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EVALUATION OF INSERTION TORQUE AND INITIAL STABILITY OF SINGLE THREAD IMPLANTS VERSUS DOUBLE AND TRIPLE THREAD IMPLANTS: AN ANIMAL STUDY

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ABSTRACT

Aim: This study aimed to evaluate the insertion torque and initial stability of single thread implants versus double and triple thread implants.

Methods: Forty-two osteotomies were prepared in fresh bovine bone. The implants used in this study were 3 types according to the thread lead design: single thread implant, double and triple thread implants (n=14). Implants were inserted in bone blocks until reaching insertion torques (30 Ncm, 40Ncm and 50Ncm) then calibration of the part of implant inserted within bone was conducted. Osstell ISQ device was used for resonance frequency analysis to assess the primary stability. The removal torque of each implant is measured at torque 50N/cm. intergroup and intragroup comparisons were performed. The p value was set to $p \leq 0.05$ for all tests.

Results: Regarding, implant insertion torque the highest value was found in single thread group followed by double thread group, while the lowest value was found in triple thread group. Primary stability results and removal torque revealed that, the highest value was found in triple thread group, followed by double thread group, while the lowest value was found in single thread group and a significant difference was found between different groups ($p<0.001$) in all measured outcomes.

Conclusions: When primary stability is a concern, as in low bone quality, double and triple threaded implants can provide greater primary stability and insertion torque. Double threaded implants combine optimum insertion speed and high primary stability and insertion torque in compromised situations.

KEYWORDS: insertion torque, primary stability, removal torque, single thread implant, double thread implant, triple thread implant, implant design, resonance frequency analysis, osstell device.

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INTRODUCTION

The aim of dental treatment is to gain total or partial replacement of the damaged/diseased tooth structure restoring function and esthetics. Many methods are available for this purpose, one of them is the implants which became popular recently. ***(Manikyamba et al., 2020)***. Osseointegration is the biological process where bone and the surface of implant show structural connection under functional load, which is considered as the parameter of clinical of dental implants ***(Falisi et al., 2017)***. ***Rosa et al., (2012)***, established 6 factors affecting reliability of osseointegration, which are: material of the implant, its design, surface quality, surgical technique, bone status and loading conditions.

A variety of designs for body of the implant are presently available such as screw, press fit, cylinder or a collection of them. Cylinder and press fit implants are inserted by friction fit with a less risk of pressure necrosis cause by high pressure during insertion. Bone tap is not needed (even in case of dense bone). Rotational force is not needed to insert the implant, so the cover screw stays steady in place. That's why press fit, and cylinder designs were very popular in the 1980s having high initial success rates. However, 5 years post-loading, loss of crestal bone and subsequent implant failure had been reported with cylindrical implants due to fatigue stress and heavy shear forces on the bone requiring high turnover resulting in decreased bone-implant contact and elevating the risk of failure due to overload ***(Manikyamba et al., 2020)***.

Threads are added for maximizing initial contact, enhance primary stability and insertion torque, increase surface area of implant, and for increasing stress distribution on the interfacial surface ***(Yadav et al., 2016)***. At the bone interface, the threaded body design of implants converts complex occlusal loads into favorable compressive load at the bone interface ***(Manikyamba et al., 2020)***.

Bolind et al., (2005) used 85-cylinder implants and 85 threaded (machined) implants recovered from humans in their study, which ended up that threaded implants had a higher bone-implant contact (BIC) and cylinder implants had a higher marginal bone loss. Threaded implants may theoretically improve initial implant stability and long-term survival by reducing bone stress and implant bone sliding distance.

The distance between pre and post single complete rotation in the axial direction within the same thread is known as lead. Lead rises by one, two, and three times the pitch on single, double, and triple threaded implants, respectively. Functional surface area per unit length modification of the implant can be done by control of several geometric thread parameters as: thread lead, depth, pitch, and shape ***(Manikyamba et al., 2020)***.

Lead highly affects determining the speed of implant insertion, as It shows how far an implant can go after a single turn. Thread lead is inversely proportional to the number of revolutions required to insert an implant. As the lead of the thread lengthens. As the thread lead grows, the helix angle of the thread grows as well, potentially affecting the forces transmitted to the bone. ***(Ormianer et al., 2016).***

Thus, many operators assume that using double and triple threaded implants can positively affect the speed and stability of insertion. So, for immediate loading of an implant, double- and triple-threaded implants are used, and the increased surface area provides greater primary stability. However, till now, there's no sufficient data to confirm these findings. ***(Yamaguchi et al., 2020).***

Thus, the aim of the current study is to assess the insertion torque and initial stability of single threaded implants versus double and triple threaded implants.

MATERIALS AND METHODS

The following materials were used in this study:

Single Threaded Implants

The first group was Single Threaded Prototype Implants *(Dual Implant Company, Titan Industries, Egypt)*. They were made from Grade 5 eli titanium rods with an external diameter of 4.1 mm and a total length of 12 mm and fabricated using Swiss type lathe star SR-20JII *(Star Micronics GB Ltd©)*.

Double Threaded Implants

The second group was Double Threaded Prototype Implants *(Dual Implant Company, Titan Industries, Egypt)* which also were made from Grade 5 eli titanium rods with an external diameter of 4.1 mm and a total length of 12 mm and fabricated using Swiss type lathe star SR-20JII *(Star Micronics GB Ltd©)*.

Triple Threaded Implants

The third group was Triple Threaded Prototype Implants *(Dual Implant Company, Titan Industries, Egypt)* which also were made from Grade 5 eli titanium rods with an external diameter of 4.1 mm and a total length of 12 mm and fabricated using Swiss type lathe star SR-20JII *(Star Micronics GB Ltd©)*. The only difference between the groups was the lead design.

Materials used in the current study was listed in **Table (1).**

Sample size calculation

Following the results of ***(González-Serrano et al. 2017)*** in which the (mean± standard deviation) value for the first group was (61.55±6.67) and for the other groups was (68.94±5.82)- and supposing an (α) level of 0.05 (5%), a (β) level of 0.20 (20%) i.e., power=80%, and an effect size (f) of (0.54); The estimated sample size (n) was a total of (36) samples i.e. (12) for each group. (20%) increase in sample size was considered to permit missing data with a total of (42) samples i.e. (14) for each group. G*Power version 3.1.9.2. was used to perform sample size calculation.

Grouping of implants

The implants were grouped to 3 main groups according to the thread lead design 14 for each, either: Single thread implant (S), Double thread implants (D) or Triple thread implants (T). For each implant, 3 different insertion torque were examined (IT); 30 Ncm (IT1), 40 Ncm (IT2), and 50 Ncm (IT3).

Description of study samples

The study was conducted on blocks of fresh bovine bone samples after the approval of (CU-IA-CUC) Institutional Animal Care and Use Committee, Cairo University with approval number (CU III -F -C- 8 -19). Fourteen (14) blocks were prepared to the following dimensions (7 cm length, 5 cm height and 2-3 cm width). The bone blocks were embedded in dental plaster for stabilization. The samples were cleaned and have been frozen till use.

TABLE (1): Thread type, pitch, lead, depth, total thread length and manufacturer:

Thread type	Pitch (mm)	Lead (mm)	Depth (mm)	Total thread length (mm)	Manufacturer
SingleThreaded Implants	0.6	0.6	0.35	12	Dual Implant Company, Titan Industries, Egypt
Double Threaded Implants	0.6	1.2	0.35	12	
Triple Threaded Implants	0.6	1.8	0.35	12	

Intervention for each group

The blocks were marked with permanent marker in the potential implant placements area for the study. A total of 42 implants were used for this study. For the control group fourteen single thread implants were inserted. While for the intervention group fourteen double and fourteen triple thread implants were inserted.

Implant's placement

Forty-twoosteotomies were prepared in the bovine bone specimens. A single operator placed all of the implants into the bovine bone blocks individually. The drilling was performed with a Surgical Electric Motor Woodpecker Implant-X© *(Woodpecker, China)*, adjusted to a torque of 50 N and 1300 rpm. For standardization, drilling was done according to the manufacturer's instructions for each osteotomy. The sequence of drills was as following: 2.2mm, 2.8mm, 3.4mm, and 3.8mm.

Implant from each group is inserted in each bone block at insertion torque pre-adjusted manually with a torque wrench *(Multi-Setting Torque wrench with a 4X4 square connection, implant direct TM, USA)*. The implants were inserted until reaching different insertion torques 30 Ncm, 40Ncm, and 50Ncm. A torque wrench was then used to record insertion torque during implant placement in the block till implant flushing with the bone.

Outcomes

Length of implant inserted within bone at different insertion torques

First, each implant from each group was inserted at torque 30 Ncm then measuring of the part of implant inserted within bone was done by calibrating the part of implant outside the bone using a digital precise caliper *(Ruifeng Foreign, China)* and subtracting the measurement from whole implant length 12 mm. The same steps were done at torque 40 Ncm and at torque 50 Ncm.

Insertion torque until implant flushes with bone

The implants inserted until flushe with bone and the insertion torque was recorded from the torque wrench.

Primary stability

Evaluating implant primary stability was done by Osstell ISQ device *(Osstell, Integration Diagnostic, Göteborg, Sweden)* which measure the (RFA) resonance frequency values. The implant is deflected on the transducer (smart peg) by a piezoelectric effect, which was adapted directly over the implant and was stimulated to vibrate by sinusoidal waves. This device's stability was graded on a scale of 1 (lowest) to 100 (highest) (maximum). Before and after each implant measurement, the torque wrench and the Osstell were calibrated. The measurements were taken three times for each implant, with the sum of the readings used to calculate the RFA results for each implant. **Figure (1)**.

Removal torque

After implant placement, the torque of each implant was determined by unscrewing the fixture with the torque wrench.

RESULTS

Regarding, implant insertion torque the highest value was found in single thread group followed by double thread group, while the lowest value was found in triple thread group and different groups showed statistically significant difference ($p<0.001$) at the three different insertion torque. At 30N, values measured in triple thread group were significantly lower than values of other groups ($p<0.001$). While for 40N, values measured in different groups were significantly different from each other ($p<0.001$). And at 50N, values measured in single thread group were significantly higher than values of other groups ($p<0.001$). Primary stability results revealed that, the highest value was found in triple thread group (81.67±1.86), followed by double thread group

(81.17±2.04), while the lowest value was found in single thread group (72.67±1.75) and there was a significant difference between different groups (p<0.001). Pairwise comparisons showed value measured in single thread group to be significantly lower than values of other groups (p<0.001). When coming to removal torque, the highest value was found in triple thread group (60.00±1.50), followed by double thread group (59.17±2.04), while the lowest value was found in single thread (52.50±2.74) and there was a significant difference between different groups (p<0.001). Pairwise comparisons showed value measured in single thread to be significantly lower than values of other groups (p<0.001) **Table (2).**

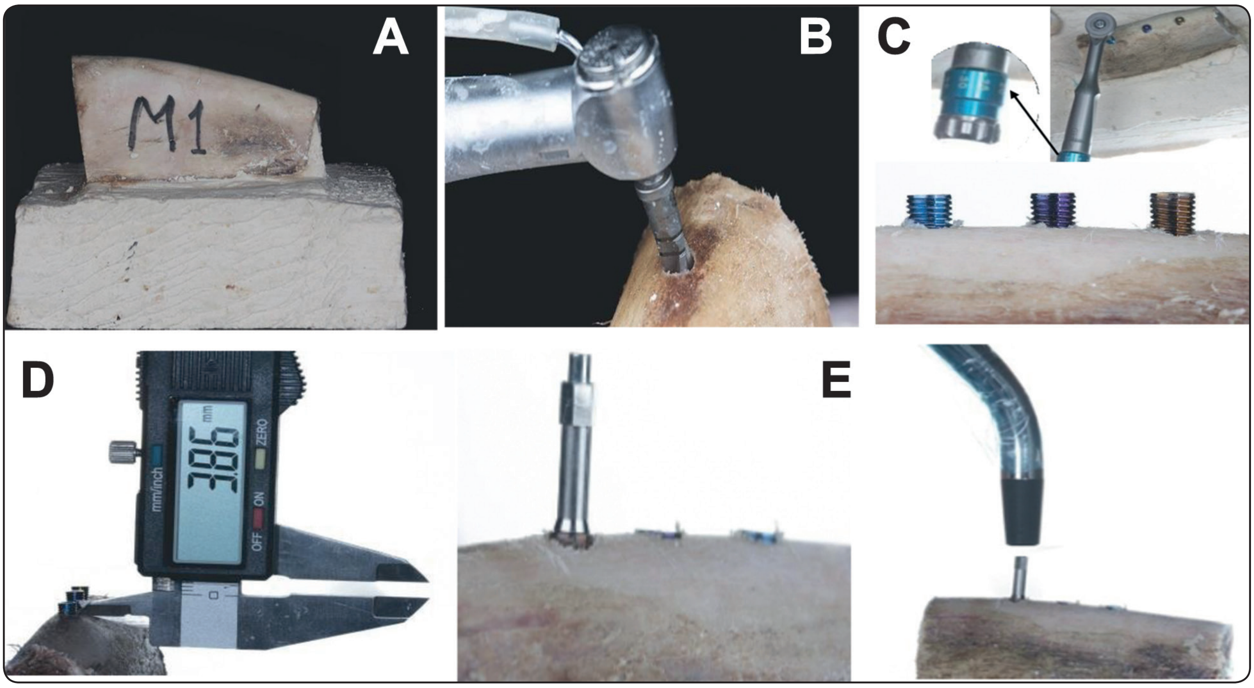

Fig. (1): A. Bovine bone blocks, B. drilling osteotomies, C. implant insertion at different torques, D. Measuring the part of implants outside the bone using digital caliber, E. RFA measurements using the Osstell ISQ device.

TABLE (2): Mean and standard deviation (SD) values:

		Single thread	Double thread	Triple thread	p-value
Implant insertion (Mean±SD)	30N	7.75±0.13^{Ac}	7.57±0.17^{Ab}	7.20±0.35^{Bb}	<0.001*
	40N	8.27±0.12^{Ab}	7.94±0.14^{Ba}	7.57±0.27^{Ca}	<0.001*
	50N	8.60±0.13^{Aa}	8.17±0.25^{Ba}	7.94±0.42^{Ba}	<0.001*
Insertion torque until bone flushing (Mean±SD)		53.50±2.42^{B}	56.50±3.37^{AB}	58.00±2.58^{A}	0.003*
Primary stability (Mean±SD)		72.67±1.75^{B}	81.17±2.04^{A}	81.67±1.86^{A}	<0.001*
Removal torque (Mean±SD)		52.50±2.74^{B}	59.17±2.04^{A}	60.00±1.50^{A}	<0.001*

Different superscript letters indicate a statistically significant difference within the same horizontal row *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

DISCUSSION

Osseointegration is a biological reaction that occurs under functional load and results in vital bone - implant surface structural connection. This is accomplished through a series of osteoblast activation processes, as well as the peri-implant osteoid tissue formation and mineralization. On other hand, in case of micromotions passing the threshold (50-150 nm) the fibrous encapsulation will overcome the osseointegration resulting in reduced implant stability. Thus, the primary stability of an implant becomes one of the most critical prerequisites for osseointgration completion, and it must be achieved throughout the surgical process and maintained during the healing period. ***(Falisi et al., 2017)***. Immediate provisional crowns should be used only in case of application of initial insertion torque, as primary stability is a critical factor for success in immediate implantation and loading cases ***(Levin et al., 2012)***.

The primary stability is affected by a number of factors including implants (design, size, macro and micro surface), the structure (bone quantity and quality and the operator (technique of the surgery). Different implant surface treatments may also enhance the primary stability ***(Falisi et al., 2017)***. Since bone quality is a given factor that cannot be altered, adaptation of the implant surface and design to the specific qualities of the host bone should be done to promote osseointegration ***(Orsini, et al., 2012).***

Another important factor is the implant microscopic and macroscopic body. The microscopic features are most important during the initial implant healing and loading phase. During early and mature loading times, the value of macroscopic implant body design is demonstrated. The implant team must be alert towards choosing product used, as it affects risk of screw loosening, crestal bone loss, implant body bone loss, peri-implantitis, soft tissue drape esthetics, implant body fracture or even total implant failure. ***(Yadav et al., 2016)***.

The failure of an implant's osteointegration is usually caused by loss in the peri-implant area or bone weakening rather than mechanical failure of the load-bearing artificial structure. When it comes to implant form, the design parameters that have the most impact on load transfer characteristics are length of the bone-implant interface and implant diameter as well as thread pitch, form, and depth in the case of threaded implants, all contribute to the stress/strain distribution in the bone. To increase the surface area of osseointegration, threaded implants are favored over cylindrical implants.

Regarding initial stability and the biomechanical nature of the bone-implant interface after the healing process, bone quality, surface treatments, and thread geometry may all have a major impact on implant effectiveness. Since threaded body designs can transform occlusal forces compressive loads at the bone interface, thread shape is especially important regarding long-term load transfer to the adjacent bone interface. ***(Yadav et al., 2016).***

Initial contact is increased through the threads which enhance initial stability and insertion torque, increase implant surface area, and promote interfacial stress dissipation. ***(Yadav et al., 2016)***. It has been highlighted that, in dense bone, regardless of the design, implants can achieve similar initial stability, while in low-density bone, primary stability may be influenced by different implant designs. Since lower-density host bone leads to a lower percentage of bone implant contact at the interface and a higher risk of early implant failure, it's possible that choosing an implant design that maximizes the available surface area for contact will help with mechanical anchorage and primary stability in poor-quality bone. ***(Orsini, et al., 2012).***

Many geometric parameters, such as depth, width, pitch, face angle, and helix angle of the thread; influence the functional thread surface, as well as the biomechanical load distribution of the implant. ***(Yadav et al., 2016)***. Thread design can increase implant surface area, stress distribution, and primary stability. Pitch, like thread shape, is a key factor in determining bone-to-implant contact and biomechanical load distribution. It's the measurement of the distance between two adjacent threads on the same plane of the axis. It's often known as the number of threads per unit length is often referred to. So, when implant lengths are equal, a smaller pitch means more threads, resulting in a larger surface area. ***(Orsini, et al., 2012).*** The threads per unit length are equal to the threaded portion height of the implant body divided by the pitch. If all other variables are equal, the finer the pitch, the more threads on the implant body. Pitch is the most effective design variable for adjusting the surface area of a threaded implant. ***(Yadav et al., 2016).***

Many studies have shown that smaller-pitch implants have increased surface area with better stress distribution, especially in low-density bone. Three-dimensional limited element analysis models found smaller pitch to have better load resistance and lower effective stress. The surface area available for load transfer to the peri-implant tissue is determined by the thread pitch. Smaller pitch provides a more favourable stress distribution and strengthens the implant's primary stability, according to common findings. ***(Ryu et al., 2014)***.

A modified thread configuration can be particularly important in the posterior region of the oral cavity, where the anatomy often limits other implant parameters, such as length and diameter ***(Orsini, et al., 2012)***. Thread pitch is more important in increasing primary stability in low-density bone rather in high-density bone, so operators should pay special attention to this geometric factor, mainly if the bone quality is weak, as decreasing thread pitch improves initial mechanical stability. (e.g., increased BIC) ***(Ryu et al., 2014)***. Since the weakest bone types are 58 percent lower than optimal bone density, the number of implant threads may be increased to improve total surface area and minimize stress on the softer (weaker) bone trabeculae. As a result, if the force increased, the implant length is decreased or the bone density is reduced, the thread pitch can be reduced to increase the thread number and functional surface area. ***(Yadav et al., 2016).*** In the current study, a pitch of 0.6 mm was used.

Lead is a geometric parameter that is related to thread pitch. The distance between pre and post single complete rotation in the axial direction within the same thread is known as lead. Lead rises by one, two, and three times the pitch for single-, double-, and triple-threaded implants, respectively. Lead is critical in determining the speed of implant insertion because it shows the distance that an implant can move after one turn. In reverse proportion, the number of revolutions needed to insert an implant is influenced by thread lead. If the thread lead lengthens, the thread helix angle lengthens as well, potentially affecting the forces transmitted to the bone. ***(Ormianer et al., 2016).***

In different words, the distance between the centre of the thread and the centre of the same thread following single turn, or more specifically, the distance that a screw shall travel in the axial direction if turned one full revolution, is known as lead. Lead equals pitch in a single-threaded screw, twice the pitch in a double-threaded screw, and triple the pitch in a triple-threaded screw. After controlling all other factors, the lead primarily determines the speed at which implants are placed in bone (distance of pitch). An implant with double threads would insert double as fast as a single threaded implant, and a triple threaded implant would only take one third of the time. ***(Abuhussein et al., 2010)***.

The number of cutting blades used to form the implant threads in the manufacturing process determines thread lead. A single-lead thread is produced by single cutting blade, a double-lead thread by two, and a triple-lead thread by three. When you rotate an implant one rotation, it will insert one thread into a single lead thread. Two threads can be inserted in one revolution in the double-lead thread. As a result, inserting a single-lead thread implant takes twice as long as inserting a double-lead thread implant. The number of threads in an implant affects its ease of insertion. The less threads on an implant, the easier it is to insert it, which could be advantageous in dense bone. ***(Ormianer et al., 2016)***.

According to ***Yamaguchi et al., 2020***, the functional surface of the thread and the biochemical load distribution are determined by characteristics of the thread as: pitch, depth, thickness and face and lead angles. Implants that are double- or triple-threaded have been produced by some manufacturers. Multiple-threaded implants can be implanted more quickly than single-threaded implants. The implant's body configuration may be altered to enhance primary stability and therefore the viability of immediate loading. By the initial contact area, the thread improves initial stability. The biomechanical load distribution of the implant is also influenced by thread depth, thread morphology, pitch, and helix angle.

Changes in implant lead design include changing spiral angle with the same pitch which is utilized in the current study or changing the pitch itself ***(Yamaguchi et al., 2020)***. Unfortunately, only a few procedures, such as limited element analysis, have been studied to see how double- or triple-threaded implants affect primary stability. ***(Ma et al., 2014)***. Thus, In contrast to single-threaded implants, many operators assume that double and triple threaded implants can decrease the time of implant insertion with increasing primary stability. So, for immediate loading of an implant, double- and triple-threaded implants are used, and the increased surface area provides greater primary stability. However, till now, there's no sufficient data to confirm these findings. ***(Yamaguchi et al., 2020).***

In the current study, modification of thread lead is utilized by using the same thread compactness of the single threaded implants but different helix angles to produce double and triple threaded implants as ***(Ma et al., 2014)*** stated that, Modifications to the implant body design are thought to improve the effectiveness of immediate loading by improving initial stability and limiting micromovement. Thread thickness, face angle, pitch, depth and helix angle are only a few of the geometric patterns being able to modify the functional thread surface and impact the implant's biomechanical load distribution. For commercial implant systems, a better thread design is thus needed.

Dental implant manufacturers currently make surface treatment using commercially pure titanium (Ti G2 and Ti G4) and Ti–6Al–4V alloy (Ti G5) to improve the interaction between bone cells and the implant (osseointegration). In medical applications that need high stresses, such as orthopaedic prostheses and narrow dental implants, Ti G2 and Ti G4 are not used. Because of their high mechanical resistance, Cr–Co, stainless steel, and Ti G5 (Ti–6Al–4V alloy) are the best materials for orthopaedic applications. These alloys ensure long-term load transmission to bone, which is critical when replacing damaged hard tissues with prostheses, especially the Ti–6Al–4V ELI alloy, which has excellent mechanical properties. ***(Elias et al., 2019)***. Thus, Ti G5 alloys were utilized in the implants used in the current study.

The implant thread form has shown influence on the type of force transmitted to the surrounding bone. V-shaped implants were the first to be introduced. Variations of the V-form thread design, such as the square shape, buttress, reverse buttress, V-shape and spiral shape; were created by observing the stress patterns. ***(Manikyamba et al., 2020)***. In cancellous bone, V-thread and thick square thread had substantially less stress. ***(Ryu et al., 2014)***. Thus, in the current study V-shaped implants were manufactured to obtain the least stresses in cases with compromised bone. The implant dimensions used in the current investigation were 12mm length and 4 mm diameter.

DEMİRKOL et al., 2019 in his retrospective study, evaluated diameter and length properties of single dental implants that is placed on posterior are of maxilla and mandible finding that the most commonly used implant diameter was the 4 mm (54, 18.4%). While 12 mm (94, 32%) was the most commonly used implant length among 293 tested dental implants. The success rate of these implants was found to be 97%.

Implant percussion, radiographs, the perio test assessment, and the control torque test are just a few of the techniques mentioned in the literature. These methods, on the other hand, produce subjective results or do not permit linear assessment of stability. On implementing the resonance frequency, a shift from self-interpreting to actual evaluation was made, with the amount of implant stability linearly correlated. ***(Falisi et al., 2017)***. Thus, resonance frequency analysis (RFA) has been used for more than a decade as a noninvasive, reliable, easily predictable, and objective method of measuring implant stability and assessment of stability changes over time ***(Shokri et al., 2013).***

Regarding monitoring of structural integrity, for decades, researchers have studied the frequency response of mechanical structures to dynamic loads. Natural frequencies are sensitive measures of structural integrity and have been used as a diagnostic parameter in structural evaluation procedures using vibration monitoring. It has been established that there is a connection between frequency changes and structural damage. The ISQ score's primary goal in a clinical setting is to provide a quantification method for operators. The RFA technique is sensitive to the rigidity of both implant and surrounding bone. ISQ values have been found to increase as a function of healing time, which has been justified as bone formation around the implant. The initial ISQ value has been found to be related to the cutting torque and bone density measurements taken by the surgeon before implantation. A correlation has also been found between cortical bone thickness and the ISQ score. There has been evidence of a connection between ISQ values and the anatomical region of implantation. ***(Mathieu et al., 2014)***.

Since we can use RFA for implant assessment at different time intervals, while insertion torque (IT) can only be assessed during the surgery, it has become an important and widely used method. The Osstell unit is used to determine RFA. This tool, which works with transducers attached to implant or prosthetic parts, is available for a variety of systems. The device change is calculated after the transducers (smartpegs) print a lateral force on the fixed components. The RFA evaluates the stiffness and deflection of the implant-bone complex.

The value obtained by Osstell is converted automatically into an index called (ISQ) Implant stability quotient, which ranges from 1 to 100 (with 100 indicating the maximum level of stability), which also permits the measurement of stability over time while defining the conditions of bone around the implant. Many clinical trials use this approach to decide when to begin loading on the implant, and the value 70 of ISQ is considered the dental prosthesis insertion and immediate loading threshold. In clinical practise, an IT of 45 Ncm for immediate loading is the most widely used and considered the best and most therapeutic. For implant stability assessment, various methods have been developed that can be compared to IT. The periotest is a different method for determining implant stability; however, it is less widely used and common than the Osstell, so the results aren't comparable. As a result, knowing IT and Osstell methods is important, as they are the most widely used. ***(Lages et al., 2018)***.

In the current study, Torque and ISQ values were the assessed outcomes as ***(Yamaguchi et al.,***

2020) stated that, torque, torsion angle and thread compactness and effect on implant stability is reflected on ISQ values. ***González-Serrano et al., 2017*** stated that, RFA is an acceptable since it's reliable and objective. And that Osstell™ system has been proved to be more reliable compared to Periotest® in measuring stability of dental implant.

Nowadays, cadaveric bone, resin models, synthetic bone or animal bone are the most common ways used for implant preparation. ***(Möhlhenrich et al., 2015)***. In our study, a bovine bone was used due to the similarity between bovine and human bone in terms of density and relationship between cortical and cancellous bone ***(El-kholey et al., 2017)***. At the same time, as this experimental study was carried out on bovine bone, it was not possible to simulate in vivo conditions such as the access to the surgical site or the blood supply to the bone. Hence, although preliminary data is important, further clinical studies are needed to confirm these findings ***(González-Serrano et al., 2017).*** Bone model implantation varies from in vivo implantation in being conducted in a dry environment, the ambient temperature is room temperature rather than the temperature of the oral cavity, and there are no physiological reactions such as osteolysis and osteogenesis. As a result, torque and ISQ values obtained with a bone model cannot be transferred directly to in vivo conditions, but they can be comparable to values obtained from similar studies under same conditions. The present study was carried out for these purposes ***(Yamaguchi et al., 2020)***.

In the current study ISQ values above 70 were obtained, Implant ISQ values usually vary between 50 and 80 on the ISQ scale, which runs from 1 to l00. When converting ISQ values to implant stability, keep in mind that ISQ values and implant micromotion have a nonlinear, inverse relationship. A rise in ISQ from 60 to 70, for example, indicates reduction to the half in implant micromobility. The following criteria are often used when looking at such benchmarks for ISQ and implant stability: ISQ 70 indicates high stability, allowing immediate loading; ISQ 60–69 indicates medium stability; ISQ 60 indicates low stability. ***(Trisi et al., 2010).***

Rather than looking at a single ISQ value, variations or patterns in ISQ by time may reveal important details about secondary implant stability and osseointegration. During the healing process, successful implants have higher ISQ values, particularly in the first six weeks after surgery. Implants with decreased (60) or medium (60–69) ISQ values often show higher values over time, while implants with high (70) ISQ values can remain stable or increase (albeit to a lesser extent) over time. ***(Atieh et al., 2014).***

Despite the three designs offer ISQ values above 70, the highest value was found in triple thread group, followed by double thread group, while the lowest value was found in single thread group and there was a significant difference between different groups. Our study proved that triple and double thread design implants had better primary stability in comparison to single thread design implants. This was in agreement with ***(González-Serrano et al., 2017)*** who justified these results with a better bone to implant contact obtained in trabecular bone with triple and double thread design implants and concluded that, , double and triple implants seems to be more suitable in low quality bones.

In disagreement, ***Yamaguchi et al., 2020*** declared that, despite the benefit of higher speed of insertion, double-threaded implants with a incresed lead angle could have decreased initial stability because, despite their faster insertion, they can cause significant bone tissue damage. Also, finite element analysis (FEA) done by ***(Ma et al., 2007 and Ma et al., 2014)*** clarified that a single-lead threaded implant has the best primary stability, followed by a double-lead threaded implant. The least stable implant is a triple-threaded implant. They claimed that an increased lead angle for these implants may jeopardize their ability to sustain axial load despite faster insertion. Furthermore, as micromotion is measured between implants with variable lead angles and the same thread pitch, single-threaded implants have the least micromotion, while triple-threaded implants have the highest, with both vertical and horizontal loading.

Thus, the null hypothesis was rejected as double and triple threaded implants provided greater primary stability and insertion torque than single threaded implants.

CONCLUSION

1. When primary stability is a concern, as in low bone quality, double and triple threaded implants can provide greater primary stability and insertion torque than single threaded implants.
2. Double threaded implants combine optimum insertion speed and high primary stability and insertion torque in compromised situations.

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