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A novel approach for underpreparation protocol in dental implant with low bone quality depending on hounsfield unit presurgically

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Abstract---*Objective:* The purpose of this research was to adapt a normal or undersized implant preparation protocol for different bone densities depending on the density measure (Implant stability quotient ISQ, Newton centimeter NCM) and from Cone Beam Computed Tomography reading pre-surgically. To eliminate the need for practice and experience in inserting implants in poor bone quality areas to enhance implant primary stability and survival rate. *Material and methods:* Fifty-nine patients were selected for inclusion in the study. A total of fifty-nine implants were placed. Insertion torque data were recorded, resonance frequency analysis measurements were taken at first stage surgery, and Hounsfield Unit HU was assessed before surgery and kept hidden to prevent bias. The implant preparation protocol divided the patients into two groups whether standard or undersized, which was determined according to the tactile sensation of the operator. Depending on primary stability measures (ISQ, NCM) samples were divided into 4 subgroups. Finally, HU measurements were taken from subgroups with high stability measures to assess whether to do a standard or underprepared surgical preparation. Result: the result showed a positive and strong correlation with a high significance between ISQ, HU, and insertion torque. So, practitioners can depend on HU to assess the surgical protocol. Furthermore, whenever we get a HU of 528.5 +/- 26.5 and below we should obtain an under-preparation protocol and vice versa. Conclusion: The placement of implants by an adapted drilling technique in sites with poor bone density is beneficial in enhancing primary implant stability. The HU is positively and significantly correlated with Implant stability quotient and insertion torque. There

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is a high recommendation to utilize the HU as a dependent and novel determinant to select a specific protocol for preparation as undersizing is recommended in bone with a HU of less than 528.5 +/- 26.5.

***Keywords*---**CBCT, Dental Implant, HU, Primary Stability, Undersized Preparation.

Introduction

Dental implantology has been one of the most extensively utilized therapy choices for edentulous individuals in recent decades. Dental implants act as artificial roots in the jawbones, supporting different fixed and removable (partial) dentures mechanically. As a result, their well-established mechanical stability serves as the biological foundation for their effective use in everyday life. Adequate primary stability must be obtained, which creates an essential mechanical microclimate for osseointegration, or the progressive establishment of bone repair. (Parithimarkalaignan & Padmanabhan, 2013)

According to clinical evidence, dental implants for the mandible have a greater success rate than those for the maxilla, particularly in the posterior maxilla. When compared to the mandible (Friberg & Jemt, 2008). Bone quality, according to most clinicians, is the fundamental source of the variation in survival rates between the maxilla and the mandible. Implants having a low degree of bone mineralization or minimal bone stiffness, as determined by tactile evaluation while drilling, appear to have a higher failure rate. The mandible often has more and higher quality bone around the implant than the maxilla. (Turkyilmaz et al., 2007)

Because the mechanical behavior of bone appears to be an important aspect of osseointegration, numerous categorization systems and methodologies for measuring bone quality have been proposed. (Trisi & Rao, 1999) The most widely used contemporary technique of assessing bone quality is that proposed by Lekholm and Zarb, who presented a scale of 1 - 4 based on both radiographic examination and the surgeon's sense of resistance when preparing the implant site. (Adell, 1985) The grade is based on personal experience, and it only offers a general average value for the entire jaw. As a result of their lack of impartiality and repeatability, their categorization has lately been put into doubt. (Todisco & Trisi, 2005)

Dental implant manufacturers recommend adaptation of surgical protocol for standard bone quality and consider bone as on quality with different cortex thickness (preparation with or without countersinking), and we need to adopt a protocol for optimizing primary stability for various bone quality. (Karl & Grobecker-Karl, 2018)

Primary stability, which is one of the key variables impacting implant survival rates, is influenced by several factors such as implant shape, preparation method, and the quality and amount of local bone. (N Meredith, 1998)

Implant stability can be assessed by clinical diagnostic procedures (i.e., insertion torque, resonance frequency analysis). (Degidi et al., 2010) The insertion torque described by Johansson and Strid is one of these quantitative approaches. (P Johansson, 1994) This approach records the amount of force necessary to insert the implant and offers useful information on the quality of the local bone. Torque is a measurement of the rotational friction between the implant surface and the bone, as well as the force required to cut the bone if necessary and the pressure force from the surrounding bone; however, torque does not always correspond to implant stability. (Bardyn et al., 2010)

The stiffness of the bone/implant interface is determined using resonance frequency analysis (RFA) as a reaction to oscillations applied to the implant/bone system. An oscillating transducer is put onto the implant and used to stimulate it. Over a frequency range of 5 to 15 kHz, the resonance peculiar to the resonance system 'implant/bone' is collected electrically. The implant's own oscillation at a certain transducer frequency is mostly determined by the implant's bone fixation. The implant stability quotient (ISQ) is the unit of measurement in this technique, which is determined from the resonance frequency and ranges from 0 to 100 units as the interface stiffness increases. (Meredith et al., 1996)

Computed tomography (CT), which is more objective and dependable in assessing bone quality, may be the most appropriate radiographic approach for morphological and qualitative characterization of residual bone. Several researches have employed this imaging approach. (Beer et al., 2003) The software systems in the CT equipment determine the Hounsfield units. The absolute and quantitative density of structures within the picture can be utilized to distinguish tissues in the area. (Randolph Resnik, 2020)

The preparation of the bone for the reception of an oral implant should allow for intimate contact between the bone and the implant surface. The goal of implant placement is to drill a hole in the bone into which the implant will be inserted such that the implant and bone surfaces are tightly apposed. (Alghamdi et al., 2011)

When it comes to dental implant placement, using a bone site preparation procedure might result in the greatest primary implant stability. Indeed, excellent primary stability allows for lower micromotions between the implant and the bone, allowing for ideal implant osseointegration conditions; on the other hand, poor primary stability levels can lead to fibrointegration and early implant failure. (LEKHOLM U., 1985)

The appropriate decision might improve primary stability, especially in low-density bone. To improve bone density and, as a result, implant stability, Friberg et al. suggested using undersized drilling (a drill with a smaller diameter than the implant). (Friberg et al., 2001) Evidence on biomechanical, biological, and clinical outcomes of undersized surgical preparation protocols in dental implant surgery was discussed in a recent systematic review and many researches, and it was concluded that an undersized drilling protocol is effective in increasing insertion torque in low-density bone from a biomechanical standpoint. (Stocchero et al., 2016) In terms of biological response, long-term healing following undersized implant insertion is comparable to that seen after non-undersized surgical drilling. So, drilling low-density bone with an undersized drill is a clinically safe technique. (Trisi & Rao, 1999) Indeed, it is widely recognized that the undersized surgical method not only provides greater primary implant stability but also creates more translocated bone particles, influencing the osteogenic response positively. (Tabassum et al., 2010) In animal trials, using an adaptive surgical technique that undersizes the implant bed preparation in weak bone areas resulted in higher osseointegration and implant durability. (Al-Marshood et al., 2011a; Shalabi et al., 2007; Tabassum et al., 2009)

The decision for undersizing till now depends on clinical predicting the quality of bone in a specific site, tactile sensation, and experience of the surgeon. Therefore, till now, there is no protocol regarding the use of undersizing. The purpose of this research was to adapt a normal or undersized implant preparation protocol for different bone densities depending on the density measure (ISQ, Ncm) and from CBCT reading pre-surgically so that we eliminate the need for practice and experience in inserting implants in poor bone quality areas to enhance implant primary stability and survival rate.

Methods

Study Design

Effectiveness comparison clinical trail

Study Setting

All the clinical investigations are done in the oral surgery department \ College of the Dentistry \ University of Sulaimani, and a private clinic (Harmony Dental Center). The radiographical and laboratory investigations were done in a private center by a specialist.

Study Period

The study was carried out for six months, from September 2021 to February 2022.

Patients' Selection

Fifty-nine patients of different ages were recruited for the study; all the patients were with edentulous ridge potential for implant insertion and were randomly enrolled for inclusion in this study (from the postgraduate department in the College of Dentistry / University of Sulaimani). All were prepared to have a total of fifty-nine implants placed. In different maxillary and mandibular edentulous sites. Also, they were treated in the maxillofacial surgery department. The patient information sheets and consent form enclosed are a routine protocol for every patient automatically taken before any treatment.

Inclusion and exclusion criteria

Inclusion: Adult patients of different age ranges (18-65) and different jawedentulous sites, the potential for implant insertion.

Exclusion: Children and adolescent, patients with any systemic disease, patients with a history of chemotherapy or radiotherapy, pregnant or lactating ladies, smokers, patients taking medication that affect the bone density, and patients who necessitated bone graft, or alloplastic augmentation, or sinus lift surgery.

Method

Patients who enrolled in the study had their data analyzed and CBCT (Acteon, xmind trium, France/ 2017) was done for different jaw potential implant sites of all patients to assess anatomy, bone width, height, relative vital structures and bone density which was measured by the Hounsfield unit (HU) and kept hidden for blindness. Root from the two-piece implant (Neobiotech, IS2 Active Line / South Korea) was inserted by one operator. The site preparation adopts normal or undersized depending on the density of the bone according to the tactile sensation of the operator, while HU data is kept hidden for the operator to prevent bias when radiographical density data is present. Implant dimensions were used in this study (4 mm in diameter and 10 mm in length) for a more reliable outcome. The maximum implant insertion torque data was recorded at the time of the insertion with the torque wrench and by using a resonance frequency analysis (RFA) device (Osstell, Beacon, Sweden / 2021). The correlation, including Hounsfield unit (HU), torque (Ncm), and resonance frequency analysis (ISQ), were evaluated in two main groups:

1- First group: includes all the patients that the operator used regular drilling preparation of implant site with no modification
2- Second group: in which the operator follows the drilling protocol or under-sizing the preparation site, which involves a thinner last drill preparation of the implant site.

Dental implant treatment was provided, and all the procedures were under the observation of my supervisor (expert authorized maxillofacial surgeon) at The College of the Dentistry /University of Sulaimani.

Result

Demography

Fifty-nine patient who needed a dental implant restoration was enrolled in this research. 28 patients were males, and 31 patients were females. The age ranges from 18 years to 65 years, with a mean age of 45 years. The jaw location for implants was evenly distributed between jaws.
30 implants in the mandible, 7 of them in the anterior area and 23 in the posterior region. 29 implants in the maxilla, 5 in the anterior region, and 24 posteriorly.

Data Analysis and Classification

There is a 59-implant placed under different preparation protocols and conditions, by depending on tactile sensation during implant drilling, we get 2 groups. **Group A** has 33 cases with standard preparation surgical techniques; Group **B** includes 26 cases with undersize preparation techniques.
Immediately after the implant insertion analysis of primary stability is done by ISQ measurements using Osstell were dependent in all implants for both groups

A and B. the aim of any preparation was to get good primary stability which is equal to 65 ISQ as an optimum measurement.
According to the results of stability analyzed by RFA for each implant, the samples were divided into 4 groups of data depending on preparation protocol, whether doing undersize drill skipping or not, and on the resonance frequency analysis as we get a good ISQ stability reading or not. The **Group1** (under preparation – ISQ>=65) has a 39% of cases, **Group2** (under preparation – ISQ<65) has a 5.1% percentage, **Group3** (standard preparation – ISQ<65) has a 13.6% percentage and **Group4** (normal preparation – ISQ>=65) has a 42.4% of cases.
We analyze and classify the data by hierarchical clustering (Figure 1) and Tow Step Cluster, as shown in (Figure 2).

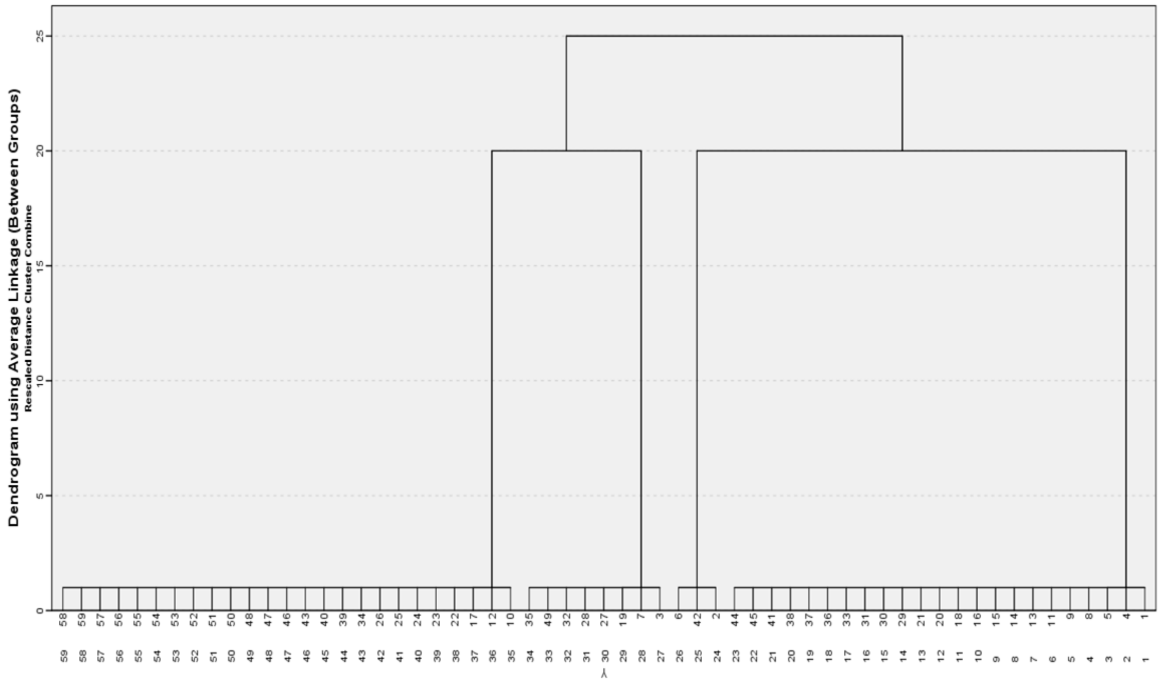

Figure 1: Hierarchical dendrogram classifies samples according to ISQ and preparation protocol

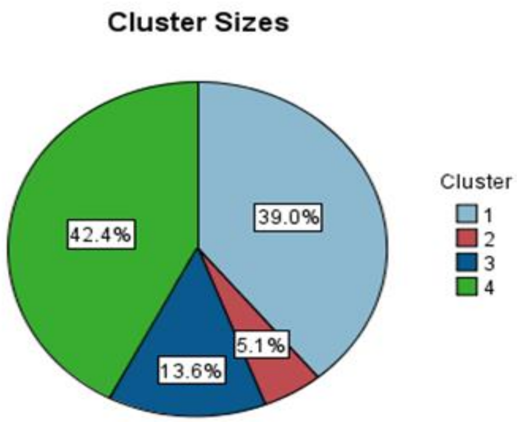

Figure 2: Two Step Cluster proportional classification. (1): Underpreparation-ISQ>=65, (2): Normal preparation-ISQ<65, (3): Underpreparation-ISQ<65, (4): Normal preparation-ISQ>=65.

HU Analysis

HU Comprehensiveness

It's an effective way to ensure that analytical models are reliable and produce an accurate result, sample size diversity in patients, and ranged HU measurements. The stability of the analysis of HU measurement can be seen In Table (1) and (Figure 3)

Table 1: Bootstrapping for the confidence level of HU

Bootstrap*						
HU					95% Confidence Interval	
		Statistic	Bias	Std. Error	Lower	Upper
N†	Valid	59	0	0		
	Missing	0	0	0		
Mean		522.37	-0.34	33.43	455.99	587.23
Median		488.00‡	-5.37	41.16	397.34	577.31
Mode		885				
Std. Deviation		257.965	-2.500	17.876	217.173	289.821
Skewness		0.288	0.006	0.192	-0.087	0.675
Std. Error of Skewness		0.311				
Kurtosis		-0.868	0.034	0.303	-1.306	-0.084
Std. Error of Kurtosis		0.613				

* Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples
† number of cases.
‡ Calculated from grouped data.

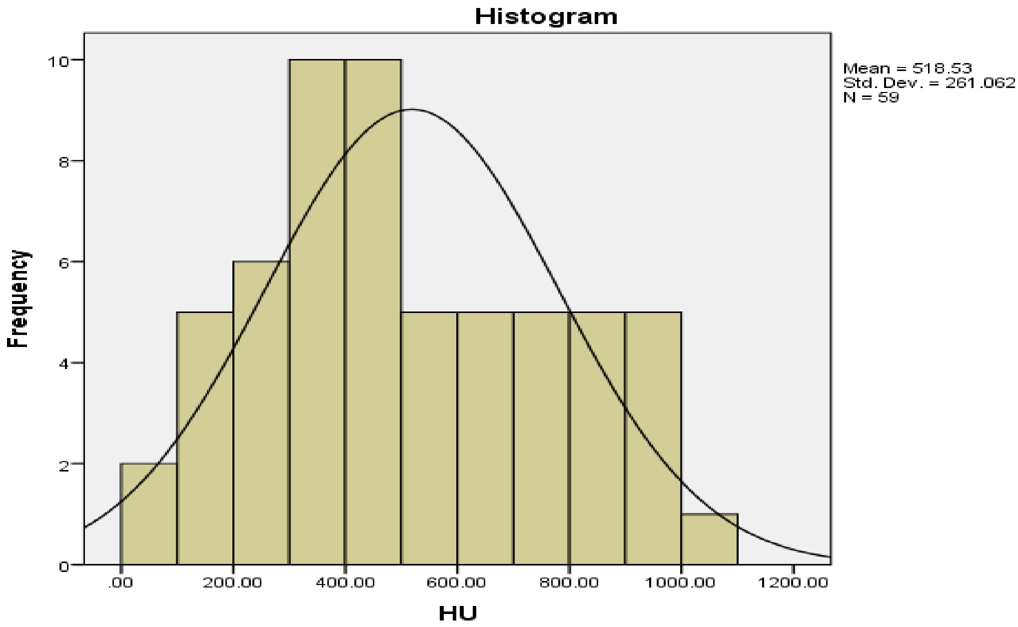

Figure 3: Bootstrap histogram for HU measurements

The mean statistics of bootstrapping HU is 522.37, which is a very accurate value lying between the upper limit interval 587.23 and lower limit interval 455.99, which gives a 95% confidence. It's also similar in standard deviation 257.965, skewness 0.288 (fairly symmetrical value) about 0 skewness, and kurtosis -0.868, which all have a high level of confidence.

Drilling Protocol in Relation to HU

We will depend on the g1 and g2 clusters to get the optimal HU measure because they both have a high ISQ reading, a filtration to g1 to get the maximum HU reading (502), also the same for g4 to get the minimum HU reading (555). By calculating the mean between these readings (528.5), and the standard deviation (26.5), so we get the readings that we should depend on it when doing under preparation or not in the future. Finally, whenever we get a HU of 528.5 +/- 26.5 and below, we should obtain an under-preparation protocol and vice versa.

HU Across Jaws

The mean of the Hounsfield unit according to jaw location shows normal data, as in anterior mandible is 869, which is D2 bone, HU in the posterior mandible is 643.391 and 498.6 in anterior maxilla considered as D3 bone and 310.25 in posterior maxilla (D4). As seen in Table 2.

Table 2: HU mean across

HU[§] Across jaws		
Location	**Mean HU**	**Classification**
LA[**]	869	D2
LP[††]	643.391	D3
UA[‡‡]	498.6	D3
UP[§§]	310.25	D4

Correlation between HU, torque and RFA

bivariate comparison to correlate between all variables by spearman rho is shown in Table (3). The correlation will be explained in the matter of research concern. We can measure this type of relation depending on the relationship, strength (proximity to 1), and significance. HU analysis shows it positively correlates with ISQ cc= 0.583 and torque cc= 0.332, with high significance for both values.

Table 3: bivariate comparison to correlate between

Correlations				
Spearman		**[***]HU**	**NCM[†††]**	**ISQ[‡‡‡]**
HU	**Correlation coefficient**	**1.000**	**0.332**	**0.582**
	Sig.[§§§]		**0.00001**	**0.000001**
	N	**59**	**59**	**59**

Discussion

Achieving Successful osseointegration has an important influence on the predictable long-term outcome of dental implant restorations. Although primary implant stability and osseointegration can be predictably achieved in dense bone, it is often challenging to achieve the same in areas with poor bone density. Many studies have demonstrated that initial implant stability is determined by the bone density, the surgical technique used, and the implant design. (Abrahamsson et al., 2009) Therefore, many investigators have attempted to determine the utility of modified surgical protocols for implant placement in low-density bone.(Al-Marshood et al., 2011b)

In the current study, the sample size diversity in patients and ranged HU measurements was comprehensive, with a high confidence level of 95% (Table 1). So, no further studies to increase the patient number are needed. So, in the

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[§] Hounsfield Unit
[**] Lower anterior
[††] Lower posterior
[‡‡] Upper anterior
[§§] Upper posterior
[***] Hounsfield Unit
[†††] Newton per centimeter
[‡‡‡] Implant stability quotient
[§§§] P=0.001

current study, the intraoperative assessment of the bone quality was dependent totally on the tactile sensation. To evaluate the success of the skipping maneuver, which was influenced by the tactile evaluation of the bone density, the patients were clustered into 4 subgroups (Fig. 1and2)

G1 group: is an under-preparation protocol with ISQ>=65 accounting for 39%.

G2: is an under-preparation protocol with ISQ<65 accounting for 5.1%.

G3: is a normal-preparation protocol with ISQ<65 accounting for 13.6%.

G4: is a normal-preparation protocol with ISQ>=65 accounting for 42.4%.

Reliability of Hounsfield Unit

The bone classification proposed by Lekholm and Zarb is now commonly used. However, this classification has its limitations in objectivity and reproducibility. In order to overcome the limitations of this classification, the evaluation of bone density using CT has been presented in several previous studies as an objective and reliable method. The mean bone density value of the posterior maxillary region reported by Fuster et-al (Fuster-Torres et al., 2011) was 464 HU for 25 implant sites, while Norton et-al (Norton & Gamble, 2001) reported the mean bone density in 27 maxillary implant sites to be 417 HU, in this study the posterior maxilla mean bone density was 310.25 HU which is similar to other researches result. The anterior maxillary region HU is 498.6. Also, a similar result was reported by FUH LJ el-al (FUH et al., 2010) The posterior mandibular area HU is 643, which is similar to the result of Turkyilma et-al (Turkyilmaz & McGlumphy, 2008) 698. At last, the anterior mandible density is 869, similar to the Shapurian et-al (Shapurian et al., 2006) study (Table 2).

Based on the results of this study, there were statistically significant correlations between HU and the parameters of primary stability (IT and RFA); the same results approximately were reported by Isoda K et-al. (Isoda et al., 2012) These results were also found in our study. It can be concluded that GSVs from CBCT can be used to derive the HU required to determine the exact bone quality in that region of the jaw so that we can directly obtain the final HU from GSVs by calculation within the CBCT software. This can be incorporated into the CBCT software for implant planning and placement.

Adapted Preparation Method

In the present study, an adapted surgical drilling method was used to prepare the implant bed to enhance the primary stability in low-bone-density areas (by skipping one drill size when sensing low-quality bone tactilely). The observations of the present study suggest that using undersized bone drilling for implant placement in low HU measurement, where the bone density is relatively low, might be a viable option to increase primary implant stability, which is crucial in implant survival rates. (Calandriello et al., 2003) The quantitative measurements of primary stability are the measurement of insertion torque as an invasive, single-use technique and non-invasive RFA by Osstell.

In the present study, one operator did the implantation depending on tactile sensation to assess bone quality without knowing the HU readings to prevent bias. Undersized bone drilling was performed with 3-mm twist drills to place 4-

mm diameter and 10-mm length implants; high RFA >65 was gotten in these cases. Afterword HU data is prepared for correlation, we find that HU is an accurate reading to assess the density of bone, and it's a dependable value whether to do under preparation or not.

The initial implant insertion torque and ISQ values can be considered an indicator. Implant stiffness means a greater bone-to-implant contact percentage, explaining the better prognosis. The design of the implants used also might have helped in obtaining good primary stability because of the unique features. So, depending on this study, in the future, we will take CBCT and count the HU for the patient. If it is 528.5 +/- 26.5 or below, we will do underpreparation, and if it's more, we will adapt the manufacturer protocol.

Alghamdi et al. in a clinical study, compared implant stability by measuring the IT and ISQ for two types of drilling techniques. Although these values were not statistically significant, a tendency of increasing implant stability on the low-density bone with this under-sizing drilling technique was observed. (Alghamdi et al., 2011) Results similar to those were found in the present work. Bilhan et al. showed results similar to those found in this study, showing statistically significantly higher **IT** values with underpreparation, while the **RFA** values were not statistically significantly different but tended to be higher. The authors concluded that the underpreparation drilling technique enhances the primary implant stability, especially when the implants are inserted in low-density bone types (III and IV). (Bilhan et al., 2010)

Best Stability Measure

The bone in the posterior maxilla is of poor density, and earlier reports have advocated the use of undersizing surgical techniques in the placement of oral implants in the posterior maxilla. The ISQ reading is considered a reliable noninvasive indicator to assess the implant stability, better than insertion torque because it measures the BIC, as we find in this study that ISQ is strongly related to insertion torque with a p-value: of 0.004 (Table 3). As like in torque, when there is an increase in cortex thickness, there will be an increase in torque. but it's not related together in the matter of ISQ regarding cortex thickness. (Nkenke et al., 2003) a human cadaver study found that resonance frequency analysis values did correlate with the surface of bone-to-implant contact.

Double Drill Size Undersizing

Very low HU measurement may find especially in type 5 bone that indicates to do double undersizing because of soft, low-quality bone. Like in the G2 group, we found that the mean of HU is 96. Even if undersize preparation was perfomed, there are still low primary stability measures ISQ: 52 and torque: 15. So, we can skip by 2 size drills about 1.5 mm with respect to cortex thickness to get a satisfying primary stability measure and osteointegration. (Friberg et al., n.d.) used a final implant bed diameter of 3 mm to insert 5-mm diameter implants in a maxillary site with poor texture. This technique needs more studies and large sample size.

Cortex Effect

Cortex has dense bone quality with more stiffness that cannot be compressed like a trabecular bone which may affect the primary stability upon increasing thickness. So, in some cases we get a high insertion torque, but the ISQ measure was not as high as torque that's because of cortex thickness, which increased the insertion torque but still needs more BIC to get a good RFA reading. Furthermore, in this group, we didn't do undersizing because of hard bone sensed tacitly at the crest, but there is a low-quality trabecular bone that needs compaction.

Conclusion

- It is important for the clinician to have adequate information about the bone quality of the prospective implantation site. It can be concluded that CT-derived HU is significantly correlated to the parameters of primary stability. If the HU value is evaluated preoperatively to allow objective assessment of bone quality, a modification to a more appropriate surgical plan (underpreparation) to get good primary stability, especially in sites of poor bone quality (<528.5 HU).
- The placement of implants by an adapted drilling technique in sites with poor bone density is beneficial in enhancing primary implant stability and improving the implant survival rate.
- HU is positively and significantly correlated with stability ISQ and insertion torque.
- When we have a D4 bone, a double skipping of osteotomy drill is recommended.
- Caution should be taken when adapting an underpreparation surgical protocol to high cortex thickness because it may fracture the implant threads or crestal resorption by pressure necrosis will take place.

The last two points need further research.

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