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Evaluation of different osteotomy techniques on primary stability of implants using RFA: A study on goat mandible

Dr. Mohanraj J P
Reader, Department of Periodontics and Implantology, Rajas Dental College and Hospital, Kavalkinaru, Tirunelveli – 627105, Tamil Nadu, India
Corresponding author email: drjpmohanraj@gmail.com

Dr. Delsa Mariam Raju
Postgraduate student, Department of Periodontics and Implantology, Rajas Dental College and Hospital, Kavalkinaru Junction, Tirunelveli dt, Pincode-627105 Tamilnadu, India
Email: delsa1011@gmail.com

Dr. Babu Salam
Postgraduate, Department of Periodontics and Implantology, Rajas Dental College and Hospital, Kavalkinaru Junction, Tirunelveli dt, Pincode-627105 Tamilnadu, India
Email: babumitzvah@gmail.com

Dr. Jacob Raja S A, MDS,
Professor, Department of Periodontics and Implantology, Rajas Dental College and Hospital, Kavalkinaru, Tirunelveli – 627105, Tamil Nadu, India
Email: antomadona92@gmail.com

Dr. Johnson Raja James, MDS,
Professor and Head of the Department, Department of Periodontics and Implantology, RajasDental College and Hospital, Kavalkinaru Junction, Tirunelveli dt, Pincode-627105 Tamilnadu, India
Email: viceprincipal@rajasdentalcollege.com

Dr. Tamilselvan, MDS
Senior Lecturer, Department of Periodontics and Implantology, Rajas Dental College and Hospital, Kavalkinaru, Tirunelveli – 627105, Tamil Nadu, India
Email: tamilbdstirupur@gmail.com

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***Abstract*---**Primary stability of implant is based on its mechanical engagement to the surrounding bone at the time of installation. It can be affected by patient- related factors like the bone quality and quantity and underlying systemic diseases and the surgical technique. Among various methods available for measuring primary implant stability, the most recommended method is the use of Resonance Frequency Analysis (RFA) due to its versatility. The aim of this study was to evaluate the influence of 4 different osteotomy techniques on the primary stability of implants using RFA. Forty implants of same size and system were installed on goat's mandible under four osteotomy approaches 1) undersized (two-step down) 2) subcrestal 3) osteotome technique 4) bicortical anchorage. Primary stability of all the implants placed was measured using RFA test. The results were statistically analyzed and highest mean ISQ value was observed when implants were placed under bicortical anchorage. Implants when placed under bicortical anchorage achieved better primary stability and hence this osteotomy approach can be followed in areas where primary stability is expected to be compromised.

***Keywords*---**implant, osseointegration, osteotomy techniques primary stability, resonance frequency analysis.

Introduction

Over the past 30 years, implants have become a reliable solution in replacing partially and completely edentulous ridges. The key to successful implantation depends on the ability of the implant to osseointegrate with the surrounding bone (Gehrke et al., 2015). To achieve this, several factors like the bone quality and quantity at the site of implant placement, surgical technique and implant design plays an important role. Implant stabilization is an important parameter for preventing micromovements, thereby establishing a desirable bone–to-implant contact (O'Sullivan et al., 2004). Research data demonstrated thet the maximum acceptable micromovement is in the range of 50-150μm. Micromovements greater than this can lead to fibrous tissue formation between implant and bone, which in turn can lead to implant failure (Esposito et al., 1998). Understanding these elements and incorporating them into the science of dental implants can help us achieve predictable osseointegration, reducing the risk of implant failure. Both primary and secondary stability are important parameters for successful osseointegration. The implant osteotomy plays a decisive role in the long term success of implant restorations particularly because of the variations in the quantity and quality of the bone in different sites of the jaw. Various osteotomy techniques have been described in literature each having their own potential advantages and limitations such as improved mechanical engagement in case of undersized preparation but increased probability of microfractures, prevention of contamination of implant surface in case of subcrestal placement but increased chance of crestal bone loss, improved stability associated with bicortical anchorage, however, it is technique sensitive (Shadid et al., 2014). Bicortical anchorage has been of interest to clinicians now especially in the light of advancement in immediate implant placements. Clarity is required on the impact of the different osteotomy techniques in the stability of implants. Visual evaluation, Ping test (percussion test that involves tapping on the implant-abutment interface with a metallic instrument), insertion torque, Periotest and resonance frequency analysis are just a few of the non-invasive clinical test methods for determining implant stability that have been described in the literature till date (RFA) (Cehreli et al., 2009). Despite the availability of these many stability quantifiers, only some of these have proved valid. In today's world, the gold standard for evaluating in-vivo implant stability is Insertion torque and RFA (Elias et al., 2009). Insertion torque quantifiers allow only a single measurement of primary stability, while RFA offers the advantage of checking in-vivo implant stability at different times. Resonance frequency analysis (RFA) was first described by Meredith in 1996 (Meredith et al., 1996). It has a transducer which is L-shaped and gets fastened with the help of a screw. The peak amplitude of the signal is used to evaluate the transducer/implant system's resonance frequency, which is termed as the implant stability quotient (ISQ) (Swami et al., 2016). The ISQ values can range from 0 (in the case of a completely movable implant) to 100 (in the case of a perfectly stable implant-bone complex).

Resonance frequency analysis is used to assess the stability of single unsplinted implants at the time of implantation, at any point during healing, and after loading in the case of screw-retained prostheses—it cannot be utilised if the prosthesis is cemented (Meredith et al., 1997). The purpose of this study was to test the primary stability of implants, using RFA, when placed under different osteotomy techniques in a goat's mandible.

Materials and Methods

The present study was carried out on 8 goat mandibles, obtained from slaughter-house. The goat mandibles were defleshed, cleaned and dried, and the study was done within 2 hours of specimen collection. The goat mandibles' were subjected to CBCT evaluation to determine the bone density and to standardize the site selected for implant placement. Areas of D1 quality bone (> 1250 HU) were selected and the implants were placed from inferior border of the mandible, towards occlusal direction, so that the variations in the site at the dentulous region does not affect the outcome of the study.

Implant Characteristics: A total of fourty Noris Tuff Implants (Noris Medical – Dental Implant Solutions, Israel) of dimension 3.75 * 13 mm were used (Figure 1). According to the surgical and Implant placement techniques described earlier, four approaches were followed for implant placement. For all approaches, a 2mm pilot drill was used followed by sequential drilling using drills of varying diameter and depth depending on the surgical approach. The drill sequence for each of the approaches is given in table 1. To counter-check the surgical technique accuracy, CBCT evaluation was done after the implant installation by each of the approaches (Figure 2).

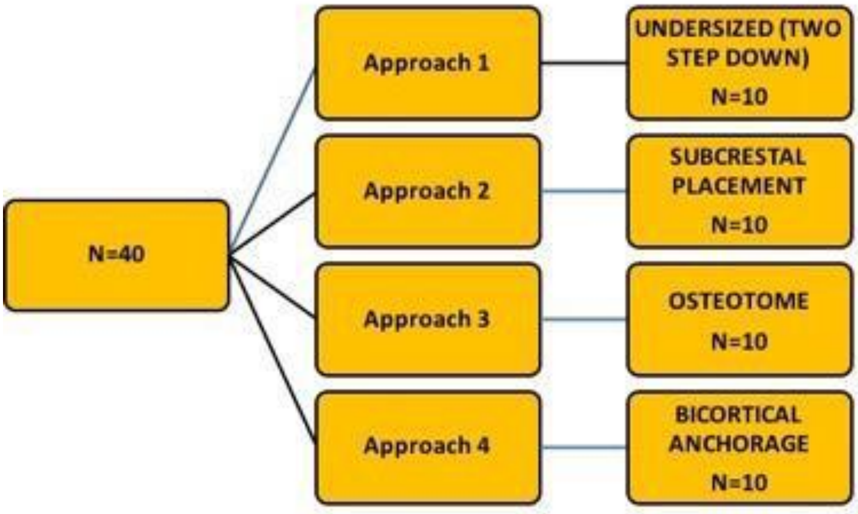

Figure 1. Sample distribution

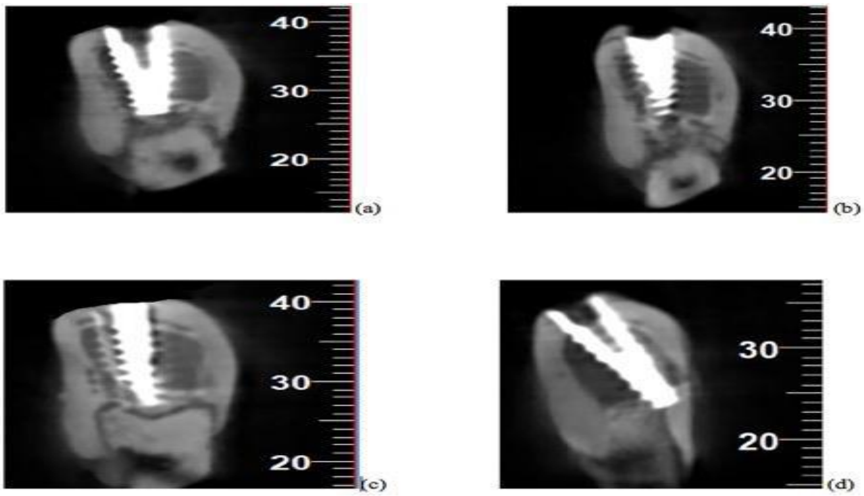

Figure 2. (a) Undersized (approach 1) (b) Subcrestal (approach 2) (c) Osteotome (approach 3) (d) Bicortical anchorage (approach 4)

Approach 1—Under-sized preparation (Two step down): The final drill used in the procedure had a diameter of 2.8mm (less than the actual diameter of the implant to be placed).

Approach 2- Subcrestal placement: Implant placement was done 0.5mm subcrestally unlike the other approaches where the implants were placed on par with the alveolar bone crest.

Approach 3—Osteotome technique: A pilot hole was prepared with a drill of 2mm in diameter. A series of consecutive osteotomes were then used to enlarge the diameter of the pilot hole to a diameter of 3.2 mm. Each osteotome or spreader was placed for one minute.

Approach 4: Bicortical anchorage: Implants were placed in such a way that they engaged the cortical plates both on the facial and lingual aspects. (Table 1)

Table 1
Drill sequence for various osteotomy approaches

Approaches	Technique	Drill Sequence
Approaches 1	Undersized (Two – step down)	2, 2.5, 2.8 * 13mm
Approaches 2	Subcrestal	2, 2.5, 2.8, 3.2 * 13mm
Approaches 3	Osteotome	Pilot drill: 2mm Osteotomes: 2.5, 2.8 * 13mm
Approaches 4	Bicortical anchorage	2, 2.5, 2.8, 3.2 * 13mm

Drilling speed: 1200rpm; Implant size: 3.75*13 mm. Bone density evaluation: CBCT (pre and post-operative). Implant stability measurement Immediately after implant placement, the primary stability was recorded using Penguin RFA device which provides information about the rigidity of the implant-bone junction (Figure 3) (a) and (b)). The digital reading on the device correlates with the implant stability quotient (ISQ). The resonance frequency analyser works on the principle of sending magnetic pulses to a small metal rod temporarily attached to the implant. As the rod vibrates, the probe reads its resonance frequency and translates it into an ISQ value

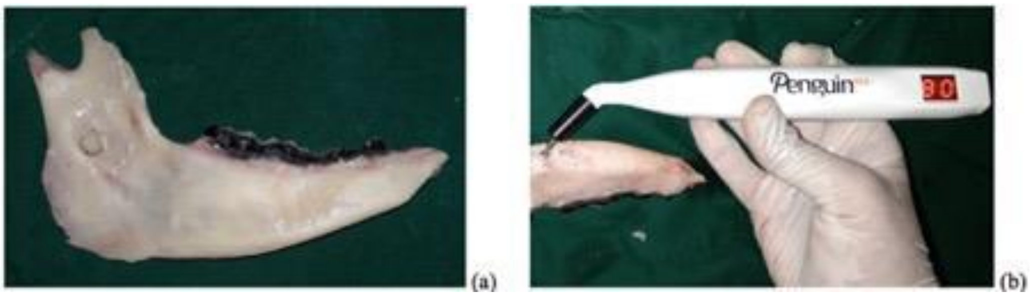

Figure 3. (a) Defleshed goat mandible (b) Primary stability measurement using

Statistical Analysis

The results obtained were statistically analyzed. Overall comparison of the four approaches was done using Analysis of variance (ANOVA) test and individual inter-group comparison was done based on Post-hoc analysis using Bonferroni test.

Results

Under-sized preparation, subcrestal approach, Osteotome and Bicortical anchorage approaches showed a mean ISQ value of 74.4, 78.0, 80.5, and 89.3 respectively (Figure 4) indicating high stability in all the surgical approaches. The highest mean ISQ value (89.30) was observed when the implants were placed with bicortical anchorage. An overall comparison made for all surgical approaches using analysis of variance (ANOVA), showed a statistically significant ($p < 0.001$) difference among all the four groups (Table 2). Statistically significant difference ($p < 0.05$) was found in individual inter-group comparison (Table 3)

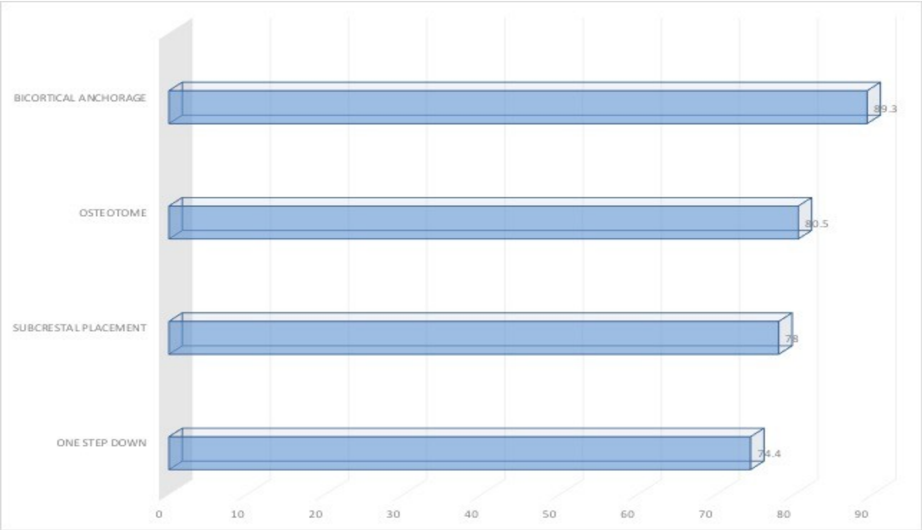

Figure 4. Bar chart showing mean ISQ values

Table 2
Overall comparison statistical analysis

Approaches	N	Mean	Standard Deviation	p-value
One step down	10	74.4	1.95	<0.001*
Subcrestal placement	10	78.0	2.00	
Osteotome	10	80.5	1.43	
Bicortical Anchorage	10	89.3	1.61	
p-value is based on analysis of variance (ANOVA) * = Statistically Significant (p < 0.001)				

Table 3
Individual inter-group statistical analysis

APPROACHES	APPROACHES	p-value
One step down	Subcrestal placement	0.001*
One step down	Osteotome	<0.001*
One step down	Bicortical Anchorage	<0.001*
Subcrestal placement	Osteotome	0.045*
Subcrestal placement	Bicortical Anchorage	<0.001*
Osteotome	Bicortical Anchorage	0.002*
p-value based on Post-hoc analysis using Bonferroni test *= Statistically significant (p<0.05)		

Discussion

Primary stability of implants play a key role in successful osseointegration of the implant to the bone. A poor initial stability may lead to micromovements that promotes intervening of soft tissue between the implant and bone causing fibro-osseous integration, ultimately leading to implant failure. Primary stability to a greater extent depends on the bone quality, quantity, surgical technique and the implant design used. The methods commonly used to clinically assess implant stability and osseointegration include percussion, mobility tests and clinical radiographs (Dos Santos et al., 2011). Lack of standardization, poor sensitivity, and susceptibility to operator variations limits the use of these methods and has paved way for better reliable, non-invasive and quantifiable method which is not subject to observer variations.

To better standardize the results of this study, primary stability was determined using only RFA. This technique can be used as a part of routine clinical procedure, as it is rapid and there is no risk of discomfort to the patient. Resonance frequency is determined by both the rigidity (stability) of the implant-bone interface and the distance from the transducer to the first bone-implant contact (Meredith et al., 1997). The numerical output is interpreted as a value that is linearly related to the degree of micromotion at the implant-bone interface, referred to as implant stability quotient (ISQ) value (Mistry et al., 2014).

According to the ISQ scale, a value less than 60 suggests low stability. An ISQ value of 60 – 70 indicates medium stability and the implant should be considered for traditional two-stage loading and a value greater than 70 suggests high stability, which is ideal for immediate or one-stage loading (Meredith et al., 1997). The present study compared the primary stability achieved by implants when placed under different osteotomy techniques, keeping all other parameters standardized. Hence, the implants were placed in sites having D1 quality bone. To measure the primary stability, RFA was used. All the implants showed an ISQ value greater than 70. This was perhaps not surprising as in good, dense bone as that of D1 quality, it would be anticipated that the implants would achieve an acceptable primary stability. The one-step down surgical technique showed the lowest mean ISQ value comparatively while implants placed with bicortical anchorage showed a steep rise in the ISQ value which is attributable to the superior bone quality of cortical plates providing additional support. Niimi et al., assessed the bone quality and cortical bone thickness of fibula, iliac crest, and scapula by using removal torque of an implant immediately after placement (Niimi et al., 1997). It was found that there exists a significant correlation between cortical bone thickness and removal torque but not between bone quality and removal torque (Niimi et al., 1997). The present study showed a statistically significant mean ISQ value for implant placed with bicortical anchorage. This could probably be due to the engagement of implant threads onto the dense cortical bone, both at the crestal and apical region of the implant which adds to the improved primary stability. Other comparable studies have been performed by Manal M. Shalabi et al., to assess the effects of surgical technique (conventional technique, by undersized preparation, or by the osteotome technique) and implant surface roughness on implant fixation and concluded the undersized preparation technique improved the early fixation of oral implants (Shalabi et al., 2007). To the best of our knowledge, the present study is the first to investigate the primary stability comparing various surgical techniques and implant macrodesign.

Conclusion

Within the limitations of this study, it was observed that implants when placed under bicortical anchorage achieved better primary stability. Hence, in areas where primary stability is expected to be compromised, implants can be installed taking advantage of bicortical anchorage method.

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