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Einfluss des Makrodesigns von durchmesserreduzierten Implantaten auf die Primärstabilität

(Influence of macro-design of reduce diameter Dental Implants on Primary Stability)

Dissertation

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List of Abbreviations:

BIC	Bone Implant Contact
BMD	Bone Mineral Density
CT	Computed Tomography
EIL	Measuring Implant Length
ISQ	Implant Stability Quotient International Stability Quotient
ITV	Insertion Torque Value
KHz	Kilohertz
MDI	Mini Dental Implant
Mm	Millimeter
Ncm	Newton Centimeter
NP	Narrow Platform
PF	Pullout Force
RFA	Resonance Frequency Analysis
Rpm	Revolutions per Minute
RTV	Reverse Torque Value
SLA	Sand Blast acid etch
SP	Standard Plus
SPSS	Statistical Package for Social Sciences
TE	Tapered Effect
TiO2	Titanium dioxide
TPS	Titanium Plasma Sprayed
WP	Wide Platform

1. Introduction

The concept of osseointegrated implants in dentistry symbolises a turning point in this field and has resulted in considerable progress in clinical dental practice. According to Dr. Per-Inngvar Branemark, the term osseointegration is defined as “direct structural and functional contact between bone and titanium implant surface” (1).

Importantly, the achievement and maintenance of implant stability indicates established osseointegration, which is fundamental for a successful implant (2). Presently, the general concept of stability is of paramount importance; this describes an implant’s resistance to movement (3).

The implant stability divided into two stabilities (primary and secondary stability) (2). The former type of stability is established by mechanical events between the implant and bone. In contrast, the latter type of stability is a biological process that is associated with bone formation and remodeling (3; 4). Over time, primary stability rapidly changes and expands to secondary stability (5).

Generally, implant stability is affected by implant shape, size, surgical site, and bone quality. The density of bone is a significant determinant of implant success, since failure is more common in bone with low mineral content (4; 6; 7).

Presently, in order to objectively assess implant stability, several invasive and non-invasive tests are available. Non-invasive systems include radiological evaluation, percussion tests, impact hammer tests, periotests, and resonance frequency analysis. In contrast, histological and histomorphometric evaluation, cutting torque resistance analysis, insertion torque tests, and pullout tests are invasive tests to evaluate implant stability (90).

Aims:

The correlation between macro-design and reduce diameter implants into implant stability is a controversial issue. This study is designed to measure the initial stability of Macro-design and reduce diameter implants in different bone densities. The resonance frequency value will be correlated with reverse and insertion torque values from implants that are placed in porcine fresh bone.

2. Literature Review

2.1: History of dental implants

“A dental implant is defined as a device that is composed of alloplastic materials and that is inserted or implanted into the oral cavity. The purpose of a dental implant is to retain and support fixed dental prostheses’’ (132;10). The concept of using implants to replace natural teeth is historical and has been used by the ancient Chinese (4,000 years ago) and Egyptians (2,000 years ago). Archaeological discoveries have confirmed several materials that were used to replace lost human teeth. Traditionally, ox bone, ivory (elephant tusk), stones, wood, human teeth from corpses, and metals (gold or silver) were popular materials to replace natural teeth. However, ivory has been shown to be biologically inappropriate for use in animal models, due to its property of resorption (11; 113; 114).

2.2: Osseointegration of dental implants

Generally, dental implants are considered as restoration tools for replacing missing teeth that are difficult to treat (12). There are two known types of implant adjustments, which are immediate/early loading and delay/osseointegrated implant placements (13-16). Healthy osseointegration is defined as the “direct connection between the implant and bone, without connective tissue formation in the connection site’’, and it is important for reinforcing implants (115; 34). Furthermore, osseointegration has been conceptually divided into adaptive osseointegration and biointegration (17).

Osseointegration is related to the development of bone in and around the implant (18).

The preconditions for osseointegration have been established by primary stability, which cooperates to achieve osteogenesis through mechanical background (19).

2.3: Arrangement of dental implants in different regions of jaw bone

In general, the types of dental implants in current use are divided according to the status of the implant in relation to the bone, the implant design, and their respective diameters (20). Implant classification relative to position delineates three basic types:

1-Subperiosteal implants are positioned over the bone. They are used to support removal denture prostheses.

2- Transosteal implants are inserted through the bone. Placement of this implant type requires a surgical incision through the anterior mandible to allow passage of the implant from the bottom of the chin up into the mouth. Similar to subperiosteal implants, these are used for denture support.

3- Presently, the most commonly used implant is the endosseous type, which is placed directly in the bone (21). Endosseous implants are further subclassified into two main forms, blade (platform) and root cylinder forms. Root form implants offer a variety of patterns including conical, cylindrical, threaded screw, and perforated or hollow baskets (20). Root form implants are preferred to blade implants in wide and shallow mandibles (22).

2.4: Classification of dental implants according to platform and size

Currently, there are several different diameter of dental implants available, which are mini or narrow implants, ranging from 2 mm to 3.5 mm, regular-diameter implants, which have a diameter of 3.75 mm, and wide-platform implants, which range from 4.0 mm to 5.0 mm in diameter. The lengths of implants are most commonly 10, 13, and 15 mm (23).

Small or mini dental implants

The names of narrow-diameter or mini implants indicate that these range from 2.0 mm to 3.5 mm (23) or diameters smaller than 3.75 mm (124). They are used in individuals with limited interdental space. In addition, narrow-diameter implants are clinically superior in cases of inadequate bone without using bone augmentation procedures (29). However; 3.3mm to 3.5mm narrow diameter implants more indicated for load- bearing in the posterior region; otherwise diameters from 3.0 to 3.25mm indicated for single tooth and non-loading region, and its essential for the clinical success rate (137).

Small sizes mini dental implants make procedures quicker, easier, with less invasive preserve removable prostheses, and support fixed partial and complete dentures (24-27).

FIG. 1 FIG. 2

MDI MINI DENTAL IMPLANT SYSTEM (1.) A minimum of four implants placed 5 mm apart are required to stabilize a full lower denture. **(2.)** 1.8-, 2.1-, 2.4-, and 2.9-mm wide titanium-alloy implants.

Figure 1: Mini dental implants with denture support. Reproduced from the 3M ESPE MDI Mini Dental Implants (Bulard RA, Vance JB. 2005). Multi-clinic evaluation using mini-dental implants for long-term denture stabilization: a preliminary biometric evaluation. Available from http://www.dentalaegis.com/id/2011/11/3m-espe-mdi-mini-dental-implants. (8).

The o-ring in the MDI mini dental implant acts as a segment retention mechanism and allows dentures to be more stable (27; 28).

Reinforcing the stability of the mini diameter dental implant is associated with increasing implant length. This technique is followed by MDI to achieve more stability in compact bone (30). Survival of dental implants over long period is correlated with an adequate interface between the implant surface and the bone, which is required to achieve the osseointegration process (4; 31).

Regular-diameter dental implants

Generally, implant design can be classified according to the material that constitutes the implant and its morphology. Implant diameter represents the distance between external parts of the threads engaged into the bone. The optimal diameter selection should allow the engagement of a sufficient surface area of cortical plates and provide an adequate emergence profile for cosmetic and oral hygiene (32). In addition, the specification of implants could be varied according to the type of screw, length, and diameter (33).

Figure 2: Dental implants in various design. Adapted from the Biohorizons implant system. With permission and available from (www.biohorizons.com).

Generally, dental implants are classified according to the following criteria:

- Implant shape: ‘Cylindrical, conical, and hybrid
- Implant connection type: External hexagon, internal hexagon, Morse taper, and dodecagon’ (109)

- Surface treatment of implant: 1-Acid etching, 2- Sandblasting, 3- Anodizing, 4- Coating with TiO2 by plasma sprays, and 5- Laser treatment (109)
- Surface roughness: Macro-roughness (Figure 5D), micro-roughness (Figure 5A), and non-roughness.
- Surface morphology (109) of titanium dental implants.

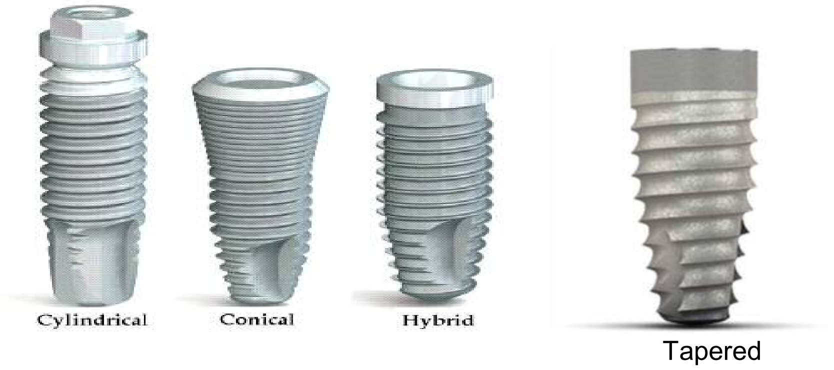

Figure 3: Different shapes of dental implants (cylindrical, conical, Hybrid and Tapered (Biohorizons) reproduced from (Carlos Nelson Elias 2011).
Factors Affecting the Success of Dental Implants, Implant Dentistry - A Rapidly Evolving Practice, Prof. Ilser Turkyilmaz (Ed.), ISBN: 978-953-307-658-4, InTech, Available from: http://www.intechopen.com/books/implant-dentistry-a-rapidly-evolving-practice/factors-affecting-the-successof-dental-implants. (109).

Figure 4: Different types of implant connections. Figure duplicated from www.periobasics.com. Reproduced with permission (Dr. Nitin Saroch 2013) (134).

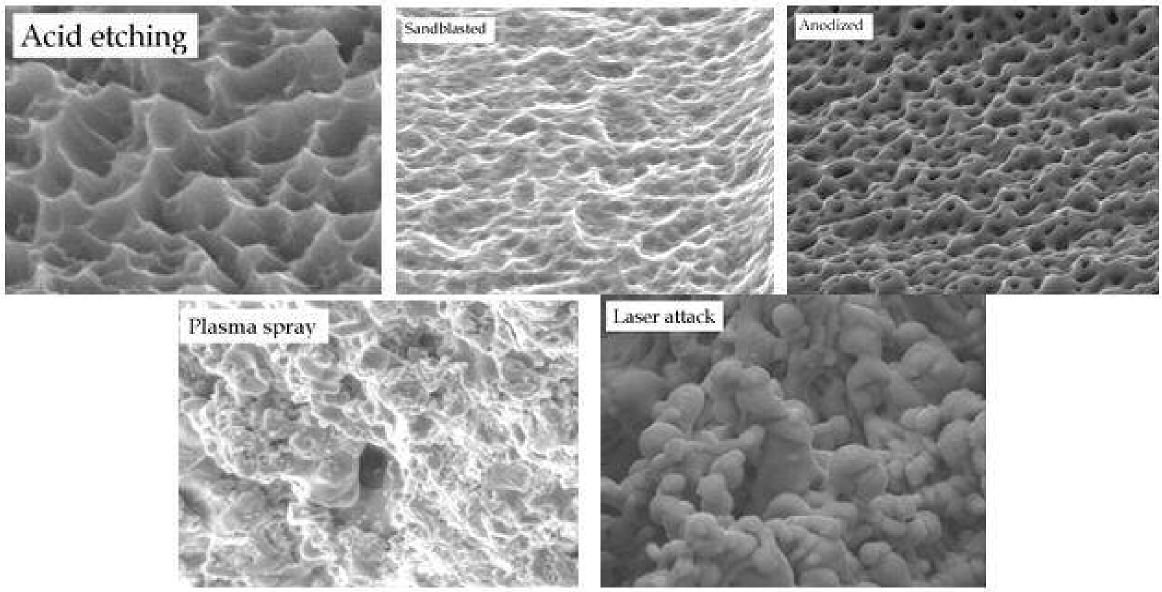

Figure 5: ‘‘Dental implants showing differing surface morphologies and surface treatments’’

A-Surface resulting from acid etching.
B- Surface resulting from sandblasting.
C- Anodizing surface.
D- Surface was coated with TiO_2 by plasma sprays.
E-surface in form of laser treatment”.

Reproduced from (Carlos Nelson Elias 2011).Factors Affecting the Success of Dental Implants, Implant Dentistry - A Rapidly Evolving Practice, Prof. Ilser Turkyilmaz (Ed.), ISBN: 978-953-307-658-4, InTech, Available from: http://www.intechopen.com/books/implant-dentistry-a-rapidly-evolving-practice/factors-affecting-the-successof-dental-implants. (109).

2.5: Biomaterials of Implants

At present, many companies are producing various implant systems. The ideal biomaterial does not elicit reactive changes in surrounding tissues. Titanium is a metal commonly used for implant construction due to its superior biocompatibility and its ability to osseointegrate (43).Titanium possesses a favorable combination of mechanical strength, chemical stability, and biocompatibility (44). Furthermore, the implant biomaterials range from commercially pure titanium and titanium alloys to hydroxyapatite-coated devices (45). Forces exerted on the implant material consist of tensile, compressive, and shear components (46).

Pure titanium is light in weight and highly resistant to corrosion (47). It undergoes crystallographic changes from the alpha to the beta phase upon heating to 883 °C, and the melting point is 1,680 °C (48). Titanium is characterised as an alloy material (Ti-6Al-4V). As a result of its low-elasticity properties, it facilitates the production of products for biomedical purpose (48). The most important characteristic of titanium is its specific (titanium dioxide) (TiO2) nanotube morphology. Its advantages include cell adhesion and growth, and spreading of the cells with antibacterial properties and protein interactions, followed by increasing osseointegration (49). The implant surface may be smooth or deliberately roughened and modified by laser to achieve a more stable bone-implant interface (50).

Notoriously, biomedical implants induce host immune responses and subsequent unresolved host inflammation. The concept of implant biocompatibility is applied when the material is reliably integrated within the host tissue (51).

Host response to all implants has its foundation in molecular and cellular reactions to materials in the tissue bed (52). Macrophages are an important class of host cells that respond to biomaterials universally and to varying degrees; each response is unique depending upon the implant location and the bulk material.

Moreover, during normal wound repair, host tissue undergoes acute inflammation, scarring, tissue reconstruction, and remodeling (53). However, the presence of foreign material interrupts the normal wound healing response, and the inflammatory phase persists in a modified form, leading to a pathological condition at the implant sites; this is termed the *foreign body response*. The acute inflammatory response is produced early by infiltrating polymorphonuclear leukocytes, including neutrophils. This type of response is generally resolved quickly (within ≤3 weeks) (38) and may appear normal. However, subsequent chronic inflammatory events persist at the implant site accompanying all implanted materials and elicit exaggerated and prolonged pathological responses that counteract normal healing processes. The foreign body response is implicated in several failure modes of implant materials including osteolysis, fibrous encapsulation, sepsis, and failure.

2.6 Effect of implant morphology on mechanical implant contact

Three main factors affect the initial stability of implants: Firstly, the morphology and geometry of the implant; secondly, surgical technique; and thirdly, bone quality and quantity in the receipt site. (3; 4; 21; 23).

Specifically, the achievement of valuable osseointegration leads to successful initial stability (35, 36). It has been suggested that the titanium surface implant with rough surface has advantages that it reduces friction and reinforces initial stability (13 – 15; 37).

Biocompatibility in the implant surface has been shown to be clinically important as it facilitates bone regeneration and increases bone implant contact (BIC) (38; 123 125). For example, internal connection tapered implants, will increase bone implants contact and conserve marginal bone level after 1 year (39). However, cylindrically-shaped implants to tend serve as anchors for high-density bone (40).

Interestingly, the self-tapping implant is a modified design of dental implant that has been explicitly designed for use in bones with poor quality (i.e. Type 3 and Type 4 bones) and low-density bone that presents in the posterior maxilla (41). In addition; wide platform implants indicated, in areas of inadequate bone height, areas of insufficient mineral bone density (type IV), and preferable for replacement of non-integrated or fractured implants (121).

The insertion of a self-tapping design implant into compact density bone thereby enhances the bone implant contact in single-stage implant placement (42). The self-tapping implant also has an increased cutting characteristic. This design would help to eliminate pre-tapping procedures in immediate implant placement, resulting in improved initial implant stability (54).

2.7: Effect of quantity and quality of bone on primary stability

In principle, bone quality is a function of bone density, anatomical structure, and volume of bone mineralisation (55). Bone density is evaluated in the classification system of Lekhom and Zarb (56).

This classification scheme relates to the degree of thickness and density of compact and spongy bone. However; in order to obtain success rate of implant it is necessary to estimate the site prior to implantation (57).

Commonly, bone mineral density has been distinguished according to positions in skeletal human bone and according to the locations that allow implants to be osseointegrated (58; 59).

According Ribeiro-Rotta et al., the accuracy of diagnosis with evaluation of bone tissue characteristics is critical to clinical implant outcomes (56). Seemingly, proper implantation procedure depends on adequate osseointegration obtained by adequate bone density, effective surgical technique, applicable functional loading, and extended healing time (60; 61). The primary stability of dental implants have been most commonly estimated by the volumetric mass of bone density (62).

Bone mineral density has been classified by four bone types, ranging from high-density to low-density groups. This has been described by Lekholm and Zarb, and by Mish classification system (56).

According to the Lekholm and Zarb classification system (9), the following distinctions are made:

Type I: Homogenous and cortical bone.

Type II: Structure of cortical bone performs as a thick layer and is surrounded with dense trabecular bone.

Type III: Low cortical trabecular bone.

Type IV**:** Structure of cortical bone performs as a thin layer and is surrounded with a low density of trabecular bone.

Frequently, higher implantation failure rates or lower success rates in the maxilla are seen in comparison with the mandible, due to the poor-quality bone in the maxilla (58; 63; 64; 116).

In contrast, Mish explained the volumetric density of bone as being arranged from ratings of D1 to D4.

Bone Density	Description	Tactile Analog	Typical Anatomical Location
D1	Dense Cortical	Oak or maple wood	Anterior mandible
D2	Porous cortical and coarse trabecular	White spine or spruce wood	Anterior mandible Posterior mandible Anterior maxilla
D3	Porous cortical (thin) and fine trabecular	Balsa wood	Anterior maxilla Posterior maxilla Posterior mandible
D4	Fine trabecular	Styrofoam	Posterior maxilla

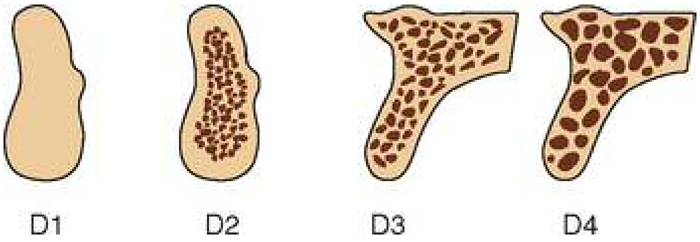

Table 1: Mish classification system based on bone density.

2.8: Effect of surgical technique on primary stability

It has been established that surgical technique in combination with implant morphology and the characteristics of bone type further influence primary stability. Prominently, the surgical principle is based on two primary factors to achieve a proper initial stability. These two main factors are a traumatic implant placement and sufficient bone quality and quantity. A traumatic surgical implant placement is of paramount importance to enhance cell growth and improve the healing process (66; 67). Decreasing surgical trauma during implantation to conserve bone mass has been practiced to obtaining proper initial stability (68). However, the influence of the morphology of the implant on primary stability is preferable than surgical implantation procedure (34).

Osteotome technique is technique for enhancing bone mass around implant site and to increasing implant stability. The main benefit of this technique is to preserve bone mineral density (69; 70).

2.9: Previous research about design of implants and relation to primary stability

A previously conducted meta-analysis of 47 methods from in vitro and in vivo studies determined initial stability by using different apparatus, and explained significant correlations between implant stability values (Resonance frequency analysis (RFA, Insertion torque value (ITV) and Reverse torque value (RTV).

Table 2: In vitro previous research studies of dental implant from 2009-2014.

Author	Year	Study	Type Implant	Measurement	Conclusion
Trisi P et al (71)	2009	In vitro	Titanium bone level implant inserted into different bone density	Torque test, force gauge and digital micromotor	High insertion torque achieve implant reinforced, also implant was shifting in improper bone density.
Chong L et al. (6)	2009	In vitro	Different design of implants inserted into different density of polyurethane block.	RFA	Non-self-tapping had more stability compared with self-tapping implants; However bone density more effect on initial stability.
Lachmann S et al. (7)	2011	In vitro	Implant geometry (screw type)	Periotest and Osstell	Stability of implant depend on bone mass density and implant design.
Kim DR et al.(72)	2011	In vitro	Self-cutting blade and without self-cutting blade implant design.	RFA, Reverse Torque, Pullout and Pull-in test.	Enhancing implant/tissue interface in non-self-cutting blades produce lateral compression and improving primary stability.
Kim YS et al. (73)	2011	In vitro	Different implant design.	RFA, Reverse Torque, Pullout and Push-in test.	Without tapping blades more stability compared with self-tapping blade in medium bone density.

Dos Santos MV et al. (13)	2011	In vitro	Different implant design (conical and cylindrical) in three implants surface.	RFA, Insertion Torque (IT)	High insertion torques in conical design than other it.
Krafft T et al. (74)	2012	In vitro	Dental implant	Bone probe testing.	Bone quality not accurate determine, but more variation in human cadaver bone.
Elias CN et al. (34)	2012	In vitro	225 implants inserted into Pig rib.	ITV	Implant stability value higher in tapered than straight implant, the primary stability was liable on morphology implant, implantation procedure and bone quality.
Mazzo CR et al. (75)	2012	In vitro	Different surface of dental implants	Insertion Torque (IT) and Pullout force (PF)	Acid surface treatment in External hexagonal implants achieved good stability with highest values of pullout strength in compared with machine surface.
Hong J et al.(76)	2012	In vitro	Two different types of dental implants	RFA, Insertion Torque (IT)	Primary stability formed by existence of cortical plate bone.

Kumar VV et al.(133)	2012	In vitro	Astra implant system	RFA, Push-out test	Ultrasound transmission velocity (UTV) evaluated bone quality and determine primary stability before implant placement.
Oliscovicz NF et al. (77)	2013	In vitro	Implants after inserted into 4 different substrates.	Pullout test and Insertion Torque test.	More rigidity and highest stability achieved by polyurethane Nacional 40 PCF and pinus wood.
Divac M et al. (78)	2013	In vitro	Hybrid Tapered (TE) and Cylindric (SP) Wide neck Staumann implants	RFA	TE implants more lateral compression than SP implants; also RFA was increased with greater bone thickness.
Barikani H et al. (79)	2013	In vitro	Nobel Bio care Replace (TiUnit) tapered with Wide platform (WP) implants.	Osstell	To maintain the highest initial stability recommended that enhancing length and diameter of implants.
Barikani H et al. (80)	2014	In vitro	Replace select tapered and Branemark MKIII implants	RFA	Replace select system higher primary stability also recommended that the tapered implant especially when using short implant.

Author	Year	study	Type Implant	Measurement	Conclusion
Rozé J et al.(81)	2009	In vivo	Placed 22 implant in human Maxilla and Mandible.	RFA	ISQ associated with bone thickness and analyzed by CT scan
Rodrigo D et al. (82)	2010	In vivo	Straumann Implant	RFA	Secondary stability estimate more implant success than primary stability.
Alsabeeha NH et al. (83)	2010	In vivo	3 different types of implants. Southern 8mm wide diameter implants, Neoss 4 mm regular diameter implants	ISQ (RFA)	Southern 3.75mm was lower mean ISQ than same implants with 8mm diameter; However no fixed relation between implant diameter and ISQ.
Toyoshima T et al .(84)	2011	In vivo	Hybrid-self tapping implants (Straumann BL and tapered effect TE implant) with one type cylindrical non-self-tapping implant.	RFA	Hybrid self-tapping implants achieve high stability in low density bone.
Marquezan M et al.(85)	2012	In vivo	Bone density, dental implant (mini screws).	Insertion Torque, Pullout test, computed Tomography.	Bone density effect on IT and Pullout test.

Mijiritsky E et al.(86)	2013	In vivo	Different implant diameters (narrow, regular and wide) with different lengths.	RFA	Success rate of dental implants not related to diameter and length of implants.

Table 3: Previous in vivo research studies of dental implant from 2009-2014.

2.10: Resonance frequency analysis

Resonance frequency analysis (RFA) is a noninvasive test that has recently gained popularity. RFA is a technique to estimate an implant's stability at the level of implant-to-bone contact and to evaluate implant mobility inside the bone. RFA is most significantly affected by bone mass density and implant height in the marginal bone. This tool consist of a small transducer fixed to the implant fixture or abutment. The unit of assessment for the transducer was the International Stability Quotient (ISQ) (87-92).

(Magnetic RFA) was the device of resonance frequency analysis which is wireless (MentorTm; OsstellAB) that (Smart peg) which fixed to it. This technique determines the degree of stiffness during the immediate implant placement and estimates the lowest and highest implant stability quotients. The variability in the measurement of RFA may be achieved due to change in the direction of the transducer. However, the new RFA device was designed to be similar to an electric device in the phase of initial loading (92; 93).

A decrease in the RF value is related to a decrease in stiffness, which can indicate a potential for failure. Thus, RF analysis can be used to show differences between successful implants and clinical failures in order to predict condition that predispose an implant to fail (94; 95). A high ISQ value indicate high stability, while a low ISQ value show low stability (96).

2.11: Measurement of insertion torque

Additional methods to determine primary stability include insertion torque value (110). However, the success of dental implants during implant placement is achieved by implant stability and it is important to maintain osseointegration, although implant stability is not affected by insertion torque but depend on bone mass density (111; 101).

The measurement of insertion torque value (ITV) serves as an indication of initial implant stability and has been used to determine the quality of bone during placement (112). Furthermore, high insertion torque value in higher-density bone enhances initial stability but does not cause bone necrosis or failure of implant (97).

Commonly, an ITV value of 32-40 Ncm is used as a threshold to allow immediate loading (98; 99). It has been suggested that ITV greater than 50 Ncm may obtain more bone/implant tissue interface and compromise the osseointegration as a result of the transmission of excessive forces to the surrounding bone, compared with implants with ITV less than 50 Ncm (100; 110).

Additionally, the primary stability of mini screw implants is associated with implant geometry characteristics such as diameter and length of the implants (102).

2.12: Reverse torque analysis

Removal torque value is crucial to determine the strength of osseointegration (103; 104). Reverse torque is correlated with the roughness of the implant surface and the reinforcement of mechanical phenomena between bone and implant (103; 105). Reverse-torque testing at 20 Ncm is an applicable method to obtain osseointegration information (106).

It appears that diameters and implant-abutment connection (external and internal connection design) as a result of loss rate of reverse torque are essential to screw loosening or fracture. Furthermore, external hex connections and wide-diameter implants are preferable and are resistant to reverse torque; however, internal connections are more commonly selected in a clinical setting (107;108).

3. Material and Method:

An in vitro study was established at the department of Oral, Maxillofacial and Plastic Surgery at the University medical of Johannes Gutenberg-Mainz in Germany. This study was performed between the periods of January 2012 to March 2014.

Five different implants were chosen for this study as listed in (Table4) (Camlog, DENTSPLY Friadent, BEGO, Biomet 3i implants system) (n=60). The profile of the implants is used with a diameter in the range of 3.0 to 3.3 mm, with different length. In addition one mini-implant system (3M ESPE) (n=45) is used with different diameters of 1.8 mm, 2.1 mm and 2.4 mm in same length (13mm)

The fresh porcine bones were obtained from the local butcher shop (Figure 6). The implants were inserted into mandible, scapula and pelvic bone which each possess a different bone density.

The drilling sequences for the five implant systems were (initial drill, 2.0mm pilot drill, then 2.8mm twist drill) followed by placed implants into porcine bones.

Figure 6: Fresh porcine bone in different bone densities (Mandible, Scapula and Pelvis)

Implant Systems	Description	Shape implant	Diameter[mm]	Length[mm]	Number of Implants	Symbol
BEGO	Bego-Semados.Implantate Tipure plus	Tapered, cone Apex	3,25	10	12	A
CAMLOG	Conelog screw-line implant	Conical, self-taping	3,3	9	12	B
FRIADENT (Dentsply)	XIVE Plus	Parallel wall(Tapered)	3,0	11	12	C
FRIADENT (Dentsply)	XIVE Plus	Parallel wall(Tapered)	3,0	13	12	D
BIOMET 3i	Osseotite	Tapered	3,25	10	12	E
3M ESPE	Mini Implants	Tapered, Thread	1,8 ,2,1, 2,4	13	45	F

Table 4: Classification of implant systems according to shape, daiemeter and length.

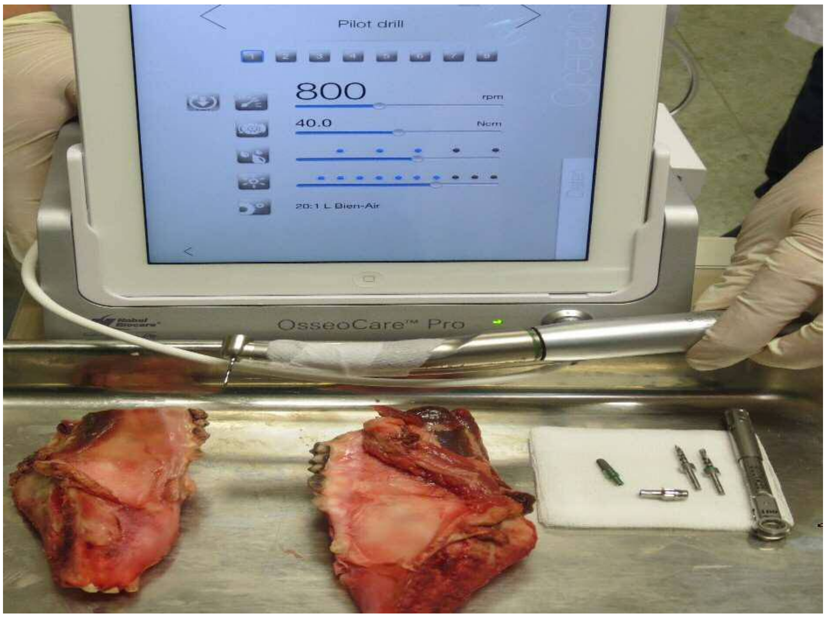

Figure 7: figure show Motor machine with mandible porcine bone.

3.1 Implantation protocol:

The experiments were undertaken after the implant site is prepared for (BEGO) implant system by a series of gradually enlarging burs. All implant systems have an initial small diameter drill that is used to mark the implant site. The center of the implant site is marked with the initial drill and a pilot bur (2.5mm) followed by (2.8mm) pilot bur is prepared as for the 90° degree implant insertion. The distance between implants was approximately about 3mm. The speed for the depth drill was (800rpm). Finally, 3.25mm implant bone preparation bur was used with the speed (800rpm). After the desired depth of an implant site preparation and a diameter of the site are achieved, the titanium implants are placed into different bone densities of the fresh porcine bone with speed (15rpm).

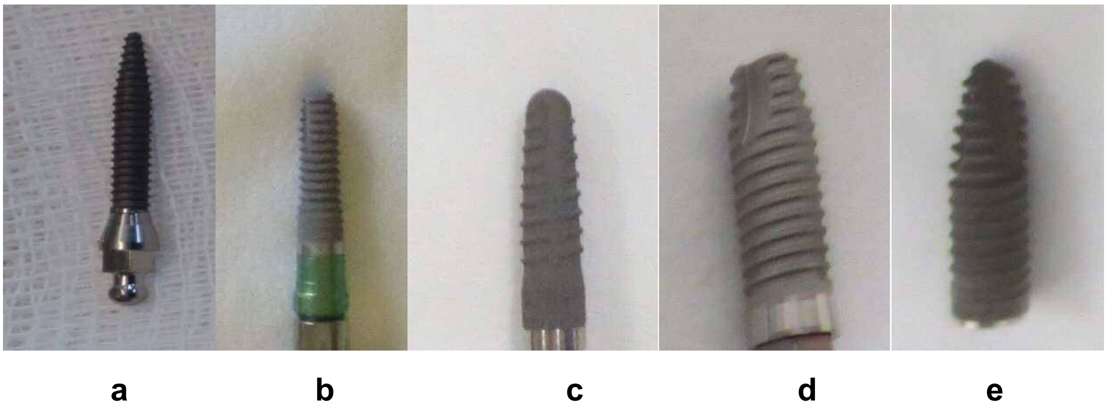

Figure 8: different implant systems. From right to left:

a- 3M ESPE. b- BEGO. c- CAMLOG. d- BIOMET 3I. e- DENTSPLY-FRIADENT Xive.

Figure 9: Bego Implant system and surgical pilot burs.

Similarly, the implant site is prepared for (CAMLOG) implant system by a series of gradually enlarging burs. All implant system has an initial small diameter drill that is used to mark the implant site. The center of the implant site is marked with the initial drill and a pilot bur (2.0 mm then 2.8mm pilot bur) is prepared, thus to allow insertion to be perpendicularly performed in relation to the bone surface. The distance between each implant was approximately about 3mm. The rotation speed for the depth drill was (800rpm), finally 3.3 mm pilot bur was used with the speed (800rpm), after the desired depth of an implant site preparation and a diameter of the site are achieved, followed by titanium implant is placed into different bone densities of the fresh porcine bone.

Figure 10: Camlog Implant system and surgical pilot burs.

Like wise, the implant site is prepared for (Dentsply Friadent- Xive) implant system by drilling sequence (round drill, 2.0 mm twist drill, and 3.0 mm twist drill). All implant system has an initial small diameter drill that is used to mark the implant site. The center of the implant site is marked with the initial drill followed by a pilot bur is prepared, thus to allow insertion to be perpendicularly performed in relation to the osseous surface. The distance between implants was approximately about 3mm. All Xive twist drills are operated intermittently on (800rpm). Behind the desired depth of an implant sites preparation and a diameter of the site is achieved, followed by titanium implants are placed into different bone densities of the porcine bone.

Figure 11: Dentsply Friadent Xive implant system with surgical pilot burs.

Also, the implant site is prepared for (BIOMET 3I) implant system by drilling sequence (round bur, 2.0 mm pilot bur). The center of the implant site is marked with the initial drill and a pilot bur is prepared, thus to allow insertion to be perpendicularly performed in relation to the osseous surface. The distance between implants was approximately about 3mm. Finally 2.3 mm pilot bur are operated with a speed on (800 rpm). Once the desired depth of an implant sites preparation and a diameter of the sites are achieved, followed by titanium implants are placed into different bone densities of porcine bone.

Figure12: BIOMET 3i implant system with surgical pilot burs.

3.2: Implantation protocol for mini implant (3M ESPE):

The implant site was prepared for different mini diameter implants (3M ESPE). The pilot bur (1.1 mm 3M ESPE MDI Surgical drill S1011) is used to insert 1.8mm (n=15) mini-implant diameter. However, 1.3 mm pilot bur (3M ESPE Surgical drill S1013) is used to insert 2.1mm (n=15) and 2.4mm (n=15) mini-implants diameter. Follow by to insert the implant into the porcine bones (3M ESPE MDI Winged Thumb Wrench, S9032) was used. The perpendicular pressure was enforced on the mini-implants by using a torque screwdriver. The guidance pressure according to bone material was parallel to the extending line of the porcine bones. Increasing force from zero to the greatest point in order to determine the maximum insertion torques for different mini implant was measured according to diameters and different bone densities.

Table 5: Implantation protocol for mini implant (3M ESPE)

Implant diameter[mm]	Pilot bur-Initial drill	Pilot bur 1,1mm	Pilot bur 1,3mm	Canal extension
1,8	√	√	Ø	Ø
2,1	√	√	√	Ø
2,4	√	√	√	√

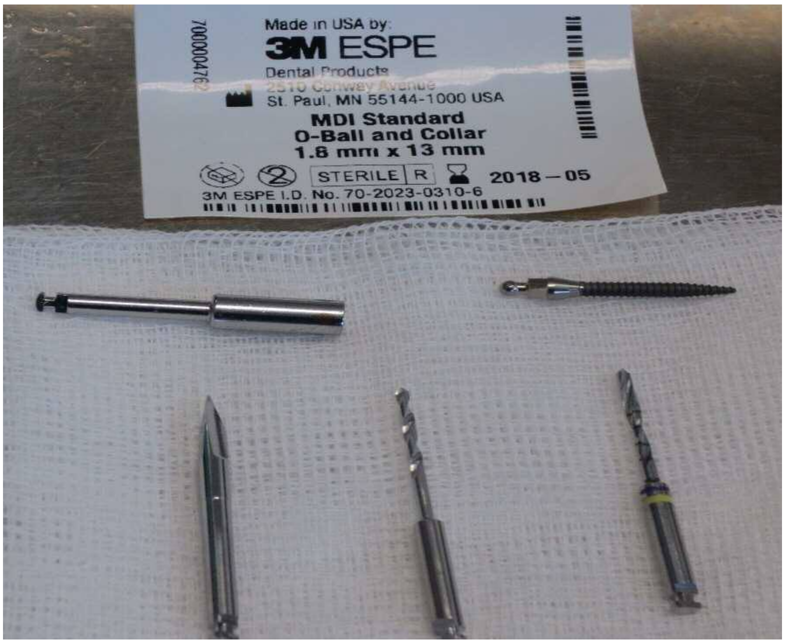

Figure 13: Mini implant system (3M ESPE) and surgical pilot burs.

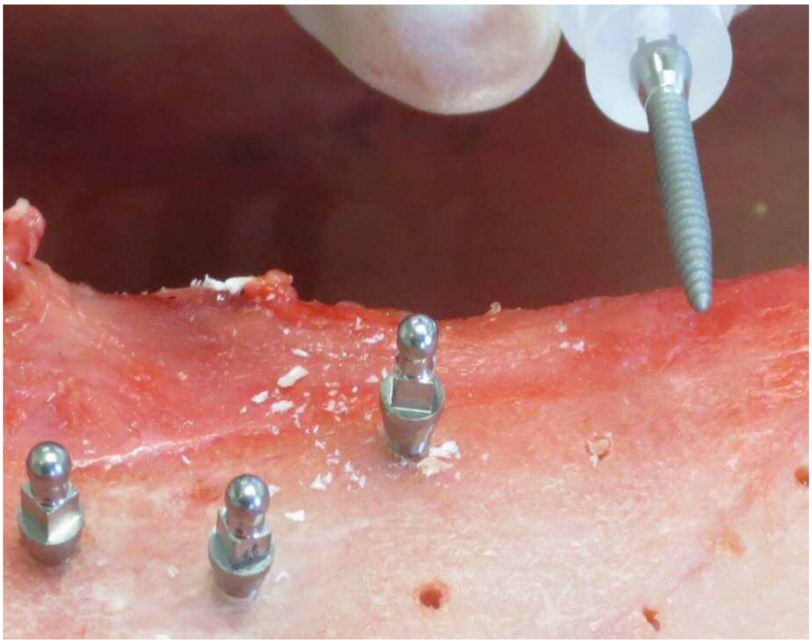

Figure 14: Mini Implants and inserted into porcine bone.

3.3: Measurements of implant stability:

Measurements were taken immediately after placement of implants for all preparation sites. The new device of Resonance frequency analysis was used (MentorTm; OsstellAB) that (Smart peg) which fixed to the implants. This apparatus is used to determine the degree of stiffness during the immediate implant placement and estimate the lowest and highest implant stability quotient ranging from 1 (least stable) to 100 (most stable), the variability in the measurement of RFA may be achieved due to change in the direction of the transducer. However, RFA new one device design has similar function in compared with electric device design in the phase of initial loading measurement. (92;93).

Furthermore, after implant placement; insertion torque values in (Ncm) were evaluated biomechanically for all the implants using handheld portable torque gauge screw driver (Halmtec, Mecmesin, Germany). However, removal torque values in (Ncm) were recorded by using the same portable screw driver during a counter-clockwise quarter-turn of the implant.

Figure 15: Primary stability measurement by ISQ

Figure 16: Torque in measurement by handheld torque measuring screw driver (Halmtec, Mecmesin, Germany)

Figure 17: Osstell-ISQ apparatus is using to determine RFA.

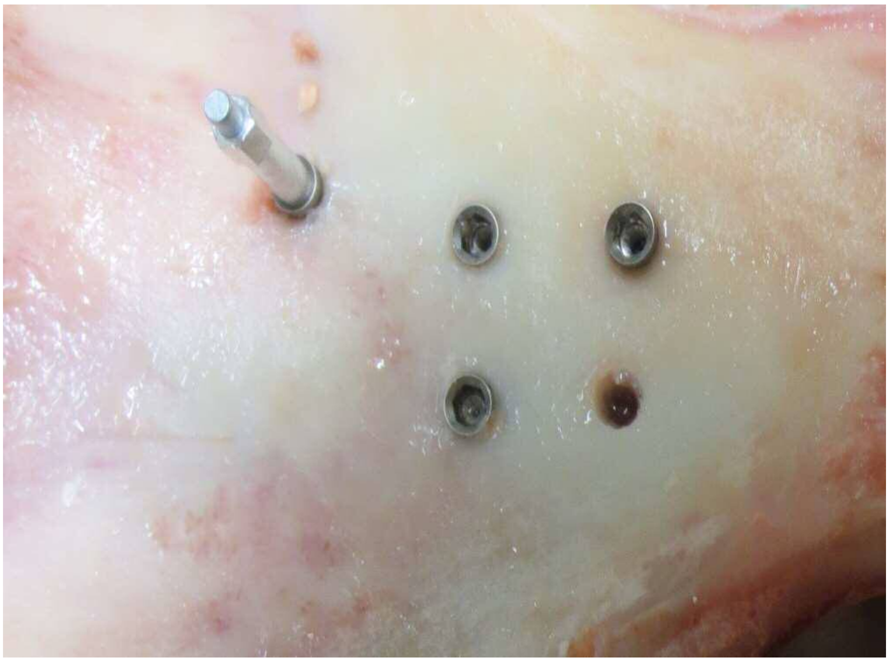

Figure 18: Smart-peg shows fixed with an implant and implants inserted into porcine bone.

4. Results:

In this study there were a total of 105 dental implants placement from 5 different manufactures inserted in mandible, scapula, and pelvic porcine bone.

For consistency of the data and reproducibility of implant placement in each different bone, 4 implants system of the same type were inserted successively by a single operator. The operator strictly followed and adopts the same surgical protocol for each placement. For reliability of our results and in order to establish a degree of reproducibility, intra-bone variability of each implants e.g. Bego system and bone to bone (inter-bone) variation were planned. Inter-bone variation was assessed by comparing all the three parameter measurement (ITV, RTV and ISQ as was previously described in our methodology) in the three different porcine bones of mandible, scapula, and pelvis accordingly.

The coefficient of variations (CV=SD/Mean*100) for stability parameters was calculated. Firstly, the coefficients of variations of for ISQ measurement for Bego implant system were 3%, 5% and 6% for mandible, scapula and pelvic bone respectively. Secondly, the coefficients of variations of reverse torque value RTV for Bego implant system 32%, 13% and 14% for mandible, scapula and pelvic bone in that order. Thirdly, the coefficients of variations of insertion torque value ITV for Bego implant system 26%, 19% and 13% for mandible, scapula and pelvic bone correspondingly.

The variability measurements of RTV, ITV and ISQ within the same bone and for the same implant systems was shown by mean, standard deviation and coefficient of variations. (Table 6).

Table 6: Implant stability parameters (ITV, RTV and ISQ) with mean, SD, and coefficient of variations (CV1) for Bego, Camlog, Biomet 3I, Friadent-Dentsply 11 and 13 mm implant systems in four experiments (four implants for each systems inserted into different bone types with approximately about 3mm distance between each experiments).

Bego Mandible	Exp1	EXp2	EXp3	Exp4	Mean	SD	CV1
ITV	47.05	68.50	91.10	66.03	68.17	18.04	26.47
RTV	40.04	61.91	90.14	62.04	63.53	20.53	32.32
ISQ	69.00	73.00	72.00	75.00	72.25	2.50	3.46
Scapula							
ITV	77.83	62.30	53.90	51.65	61.42	11.86	19.31
RTV	65.42	58.70	51.00	49.60	56.18	7.35	13.07
ISQ	78.00	72.00	75.00	69.00	73.50	3.87	5.27
Pelvis							
ITV	69.00	65.75	89.12	75.00	74.72	10.34	13.84
RTV	60.41	65.25	84.07	73.32	70.76	10.35	14.62
ISQ	69.00	71.00	70.00	62.00	68.00	4.08	6.00
Camlog							
Mandible							
ITV	90.02	70.80	82.30	71.15	78.57	9.32	11.86
RTV	85.44	69.15	76.42	70.19	75.30	7.48	9.94
ISQ	84.00	84.00	84.00	85.00	84.25	0.50	0.59
Scapula							
ITV	41.90	53.44	60.40	61.30	54.26	8.96	16.51
RTV	35.45	52.75	47.25	59.80	48.81	10.28	21.07
ISQ	60.00	66.00	76.00	74.00	69.00	7.39	10.72
Pelvis							
ITV	50.33	79.09	48.20	89.45	66.77	20.67	30.95
RTV	30.60	75.50	37.56	80.15	55.95	25.49	45.55
ISQ	60.00	80.00	65.00	82.00	71.75	10.90	15.20
Biomet 3I							
Mandible							
ITV	90.47	80.09	79.88	88.98	84.86	5.66	6.67
RTV	87.62	76.43	70.19	88.75	80.75	8.97	11.11
ISQ	80.00	76.00	72.00	78.00	76.50	3.42	4.46
Scapula							
ITV	47.98	65.59	69.08	66.54	62.30	9.66	15.50
RTV	43.72	60.47	69.81	63.27	59.32	11.11	18.73
ISQ	68.00	70.00	69.00	74.00	70.25	2.63	3.74
Pelvis							
ITV	78.60	98.42	91.57	76.93	86.38	10.36	11.99
RTV	70.38	90.29	90.74	70.86	80.57	11.49	0.14
ISQ	78.00	82.00	78.00	76.00	78.50	2.52	0.03

Dentsply11							
Mandible	Exp1	EXp2	EXp3	Exp4	Mean	SD	CV1
ITV	39.00	70.50	80.50	61.09	62.77	17.72	28.23
RTV	38.00	48.50	63.00	48.98	49.62	10.26	20.67
ISQ	66.00	56.00	67.00	65.00	63.50	5.07	7.98
Scapula							
ITV	74.14	56.40	57.50	47.12	58.79	11.24	19.12
RTV	45.00	33.20	41.00	32.50	37.93	6.09	16.06
ISQ	55.00	59.00	53.00	48.00	53.75	4.57	8.51
Pelvis							
ITV	70.30	78.20	54.90	45.70	62.28	14.69	23.58
RTV	53.40	49.40	46.00	39.05	46.96	6.08	12.95
ISQ	58.00	55.00	63.00	59.00	58.75	3.30	5.62
Dentsply13							
Mandible							
ITV	41.04	65.40	59.52	61.29	56.81	10.80	19.01
RTV	38.97	52.00	53.09	54.71	49.69	7.23	14.56
ISQ	52.00	50.00	49.00	46.00	49.25	2.50	5.08
Scapula							
ITV	45.50	58.40	39.30	46.50	47.43	7.98	16.83
RTV	36.80	51.00	35.40	37.74	40.24	7.24	18.00
ISQ	56.00	58.00	43.00	50.00	51.75	6.75	13.05
Pelvis							
ITV	71.50	65.50	68.30	58.09	65.85	5.72	8.69
RTV	70.25	53.63	49.50	51.48	56.22	9.51	16.91
ISQ	64.00	58.00	59.00	55.00	59.00	3.74	6.34

Continuation of the Results:

Interestingly, the Camlog implant system showed a higher ISQ value (mean of 84.25 ± 0.5) in mandibular bone compared to the other types of implant systems. However, the lowest ISQ mean value of (49.25±2.5) was observed in Dentsply 13 mm implant system.

Remarkably, the highest mean of insertion torque values (86.38±17.93) were reached by the Biomet implant system in the pelvis in comparison to the lowest mean of ITV (47.42±11.28) in scapula for Dentsply 13 mm.

Furthermore, the Biomet implant system exhibited a maximum mean removal torque value of (80.74±8.96) in mandible in comparison to the lowest mean of RTV of (37.92±8.61) in scapula for Dentsply 11 mm implant system. (Table 6)

Correlation:

Correlations were computed among 7 factor variables on data onto 60 implants. The results suggest that 5 out of 7 correlations were statistically significant. (Table 7).

Essentially, the results indicated a positive correlation between length and different implant design in this study *($p < 0.001$).* However, there was an inverse relationship between length and implant diameter *($p <0.001$).* Furthermore, length of the implant has a significant inverse relationship between the means of RTV and ISQ values ($p < 0.001$) respectively. Further inverse relationship of length and the mean of ITV is observed with a lesser significance ($p <0.001$).

Moreover, a significantly positive correlations among the means of ISQ, ITV and RTV parameters was noted with *($p < 0.001$)* correspondingly.

Spearman's correlation at the level of 0.01 (2-tailed) showed significant difference among implant designs (Bego, Camlog, Biomet, Dentsply 11 and Dentsply 13) on the variables RTV, ITV and ISQ values. There were equal variances for ITV and RTV and ISQ measurements; since there were equal numbers of implant design in each group.

For e.g. there were a significant difference between implant on ITV, p=0.036 at the level of 0.05 (2-tailed) and similarly to RTV and ISQ (See Table.7 for more details).

Furthermore Spearman’s correlation was conducted and there was a significant difference at the alpha level of 0.01 between the bone types when considered jointly on the variables RTV, ITV and ISQ measurements. For e.g. significant difference between implant on ISQ p=0.001 and similarly to ITV and RTV (See Table 7 for more details).

In summary, the result analysis indicated that the various implant design and different bone location differed significantly in respect of the combination of variables RTV, ITV and ISQ measurements. However, there were less significant effects of different diameter and length on the RTV, ITV and ISQ measurements.

Table 7: Spearman's correlation (*P* value) computed among 7 factor variables.

		Implant	Diameter	Length	ITV	RTV	ISQ	Bone
Implant	Correlation Coefficient	1.000	-0.791**	0.821**	-0.271*	-0.376**	-0.674**	0.000
	Sig. (2-tailed)	.	0.001	0.001	0.036	0.003	0.001	1.000
	N	60	60	60	60	60	60	60
Diameter	Correlation Coefficient	-0.791**	1.000	-0.973**	0.297*	0.423**	0.766**	0.000
	Sig. (2-tailed)	0.001	.	0.001	0.021	0.001	0.001	1.000
	N	60	60	60	60	60	60	60
Length	Correlation Coefficient	0.821**	-0.973**	1.000	-0.315*	-.389**	-0.773**	0.000
	Sig. (2-tailed)	0.001	0.001	.	0.014	0.002	0.001	1.000
	N	60	60	60	60	60	60	60
ITV	Correlation Coefficient	-0.271*	0.297*	-0.315*	1.000	0.894**	0.615**	0.011
	Sig. (2-tailed)	0.036	0.021	0.014	.	0.001	0.001	0.936
	N	60	60	60	60	60	60	60
RTV	Correlation Coefficient	-0.376**	0.423**	-0.389**	0.894**	1.000	0.726**	-0.028
	Sig. (2-tailed)	0.003	0.001	0.002	0.001	.	0.001	0.830
	N	60	60	60	60	60	60	60
ISQ	Correlation Coefficient	-0.674**	0.766**	-0.773**	0.615**	0.726**	1.000	-0.089
	Sig. (2-tailed)	0.001	0.001	0.001	0.001	0.001	.	0.499
	N	60	60	60	60	60	60	60
Bone	Correlation Coefficient	0.000	0.000	0.000	0.011	-.028	-.089	1.000
	Sig. (2-tailed)	1.000	1.000	1.000	0.936	0.830	0.499	.
	N	60	60	60	60	60	60	60

**.Significant correlation at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed)

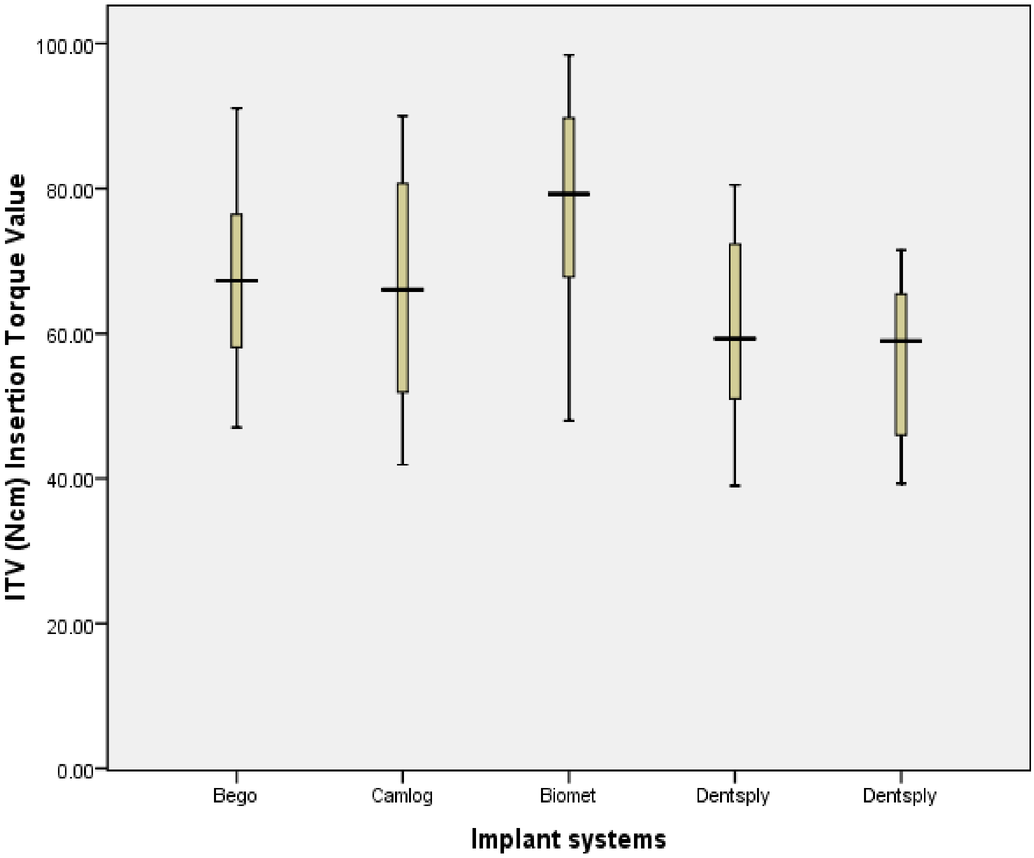

Figure 19: Box plot showing values of insertion torque (ITV) according to various implants designs system.

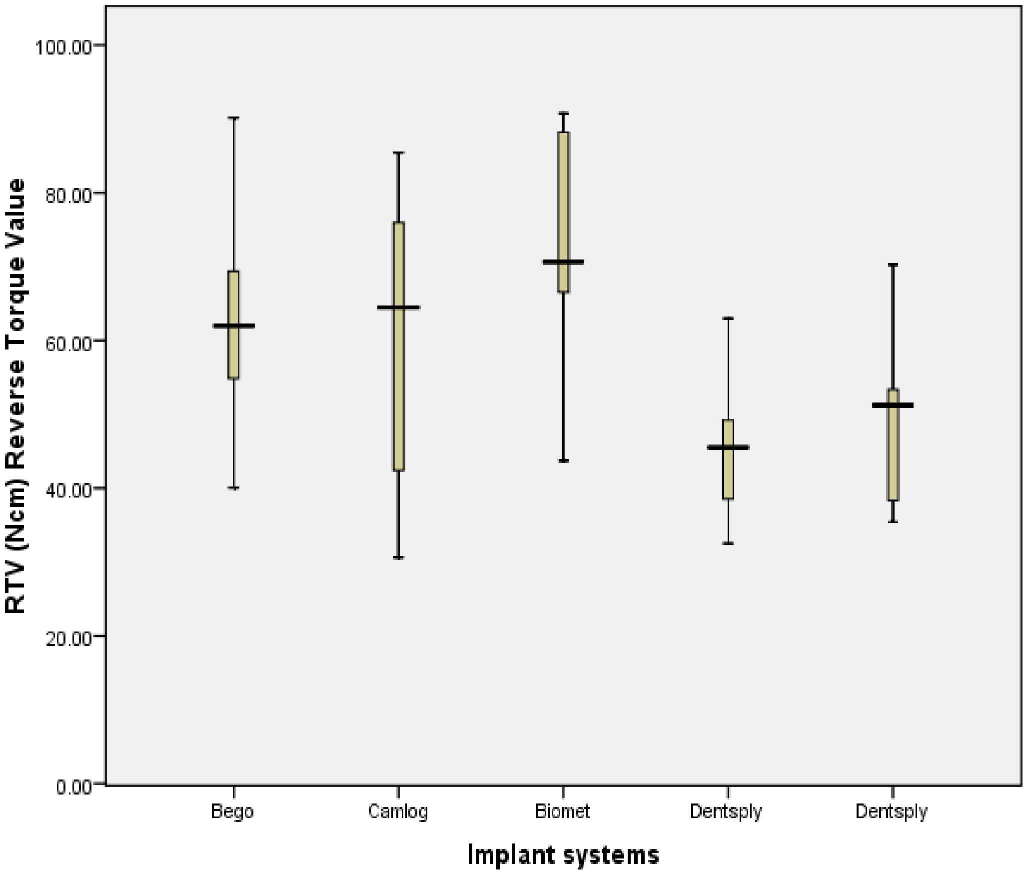

Figure 20: Box plot showing values of reverse torque (RTV) according to various implants designs system.

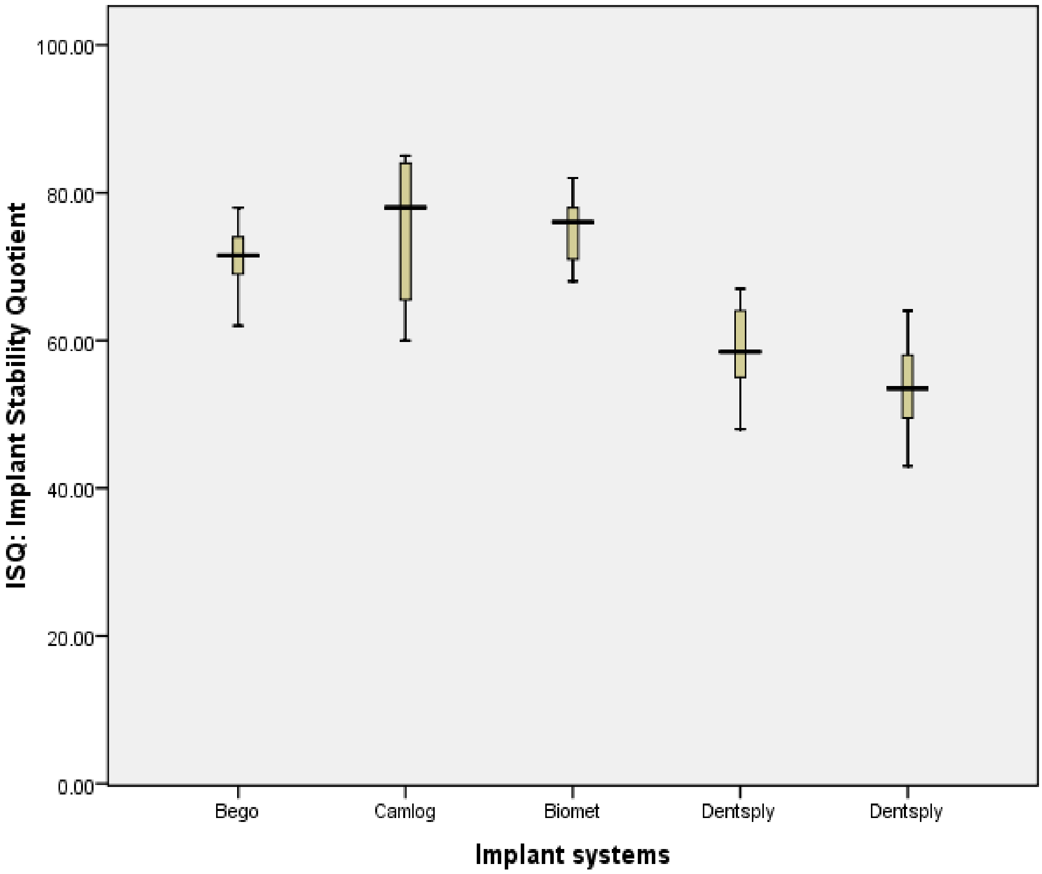

Figure 21: Box plot showing values of implant stability quotient (ISQ) according to various implant design systems.

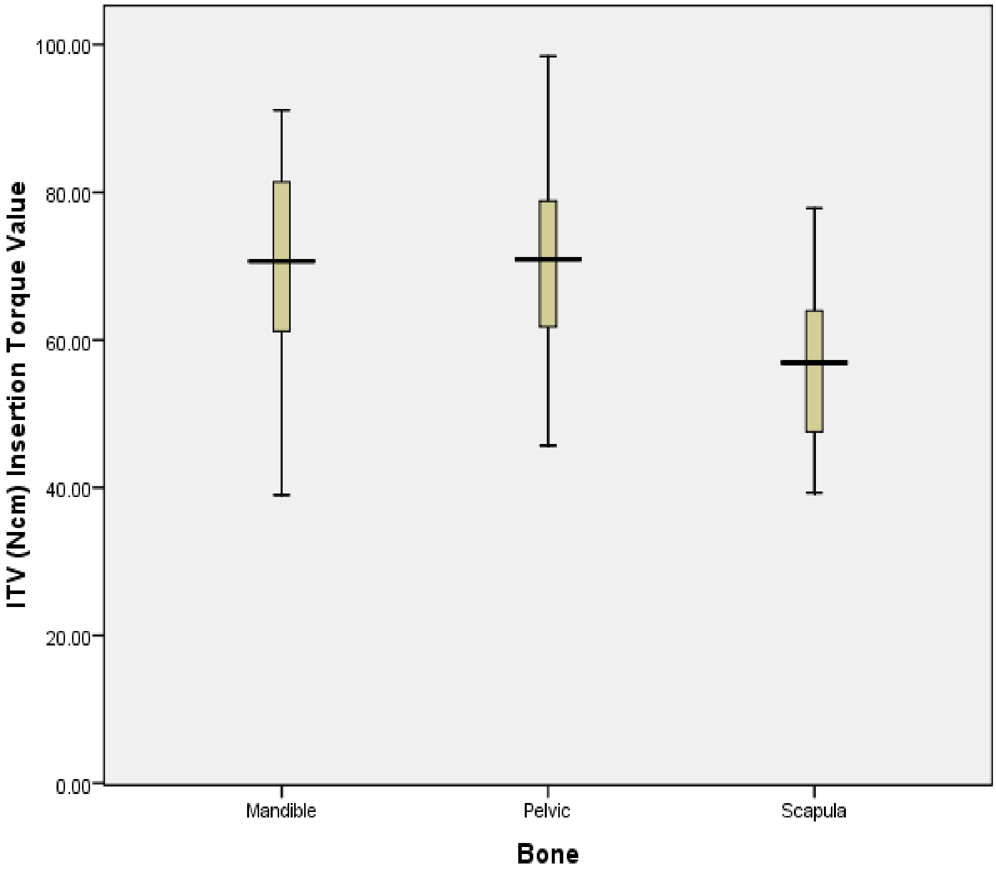

Figure 22: Box plot showing values of insertion torque (ITV) according to different bone types.

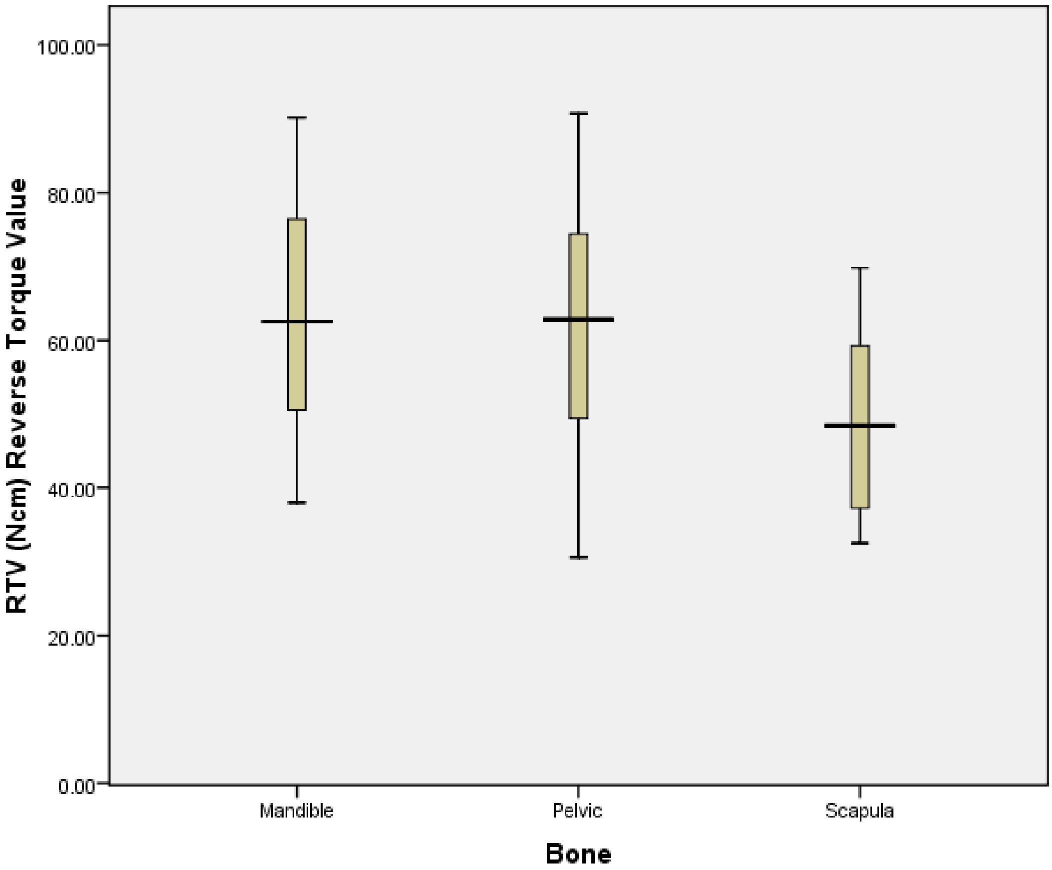

Figure 23: Box plot showing values of reverse torque (RTV) according to different bone types.

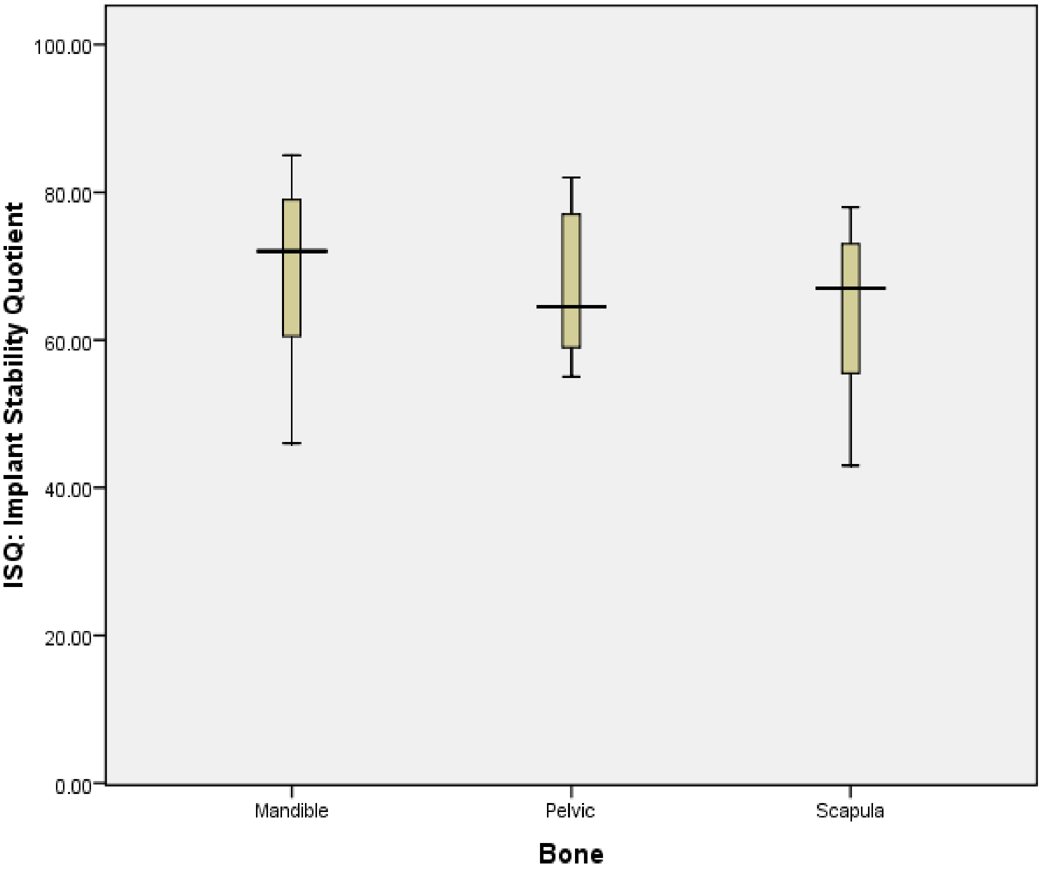

Figure 24: Box plot showing values of implant stability quotient (ISQ) according to different bone types.

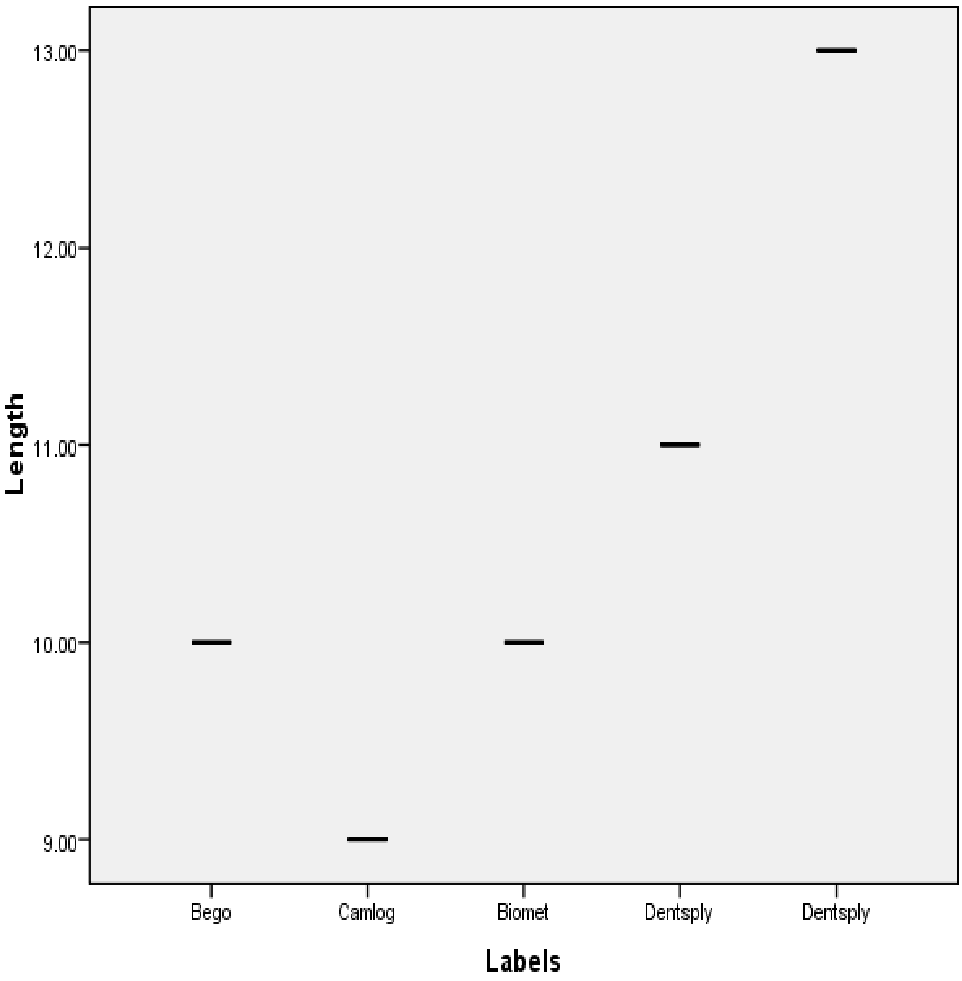

Figure 25: Different length of various implants designs system as labeled.

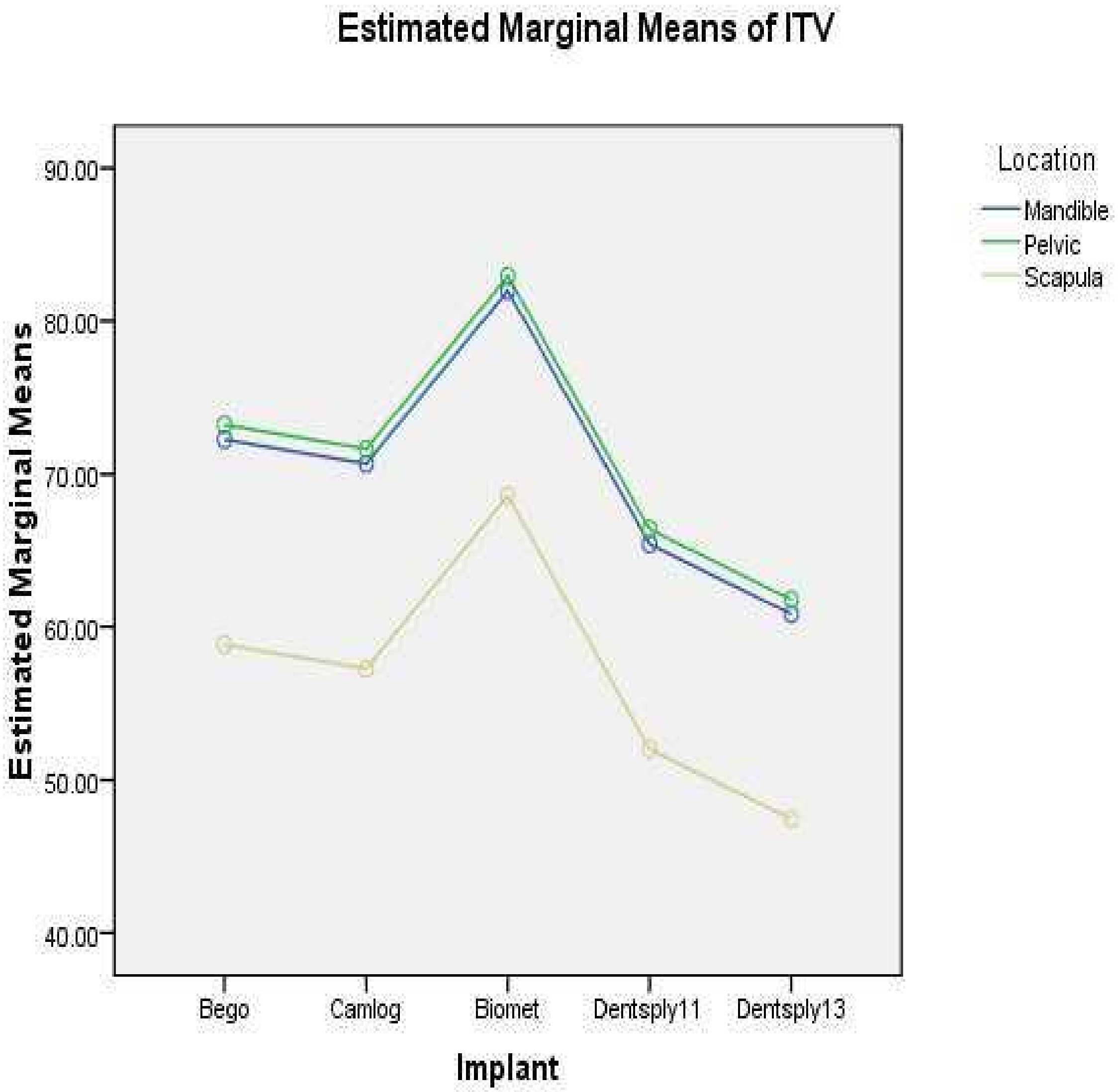

Table 26: Estimated marginal means of (ITV) for different implant systems.

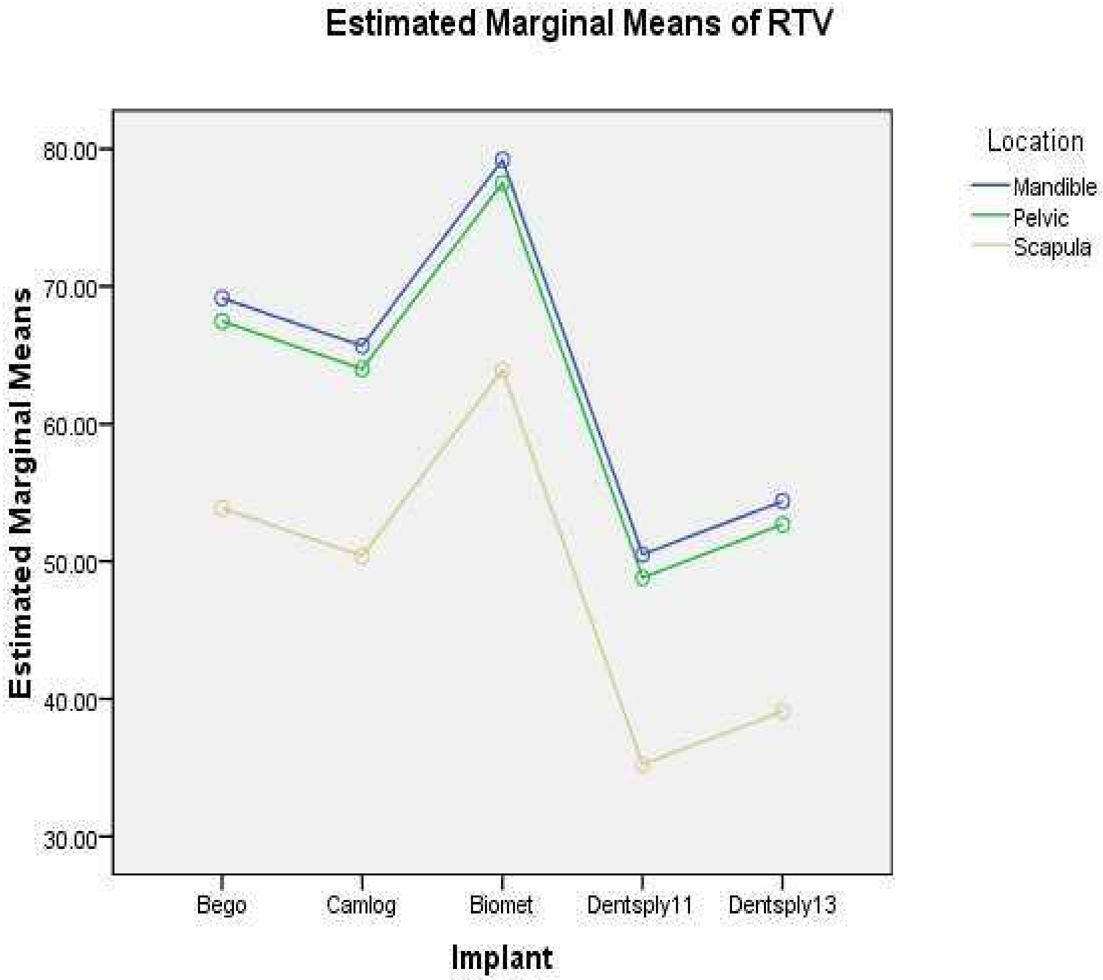

Table 27: Estimated marginal means of (RTV) for different implant systems.

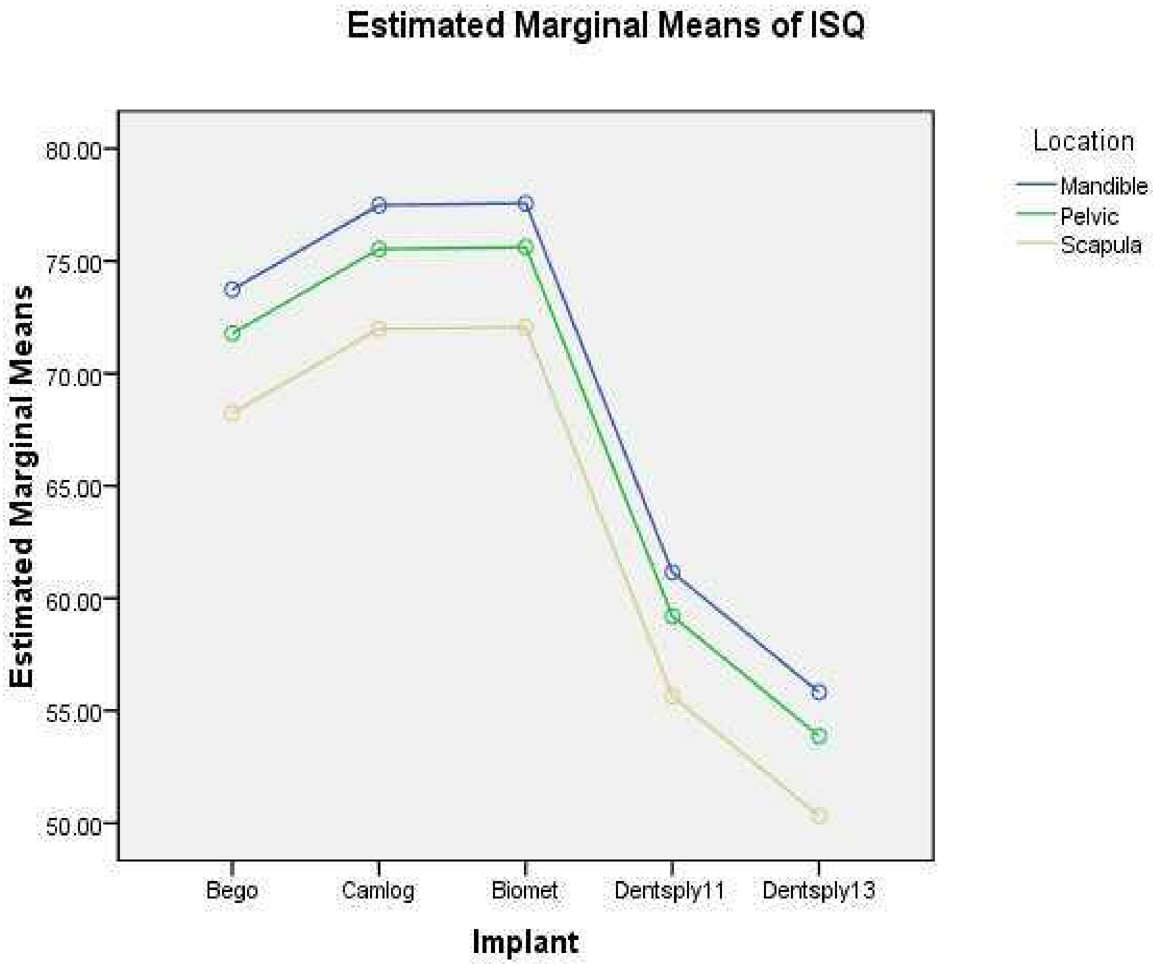

Table 28: Estimated marginal means of (ISQ) for different implant systems.

3M ESPE implant systems:

In regards to the 3M ESPE implant system; the highest mean of insertion torque values 82.99±11.51 were reached by the 2.1mm diameter implant system in mandible in comparison to the lowest mean of ITV 10.41±4.27 in the same bone type.

Notably, the ESPE 2.1 mm show the highest removal torque value of 77.62±9.82 in mandible bone compared to the lowest RTV of 9.18±3.56 in the same bone.

A significantly positive correlation between ITV with 2.1mm, 2.4mm mini implants diameter was observed. Furthermore, RTV was positively correlated with the 3M ESPE mini implant diameter. And correlation between ITV and RTV were positive, with (p value 0.01 two tailed).

However, there were no significant associations between implant length, diameter (1.8; 2.1 & 2.4), and insertion or removal torque values. Conversely, there was a linear by linear association between ITV and mandible (*p* value 0.01 significance). A significantly positive correlation between ITV with mandibular bone. Nevertheless, there were no significant associations between ITV with the other two bone types (Scapula & Pelvis).

Table 8: Intra-osseous stability values (ITV, RTV) measurements of porcine bone for mini-diameter implant 3M ESPE 1.8 system.

ESPE 1.8					**95% Confidence Interval for Mean**	
	Bone	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
ITV	Mandible	5	10.42	4.27	5.11	15.73
	Scapula	5	48.84	13.71	31.82	65.86
	Pelvis	5	34.53	25.1	3.37	65.69
RTV	Mandible	5	9.18	3.56	4.76	13.59
	Scapula	5	43.14	12.97	27.04	59.24
	Pelvis	5	28.33	19.53	4.08	52.58

Table 9: Intra-osseous stability values (ITV, and RTV) measurements of porcine bone for mini-diameter Implant 3M ESPE 2.1 system.

ESPE 2.1					**95% Confidence Interval for Mean**	
	Bone	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
ITV	Mandible	5	82.99	11.51	68.70	97.28
	Scapula	5	23.81	3.42	19.56	28.06
	Pelvis	5	30.72	17.06	9.54	51.91
RTV	Mandible	5	77.62	9.82	65.43	89.82
	Scapula	5	23.13	3.07	19.32	26.94
	Pelvic	5	34.46	18.13	11.95	56.96

Table 10: Intra-osseous stability values (ITV, and RTV) measurements of porcine bone for mini-diameter implant 3M ESPE 2.4 system

ESPE 2.4					**95% Confidence Interval for Mean**	
	Bone	**N**	**Mean**	**SD**	**Lower Bound**	**Upper Bound**
ITV	Mandible	5	45.09	24.68	14.45	75.73
	Scapula	5	55.81	14.42	37.9	73.72
	Pelvic	5	62.38	9.95	46.56	78.21
RTV	Mandible	5	42.92	24.55	12.43	73.4
	Scapula	5	49.18	12.8	33.28	65.08
	Pelvis	4	59.2	8.11	46.3	72.09

Table 11: Correlation between diameters of mini implant 3M ESPE with ITV and RTV in porcine bone placement.

Correlations					
			Diameter	ITV	RTV
Spearman's rho	Diameter	Correlation Coefficient	1.000	0.415**	0.426**
		Sig. (2-tailed)	.	0.005	0.004
		N	45	45	44
	ITV	Correlation Coefficient	0.415**	1.000	0.963**
		Sig. (2-tailed)	0.005	.	0.000
		N	45	45	44
	RTV	Correlation Coefficient	0.426**	0.963**	1.000
		Sig. (2-tailed)	0.004	0.000	.
		N	44	44	44

**. Correlation is significant at the 0.01 level (2-tailed).

Multivariate Tests			
	Value		Sig.
Effect Intercept (Bone)	Wilks' Lambda test	0.207	0.000
Implant	Wilks' Lambda test	0.689	**0.005**

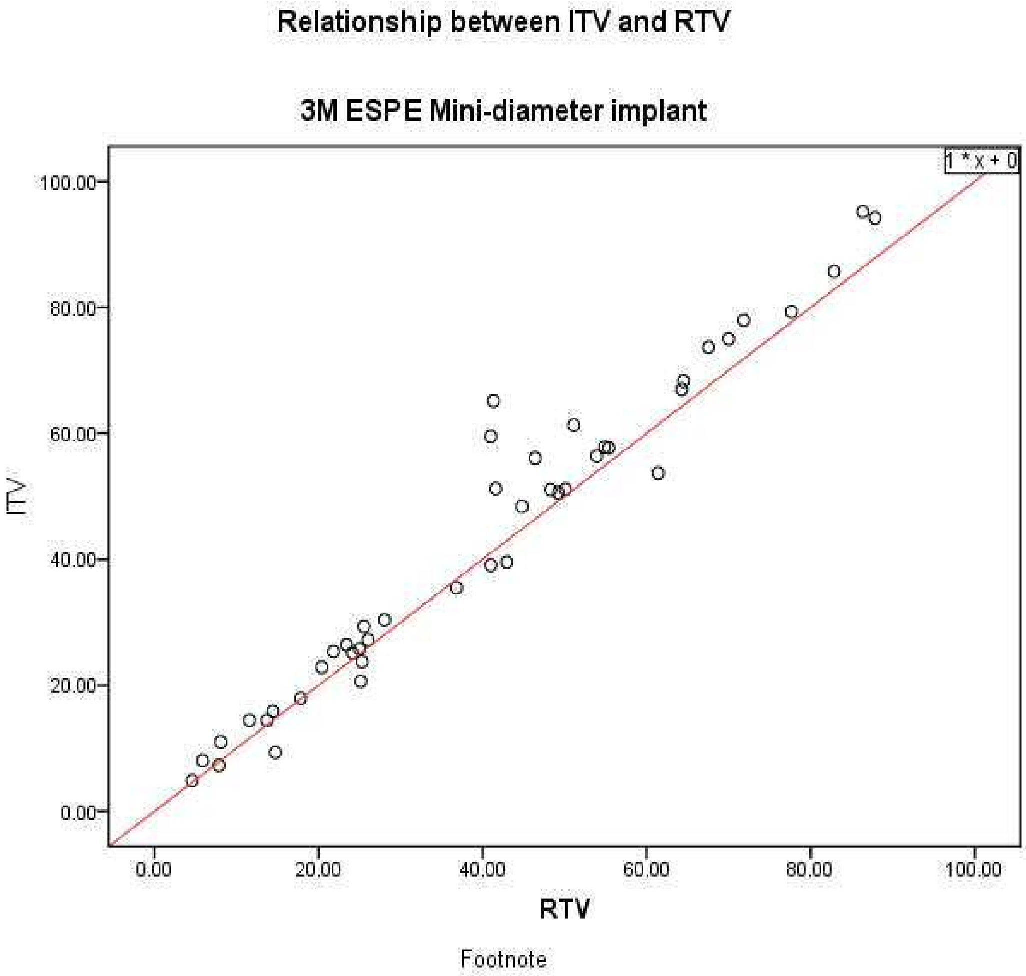

Figure 29: Scatter Plot diagram showing linear relationship between insertion and reverse torque values with fit line in mini diameter implant 3M ESPE.

Result analysis:

Result analysis confirmed that there was a significant effect of the three implant diameters ESPE (1.8, 2.1 & 2.4) on RTV and ITV (p=0.005).

Spearman's correlation at level of 0.01 (2-tailed) showed significant main effects of diameter on ITV and RTV values. There were equal variances for ITV and RTV measurements; since there were equal numbers of different diameter in each group.

Result analysis suggested ESPE 1.8 diameter were significantly having a lower means on ITV and RTV than 2.1 and 2.4. (Figure. 31, 32)

In regards to three bone types (mandible, scapula and pelvis), multivariate analysis confirmed that there were no significant effect on RTV and ITV measurement.

Furthermore, Spearman's correlation (Table.11) was conducted that the difference at the alpha level of 0.01 between the bone types were no significant, when considered jointly on the variables RTV and ITV.

In Summary, the result analysis with multivariate analysis indicated that the three ESPE diameters differed significantly in respect of a combination of ITV and RTV measurement. However, there were no significant effects of the three bone types on RTV and ITV measurements.

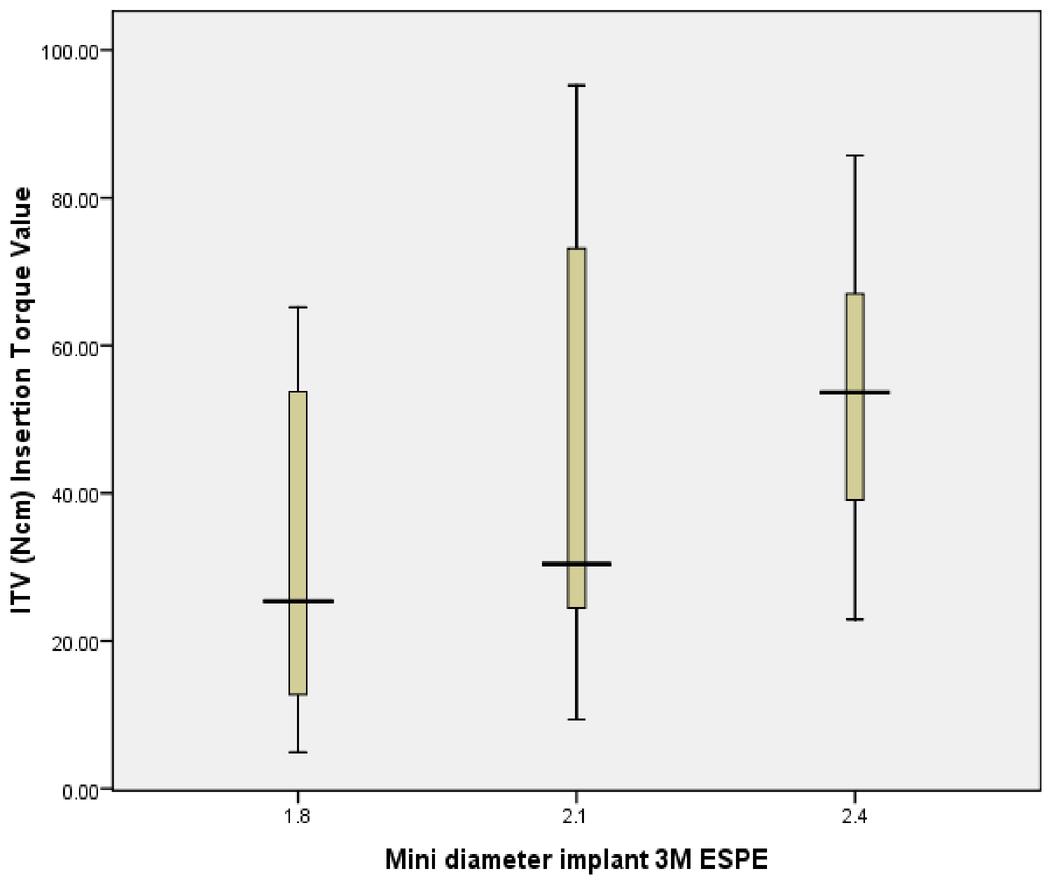

Figure 30: Box plot showing values of insertion torque (ITV) according to different diameters mini implant 3M ESPE.

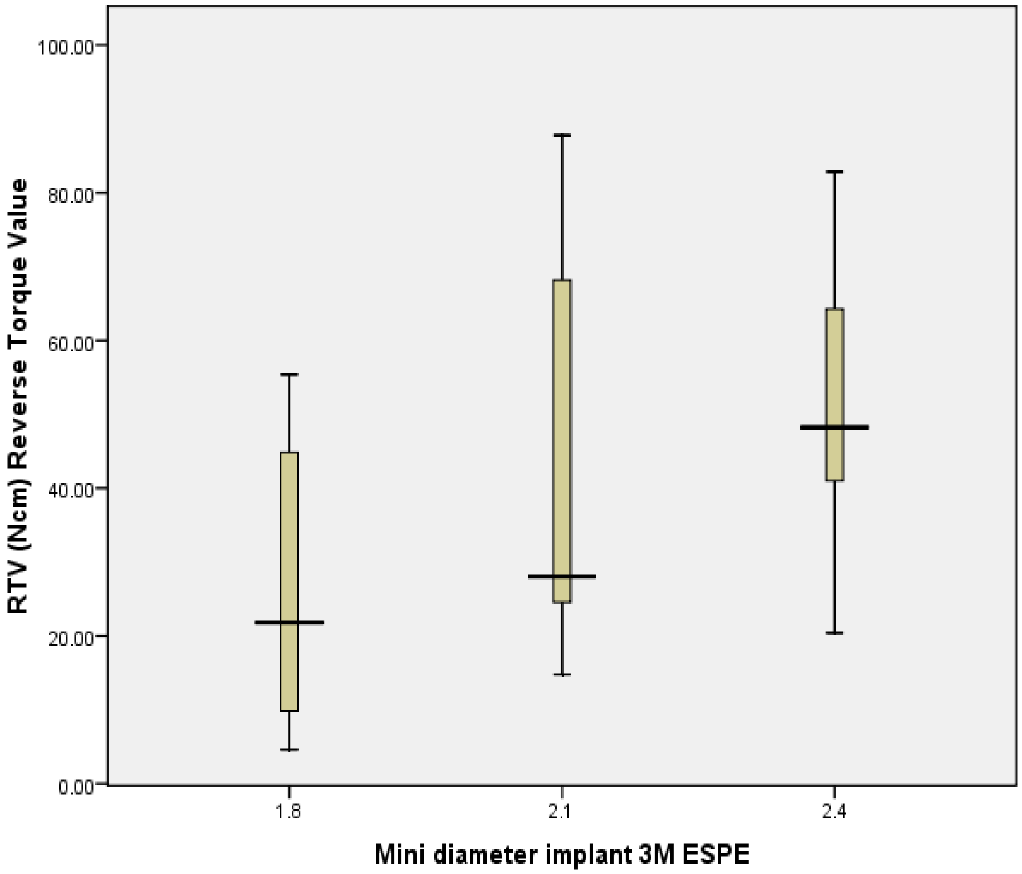

Figure 31: Box plot showing values of reverse torque (RTV) according to different diameters mini implant 3M ESPE.

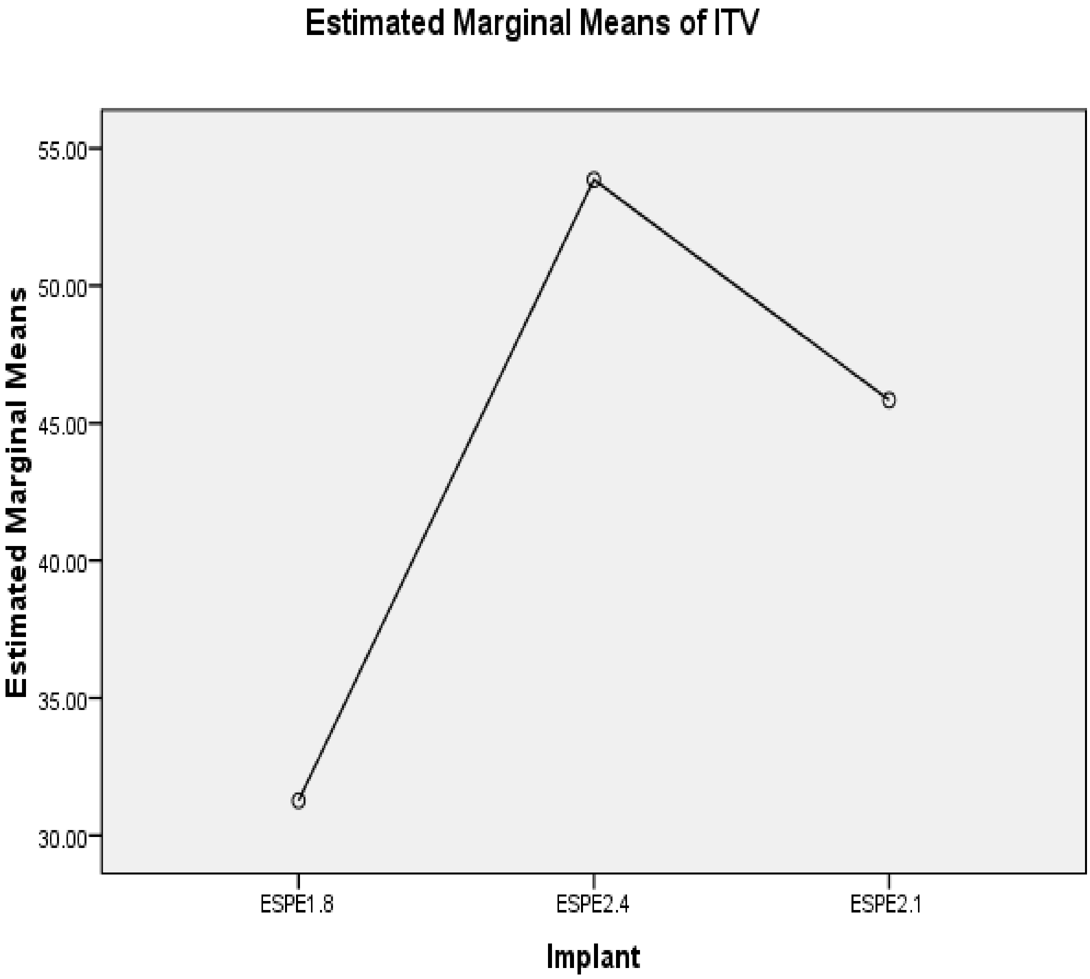

Figure 32: Estimated marginal means of (ITV) for mini-diameter implant system (3M ESPE).

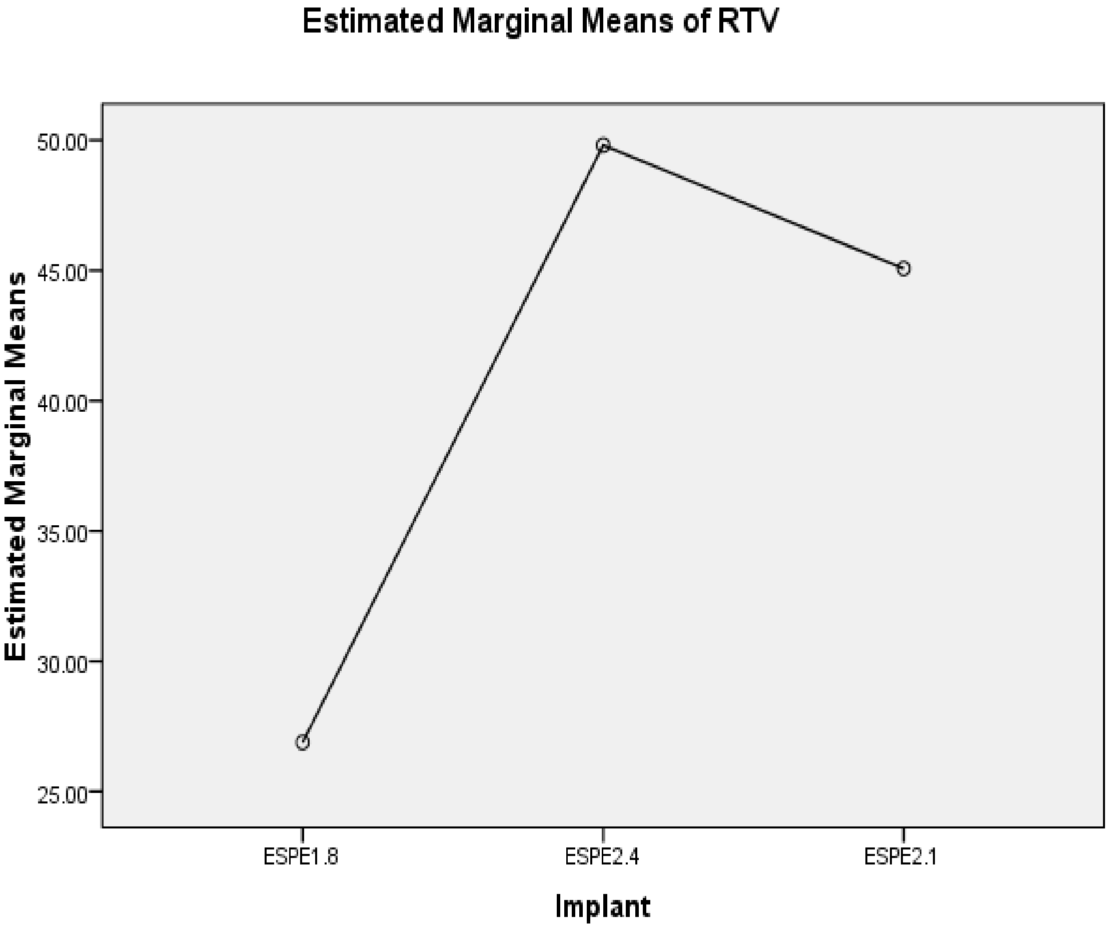

Figure 33: Estimated marginal means of (RTV) for mini-diameter implant system (3M ESPE).

5. Discussion:

In our study finding, the different implants design that Placement of different bone densities had superior effect on different stability values (ITV, RTV and ISQ). It is clear that the difference in implant designs is due to the manufacturer's specification for each implants system.

Our results are consistent with previous studies with respect to the significant relationship between implant morphology and initial stability. O'Sullivan et al. observed significant differences in primary stability when five different implants of various designs were inserted in the maxilla of human cadavers (33).

In this study no significant difference observed between same implants design, in regard to previous studies that significant difference in ISQ values between the conical and cylindrical Camlog implants system (135). In addition, the ISQ values were symmetrical for different implant systems, and RFA has not been applicable to assess implant stability, especially as a standalone approach (136).

Notwithstanding, the quality and quantity of bone at the implant site is very important local factors to determining the success of dental implants (58; 59). Several authors have confirmed a positive correlation between the quality of bone and primary stability, and have elucidated that the initial implant stability would be jeopardized in bone of low density, with potential risk of failure (33; 100; 117; 118; 119).

Notably, the length of the implant has to reverse significant relationship on the means of the RTV and ISQ value. Therefore, a shorter implant would acquire higher values of ITV, RTV, and ISQ, and would subsequently promote stability. In addition, our results confirm a significant reverse relationship between length and implant diameter ($p < 0.01$). Therefore, length of the implant on it's own, upon result analysis, did not reach a significant level. As such, our finding is in line with previous studies, as the length of the implant has been found to have minimal or perhaps no effect on stability (89; 120). This leads us to the interesting question of what would be the optimum implant length to be used clinically.

Notably, the present results indicated a positive correlation between implant diameter and the means of ISQ, RTV, and ITV (Figures 26 – 28). Several authors suggested the use of wider-diameter implants to increase the amount of bone and titanium surface contact area and preferable for enhancing primary stability (121; 122; 123). Another author observed that the resonance frequency was associated with the height of the implant not embedded by bone (89).

With respect to the mini-diameter dental implant (3M ESPE), our results demonstrate a statistically significant effect on the mean of the ITV and RTV measurements. This significant difference indicates a better stability with 3M ESPE 2.4 mm diameters than the other 2 counterparts of 1.8 and or 2.1 mm mini-diameter implants. Furthermore, there are no significant multivariate issues related to the three bone sites of the mandible, scapula and pelvis on the RTV and ITV measurements. However, this is in contrast to the macro-diameter implant, for which there is a significant effect of bone site on the stability parameters.

Our results indicate a degree of variability on the means of RTV, ITV, and ISQ values within the same bone and for the same implant design system (Table 6) despite previous studies indicating a high degree of interoperator accuracy and repeatability for such measurements (126). There is a high degree of agreement between ISQ measures on the same bone. However, a lower degree of agreement among ITV and RTV measurements was observed. The difference achievable as a result of the implantation technique, despite a single operator performing the implantation. It’s also important to consider the bone quality space in between the insertion site (4 mm space between identical implant placements), reliability and test variability measures in an identical implant system, and sensitivity of the machine and troubleshooting procedures during each measurement.

Previously, the reliability of the implant stability value (ISQ) associated with implant stability has been explored (127; 128). In addition, it has been reported that the RFA method does not provide sufficient information about the bone implant interface, in comparison with the torque test method (129; 130)

Correlataion:

A significant positive correlation is found between mean values of RTV, ITV and ISQ parameters (Figure 16).

Limitation:

Lack of radiological imaging and histological evidence to establish quality and density of bone would have added objective evidence to our project.

Secondly, repeated measurement of the ISQ on the day or different day would may have reduce the error?

Conclusion:

In macro- and reduced-diameter dental implants, a positive correlation was observed to exist among the three primary stability parameters of reverse torque, insertion torque, and initial stability quotients. Furthermore, bone type and location influence the primary stability of dental implants.

Zusammenfassung:

Die Korrelation zwischen Implantatdesign und Primärstabilität ist ein kontrovers diskutiertes Thema. Das Ziel dieser Studie ist es, die Wirkung von Makrodesign, sowie reduziertem Implantatdurchmesser auf die Primärstabilität in verschiedenen Knochendichten zu untersuchen.

Material und Methode:

Es wurden im Rahmen einer in-vitro-Studie vier verschiedene Implantat Systeme (Camlog, DENTSPLY Friadent, BEGO,Biomet 3i Implantate-System) untersucht. Diese wurden in Schweineknochen verschiedener Dichte (Unterkiefer, Schulterblatt und Becken) eingedreht. Des Weiteren wurde ein Mini-implantat (3MESPE) mit einem Durchmesser von 1.8mm, 2.1mm und 2.4mm untersucht. Es wurde die Primärstabilität über die Parameter Eindrehmoment (ITV), Ausdrehmoment (RTV) und Resonanzfrequenzanalyse (ISQ) bestimmt.

Ergebnis:

Es besteht ein signifikanter Unterschied zwischen den verschiedenen Implantatdesigns auf die Variablen RTV, ITV und ISQ-Werte (p = 0,001). In Bezug auf die Knochendichte (Unterkiefer, Schulterblatt und Becken) besteht, ebenfalls ein signifikanter Unterschied der Variablen RTV, ITV und ISQ-Werte (p=0,004).

Für das Mini-Implantat zeigte sich eine signifikant positive Korrelation zwischen ITV und Implantat durchmesser. Darüber hinaus korreliert RTV positiv mit dem Durchmesser des Mini-Implantats. Des Weiteren zeigte sich eine positive Korrelation zwischen ITV und RTV (P-Wert 0,01 zweiseitig).

Schlussfolgerung:

Für Zahnimplantate mit reduziertem Durchmesser gibt es eine positive Korrelation zwischen den Primärstabilitäts-Parametern Ausdrehmoment, Eindrehmoment und ISQ. Des Weiteren beeinflusst die Knochendichte die Primärstabilität von Zahnimplantaten.

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