# THE COMPARISON OF IMPLANT STABILITY BETWEEN TWO IMPLANT SURFACES USING THE RESONANCE FREQUENCY ANALYSIS MEASUREMENT : RANDOMIZED CONTROLLED TRIAL

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# การเปรียบเทียบเสถียรภาพของรากเทียมระหว่างพื้นผิวสองแบบ โดยใช้คลื่นความถี่เรโซแนนซ์: การวิจัยเชิงทดลองแบบสุ่มและมีกลุ่มควบคุม

นางสาวศศิกานต์ ทองบริสุทธิ์

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| By | Miss Sasikran Thongborisoot |
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ศศิกานต์ ทองบริสุทธิ์ : การเปรียบเทียบเสถียรภาพของรากเทียมระหว่างพื้นผิวสองแบบโดยใช้คลื่นความถี่เรโซแนนซ์: การวิจัยเชิงทดลองแบบสุ่มและมีกลุ่มควบคุม. (The Comparison of Implant Stability between Two Implant Surfaces Using the Resonance Frequency Analysis Measurement : Randomized Controlled Trial) อ.ที่ปรึกษาวิทยานิพนธ์หลัก : ผศ.ทพ.ดร.อาทิพันธุ์ พิมพ์ขาวขำ : 97 หน้า.

**วัตถุประสงค์** เพื่อเปรียบเทียบผลกระทบของลักษณะพื้นผิวรากเทียมสองชนิดที่มีต่อการเปลี่ยนแปลงของค่าอาร์เอฟเอซึ่งเป็นค่าที่แสดงเสถียรภาพรากเทียมตั้งแต่ภายหลังการฝังทันทีจนสัปดาห์ที่ 8 และกำหนดเวลาการโหลดแรงบนรากเทียมชนิดเอสแอลเอและเอสแอลแอคทีฟด้วยเครื่องวัดคลื่นความถี่เรโซแนนซ์ เมื่อรากเทียมถูกฝังโดยผู้เชี่ยวชาญการฝังรากเทียม **วิธีการทดลอง** ผู้ป่วยจำนวน 30 คนที่ต้องการรากเทียมทดแทนฟันหลังล่างจากคลินิกทันตกรรมพิเศษ คณะทันตแพทย์ศาสตร์จุฬาลงกรณ์มหาวิทยาลัย ได้รับการสุ่มเพื่อรับการรักษาด้วยรากเทียมสองชนิด กลุ่มแรกได้รับการรักษาด้วยรากเทียมชนิดเอสแอลเอ (n = 25) กลุ่มที่สองได้รับการรักษาด้วยรากเทียมชนิดเอสแอลแอกทีฟ (n = 26) ปริมาณและคุณภาพของกระดูกถูกประเมินด้วยภาพรังสีดิจิตอลสามมิติก่อนการฝัง สันกระดูกที่ถูกถอนฟันไป < 6 เดือนหรือให้ค่าทอร์ก < 20 นิวตันซม.จะถูกคัดออกจากการศึกษา รากเทียมที่สามารถเข้าเกณฑ์การศึกษาจะถูกบันทึกค่าเสถียรภาพรากเทียมด้วยวิธีวิเคราะห์คลื่นความถี่เรโซแนนซ์เป็นค่าไอเอสคิวทันทีหลังการฝัง(วันที่ 0 ), วันที่ 2, สัปดาห์ที่ 1, 2, 3, 4 และ 8 โดยวัดจากด้านแก้ม ด้านลิ้น และด้านใกล้กลาง ค่าเฉลี่ยของค่าไอเอสคิวที่ได้ถูกนำมาวิเคราะห์หาความสัมพันธ์ของลักษณะพื้นผิวรากเทียมหรือความหนาแน่นกระดูกที่มีต่อค่าไอเอสคิวในช่วงเวลาต่างๆ **ผลการทดลอง** ค่าไอเอสคิวของรากเทียมทั้งสองชนิดมีค่าลดลงอย่างมีนัยสำคัญในวันที่สอง หลังจากนั้นไม่พบการเปลี่ยนแปลงของค่าไอเอสคิว จนกระทั่งในสัปดาห์ที่ 4 ที่ค่าไอเอสคิวของรากเทียมชนิดเอสแอลแอคทีฟกลับมาสูงขึ้นอย่างมีนัยสำคัญ ในขณะที่รากเทียมชนิดเอสแอลเอให้ค่าไอเอสคิวที่สูงขึ้นอย่างมีนัยสำคัญ ณ สัปดาห์ที่ 8 ในทุกช่วงเวลาที่ทำการวัดไม่พบว่ารากเทียมสองชนิดมีเสถียรภาพที่ต่างกันทางสถิติ อย่างไรก็ตามในกรณีที่รากเทียมถูกฝังในกระดูกความหนาแน่นระดับ 4 รากเทียมชนิดเอสแอลแอกทีฟให้ค่าไอเอสคิวที่สูงกว่าอย่างมีนัยสำคัญในสัปดาห์ที่ 4 และ 8 **สรุป** คุณลักษณะทางเคมีของรากเทียมมีผลต่อค่าเสถียรภาพของรากเทียม โดยเฉพาะเมื่อรากเทียมถูกฝังในกระดูกความหนาแน่นระดับ 4 โดยรากเทียมชนิดเอสแอลแอคทีฟให้ค่าเสถียรภาพรากเทียมสูงขึ้นเร็วกว่าชนิดเอสแอลเอ ดังนั้นรากเทียมชนิดเอสแอลแอคทีฟน่าจะเป็นตัวเลือกที่ดีในการบูรณะรากเทียมโดยให้แรงโหลดเร็วโดยเฉพาะในกรณีที่กระดูกรอบรากเทียมมีความหนาแน่นต่ำ

สาขาวิชา ทันตกรรมบูรณะเพื่อความสวยงาม และทันตกรรมรากเทียม ลายมือชื่อนิสิต.....

ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก.....

ปีการศึกษา.....2555.....

# # 5276158732 : MAJOR Esthetic Restorative and Implant Dentistry
KEYWORDS : CLINICAL TRIAL / DENTAL IMPLANTS / SLA-SURFACE / SLACTIVE-SURFACE / IMPLANT STABILITY / RESONANCE FREQUENCY ANALYSIS / ISQ / LOADING TIME / BONE DENSITY

SASIKRAN THONGBORISOOT : THE COMPARISON OF IMPLANT STABILITY BETWEEN TWO IMPLANT SURFACES USING THE RESONANCE FREQUENCY ANALYSIS MEASUREMENT : RANDOMIZED CONTROLLED TRIAL ADVISOR : ASST. PROF. ATHIPHAN PIMKHAOKHAM, Ph.D. : 97 pp

**Objective** to observe the longitudinally changes in the stability of implants with 2 different surface chemistries by using Resonance Frequency Analysis (RFA) over the first 8 weeks and to determine the functional loading protocol for implants with the SLA and SLActive, placed by experienced surgeons. **Materials and methods** Thirty patients were randomized into 2 groups. The first group (n = 25) received Straumann SLA implants while the second group (n = 26) received Straumann SLActive implants. Cone Beam Computed Tomography Scan was used to determine the bone quantity and quality. Healed ridge with < 6 months postextraction or ridge that failed to accommodate the primary stability of 20 Ncm were excluded. Each RFA measurement was performed at the buccal, lingual, and mesial side on day 0, 2, week 1, 2, 3, 4 and 8. The mean value of measurements was represented the Implant Stability Quotient (ISQ) of the particular point in time. The relationships between ISQ values and the implant surface or the bone quality were statistically analyzed. **Result** Regarding the implant surface, both implant surfaces showed dramatically decrease of ISQ values at day 2 and stayed at the same level until week 3. The SLActive surface showed a significant increase in ISQ values ($P<.05$) at $4^{th}$ week as compared to $3^{rd}$ week while the SLA implant surface exhibited a significant increase in ISQ value at $8^{th}$ week as compared to $4^{th}$ week. There was no significantly different in ISQ values between the 2 surfaces at any observation period. However, in the Type IV bone, SLActive implants showed a statistically higher in ISQ values at $4^{th}$ and $8^{th}$ week, as compared to SLAs. **Conclusion** The implant surface played an important role in implant stability particularly in bone type IV. Therefore, it is advantageous to utilize the SLActive surface for the early loading protocol, especially in the poor type of bone.

Field of Study: Esthetic Restorative and Implant Dentistry  Student's Signature.....
Advisor's Signature.....
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Finally, I am deeply grateful for the kind unwavering support from my beloved family and my wonderful friends . They are the source of my inspirations. I am grateful to all of them.

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# CHAPTER I

# INTRODUCTION

## Rationale and Significance of the Problem

More than half of the century, the tissue-integrated implant has greatly broaden the scope of medical treatments — craniofacial and orthopedic surgery for instance. Dental implant has also become increasingly important in the oral rehabilitation, either for fully or partially edentulous patients. The dental implant breakthrough is based upon the idea of osseointegration or functional ankylosis that firstly described by the two research groups namely Branemark *et al.*(1) and Schroeder *et al.* (2). The osseointegration is a stability concept in which achieving and maintaining the implant stability during functional loading are prerequisites for the successful long-term function (3). In fact, the osseointegration occurs instantaneously on implant placement. It was firstly defined as "bone-to-implant contact at light microscope level". After that, it was defined as "the direct structural and functional connection between the ordered living bone and the surface of a load-carrying implant"(4). It has also been defined in clinical terms as "a process in which clinically asymptomatic rigid fixation of alloplastic materials is achieved and maintained in bone during functional loading"(5).

Initially, the implant stability was provided by the mechanical retention between the implant surface and the cortical part of the recipient bone. This was so-called "primary stability". Because the bone tissue is dynamic and remodel over time, these areas of the bone contact are remodeled and replaced by the new bone formation (Appositional bone formation or Contact osteogenesis) (6). At the same time, the new bone is also formed on the implant surface (Distance osteogenesis) (6). These new bones are termed as "secondary bone formation".

At the early phase, the primary bone contact is the majority due to the mechanical retention including the existing quantity and quality of bone at the implant site whilst the secondary bone formation is the minority. Subsequently, the biological responses such as osteoclastic activity, remodeling process and formation of new bone occurs, after that the secondary bone formation takes place of primary intimate bone

contact. As a result, the ratio reverses such that primary bone contact decreases and secondary bone contact increases as shown in Figure 1 (7). These findings suggested that at the beginning, the stability of the implant is maintained by the primary contact. Later the remodeling and formation of new bone can occur to such a degree as to further maintain the stability. The time point when implant undergoes a decreasing primary stability to an increasing secondary stability is called “stability dip” (7).

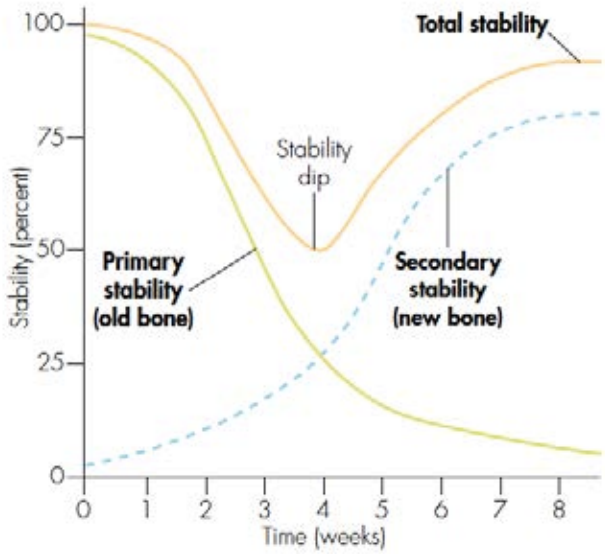


***Figure 1*** *The decreasing primary stability and increasing secondary stability result in a decrease in overall stability (dip) between week 2 and 4 after implant placement (7).*

Three main factors affecting implant primary stability are the bone density, the surgical technique, and the microscopic and macroscopic morphology of the implant (7, 8).

The lower primary stability would be expected in the soft bone quality (9, 10) Previous study demonstrated that the firmly primary stability could be achieved in soft bone similar to dense bone (11)(12) with the modified surgical technique, including reduced drilled diameters, the use of self-tapping implants, wider implants, tapered implants and precise surgical drilling. Regarding the macroscopic characteristics of the implant, a human cadaver study showed higher stability as recorded by Resonance Frequency Analysis (RFA) method for tapered implants than for tapered implants, irrespective of bone quality (13). One multicenter study by Friberg *et al.* (14) also reported a significant higher RFA values for tapered implants (Branemark System, Mk IV) than non-tapered implants (standard fixture, Branemark System) in the posterior maxilla (14).

It is evident that the implant stability plays an essential role in the long-term successful osseointegration (15)(16). Moreover, primary stability is prerequisite for early loading protocol. It ensures a predictable immediate loading.(17, 18) Consequently, knowing the implant stability level, an optimal healing period that suitable for loading could be pointed out and an appropriate loading protocol could be established.

In 1998, Meredith(19) introduced the method of using Resonance Frequency Analysis (RFA) for the implant stability evaluation. The Resonance Frequency of the system is dependent on the stiffness of the implant/tissue interface and the distance from the transducer to the first bone contact(20), RFA can detect the overall stiffness of the implant/bone complex that comes from the summation between mechanical stability and biological stability occurred at that particular observing time. This means the RFA measures the “cumulative stability” of a dental implant and expresses as the implant stability quotient (ISQ) with values ranging from 1 to 100. The increased ISQ values indicate increasing in the implant stability, whereas the decreased ISQ values indicate decreasing in the implant stability.

By monitoring the consecutive variation of ISQ values, it allows clinicians to deliver a better patient care and lead to superior long-term results of the dental implants. As claimed by Bornstein *et al.* (21), Osstell is a valuable tool for determining the minimum level of the implant stability required for optimal loading. Prior to loading, it is recommended that a stability level of ISQ 65 should be reached. If the ISQ value is less than 65, the author suggested to extend the healing for 3 weeks before re-evaluation. This allows for the case-by-case basis treatment and resulting in 100% 6-month survival and success rate of the early loading implants (21).

For many years, the Sandblasted, Large grit, Acid-etched (SLA) implant surface has proven itself both in vitro (22-25) and in vivo (26-28) to be a superior choice of implant-to-bone interface, in particular during the early healing phase. Because of the roughness of SLA surface, it produced higher local cytokines and growth factor, increased fibronectin adsorption, enhanced bone apposition and higher removal torque values. Moreover, osteoblast cells that grew upon SLA surface exhibited properties of highly differentiated bone cells, suggesting that SLA was osteoconductive. Thus restoration over the SLA implant could be done as early as 6-8 weeks of healing with 99% predictability of success in 2-5 years observation period (10, 29, 30).

Another important factor for peri-implant/bone healing is surface chemistry, since it influences surface charge and surface wettability, thus it enhances the degree of contact and interaction between implant surface and biologic environment(31). The most recent version of Straumann dental implant is a chemically active and hydrophilic SLActive surface. With the same scientifically proven SLA micro- and macro-topography, SLActive produced under $N_2$ atmosphere then submerged in an isotonic NaCl solution. These procedures give the properties of super-hydrophilicity, 0 degree water contact angles, highly chemical activity and high surface free energy (32). These properties render SLActive surface a promising solution for rapid bone anchorage (33, 34). This, in turn, shorten the healing phase and allow patient a benefit of earlier-loading implant restorations.

In spite of that, the comparative clinical studies on the changes of RFA values over time in relation to two different implant surface modifications: the Standard sandblasted, large-grit, acid-etched (SLA) implant surface and the newly launched Chemical modified SLA implant surface (SLActive) , are limited. Thus little information had us known about the advantages of SLActive dental implant in term of early loading.

## Research Question

Does the different surface modification technique significantly affect the changes of RFA values during the early healing period of dental implants?

## Objective of the Study

(I) to observe the longitudinally changes in the stability of implants with 2 different surface chemistries by using Resonance Frequency Analysis (RFA) over the first 8 weeks and (II) to determine the functional loading protocol for implants with the SLA and SLActive by experienced surgeons.

## Statement of Hypothesis

**Null Hypothesis :**

There is no significant difference in the pattern of implant stability changes or stability dip during early healing period between two different surface modified dental implants.

**Alternative Hypothesis :**

There is a significant difference in the pattern of implant stability changes or stability dip during early healing period between two different surface modified dental implants.

## Scope of the Study

This clinical prospective study was designed to analyze the development of implant stability of the standard SLA implants (Straumann AG, Basel, Switzerland) relative to implants having the same physical properties but a chemically modified surface (SLActive®, Institut Straumann) by monitoring changes in ISQ values with Resonance Frequency Analysis. Furthermore, the correlations between probing directions of the Osstell device and ISQ values were evaluated. Prior to the operation, a preoperative Computerized Tomography scan was used to determined the bone density in Hounsfield units and to classify bone quality into four classes, according to Misch's bone classification(35). To control other factors, inclusion and exclusion criteria were used in recruiting the patients into the present study. Therefore, the result cannot be generalized to other cases with insufficient bone quantity or bone quality to gain the primary implant stability as judged clinically. Moreover, the results found here may not be able to be extrapolated to other implant systems as the present experiment only utilized the Straumann dental implant system.

## Basis Assumption

From the literature review, three most influential factors that influence both the osseointegration process and implant stability are the level of intimate bone contact, conditions of the implant bed and implant characteristics(topography, chemistry, surface charge, and wettabilty). Therefore, chemically-improved implant surface may enhance the biological healing process, and lead to the shorter clinical loading protocols for dental implant therapy.

## Study Limitation

1. The study was a random clinical trial, it didn't include distribution of all bone densities. For example, none of D1 bone density sample was found in this study.
2. Implant stability could only be analyzed when the implant was available for direct attachment by Osstell. Hence, it was impossible for the RF measurement after the prostheses placement.
3. The study only limited to the dental implant placed in lower posterior edentulous ridges with sufficient bone quantity and quality. Therefore, the findings in this study couldn't be extrapolated to those implants in other sites of jaw bone or those implants with bone defect. A non-submerged implant installation could not be performed without the need for lateral bone augmentation,

## Keywords

Clinical Trial, Dental Implants, SLA-surface, SLActive-surface, Implant Stability, Resonance Frequency Analysis, ISQ, Loading Time, Bone density

## The Expected Benefits

The results from this prospective study could be used to determine a proper timing for implant exposure to for functional loading regarding the implant surface characteristics. And to establish a proper loading protocol for the precisely placed non-submerged endosseous implant in lower posterior region.

# CHAPTER III

# MATERIALS AND METHODS

## Research Design

Experimental research

## Sample Description

This prospective study protocol was submitted to and approved by the Ethics Committee for Human Research, Chulalongkorn University, Thailand.

The study population consisted of thirty patients seeking lower posterior implant-supported restorations at the Special Dental Clinic in Faculty of Dentistry, Chulalongkorn University, Thailand. At the initial screening appointments, the subjects' medical and dental histories were reviewed and inclusion/exclusion criteria was confirmed. Clinical and radiographic screening were used to limit the study to patients with sufficient bone quantity to completely encase the implant.

All patients understood and signed an informed consent for the research prior to starting of treatment.

| Table 1 : Patient Inclusion Criteria |
| --- |
| a. Age 21 years or older |
| b. Ability to understand and sign the informed consent prior to starting the study |
| c. Ability and willingness to comply with all study requirements |
| d. Systemically healthy (ASA I or II) |
| e. Adequate bone volume to accommodate the endosseous dental implants (e.g., sufficient height such that the implant would not encroach on vital structures such as inferior alveolar nerve and sufficient width that the implant could be placed within the confines of the existing bone.) |

| Table 1 : Patient Inclusion Criteria |
| --- |
| f. Healed ridge with more than 6 months post-extraction and present Seibert's bone classification I to accommodate the primary stability of planned endosseous dental implants (139). |
| g. Implant placement with one staged protocol. |
| h. All implants will achieve the optimal primary stability measured by number of torque insertion with torque wrench or implant drill machine which is provided > 20 Ncm (8). |

| Table 2 : Patient Exclusion Criteria |
| --- |
| a. Heavy smoking (more than 10 cigarettes per day) or tobacco chewing. |
| b. History of alcoholism or drug abuse |
| c. Patients on medication which involving bone metabolism such as bisphosphonate. |
| d. Physical handicap that would interfere with the patient's ability to exercise good oral hygiene on a regular basis. |
| e. Pregnancy (self-declared) |
| f. A need for submersion of implants. |
| g. Presence of infection at the implant site. |
| h. Placement of implant in an extraction site that had been healing for less than 6 months. |

Preoperative Radiographic Evaluation

CBCT (Hitachi, CB Mercuray) was used for preoperative evaluation of the jaws for each patient. CBCT scanning of the edentulous mandible was performed after positioning a pre-fabricated acrylic resin surgical template, which incorporated a 4-mm diameter indicator gutta percha at the center of each proper designated implant area.

InVivo5 software (Anatomage) was used to measure the mean bone density of the implant area in Houndsfield units (HU). The HU measurements were performed at seven different cross-sectional images which were at the center of gutta percha, 1, 2, 3 mm mesial and distal to the center of the gutta percha in order to cover the area of future implant (Figure 4). Each image, three measurements were performed by defining a 5 x 5 mm square-shaped area at the crest of the edentulous ridges (Figure 5). Then, the mean HU values were used to classify bone quality of each implant area according to Misch's criteria (table 3).

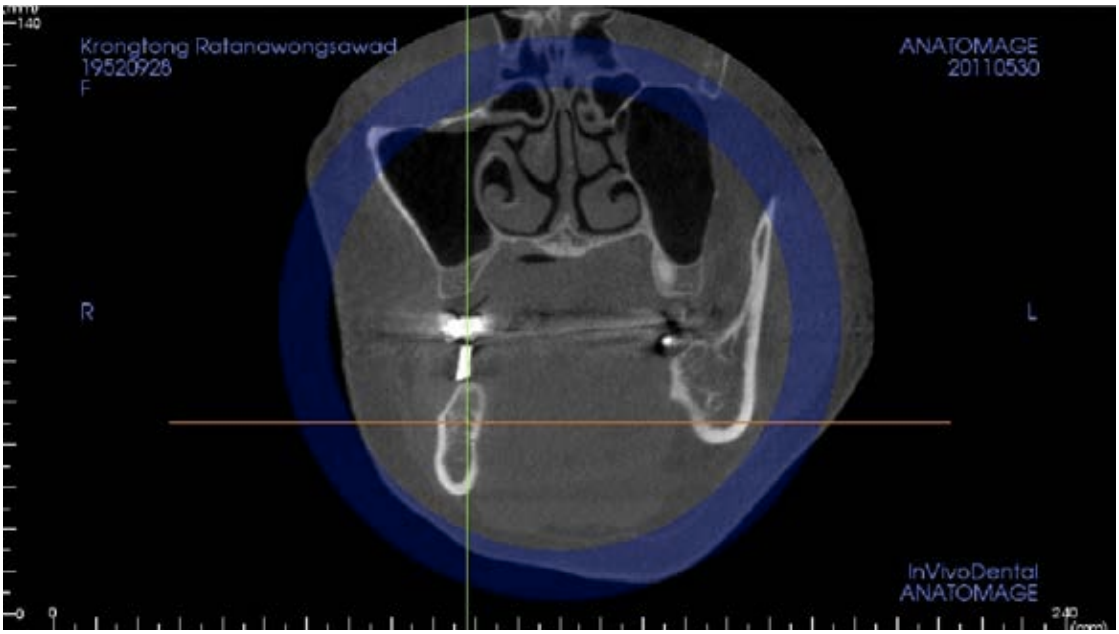


***Figure 4*** *The center of planned implant in mandible, Cross-sectional CBCT view.*

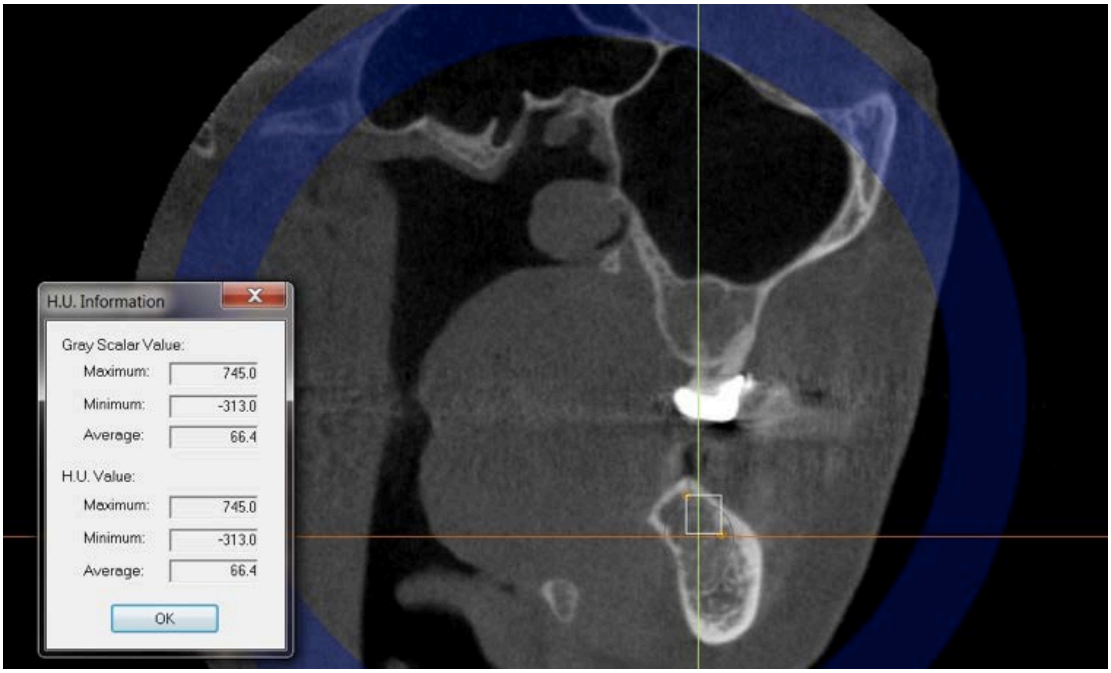


***Figure 5*** *After the 5 x 5 mm area was determined, the InVivo5 software indicated the HU value of each defined area.*

| Bone Type | Houndsfield unit |
|---|---|
| **D1** | > 1,250 HU |
| **D2** | 850-1250 HU |
| **D3** | 350-850 HU |
| **D4** | 150-350 HU |

***Table 3*** *Bone density classification of Houndsfield units (HU) according to Misch's criteria* (35)

## Clinical Protocol

Prior to surgery, the CBCT was used to plan the suitable position of implant and to assess an available bone quantity and bone quality following the classification by Misch's criteria (35). The implants used in this study were the Straumann® ITI dental implant system (Straumann Institute AG, Waldenburg, Switzerland) with the standard plus SLA-surface topography or the modified SLA-surface (SLActive). Every single placed implant was allotted for the Standard SLA-surface or the Modified SLA-surface (SLActive). Implants no. 1 to 5 were assigned for SLA surface implants meanwhile implant no. 6 to 10 were assigned for SLActive surface implants. The type of implant alternated between SLA and SLActive for every 5 implants till implant number 51. The implant no.was kept anonymous from the surgeons.

All implants were placed by two highly experienced oral surgeons (more than 50 implants with minimum of 2 years implant experience (8, 116), using a non-submerged technique, according to a strict surgical protocol following the manufacturer's instructions. The choice of the implant size (more than 4.0 mm) and length (ranging between 8 and 12 mm) were left to the decision of the surgeons and depending on available bone volume and quality.


***Figure 6*** *Osstell® ISQ (Osstell AB, Gamlestadsvägen 3B, Göteborg, Sweden).*

***Figure 7*** *SmartPeg is attached to the implant.*

Immediately after the implant was placed, the RFA values were determined using an Osstell® ISQ (Osstell AB, Gamlestadvägen 3B, GÖteborg, Sweden) (Figure 6). The standardized SmartPeg for Straumann® dental implants with fixed length was screwed into internal connection of the implant with mounting instrument via hand tightening (Figure 7). Then, mounting was removed gently and the transducer probe tip was held in the right angle to the small magnet on top of the SmartPeg at a distance of 2-3 mm (Figure 8, 9). The readings were obtained three times buccally, lingually and mesially to ensure repeatability of the instrument.

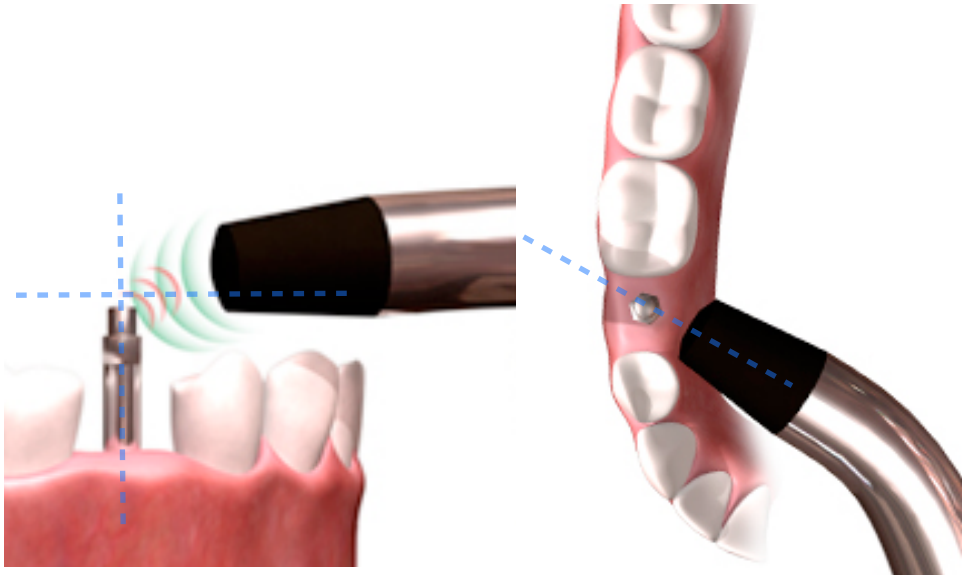

***Figure 8*** *The probe is held perpendicular to the magnet on top of the SmartPeg for 1-2s in order to stimulate the magnetically effect.*

A RFA measurement were scheduled and taken immediately following implant installation (day 0) and then at 2nd day, 1st, 2nd, 3rd, 4th and 8th week post-operatively. The data from day 0 were served as a baseline or control. Each visit involved assessment of pain level, clinical palpation, removal of the healing abutment, and the RFA values measurement. To reduce observer bias, the previous recordings on the implant were not accessed prior to each RFA measurement. All measurements were done by an individual investigator who conducted this study.

***Figure 9*** *The probe is held perpendicular to the magnet on top of the SmartPeg for 1-2 s in order to get the ISQ value.*

Statistical Analysis

All statistical analyses were conducted using the SPSS software version 17.0 (SPSS Inc., Chicago, IL). Following descriptive data analyses, Kolmogorov-Smirnov test was used to test the distribution normality. Since the data distribution was not normal, Friedman test was used to compare the ISQ variables of the SLA and SLActive groups in longitudinally model. Each pair of within-implant differences across the time periods were assessed using Wilcoxon Signed-Rank tests. Mann-Whitney U test was used to determine statistical significance between mean ISQ values of SLA and SLActive at each single point of observations.

Differences between the ISQ values of various bone structures at each point of observations were compared using Kruskal-Wallis test. With regard to the mean ISQ values of SLA and SLActive in different types of bone, Friedman test was used to indicate statistical significance of implant surfaces and bone quality in longitudinal pattern. Multiple Wilcoxon Signed-Rank tests were used to analyze the differences of ISQ values across each pair of observations.

Likewise, Kruskal Wallis test was performed to identify the significance of Implant Stability According to Positioning of the Osstell™mentor device. The longitudinal development of the RFA collecting from each probing direction were compared using Friedman test. To confirm the statistical differences of ISQ values between each observation periods, Multiple Wilcoxon Signed-Rank tests were performed. The level of significance for all statistical tests was set at $\alpha$=0.05.

# CHAPTER II

# REVIEW of LITERATURES

## Endosseous Implant and Osseointegration

More than half of century the tissue-integrated implant has greatly broaden the scope of medical treatments — craniofacial and orthopedic surgery for instance. Dental implant has also become increasingly important in oral rehabilitation, either for fully or partially edentulous patients. Dental implant breakthrough is based upon the idea of osseointegration or functional ankylosis that firstly described by the two research groups namely Branemark *et al.* (1) and Schroeder e *et al.* (2). The osseointegration is a stability concept in which achieving and maintaining implant stability during functional loading are prerequisite for the successful long-term function (3). In fact, the osseointegration occurs instantaneously on implant placement. It was firstly defined as “bone-to-implant contact at light microscope level” and after that, it is defined as “the direct structural and functional connection between ordered living bone and the surface of a load-carrying implant”(4). It has also been defined in clinical terms as “a process in which clinically asymptomatic rigid fixation of alloplastic materials is achieved and maintained in bone during functional loading”(5).

## Implant Stability

Initially, implant stability was provided by mechanical retention between the implant surface and the cortical part of the recipient bone. This was the so-called “primary stability” and those areas of bone that have intimate contact with implant surfaces are referred to “primary bone contact”.

Histological analysis of the primary intimate bone to implant contact includes lamellar plastic deformation, elongated Haversian systems, and micro-fractures in the bone. (Figure 2) Because bone tissues are dynamic and remodeled over time, these areas of bone contact are remodeled and replaced by new bone formation (Appositional bone formation or Contact osteogenesis(6)). At the same time, new bone is also formed on the

implant surface (Distance osteogenesis(6)). These new bones are termed as “secondary bone formation”.

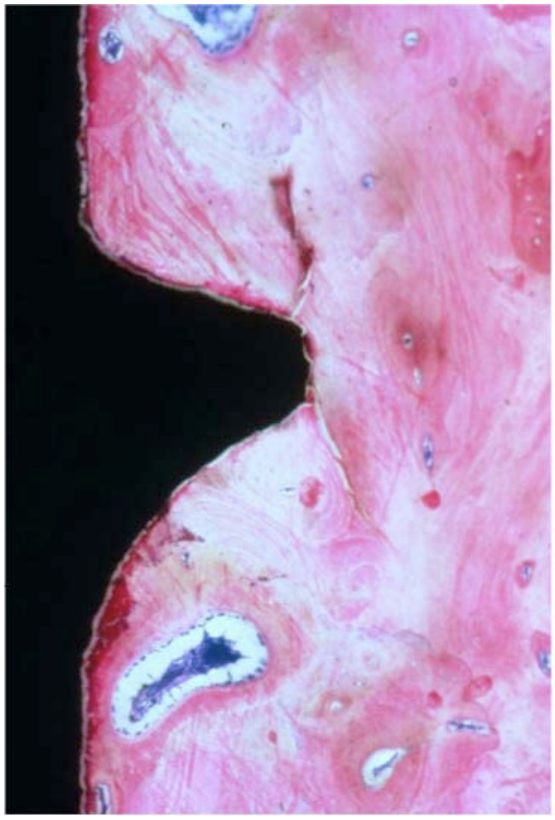

***Figure 2*** *Primary contact of implant with cortical bone. Original magnification: X25. Compression of the cortical bone can be observed. Reprinted with permission from Cochran DL, Schenk RK, Lussi A, Higginbottom FL, Buser D. Bone response to unloaded and loaded titanium implants with a sandblasted and acid-etched surface: a histometric study in the canine mandible. J Biomed Mater Res. 1998 Apr;40(1): 1-11(28).*

At the early phase, the primary bone contact was the majority due to the mechanical retention including existing quantity and quality of bone at the implant site while the secondary bone formation was minority. Subsequently, the biological responses such as osteoclastic activity, remodeling process and formation of new bone occurs, after that, the secondary bone formation takes the place of primary intimate bone contact. As a result, the ratio reverses such the that primary bone contact decreases and the secondary bone contact increases as shown in Figure 1. These findings suggested that at the beginning, the stability of the implant is maintained by the primary contact. After that, the remodeling and formation of new bone can occur to such a degree to further maintain the stability. The time point when implant undergoes a decreasing primary stability to an increasing secondary stability is called “stability dip” (7).

It is essential for clinical success that the implant has adequate stability to allow undisturbed healing. If an implant is not sufficiently stable at the transitional time from primary bone contact to secondary bone contact, micromotion may occur.(36) The normal

healing process may then be disrupted, and lead to a fibrous tissue encapsulation or the so-called fibroosseous integration, instead of osseointegration. This results in mobility and subsequent clinical failure of the implant (37).

Factors Affecting Implant Stability

Three main factors, which are the level of intimate bone contact, implant characteristics and conditions of the implant bed, influence the level of implant stability.

The first factor is the amount of bone-implant contact which depends upon bone quantity, bone quality as well as the ratio of cortical to trabecular bone (38, 39). It is clear that a high incidence of implant failure may be expected in the situation of a small bone volume in conjunction with soft bone quality. In 1985, Lekholm and Zarb (40) described four classes of bone by its morphology and quality or density based on the pre-operative radiographic assessment and the sensation of resistance experienced during drilling procedure. Three years later, Carl E Misch (41) proposed an extension of this idea by providing four bone groups based on cortical and trabecular bone, in which D1 has dense cortical bone. D2 bone has dense to porous cortical bone on the crest and coarse trabecular bone. D3 bone has thinner porous cortical crest and fine trabecular bone whereas D4 bone has almost no crestal cortical bone. Many researchers demonstrated that an implant placed in dense cortical bone has better primary stability than an implant placed in an open trabecular network (42, 43). Bone D1 and D2, thus, seem to be favorable for implant placement. However, they were tend to cause overheat to bone tissue during osteotomy, especially in D1 bone type, which underwent necrosis and caused more failure. On one hand, bone remodeling and new bone formation process require the viable cellular component. Bone type 4 although provides the least cortical bone, it delivers high number of viable cells.

The second factor is the implant characteristics whether their topography, chemistry, surface energy, or surface wettability which has been recognized to play an essential part in osteoblast adhesion and achievement of osseointegration (44). Surface properties affect several biological processes such as protein adsorption, cell-surface interaction, and cell/tissue development at the implant surface (45). One of the most important property is surface roughness. Surface roughness was shown to have an effect on the spreading, proliferation, differentiation of human osteoblast-like cells, the production of alkaline phosphatase, collagen, proteoglycans and osteocalcin, synthesis of

growth regulatory substances such as cytokines and growth factors (TGF-$B_1$ and $PGE_2$) (22, 23) and the cells' ability to respond to signaling molecules such as 1$\alpha$,25-$(OH)_2D_3$ (46, 47). As roughness increases, MG63 cells (osteoblast-liked cells) release increased levels of prostaglandin, including $PGE_1$ and $PGE_2$, the marker for early differentiation (23). $PGE_2$, a local factor produced by osteoblasts, is important in promoting wound healing and bone formation. Its high production enhances implant integration. Kieswetter *et al.* (23) further looked at cytokines and growth factors, which could influence the quality, extent, and rate of bone formation at the bone/implant interface. This might be the answer why several studies demonstrated that the quality and rate of osseointegration are influenced by the surface roughness of the implant (28, 48, 49).

During the past two decades, various in vivo studies suggested that moderately rough implant surfaces (Sa 1-2 $\mu$m), produced by different surface modifications, such as particle-blasting and/or etching, not only promote the osteoblastic cell activities but also alter the surface topography and hydrophilicity of the implant and ensure the improvement of osseointegration by enhancing contact area between the bone and the implant or by increasing the ability to retain the initial blood clot (29, 50-54).

While the bone cell ignores the surface topography with narrower than 0.5 $\mu$m grooved surface (55), microroughness of the implant surface provides a significantly greater percentage of bone-to-implant contact when compared with the machined or polished surfaces.(26, 46, 56, 57) On the contrary, the result from cultivation of osteoblast cells on Ti material with ultra-high roughness (18-74 $\mu$m) suggested that the roughness greater than cell dimension did not enhance the cell response (58). In year 1991 Buser *et al.*(26) performed a histomorphometric study of the modified Titanium implant surface and introduced the Sandblasted, Large grit, Acid-etched (SLA) endosseous implant surface. This surface has shown to produce higher amount of local cytokines and growth factors, as demonstrated by Kieswetter *et al.* (23). Moreover, in vivo studies, the SLA surface demonstrated predominantly superior results concerning implant integration and implant anchorage compared with TPS or machined surface (25, 28). Data reported that using the gold-standard SLA surface implants would lead to the reduction of healing periods from 6 months to 3 months in implant sites with regular bone density (10, 29, 30).

Recent studies have shown the synergistic effects of titanium surfaces with microtopography and additional submicrotopography (nanotopography) resulting in positive host response at both cellular and tissue levels (57, 59). At present, a CaP

nanoparticle modification of a minimally rough titanium implant surface is already for clinical use. This particular surface with the complexity of topography demonstrated significant increase in osteoconduction and rendered a better bone-bonding ability in rat models (60, 61).

As well as the physical properties modification, titanium surface modifications with bioactive molecules enhance and/or accelerate the process of osteoblastic differentiation, finally, improve osseous healing (62). The examples of biochemical modifications of biomaterial surfaces are CaP coating, which possess the benefit of chemical similarity to natural bone along with the nano-feature size (20-200 nm) of CaP/ DCD crystals (61), bone morphogenic proteins(63, 64), protein-like collagen(65), peptides and/or protein domains with Arg-Gly-Asp or RGD (65, 66).

One of the surface modification methods is the alteration of surface chemical composition, such as by addition of fluoride to implant surface. In vitro experiments indicated that fluoride ions influenced formation of both organic and inorganic components of bone tissue. Indeed, fluoride modification appeared to optimize the upregulation of transcription factors responsible for the expression of bone matrix formation genes (67-69). Hence, it promotes cellular differentiation and consequently enhances osteogenesis (70). Furthermore, results reported from in vivo experiments (71) revealed that the addition of fluoride ions on the titanium surface gives rise to an increase in the bone-to-implant bond strength and exhibits a significantly increased mechanical retention to bone. The fluoride-modified surface has shown more rapid bone formation and stronger bone-to-implant contact in animal studies (72) as well as in humans (73).

Moreover, the hydrophilicity, which favors the interactions with biological fluids and cells, is affected by the surface chemical composition (66, 71). In September 2005, SLActive, the next generation in implant technology, was officially launched. The idea of SLActive is to avoid carbon contamination of the implant surface from the atmosphere by rinsing a sandblasted/acid-etched surface under $N_2$ atmosphere. It is then submerged in an isotonic NaCl solution following acid etching to avoid contact with molecules from the atmosphere. Unique properties of SLActive are its super-hydrophilicity, water contact angles of 0° (compared to 139.9° for a standard SLA surface)(32) and its chemical activity. These properties render SLActive surface to be more attractive to blood and proteins (32) and promote faster osteointegration process (33, 34).

Therefore recent in vivo evidence has supported the use of alterations in surface chemistry to modify osseointegration events. For example, a histological study in miniature pigs revealed the significant differences in percentage of bone-to-implant contact (BIC) between the isotonic NaCl solution-treated surface with the control SLA surface were observed during the early stages of bone regeneration at $2^{nd}$ and $4^{th}$ week. At $2^{nd}$ week, the modified SLA surface demonstrated a mean of 49.3% BIC, while the conventional SLA surface showed a mean of 29.4% BIC. The authors also noted that this modified SLA-surface could offer a further reduction of the healing period following implant placement (33). Implant rehabilitation with these physio-chemical modified implant surfaces might simplify treatment, widen the treatment indication spectrum and further reduce the treatment time as compared with standard treatment protocols.

The last factor that might associate the implant stability and implant failure is the surgical technique and condition of the implant bed. A precise drilling technique to avoid overpreparation of implant sites has been cited as important, especially in poor-quality bone. In fact, when an implant drill has a slightly smaller diameter than the implant fixture, the implant is “press-fit” along the cut bone edges (28). There is marked local compression of the bone when an implant is inserted. This can result in hoop stresses. Such stresses may be beneficial in enhancing the primary stability of an implant (19). However, as the inexperienced clinicians tend to create less well-fitted implant bed, poor initial stability was expected. The process of osseointegration was also affected (74, 75). Consequently, a longer healing period should be allowed in such situation (76). In addition, such stresses and heat are always generated during the drilling and placement process. It appears that when the bone is continuously heated over 47°C for a period of time of one minute or more, local ischemia of the bone and osteonecrosis occur (76-78). This prevents the osseointegration.

## Measurement of Implant Stability and Osseointegration

Several techniques have been suggested for the determination of implant stability (8,72-95). It is highly desirable to have a quantitative method for measuring the primary stability of an implant at the time of placement. Such information may be used to predict the optimum healing period and point at which an implant may be suitable for loading.

The gold standard for primary stability measurements would be histologic and histomorphometric analyses of primary bone contact (79, 80). However, neither of these two methods is performed routinely in the clinical situation.

Peak insertion and removal torque values may be used clinically to represent the primary and secondary stability of the dental implants, respectively, but torque measurements are destructive methodologies and can be performed only during insertion or implant/abutment connection surgery. Hence, these two assessments are generally used only in pre-clinical applications as research techniques.

The most common, simplest test used in clinical practice, was the percussion test, carried out by tapping an implant or an abutment with a the handle of a metallic dental instrument (19, 81). The aim was to determine the resonances and damping of an implant from the audible ringing produced. However, such a test is relatively insensitive. Not only because the ear is insufficiently sensitive to discriminate the resonance frequency, damping and amplitude of the tone produced, but also simple tapping a complex system of the implant and abutment with a mirror handle will not transfer sufficient energy to the implant fixture to enable accurate measurements.

Another commonly used method was the use of radiographic interpretation. The objective is to identify peri-implant radiolucencies and to evaluate the degree of osseointegration. Nonetheless, the radiographic data provides two-dimensional, unsatisfactory resolution information with difficulties in standardization (74-76)(82-84). Sunden *et al.*(85) assessed the accuracy and precision of diagnosing clinical stability using radiographs. They concluded that, despite the relatively good diagnostic accuracy of the technique, the reliability of predicting clinical implant instability from radiographic examination was low.

On that account, the need for an objective, quantitive classification of bone density that can be applied pre-operatively, and which is not operator experience dependent is still very much in need. In 1987 Schwartz *et al.* (86, 87) introduced the concept of using computed tomography scans (CT) for pre-operative assessment of dental implant candidates as it can provide bone density in Houndsfield units (HU). The Houndsfield units represent the amount of attenuation of x-ray ranges from -1000 to +1000. Air is assigned to be -1000, whereas water is assigned to be 0, and dense material is assigned to be +1000. According to the classification of Misch for bone density, a correlation between bone and Houndsfield units was established.(88) D1 bone provides more than 1,250 HU, D2 shows 850 to 1,250 HU, D3 gains 350 to 850 HU and D4 ranges from 150 to 350 HU. Studies demonstrated a strong correlation between Houndsfield values and subjective bone quality assessment as quality 1-4 (89)(90) as well as the regions of mouth (90). Nevertheless, there has been concern regarding the radiation dosage that such a technique imparts(91-93).

The need for a clinically effective non-invasive technique for monitoring implant stability has led to the development of two major diagnostic tools — the periotest and the Resonance Frequency Analysis (RFA) (94, 95).

The Periotest instrument has been developed to measure the degree of the periodontal integration of teeth and the stiffness of the bone/implant interface in oral implantology. It measures the deflection/deceleration of a tooth or implant that has been struck by a small hitting pistil. The contact time of the accelerated pistil to the implant is calculated into a value called the Periotest value (PTV) which ranges from - 8 (rigid integration) to + 50 (non-integration) PTV units (95). Values above 10 PTV units are associated with failure of osseointegration (95, 96). Notwithstanding, there seems to be controversy regarding whether periotest is a reliable method to quantify implant stability clinically (94). Faulkner *et al.* (97) demonstrated that percussion testing might have good accuracy and/or reproducibility to measure implant stability, if some of the affecting variables — angulation of the hand piece, vertical striking height, and horizontal distance between the hand piece and the implant — could be controlled. To meet these requirements, the percussion test might be limited to apply only to well-standardized in vitro studies (98, 99).

Resonance Frequency Analysis

The Resonance Frequency Analysis (RFA) was firstly proposed by Meredith *et al.* (20) using the basic vibration theory. This non-invasive assessment originally used an L-shaped transducer designed as a simple offset cantilever beam that is attached to an implant or abutment. The transducer has a vertical beam with 2 attached piezo-ceramic elements (38). One piezo-ceramic element transmits a small sinusoidal signal over the range of frequencies, typically from 5 to 15 kHz. Subsequently a frequency response analyzer, the other piezo-ceramic element, analyzes the response of the transducer to the vibration. At the first flexural resonance of the beam, there was a marked change in amplitude and in phase of the received signal. The resonance frequency can, thus, be identified in a plot of the frequency (Hz) against the amplitude (V). Initially, prototype instruments indicated results in Hz. One disadvantage of the technique is the fact that each transducer has its own genuine Resonance Frequency (RF) and that the RF of the same implant varies between transducers. A linear relation was found between abutment length and RF, and measurements with different transducers (94).

The first commercial version of the RFA technique (Osstell, Integration Diagnostic AB, Go¨teborg, Sweden) used transducers that were calibrated by the manufacturer. Before performing RFA, a registration of the implant length was needed. RF measurements were now expressed as the implant stability quotient (ISQ) with values from 1 to 100, based on the calibrated RF of the transducer used. An increased ISQ value indicates increasing in implant stability, whereas a decreased ISQ value indicates decreasing in implant stability (82, 100). The manufacturer's guideline recommends that successful implant typically has an ISQ more than 65 while ISQ less than 50 might indicate potential failure (101, 102).

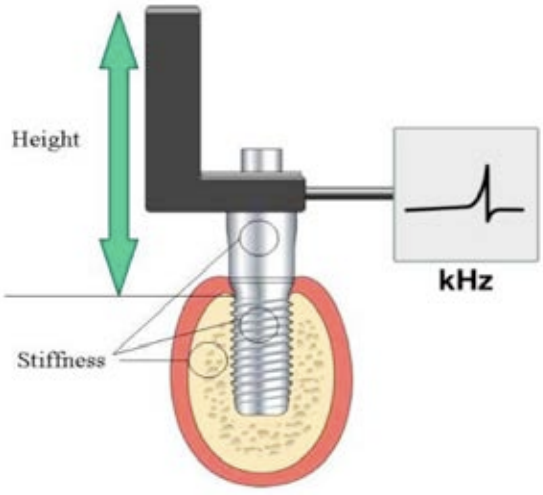


***Figure 3*** *The RF value is dependent on the stiffness of the implant/bone/transducer complex and on the vertical distance between first BIC and transducer (20, 103, 104).*

The resonance frequency of the system was dependent on the stiffness of the structure(20), a decrease in frequency being related to a decrease in bone/implant interfacial stiffness or the stiffness of the surrounding bone or the lack of solid connection between the transducer and implant fixture(103), as shown in Figure 3.

A linear relationship was found between exposed implant heights and marginal bone loss. One experiment placed implants in an aluminum block, which indicated that vertical implant placement, marginal bone height/ loss and abutment height influenced RF. Consequently, it has been shown that a linear relationship existed between the distance from the transducer to the first bone–to–implant contact and ISQ values (104).

Animal studies have shown that ISQ values increase with time after implant placement. In one study, commercially pure titanium implants were placed in the right tibia of 10 rabbits and ISQ measurements obtained at regular intervals up to 168 days, after which the rabbits were sacrificed and subjected to histomorphometric analysis. There was a significant increase in ISQ values for the first 40 days of healing, after which there was little further change (105). In another study, the stability of implants placed in the tibia of rabbits was measured weekly during a 15-week healing period. The study showed that the ISQ values increased significantly during the healing phase before reaching a plateau between $6^{th}$ and $8^{th}$ week (106, 107).

Moreover, a correlation between bone quality(40) and ISQ values was observed (107-109). Higher bone quality has found to relate with higher RFA values. Whereas some studies failed to confirm such relationships (96, 110).

To confirm the vibrational characteristics of an implant, Huang *et al.* established a finite element model to calculate the RF values of a vibrated implant. Their results showed that the RF value of an implant was affected by its marginal bone characteristics including type, density, and level (111). In two finite element analyses (FEAs), good correlations between the level of osseointegration and RFA were found (112, 113). Similarly, in 20-month clinical study, close correlation was observed between the resonance frequency measurements of primary implant stability, and the mean cutting resistance measurements were made for the most coronal third of the implant (114).

Furthermore, the influence of implant diameter, implant length and implant position on RFA values was documented as well. Some of these studies revealed that implant position, implant length, implant diameter, and implant depth did not affect primary stability as determined by RFA (108). However, O¨stman *et al.* exhibited

decreasing ISQ values with increasing implant length, which may be explained by the fact that long implants may have a reduced diameter in the coronal direction (107).

According to these studies, the RF value of an implant is a candidate parameter for early assessment of the implant/bone interface. Consequently, an optimal healing period that suitable for loading could be pointed out and an appropriate loading protocol could be established by monitoring the consecutive variation of ISQ values. This may allow the clinicians to deliver a better patient care and lead to better long-term results of the dental implants. As claimed by Bornstein, Osstell is a valuable tool for determining the minimum level of implant stability required for optimal loading. Prior to loading, it is recommended that a stability level of ISQ 65 is reached. If the ISQ value is less than 65, the author suggested for further 3 weeks of healing before re-evaluation. This allows for the case-by-case basis treatment and resulted in 100% 6-month survival and success rate of the early loading implants (21).

To date, several investigations have followed the stability of implants over early healing time with Resonance Frequency measurements (74, 98, 102, 115). In spite of that, the comparative clinical studies on the changes of RFA values over time in relation to two different implant surface modifications: the Standard sandblasted, large-grit, acid-etched (SLA) implant surface and the Chemical modified SLA implant surface, are limited.

# CHAPTER IV

# RESULT

## Sample

Thirty patients (17 women and 13 men with a mean age of 55.1 ± 10 years) were included in this study. Fifty-one implants were placed in the mandible (14 in the premolar area and 37 in the molar area). Eight patients of thirty patients needed two implants replacement whilst 3, 1 and 1 patients needed a replacement of three, four and five implants respectively.

***Table 4*** *Demographic Data of the SLA Group*

| No. | Age | sex | Tooth No. | Ø | Length | Bone Quality |
|---|---|---|---|---|---|---|
| SLA 1 | 55 | M | #46 | 4.1 | 10 | D4 |
| SLA 2 | 50 | F | #46 | 4.8 | 10 | D3 |
| SLA 3 | 45 | M | #36 | 4.8 | 10 | D3 |
| SLA 4 | 63 | F | #36 | 4.8 | 10 | D3 |
| SLA 5 | 56 | M | #46 | 4.8 | 10 | D3 |
| SLA 6 | 65 | M | #34 | 4.1 | 10 | D2 |
| SLA 7 | 65 | M | #35 | 4.8 | 10 | D2 |
| SLA 8 | 65 | M | #36 | 4.8 | 8 | D2 |
| SLA 9 | 55 | F | #46 | 4.8 | 10 | D3 |
| SLA 10 | 55 | F | #47 | 4.8 | 10 | D3 |
| SLA 11 | 60 | M | #35 | 4.1 | 10 | D2 |
| SLA 12 | 60 | M | #36 | 4.8 | 10 | D3 |
| SLA 13 | 47 | F | #44 | 4.1 | 10 | D4 |
| SLA 14 | 47 | F | #46 | 4.8 | 10 | D4 |
| SLA 15 | 56 | M | #46 | 4.8 | 10 | D3 |
| SLA 16 | 25 | F | #36 | 4.8 | 10 | D3 |
| SLA 17 | 60 | M | #47 | 4.8 | 10 | D3 |
| SLA 18 | 60 | F | #45 | 4.8 | 12 | D3 |
| SLA 19 | 60 | F | #46 | 4.8 | 10 | D4 |
| SLA 20 | 66 | F | #36 | 4.8 | 10 | D2 |
| SLA 21 | 53 | M | #36 | 4.8 | 8 | D2 |
| SLA 22 | 53 | M | #47 | 4.8 | 10 | D3 |
| SLA 23 | 66 | M | #47 | 4.8 | 10 | D2 |
| SLA 24 | 66 | F | #46 | 4.8 | 10 | D4 |
| SLA 25 | 53 | F | #36 | 4.8 | 10 | D3 |

***Table 5*** *Demographic Data of the SLActive Group*

| No. | Age | sex | Tooth No. | Ø | Length | Bone Quality |
|---|---|---|---|---|---|---|
| SLActive 1 | 59 | F | #36 | 4.1 | 10 | D2 |
| SLActive 2 | 59 | F | #37 | 4.8 | 10 | D3 |
| SLActive 3 | 47 | M | #46 | 4.8 | 10 | D3 |
| SLActive 4 | 67 | F | #35 | 4.1 | 10 | D4 |
| SLActive 5 | 29 | F | #36 | 4.8 | 10 | D4 |
| SLActive 6 | 54 | M | #34 | 4.1 | 8 | D2 |
| SLActive 7 | 54 | M | #44 | 4.1 | 8 | D2 |
| SLActive 8 | 59 | F | #46 | 4.8 | 10 | D4 |
| SLActive 9 | 75 | M | #46 | 4.8 | 10 | D3 |
| SLActive 10 | 55 | F | #35 | 4.1 | 10 | D3 |
| SLActive 11 | 55 | F | #36 | 4.8 | 8 | D4 |
| SLActive 12 | 55 | F | #37 | 4.8 | 8 | D4 |
| SLActive 13 | 62 | F | #35 | 4.1 | 10 | D2 |
| SLActive 14 | 62 | F | #36 | 4.1 | 10 | D2 |
| SLActive 15 | 62 | F | #37 | 4.1 | 8 | D2 |
| SLActive 16 | 53 | F | #45 | 4.1 | 10 | D3 |
| SLActive 17 | 53 | F | #46 | 4.8 | 10 | D3 |
| SLActive 18 | 66 | M | #36 | 4.8 | 10 | D4 |
| SLActive 19 | 66 | M | #37 | 4.8 | 10 | D4 |
| SLActive 20 | 60 | M | #34 | 4.1 | 10 | D3 |
| SLActive 21 | 60 | M | #35 | 4.1 | 10 | D3 |
| SLActive 22 | 60 | M | #36 | 4.8 | 10 | D3 |
| SLActive 23 | 47 | F | #45 | 4.1 | 12 | D2 |
| SLActive 24 | 47 | F | #46 | 4.1 | 10 | D2 |
| SLActive 25 | 46 | F | #46 | 4.8 | 8 | D3 |
| SLActive 26 | 46 | F | #47 | 4.8 | 8 | D3 |

Twenty-five standard plus SLA Straumann implants (Straumann Institute AG, Waldenburg, Switzerland) and twenty-six modified SLA-surface(SLActive) implants were placed in controlled and test group consecutively. Most of implants (40 implants) were 10 mm in length while 9 and 2 implants were 8 and 12 mm in length respectively. Seventeen implants were 4.1mm in diameter with regular neck platform while 34 implants were 4.8 mm in diameter with wide neck platform. The bone density varied from 188.66 to 968.29 HU, with the mean bone density of 609.06 HU. Regarding the bone classification, 15 of the 51 implants were placed in type II bone, 24 implants were placed in type III bone, and 12 implants were placed in type IV bone. Demographic data of the implants analyzed are

presented in Table 4 and 5. Good primary stability was achieved and healing was uneventful in all cases. No implant exhibited clinical mobility at any time point.

Overall Implant Stability

The mean ISQ values and the standard deviation at baseline and in the subsequent time points of the measurement are presented in Table 6 and Figure 10. On an average, at the first measurement (after surgery) ISQ values were ranged from 67 to 90 with a mean value of 79.2 (SD: 4.69). ISQ values were ranged from 58 to 88 at 2nd day (mean: 73.9; SD: 6.42), from 57 to 85 at 1st week (mean: 74.7; SD: 6.28), from 48 to 87 at 2nd week (mean: 75.2; SD: 6.88), from 52 to 87 at 3rd week (mean: 75.4; SD: 6.12), and from 66 to 85 at 2nd week (mean: 77.0; SD: 4.54). By 8th week, the range had narrowed down. They were ranged between 70 and 87 ISQ units (mean: 79.1; SD: 3.64) (Table 6, Figure 10). Interestingly, the mean stability for all implants decreased (5.28 units) during the first 2 days, thereafter continuously rose back to the level of the initial stability at 8th week. Figure 4 illustrated that the minimum ISQ values occurred on the 2nd day of healing. Subsequently, the mean ISQ values continuously increased and reached statistical significance (P=0.001) at 4th week of healing relative to at 2nd day. At any given observation period, ISQ values of all implants were varied between 48 and 87.

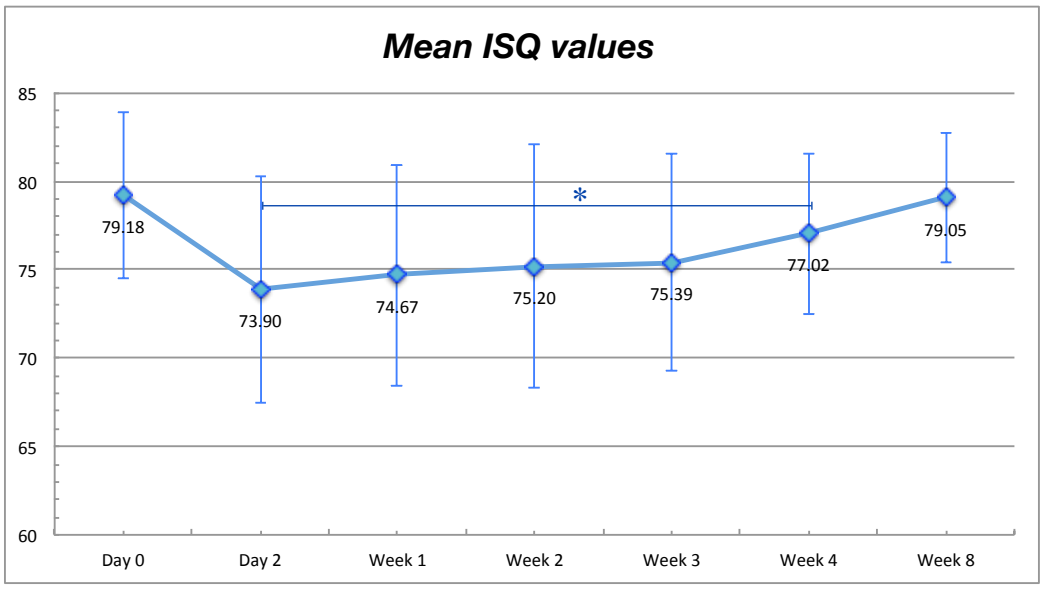


***Figure 10*** *Mean implant stability quotient (ISQ) values for overall assessment at the various observation points. n=51.(*Statistically significantly different from Week 0 (P<0.05).)(40)*

***Table 6*** *Mean ISQ values, Standard Deviation, Maximum and Minimum ISQ values for all observation points (ISQ, implant stability quotient; SD, standard deviation)*

| | Day 0 | Day 2 | Week 1 | Week 2 | Week 3 | Week 4 | Week 8 |
|---|---|---|---|---|---|---|---|
| ISQ | 79.18 | 73.90 | 74.67 | 75.20 | 75.39 | 77.02 | 79.05 |
| SD | 4.69 | 6.42 | 6.28 | 6.88 | 6.12 | 4.54 | 3.64 |
| Max | 90 | 88 | 85 | 87 | 87 | 85 | 87 |
| Min | 67 | 58 | 57 | 48 | 52 | 66 | 70 |

Implant Stability According to Implant Surface

The influence of the implant surface on ISQ values were depicted in Figure 11 and Table 7. At baseline, the stability quotients for both surfaces tested were not significantly different and yielded mean ISQ values of 80.44 (SD 4.24) for the SLActive implants and 77.87 (SD 4.78) for the SLA implants.

For SLA ; at the implant installation, the ISQ values were ranged from 64 to 78, with a mean value of 77.87 (SD ±4.78). On the second day after implant placement, the mean lowest ISQ value was reached (73.77) and stayed unchanged at 1st, 2nd, 3rd and 4th week with the mean values of 74.99, 74.41, 74.47 and 75.68 respectively. After that, the stability increased to 77.89 at the end of observation. (Table 7, Figure 11)

***Figure 11*** *Mean implant stability quotient (ISQ) values for the SLActive-surface (red) and the standard SLA-surface (green); Overall assessment at the various observation points. (n=51)*

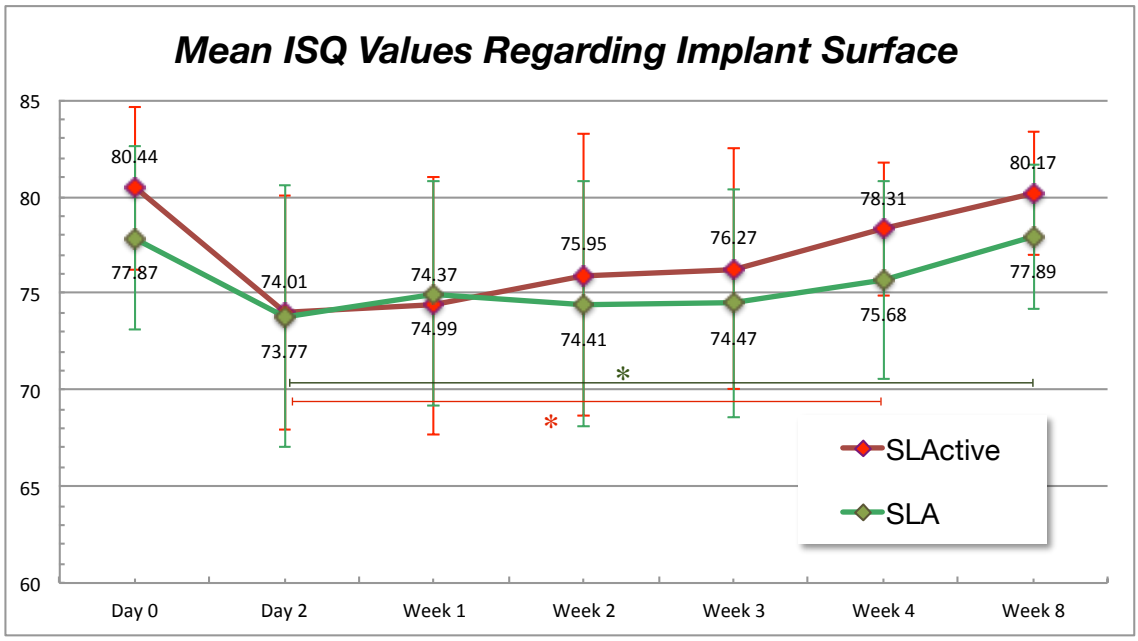

***Table 7*** *Mean ISQ values and Standard Deviation for all observation points during osseointegration for implants with the standard SLA-surface (n=25) and the SLActive-surface (n=26)*

| | | Day 0 | Day 2 | Week 1 | Week 2 | Week 3 | Week 4 | Week 8 |
|---|---|---|---|---|---|---|---|---|
| SLA | ISQ | 77.87 | 73.77 | 74.99 | 74.41 | 74.47 | 75.68 | 77.89 |
| | SD | 4.78 | 6.76 | 5.80 | 6.34 | 5.88 | 5.13 | 3.73 |
| | Max | 85 | 88 | 85 | 84 | 83 | 82 | 84 |
| | Min | 67 | 58 | 59 | 63 | 62 | 66 | 70 |
| SLActive | ISQ | 80.44 | 74.01 | 74.37 | 75.95 | 76.27 | 78.31 | 80.17 |
| | SD | 4.24 | 6.07 | 6.69 | 7.28 | 6.22 | 3.43 | 3.18 |
| | Max | 90 | 84 | 84 | 87 | 87 | 85 | 87 |
| | Min | 69 | 59 | 57 | 48 | 52 | 70 | 74 |

Regarding SLActive group; at implant installation, the individual ISQ values were ranged from 65.3 to 81.3, with a mean value of 80.26 (SD ±4.42). The longitudinal development of ISQ values of the SLActive implants showed that the mean ISQ values of the SLActive implants were decreased to 74.01, 74.37, 75.95 and 76.27 after $2^{nd}$ day, $1^{st}$, $2^{nd}$ and $3^{rd}$ week, respectively. At $2^{nd}$ day, the lowest stability value of 74.01 was reached. This was similar to SLA case. However, from statistical analysis using the repeated Friedman's model, no significant difference of the mean stability values across time was observed among $2^{nd}$ day, $1^{st}$, $2^{nd}$ and $3^{rd}$ week. The longitudinal change in the mean ISQ values showed variations within a range of 71.4 – 78.8. (Table 7, Figure 11) From Figure 11, it was evident that patterns of ISQ values changing during early healing for two groups of implant were consistent. With regards to initial ISQ levels, both SLA and SLActive implants showed decreasing in stability level immediately at $2^{nd}$ day after the surgery. Thereafter, the RF values of both implant types continuously increased and reached their initial stability levels at $8^{th}$ week time point. The evaluation of the stability patterns over time showed a significant change (P=0.015) in the pattern of stability for the SLActive surface implants at the $4^{th}$ week time point from decreasing stability to increasing stability (Table 7). This is in contrast to the SLA surface implants, in which a similar (P=0.02) change in the pattern of stability was identified at the $8^{th}$ week time point (Figure 11). However, no statistically significant difference of ISQ values between SLA and SLActive surface implants at any observation point was found ($P<0.05$).

Implant Stability According to Bone Type

The distribution of the implants according to the bone structure is presented in Table 8. The distributions of implants according to bone type were 29.4% (n = 15) in Type II bone, 47.1% (n = 24) in Types III bone, and 23.5% (n = 12) in Type IV bone.

***Table 8*** *Distribution of the implants based on implant length and bone structure (Misch's bone classification. (35))*

| | Bone Type II | Bone Type III | Bone Type IV |
|---|---|---|---|
| SLA-surface | 7 | 13 | 5 |
| SLActive-surface | 8 | 11 | 7 |
| Total n (%) | 15 (29.4%) | 24 (47.1%) | 12 (23.5%) |

***Table 9*** *Mean ISQ values and Standard Deviation for all observation points during osseointegration for various bone structures according to (Misch's bone classification. (35))*

| | | Day 0 | Day 2 | Week 1 | Week 2 | Week 3 | Week 4 | Week 8 |
|---|---|---|---|---|---|---|---|---|
| Type II | ISQ | 79.78 | 77.07 | 76.47 | 78.33 | 77.47 | 77.40 | 78.87 |
| | SD | 3.40 | 4.54 | 5.99 | 2.91 | 2.92 | 3.86 | 3.14 |
| Type III | ISQ | 78.81 | 71.92 | 73.18 | 74.43 | 76.67 | 77.31 | 79.50 |
| | SD | 3.93 | 6.51 | 6.42 | 6.02 | 4.24 | 3.97 | 3.39 |
| Type IV | ISQ | 78.89 | 73.86 | 75.42 | 72.69 | 70.42 | 75.94 | 78.47 |
| | SD | 7.09 | 6.73 | 5.57 | 9.87 | 8.98 | 6.01 | 4.53 |

The implant stability patterns in each type of bone are shown in Figure 12 and Table 9. It revealed that the lowest mean stability measurement for bone Type II was at 1 weeks with the mean ISQ difference of 2.71. However, the changes of stability in Types II bone were relatively stable throughout the observations. Contrastingly, Type III bone showed more markedly (6.89 units) ISQ decrease during the first two days after implant placement, followed by a period of increasing ISQ value, until it returned to the level of initial value at 8$^{th}$ week. Type IV bone, differently, showed the fluctuation stability pattern. The mean ISQ value decreased at day 2 and increased slightly at 1$^{st}$ week. Later at 2$^{nd}$ week, ISQ value decreased and demonstrated the lowest stability value at 3$^{rd}$ week. After 4$^{th}$ week, the mean ISQ value rose up and returned to its initial ISQ value at 8$^{th}$ week. By 8 weeks, no bone groups showed any difference in implant stability, except at 3$^{rd}$ week that Type IV bone showed significant difference of ISQ values, compared with the other bone types.

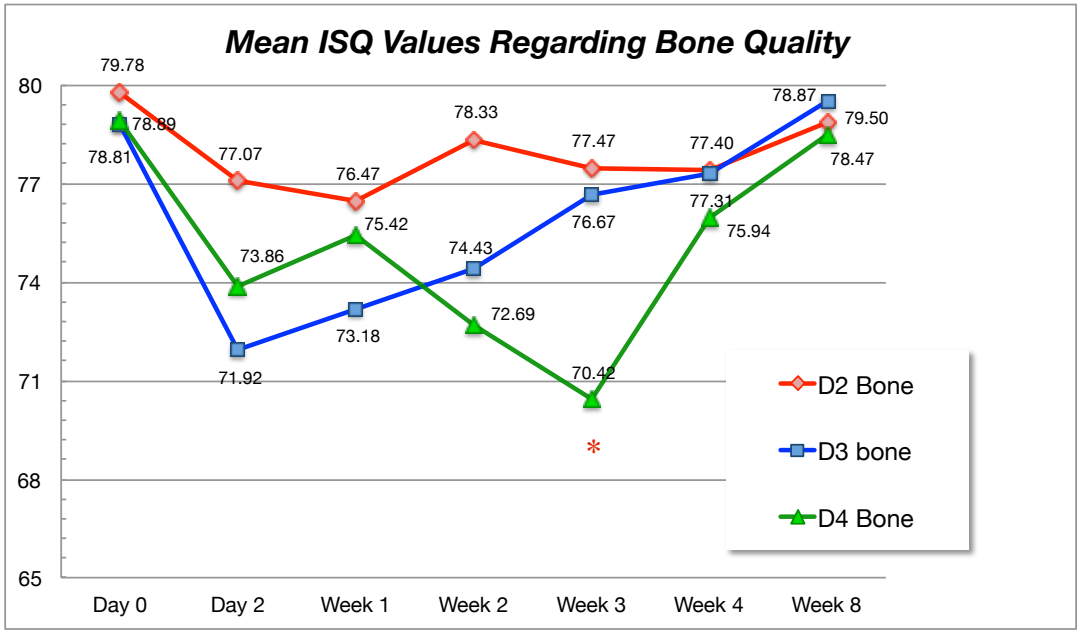


*Figure 12* *Mean implant stability quotient (ISQ) values for all implants and observation points stratified according to bone structures* (35). *Type II bone: n=15, Type III bone: n=24 and Type IV bone: n=1 (*Statistically significantly different from Week 0 (P<0.05).*

Implant Stability on Different Surfaces in Each Type of Bone

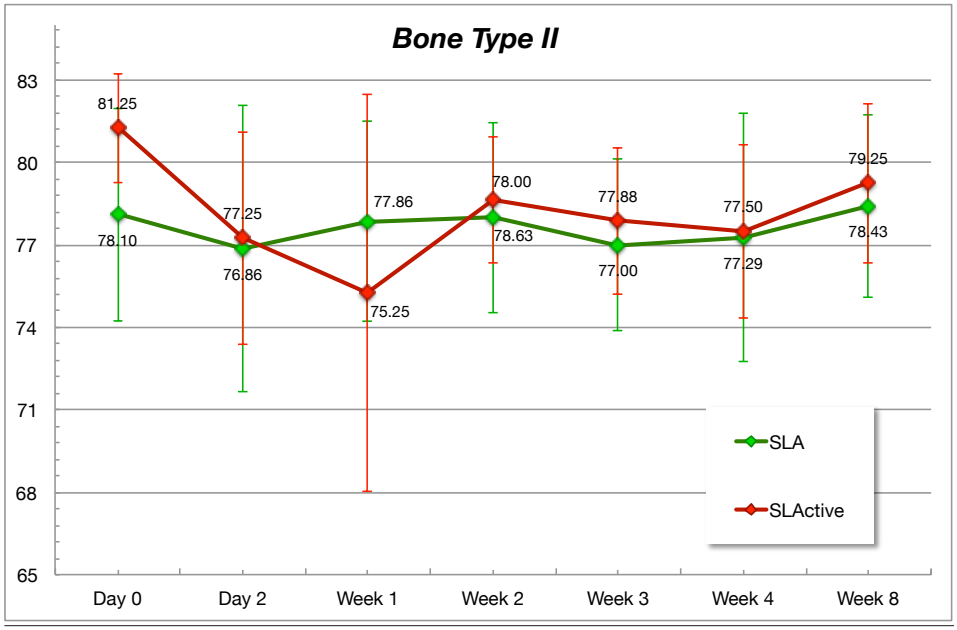


*Figure 13* *Mean implant stability quotient (ISQ) values for SLA- and SLActive-surface implants placed in bone Type II as according to Misch's bone classification*(35).

In Type II bone, (Figure 13) the greater initial RF value was observed in SLActive-surface group (81.25 vs 78.10). Comparatively little change in stability from baseline readings was observed in SLA, while the change of ISQ values of the SLActive group decreased markedly during the first week after implant surgery. Then, it rose back at 2nd week and remained stable at this level throughout the end of observation. By 8 weeks, there was no significant difference of ISQ values between SLA and SLActive implants in Type II bone (P=0.05). These results are shown in Figure 13.

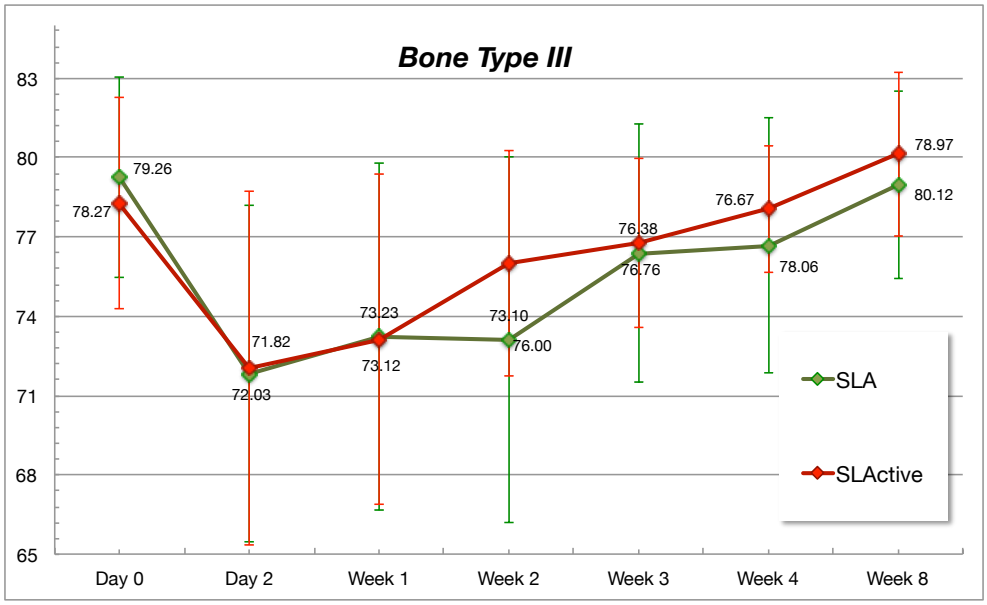


***Figure 14*** *Mean implant stability quotient (ISQ) values for SLA- and SLActive-surface implants placed in bone type III as according to Misch's bone classification*(35).

In bone Type III, (Figure 14) both types of implants showed similar ISQ pattern. There was no significant difference of initial stability at the installation visit. Both of implant types showed a significant decreasing stability at 2nd day. After 2 days time point, the mean ISQ values constantly climbed up to reach initial values at 3rd week. Likewise, no significant difference of ISQ values of SLA and SLActive implants could be found at any observation time point for Type III bone (P=0.05).

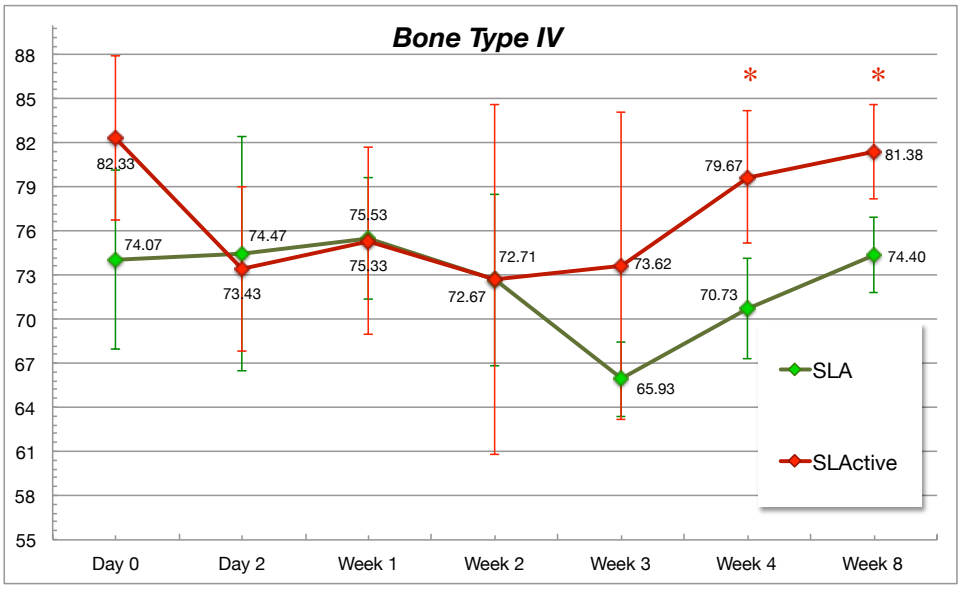


***Figure 15*** *Mean implant stability quotient (ISQ) values for SLA- and SLActive-surface implants placed in bone type 4 as according to Misch's bone classification*(35). *(*Statistically significantly different from Week 0 (P<0.05))*

In bone Type IV, (Figure15) the result showed a drastic decrease for SLActive on 2nd day while ISQ values of SLA group remained relatively constant for the first two weeks before experiencing a significant decrease from 2nd week to 3rd week. After reaching their minima at the 3rd week of healing, SLA-surface implants rose drastically throughout the end of the study. For SLActives, however, values did not show significant change after the drop on the first 2 days after surgery, before starting to increase after 3rd week. Both implant surfaces showed a significant improvement in stability from 3rd week to 8th week. SLActive-surface implants returned to the initial stability level at 4th week, however it took SLA-surface implants 8 weeks of healing to achieve the same result. Interestingly, SLActive implants displayed significant higher in RF values as compared to SLAs at 4th week and 8th week in Type IV bone.

<u>Implant Stability According to Positioning of the Osstell™ *mentor* device</u>

ISQ values calculated at each observation point were obtained from buccal, lingual and mesial positioning of the Osstell™ *mentor* device (Table 10, Figure 16). It was evident that there was no difference among the readings from three different positions of the device were noted (Figure 16). The increased in ISQ values from 2nd day to 4th week were significant for all positions of the Osstell™ *mentor* Probe (buccal, lingual and mesial), as depicted in Figure 16.

*Table 10* Mean ISQ values and Standard Deviation for all observation points and all implants with the Osstell™mentor device positioned Buccally, Lingually or Mesially.

| | | Day 0 | Day 2 | Week 1 | Week 2 | Week 3 | Week 4 | Week 8 |
|---|---|---|---|---|---|---|---|---|
| Buccal | ISQ | 78.41 | 73.47 | 73.82 | 73.98 | 74.98 | 76.57 | 78.78 |
| | SD | 5.56 | 7.23 | 7.58 | 7.72 | 6.94 | 5.26 | 4.33 |
| Lingual | ISQ | 79.24 | 73.53 | 74.61 | 75.31 | 75.08 | 77.10 | 78.71 |
| | SD | 5.37 | 7.41 | 6.52 | 7.71 | 6.98 | 4.78 | 3.97 |
| Mesial | ISQ | 79.73 | 74.69 | 75.59 | 76.29 | 76.12 | 77.41 | 79.80 |
| | SD | 5.51 | 7.36 | 7.40 | 7.39 | 6.69 | 5.20 | 4.27 |
| Overall | ISQ | 79.12 | 73.90 | 74.67 | 75.20 | 75.39 | 77.03 | 79.10 |

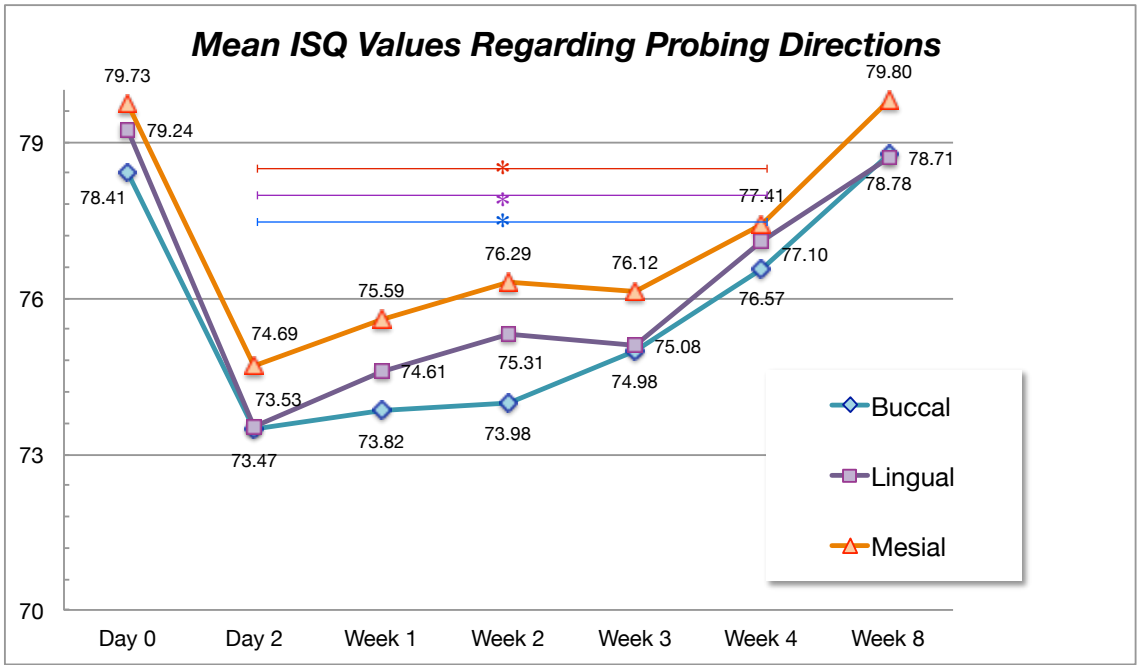


*Figure 16* Mean overall implant stability quotient (ISQ) values obtained separately with a Buccally, Lingually and Mesially positioned Osstell™mentor Probe, respectively. (n=51) (*Statistically significantly different from Week 0 (P<0.05))

# CHAPTER V

# DISCUSSION

The objective of this investigation was to compare longitudinal implant stability patterns of two different surfaces Straumann implants over the first 8 weeks following implant installation. One of the most recent objective measurements in dental implant stability is the Resonance Frequency Analysis (RFA). The RFA method has now been recognized as non-invasive technique with high sensitivity and reproducibility in detecting an early change of implant stability level (as assessed in ISQ units) during osseous healing (105, 117, 118). In addition, RFA clinically determines a functional loading time of a particular implant which allows individual dental treatment care (18, 102).

The latest version of RFA, the Osstell™mentor system, was used to assess ISQ values in this current study. It was demonstrated that Osstell served as a sensitive tool for clinically monitoring implant stability in bone of varying density (114, 119). Implant stability that measured from this machine is the so-called “initial stability” (day 0) and “cumulative stability”. In this study, authors collected ISQ values immediately after implant placement (day 0) and used as baseline values to represent initial stability. Regarding the cumulative stability, Bornstein *et al.* (21) showed a dip of stability of implants placed in mandible between 2$^{nd}$ week and 6$^{th}$ week. This confirmed an initial decrease in the ISQ values within the first three weeks of healing (100, 120, 121). The cumulative stability of modified SLA implants changed from downward trend to upward trend at 2$^{nd}$ week meanwhile it was found at 4$^{th}$ week in the conventional SLA implants (21, 122). Therefore the implant loading protocol established the concept of early loading at 3$^{rd}$ week after placement while the concept of immediate loading and delayed loading were set at 2$^{nd}$ day and 8$^{th}$ week respectively (123). In order to monitor the implant stability by using RFA and to determine the time point when the implant has lowest stability, this study measured ISQ values weekly in the first month and the final ISQ measurement were set at 8$^{th}$ week after surgery.

Initial Implant Stability

The RFA measurements showed an ISQ value of 79.1 ± 5 as a mean value, which indicated that the majority of implants obtained high initial stability (21). One explanation could possibly be the high surgical skill level of surgeons used in our study. As less experienced surgeons tended to create traumatic preparation or oversized preparation. In contrast, highly experienced surgeons were able to prepare implant bed precisely and minimize the risk of bone necrosis. As the quality of initial stability is known as the prerequisite for the osseointegration in an early loading cases (3), Lembert *et al.* (116) reported the number of failed implants placed by inexperienced operators were twice as high as those placed by well-experienced operators.

In this study, descriptive analysis of the ISQ values by patient gender and implant diameter, implant platform, implant length, implant surface and bone density at implant site demonstrated that none of them had influence on the initial ISQ values. This was correspondent with other studies (115, 124, 125). The result from this study also revealed that implant with the chemically modified surface exhibited higher initial ISQ scores, but it did not reach statistically significant difference, which corresponding with Han's study (115). Moreover, the study showed no significant correlation between bone density and the initial ISQ values. The result dissented from several studies reported higher initial implant stability in denser bone site, regardless implant types (Brånemark® Mk III, Astratech or Straumann implants (126-129). One possible explanation was the difference in surgical technique. In this study the operators decided not to use the final profile drill nor tapping step if the patient had soft type of bone. This was to ensure that the maximum initial stability of each single placed implant was achieved.

Influence of Implant Surface

According to the result, it was revealed that both SLActive and SLA implants displayed the same point of stability change from decreasing cumulative stability to increasing cumulative stability at 2nd day and gained the maximum cumulative stability by 8th week. This was the result from reducing in purely mechanical or the initial stability and followed by the increasing in biological stability, the secondary stability. After 2nd day of markedly reduction of cumulative stability, the increasing pattern of cumulative stability was found. However, within implant surface analyses, the increasing cumulative stability did not reach a significant level until 4th week for SLActive group and 8th week for the SLA group. Apart from that the decrease of ISQ values within the early period was consistent to the results of other studies (100, 102, 121). Interestingly, when compared the difference between SLA and SLActive at each point observation, no statistical difference of ISQ values was observed.

From the result of this study, within implant surface analyses, there was a significant difference of ISQ values of SLActive between 2nd day and 4th week. The SLA group, meanwhile, demonstrated a significant increase of ISQ values between 2nd day and 8th week. Nevertheless, no significant in-between two implant surfaces at any point in time could be found. The result of this finding was similar to the study from Han *et al.* (115) where they investigated the influence of implant surface modification upon the development of the implant stability. Their study compared 15 SLA implants to 8 SLActive implants in human clinical model. The cumulative stability values were collected at 4th day, 1st, 2nd, 3rd, 4th, 6th, 8th and 12th weeks post-surgery. The results also showed no significant difference in ISQ values between SLA and SLActive implants at any point of the observation periods. Correspondently, Valderrama *et al.* (121) studied ISQ values of 17 SLA implants and 17 SLActive (Straumanns) implants over 12 weeks in human model. In this study, the type of implant surface did not reveal any significant difference in ISQ values either in early healing or over time. Therefore it may be speculated that either no differences exist in the extent of implant stability between the two implant surfaces in the early phase of healing or that the RFA may not be sensitive enough to detect minute differences. Moreover, the possibility of underpowered sample size has to be realized.

However, there were some studies that showed a significant difference of implant stability values between SLA and SLActive implants.(33, 122) A spit-mouth design experiment validated a significant greater bone apposition upon the modified SLA surface (up to 60%) after 2 weeks, compared to the SLA surface.(33) The evidence from their study suggested a possible further reduction of the healing period of 6-8 weeks to 4 weeks for the SLActive-surface implant, which was a result of the favorable properties of the chemically modified SLA surface implants (with a survival rate and success rate of 100% at the 2-month follow-up period). Nonetheless, the study was done in miniature pigs model.

In human study, Oates *et al.*(122) demonstrated the breaking point (a transition point from a decreasing trend to an increasing trend) at 2$^{nd}$ week for SLActive implant compared to at 4$^{th}$ week for SLA implant. The identification of these transition points suggested an enhanced healing process associated with the modified implant surface. Although one of the apparent benefits of the modified implant surface was a shift in the transition point from 4$^{th}$ week to 2$^{nd}$ week, these results must be considered within the broader scope of implant stabilization during the healing process. The difference in stability levels (ISQ) on a 100-point scale was approximately 2 points between the test and control surfaces. The clinical significance of the difference in stability between the 2 implant surfaces has yet to be determined.

Influence of Bone Types

As discussed earlier, many articles proved a positive correlation between bone density and dental implant stability. Considering the fact that the bone quality of the implant site might influence the initial stability of implants, many bone classifications have been proposed in implant dentistry. One of the most accepted classification was proposed by Lekholm & Zarb (40). They categorized bone as Type I, II, III, or IV. This determination was based upon the drilling resistance during implant placement, which could be an operator subjective. In order to classify bone type with more solid evidence, Schwarz *et al.* (87) proposed to use cone beam computed tomography (CBCT) as a preoperative implant examination. With three-dimensional and cross-sectional analysis, CBCT allowed the mineral density of jawbones in specific sites to be quantified and expressed in Hounsfield units (HU). In addition, CBCT helped to measure bone quantity and detect any bone defect at the implant site preoperatively. In this case, Misch (35) described the relationship between bone classification and Houndsfield units in order to establish objective 4 types of bone density : D1 bone provides more than 1,250 HU, D2 shows 850 to 1,250 HU, D3 gains 350 to 850 HU and D4 ranges from 150 to 350 HU. This method caused the objective assessment of bone quality.

The mean of bone density in this study was 609.06 HU lower than previous records.(130, 131) The difference might be attributed to the variation of implant sites, ages, and gender. Even though this study showed no significant difference in initial stability among bones types, the trend clearly revealed three different patterns over the 8 week of recovery, measured by Resonance Frequency Analysis as following (Figure 12).

Pattern 1 was mainly found in Type II bones, regardless of implant surface. (Figure 12) The trend of ISQ values over the eight-week period was non-fluctuating. There was also no significant change in stability between two types implant over the same observation period (Figure 13). This concurred with Sim & Lang(125) and Barewal *et al.* (100). Sim & Lang (125) discovered that in denser bone type (Type 1 & Type 2) ISQ values were above 70 throughout the entire 12 weeks of recovery period. Likewise, Barewal *et al.* (100) found no statistically significant change implant stability at all 4 times of observations (0, 3$^{rd}$, 6$^{th}$, 10$^{th}$ week). Nonetheless, they found particular ISQ change pattern for bone Type I, which was categorized by the drilling resistance at the time of implant placement according to Lekholm and Zarb's classification (40). In contrast, this

study found that ISQ pattern was steady in Type II bone according to Houndfied unit-based classification. The reason for non-detectable change in ISQ for denser type of bone could be due to the better resistance to the lateral bending forced for the RFA as a result of the larger cortical bone around the neck of implant.

Pattern 2 began with a strong decrease in ISQ values as early as the 2nd day of healing. After that the ISQ values increased with the significant change occurred between 2nd day and 8th week (Figure12). This pattern was mainly found in Type III bones. It demonstrated the stability pattern change with decreasing values in the early phase of healing, before consistently increasing to an acceptable level. This pattern was named as "the dipping effect". The dipping pattern of implant stability was also found in Type II and III bone by Boronat Lopez *et al.* (132). However, the lowest stability value was found at 4th week. Subsequently, the stability increased to an initial level at 10th week.

Pattern 3 was observed in bone type IV (Figure12). It displayed the greatest change in stability from 2nd day to 3rd week. Stability level reached minima on 3rd week of healing. The result was in agreement with Barewal *et al.* (100) and Ersanli *et al.* (133). Ersanli *et al.* (133) analyzed the development of ISQ levels for three implant systems (122 implants), placed in different anatomical locations at different healing times (day 0, 3rd week, 6th week, and 3rd or 6th month). All three implant systems demonstrated the lowest stability at 3rd week and 6th week of postoperative period. Regarding the Straumann implants, they found a gradual decrease of ISQ values after surgery. However, the statistically significant differences were noted at the 3rd week postoperative period for implants placed in maxillary arches. After that, a significant increase was detected from 3rd week to 6th week postoperative for both maxillary and mandibular implants. Barewal *et al.* (100) conducted stability measurements in 27 implants during 10 weeks. After three weeks they found decreasing values in all bone types, particularly in Type IV bone. However, the author reported complete recovery of the implants placed in Type IV bone at 6th week of healing. This stability reduction may be partly explained by bone remodeling process during the early phase of healing. During the 1st week after surgery, the formation of lamellar bone from woven bone caused a decrease in primary bone contact, as a result, stability decreased(28). One histological study in rabbit model reported by Roberts explained the significant changes of bone density during the early period by the callus bridging formation from week 0 to 6th week (when extrapolated to humans) and later lamellar compaction within the loose stroma of woven bone from 6th week to 18th week

(134). Consequently, the 3rd week after surgery was considered the most critical healing time point for a dental implant.

In conclusion, the finding from this analysis suggested that differences in bone quality affected the implant stability during the early healing phase. High initial stability and insignificant change of stability during the early healing phrase in which mostly found in denser type of bone would be considered as a good candidate for an early loading protocol. Several articles from literatures therefore suggested an early loading protocol to implants placed in Type I and Type II bone. (17, 26)

Apparently, implant surface modification played a significant role in improving implant stability especially within poorer type of bone (D4) (122, 135, 136). The stability patterns of SLA and SLActive implants were statistically significant different in Type IV bone at 4th week (P=0.018) and 8th week (P=0.006), as depicted in Figure 15. The outcome implied that SLActive implants provided a better and faster RF values when compared to the SLA implants in poor bone quality. Further, the most critical period for the SLA-surface implant exclusively when placed in the poor bone quality was at 3rd week post operative. Subsequent to the critical 3rd week, SLA implants experienced a consistent increasing ISQ values and returned to its initial stability at 8th week. This was in line with the result from Barewal *et al.* who found the dramatic 27% increase in stability (P<0.0001) for Type IV bone from 3rd to 10th week.

## Influences of Transducer Probe Position

The result of this study showed no statistically differences of ISQ values when placed the transducer buccally, lingually, nor mesially at all times of measurements (Figure 16). Contrastingly the RF values was influenced by transducer position when piezoelectric RFA was used as showed in Veltri's and Fisher's studies. (137, 138) This could be explained by the fact that piezoelectric RFA reflects the bone/implant stiffness only in one direction, either buccolingual or mesiodistal, depending on the direction of mounted transducer. However, our study used the latest version of RFA; the magnetic-based Osstell Mentor™ instrument. (Osstell AB, Goteborg, Sweden). Unlike piezoelectric RFA, magnetics RFA makes the metal peg vibrate in all direction and reflect 360 degree implant/bone stiffness. Hence, it appears that the new Osstell™*mentor* indeed represents an improved device for determining ISQ values during early phase of osseous healing.

## Conclusion

Under the limitations of this study, the following conclusions can be drawn:

1. Bone density apparently influences the development of implant stability during the early phase of healing. In dense bone type, the cumulative stability as displayed in ISQ values was found to be steady during early healing phase. Meanwhile, ISQ values changed more distinctly for the poor bone type.
2. Regardless of bone type, there was no significant difference in RF values between types of implant surface.
3. Regarding bone type, implant surface played a significant role in the initial phase of healing, particularly in bone Type IV. SLActive implant showed a better and faster RF values at $4^{th}$ week and $8^{th}$ week.
4. The chemical modification of the SLA surface potentially promoted faster healing and demonstrated significant increased in the cumulative stability at $4^{th}$ week. Meanwhile the cumulative stability of SLA implant increased significantly at $8^{th}$ week.
5. The magnetic-based Osstell Mentor proved to show no significant different in ISQ values irrespective of the direction of probing used (buccal, lingual, mesial).

Implication of the Result of this Study

In poor bone quality, SLActive promotes faster and better implant stability in early phase of healing. Moreover, the study supports the use of Osstell Mentor, with the basis of Resonance Frequency Analysis, as a tool for clinically monitoring implant stability.

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# APPENDICES

**Appendix A** Descriptive Statistics of all data

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 51 | 79.24 | 4.807 | 67 | 90 | 77.00 | 80.00 | 83.00 |
| ISQd2 | 51 | 73.92 | 6.514 | 58 | 88 | 70.00 | 75.00 | 78.00 |
| ISQw1 | 51 | 74.75 | 6.349 | 57 | 85 | 71.00 | 76.00 | 80.00 |
| ISQw2 | 51 | 75.18 | 6.959 | 48 | 87 | 73.00 | 77.00 | 80.00 |
| ISQw3 | 51 | 75.39 | 6.216 | 52 | 87 | 74.00 | 77.00 | 80.00 |
| ISQw4 | 51 | 77.04 | 4.617 | 66 | 85 | 75.00 | 78.00 | 80.00 |
| ISQw8 | 51 | 79.06 | 3.652 | 70 | 87 | 77.00 | 79.00 | 82.00 |

**Appendix B** The Kolmogorove-Smirvnov results of non-normal distribution of data as grouped by implant surface.

| Test of Homogeneity of Variances | | | | |
|---|---|---|---|---|
| | Levene Statistic | df1 | df2 | Sig. |
| ISQd0 | 7.887 | 2 | 48 | 0.001 |
| ISQd2 | 0.846 | 2 | 48 | 0.435 |
| ISQw1 | 0.805 | 2 | 48 | 0.453 |
| ISQw2 | 5.514 | 2 | 48 | 0.007 |
| ISQw3 | 7.086 | 2 | 48 | 0.002 |
| ISQw4 | 4.076 | 2 | 48 | 0.023 |
| ISQw8 | 1.117 | 2 | 48 | 0.336 |

**Appendix C** The Friedman test of all ISQ values in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.38 |
| ISQd2 | 3.07 |
| ISQw1 | 3.48 |
| ISQw2 | 3.46 |
| ISQw3 | 3.38 |
| ISQw4 | 4.08 |
| ISQw8 | 5.15 |

| Test Statistics[a] | |
|---|---|
| N | 51 |
| Chi-Square | 57.419 |
| df | 6 |
| Asymp. Sig. | 0.000* |

a. Friedman Test

**Appendix D** The Wilcoxon Signed Ranks test for all ISQ values in longitudinal model.

Ranks

| | Z | Asymp. Sig. (2-tailed) |
|---|---|---|
| ISQd2 - ISQd0 | -4.549b | 0.000* |
| ISQw1 - ISQd0 | -4.292b | 0.000* |
| ISQw2 - ISQd0 | -4.080b | 0.000* |
| ISQw3 - ISQd0 | -4.720b | 0.000* |
| ISQw4 - ISQd0 | -2.866b | 0.004* |
| ISQw8 - ISQd0 | -.416b | 0.677 |
| ISQw1 - ISQd2 | -1.002c | 0.316 |
| ISQw2 - ISQd2 | -1.266c | 0.205 |
| ISQw3 - ISQd2 | -1.420c | 0.156 |
| ISQw4 - ISQd2 | -3.121c | 0.002* |
| ISQw8 - ISQd2 | -4.401c | 0.000* |
| ISQw2 - ISQw1 | -.207c | 0.836 |
| ISQw3 - ISQw1 | -.456c | 0.649 |
| ISQw4 - ISQw1 | -2.058c | 0.040* |
| ISQw8 - ISQw1 | -3.779c | 0.000* |
| ISQw3 - ISQw2 | -.351c | 0.725 |
| ISQw4 - ISQw2 | -1.851c | 0.064 |
| ISQw8 - ISQw2 | -3.623c | 0.000* |
| ISQw4 - ISQw3 | -1.935c | 0.053 |
| ISQw8 - ISQw3 | -4.385c | 0.000* |
| ISQw8 - ISQw4 | -3.743c | 0.000* |

a Wilcoxon Signed Ranks Test

b Based on positive ranks.

c Based on negative ranks.

**Appendix E** Descriptive Statistics of SLA group

| | ISQd0 | ISQd2 | ISQw1 | ISQw2 | ISQw3 | ISQw4 | ISQw8 |
|---|---|---|---|---|---|---|---|
| SLA 1 | 84 | 88 | 81 | 80 | 69 | 68 | 76 |
| SLA 2 | 77 | 65 | 69 | 63 | 72 | 80 | 80 |
| SLA 3 | 85 | 76 | 80 | 80 | 83 | 80 | 83 |
| SLA 4 | 77 | 58 | 82 | 82 | 80 | 81 | 82 |
| SLA 5 | 75 | 63 | 65 | 65 | 63 | 68 | 73 |
| SLA 6 | 78 | 75 | 76 | 75 | 75 | 73 | 75 |
| SLA 7 | 73 | 73 | 76 | 76 | 72 | 69 | 72 |
| SLA 8 | 74 | 75 | 77 | 73 | 75 | 76 | 79 |
| SLA 9 | 79 | 74 | 72 | 63 | 77 | 72 | 77 |
| SLA 10 | 81 | 73 | 75 | 76 | 75 | 77 | 78 |
| SLA 11 | 82 | 69 | 73 | 79 | 80 | 82 | 81 |
| SLA 12 | 83 | 70 | 80 | 78 | 77 | 67 | 77 |
| SLA 13 | 67 | 66 | 71 | 64 | 66 | 71 | 77 |
| SLA 14 | 75 | 77 | 79 | 69 | 68 | 66 | 73 |
| SLA 15 | 82 | 74 | 74 | 73 | 76 | 81 | 84 |
| SLA 16 | 79 | 77 | 76 | 69 | 72 | 75 | 82 |
| SLA 17 | 85 | 73 | 67 | 64 | 81 | 82 | 81 |
| SLA 18 | 80 | 82 | 81 | 81 | 80 | 79 | 72 |
| SLA 19 | 68 | 66 | 71 | 73 | 65 | 72 | 70 |
| SLA 20 | 75 | 79 | 77 | 81 | 81 | 82 | 80 |
| SLA 21 | 83 | 86 | 81 | 78 | 80 | 80 | 80 |
| SLA 22 | 78 | 78 | 74 | 78 | 77 | 76 | 78 |
| SLA 23 | 82 | 81 | 85 | 84 | 76 | 79 | 82 |
| SLA 24 | 76 | 75 | 76 | 78 | 62 | 76 | 76 |
| SLA 25 | 71 | 71 | 59 | 78 | 80 | 80 | 80 |
| N | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Std. Error | 0.992 | 1.388 | 1.182 | 1.304 | 1.207 | 1.052 | 0.764 |
| Mean | 77.96 | 73.76 | 75.08 | 74.40 | 74.48 | 75.68 | 77.92 |
| Median | 78.00 | 74.00 | 76.00 | 76.00 | 76.00 | 76.00 | 78.00 |
| Minimum | 67 | 58 | 59 | 63 | 62 | 66 | 70 |
| Maximum | 85 | 88 | 85 | 84 | 83 | 82 | 84 |
| Std. Deviation | 4.962 | 6.942 | 5.908 | 6.519 | 6.035 | 5.258 | 3.818 |
| Kurtosis | -0.223 | 0.302 | 1.002 | -0.879 | -0.538 | -1.150 | -0.698 |
| Skewness | -0.557 | -0.133 | -0.849 | -0.617 | -0.686 | -0.477 | -0.436 |

**Appendix F** Descriptive Statistics of SLA group (continued)

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 25 | 77.96 | 4.962 | 67 | 85 | 75.00 | 78.00 | 82.00 |
| ISQd2 | 25 | 73.76 | 6.942 | 58 | 88 | 69.50 | 74.00 | 77.50 |
| ISQw4 | 25 | 75.68 | 5.258 | 66 | 82 | 71.50 | 76.00 | 80.00 |
| ISQw1 | 25 | 75.08 | 5.908 | 59 | 85 | 71.50 | 76.00 | 80.00 |
| ISQw2 | 25 | 74.40 | 6.519 | 63 | 84 | 69.00 | 76.00 | 79.50 |
| ISQw3 | 25 | 74.48 | 6.035 | 62 | 83 | 70.50 | 76.00 | 80.00 |
| ISQw8 | 25 | 77.92 | 3.818 | 70 | 84 | 75.50 | 78.00 | 81.00 |

**Appendix G** The Friedman test of ISQ values (SLA group) in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.06 |
| ISQd2 | 3.32 |
| ISQw1 | 4.16 |
| ISQw2 | 3.60 |
| ISQw3 | 3.20 |
| ISQw4 | 3.78 |
| ISQw8 | 4.88 |

| Test Statistics[a] | |
|---|---|
| N | 25 |
| Chi-Square | 18.212 |
| df | 6 |
| Asymp. Sig. | 0.006* |

a. Friedman Test

**Appendix H** The Wilcoxon Signed Ranks test for ISQ values (SLA group) in longitudinal model.

| Ranks | | |
|---|---|---|
| | Z | Asymp. Sig. (2-tailed) |
| ISQd2 - ISQd0 | -2.553b | 0.011* |
| ISQw1 - ISQd0 | -2.078b | 0.038* |
| ISQw2 - ISQd0 | -2.163b | 0.031* |
| ISQw3 - ISQd0 | -2.892b | 0.004* |
| ISQw4 - ISQd0 | -1.678b | 0.093 |
| ISQw8 - ISQd0 | -.081b | 0.935 |
| ISQw1 - ISQd2 | -.975c | 0.33 |
| ISQw2 - ISQd2 | -.305c | 0.76 |
| ISQw3 - ISQd2 | -.644c | 0.52 |
| ISQw4 - ISQd2 | -1.240c | 0.215 |
| ISQw8 - ISQd2 | -2.436c | 0.015* |
| ISQw2 - ISQw1 | -1.104b | 0.269 |
| ISQw3 - ISQw1 | -.658b | 0.51 |
| ISQw4 - ISQw1 | -.261c | 0.794 |
| ISQw8 - ISQw1 | -1.859c | 0.063 |
| ISQw3 - ISQw2 | -.260c | 0.795 |
| ISQw4 - ISQw2 | -.774c | 0.439 |
| ISQw8 - ISQw2 | -2.051c | 0.04 |
| ISQw4 - ISQw3 | -1.238c | 0.216 |
| ISQw8 - ISQw3 | -2.963c | 0.003* |
| ISQw8 - ISQw4 | -2.773c | 0.006* |
| a Wilcoxon Signed Ranks Test | | |
| b Based on positive ranks. | | |
| c Based on negative ranks. | | |

**Appendix I** Descriptive Statistics of SLActive group

| | ISQd0 | ISQd2 | ISQw1 | ISQw2 | ISQw3 | ISQw4 | ISQw8 |
|---|---|---|---|---|---|---|---|
| SLActive 1 | 80 | 83 | 84 | 83 | 80 | 77 | 85 |
| SLActive 2 | 80 | 77 | 75 | 77 | 75 | 76 | 81 |
| SLActive 3 | 85 | 70 | 57 | 83 | 78 | 75 | 77 |
| SLActive 4 | 83 | 70 | 67 | 75 | 79 | 81 | 82 |
| SLActive 5 | 81 | 78 | 74 | 80 | 75 | 84 | 83 |
| SLActive 6 | 83 | 74 | 66 | 81 | 74 | 85 | 84 |
| SLActive 7 | 81 | 77 | 78 | 77 | 78 | 80 | 79 |
| SLActive 8 | 79 | 74 | 77 | 78 | 80 | 78 | 75 |
| SLActive 9 | 78 | 79 | 73 | 73 | 74 | 81 | 83 |
| SLActive 10 | 80 | 78 | 78 | 78 | 77 | 77 | 82 |
| SLActive 11 | 78 | 70 | 76 | 78 | 80 | 80 | 84 |
| SLActive 12 | 70 | 64 | 67 | 65 | 52 | 70 | 79 |
| SLActive 13 | 90 | 72 | 81 | 87 | 87 | 81 | 87 |
| SLActive 14 | 85 | 83 | 82 | 74 | 83 | 80 | 81 |
| SLActive 15 | 84 | 62 | 66 | 79 | 77 | 78 | 80 |
| SLActive 16 | 85 | 75 | 83 | 74 | 76 | 81 | 77 |
| SLActive 17 | 82 | 69 | 75 | 48 | 68 | 78 | 78 |
| SLActive 18 | 82 | 75 | 77 | 77 | 79 | 78 | 78 |
| SLActive 19 | 81 | 84 | 82 | 82 | 84 | 85 | 84 |
| SLActive 20 | 83 | 75 | 75 | 78 | 78 | 79 | 79 |
| SLActive 21 | 77 | 71 | 71 | 75 | 74 | 75 | 78 |
| SLActive 22 | 76 | 59 | 74 | 71 | 74 | 74 | 79 |
| SLActive 23 | 78 | 79 | 78 | 77 | 77 | 75 | 79 |
| SLActive 24 | 81 | 80 | 80 | 77 | 75 | 75 | 74 |
| SLActive 25 | 81 | 76 | 78 | 80 | 79 | 79 | 78 |
| SLActive 26 | 69 | 72 | 61 | 67 | 70 | 75 | 78 |
| N | 26 | 26 | 26 | 26 | 26 | 26 | 26 |
| Mean | 80.46 | 74.08 | 74.42 | 75.92 | 76.27 | 78.35 | 80.15 |
| Median | 81.00 | 75.00 | 75.50 | 77.00 | 77.00 | 78.00 | 79.00 |
| Std. Error | 0.863 | 1.218 | 1.343 | 1.453 | 1.251 | 0.693 | 0.624 |
| Minimum | 69 | 59 | 57 | 48 | 52 | 70 | 74 |
| Maximum | 90 | 84 | 84 | 87 | 87 | 85 | 87 |
| Std. Deviation | 4.402 | 6.209 | 6.848 | 7.408 | 6.378 | 3.532 | 3.184 |
| Kurtosis | 1.986 | 0.378 | 0.418 | 7.618 | 8.064 | 0.210 | -0.418 |
| Skewness | -0.802 | -0.646 | -0.905 | -2.272 | -2.158 | -0.010 | 0.235 |

**Appendix J** Descriptive Statistics of SLActive group (continued)

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 26 | 80.46 | 4.402 | 69 | 90 | 78.00 | 81.00 | 83.00 |
| ISQd2 | 26 | 74.08 | 6.209 | 59 | 84 | 70.00 | 75.00 | 78.25 |
| ISQw4 | 26 | 78.35 | 3.532 | 70 | 85 | 75.00 | 78.00 | 81.00 |
| ISQw1 | 26 | 74.42 | 6.848 | 57 | 84 | 70.00 | 75.50 | 78.50 |
| ISQw2 | 26 | 75.92 | 7.408 | 48 | 87 | 74.00 | 77.00 | 80.00 |
| ISQw3 | 26 | 76.27 | 6.378 | 52 | 87 | 74.00 | 77.00 | 79.25 |
| ISQw8 | 26 | 80.15 | 3.184 | 74 | 87 | 78.00 | 79.00 | 83.00 |

**Appendix K** The Friedman test of ISQ values (SLActive group) in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.69 |
| ISQd2 | 2.83 |
| ISQw1 | 2.83 |
| ISQw2 | 3.33 |
| ISQw3 | 3.56 |
| ISQw4 | 4.37 |
| ISQw8 | 5.40 |

| Test Statistics[a] | |
|---|---|
| N | 26 |
| Chi-Square | 48.183 |
| df | 6 |
| Asymp. Sig. | 0.000* |

a. Friedman Test

**Appendix L** The Wilcoxon Signed Ranks test for ISQ values (SLActive group) in longitudinal model.

| Ranks | | |
|---|---|---|
| | Z | Asymp. Sig. (2-tailed) |
| ISQd2 - ISQd0 | -3.751b | 0.000* |
| ISQw1 - ISQd0 | -4.016b | 0.000* |
| ISQw2 - ISQd0 | -3.983b | 0.000* |
| ISQw3 - ISQd0 | -3.844b | 0.000* |
| ISQw4 - ISQd0 | -2.459b | 0.014* |
| ISQw8 - ISQd0 | -.446b | 0.656 |
| ISQw1 - ISQd2 | -.407c | 0.684 |
| ISQw2 - ISQd2 | -1.398c | 0.162 |
| ISQw3 - ISQd2 | -1.402c | 0.161 |
| ISQw4 - ISQd2 | -3.079c | 0.002* |
| ISQw8 - ISQd2 | -3.792c | 0.000* |
| ISQw2 - ISQw1 | -1.171c | 0.242 |
| ISQw3 - ISQw1 | -1.509c | 0.131 |
| ISQw4 - ISQw1 | -2.562c | 0.01* |
| ISQw8 - ISQw1 | -3.395c | 0.001* |
| ISQw3 - ISQw2 | -.199c | 0.842 |
| ISQw4 - ISQw2 | -1.805c | 0.071 |
| ISQw8 - ISQw2 | -3.130c | 0.002* |
| ISQw4 - ISQw3 | -1.500c | 0.134 |
| ISQw8 - ISQw3 | -3.154c | 0.002* |
| ISQw8 - ISQw4 | -2.509c | 0.012* |
| a Wilcoxon Signed Ranks Test | | |
| b Based on positive ranks. | | |
| c Based on negative ranks. | | |

**Appendix M** The Mann-Whitney test results no significant effect of Implant surface chemistry upon implant stability at each point of observation.

Ranks

| | Brand | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| ISQd0 | SLA | 25 | 22.16 | 554.00 |
| | SLActive | 26 | 29.69 | 772.00 |
| ISQd2 | SLA | 25 | 25.30 | 632.50 |
| | SLActive | 26 | 26.67 | 693.50 |
| ISQw1 | SLA | 25 | 26.18 | 654.50 |
| | SLActive | 26 | 25.83 | 671.50 |
| ISQw2 | SLA | 25 | 24.20 | 605.00 |
| | SLActive | 26 | 27.73 | 721.00 |
| ISQw3 | SLA | 25 | 24.10 | 602.50 |
| | SLActive | 26 | 27.83 | 723.50 |
| ISQw4 | SLA | 25 | 23.04 | 576.00 |
| | SLActive | 26 | 28.85 | 750.00 |
| ISQw8 | SLA | 25 | 22.02 | 550.50 |
| | SLActive | 26 | 29.83 | 775.50 |

Test Statistics[a]

| | ISQd0 | ISQd2 | ISQw1 | ISQw2 | ISQw3 | ISQw4 | ISQw8 |
|---|---|---|---|---|---|---|---|
| Mann-Whitney U | 229.000 | 307.500 | 320.500 | 280.000 | 277.500 | 251.000 | 225.500 |
| Wilcoxon W | 554.000 | 632.500 | 671.500 | 605.000 | 602.500 | 576.000 | 550.500 |
| Z | -1.815 | -0.330 | -0.085 | -0.851 | -0.899 | -1.400 | -1.882 |
| Asymp. Sig. (2-tailed) | 0.070 | 0.741 | 0.932 | 0.395 | 0.369 | 0.162 | 0.060 |

a. Grouping Variable: Brand

**Appendix N** The Kolmogorove-Smirvnov results of non-normal distribution of data as grouped by bone quality.

Test of Homogeneity of Variances

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| ISQd0 | 7.887 | 2 | 48 | 0.001 |
| ISQd2 | 0.846 | 2 | 48 | 0.435 |
| ISQw1 | 0.805 | 2 | 48 | 0.453 |
| ISQw2 | 5.514 | 2 | 48 | 0.007 |
| ISQw3 | 7.086 | 2 | 48 | 0.002 |
| ISQw4 | 4.076 | 2 | 48 | 0.023 |
| ISQw8 | 1.117 | 2 | 48 | 0.336 |

**Appendix O** The Kruskal-Wallis results the significant effect of bone quality upon implant stability each observation point.

Ranks

| | Bone | N | Mean Rank |
|---|---|---|---|
| ISQd0 | D2 | 15 | 27.20 |
| | D3 | 24 | 24.65 |
| | D4 | 12 | 27.21 |
| ISQd2 | D2 | 15 | 33.50 |
| | D3 | 24 | 21.79 |
| | D4 | 12 | 25.04 |
| ISQw1 | D2 | 15 | 30.83 |
| | D3 | 24 | 22.38 |
| | D4 | 12 | 27.21 |
| ISQw2 | D2 | 15 | 31.77 |
| | D3 | 24 | 23.90 |
| | D4 | 12 | 23.00 |
| ISQw3 | D2 | 15 | 30.10 |
| | D3 | 24 | 28.50 |
| | D4 | 12 | 15.88 |
| ISQw4 | D2 | 15 | 25.90 |
| | D3 | 24 | 26.88 |
| | D4 | 12 | 24.38 |
| ISQw8 | D2 | 15 | 25.67 |
| | D3 | 24 | 27.83 |
| | D4 | 12 | 22.75 |

Test Statistics[a,b]

| | ISQd0 | ISQd2 | ISQw1 | ISQw2 | ISQw3 | ISQw4 | ISQw8 |
|---|---|---|---|---|---|---|---|
| Chi-Square | 0.379 | 5.813 | 3.104 | 3.253 | 7.448 | 0.229 | 0.954 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | 0.828 | 0.055 | 0.212 | 0.197 | 0.024* | 0.892 | 0.621 |

a. Kruskal Wallis Test

b. Grouping Variable: Bone

**Appendix P** Descriptive Statistics of Bone Type II group

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 15 | 79.80 | 3.529 | 73 | 85 | 78.00 | 81.00 | 82.00 |
| ISQd2 | 15 | 77.07 | 4.698 | 69 | 86 | 75.00 | 77.00 | 80.00 |
| ISQw1 | 15 | 76.47 | 6.198 | 57 | 85 | 75.00 | 77.00 | 80.00 |
| ISQw2 | 15 | 78.33 | 3.016 | 73 | 84 | 77.00 | 78.00 | 81.00 |
| ISQw3 | 15 | 77.47 | 3.021 | 72 | 84 | 75.00 | 77.00 | 80.00 |
| ISQw4 | 15 | 77.40 | 3.996 | 69 | 85 | 75.00 | 77.00 | 80.00 |
| ISQw8 | 15 | 78.87 | 3.248 | 72 | 84 | 77.00 | 79.00 | 81.00 |

**Appendix Q** The Mann-Whitney U results of no significant effect of implant surface upon the ISQ values in Type II bone.

| | ISQd0 | ISQd2 | ISQw1 | ISQw2 | ISQw3 | ISQw4 | ISQw8 |
|---|---|---|---|---|---|---|---|
| Mann-Whitney U | 18.000 | 25.500 | 27.000 | 25.000 | 25.000 | 25.000 | 27.000 |
| Wilcoxon W | 46.000 | 53.500 | 63.000 | 53.000 | 53.000 | 61.000 | 55.000 |
| Z | -1.166 | -0.292 | -0.116 | -0.352 | -0.351 | -0.349 | -0.116 |
| Asymp. Sig. (2-tailed) | 0.244 | 0.770 | 0.907 | 0.725 | 0.725 | 0.727 | 0.907 |
| Exact Sig. [2*(1-tailed Sig.)] | .281[b] | .779[b] | .955[b] | .779[b] | .779[b] | .779[b] | .955[b] |

a. Grouping Variable: Brand

b. Not corrected for ties.

**Appendix R** The Friedman test of ISQ values (Bone Type II) in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.13 |
| ISQd2 | 3.70 |
| ISQw1 | 3.83 |
| ISQw2 | 3.73 |
| ISQw3 | 3.37 |
| ISQw4 | 3.57 |
| ISQw8 | 4.67 |

| Test Statistics[a] | |
|---|---|
| N | 15 |
| Chi-Square | 8.492 |
| df | 6 |
| Asymp. Sig. | 0.204 |

a. Friedman Test

**Appendix R** The Wilcoxon Signed Ranks test for ISQ values (Bone Type II) in longitudinal model.

| Ranks | | |
|---|---|---|
| | Z | Asymp. Sig. (2-tailed) |
| ISQd2 - ISQd0 | -1.419b | 0.156 |
| ISQw1 - ISQd0 | -1.418b | 0.156 |
| ISQw2 - ISQd0 | -1.683b | 0.092 |
| ISQw3 - ISQd0 | -2.171b | 0.030* |
| ISQw4 - ISQd0 | -1.929b | 0.054 |
| ISQw8 - ISQd0 | -.788b | 0.431 |
| ISQw1 - ISQd2 | -.040b | 0.968 |
| ISQw2 - ISQd2 | -.992c | 0.321 |
| ISQw3 - ISQd2 | -.079c | 0.937 |
| ISQw4 - ISQd2 | -.142b | 0.887 |
| ISQw8 - ISQd2 | -1.420c | 0.156 |
| ISQw2 - ISQw1 | -.581c | 0.562 |
| ISQw3 - ISQw1 | -.189c | 0.850 |
| ISQw4 - ISQw1 | -.086c | 0.932 |
| ISQw8 - ISQw1 | -1.425c | 0.154 |
| ISQw3 - ISQw2 | -.860b | 0.390 |
| ISQw4 - ISQw2 | -.600b | 0.548 |
| ISQw8 - ISQw2 | -.696c | 0.487 |
| ISQw4 - ISQw3 | -.199b | 0.842 |
| ISQw8 - ISQw3 | -1.720c | 0.085 |
| ISQw8 - ISQw4 | -2.208b | 0.027* |
| a Wilcoxon Signed Ranks Test | | |
| b Based on positive ranks. | | |
| c Based on negative ranks. | | |

**Appendix T** Descriptive Statistics of Bone Type III group

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 24 | 79.08 | 3.933 | 69 | 85 | 77.00 | 79.00 | 81.75 |
| ISQd2 | 24 | 71.96 | 6.630 | 58 | 83 | 70.00 | 73.00 | 76.75 |
| ISQw1 | 24 | 73.29 | 6.590 | 59 | 84 | 67.50 | 74.00 | 78.00 |
| ISQw2 | 24 | 74.42 | 6.220 | 63 | 83 | 69.50 | 76.50 | 78.75 |
| ISQw3 | 24 | 76.58 | 4.363 | 63 | 83 | 74.00 | 77.00 | 80.00 |
| ISQw4 | 24 | 77.33 | 4.007 | 67 | 82 | 75.00 | 78.50 | 80.00 |
| ISQw8 | 24 | 79.50 | 3.362 | 72 | 85 | 78.00 | 79.50 | 82.00 |

**Appendix U** The Mann-Whitney U results of no significant effect of implant surface upon the ISQ values in bone Type III.

| | ISQd0 | ISQd2 | ISQw1 | ISQw2 | ISQw3 | ISQw4 | ISQw8 |
|---|---|---|---|---|---|---|---|
| Mann-Whitney U | 66.000 | 71.500 | 69.000 | 59.000 | 69.000 | 70.000 | 60.000 |
| Wilcoxon W | 132.000 | 137.500 | 135.000 | 150.000 | 135.000 | 161.000 | 151.000 |
| Z | -0.320 | 0.000 | -0.145 | -0.728 | -0.146 | -0.088 | -0.671 |
| Asymp. Sig. (2-tailed) | 0.749 | 1.000 | 0.885 | 0.467 | 0.884 | 0.930 | 0.502 |
| Exact Sig. [2*(1-tailed Sig.)] | .776[b] | 1.000[b] | .910[b] | .494[b] | .910[b] | .955[b] | .531[b] |

a. Grouping Variable: Brand

b. Not corrected for ties.

**Appendix R** The Friedman test of ISQ values (Bone Type III) in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.48 |
| ISQd2 | 2.60 |
| ISQw1 | 2.94 |
| ISQw2 | 3.31 |
| ISQw3 | 3.85 |
| ISQw4 | 4.25 |
| ISQw8 | 5.56 |

| Test Statistics[a] | |
|---|---|
| N | 24 |
| Chi-Square | 44.172 |
| df | 6 |
| Asymp. Sig. | 0.000* |

a. Friedman Test

**Appendix W** The Wilcoxon Signed Ranks test for ISQ values (Bone Type III) in longitudinal model.

Ranks

| | Z | Asymp. Sig. (2-tailed) |
|---|---|---|
| ISQd2 - ISQd0 | -3.705b | 0.000* |
| ISQw1 - ISQd0 | -3.648b | 0.000* |
| ISQw2 - ISQd0 | -3.015b | 0.003* |
| ISQw3 - ISQd0 | -2.783b | 0.005* |
| ISQw4 - ISQd0 | -1.691b | 0.091 |
| ISQw8 - ISQd0 | -0.427c | 0.669 |
| ISQw1 - ISQd2 | -0.716c | 0.474 |
| ISQw2 - ISQd2 | -1.270c | 0.204 |
| ISQw3 - ISQd2 | -2.925c | 0.003* |
| ISQw4 - ISQd2 | -3.250c | 0.001* |
| ISQw8 - ISQd2 | -3.713c | 0.000* |
| ISQw2 - ISQw1 | -0.585c | 0.558 |
| ISQw3 - ISQw1 | -2.302c | 0.021* |
| ISQw4 - ISQw1 | -2.594c | 0.009* |
| ISQw8 - ISQw1 | -3.395c | 0.001* |
| ISQw3 - ISQw2 | -2.045c | 0.041* |
| ISQw4 - ISQw2 | -2.195c | 0.028* |
| ISQw8 - ISQw2 | -3.122c | 0.002* |
| ISQw4 - ISQw3 | -1.126c | 0.260 |
| ISQw8 - ISQw3 | -2.723c | 0.006* |
| ISQw8 - ISQw4 | -2.755b | 0.006* |

a Wilcoxon Signed Ranks Test

b Based on positive ranks.

c Based on negative ranks.

**Appendix X** Descriptive Statistics of Bone Type IV group

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 12 | 78.83 | 7.493 | 67 | 90 | 71.25 | 81.50 | 84.75 |
| ISQd2 | 12 | 73.92 | 7.141 | 64 | 88 | 66.75 | 74.50 | 77.75 |
| ISQw1 | 12 | 75.50 | 5.854 | 66 | 83 | 71.00 | 75.50 | 81.00 |
| ISQw2 | 12 | 72.75 | 10.314 | 48 | 87 | 66.00 | 74.00 | 80.00 |
| ISQw3 | 12 | 70.42 | 9.395 | 52 | 87 | 65.25 | 68.50 | 75.75 |
| ISQw4 | 12 | 76.00 | 6.439 | 66 | 85 | 70.25 | 77.00 | 81.00 |
| ISQw8 | 12 | 78.42 | 4.757 | 70 | 87 | 76.00 | 77.50 | 82.50 |

**Appendix Y** The Mann-Whitney U results of significant effect of implant surface upon the ISQ values in bone Type IV.

| | ISQd0 | ISQd2 | ISQw1 | ISQw2 | ISQw3 | ISQw4 | ISQw8 |
|---|---|---|---|---|---|---|---|
| Mann-Whitney U | 6.000 | 16.500 | 16.500 | 13.500 | 6.500 | 3.000 | 0.500 |
| Wilcoxon W | 21.000 | 44.500 | 31.500 | 28.500 | 21.500 | 18.000 | 15.500 |
| Z | -1.871 | -0.163 | -0.163 | -0.652 | -1.790 | -2.359 | -2.770 |
| Asymp. Sig. (2-tailed) | 0.061 | 0.871 | 0.871 | 0.514 | 0.074 | 0.018* | 0.006* |
| Exact Sig. [2*(1-tailed Sig.)] | .073[b] | .876[b] | .876[b] | .530[b] | .073[b] | .018[b] | .003[b] |

a. Grouping Variable: Brand

b. Not corrected for ties.

**Appendix Z** The Friedman test of ISQ values (Bone Type IV) in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.50 |
| ISQd2 | 3.21 |
| ISQw1 | 4.13 |
| ISQw2 | 3.42 |
| ISQw3 | 2.46 |
| ISQw4 | 4.38 |
| ISQw8 | 4.92 |

| Test Statistics[a] | |
|---|---|
| N | 12 |
| Chi-Square | 17.493 |
| df | 6 |
| Asymp. Sig. | 0.008* |

a. Friedman Test

**Appendix AA** The Wilcoxon Signed Ranks test for ISQ values (Bone Type IV) in longitudinal model.

| Ranks | | |
|---|---|---|
| | Z | Asymp. Sig. (2-tailed) |
| ISQd2 - ISQd0 | -2.201b | 0.028* |
| ISQw1 - ISQd0 | -1.476b | 0.140 |
| ISQw2 - ISQd0 | -2.278b | 0.023* |
| ISQw3 - ISQd0 | -3.063b | 0.002* |
| ISQw4 - ISQd0 | -1.591b | 0.112 |
| ISQw8 - ISQd0 | -.446b | 0.656 |
| ISQw1 - ISQd2 | -1.021c | 0.307 |
| ISQw2 - ISQd2 | -.393b | 0.694 |
| ISQw3 - ISQd2 | -1.486b | 0.137 |
| ISQw4 - ISQd2 | -1.143c | 0.253 |
| ISQw8 - ISQd2 | -1.728c | 0.084 |
| ISQw2 - ISQw1 | -.865b | 0.387 |
| ISQw3 - ISQw1 | -1.846b | 0.065 |
| ISQw4 - ISQw1 | -.297c | 0.766 |
| ISQw8 - ISQw1 | -1.162c | 0.245 |
| ISQw3 - ISQw2 | -.890b | 0.374 |
| ISQw4 - ISQw2 | -1.139c | 0.255 |
| ISQw8 - ISQw2 | -1.967c | 0.049* |
| ISQw4 - ISQw3 | -2.119c | 0.034* |
| ISQw8 - ISQw3 | -2.759c | 0.006* |
| ISQw8 - ISQw4 | -1.483b | 0.138 |
| a Wilcoxon Signed Ranks Test | | |
| b Based on positive ranks. | | |
| c Based on negative ranks. | | |

**Appendix AB** The Kruskal-Wallis results the significant effect of probing position upon implant stability each observation point.

Ranks

| | surface | N | Mean Rank |
|---|---|---|---|
| ISQd0 | buccal | 51 | 69.37 |
| | lingual | 51 | 78.05 |
| | mesial | 51 | 83.58 |
| ISQd2 | buccal | 51 | 74.68 |
| | lingual | 51 | 75.41 |
| | mesial | 51 | 80.91 |
| ISQw1 | buccal | 51 | 72.05 |
| | lingual | 51 | 74.59 |
| | mesial | 51 | 84.36 |
| ISQw2 | buccal | 51 | 67.91 |
| | lingual | 51 | 78.55 |
| | mesial | 51 | 84.54 |
| ISQw3 | buccal | 51 | 74.06 |
| | lingual | 51 | 75.33 |
| | mesial | 51 | 81.61 |
| ISQw4 | buccal | 51 | 72.44 |
| | lingual | 51 | 76.86 |
| | mesial | 51 | 81.70 |
| ISQw8 | buccal | 51 | 73.81 |
| | lingual | 51 | 72.76 |
| | mesial | 51 | 84.42 |

Kruskal Wallis Test

| | ISQd0 | ISQd2 | ISQw1 | ISQw2 | ISQw3 | ISQw4 | ISQw8 |
|---|---|---|---|---|---|---|---|
| Chi-Square | 2.687 | 0.606 | 2.205 | 3.703 | 0.855 | 1.119 | 2.180 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | 0.261 | 0.739 | 0.332 | 0.157 | 0.652 | 0.571 | 0.336 |

b. Grouping Variable: surface

**Appendix AC** Descriptive statistics of ISQ values, collected from lingual probing position

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 51 | 78.41 | 5.618 | 64 | 90 | 75.00 | 79.00 | 82.00 |
| ISQd2 | 51 | 73.47 | 7.303 | 56 | 85 | 70.00 | 75.00 | 79.00 |
| ISQw1 | 51 | 73.82 | 7.652 | 53 | 85 | 69.00 | 75.00 | 80.00 |
| ISQw2 | 51 | 73.98 | 7.799 | 48 | 87 | 70.00 | 75.00 | 80.00 |
| ISQw3 | 51 | 74.98 | 7.007 | 48 | 85 | 72.00 | 76.00 | 80.00 |
| ISQw4 | 51 | 76.57 | 5.311 | 63 | 87 | 73.00 | 77.00 | 80.00 |
| ISQw8 | 51 | 78.78 | 4.374 | 70 | 88 | 75.00 | 80.00 | 82.00 |

**Appendix AD** The Friedman test of ISQ values, collected from buccal probing position in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.34 |
| ISQd2 | 3.03 |
| ISQw1 | 3.34 |
| ISQw2 | 3.55 |
| ISQw3 | 3.60 |
| ISQw4 | 4.02 |
| ISQw8 | 5.12 |

| Test Statistics[a] | |
|---|---|
| N | 51 |
| Chi-Square | 54.408 |
| df | 6 |
| Asymp. Sig. | 0.000* |
| a. Friedman Test | |

**Appendix AE** The Wilcoxon Signed Ranks Test of ISQ values, collected from buccal probing position in longitudinal model.

| Ranks | | |
|---|---|---|
| | Z | Asymp. Sig. (2-tailed) |
| ISQd2 - ISQd0 | -4.423b | 0.000* |
| ISQw1 - ISQd0 | -3.958b | 0.000* |
| ISQw2 - ISQd0 | -3.887b | 0.000* |
| ISQw3 - ISQd0 | -3.614b | 0.000* |
| ISQw4 - ISQd0 | -2.306b | 0.021* |
| ISQw8 - ISQd0 | -.437c | 0.662 |
| ISQw1 - ISQd2 | -.539c | 0.590 |
| ISQw2 - ISQd2 | -.526c | 0.599 |
| ISQw3 - ISQd2 | -1.458c | 0.145 |
| ISQw4 - ISQd2 | -2.365c | 0.018* |
| ISQw8 - ISQd2 | -4.193c | 0.000* |
| ISQw2 - ISQw1 | -.266c | 0.790 |
| ISQw3 - ISQw1 | -.938c | 0.348 |
| ISQw4 - ISQw1 | -1.910c | 0.056 |
| ISQw8 - ISQw1 | -3.587c | 0.000* |
| ISQw3 - ISQw2 | -1.271c | 0.204 |
| ISQw4 - ISQw2 | -1.993c | 0.046* |
| ISQw8 - ISQw2 | -3.511c | 0.000* |
| ISQw4 - ISQw3 | -1.546c | 0.122 |
| ISQw8 - ISQw3 | -3.792c | 0.000* |
| ISQw8 - ISQw4 | -3.145c | 0.002* |
| a Wilcoxon Signed Ranks Test | | |
| b Based on positive ranks. | | |
| c Based on negative ranks. | | |

**Appendix AF** Descriptive statistics of ISQ values, collected from lingual probing position

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 51 | 79.24 | 5.424 | 68 | 90 | 75.00 | 80.00 | 83.00 |
| ISQd2 | 51 | 73.53 | 7.482 | 58 | 88 | 70.00 | 75.00 | 79.00 |
| ISQw1 | 51 | 74.61 | 6.588 | 59 | 85 | 70.00 | 76.00 | 80.00 |
| ISQw2 | 51 | 75.31 | 7.788 | 46 | 87 | 73.00 | 77.00 | 80.00 |
| ISQw3 | 51 | 75.08 | 7.045 | 48 | 85 | 73.00 | 76.00 | 80.00 |
| ISQw4 | 51 | 77.10 | 4.830 | 66 | 88 | 75.00 | 78.00 | 80.00 |
| ISQw8 | 51 | 78.71 | 4.006 | 70 | 88 | 76.00 | 79.00 | 81.00 |

**Appendix AG** The Friedman test of ISQ values, collected from lingual probing position in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.32 |
| ISQd2 | 3.18 |
| ISQw1 | 3.51 |
| ISQw2 | 3.75 |
| ISQw3 | 3.29 |
| ISQw4 | 4.04 |
| ISQw8 | 4.90 |

| Test Statistics[a] | |
|---|---|
| N | 51 |
| Chi-Square | 45.978 |
| df | 6 |
| Asymp. Sig. | 0.000* |
| a. Friedman Test | |

**Appendix AH** The Wilcoxon Signed Ranks Test of ISQ values, collected from lingual probing position in longitudinal model.

| Ranks | | |
|---|---|---|
| | Z | Asymp. Sig. (2-tailed) |
| ISQd2 - ISQd0 | -4.358b | 0.000* |
| ISQw1 - ISQd0 | -3.538b | 0.000* |
| ISQw2 - ISQd0 | -3.308b | 0.001* |
| ISQw3 - ISQd0 | -3.958b | 0.000* |
| ISQw4 - ISQd0 | -2.637b | 0.008* |
| ISQw8 - ISQd0 | -1.266b | 0.205 |
| ISQw1 - ISQd2 | -1.069c | 0.285 |
| ISQw2 - ISQd2 | -1.144c | 0.253 |
| ISQw3 - ISQd2 | -.689c | 0.491 |
| ISQw4 - ISQd2 | -3.141c | 0.002* |
| ISQw8 - ISQd2 | -4.040c | 0.000* |
| ISQw2 - ISQw1 | -1.028c | 0.304 |
| ISQw3 - ISQw1 | -.508c | 0.611 |
| ISQw4 - ISQw1 | -1.870c | 0.061 |
| ISQw8 - ISQw1 | -3.481c | 0.000* |
| ISQw3 - ISQw2 | -.926b | 0.355 |
| ISQw4 - ISQw2 | -1.411c | 0.158 |
| ISQw8 - ISQw2 | -2.676c | 0.007* |
| ISQw4 - ISQw3 | -2.238c | 0.025* |
| ISQw8 - ISQw3 | -4.056c | 0.000* |
| ISQw8 - ISQw4 | -2.475c | 0.013* |
| a Wilcoxon Signed Ranks Test | | |
| b Based on positive ranks. | | |
| c Based on negative ranks. | | |

**Appendix AI** Descriptive Statistics of ISQ values, collected from mesial probing position.

| | N | Mean | Std. Deviation | Min | Max | Percentiles | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 25th | 50th (Median) | 75th |
| ISQd0 | 51 | 79.73 | 5.564 | 65 | 90 | 77.00 | 81.00 | 84.00 |
| ISQd2 | 51 | 74.69 | 7.434 | 58 | 92 | 70.00 | 75.00 | 80.00 |
| ISQw1 | 51 | 75.59 | 7.473 | 53 | 85 | 71.00 | 78.00 | 81.00 |
| ISQw2 | 51 | 76.29 | 7.460 | 50 | 87 | 75.00 | 78.00 | 81.00 |
| ISQw3 | 51 | 76.12 | 6.758 | 56 | 90 | 74.00 | 78.00 | 80.00 |
| ISQw4 | 51 | 77.41 | 5.254 | 66 | 85 | 75.00 | 79.00 | 82.00 |
| ISQw8 | 51 | 79.80 | 4.317 | 70 | 88 | 77.00 | 80.00 | 83.00 |

**Appendix AJ** The Friedman test of ISQ values, collected from mesial probing position in longitudinal model.

| Ranks | |
|---|---|
| | Mean Rank |
| ISQd0 | 5.40 |
| ISQd2 | 3.05 |
| ISQw1 | 3.68 |
| ISQw2 | 3.86 |
| ISQw3 | 3.31 |
| ISQw4 | 3.74 |
| ISQw8 | 4.96 |

| Test Statistics[a] | |
|---|---|
| N | 51 |
| Chi-Square | 51.472 |
| df | 6 |
| Asymp. Sig. | 0.000* |
| a. Friedman Test | |

**Appendix AK** The Wilcoxon Signed Ranks test of ISQ values, collected from mesial probing position in longitudinal model.

| Ranks | | |
|---|---|---|
| | Z | Asymp. Sig. (2-tailed) |
| ISQd2 - ISQd0 | -4.025b | 0.000* |
| ISQw1 - ISQd0 | -3.761b | 0.000* |
| ISQw2 - ISQd0 | -3.529b | 0.000* |
| ISQw3 - ISQd0 | -4.822b | 0.000* |
| ISQw4 - ISQd0 | -2.987b | 0.003* |
| ISQw8 - ISQd0 | -.307b | 0.759 |
| ISQw1 - ISQd2 | -.996c | 0.319 |
| ISQw2 - ISQd2 | -1.540c | 0.124 |
| ISQw3 - ISQd2 | -1.084c | 0.279 |
| ISQw4 - ISQd2 | -2.300c | 0.021* |
| ISQw8 - ISQd2 | -4.159c | 0.000* |
| ISQw2 - ISQw1 | -.579c | 0.563 |
| ISQw3 - ISQw1 | -.531b | 0.596 |
| ISQw4 - ISQw1 | -1.145c | 0.252 |
| ISQw8 - ISQw1 | -3.160c | 0.002* |
| ISQw3 - ISQw2 | -.894b | 0.371 |
| ISQw4 - ISQw2 | -.339c | 0.734 |
| ISQw8 - ISQw2 | -2.838c | 0.005* |
| ISQw4 - ISQw3 | -1.433c | 0.152 |
| ISQw8 - ISQw3 | -3.643c | 0.000* |
| ISQw8 - ISQw4 | -3.927c | 0.000* |
| a Wilcoxon Signed Ranks Test | | |
| b Based on positive ranks. | | |
| c Based on negative ranks. | | |

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| | |
|---|---|
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