A COMPARISON OF TAPER-

IMPLANT DESIGNS AND BONE QUALITY ON THE PRIMARY STABILITY: AN *IN VITRO*

BIOMECHANICAL STUDY

Mr. Ratchaya Chayangsu

จุฬาลงกรณ์มหาวิทยาลัย
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บทคัดย่อและแฟ้มข้อมูลฉบับเต็มของวิทยานิพนธ์ตั้งแต่ปีการศึกษา 2554 ที่ให้บริการในคลังปัญญาจุฬาฯ (CUIR)
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การเปรียบเทียบเสถียรภาพขั้นแรกระหว่างรากเทียมชนิดปลายสอบและคุณภาพกระดูกโดยการ
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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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รัชชย ชยางศุ : การเปรียบเทียบเสถียรภาพขั้นแรกระหว่างรากเทียมชนิดปลายสอบและคุณภาพกระดูกโดยการทดลองชีวกลศาสตร์ (A COMPARISON OF TAPER-IMPLANT DESIGNS AND BONE QUALITY ON THE PRIMARY STABILITY: AN *IN VITRO* BIOMECHANICAL STUDY) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ทพ. ประเวศ เสรีเชษฐพงษ์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ. ทพ. ดร. อาทิพันธุ์ พิมพ์ขาวขำ, 71 หน้า.

วัตถุประสงค์ เพื่อศึกษาผลของแบบรากเทียมชนิดปลายสอบและผลของคุณภาพกระดูกที่แตกต่างกัน โดยการวัดเสถียรภาพขั้นแรกด้วยการวัดค่าแรงบิดการใส่ ค่าแรงบิดการถอน และค่าความถี่เรโซแนนซ์

วิธีการทดลอง นำรากเทียบชนิดปลายสอบที่มีแบบแตกต่างกันจำนวนห้าแบบฝังลงในกระดูกเทียมที่มีคุณภาพกระดูกแตกต่างกันสี่ระดับ โดยรากเทียมแต่ละแบบจะถูกฝังเป็นจำนวนซ้ำกันห้าตัวในกระดูกแต่ละระดับ ไล่จากกระดูกที่มีความแข็งต่ำที่สุดก่อน กระดูกจะถูกกรอตามขั้นตอนที่แนะนำโดยผู้ผลิต จากนั้นฝังรากเทียมลงในกระดูก วัดและบันทึกค่าแรงบิดการใส่สูงสุดของรากเทียมด้วยเครื่องมอเตอร์ฝังรากเทียมจนฐานส่วนบนของรากเทียมจมลงเท่าระดับกระดูกที่กำหนดไว้ จากนั้น ใช้เครื่องวัดความถี่เรโซแนนซ์ วัดและบันทึกค่าความถี่เรโซแนนซ์ สุดท้ายใช้เครื่องมอเตอร์ฝังรากเทียมในการนำรากเทียมออก ค่าแรงบิดการถอนสูงสุดจะถูกวัดและบันทึก เมื่อรากเทียมเริ่มถูกถอนออก รากเทียมจะถูกนำไปใช้ซ้ำในกระดูกที่แข็งขึ้นตามลำดับจนครบสี่ระดับ โดยทำซ้ำขั้นตอนดังที่กล่าวมาข้างต้น ข้อมูลในแต่ละกลุ่ม (ค่าแรงบิดการใส่ ค่าความถี่เรโซแนนซ์ และค่าแรงบิดการถอน) จะถูกนำมาวิเคราะห์ทางสถิติด้วยสถิติความแปรปรวนสองทางแบบแฟคทอเรียลเพื่อดูปฏิสัมพันธ์ของตัวแปรอิสระสองตัว (แบบของรากเทียมชนิดปลายสอบห้าแบบและคุณภาพกระดูกสี่ชนิด) ที่ระดับนัยสำคัญ 0.05

ผลการทดลอง พบว่าในการวัดค่าแรงบิดการใส่และแรงบิดการถอน แบบของรากเทียมและคุณภาพกระดูกมีปฏิสัมพันธ์ต่อกันอย่างมีนัยสำคัญทางสถิติ ในขณะที่ค่าความถี่เรโซแนนซ์ พบว่าแบบของรากเทียมและคุณภาพกระดูกไม่มีปฏิสัมพันธ์ต่อกัน แต่ผลของแต่ละปัจจัยส่งผลแยกกันอย่างมีนัยสำคัญทางสถิติ

สรุป จากการศึกษาพบว่าแบบของรากเทียมและคุณภาพกระดูกมีปฏิสัมพันธ์ต่อกัน ดังนั้นการคาดการค่าแรงบิดการใส่และแรงบิดการถอนจึงต้องคำนึงถึงปัจจัยทั้งคู่

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สาขาวิชา	ทันตกรรมบูรณะเพื่อความสวยงามและทันตกรรมรากเทียม	ลายมือชื่อนิสิต ....
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5775819132 : MAJOR ESTHETIC RESTORATIVE AND IMPLANT DENTISTRY
KEYWORDS: DENTAL IMPLANT / IMPLANT DESIGN / PRIMARY STABILITY / BONE QUALITY / RESONANCE FREQUENCY ANALYSIS / INSERTION TORQUE / REMOVAL TORQUE

RATCHAYA CHAYANGSU: A COMPARISON OF TAPER-IMPLANT DESIGNS AND BONE QUALITY ON THE PRIMARY STABILITY: AN *IN VITRO* BIOMECHANICAL STUDY. ADVISOR: ASSOC. PROF. PRAVEJ SERICHETAPHONGSA, CO-ADVISOR: ASSOC. PROF. ATIPHAN PIMKHAOKHAM, Ph.D., 71 pp.

Objective To investigate the effect of the taper-implant design and the effect of bone quality on the primary stability in terms of insertion torque test, removal torque test and resonance frequency analysis.

Methods Five taper-implant designs were test in artificial bone blocks with four qualities. Five repetitions per implant design were placed in each bone quality started from softest bone block. The implant motor was used to prepared the osteotomy sites and implant insertion according to manufacturers' recommendation. Peak insertion torque values were measured and recorded by implant motor when the platform of the implant flush to the bone level. Resonance frequency analysis was measure by Osstell ISQ device. The implant stability quotients were recorded. Finally, the implants were unscrewed by implant motor and the peak removal torque values were recorded. Same implants were reused with the same protocol in the rest of the test, from softer to harder test blocks respectively. The data of insertion torque values, implant stability quotients and removal torque values were statistically analysed by two-way factorial ANOVA to investigate the interaction effect of two independent variables (implant design and bone quality), ($p=0.05$).

Results In insertion torque and removal torque tests, the interaction effects of implant design and bone quality were statistically significant. However, the interaction effect was not found in resonance frequency analysis group.

Conclusion Within the limitations of this study, it can be concluded that selecting the proper design of tapered implant regarding to the quality of surgical bone site can achieve predictable primary stability outcome in terms of insertion torque and removal torque.

Field of Study:	Esthetic Restorative and Implant Dentistry	Student's Signature	....
		Advisor's Signature	....
Academic Year:	2017	Co-Advisor's Signature	....

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Background and rationale

The clinical use of dental implants as dental substitutions has increased by the day since their long-term success rates are very high [1, 2]. In the past, success dental implant commonly defined as a survival of implant and successful osseointegration [3]. Although new parameters have been introduced such as natural looking implant restorations and peri-implant tissue to assess the success of dental implants, osseointegration remains the predominant parameter in implant dentistry [4, 5].

Implant stability at the time of implant placement, known as the primary stability, is a crucial factor for achieving successful osseointegration [6, 7]. Primary stability has been thought to be influenced by three main factors such as local bone quality, implant design and surgical technique [1]. The interplay of these three factors determines the primary stability of the implant.

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Primary stability can assess by many methods such as resonance frequency analysis, insertion torque and removal torque measurement [1, 8]. Resonance frequency analysis (RFA) is proved to be reliable, reproducible, and user-friendly non-invasive methods [1, 8-10]. Insertion torque (IT) measurement, which is frequently used in both in vivo and in vitro study, was described by Johansson and Strid [11]. This method records the torque required to place the implant and provides valuable information about local bone quality. For removal torque (RT) measurement, although it is currently has not been used in clinical practice owing to their invasive approach, but still a beneficial tool in research [1, 8, 12].

Bone quality or bone density is decisive factor in the success of gaining primary stability. Although there are many bone assessments were introduced but they were generally classified into four groups of bone density [13]. The volume of bone available and density of the bone are highly associated with the type of surgical procedure and the type of implant, and both factors play a vital role in the success of dental implant surgery [14].

Currently, there are many features of the implant such as diameter, length, surface thread designs and topography of the implant such as parallel shape, taper shape.

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Original implants were parallel in design. However, the original design was not suitable for all applications. Consequently, taper implant was especially designed for immediate implant placement after tooth extraction. The theory behind the use of taper implants is to provide for a degree of compression of the cortical bone in a poor bone implant site [15]. When taper implant was inserted, it creates a lateral compression of the bone [16].The advantages of the taper implant can be seen especially with anatomic limitation, including ridges with concavities or narrow ridges. Parallel implants tend to run the risk of labial perforation due to buccal concavities, while the decrease in diameter toward the apical region of the taper implant can avoids the labial concavity [17].

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Presently, most implant companies offer taper implants. Nevertheless, there are lack of information of how the macro-designs of the taper-implant such as the body shape, threads, thread shape of the taper implant affect the primary stability and what is the proper design for each bone quality in terms of primary stability.

Therefore, the aim of this study is to investigate the effects of taper-implant designs in different bone quality and their relation in terms of primary stability.

Review of literature

1. Implant geometry

1.1 Diameter and length

From the study of Winkler et al., shorter implants showed statistically lower survival rates as compared with longer implants and narrower diameter implants had lower survival rate than wider implants [18]. Renouard & Nisand demonstrated a trend for an increase failure rate with short implants and wide-diameter implants. However, they found that the survival rates for short and for wide-diameter implants has been comparable with those obtained with longer implants and those of a standard diameter in carefully considered cases [19]. In addition, Baggi et al. suggested that implant diameter maybe more effective than implant length as a design parameter to control the risk of bone overload [20].

Influence of implant diameter and length on primary stability is still inconclusive. Östman et al. found decreasing stability with increasing implant length [21]. Miyamoto et al. found similar result which may be explained by the fact that some long implant designs have a reduced diameter in the coronal part to reduce friction heat and facilitate easy insertion [22]. However, Bischof et al. found that implant position, implant length, implant diameter and vertical position did not influence the implant stability quotient (ISQ) values of the implants placed in both maxilla and the mandible [23]. The study of Ito et al. also showed that implant length might not have a significant effect on resonance frequency analysis measurements[24] which also has been support in in vitro [25] and in clinical [21, 23, 26] studies. On the other hand, Romanos et al. suggest that in dense bone blocks, the wider diameter implants are more stable than narrow implants [27]. Moreover, increasing in diameter size resulted in higher insertion torque gain but increasing in length did not offer greater value in self-tapping implant [28].

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1.2 Implant surface

Implant surface modification has been developing to improve osseointegration and increase bone to implant contact. Cooper et al. claimed that from animal studies and emerging information from human investigations suggested that enhanced surface topography beyond a machined surface is associated with increased bone-to-implant contact and increased biomechanical interlocking with bone [29]. Additionally, Guehennec et al. demonstrated that there are several surfaces commercially available for dental implants and most of these surfaces have proven clinical efficacy. However, such changes may enhance the osseointegration of implants during the healing period but have little effect on the primary stability of the fixtures immediately after placement [30].

1.3 Implant macro-design

There are two major categories of implant design: macro-design and micro-design. Macro-design consists of body shape, thread, and thread design (e.g., thread geometry, face angle, thread pitch, thread depth, thread width and microthreads) [31].

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In this study, we mainly focus on overall implant macro-designs and how they impact the primary stability in different bone quality. However, some specific characteristics were worth to give the attention.

Thread shape was believed to have an important in stress transfer between the surrounding bone and the implant [32]. There are many types of thread shapes such as

V-shape, square shape, buttress and reverse buttress that are distinct by the thread thickness and face angle [33].

Thread pitch is the distance, parallel to the implant axis, between the center of one thread to the center of next thread [34]. From the finding of Ryu et al., smaller pitch has better stress distribution and supports the primary stability. Though, the optimal thread pitch was depending on the thread design [32].

Thread depth is the distance from the tip of the thread to the body of the implant and thread width is the axially distance between the most coronal and the most apical of the base of single thread. Deeper threads may advantage in softer bones, on the other hand, shallower threads offer easier insertion in denser bones [35].

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Crestal module, or the neck portion of the implant, previously was smooth to prevent plaque accumulation. Later, microthreads was introduced and multiple studies indicate that they promote bone formation and effective in stress distributions [32].

2. Bone Assessment

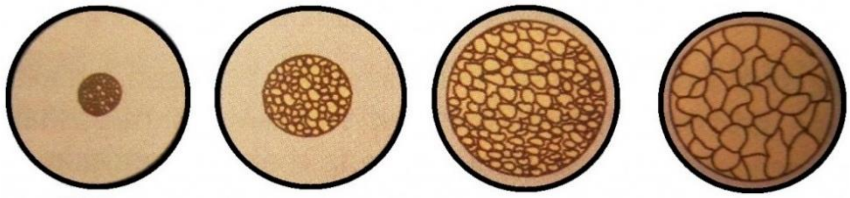

Figure 1: Bone density classification (Misch, 1999)

There are many bone quality assessment studies which generally categorized the bone quality into four groups according to the proportion and structure of compact and trabecular bone tissue [13] . In 1999, Misch et al. proposed four bone density groups based on cortical and trabecular bone which similar to the classification of Lekholm and Zarb in 1985 [36]. Bone density groups divided into D1 to D4: D1 bone is almost dense compact, D2 bone is a combination of dense to porous compact cortical bone on the outside and "coarse" trabecular bone on the inside, D3 bone is porous, thinner cortical bone and "fine" trabecular bone, D4 bone is "fine" trabecular bone that has very light density and little or no cortical crestal bone [37].

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3. Polyurethane foam block

Polyurethane foam block is the mechanical test-block which equivalent to jaw bone (Sawbones®; Pacific Research Laboratories Inc., Washington, USA). Polyurethane foam is considered to be the standard material used for performing mechanical tests on orthopedic implants [38]. Moreover, this biomechanical test material offers uniform and consistent physical properties that eliminate the variability encountered when testing with human cadaver bone. Using Misch classification of bone density, D1 bone was simulated using 40 pounds per cubic foot (pcf) with a bone density of 0.64 g/cm3 polyurethane blocks, D2 bone was simulated using 30 pcf polyurethane blocks with a bone density of 0.48 g/cm3, D3 bone was simulated using 20 pcf polyurethane blocks with a bone density of 0.32 g/cm3, and D4 bone was simulated using 10 pcf with a bone density of 0.48 g/cm3. For the mean bone mineral density, posterior maxilla bone density is 0.31 g/cm3 and anterior maxilla is 0.55 g/cm3 [39].

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4. Primary stability assessments

Presently, various diagnostic methods and tools have been suggested to define implant stability: non-invasive clinical test methods such as radiographic methods, Periotest, insertion torque (cutting torque, cutting resistance test) and resonance frequency analysis or the invasive research test methods such as histomorphometry and removal torque test [1].

4.1 Resonance Frequency Analysis

The resonance frequency analysis (RFA) technique for implant stability measurements was developed by Meredith and coworkers more than 20 years ago [40] which this technique today is commercially available as Osstell ISQ device (Osstell AB, Gothenburg, Sweden)(Figure 1). The Osstell ISQ is highly reliable regarding reproducibility [9, 10]. RFA makes use of a transducer (peg), which is attached to the implant and excited over a range of frequencies by electro-magnetic waves to measure the resonance frequency of the transducer. The underlying RF measurements in Hz are

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translated to Implant Stability Quotients (ISQ) units from 1 (lowest stability) to 100 ISQ units (highest stability).

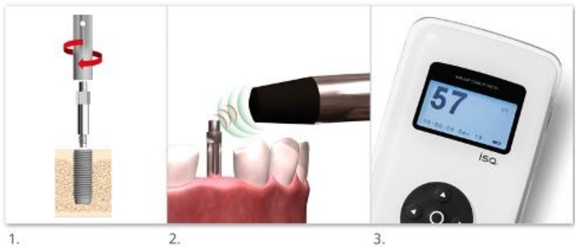

Figure 1

Osstell ISQ device (Osstell AB, Gothenburg, Sweden) and the work flow.

RFA measures implant stability in bending as a function of interface stiffness and correlates with implant displacement, i.e. micro-mobility, under lateral loading [41]. The ISQ value is determined by the local bone density and is influenced by implant placement technique, implant design, healing time and exposed implant height above the alveolar crest [42].

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Bone density is a major determinant of RFA measurement as shown in numerous studies. A positive correlation between ISQ units and bone density with insertion torque measurements has been demonstrated [43].

Implant stability is usually higher in the mandible than in the maxilla [21] due to the fact that mandibular bone is often denser than maxillary. Moreover, the properties of the marginal bone influence RFA measurements [22, 24].

The influence of implant length and diameter on RFA measurements is not clear and seems to vary between studies. The use of technique to create increased lateral compression during insertion seems to result in higher stability. This may be due to undersized preparation before placing the implant or the use of taper implant [44].

Most researchers have not found implant surfaces to impact on ISQ measurements. A clinical study on immediate loading in the posterior mandible found no difference in primary stability between machined and oxidized titanium implants [45]. However, the machined implants showed a significant loss of stability, while the oxidized implants remained their stability after 4 months of loading.

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It seems like implants with low and/or falling ISQ values pose an increased risk for failure compared with implants with high and/or increasing values. The RFA technique can be used at any stage during treatment as one additional parameter to support decision making during implant treatment and follow-up.

4.2 Insertion torque (IT)

Insertion torque, cutting torque or cutting resistance measurement technique was introduced by Johansson and Strid to determining bone density during implant site preparation during low speed drilling. This method was further explored by Friberg et al. and found a technique to be reliable and applicable in clinical routine work. However, the major limitation of insertion torque is that it does not give any information on bone quality until the osteotomy site is prepared. Insertion torque value could measure as Newton-Centimeter (N-cm) scale. The Insertion torque value is determined by the local bone density and is influenced by implant placement technique[25]. Bone density is not only a major determinant of insertion torque measurement, as shown in many studies, but the thickness of the cortical bone also [25, 43, 46]. The under preparation of the osteotomy site technique has been used to increase the IT value [46, 47]. However, the primary

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stability cannot be acquired by simply reducing the diameter of the final drill in attempts to increase the insertion torque [46].

4.3 Removal Torque (RT)

Removal torque test is an invasive clinical method since it is a measurement of resistance force in removing the implant. However it is still a beneficial measurement in animal research when comparing material, implant design, surface treatment in terms of shear strength, quality of bone-implant contact, and speed of formation of contact [12]. Several in vitro studies, without the osseointegration of implants, found that there are obvious problems when drawing conclusion from removal toque data gathered immediately after insertion.

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A high immediate removal torque may not indicate that a high removal torque would be gained once osseointegration has taken place. However, immediate removal torque does provide a measure of the resistance of an implant to rotational displacement in the vulnerable post-insertion healing period [44].

Research questions

1. Does implant design affect primary stability?

2. Does bone quality affect primary stability?

3. Are there any interaction of implant design and bone quality on primary stability?

Research objectives

The aim of this study was to investigate the effect of taper-implant designs in different bone quality in terms of the primary stability (insertion torque (IT), removal torque (RT) and resonance frequency analysis (RFA))

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Statement of hypothesis

Null hypothesis:

1. There was no significant difference on insertion torque based on implant designs.

2. There was no significant difference on insertion torque based on bone quality.

3. There was no significant interaction effect between the implant designs and bone quality in terms of the insertion torque.

4. There was no significant difference on removal torque based on implant designs.

5. There was no significant difference on removal torque based on bone quality.

6. There was no significant interaction effect between the implant designs and bone quality in terms of the removal torque.

7. There was no significant difference on RFA based on implant designs.

8. There was no significant difference on RFA values based on bone quality.

9. There was no significant interaction effect between the implant designs and bone quality in terms of the RFA.

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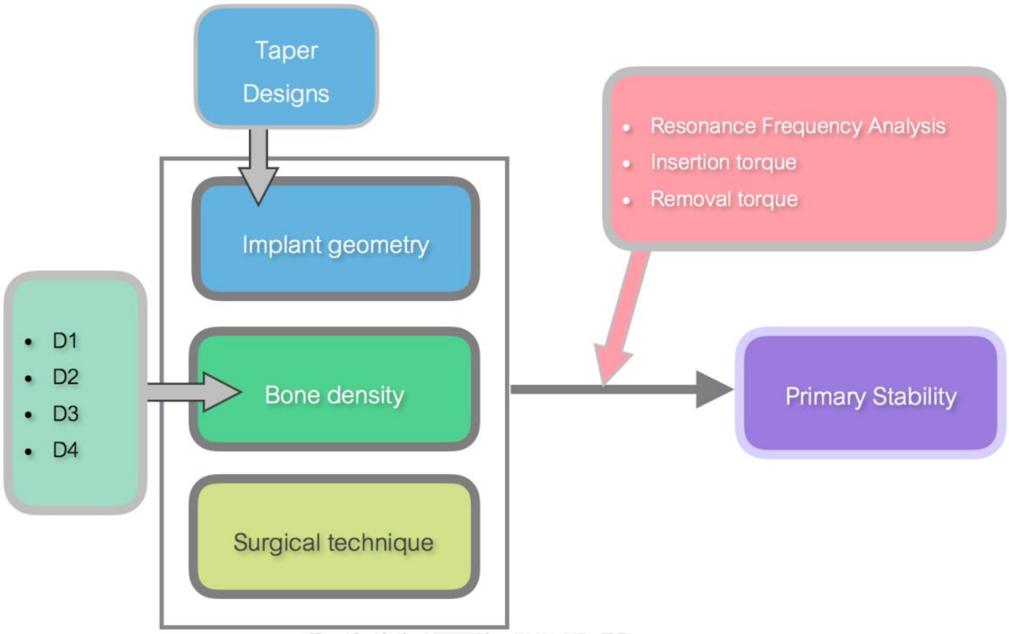
Conceptual framework



Type of study

Experimental study

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Research methodology

1. Materials

Polyurethane blocks

Figure 2

Polyurethane blocks

To simulate bone in an in vitro setting, rigid polyurethane blocks with the dimension of 13 cm x 18 cm x 4 cm will be used at different densities (Figure 2). The American Society for Testing Materials has shown that polyurethane blocks have mechanical properties simulating human bone. Polyurethane is considered to be the standard material used for performing mechanical tests on orthopedic implants. The blocks came from the same batch and were accurately weighed. Using the Misch's classification of bone density, D1 bone will be simulated using 40 pounds per cubic foot

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(pcf) polyurethane blocks, D2 bone will be simulated using 30 pcf polyurethane blocks, D3 bone will be simulated using 20 pcf polyurethane blocks and D4 bone will be simulated using 10 pcf polyurethane blocks.

Implants

Five different taper-implant designs with the closest diameter and length available for the test version will be used for this study (Figure 3): (1) NobelActive® RP 4.3,13 mm REF 34131 (Nobel Biocare®, Switzerland); (2) NobelReplace® RP 4.3, 13 mm REF 32216 (Nobel Biocare®, Switzerland); (3) Osseospeed™ EV conical implant 4.2, 13 mm REF25264 (ASTRA TECH Implant System™, Sweden); (4) OsseoSpeed™ TX conical implant 4.5, 11 mm REF 24952 (AstraTech implant system™, Sweden); (5) Straumann® Bone Level Taper implant, 4.1, 10 mm REF 021.5412 (Straumann®, Switzerland); (6). The implants will be placed using the drilling technique and insertion protocols as described below.

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Figure 3

Implants used in this study

A total of 100 osteotomies will be created in the above-mentioned rigid polyurethane blocks; 25 in D1 bone block, 25 in D2 bone block, 25 in D3 bone block and 25 in D4 bone block (Sawbones; Pacific Research Laboratories Inc., WA, USA). In each bone density, thirty osteotomies are consisted of five implants from six systems.

2. Methods

2.1 Sample description

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The number of sample size in this study is designed according to the previous studies (Wang, 2015), which conduct the primary stability test in different implant design and different bone density. The study suggested 5 subjects per implant design.

In this study, there are four artificial bone blocks that simulate four types of bone density. Each bone block consists of five different designs of taper implant and each design has five repeats.

2.2 Intervention

2.2.1 Drilling procedure

The blocks will be fixed in a metallic platform to reduce movements during the drilling procedure and to ensure consistent experimental conditions. Drilling was performed by one calibrated clinician with electronic surgical unit (EXPERTsurg, Kavo Dental Gmbh, Germany).

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The osteotomy site preparation will be performed as manufacturer's recommendation for each of the five respective implant systems (Figure 4). During drilling, an in-and-out motion was performed in bone blocks for 1–2 s without stopping the handpiece motor. This motion was repeated until the drill reached the depth of the reference line depending on systems.

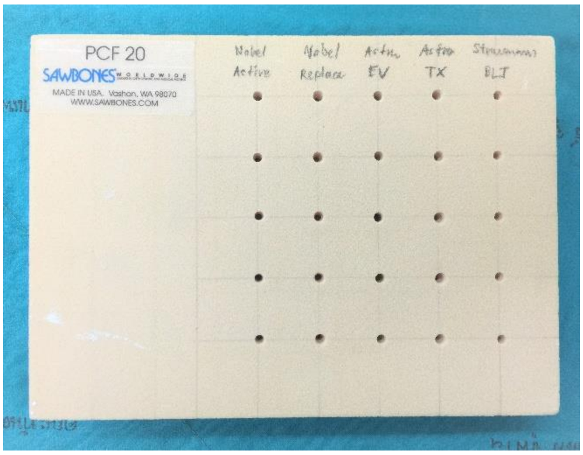

Figure 4

Prepared test block

Drilling sequences for bone type 1 (Dense bone)

(1) NobelActive® RP 4.3,13 mm REF 34131 (Nobel Biocare®, Switzerland)

- Twist Drill with 2.0 mm diameter (REF 32299) will be used for the initial perforation inserted up to 10 mm depth with the maximum of 2000 rpm.

- Twist Step Drill with 2.4/2.8 mm diameter (REF 32262) will be inserted up to 13 mm depth with the maximum of 2000 rpm.

- Twist Step Drill with 3.2/3.6 mm diameter (REF 32264) will be inserted up to 13 mm depth with the maximum of 2000 rpm.

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- Twist Step Drill with 3.8/4.2 mm diameter (REF 32277) will be inserted up to 13 mm depth with the maximum of 2000 rpm.

(2) NobelReplace® taper Groovy RP 4.3, 13 mm REF 32216 (Nobel Biocare®, Switzerland)

- Tip taper with 2.0 mm diameter (REF 36117) will be used for the initial perforation inserted up to 13 mm depth with the maximum of 2000 rpm.
- Drill with 3.5 mm diameter (REF 29367) will be inserted up to 13 mm depth with the maximum of 2000 rpm.
- Drill with 4.3 mm diameter (REF 29370) will be inserted up to 13 mm depth with the maximum of 2000 rpm.
- Dense Bone Profile with 4.3 mm diameter (REF 29381) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 800 rpm.
- Tap with 4.3 mm diameter (REF 32090) will be used to precut the threads over the full depth of the implant bed preparation with the maximum of 25 rpm.

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(3) Osseospeed™ EV conical implant 4.2, 13 mm REF25264 (ASTRA TECH Implant System™, Sweden)

- Twist Drill EV with 1.9 mm diameter (REF 25162) will be used for the initial perforation inserted up to 13 mm depth with the maximum of 1500 rpm.
- Step Drill EV with 2.5/3.1 mm diameter (REF 25168) will be inserted up to 13 mm depth with the maximum of 1500 rpm.
- Conical Drill with 3.1/4.2 mm diameter (REF 25188) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 1500 rpm.

(4) OsseoSpeed™ TX conical implant 4.5, 11 mm REF 24952 (AstraTech implant system™, Sweden)

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- Twist Drill with 2.0 mm diameter (REF 22886) will be used for the initial perforation inserted up to 11 mm depth with the maximum of 1500 rpm.
- Twist Drill with 3.2 mm diameter (REF 22807) will be inserted up to 11 mm depth with the maximum of 1500 rpm.

- Conical Drill with 3.2/4.5 mm diameter (REF 22895) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 1500 rpm.
- Twist Drill with 3.35 mm diameter (REF 22808) will be inserted up to 11 mm depth with the maximum of 1500 rpm.

(5) Straumann® Bone Level Taper implant, 4.1, 10 mm REF 021.5412 (Straumann®, Switzerland)

- Pilot Drill with 2.2 mm diameter (REF 026.0002) will be used for the initial perforation inserted up to 10 mm depth with the maximum of 800 rpm.
- BLT Drill with 2.8 mm diameter (REF 026.2201) will be inserted up to 10 mm depth with the maximum of 600 rpm.
- BLT Drill with 3.5 mm diameter (REF 026.4201) will be inserted up to 10 mm depth with the maximum of 500 rpm.
- Profile Drill with 4.1mm diameter (REF 026.0004) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 300 rpm.

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- BLT Tap drill with 4.1 mm diameter (REF 026.0010) will be used to precut the threads over the full depth of the implant bed preparation with the maximum of 15 rpm.

Drilling sequences for bone type 2 and 3 (Normal bone)

(1) NobelActive® RP 4.3,13 mm REF 34131 (Nobel Biocare®, Switzerland)

- Twist Drill with 2.0 mm diameter (REF 32299) will be used for the initial perforation inserted up to 13 mm depth with the maximum of 2000 rpm.
- Twist Step Drill with 2.4/2.8 mm diameter (REF 32262) will be inserted up to 13 mm depth with the maximum of 2000 rpm.
- Twist Step Drill with 3.2/3.6 mm diameter (REF 32264) will be inserted up to 13 mm depth with the maximum of 2000 rpm.

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(2) NobelReplace® taper Groovy RP 4.3, 13 mm REF 32216 (Nobel Biocare®, Switzerland)

- Tip taper with 2.0 mm diameter (REF 36117) will be used for the initial perforation inserted up to 13 mm depth with the maximum of 2000 rpm.

- Drill with 3.5 mm diameter (REF 29367) will be inserted up to 13 mm depth with the maximum of 2000 rpm.
- Drill with 4.3 mm diameter (REF 29370) will be inserted up to 13 mm depth with the maximum of 2000 rpm.

(3) Osseospeed™ EV conical implant 4.2, 13 mm REF25264 (ASTRA TECH Implant System™, Sweden)

- Twist Drill EV with 1.9 mm diameter (REF 25162) will be used for the initial perforation inserted up to 13 mm depth with the maximum of 1500 rpm.
- Step Drill EV with 2.5/3.1 mm diameter (REF 25168) will be inserted up to 13 mm depth with the maximum of 1500 rpm.
- Conical Drill with 3.1/4.2 mm diameter (REF 25188) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 1500 rpm.

(4) OsseoSpeed™ TX conical implant 4.5, 11 mm REF 24952 (AstraTech implant system™, Sweden)

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- Twist Drill with 2.0 mm diameter (REF 22886) will be used for the initial perforation inserted up to 11 mm depth with the maximum of 1500 rpm.
- Twist Drill with 3.2 mm diameter (REF 22807) will be inserted up to 11 mm depth with the maximum of 1500 rpm.
- Conical Drill with 3.2/4.5 mm diameter (REF 22895) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 1500 rpm.

(5) Straumann® Bone Level Taper implant, 4.1, 10 mm REF 021.5412 (Straumann®, Switzerland)

- Pilot Drill with 2.2 mm diameter (REF 026.0002) will be used for the initial perforation inserted up to 10 mm depth with the maximum of 800 rpm.
- BLT Drill with 2.8 mm diameter (REF 026.2201) will be inserted up to 10 mm depth with the maximum of 600 rpm.
- BLT Drill with 3.5 mm diameter (REF 026.4201) will be inserted up to 10 mm depth with the maximum of 500 rpm. This is the final drill for D3 bone type.

- Profile Drill with 4.1mm diameter (REF 026.0004) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 300 rpm. This is the final drill for D2 bone type.

Drilling sequences for bone type 4 (Soft bone)

(1) NobelActive® RP 4.3,13 mm REF 34131 (Nobel Biocare®, Switzerland)

- Twist Drill with 2.0 mm diameter (REF 32299) will be used for the initial perforation inserted up to 13 mm depth with the maximum of 2000 rpm.
- Twist Step Drill with 2.4/2.8 mm diameter (REF 32262) will be inserted up to 13 mm depth with the maximum of 2000 rpm.
- Twist Step Drill with 2.8/3.2 mm diameter (REF 34639) will be inserted up to 13 mm depth with the maximum of 2000 rpm.

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(2) NobelReplace® taper Groovy RP 4.3, 13 mm REF 32216 (Nobel Biocare®, Switzerland)

- Tip taper with 2.0 mm diameter (REF 36117) will be used for the initial perforation inserted up to 13 mm depth with the maximum of 2000 rpm.

- Drill with 3.5 mm diameter (REF 29367) will be inserted up to 13 mm depth with the maximum of 2000 rpm.
- Drill with 4.3 mm diameter (REF 29370) will be inserted up to 13 mm depth with the maximum of 2000 rpm.

(3) Osseospeed™ EV conical implant 4.2, 13 mm REF25264 (ASTRA TECH Implant System™, Sweden)

- Twist Drill EV with 1.9 mm diameter (REF 25162) will be used for the initial perforation inserted up to 13 mm depth with the maximum of 1500 rpm.
- Step Drill EV with 2.5/3.1 mm diameter (REF 25168) will be inserted up to 13 mm depth with the maximum of 1500 rpm.
- Conical Drill with 3.1/4.2 mm diameter (REF 25188) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 1500 rpm.

(4) OsseoSpeed™ TX conical implant 4.5, 11 mm REF 24952 (AstraTech implant system™, Sweden)

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- Twist Drill with 2.0 mm diameter (REF 22886) will be used for the initial perforation inserted up to 11 mm depth with the maximum of 1500 rpm.
- Twist Drill with 3.2 mm diameter (REF 22807) will be inserted up to 11 mm depth with the maximum of 1500 rpm.
- Conical Drill with 2.7/4.5 mm diameter (REF 24925) will be used to shape the coronal part of the implant bed by using the orientation features as guidelines for vertical positioning with the maximum of 1500 rpm.

(5) Straumann® Bone Level Taper implant, 4.1, 10 mm REF 021.5412 (Straumann®, Switzerland)

- Pilot Drill with 2.2 mm diameter (REF 026.0002) will be used for the initial perforation inserted up to 10 mm depth with the maximum of 800 rpm.
- BLT Drill with 2.8 mm diameter (REF 026.2201) will be inserted up to 10 mm depth with the maximum of 600 rpm.

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2.2.2 Implant insertion

After the osteotomy site preparation completed in all blocks. Implants will be inserted with electronic surgical unit by the manufacturer's recommendations until they reach the crestal level leaving the implant platforms flush with the block surface.

2.2.3 Insertion torque (IT)

Insertion torque values (Ncm) will be recorded during implant insertion by the electronic surgical unit. The peak value of insertion from the beginning until the implant platform leveled to the surface of the bone block were recorded (figure 5). Each inserted implant had single value then mean values by group will be collated and compared

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Figure 5

Maximum torque (IT and RT) was recorded by electronic surgical unit (EXPERTsurg, Kavo Dental Gmbh, Germany).

2.2.4 Resonance frequency analysis (RFA)

Implant stability will be evaluated after implant placement using RFA with the Osstell ISQ device. Specific transducers (SmartPeg, Osstell AB, Gothenburg, Sweden)(Figure 6) for each implant system will be used . Measurements will be taken as follows: screw the transducer into the inserted implant. Laterally orient the probe in relation to the transducer and measure. Each measurement will be repeated twice and record the mean values. All measurements will be performed by independent, unbiased examiner. Data will express as a range of ISQ values (1–100). Mean values will be collated by group and compared.

Figure 6

SmartPeg

2.2.5 Removal torque (RT)

Removal torque values (Ncm) will be recorded after implant insertion and RFA measurements by the electronic surgical unit. The peak values to remove the implant from the test block will be registered and should result in a single value. Mean values by group will be collated and compared

3. Data collection and Analysis

Data were collected by the author and analyses using SPSS 23.0 (SPSS, Chicago, IL, USA). Following descriptive data analysis, the Shapiro-Wilk test was used to test the distribution normality. Factorial ANOVA was used to compare studies variables. The level of significance for all statistical tests will be set (at alpha level = 0.05).

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Ethical consideration

There is no ethical consideration since this study is the experimental study in laboratory setting.

Expected benefit

The results from this study will be useful for the dentist not only to choose between many commercially available taper-implants but also useful in choosing the proper implant in the different recipient bone density regarding to the primary stability standpoint.

Limitation

The major limitation of this study is the artificial bone block cannot exhibit the healing ability that leads to osseointegration of the implant. Although this block is standard material used for performing mechanical tests on orthopedic implants, it is not a radiopacity material thus we cannot check the fit of the bone-implant interface with radiographic method.

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Results

1. Result of the insertion torque test

A two-factor (4×5) Analysis of Variance was conducted to evaluate the effects of the implant design and bone quality on the primary stability (insertion torque test, removal torque test and resonance frequency analysis). The two independent variables in this study are implant design (NobelActive, NobelReplace, OsseoSpeed EV, OsseoSpeed TX and Straumann BLT) and bone quality (D1, D2, D3 and D4). The dependent variable is the score on the primary stability.

The means and standard deviations for insertion torque as a result of the two factors are presented in Table 1

Table 1 *Descriptive statistics for insertion torque test*

	Implant Design					
	NobelActive	NobelReplace	OsseoSpeed EV	OsseoSpeed TX	Straumann BLT	Total
Bone D1	31.40	50.60	52.40	10.80	30.60	35.16
	(2.88)	(10.90)	(5.64)	(2.59)	(6.84)	(16.67)
Bone D2	17.60	41.80	38.20	8.00	37.20	28.56
	(2.19)	(4.44)	(7.33)	(2.35)	(5.76)	(14.28)
Bone D3	29.60	23.00	23.60	6.60	25.20	21.60
	(1.82)	(0.71)	(2.19)	(1.34)	(1.10)	(8.13)
Bone D4	14.60	7.60	6.80	4.60	10.80	8.88
	(1.34)	(0.55)	(2.17)	(0.55)	(0.45)	(3.72)
Total	23.30	30.75	30.25	7.50	25.95	23.55
	(7.75)	(17.94)	(17.95)	(2.89)	(10.80)	(15.23)

* Standard Deviations shown in parentheses

The Shapiro-Wilk test showed a normal distribution of the data ($p > 0.05$). For insertion torque test (Table 2), the main effect for implant design yielded an F ratio of

$F(4,80)= 103.433$, $p < .001$, indicating a significant different between NobelActive (M=23.30, SD=7.75), NobelReplace (M=30.75, SD=17.94), OsseoSpeed EV (M=30.25, SD=17.95), OsseoSpeed TX (M=7.50, SD=2.89) and Straumann BLT (M=25.95, SD=10.80). The main effect for bone quality yielded an F ratio of $F(3,80)=181.363$, $p < .001$, indicating a significant different between D1 (M=35.16, SD=16.67), D2 (M=28.56, SD=14.28), D3 (M=21.60, SD=8.13) and D4 (M=8.88, SD=3.72). The interaction effect was significant $F(12,80)=23.398$, $p < .001$.

Table 2 *Factorial ANOVA results to test the influence of design and bone type on insertion torque*

Source	SS	df	MS	F	Sig.
Design	7203.100	4	1800.775	103.433	.000
BoneType	9472.590	3	3157.530	181.363	.000
Design * BoneType	4888.260	12	407.355	23.398	.000
Error	1392.800	80	17.410		
Total	78417.000	100			

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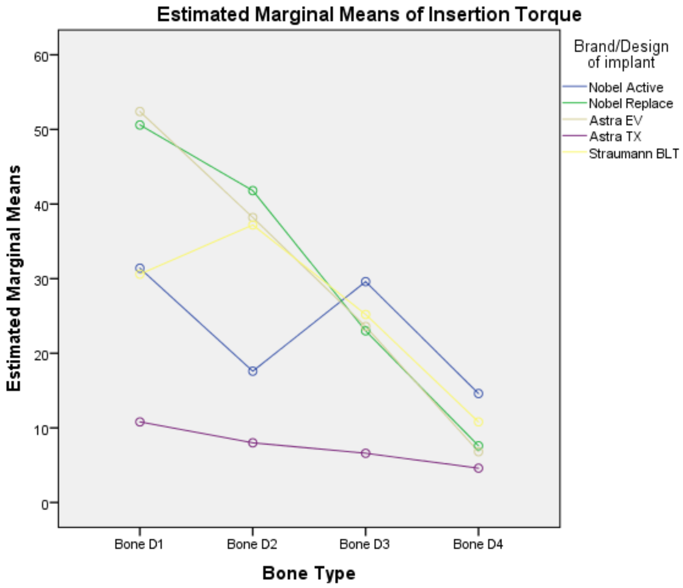

Figure 7

Interaction plot for insertion torque values

Because the interaction between implant design and bone quality was significant, we chose to ignore the two main effects and instead examined the bone quality simple main effects first, which is the differences among the five designs of the implant for each bone quality separately. There were significant differences among the five designs of implants for bone D1, $F(4,80) = 83.57$, $p < .001$, bone D2, $F(4,80) = 63.59$, $p < .001$, bone D3, $F(4,80) = 22.11$, $p < .001$ and for bone D4, $F(4,80) = 4.36$, $p < .001$.

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Follow up tests were conducted to evaluate the five designs of implants' pairwise differences for all bone types. In bone D1 group, OsseoSpeed EV (M=52.40) and NobelReplace (M=50.60) had significant higher insertion torque than NobelActive (M=31.40), Straumann BLT (M=30.60) and OsseoSpeed TX (M=10.80) while NobelActive (M=31.40) and Straumann BLT (M=30.60) had significant higher insertion torque than OsseoSpeed TX (M=10.80).

In bone D2 group, NobelReplace (M=41.80), OsseoSpeed EV (M=38.20) and Straumann BLT (M=37.20) had significant higher insertion torque than NobelActive (M=17.60) while NobelActive was significant higher than OsseoSpeed TX (M=8.00).

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In bone D3 group, NobelActive (M=29.60), Straumann BLT (M=25.20), OsseoSpeed EV (M=23.60), NobelReplace (M=23.00) had significant higher insertion torque than OsseoSpeed TX (M=6.60).

In bone D4 group, NobelActive (M=14.60) had significant higher insertion torque than OsseoSpeed EV (M=6.80) and OsseoSpeed TX (M=4.60) while Straumann BLT

(M=10.80), NobelReplace (M=7.60), OsseoSpeed EV and OsseoSpeed TX had no significant differences.

Additionally, we examined the implant design simple main effects, that is, the differences among the bone quality for each implant designs separately. There was a significant difference among the four type of bones for NobelActive, $F(3, 80) = 20.44$, $p < .001$, NobelReplace, $F(3, 80) = 106.46$, $p < .001$, OsseoSpeed EV $F(3, 80) = 109.89$, $p < .001$ and Straumann BLT $F(3, 80) = 36.21$. However, OsseoSpeed TX had no significant difference in any bone quality ($p>.05$).

Follow up tests were conducted to evaluate the four types of bone quality's pairwise differences.

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In NobelActive group, placing the implant in bone D1 (M=31.40) and bone D3 (M=29.60) had significant higher insertion torque than in bone D2 (M=17.60) and bone D4 (M=14.60), which bone D2 and D4 had no significant between them.

In Nobel Raplace, in bone D1 (M=50.60) had significant higher insertion torque than bone D2 (M=41.80), bone D3 (M=23.00) and D4 (M=7.60) respectively.

In OsseoSpeed EV group, in bone D1 (M=52.40) had significant higher insertion torque than bone D2 (M=38.20), bone D3 (M=23.60) and D4 (M=6.80) respectively.

For Straumann BLT group, bone D2 (M=37.20) had significant higher insertion torque than in bone D3 (M=25.20) and D4 (M=10.80). Bone D1 (M=30.60) had no significant different from bone D3 (M=25.20). Bone D4 had significant lower insertion torque than other groups.

2. **Result of the removal torque test**

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The means and standard deviations for removal torque as a result of the two factors are presented in Table 3.

Table 3 *Descriptive statistics for removal torque test*

	Implant Design					
	NobelActive	NobelReplace	OsseoSpeed EV	OsseoSpeed TX	Straumann BLT	Total
Bone D1	16.80	40.40	41.60	7.70	22.80	25.88
	(3.35)	(9.40)	(5.32)	(1.30)	(4.82)	(14.43)
Bone D2	10.20	36.60	31.20	6.20	33.40	23.52

	(1.64)	(3.91)	(4.55)	(1.64)	(6.15)	(13.45)
Bone D3	16.00	16.60	15.20	4.60	18.00	14.08
	(0.71)	(1.67)	(2.49)	(0.55)	(1.41)	(5.12)
Bone D4	7.00	4.00	5.60	3.20	7.40	5.44
	(0.71)	(0.71)	(0.89)	(0.45)	(0.55)	(1.78)
Total	12.50	24.40	23.40	5.45	20.40	17.23
	(4.54)	(15.96)	(14.70)	(2.04)	(10.26)	(12.96)

* Standard Deviations shown in parentheses

The Shapiro-Wilk test showed a normal distribution of the data ($p > 0.05$). For removal torque test (Table 4), The interaction effect was significant $F(12,80)=26.054$, $p < .001$.

Table 4 *Factorial ANOVA results to test the influence of design and bone type on removal torque*

Source	SS	df	MS	F	Sig.
Design	5213.360	4	1303.340	105.963	.000
BoneType	6582.830	3	2194.277	178.396	.000
Design * BoneType	3845.520	12	320.460	26.054	.000
Error	984.000	80	12.300		
Total	46313.000	100			

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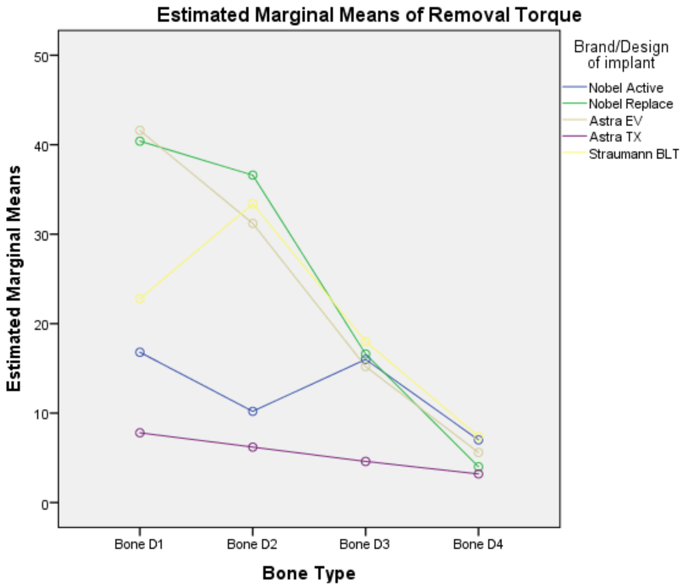

Figure 8

Interaction plot for removal torque values

Because the interaction between implant design and bone quality was significant, we chose to ignore the two main effects and instead examined the bone quality simple main effects first, which is the differences among the five designs of the implant for each bone quality separately. There were significant differences among the five designs of implants for bone D1, $F(4,80) = 89.10$, $p < .001$, bone D2, $F(4,80) = 81.82$, $p < .001$, and bone D3, $F(4,80) = 11.84$, $p < .001$. However, in bone D4, the significant difference was not found.

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Follow up tests were conducted to evaluate the five designs of implants' pairwise differences for all bone types. In bone D1 group, OsseoSpeed EV (M=41.60) and NobelReplace (M=40.40) had significant higher removal torque than Straumann BLT (M=22.80), NobelActive (M=16.80) and OsseoSpeed TX (M=7.80) while Straumann BLT (M=22.80) and NobelActive (M=16.80) had significant higher removal torque than OsseoSpeed TX (M=7.80).

In bone D2 group, NobelReplace (M=36.60), Straumann BLT (M=33.40) and OsseoSpeed EV (M=31.20) had significant higher removal torque than NobelActive (M=10.20) while NobelActive was significant higher than OsseoSpeed TX (M=6.20).

In bone D3 group, Straumann BLT (M=18.00), NobelReplace (M=16.60), NobelActive (M=16.00), and OsseoSpeed EV (M=15.20) had significant higher removal torque than OsseoSpeed TX (M=4.60).

Additionally, we examined the implant design simple main effects, that is, the differences among the bone quality for each implant designs separately. There was a significant difference among the four type of bones for NobelActive, $F(3, 80) = 8.981$, $p <$

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.001, NobelReplace, $F(3, 80) = 119.491$, $p < .001$, OsseoSpeed EV $F(3, 80) = 105.171$, $p < .001$ and Straumann BLT $F(3, 80) = 47.36$. However, OsseoSpeed TX had no significant difference in any bone quality ($p>.05$).

Follow up tests were conducted to evaluate the four types of bone quality's pairwise differences.

In NobelActive group, removing the implant in bone D1 (M=16.80) and bone D3 (M=16.00) had significant higher removal torque than in bone D2 (M=10.20) and bone D4 (M=7.00), which bone D2 (M=10.20) and D4 (M=7.00) had no significant between them.

In NobelReplace, in bone D1 (M=40.40) and bone D2 (M=36.60) had significant higher removal torque than bone D3 (M=16.60) and D4 (M=4.00).

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In OsseoSpeed EV group, in bone D1 (M=41.60) had higher removal torque than bone D2 (M=31.20), bone D3 (M=15.20) and D4 (M=5.60) respectively.

For Straumann BLT group, bone D2 (M=33.40) had significant higher removal torque than in bone D3 (M=18.00) and D4 (M=7.40). Bone D1 (M=22.80) had no significant different from bone D3 (M=25.20). Bone D4 had significant lower removal torque than other groups.

3. <u>Result of resonance frequency analysis</u>

The means and standard deviations for resonance frequency analysis (RFA) test as a result of the two factors are presented in Table 5.

Table 5 *Descriptive statistics for RFA*

	Implant Design					
	NobelActive	NobelReplace	OsseoSpeed EV	OsseoSpeed TX	Straumann BLT	Total
Bone D1	72.20	71.80	65.70	67.60	65.70	68.60
	(1.44)	(3.05)	(4.04)	(5.10)	(4.15)	(4.51)
Bone D2	69.20	70.90	64.60	63.60	65.90	66.84
	(3.47)	(0.65)	(3.83)	(2.30)	(1.78)	(3.74)
Bone D3	67.70	67.20	65.10	60.80	62.50	64.66
	(2.61)	(0.97)	(2.25)	(2.97)	(1.00)	(3.34)
Bone D4	56.20	54.00	55.10	49.60	50.50	53.08
	(0.27)	(1.17)	(0.74)	(2.27)	(1.27)	(2.90)
Total	66.33	65.98	62.63	60.40	61.15	63.30
	(6.57)	(7.48)	(5.27)	(7.52)	(6.82)	(7.08)

* Standard Deviations shown in parentheses

The Shapiro-Wilk test showed a normal distribution of the data ($p > 0.05$). The test of resonance frequency analysis (RFA) (Table 6), the main effect for implant design yielded an F ratio of $F(4,80)=21.578$, $p < .001$, indicating a significant different between

NobelActive (M=66.33, SD=6.57), NobelReplace (M=65.98, SD=7.48), OsseoSpeed EV (M=62.63, SD=5.27), OsseoSpeed TX (M=60.40, SD=7.52) and Straumann BLT (M=61.15, SD=6.82). The main effect for bone quality yielded an F ratio of $F(3,80)= 177.343$, $p < .001$, indicating a significant different between D1 (M=68.60, SD=4.51), D2 (M=66..84, SD=3.74), D3 (M=64.66, SD=3.34) and D4 (M=53.08, SD=2.90). However, the interaction effect was not significant $F(12,80)= 1.761$, $p>.05$.

Table 6 Factorial ANOVA results to test the influence of design and bone type on removal torque

Source	SS	df	MS	F	Sig.
Design	595.885	4	148.971	21.578	.000
BoneType	3672.988	3	1224.329	177.343	.000
Design * BoneType	145.875	12	12.156	1.761	.069
Error	552.300	80	6.904		
Total	405592.750	100			

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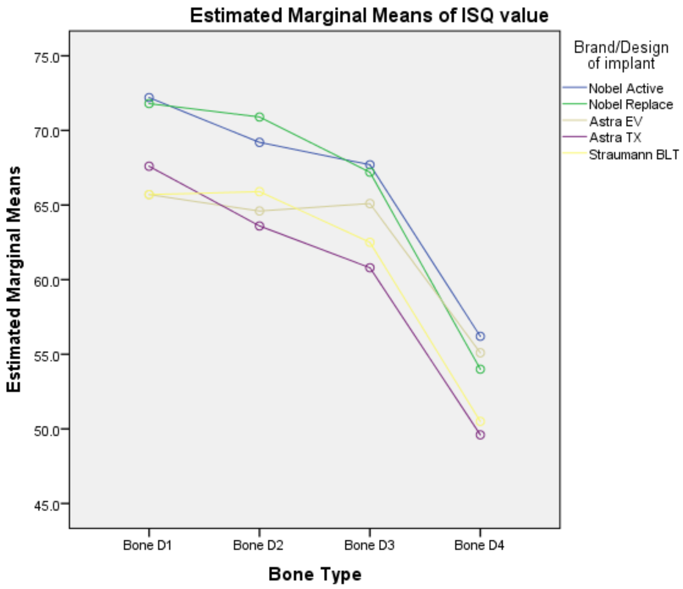

Figure 9

Interaction plot for ISQ values

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Discussion

The interaction effects between implant design and bone quality were presented in IT and RT test groups whereas no interaction effect was found in RFA group.

The interaction effect means there was the relation of the test variables which were bone with different quality and the different implant design. One variable depends on another variable. However, in the RFA group, no significant interaction effect has been found so the variables were interpreted separately.

The present study showed significant differences in bone quality. Better bone quality had better ISQ value which was in agreement of Bayarchimeg et al, 2013 [46]. Although the significant differences between the implant design was found, no obvious feature was found to be the major factor to increase the ISQ value. NobelActive was not significant different from NobelReplace while both are different from the rest. In the meantime, no significant differences among Straumann BLT, AstraTX and AstraEV.

Bone properties, implant factors and surgical technique are the determinant of RFA measurement. Bone density was believed a major determining factor as shown in many studies. A positive correlation between ISQ units and bone density as assessed with the Lekholm & Zarb index [48, 49], with insertion torque measurements [25, 50, 51] has been demonstrated. The taper implant which used the technique in increasing the lateral compression during insertion seems to result in higher stability [44, 52]. Other Implant factors for example implant length, implant diameter, implant position is not clear and seems to vary between studies. Very few studies on RFA measurements were interested in implant factor in the mean of macro-design. Tapered implant also sometimes categorized as a surgical technique.

Insertion torque and removal torque had statistically significant interaction effect, which means, insertion torque and removal torque values depends on design of the implant together with the type of bone. Changing one of these variables can affect the outcome. Therefore, separately interpreting the main effect may lead to error conclusion. The Post Hoc tests have been done to clarify the outcome of the test.

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Within the limitation of this *in vitro* study, on the insertion torque and removal torque aspects, we found that, NobelActive showed significant higher insertion torque and removal torque in poorer bone quality such as D4 thanks to its deep threads which in the agreement of Misch et al [33]. On the other hand, deeper threads showed less important in achieving high insertion compare to the shallower threads like NobelReplace and OsseoSpeed EV in hard bone setting like D1. The possibly reason might be the hard bone protocol that over prepare the osteotomy site to avoid the excessive force when turning the implant with deeper threads in.

In D2 bone quality, hard bone protocol has been used in NobelActive instead of standard protocol which probably made NobelActive had lower IT than NobelReplace, OsseoSpeed EV and Straumann BLT. Generally, D2 bone was categorized as normal bone density respect to most of the manufacturers' manual however, this *in vitro* setting, the bone blocks were homogenously had D2 density without cortical and cancellous bone. Therefore, manufacturers' protocol should be applicable in most of the clinical situation.

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In D3 bone, there was only OsseoSpeed TX that had significant lower IT than the others.

Poor bone condition (D4 bone), taper implant with deeper thread depth design (NobelActive) show greater insertion torque than others.

Within the NobelActive group, the results in D1 bone and D3 bone showed higher insertion torque compared to D2 because the dense bone protocol was used instead to fully insert the implant that got congested with the standard bone protocol. Whereas OsseoSpeed TX showed lower insertion torque than other designs in all bone quality might because of nearly half of the implant length was microthreads which this features benefit in enhancing bone formation compare to the regular threads [53]. The bone preparation of the microthreads part was like profile drilling which facilitate the implant insertion. Moreover, the diameter of the final drill was equal to the implant diameter. However, microthreads in OsseoSpeed EV did not lower its insertion torque compare to OsseoSpeed TX. The differences between OsseoSpeed EV and OsseoSpeed TX were OsseoSpeed EV had more regular threads length than OsseoSpeed TX and total length was greater. However, from the study of Gomez-Polo et al. [28] showed that IT was not significant influenced by implant length which similar to our finding that Straumann BLT

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(10 mm length) had comparable IT to longer implant in most of the bone types while OsseoSpeed TX (11 mm length) had lower IT compare to other implants.

The compression technique was used in most of the certain tapered implant [15] to increase the primary stability. The implant design was also related to the surgical technique consequently to distinct the implant factor and the surgical technique was difficult.

High insertion torque did not always result in good primary stability. Over torque can lead to failure due to stress and strain on peri-implant bone [54]. Higher insertion toque benefit in reducing the micromotion however more than 40 N.cm does not further protect the implant from micromotion [55].

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In the clinical situation, consideration of the implant design in the treatment planning could make the clinician to achieve the successful implant therapy. Therefore, it is important to evaluate patient's biological condition. Particularly, in compromised bone quality some features of the implant may be beneficial, on the other hand, in good bone quality some features might not necessary. However, it has to be concerned that when using the dental implant the effect of a single feature cannot overcome the rest components of the selected implant. The benefits from a single design feature could be enhanced or weakened by the other variables of the implant. Clinicians should understand that just a design factor alone will not guarantee implant success and survival.

Conclusion

Within the limitations of this study, it can be concluded that the clinician should consider the implant design and its features of the taper implant regarding to the quality of surgical bone site in decision making to achieve the favorable primary stability by means of insertion and removal torque.

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In the comparison of implant design mechanical study in different bone quality, insertion torque and removal torque measurements are the appropriate primary stability assessments.

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