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Effect of a Modified Stepped Osteotomy on the Primary Stability of Dental Implants in Type D4 Bone: A Cadaver Study

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Abstract

Effect of a Modified Stepped Osteotomy on the Primary Stability of Dental Implants in Type D4 Bone: A Cadaver Study

Chad M. Boustany, D.D.S.

Purpose: The aim of this study was to examine the effect of an alternative surgical technique on endosseous dental implant stability parameters in Class D4 Bone. Significant differences between insertion torques (Ncm) produced by a conventional osteotomy verses a modified stepped osteotomy were examined. Significant differences between Implant Stability Quotients (ISQ) produced by a conventional osteotomy verses a modified stepped osteotomy were examined. Correlations between Hounsfield units (HU), Implant Stability Quotient (ISQ), and insertion torque (IT) were examined.

Materials and Methods: Sixteen preserved cadaver heads were radiographically examined with a Toshiba Aquilion® 64 Fast Whole Body Computerized Tomography (CT) Scanner. A total of 22 implants were placed in the maxillary bone of nine preserved cadavers which possessed Misch Class D4 bone with adequate volume for this study. The control group consisted of 11 conventional osteotomies. The test group consisted of eleven modified stepped osteotomies. The maximum insertion torque (Ncm) data were recorded with the Zimmer™ Implant Motor and confirmed with the Thommen™ Torque Driver. Implant Stability Quotient (ISQ) was measured with the Osstell Mentor™ (Integration Diagnostics AB, Göteborg, Sweden) via resonance frequency analysis. Significant differences insertion torques (IT) and Implant Stability Quotient (ISQ) were analyzed with a Wilcoxon Signed Rank Test. Correlations were analyzed with the Pearson Correlation Test.

Results: Maxillary cadaver bone utilized in this study ranged from 173.4 – 312.1 HU. The mean insertion torque in the conventional osteotomy group was 15.91 Ncm. The mean insertion torque in the modified stepped osteotomy group was 26.82 Ncm. A Wilcoxon Signed Rank test also showed the modified stepped osteotomy had a significantly greater mean insertion torque than the conventional osteotomy ($S = 33.00$ $p = 0.0010$,). A Wilcoxon Signed Rank test also showed no significant difference between ISQ in the conventional osteotomy group and the modified stepped osteotomy test group ($S = 17.00$, $p = 0.01475$). Pearson correlations showed a significant positive correlation between the insertion torques in the conventional osteotomy test group and the modified stepped osteotomy test group ($r = 0.817$, $p = 0.0021$). Significant correlation between between the ISQ in the modified stepped osteotomy and HU also found ($r = 0.7099$, $p = 0.0144$). There were no other significant correlations between HU and ISQ. There were no significant correlations between HU and IT. There were no significant correlations between the ISQ in the conventional osteotomy test group and the modified stepped osteotomy group. There were no significant correlations between ISQ and IT in the conventional osteotomies. There were no significant correlations between ISQ and IT in the modified stepped osteotomies .

Conclusion: Within the limits of the study, the following conclusion can be drawn: The modified stepped osteotomy resulted in significantly greater implant stability in terms of insertion torque (IT) than the conventional osteotomy in Misch Class D4 bone. Significant correlations were found between the insertion torque (IT) produced in the modified stepped osteotomy and bone density (HU). No other correlations between insertion torque (IT) and bone density (HU) were found. No correlation could be found between insertion torque (IT) and Implant Stability Quotient (ISQ).No correlation could be found between Implant Stability Quotient (ISQ) and bone density (HU).

Dedication

To my parents, **Dr. Michael and Sara Boustany**, for the unconditional support during my studies. Thank you for instilling the importance of education, family, and hard work. You have always believed in me, even when I did not believe in myself.

To my brother, **Ryan Boustany**, for teaching me the meaning of loyalty and friendship. Thank you for being my best friend.

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Introduction

Background

Technological and clinical research has focused heavily on the achievability of primary stability with endosseous dental implants. The primary stability of dental implants refers to the resistance of micromotion immediately post placement (Meridith 491-501). Primary implant stability has been established as a pre-requisite and predictor to achieving full osseointegration (Seong et al. 2009 ; Brouwers et al. 2008 ; Dilek, Tezulas, and Dincel 2008 ; Okazaki et al. 2008). A study by Lopez et al. quotes, “The most important requirement in oral implantology is to achieve and maintain fixation stability…” (Lopez et al. 2006) Friberg et al. reported an implant failure rate of 32% for those implants that showed inadequate initial stability (Friberg, Jemt, and Lekholm 1991). .

Primary stability can be effected by variety of factors including surgical placement technique, implant design/geometry, local bone quality, and local bone quantity (Turkyilmaz et al. 2008). Clinicians must attempt to control each of these factors in the quest to achieve predictably high success rates in dental implantology. Maintaining control of prosthetic and surgical factors in dental implantology is directly associated with meticulous treatment planning. Utilization of proper technologies can help the clinician evaluate surgical anatomic sites, predict complications, evaluate primary stability.

Currently, computerized tomography (CT) is the most accepted method in the objective evaluation of bone, providing three-dimensional views, cross-sectional views, and bone density values via Hounsfield units. This radiographic method provides the best analysis of morphologic and qualitative characteristics of bone (Turkyilmaz et al. 2006 ; Turkyilmaz et al. 2007 ; Homolka et al. 2002 ; Ikumi and Tsutsumi 2005 ; Lee et al. 2007). Pre-surgical evaluation of local bone quality and quantity allows the clinician to adapt surgical treatments and techniques; , select proper implant design and surgical armament prior to the surgical appointment.

Primary stability is especially important in low density bone, where implant failures are more probable. The quality of bone is an important factor in the successful implant treatment, and it is evident that higher implant failure is more likely in poor quality of bone (Abrahams, Frisoli, and Dembner 1995 ; Bahat 1992 ;Agliardi et al. 2008 ; Bahat 2009 ;Fenner et al. 2009). Several studies have demonstrated the use of modified surgical techniques in the enhancement of primary stability of dental implants in poor quality bone. Success rates in these studies were similar to other oral regions with good bone quality (Bahat 1992 ; Bahat 1993 ; Bahat 2000 ; Bahat 2009). Modified surgical techniques include modifications in osteotomy diameter, drilling protocols, irrigation protocols, and condensing protocols. In the presence of poor quality bone, a bone dependent drilling sequence can increase primary stability (Turkyilmaz, Aksoy, and McGlumphy 2008 ; Fanuscu, Chang, and Akca 2007 ; Shalabi et al. 2007 ; Bahat 2009 ; Beer et al. 2007 ; Deporter, Todescan, and Nardini 1999 ; Summers 1994 ; Summers 1994 ; Hahn 1999 ; O'Sullivan et al. 2004 ; Ostman, Hellman, and Sennerby 2005).

A common method used to enhance primary implant stability is to place the implant into a smaller diameter osteotomy than recommended by the manufacturer; this approach is used by some surgeons in regions of poor bone quality. Compressive forces are set up along the implant/tissue interface, which enhance the implant stability. The uniform under-preparation of the entire osteotomy (apical to cervical) can often result in the incomplete seating of the implant or the creation of excessive compressive forces along the implant/tissue interface resulting in pressure necrosis. The under-preparation of the only the apical portion of the osteotomy has been referred to as a stepped osteotomy (Bahat 2009). The stepped osteotomy may provide increased primary stability while also ensuring the complete seating of the dental implant and decreased incidence of pressure necrosis.

The purpose of this study is to compare the difference between a conventional osteotomy verses a modified stepped osteotomy on implant stability of dental implants in Class D4 maxillary cadaver bone. Correlations between osteotomy type, insertion torque and ISQ will be evaluated.

Statement of the Problem

Can a modified stepped osteotomy preparation provide increased primary stability as compared to the conventional osteotomy? Do correlations exist between Hounsfield Units (HU) and Implant Stability Quotient (ISQ)? Do correlations exist between Hounsfield Units (HU) and insertion torque (IT)?

Do correlations exist between insertion torque (IT) and Implant Stability Quotient (ISQ)?

Significance of the Study

Primary stability is a prerequisite for the immediate loading of dental endosseous implants. If adequate primary stability cannot be achieved the endosseous dental implant cannot be immediately loaded. Bone quality is a major determinant on the success rates and the primary stability of endosseous implants. Typically, poor bone quality (Type III and IV) is present in the posterior maxilla (Jaffin and Berman 1991).

Surgical preparation also plays a large role in the ability to achieve adequate primary stability. Zimmer Dental Inc. utilizes a surgical approach to implant placement that utilizes a stepped drill that produces a stepped osteotomy. Utilization of this conventional osteotomy preparation in combination with type III and IV bone typically does not provide adequate primary stability. However, the utilization of a modified stepped osteotomy may provide increased primary stability. Increased implant stability may be achieved by the presence of an osteotomy preparation that is slightly undersized at the apex, producing an osteocompressive fit between the implant surface and the bone.

Literature review reveals few dental implant studies utilizing maxillary osseous samples. Correlations/relationships between HU, ISQ, IT have not been established. Correlations/relationships between altered surgical techniques HU, ISQ, IT are not well established.

(Null) Hypothesis

There is no statically significant difference of endosseous dental implants placed in a conventional osteotomy preparation verses a modified stepped osteotomy preparation in terms of IT or ISQ. There is no statistically significant relationship between IT and ISQ. There is no statistically significant relationship between HU and IT. There is no statistically significant relationship between HU and ISQ.

Definition of Terms

Modified stepped osteotomy

A customized surgical osteotomy preparation, for endosseous dental implants in areas of poor bone quality. This technique utilizes conventional drills in the formation of a osteotomy with a smaller diameter apex as compared to a conventional osteotomy preparation. Principle objective is to obtain primary stability in compromised bone quality, by enhancing the osteocompressive fit between implant and bone.

Osseointegration

The firm anchoring of a surgical implant by the growth of bone around it without fibrous tissue formation at the interface.

Two Stage Surgical Protocol/Conventional Loading

Obtaining and maintaining soft tissue coverage for 3 - 6 months.

Maintaining a non-loaded implant environment for 3 - 6 months.

Early Loading

Functional loading no earlier than 48 hours after implant placement and no later than 3 months afterward.

One Stage Surgical Protocol/Immediate Loading

A non-submerged, one-stage surgery which loads the implant within 48 hours of placement.

Osstell Mentor: A unique digital probe that emits and measures implant stability through resonance frequency analysis.

Resonance: a vibration of large amplitude in a mechanical or electrical system caused by a relatively small periodic stimulus of the same or nearly the same period as the natural vibration period of the system.

Resonance Frequency: The tendency of a system to oscillate at larger amplitude at some frequencies than at others.

Resonance Frequency Analysis: Analyzation using classical mechanics to ascertain the nature of the vibrational motion of an object

Implant stability quotient (ISQ): A scale that indicates the level of stability in dental implants. The scale ranges from 1 to 100 and is measured by Osstell instruments. The clinical range of ISQ for osseointegrated implants is normally 50-80.

Assumptions

1. CT evaluations are accurate.
2. Osstell Mentor provides accurate assessment of primary stability.
3. Preserved human maxilla provides close replica of in vivo study.
4. No mechanical variation among same brand implant.
5. Insertion torque greater than 25Ncm indicates primary stability.

Limitations

1. Osteotomy preparations will be performed *in vitro*, which may not correlate directly *in vivo*.
2. Many different implant designs exist. In this study only 3.7mmD x 10mm Zimmer Tapered Screw Vent™Endosseous implants will be examined. Variations may exist among implant design, osteotomy preparation, and primary stability.
3. Variation in bone quality within osseous sample.
4. Variation in Osstell™ probe orientation to SmartPeg™.
5. Variations in attachment torque between SmartPeg™ and implant.
6. Variations between individual SmartPeg™.
7. Human error in osteotomy preparation or implant placement.

Delimitations

1. Computerized Tomography evaluation of osseous sample. CT evaluation will provide Hounsfield Units (HU) which will enable bone typing.
2. CT evaluations will be performed with identical machinery and identical personnel.
3. Implant placement performed by only one clinician
4. Osstell readings performed by only one clinician.

5. Orientation of Osstell probe to SmartPeg™ performed with distance approximations of 2-4mm. Buccal/Lingual/Mesial/Distal measurements to be obtained as close to a 90 degree orientation of probe to SmartPeg™ that is clinically obtainable.
6. Accuracy for variations in attachment torque and individual variations of different SmartPeg™ is +/- 2 ISQ.
7. Osstell Mentor evaluation will provide objective/quantitative means of measuring initial stability.

Literature Review

Two Stage vs One Stage Surgical Protocol

Historically, from his study in bone physiology in rabbits, Bränemark defined osseointegration in 1952 as a direct bone-to-implant contact. It was later re-defined on a functional basis as a direct bone-to-implant contact under load (Branemark, Zarb, and Albrektsson 1985). Branemarks' original dental implant protocol utilized a two-stage surgical protocol/delayed-load approach. This approach was designed to allow adequate direct bone-to-implant contact by allowing 3-6 months of healing time prior to loading mandibular implants and maxillary implants, respectively (Branemark, Zarb, and Albrektsson 1985 ; Misch 2008). This conventional two stage approach has demonstrated excellent outcomes, with success rates ranging from 90-100% (Friberg, Jemt, and Lekholm 1991 ; Henry, Laney, and Jemt 2009, Lazzara et al. 1998 ; Fritz 1999).

Over the last several years major technologic advances have expanded the role of implant dentistry in oral rehabilitations by affording increased success rates, extension of indications, and faster rehabilitation protocols (Drago C.J. 2004 ; Joos and Meyer 2006). These technological advances in implant design, have resulted in the re-evaluation of osseointegration as a predetermined time scale event or an end state of implant healing and has provided the plausibility of accelerated loading protocols.(Drago and Lazzara 2004 ; Joos and Meyer 2006 ; Davarpanah and Szmukler-Moncler 2009). Copper and associates proposed several new terms in an attempt to define different loading protocols. These terms include immediate loading, early/rapid loading, and immediate non-occlusal loading. Immediate loading refers to the prosthetic loading of dental implants with adequate primary stability within 48 hours of placement. Early/rapid loading refers implant loading within 48 hours of placement. Immediate non-occlusal loading refers to provisionalization without occlusal contact following 48 hours of placement (Cooper et al. 2005).

Research shows high success rates in immediate loaded dental implants (Eliyas and Al-Khayatt 2008 ; Drago and Lazzara 2004 ; Siddiqui et al. 2008 ; Tarnow, Emtiaz, and Classi 1997 ; Drago and Lazzara 2004). Tarnow and co-workers completed a study in which multiple implants were placed in 10 patients with edentulous mandibles. The implants were immediately restored with a prosthesis which provided cross arch stabilization. Post-placement examinations at 1-5 years, 67 of the 69 implants were osseointegrated, a 97.1% success rate (Tarnow, Emtiaz, and Classi 1997). In another study by Drago and Lazzara, 93 implants were placed in 38 partially edentulous patients.

The implants were immediately provisionalized with fixed crowns and kept free from occlusion. Definitive restorations completed 8-12 weeks post placement. At 18 month evaluation, a 97.4% survival rate was observed (Drago and Lazzara 2004). Cooper and colleagues conducted a study in which 54 implants were immediately loaded and at 18 months reported a 100% survival rate (Cooper et al. 2002). The one-stage protocol or immediate load has shown high success rates comparable to the conventional two-stage protocol or delayed-load (Cooper et al. 2002 ; Drago and Lazzara 2004). Citing more than 25 years of experimental and clinical research, Buser et al., states "scientific evidence suggests that non-submerged titanium implants predictably achieve osseointegration as do submerged implants." Buser et al. also states a higher degree a primary stability is required for the immediate load of dental implants (Buser et al. 1999).

However, even with this evidence, some studies still support increased healing time prior to loading a dental implant. Brunski and colleagues demonstrated that fibrous connective tissue encapsulations can form around immediately loaded implants, stating that an unloaded, stress-free healing period encourages direct bone-implant contact (Brunski 1999). Various authors show that failures associated with infiltration of fibrous connective tissue can be associated with inadequate primary stability (Seong et al. 2009 ; Szmukler-Moncler et al. 1998). A satisfactory clinical outcome in dental implant treatment relies on primary stability for immediate load bearing. Elimination or minimization of micromotion (i.e. maximizing primary stability) is essential in the osseointegration of dental implants, regardless of the one or two stage approach. As stated above, it has been shown that immediate loading have become a predictable option for treatment. One of the primary requirements, if not, the main requirement for immediate loading success is achieving primary stability. (Turkyilmaz et al. 2008 ; Brouwers et al. 2008 ; Deng et al. 2008 ; O'Sullivan, Sennerby, and Meredith 2000 ; Song, Jun, and Kwon 2009 ; Seong et al. 2009)

Primary Stability

The primary stability of dental implants refers to the resistance to micromotion immediately post-placement. Secondary implant stability refers to the increase in implant stability over time, which is attributable to bone formation and remodeling at the implant/tissue interface and in the surrounding bone (Meridith 1998). A study by Lopez et al quotes, “The most important requirement in oral implantology is to achieve and maintain fixation stability…” (Lopez et al. 2006). Friberg et al. reported an implant failure rate of 32% for those implants that showed inadequate initial stability (Friberg, Jemt, and Lekholm 1991). Primary implant stability has been established as a pre-requisite and predictor to achieving full osseointegration. Primary stability is integral not only as part of the traditional two-stage approach but also following one-stage surgery and subsequent immediate loading of dental implants (Seong et al. 2009 ; Brouwers et al. 2008, Dilek, Tezulas, and Dincel 2008, Okazaki et al. 2008).

Three main points regarding the relevance of primary stability or interfacial micromotion were established by Szmukler-Moncler etal (1998), Brunski (1991), Brunski (1999) and Pilliar (1991). First, it is the absence of excessive micromotion at the bone-implant interface that is critical to osseointegration, not the absence of loading. Second, the timing in which excessive micromotion occurs is critical to the healing process. Early micromotion can damage the tissue and vascular structures, damages early scaffolding from the fibrin clot, impairs formation of new vasculature, and impairs the colonization of regenerative cells to the implant-bone interface. This results in the colonization of collagenous scar tissue as opposed to the colonization of bone. Third, maximum amount of interfacial micromotion allowable is approximately 100 microns (Szmukler-Moncler et al. 1998 ; Brunski 1991)

Primary stability can be effected by variety of factors which include, surgical placement technique, implant design/geometry, local bone quality, and local bone quantity (Turkyilmaz et al. 2008). Primary stability is especially important in low density bone, where implant failures are more likely. The quality of bone is an important factor in the successful implant treatment, and it is evident that higher implant failure rates are more likely in poor quality bone (Abrahams, Frisoli, and Dembner 1993 ; Bahat 1992 ; Agliardi et al. 2008 ; Bahat 1993 ; Fenner et al. 2009).

Measuring Primary Stability

As noted previously, primary implant stability has been established as a pre-requisite and predictor to achieving full osseointegration (Seong et al. 2009 ; Brouwers et al. 2008, Dilek, Tezulas, and Dincel 2008, Okazaki et al. 2008). Therefore, several methods have been employed in the attempt to measure implant stability. These methods include radiographic evaluation (Pikner and Grondahl 2009 ; Sunden, Grondahl, and

Grondahl 1995) , tapping the implant with a metallic instrument and assessing the emitted sound (Adell, Lekholm, and Brêanemark 1985), Periotest® (gulden, Benshein, Germany) (Schulte and Ukas 1993), Dental Fine Tester® (Kyrocera, Kyoto, Japan), insertion torque measurements, reverse torque measurements (Sullivan et al. 1996), and resonance frequency analysis (Meridith 1998) .

In 1985 Ardell et al. described the method of tapping implants with a loosely held held mouth mirror handle in the assessment of osseointegration. Percussion resulting in a dull or thud sound was said to be proof of soft tissue encapsulation and failure, while percussion resulting in a clear crystalline ring indicated osseointegration (Adell, Lekholm, and Brêanemark 1985).

Radiographic examination can provide information regarding osseointegration at second stage surgery; however, does not provide adequate information in regard to primary stability (Sunden, Grondahl, and Grondahl 1995) .

The Periotest® is marketed as a non-invasive assessment of the osseointegration of dental implants, diagnosis/assessment of periodontopathies, assessment of the occlusal load, and control of the treatment progress (Gulden, Benshein, Germany). The Periotest® utilizes an electromechanical method of measuring mobility, which involves a 4 second interval of 16 electronically monitored mechanical tapping impulses. The longer the tapping mechanism remains in contact with the implant/tooth, the higher degree of mobility present (Periotest manufacture website). Results are expressed as the Periotest values (PTVs), ranging from a negative, −8, to a positive, +50. The lower values represent more rigidity. Literature review of the Periotest reveals poor reliability due to low sensitivity and low resolution (Al-Nawas, Wagner, and Grotz 2006 ; Brouwers et al. 2009 ; Derhami et al. 1995 ; Lopez et al. 2006 ; Meridith 1998). However, an 8 year *in vivo* study of 1182 implants by Oh et al. found a direct correlation between PerioTest value and osseointegration (Oh et al. 2009).

Insertion torque has been advocated as a non-invasive diagnostic tool in assessing primary stability and local bone quality (Neugebauer et al. 2009, Misch 2008 ; Alsaadi 2007 ; Meridith 1998). Insertion torque is a determinate of primary stability therefore exact torque values are critical (Neugebauer et al. 2009 ; Traini et al. 2009). Friberg et al demonstrated a correlation between insertion torque and bone-implant contact through histomorphic and radiographic evaluation (Friberg and Johansson 1995, Friberg and Lekholm 1995) A study by Trisi et al. demonstrated that increasing the peak insertion torque reduces the level of implant micromotion. In addition, dental implants placed in poor quality bone consistently demonstrated higher levels of micromotion. As a result, Trisi et al. recommended caution when utilizing immediate functional load of dental implants in low quality bone (Trisi et al. 2009).

High levels of insertion torque are desirable, however, excessively high insertion torque may lead to bone compression resulting in an peri-implant necrosis, which can cause failure (Neugebauer 2006). Several studies suggest that a definitive upper limit for primary stability has not been established (Al-Nawas, Wagner, and Grotz 2006 ; Sullivan, Sennerby, Meredith 2004). For example, Motoyoshi et al. reported that high insertion torque with mini screws is not always likely to result in necrosis and local ischemia (Motoyoshi et al. 2006).

Two-stage surgical placements of dental implants may only require an insertion torque of 10Ncm while immediate loading requires values between 20-50Ncm (Ottoni 2005). O'Sullivan reported cutting efficiency may differ among implant design resulting variability in insertion torque and higher values of insertion torque indicate higher interfacial stiffness at the implant-bone interface (O'Sullivan, Sennerby, and Meredith 2004) . A study by Friberg et al correlated insertion torque and bone density, indicating that if bone density value is similar, the stability of the implant becomes almost equal, although the insertion torque is different (Friberg et al. 1999).

Carlsson et al. first suggested that the measurement of removal torque strength was a useful indirect biomechanical method to evaluate the bone and implant interface. The reverse torque test involves the application of an invasive counter clockwise torque applied to an implant in order to determine successful osseointegration. This test essentially attempts to unscrew the implant with limited force in order to determine if adequate osseointegration has occurred. In 1996 Sullivan et al concluded reverse torque levels of 10-20 Ncm does not lead to increased failure rates and is beneficial in determining fibrous tissue encapsulation of implants at 2nd stage surgery (Sullivan et al. 1996).

Meredith and associates introduced a non-invasive objective method of measuring primary stability known as Resonance Frequency Analysis (RFA). Both *in vitro* and *in vivo* studies demonstrated a relationship between increased resonance frequency and bone-implant interface stiffness (Meredith et al. 1996). In this technique, the implant is repeatedly exposed to a high energy pulse with probes containing piezoelectric elements, and the resonance frequency (RF) is measured and expressed in units called the implant stability quotient (ISQ) . Resonance frequency analysis (RFA) has been proposed to identify factors which govern implant stability, which include surgical technique, loading protocol, implant design, and implant boundary condition (Meridith et al 1996).

RFA has given the researcher and clinician the possibility of measuring implant stability, as a function of bone–implant interface stiffness, at various time points during the treatment. Various studies have used RFA to monitor implant stability over time revealing a correlation between osseous properties, implant stability, and ISQ. A drop in RFA values/stability reduction in the second thru fourth months post placement are indicative of the bone remodeling stage described by Bränemark et al (Bränemark 1998, Boronat et al. 2006, Barewal et al. 2003, Ersanli et al. 2005). Valderrama et al utilized two different types of RFA devices which both illustrated the initial decreases in implant stability occur following placement, while also illustrating an increase in stability during the first six weeks of functional loading (Valderrama et al. 2009). Sennerby et al. provided three theories relating to post-placement ISQ decreases. First, lateral compression of bone tissue relaxes post insertion resulting in decreased ISQ. Second, loading-induced microfractures lead to decreased ISQ. Third, post-insertion bone remodeling results in a inherent decrease in ISQ. These three theories correlate osseous properties and the bone-implant interface (Sennerby et al. 1993). Roberts et al provided time frames of bone formation and maturation around dental implants which match the

ISQ decreases seen at 1-3 months and ISQ increases at 4-12 months (Roberts et al.1993). Sennerby et al concluded that failing implants show a continuous decrease of stability until failure. Low RFA levels after 1 and 2 months seem to indicate an increased risk for future failures. Avoidance of implant failure may be accomplished by unloading implants with a decreasing degree of stability as diagnosed with the RFA technique (Sennerby et al. 1993). Further studies by Meredith and Rasmusson show increases in RFA for successful implants and a decrease for failing implants (Friberg et al. 226-33). Nedir et al reported maxillary implants with an average of <60 ISQ and mandibular implants with average of >60 ISQ (Nadir et al. 2004). This corresponds to low bone densities found in the maxilla and high densities found in the mandible.

Other studies have shown positive correlations between RFA, histologic bone-implant contact, and removal torque (Rasmusson, Meredith 1997 ; Rasmusson, Meredith, Kahnberg 1997 ; Rasmusson, Meredith, Kahnberg, Sennerby 1999). While Brouwers et al showed no correlation between ISQ values and removal torque (Brouwers et al. 2009). Positive correlations between insertion torque and RFA have been documented (Turkyilmaz 2006 ; Boronat-Lopez et al 2006). Brouwers et al conducted a study on dry human mandibles and concluded RFA reliably measured primary stability (Brouwers et al. 279-83). However, Rabel et al conducted a study assessing the stability of two implant systems concluding variation of ISQ in varying implant system and inadequacy of RFA as the sole determinate of primary stability (Rabel, Kohler, and Schmidt-Westhausen 2007).

Bone Quality/Quantity

The classification for bone quality (Type I thru Type IV) proposed by Lekholm and Zarb has been widely applied by clinicians in evaluating patient bone for implant placement. This subjective classification is based on the clinicians feel to the resistance of the hand piece cutting bone. Type I has the most cortical bone (most dense) while type IV the least cortical bone (Lekholm and Zarb 1985) . Misch also subjectively classified bone quality based on sensations during drilling protocol (Misch 2008) Johansson and Strid developed an objective technique of determining bone density from the torque needed during implant placement (Johansson and Strid 1994) . These methods were helpful in determining bone density, however they were retrospective to patient assessment, osteotomies had already been prepared and implants already placed (Turkyilmaz and McGlumphy 2008).

Currently, computerized tomography is the most accepted method in the objective evaluation of bone, providing 3-dimensional views, cross-sectional views, and bone density values via Hounsfield units. This radiographic method provides the best analysis of morphologic and qualitative characteristics of bone (Turkyilmaz et al. 2006 ; Turkyilmaz et al. 2007 ; Homolka et al. 2002 ; Ikumi and Tsutsumi 2005 ; Lee et al. 2007). Alternative methods for the evaluation of bone quality include histomorphometry of bone biopsy (Blanco et al. 2008), densitometry (Devlin 1998), digital image analysis of micro-radiographs, and ultrasound (Song, Jun, and Kwon 2009).

Bone quality and quantity are the most important factors in the successful osseointegration of dental implants. The correlation between primary stability and bone density is well established. Increased bone density is associated with increased implant stability and higher success rates. Conversely poor bone quality is associated with lower implant stability and lower success rates. Physical bone properties vary significantly depending on the anatomical location of maxilla and mandible (Seong et al. 2009). The posterior maxilla is consistently associated with poor bone density, type IV and type V bone. The quality of bone is often referred to in the implant literature as the amount of cortical and trabecular bone bed in which the recipient socket is drilled (Jaffin and Berman 1991 ; Seong et al. 2009 ; Song, Jun, and Kwon 2009). Low bone density (Type IV bone) at the site of implant placement has been associated with increased risk of implant failure in both retrospective (Jaffin and Berman 1991) and prospective investigations (Hutton et al. 1995). The investigation by Hutton et. al., also indicated that patients with low quantity and low density of bone were at highest risk for implant loss. Studies by Jaffin and Berman demonstrated that only 3% of Brånemark System implants (Nobel Biocare, Göteborg, Sweden) placed in type I, II, and III bone failed after 5 years. Whereas implants placed in type IV bone had a 35% failure rate over the same period (Jaffin and Berman 1991). In a similar study, Van Steenberghe and associates found more failures in the maxilla with poor bone quality. Due to the significant correlation between implant successes, osseous properties, and anatomical variation, proper assessment via computerized tomography can provide predictable implant therapy (Williams, Mealey, and Hallmon 1991 ; Turkyilmaz et al. 2007 ; Turkyilmaz et al. 2008 ; Turkyilmaz et al. 2006 ; Song, Jun, and Kwon 2009 ; Rothman 2009 ; Kobayashi et al. 2004 ; Ikumi and Tsutsumi 2005).

Computed-Tomography Evaluation

The strong correlations between bone quality/quantity and implant success rates require a more objective modality in the evaluation of osseous architecture in order to provide predictable dental implant therapy. Computerized tomography has provided an objective method for the evaluation of bone in 3-dimensions, providing cross-sectional images, quantification of trabecular/cancellous bone mineral densities, more accurate images(less distortion), and direct assessment of bone density in Hounsfield units (Shahlaie et al. 2003 ; Turkyilmaz et al. 2007 ; Turkyilmaz 2008 ; Sennerby 2008 ; Shahlaie 2003 ; Norton 2001 ; Shapurian 2006). A study by Friberg et al correlated insertion torque and bone density, indicating that if bone density value is similar, the stability of the implant becomes almost equal, although the insertion torque is different (Friberg et al. 1999). Bone density directly influences primary stability, thus predicting primary stability is possible via Hounsfield units obtained by CT evaluation(Turkyilmaz et al. 2008 ; Turkyilmaz 2009).

Alternative Implant Placement Techniques

As previously stated, initial stability depends on the macroscopic and microscopic design of the implant, bone quality, and surgical technique (Meredith 1998). The posterior maxilla is often associated with poor quality bone (Type III and IV bone) (Lekholm and Zarb 1985 ; Ulm et al. 1999 ; Ulm & Tepper 2004). The posterior maxilla is associated with increased dental implant failures (Jaffin and Berman 1991 ; Balshi, Lee, and Hernandez 1995 ; Balshi and Wolfinger 1999 ; Jemt and Lekholm 1995). Several studies have demonstrated the use of modified surgical techniques in the enhancement of primary stability of dental implants in the posterior maxilla. Furthermore, results of these studies show success rates similar to other regions with good bone quality. (Bahat 1992 ; Bahat 1993 ; Bahat 2000 ; Bahat 2009 ; Venturelli 1996 ; Fernandez and Fernandez 1997). Modified surgical techniques include modifications in osteotomy diameter, drilling protocols, irrigation protocols, condensing protocols.

An alternative drilling procedure designed to preserve peri-implant tissue was introduced in 2007 by Anitua et al. The technique involves a pilot drill with a very sharp tip rotating at 800rpm with serum irrigation. Subsequent drilling is performed at 50 rpm without irrigation. Implant placement completed at 15-20 rpm without irrigation. Drills are designed to collect autogenous bone from osteotomy preparation and mixed with a platelet rich growth factors (PRGF) in order to create a platelet rich fibrin matrix. This technique is designed to obtain autogenous bone during preparation and to restrict the washing away of signaling proteins and other soluble substances that play an active role in bone regeneration (Anitua 2007). Flood irrigation with apyrogen water or saline can drag and dissolve osteoconductive signaling proteins found within bone, hence stripping the tissue of the natural resources it uses to heal itself (Uchida 2003 and Bennett 1993).

The condensing osteotome technique also known as trabecular compaction or corticalization was developed to increase bone density in the attempt to achieve primary stability of dental implants in poor bone quality (Summers 1994 ; Summers 1994). This technique utilizes tapered hand instruments which compress the trabecular bone laterally and apically, while also allowing for the expansion of alveolar ridge and elevation of sinus floor (Horowitz 1997 ; Komarnyckyj and London 1998 ; Deporter, Todescan, and Nardini 1999 ; Fugazzotto 1999 ; Hahn 1999). The goal of this technique is to achieve higher levels of primary stability with minimal removal of bone (Shalabi 2007). Several studies indicate high primary stability and high success rates utilizing the condensing osteotome technique (Fagazzotto 2002, Komarnyckyji 1998, Rodoni LR 2005, Emmerich et al. 2005, Shalabi et al 2007).

A similar method used to enhance the primary implant stability is to place the implant into a smaller diameter osteotomy than is usual. This technique has been termed the undersized drilling technique or the drilling osteotome technique (Shalabi 2007, Fanuscu 2007). Studies suggest that using thinner drills for implant placement in the maxillary posterior region where bone quality is poor may improve the primary implant stability, which helps clinicians to obtain higher implant survival rates. The amount of undersized drilling can be determined by bone density. Basically the difference between the drilling osteotome technique and the condensing osteotome technique is the amount of bone compression(Shalabi 2007).

Another alternative surgical technique for increasing primary stability in compromised bone involves a stepped preparation technique described by Dr. Oded Bahat in 2009. An altered drilling protocol was utilized in the placement of the Replace Tapered implant. This technique utilized straight drills in the osteotomy preparation instead of the tapered or stepped drills (Nobel Biocare, Yorba Linda, CA) provided by the

Replace Tapered implant drilling sequence. The tapered/stepped drills are intended for all bone densities. Therefore, when poor quality bone is encountered the custom stepped preparation can be employed to enhance primary stability and increase success rates in poor quality bone (Bahat 2009). In a study involving 290 implants in 126 patients, Bahat reported a 99..3% cumulative success rate. This technique creates an apically undersized preparation, thereby reducing the amount of condensing forces on the surrounding bone. Recent studies have shown good results in soft as in dense bone (Friberg et al. 1997 ; Bahat 2000). It may be speculated that this is attributed to changes of the surgical technique in order to reach firm primary stability, including reduced drill diameters, the use of self-tapping implants, wider implants and tapered implants.

Compressive Forces

Compressive forces are set up along the implant/tissue interface, which enhance the implant stability. These compressive forces are related to the quality of the bone and the mismatch between the osteotomy and the implant diameter and are relatively evenly distributed along the length of the implant/tissue interface. This technique has the disadvantage that it is highly operator sensitive and subjective, with no way of quantifying the degree of compression generated in the bone. Theoretically, it has also been shown by (Clelland 1993) that maximum stress and strain in a poor bone model were concentrated around the apex of an implant, and this maximal stress or strain occurs in a tissue that may be expected to perform poorly under increased stress or strain. In a combined cortical/cancellous bone model, the maximal stress or strain occurred in the cortical bone layer, which may be expected to cope with the mechanical stress/strain much better. Theoretically, it may be suggested that when placing an implant into a bone of poor quality the ideal technique should ensure that the region of maximal compression should lie in the cortical bone and not within the cancellous region.

One suggested approach to enhance primary stability in poor bone quality is to insert a tapered implant into a standard parallel-sided hole. The idea behind this approach is to induce controlled compressive forces in the cortical bone layer as the implant is inserted; these forces would increase the primary stability of the implant, and would transfer the region of highest stress or strain to the cortical layer where it will be better tolerated. This technique has been used commercially in the development of the Mark IV implant (Nobel Biocare AB, Gothenburg, Sweden (Darle & Jorneus 1998; Martinez et al. 2001). One question that may arise is how much compression is advantageous and are there any deleterious effects of inducing such high compression in the cortical bone. In theory if compression is too high there may be cell death and necrosis leading to reduced stability in the cortical layer (Ueda et al. 1991).

The theory behind the use of the tapered implants in this study is to induce a degree of compression of the cortical bone in a poor bone implant site. This degree of compression is related to three factors: the degree of taper of the implant, the relationship of the final drill diameter used to the maximum diameter of the implant and the mechanical properties of the bone itself.

In addition, the degree of compression generated by the implant is very high and may be expected to cause local cellular damage in the cortical bone. A very high compression of the bone is known to cause cell death, necrosis and ultimately may lead to bone resorption in the cortical bone layer (Ueda et al. 1991). Soltesz et al. (1982) and Huiskes et al. (1984) have shown a direct correlation between high stressed regions and bone resorption by comparing experimental observations with numerical calculations.

Materials and Methods

Sixteen preserved human cadaver heads were obtained from the West Virginia University Anatomy Department following dissection from by the Medical and Dental Schools. The cadaver heads were preserved with Carolina Perfect Solution® embalming fluid with Phenol (Carolina Biological Solution). Number 90 gutta percha cones were placed 10mm apart in edentulous areas to provide reference points. Spiral CT scans of each cadaver specimen were obtained with the WVU Radiology Department (Toshiba Aquilion 64 CT scanner).

CT evaluation was utilized in the determination of appropriate implant recipient sites and bone density in Hounsfield Units (HU). Appropriate osseous samples were defined by 150-350 mean HU's, 10mm vertical height, 5mm buccal lingual width, and 11mm mesial-distal length.. The 11mm mesial-distal lengths allowed adequate space for a control group to be placed directly adjacent to an experimental group. The eFilm Lite viewer provided Unenhanced/Brain 1.0 Bone Sharp Axial and Coronal views which aided in determining osseous volume for implant recipient sites. With the eFilm Lite viewer expanded toolbar, linear measurements were obtained in centimeters to determine adequate osseous volume. The Unenhanced/Brain 1.0 Sharp Axial view was utilized for determination of osseous density in mean HU's for implant recipient sites. The elliptical measurement tool using varying square centimeter ellipses provided a mean HU for the recipient sites. Each square centimeter ellipse was made large enough to provide one mean HU measurement for the two adjacent control and experimental groups. A conventional osteotomy and a modified stepped osteotomy were placed adjacent to each other in all cases. Each HU measurement was made 5mm from the crest of the ridge.

After the appropriate implant recipient site in each cadaver sample was located implant surgical placements commenced. A full thickness surgical flap with 1-2 releasing incisions was utilized to provide direct visual access to each surgical site. Alveoplasties were not utilized.

The control group consisted of 11 conventional osteotomy sites. Conventional osteotomies were prepared with the Zimmer Dental© (Carlsbad, CA) recommended drill sequence beginning with a 2.0mm pilot drill, followed by a 2.3mm surgical drill to 10mm depth, 2.8mm surgical drill to 10mm depth, and 3.4mm surgical drill to 10mm depth. Each implant was inserted with the Zimmer Implant Motor set a maximum of 35Ncm. Each implant was torqued until flush with the osseous crest. IT measurements were provided by the Zimmer Implant Motor System and confirmed with the SPI Thommen® (Waldenburg, Switzerland) one piece adjustable torque driver.

SmartPegs™ were then screwed onto each Zimmer Tapered Screw Vent endosseous implant with the Osstell driver. Primary stability evaluation was obtained with the Osstell Mentor™ (Integration Diagnostics AB, Göteborg, Sweden), utilizing RFA and conversion to ISQ. The Osstell calibration was confirmed prior to each reading. One reading were taken from the buccal and one reading were taken from the mesial. The two Osstell readings were averaged.

The experimental group consisted of 11 modified stepped osteotomy sites. Modified stepped osteotomies were prepared with the alternate drill sequence beginning with a 2.0mm pilot drill to 10mm depth, followed by a 2.3mm *driva* surgical drill to 10mm depth, 2.8mm *driva* surgical drill to 7.0mm depth, and 3.4mm *driva* surgical drill to 4.0mm depth. Each implant was inserted with the Zimmer Implant Motor set a maximum of 35Ncm. Each implant was torqued until flush with the osseous crest. IT measurements were provided by the Zimmer Implant Motor System and confirmed with the SPI Thommen® (Waldenburg Switzerland) one piece adjustable torque driver. SmartPeg™ were then screwed onto each Zimmer Tapered Screw Vent endosseous implant with the Osstell driver. Primary stability evaluation was obtained with the Osstell Mentor™ (Integration Diagnostics AB, Göteborg, Sweden), utilizing RFA and conversion to ISQ. The Osstell calibration was confirmed prior to each reading. One reading were taken from the buccal and one reading were taken from the mesial. The two Osstell readings were averaged.

Matched paired t-tests were utilized to assess differences between of IT and ISQ in the conventional osteotomy and the modified stepped osteotomy. Wilcoxon Signed Rank t-tests were utilized to assess differences between of IT and ISQ in the conventional osteotomy and the modified stepped osteotomy. Statistical Pearson correlations were utilized to assess the correlations between osteotomy type, IT, and ISQ. Differences were be considered significant when $P < 0.05$.

Results

Spiral computerized tomography (CT) was performed on 16 human cadaver heads. CT evaluation was utilized in the determination of appropriate implant recipient sites within the limits of this study. Maxillary cadaver bone utilized in this study ranged from 173.4 – 312.1 HU. Nine human cadaver heads processed the defined appropriate implant recipient sites and a total of 22 implants were placed. Eleven implants were placed in the straight osteotomy test group and eleven implants were placed in the step back osteotomy test group. Table 1 shows the raw data of the study.

Arithmetic means of insertion torques in the conventional osteotomy and the modified stepped osteotomy were calculated. Insertion torque values in the conventional osteotomy group ranged from 5Ncm to 30Ncm. Insertion torques in the modified stepped osteotomy group ranged from 15Ncm to 40Ncm. The mean insertion torque in the conventional osteotomy group was 15.91Ncm. The mean insertion torque in the modified stepped osteotomy group was 26.82Ncm. Effects of osteotomy preparation on insertion torque can be seen in Graphic 1 and Graphic 2.

Arithmetic means of ISQ in the conventional osteotomy and the modified stepped osteotomy were calculated. ISQ values in the conventional osteotomy group ranged from 43-67 ISQ with a mean of 61.6 ISQ. ISQ values in the modified stepped osteotomy ranged from 51-75 ISQ with a mean of 66.30 ISQ. Effects of osteotomy preparation on ISQ can be seen in Graphic 3 and Graphic 4.

A Wilcoxon Signed Rank test also showed the modified stepped osteotomy had a significantly greater mean insertion torque than the conventional osteotomy (S = 0.0010, P = 0.05). See Table 2. A Wilcoxon Signed Rank test showed no significant difference between ISQ in the conventional osteotomy group and the modified stepped osteotomy test group (S = 0.0010, P = 0.05). See Table 2.

Pearson correlations showed a significant positive correlation between the insertion torques in the conventional osteotomy test group and the modified stepped osteotomy test group. There were no significant correlations between the ISQ's in the conventional osteotomy test group and the modified stepped osteotomy group. There were no significant correlations between ISQ and IT in the conventional osteotomies. There were no significant correlations between ISQ and IT in the modified stepped osteotomies. See Table 3. See Graphic 5.

Discussion

In the present study, IT and ISQ values of implants placed by either a conventional or a modified stepped technique in Misch Type D4 were analyzed. Comparisons and correlations of primary stability parameters (IT, ISQ) to bone density (HU) were made. Primary implant stability has been established as a pre-requisite and predictor to achieving full osseointegration (Seong et al. 2009 ; Brouwers et al. 2008, Dilek, Tezulas, and Dincel 2008, Okazaki et al. 2008). Primary stability is especially important in low-density bone, where implant failures are more likely. Three main factors affect primary stability: surgical placement technique, implant design/geometry, local bone quality, and local bone quantity (Turkyilmaz et al. 2008).

Bone density is an important factor in dental implantology parmarily because initial implant stability is commonly not easily achieved in low-density bone. Preoperative assessment of bone quality/quantity allows the clinician to plan alternative surgical techniques, procedures, and utilize appropriate dental implant designs when varying osseous densities and volumes are encountered. A subjective assessment of bone density was proposed by Lekolm and Zarb (1985), which used conventional radiographs to classify bone into Types I – IV. Misch (1993) improved this subjective classification system by utilizing CT to obtain a quantitative range of HU and classify bone into Class D1-D5. The present study utilized the Misch bone density classification.

Our study utilized CT evaluation of 16 cadaver heads to preoperatively determine areas of Class D4 bone with adequate volume for implant placement. Of the 16 cadaver heads scanned only nine possessed adequate volume in Class D4 bone. In the present study, the recorded bone density values ranged from 173.4 – 312.1 HU with mean of 261.2 HU. These values are lower than the mean maxillary HU recorded in previous studies. A study by Norton and Gamble stated that the mean bone density in the anterior and posterior maxilla as 696.1 HU and 417.3 HU, respectively (Norton 2001) . Shapurian et. al.reported that the mean bone density value in the anterior and posterior maxilla as 517 HU and 333 HU, respectively. (Shapurian 2006). Fuh et al. reported the mean bone density value in the anterior maxilla and posterior maxilla as 516 HU and 332 HU, respectively (Fuh 2010). The differences in mean HU may be a result from the variations in patient-related factors (i.e.. age, gender). The differences may also be a result of the formalin fixation of the embalm cadaver specimens. An assessment of CT densitometry on formalin-fixed and frozen human tissue, indicates that formalin-fixed specimens have the least change in 6% formalin and higher and lower concentrations of formalin caused considerable changes in radiation absorption. (Schmitt 1980). The formalin fixation of cadavers can also have an effect on the biomechanics of bone and may not mimic the *in vivo* testing (Wilke 2006). A study by Fonseca reported radiographic optical density of rabbit tibiae stored in 10% formalin decreased with time, suggesting the occurrence of bone demineralization (Foneseca 2008). Carolina Perfect Solution® with phenol was the embalming fluid used in this study, it consists of only 2% formalin.

The method of HU measurement is highly variable in the eFilm Lite Viewer program. The program utilized an elliptical tool that traced varying volumes of bone in either the axial or coronal view to provide an HU measurement for that given volume. HU measurements varied by volume and location of the elliptical tool. In an attempt to standardize HU measurements, all recordings of HU made in this study were 5mm from the crest in the axial view. Each elliptical HU measurement incorporated the volume of bone which received one conventional osteotomy (control) and one modified stepped osteotomy (experimental). For each measurement of HU there was a control and experimental osteotomy. In all cases there was a control and experimental osteotomy placed 3-4mm adjacent to one another.

Our study showed significant differences in the insertion torque values of the conventional osteotomy as compared to the modified stepped osteotomy (graphic 1). No significant differences were found in ISQ in the conventional verses the modified step osteotomy. No correlations between IT and ISQ existed in this study. There has been varying reports in the literature regarding the efficacy of RFA and the correlations between IT and ISQ. Turkyilmaz et. al. reported a clinical study in which 60 implants were placed in the posterior maxilla with two different surgical techniques. The result of their study showed significant differences and significant correlations between the osteotomies in terms of IT and ISQ, suggesting the utilization of thinner drills for implant placement in the maxillary posterior region where bone quality is poor may improve the primary implant stability (Turkylimaz 2008). Several studies have demonstrated the use of modified surgical techniques in the enhancement of primary stability of dental implants in the posterior maxilla. Furthermore, results of these studies show success rates similar to other regions with good bone quality. (Bahat 1992 ; Bahat 1993 ; Bahat 2000 ; Bahat 2009 ; Venturelli 1996 ; Fernandez and Fernandez 1997). Modified surgical techniques include modifications in osteotomy diameter, drilling protocols, irrigation protocols, condensing protocols. Kahraman et. al. also reported a clinical study with strong correlations between insertion torque and ISQ (Kahraman 2010). Whereas Sakoh et. al. reported findings similar to our study in regard to the correlation of IT to ISQ. They conducted a study in which two types of implants were placed in different osteotomies and primary stability was recorded with IT, RFA and the Periotest. They concluded the procedure of under-dimensional drilling increased primary stability for both types of implants, however, the effect was only seen in values of IT and not ISQ or the Periotest (Sakoh 2006).

In a review of the literature, studies indicate that implant design may influence the correlation between IT and ISQ. Most of the studies showing a correlation between IT and ISQ had been undertaken on Bränemark implants and cutting-torque measurements carried out with uncalibrated OsseoCare™ units. Rabel et. al. conducted a study assessing the stability of two implant systems and found that within the implant systems no correlation could be made between IT and ISQ. Interestingly they suggested that ISQ obtained from different implant systems may not be comparable and that ISQ alone is not suitable for the evaluation of implant stability (Rabel 2007, Friberg 1999, Akkocaoglu 2007, Da Cuhna 2004, Degidi 2007, Nkenke 2004, Schliephake 2006). Friberg et al. and Da Cunha et al. reported no relationship between insertion torque and ISQ values, probably due to the two different types of implants that were used (Friberg1999; Da Cunha 2004). A cadaver study by Akkocaoglu et. al. could not determine correlation between IT and ISQ using Straumann implants and a clinical study by Degidi et. al. using Xive implants could not find correlations between IT and ISQ (Akkocaoglu 2007, Degidi 2007). Likewise, Nkenke et. al and Schliephake et. al found no correlations between IT and ISQ using Frialt 2 implants and experimental implants, respectively (Nkenke 2004, Schliephake 2006). In the present study, Zimmer Screw Vent Implants™ were used. More studies are need in examination of correlation of IT to ISQ and more implant designs need to be utilized in these studies.

In the present study the mean ISQ in the conventional osteotomy group and modified stepped osteotomy was 61.6 HU and 66.3 HU, respectively. Sennerby and Meredith; Östman, et al; Sjöström, et al and Glauser, et al. reported studies which suggest acceptable stability range lies between 55 and 85 ISQ, with an average ISQ level of 70. Again these studies utilized Mark III Bränemark implants. According to these studies one would infer that the implants utilized in this study in both osteotomy groups could accept load in both osteotomy groups. In contrast, IT measurements in present study would question the application of load to either osteotomy group. Zix et. al attempted to determine standard ISQ values for apparently successfully osseointegrated 1-stage implants in maxilla. After looking at 120 ITI implants they reported that single RFA measurements of an implant do not allow assessment of an implants' current status or prediction of its performance. They reported no significant differences in ISQ values were found between implants with regard to loading period or location in the jaw. Implying that each implant has an ISQ value of its own and should be recorded over a period of time for ISQ to be of value (Zix 2005). In contrast, a 2009 meta-analyis of methods used to assess implant stability by Cehreli et. al. reported a significant correlation between insertion torque and RFA (Cehreli 2009). No correlations between IT, ISQ, HU were reported when Cehreli et. al. performed their own study even though they used MarkIII TiUnite Bränemark implants.

Another theory behind the lack of variation of ISQ in the conventional osteotomy and the modified stepped osteotomy may be the result of the diameter of the drill used at the coronal portion of the osteotomy. At the completion of both osteotomies the diameter at the most coronal portion measured 3.4mm. ISQ values are governed by the bone surrounding the implant neck (Akkocaoglu et al. 2005 ; Ito et al. 2008). The fact that both osteotomies had the same diameter at the neck of the implant could be attributed the lack of ISQ variation between the conventional and modified stepped osteotomies, despite the increased IT and under preparation of the apical portion of the modified stepped osteotomy.

In the present study correlations between IT and HU were only found to be significant in the modified stepped osteotomy. IT in the conventional osteotomies and HU did not have significant correlations. No significant correlations were found between ISQ and HU in either osteotomy. Again conflicting reports exist regarding correlations between ISQ and HU, as they do for correlations between ISQ and IT. Turkyilmaz et. al. has reported five studies all of which have found ISQ, IT, and/or HU to be significantly correlated to one another (Turkyilmaz 2006, 2007, 2008, 2008, 2009). The small study population may be an explanation for our lack of correlations. Only Misch Class D4 (150-350 HU) bone was utilized in this study and the HU ranged from 173.4-312.1. This range of HU (138.7 HU) is much narrower than other studies and may hamper the ability to draw statistical correlations of HU to implant stability parameters. Cehreli et. al. conducted a cadaver study in which implant IT, ISQ, and HU were assessed in conventional and osteotome surgical techniques. This study reported similar results in that only one group (osteotome) showed significant correlation to HU, but no other correlations could be found between IT, ISQ and/or HU.

Conclusion

Within the limits of the study, the following conclusion can be drawn:

I. The modified stepped osteotomy resulted in significantly greater implant stability in terms of insertion torque (IT) than the conventional osteotomy in Misch Class D4 bone.

II. Significant correlations were found between the insertion torque (IT) produced in the modified stepped osteotomy and bone density (HU). No other correlations between insertion torque (IT) and bone density (HU) were found.

III. No correlation could be found between insertion torque (IT) and Implant Stability Quotient (ISQ).

IV. No correlation could be found between Implant Stability Quotient (ISQ) and bone density (HU).

Appendix A

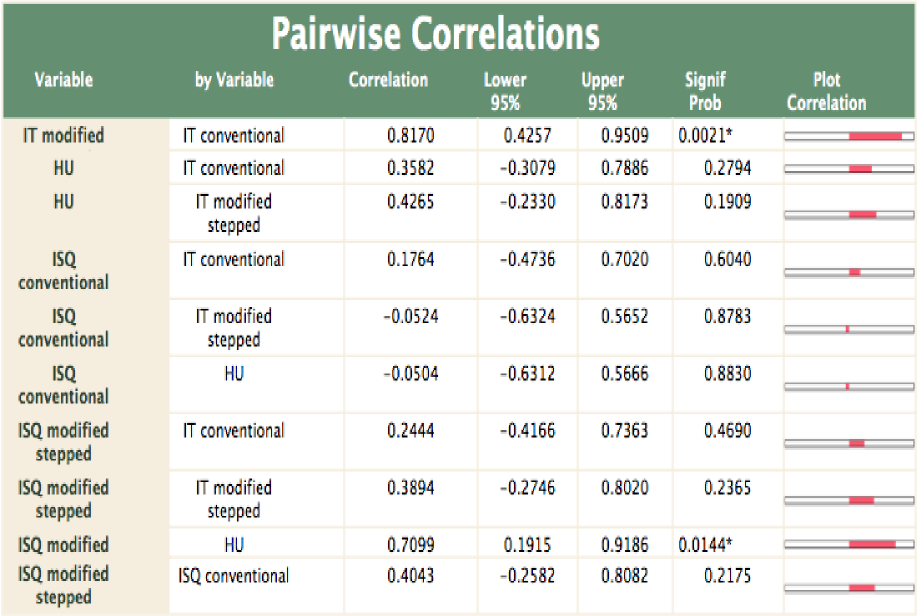
Table 1: Raw Data

Cadaver	ITc	ITe	HU mean	ISQ conventional mean	ISQ modified step mean
A	30	40	303.70	75.50	74.50
B	5	10	226.18	67.00	65.25
C	35	45	280.75	56.00	66.50
D	15	35	240.72	66.00	75.00
F	5	15	248.25	68.50	66.50
F	10	20	256.80	43.00	59.50
G	20	25	274.90	67.00	69.25
G	10	35	312.10	49.50	71.00
J	15	25	258.70	59.75	61.00
M	15	25	173.40	61.00	51.25
N	15	20	297.30	64.50	69.50
Mean	**15.91**	**26.82**	**261.16**	**61.61**	**66.30**

Table 2

Wilcoxon Signed Rank		
	IT stepped – IT conventional	ISQ stepped – ISQ conventional
Test Statistic S	33.000	17.000
Prob>|S|	0.0010*	0.1475
Prob>S	0.0005*	0.0737
Prob<S	0.9995	0.9263

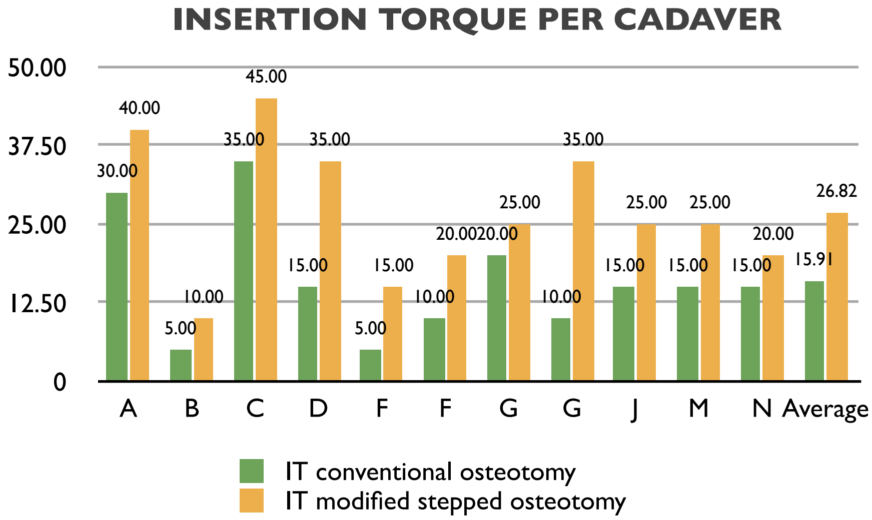
Table 3



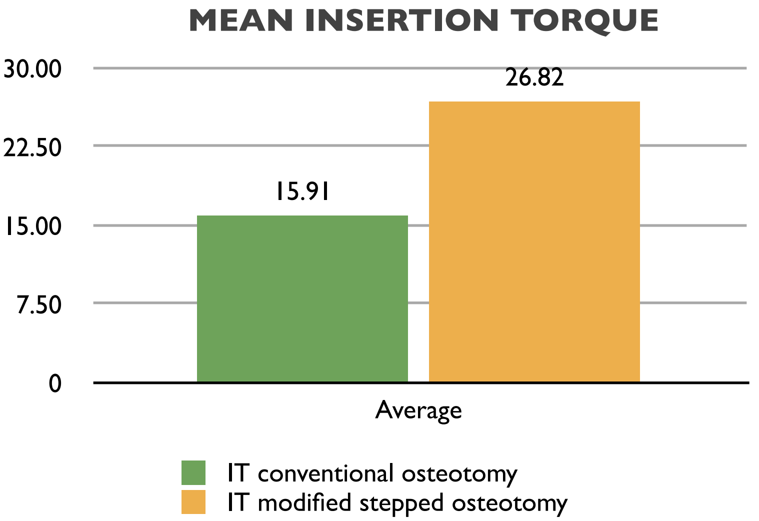
Pairwise Correlations

Variable	by Variable	Correlation	Lower 95%	Upper 95%	Signif Prob	Plot Correlation
IT modified	IT conventional	0.8170	0.4257	0.9509	0.0021*	
HU	IT conventional	0.3582	-0.3079	0.7886	0.2794	
HU	IT modified stepped	0.4265	-0.2330	0.8173	0.1909	
ISQ conventional	IT conventional	0.1764	-0.4736	0.7020	0.6040	
ISQ conventional	IT modified stepped	-0.0524	-0.6324	0.5652	0.8783	
ISQ conventional	HU	-0.0504	-0.6312	0.5666	0.8830	
ISQ modified stepped	IT conventional	0.2444	-0.4166	0.7363	0.4690	
ISQ modified stepped	IT modified stepped	0.3894	-0.2746	0.8020	0.2365	
ISQ modified	HU	0.7099	0.1915	0.9186	0.0144*	
ISQ modified stepped	ISQ conventional	0.4043	-0.2582	0.8082	0.2175	

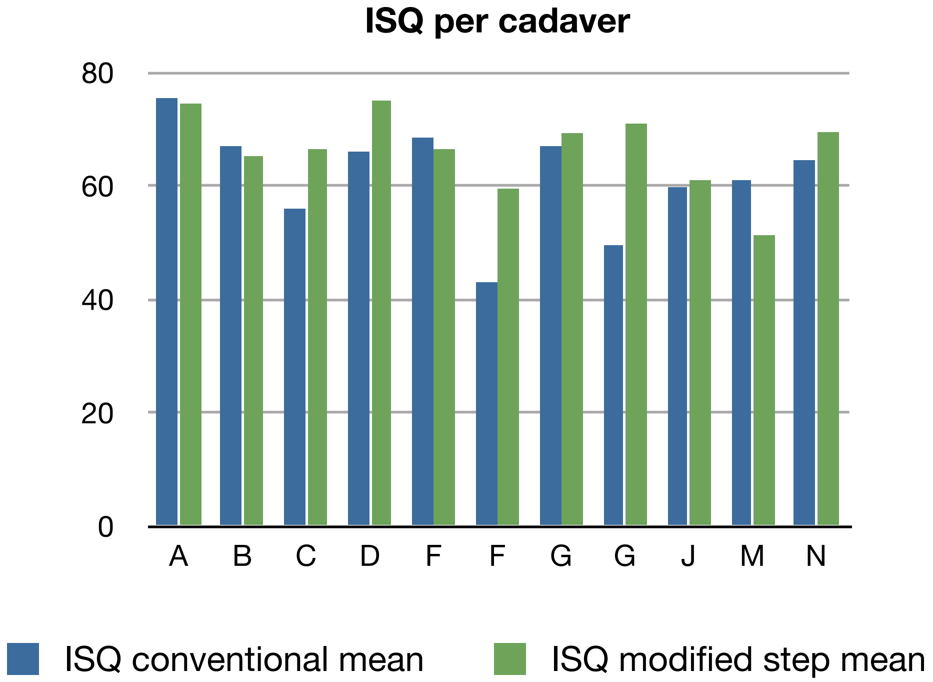
Graphic 1



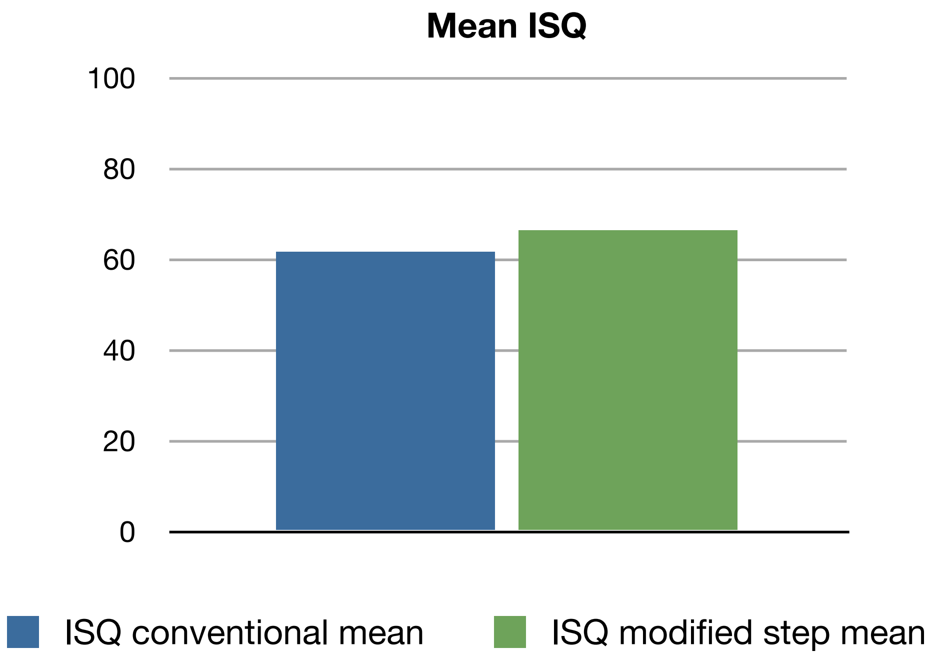
Graphic 2



Graphic 3

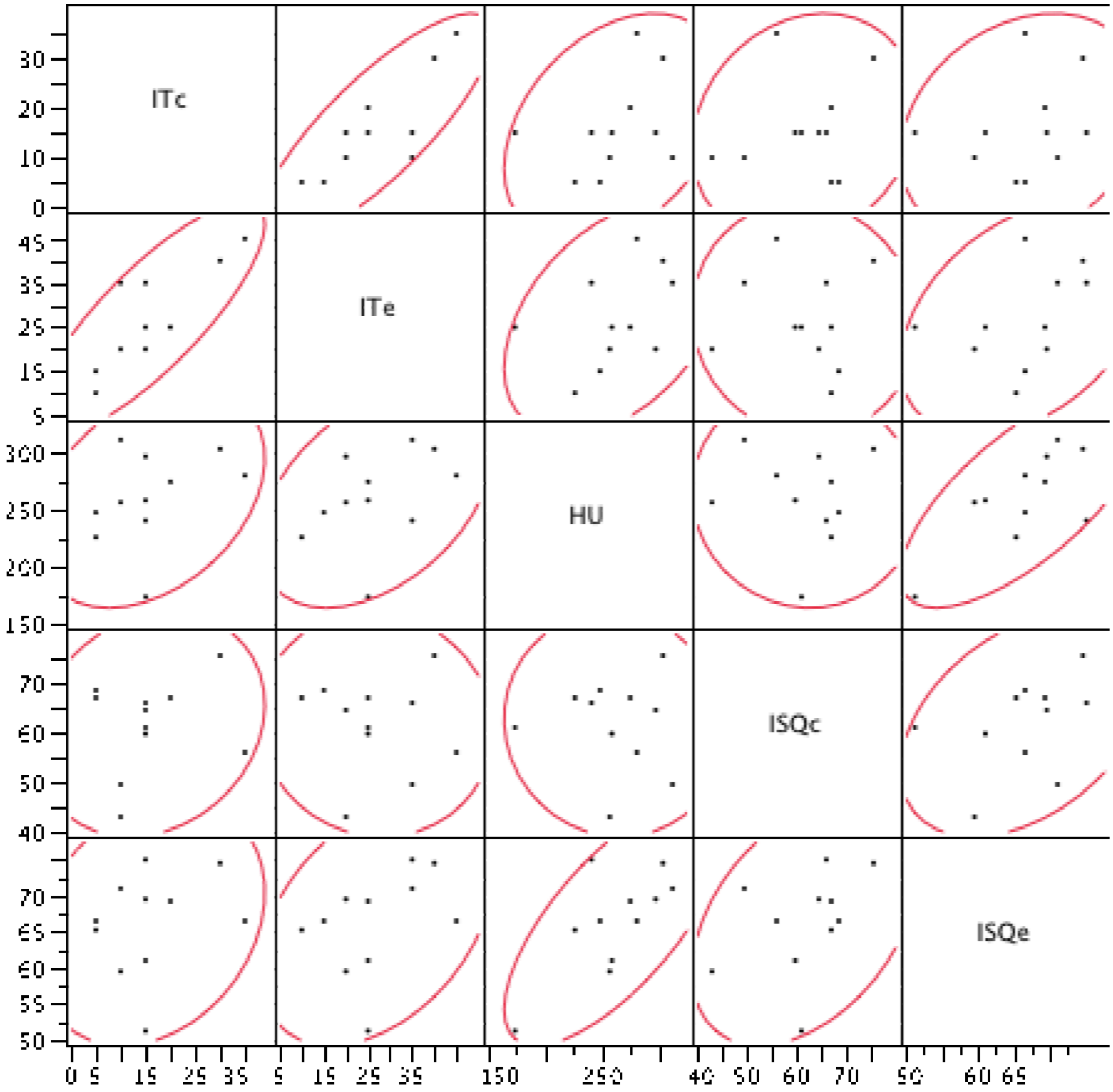

ISQ per cadaver
80
60
40
20
0
A
B
C
D
F
F
G
G
J
M
N
ISQ conventional mean
ISQ modified step mean

Graphic 4


Mean ISQ
100
80
60
40
20
0
ISQ conventional mean
ISQ modified step mean

Graphic 5

Pearson Correlation



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