even at a higher level of physical interlocking provokes no negative bone response [23]. This fact has been associated with elastic reverse compression of the bone toward the implant due to the spring-back effect created by the OD drilling protocol. This may be the main reason for improved secondary implant stability [24], [25].

The osseodensification creates compression and reverse compression between the implant and the bone. This phenomenon is completely different than the undersized that creates “misfit” between the osteotomy and the implant. This clinical situation creates an excessive strain that leads to excessive deformation, microcracking, and remodeling. OD is extremely effective in sites with adequate trabecular bone volume in both the maxilla and the mandible. It enhances both bone mineral density, due to its non-subtractive nature, and implant primary stability, due to the springback effect. These advantages are more significant in the maxilla due to the anatomically higher amount of trabecular bone [26]. Moreover, OD provides high initial stability in the maxilla and stable onset of secondary stability.

However, as any other surgical procedure, it has several limitations and drawbacks. If the surgeon is not following the proposed protocol, the bone response may not be adequate and pressure necrosis may still occur. Furthermore, the sinus membrane is still at risk for perforation while elevating the sinus. OD may only be used in trabecular bone and is contraindicated in compact bone with limited capacity for expansion and condensing ability. The overall conclusion from the literature is that in general, OD demonstrates no negative effect on the remodeling process and is safe to use provided that the surgeon has a certain amount of clinical experience [10], [26].

The continuous change of the implant design (short, wide, and narrow implants) has led to a rapid increase of clinical indications for implant placement and a simultaneous decrease OD treatment time, cost, and post-operative morbidity. The previous studies have shown a direct relationship between primary implant stability and diameter and length of the implant so wider and longer implants were preferable [27], [28], [29].

In this study, ISQ data at 4 months postoperatively, collected from implants with different dimensions – either diameter or length, showed higher values for OD relative to UD regardless of the implant length and width. This conclusion is in line with other clinical studies that point out that shorter implants have similar success rate with longer ones, while avoiding the need for minor horizontal and vertical augmentative procedures [19], [20], [21], [22], [30], [31], [32], [33]. The results from previous studies have shown higher ISQ values for implants with larger diameter, while implant diameters lower than 4.2 mm showed no significant effect on the stabilization improvement in tapered implants [34], [35]. However, the wider diameter implants placed in undersized osteotomy site caused a greater amount of bone remodeling than in implants with standard and narrow diameter placed with standard drilling protocols. The wider the osteotomy means more extracted bone and greater strain level at the implant-osteotomy interface, which seems to be the reason for bone healing with resorption [8], [22], [35].

On the other hand, OD preserves the bone bulk and produces higher implant stability due to the springback effect thus eliminating the need for undersized osteotomies [36], [37], [38].

Conclusion

Within the limitation of the sample size of this study, the conclusion is that the osseodensification method (OD) for implant osteotomy results in significantly higher secondary implant stability values that the under-drilling method (UD). This has clinical relevance regarding long-term implant survival, and therefore, the OD technique should be preferred method of choice for osteotomy in areas with low density of bone. Moreover, it positively affects the patient-reported outcomes since OD technique shortens the overall treatment time and offers predictable and effective results of the implant therapy.

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