ผลของวิธีการขันสกรูต่อความต้านทานการคลายเกลียวสกรูในส่วนเชื่อมต่อระหว่างส่วนตรึงแน่นและหลักยึดของรากเทียม 2 ระบบ

นางสาวทิชา กาญจนภูมิ

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THE EFFECT OF SCREW TIGHTENING METHODS ON SCREW LOOSENING RESISTANCE IN IMPLANT-ABUTMENT CONNECTION OF 2 IMPLANT SYSTEMS

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A Thesis Submitted in Partial Fulfillment of the Requirements
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ทิชา กาญจนภูมิ : ผลของวิธีการขันสกรูต่อความต้านทานการคลายเกลียวสกรูในส่วนเชื่อมต่อระหว่างส่วนตรึงแน่นและหลักยึดของรากเทียม 2 ระบบ.(THE EFFECT OF SCREW TIGHTENING METHODS ON SCREW LOOSENING RESISTANCE IN IMPLANT-ABUTMENT CONNECTION OF 2 IMPLANT SYSTEMS.) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : อ.ทพ.ดร. วัชรศักดิ์ ตุมราศวิน, 48 หน้า.

วัตถุประสงค์ของงานวิจัยนี้คือ การเปรียบเทียบผลของวิธีการขันสกรู 3 วิธีต่อความต้านทานในการคลายเกลียวสกรู โดยนำรากเทียม 2 ระบบได้แก่ CU dental implant และ SimpleLine II จำนวนรวม 30 รากเทียมมาฝังลงในกล่องอะคริลิก แล้วขันสกรูเพื่อยึดหลักยึดด้วยแรงบิดตามที่ผู้ผลิตแนะนำ ด้วยวิธีการขัน 3 วิธี ดังนี้ วิธีที่ 1: ขันสกรูเข้า 1 รอบ, วิธีที่ 2: ขันสกรูเข้า 1รอบ, รอ 10 นาที, ขันสกรูเข้า 1 รอบ, และวิธีที่ 3: ขันสกรูเข้า 1รอบ, รอ 3 นาที, ขันสกรูออก, ขันสกรูเข้า 1 รอบ, รอ 10 นาที, ขันสกรูเข้า 1 รอบอีกครั้ง แล้วนำชิ้นตัวอย่างไปทดสอบความล้า แล้วจึงวัดค่าแรงบิดย้อนกลับโดยใช้มาตรวัดแรงบิด ค่าความต้านทานในการคลายเกลียวสกรูจะแสดงเป็นเปอร์เซ็นต์ของค่าแรงบิดย้อนกลับต่อค่าแรงบิดเริ่มต้น ซึ่งนำมาทดสอบค่าสถิติด้วย Kruskal-Wallis และ Conover-Inman เพื่อเปรียบเทียบค่าความต้านทานในการคลายเกลียวสกรู ผลการทดสอบพบว่า วิธีที่ 1 ให้ค่าความต้านทานในการคลายเกลียวสกรูน้อยที่สุดอย่างมีนัยสำคัญทางสถิติในรากเทียมทั้ง 2 ระบบ($p<0.05$) วิธีที่ 2 และ 3 ให้ค่าความต้านทานในการคลายเกลียวสกรูไม่แตกต่างกันทางสถิติในรากเทียมทั้ง 2 ระบบ (CU:$p=0.26$,Sim:$p=0.22$) โดย SimpleLine II ให้ค่าความต้านทานในการคลายเกลียวสกรูสูงกว่า CU dental implant อย่างมีนัยสำคัญทางสถิติทุกวิธีการขันสกรู ($p<0.05$) สรุปผลการทดลองได้ว่า การขันสกรูซ้ำหลังการขันสกรูครั้งแรกจะให้ค่าความต้านทานในการคลายเกลียวสกรูสูงสุด และการขันสกรูออกก่อนการขันสกรูซ้ำหลังจากการขันสกรูครั้งแรก ไม่มีผลต่อการเพิ่มความต้านทานในการคลายเกลียวสกรูให้มีค่าสูงขึ้นอีกภายหลังจากการขันสกรูซ้ำครั้งแรก และ SimpleLine II ให้ค่าความต้านทานในการคลายเกลียวสกรูมากกว่า CU dental implant ในทุกวิธีการขันสกรู

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TICHA KANCHANAPOOMI: THE EFFECT OF SCREW TIGHTENING METHODS ON SCREW LOOSENING RESISTANCE IN IMPLANT-ABUTMENT CONNECTION OF 2 IMPLANT SYSTEMS.THESIS ADVISOR: WACHARASAK TUMRASVIN, Ph.D., 48 pp.

The propose of this study was to compare the effect of 3 screw tightening methods on screw loosening resistance. The 2 implant systems (CU dental implant and SimpleLine II were used in the study (N=30).The implant bodies were embedded in the acrylic blocks.The abutment screws were tightened to the manufacturer's recommended torque using 3 tightening methods as following; method1: tightening the screw 1 time, method2 tightening the screw, wait for 10 minutes, retightening the screw, method3: tightening the screw, wait for 3 minutes,loosening the screw, retightening the screw, wait for 10 minutes, retightening the screw. The fatigue loading was applied.The reverse torque values were measured. Kruskal-Wallis and Conover-Inman were used to compare the reverse torque value in the percentage of initial tightening torque. The method1 showed the significantly lowest screw loosening resistance in 2 implant systems ($p<0.05$). The method 2 and the method 3 showed no significant difference on screw loosening resistance in 2 implant systems.When comparing between 2 systems. SimpleLine II showed higher screw loosening resistance than those of the CU dental implant significantly ($p<0.05$).It can be concluded that the highest reverse torque values could be achieved by screw retightening,and the screw loosening before the screw retightening did not increase the reverse torque values to be higher than those achieved from the first screw retightening. SimpleLine II showed the significantly higher screw loosening resistance than CU dental implant.

Department: Prosthodontics Student's Signature…………………………….

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CHAPTER I

Introduction

Branemark et al. discovered bone formation around the Titanium embedded in the animal's bone, which he called osseointegration in the1980s. Various implant systems have been developed for use as dental implants since that time [1]. Nowadays, dental implants are commonly employed as a way to treat edentulous patients. Though most of these implants are highly successful, several studies have reported complications regarding them.

Screw loosening is one complication which has contributed to problems which can be costly and time consuming treatment, resulting from destruction of restoration work, the fracture of screws and the fistula formation [2-4]

A dental implant is a device of biocompatible material(s) placed within or against the mandibular or maxillary bone to provide additional or enhanced support for prostheses or tooth. It consists of 3 important components 1. implant body, 2. abutment, and 3. screw [5] which have different names under various systems. This implant body-abutment-screw unit is called as a screw joint. The screw connects the implant body and the abutment by applied torque. When the screw is tightened, the tension force called preload is occurred in the screw, making the screw elongates in the yield strength of the screw material. The elastic recovery of the screw holds the other 2 components of the screw joint together developing compressive clamping force in the screw joint. [6, 7]

There are several factors influencing screw joint stability such as the settling effect, preload, and screw geometry. The configuration of the implant-abutment connection and the fitting of the connected surfaces play the role of resistance to the mastication force. [7, 8]

The preload is associated with the fitting of the connecting surface. There is no interface which contacts perfectly and the highest spots of the overall rough surfaces are the only area contacting the joint. The settling effect occurs when the initial tightening torque is applied. [8, 9] Wear of the highest spots of the rough surfaces brings the contacting surfaces closer together with the initial preload losing 2-10 percent of the initial tightening torque [10]

A simple method to make the screw joint stable is to establish the tight screw. Several studies have proposed methods of screw tightening to ensure firmly connection of the screw joint components [11, 12].

In contrast, the force attempting to separate the joint is called the joint-separating force. Screw loosening occurs when the separating force is greater than the clamping force. Therefore, the preload should be increased to maximize the clamping force threshold that separating force must overcome [6].

External loading such as masticatory forces, the joint-separating forces, also influences the preload.[6] There are 2 mechanisms affect the screw loosening. First, the excessive bending force from off-axis occlusal contact causes a larger load than the yield strength of the screw. The plastic deformation of screw is occurred. The force that holds the screw joint together, the tensile force of the screw, decreases, leading to screw loosening. Second, the external load increases the settling effect. When the settling effect is larger than the elastic elongation of the screw, there are no any forces to hold the screw joint [13].

The proposes of this study were to examine the effect of screw tightening methods on screw loosening resistance and to compare the differences of screw loosening resistance of each screw tightening methods between 2 implant systems.

CHAPTER II

Literature review

1. Dental implant

A dental implant is a device of biocompatible material(s) placed within or against the mandibular or maxillary bone to provide additional or enhanced support for prostheses or teeth. It consists of 3 important components. [5]

1.1 Implant body: the portion of the implant designed to be placed in bone (Figure 1).

Figure 1 The implant body

1.2 Abutment: the portion of the implant that supports or retains the prosthesis (Figure 2).

Figure 2 The abutment

1.3 Abutment screw: the portion that joins the implant body and the abutment by tightening the screw (Figure 3).

Figure 3 The abutment screw

These three parts can be called the screw joint (Figure 4).

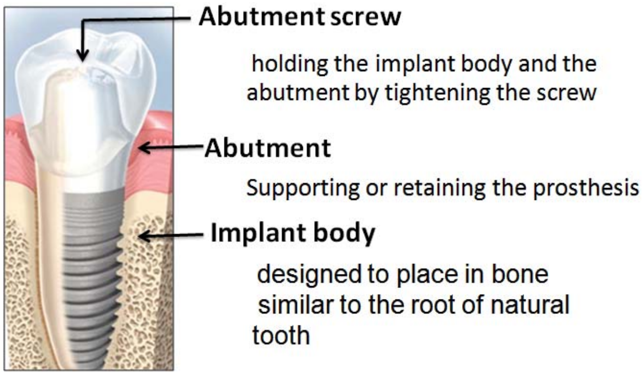

Figure 4 The screw joint

2. <u>Mechanism of the screw</u> (Figure 5)

The screw is a part of the screw joint that tighten two parts, such as abutment and implant body, by applying torque. When the screw is tightened, it elongates and produces tension force called preload.

2.1. <u>The preload</u>

The screw preload is defined as the tensile force that is built up in the screw from screw head to screw threads as a product of screw tightening[14]. This tensile force develops compressive force from elastic recovery of screw tighten between the parts of the screw joint , which is called the clamping force [15]. Then the screw contacts and pulls the two parts together. [6, 9]

The primary factor influencing the preload is the applied torque, however, the applied torque is limited is by the screw's yield strength and the strength of bone-implant interface [6, 15]. Several researchers have examined the relationship between applied torque and preload [6, 13, 16]. The applied torque and preload are proportionate to one another [13]. Other factors affecting the preload are screw alloy, screw head design, abutment alloy, lubricant and abutment surface [13]. Moreover, the implant-abutment connection and material properties also affect the preload. These factors are different in each of implant system [8].

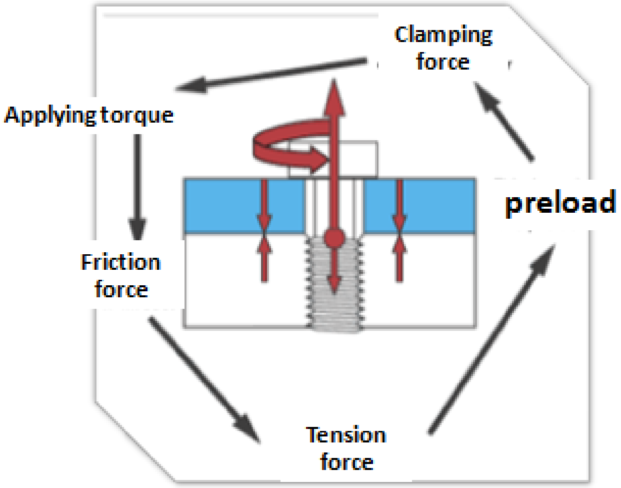

Figure 5 Mechanism of the screw [9]

2.2. Clamping force

The clamping force is the compressive force keeping the parts of the joint together. This forces is developed from preload after screw contraction when the elastic recovery of screw occurs [17]. The preload is equal in magnitude to the initial clamping force [6].

2.3. Joint-separating force

The joint-separating force is the force attempting to separate the screw joint [17]. This force includes excursive occlusal contacts, off-axis centric contacts from the using of angled abutment or wide occlusal table, interproximal contacts, and cantilever contacts. This force causes vibration and micromovement in the screw joint leading to reduction of the preload resulting in screw loosening [6, 7, 18].

2.4. Affecting factors in reduction of the preload

From the screw mechanism, preload is an important factor influencing screw joint stability; thus, the reduction of preload is a cause of screw joint instability. Khraisat et al. explained the affecting factors in reduction of the preload as following [8]:

2.4.1 Bending overload: bending force that is greater than the yield strength of screw which causes plastic deformation leading to preload loss and screw loosening [14].

2.4.2 Fatigue: dynamic fatigue is generated when applying cyclic loading to implant systems at a level below the yield strength of the screw material [19]. Fatigue is the major possible cause of preload loss and screw loosening [20].

2.4.3 Settling effect: the total settling effect that is greater than the elastic elongation of the screw loosens the screw because of the loss of tension in the screw joint. Thus, the clamping force in the joint is reduced [21].

2.4.4 Vibration or damping: as a result of the settling effect, the vibratory motion caused by the shear force of loading flexes and bends the screw, leading to disengagement and loss of contact along the screw threads. [22]

3. Screw joint stability

Joeneus et al[14] explained that the screw loosening of implant-supported prostheses is the result of two mechanisms as follows:

1. Excessive bending force: these forces cause the permanent deformation of the screw and the lost of tensile force of the screw. This contributes to a decrease in friction resulting from the elastic recovery of the screw holding the screw joint.

2. Settling effect: the settling effect which is greater than the elastic elongation of the screw makes the screw loose.

Brickford [23] explained that screw loosening has two stages.

Stage 1: when the screw is under an external load there is the thread slippage in the screw joint causing a reduction in the elongation of the screw and friction. .As a result, the elastic recovery of the screw is decreased.

Stage2: the screw becomes loose and the preload is less than the critical value. The screw is loosened by the external load and micro-movement and ultimately cannot function.

McGlumphy [6] recommended clinical procedures for stability of the screw joint as follow:

1. Implant placed parallel to the forces of occlusion.
2. Restorations designed to minimize cantilever length.
3. Occlusion adjusted to direct forces in the long axis of the implant.
    a. Eliminating posterior working and balancing contacts.
    b. Centralizing the centric contact.
    c. Sharing the guidance with the natural teeth
4. Anti-rotational features engaged for single teeth.
5. Components tightened with 20 to 30 N-cm of torque (unless specified by manufacturer).
6. Passivity fitting framework for multiple unitrestoration.

Moreover, the stability of the screw joint is related to the accuracy and fit between the components and the stability at the implant abutment connection influenced by the design of the implant-abutment connection [24].

4. Implant-abutment connection

At present, there are many designs for implant-abutment connection. The design refers to the type of implant-abutment connection and the retentive properties at the screw joint of each implant system. The design of the implant-abutment connection determines joint strength, stability, lateral stability, and rotational stability [25]. The goal of the manufacturer design is to strengthen the joint and decrease mechanical complications in the implant-abutment connection [26].

The design for implant-abutment connection can be classified by the location of the connection as following:

4.1 The external implant-abutment connection: this connection extends above the coronal area of the implant body. This connection has several designs such as hexagonal, octagonal, and spine [27] .

4.2 The internal implant-abutment connection: this connection extends into the implant body. The designs of this connection are internal hexagon, internal octagon, and Morse taper [27].

The goal of the designs is to strengthen the joint and minimize the mechanical complications between implant-abutment connections. However, the various designs of implant-abutment connection have different biomechanical behaviors resulting in difference in joint stability.[1] Several studies have demonstrated that internal connections can prevent screw loosening better than external connections because the internal connection offers greater advantages such as more efficient rotation resistance and the abutment screw being protected from the lateral force. Moreover, external connections have problems such as screw loosening, component fracture and difficulty in seating the abutment in deep subgingival tissue [28]. The important advancements of the internal connections were the developments of the internal hexagon and Morse taper implant-abutment connection designs [29].

Internal hexagon: this connection transfers the stress from the neck to the middle third of implant body. This makes the implant unit more stable and decreases the tendency of screw loosening and fracturing [30].

Morse taper: this connection has a conical union between the implant body and abutment that can withstand prolonged lateral force. The screw is not only primarily resistant to the force [31] .

5. Accuracy and fit between the components

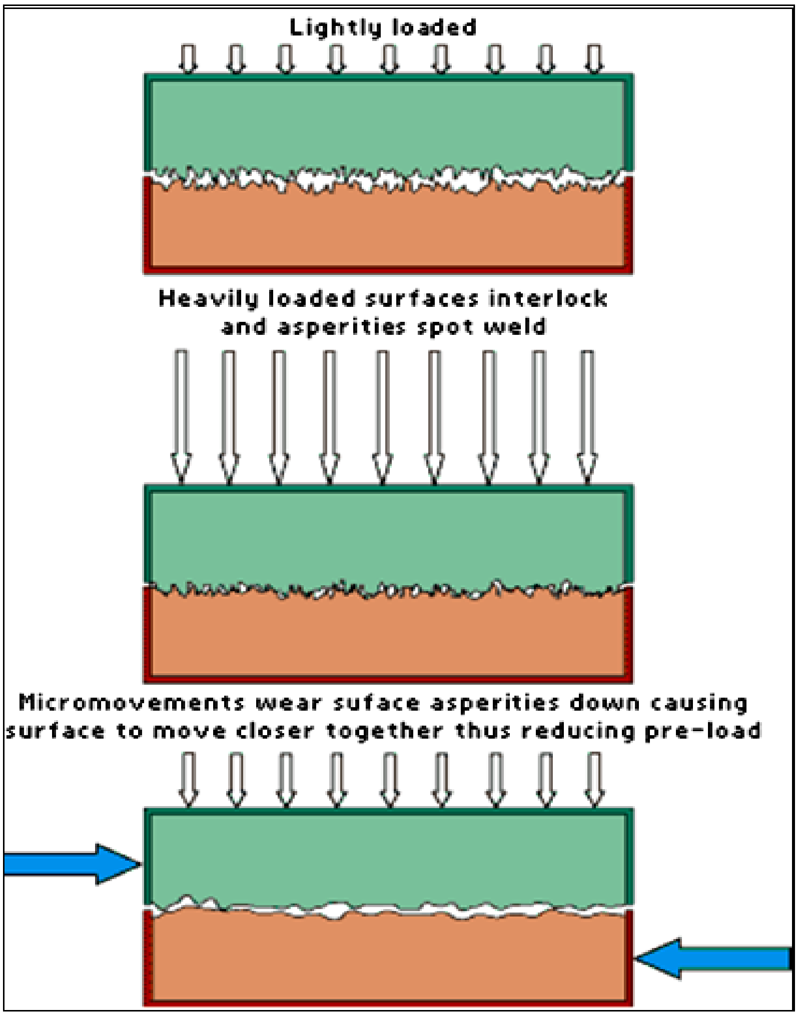

Figure 6 The settling effect [9]

In reality, no surface is completely smooth. [7] Although the implant surfaces are wholly machined, they are slightly rough when viewed under microscope. Because of this micro-roughness, no two surfaces are in contact completely. The settling effect or embedment relaxation occurs when the rough spots are flattened under a load. The rough spots are only in contacting surfaces and when the initial torque is applied, they wear down and the contact surfaces become closer together [7, 9] (Figure 6). Dixon et al. reported that the preload is lost due to the settling effect as the removal torque is less than the initial tightening torque[10]. Because of this reason, the accuracy and fit between the components is another factor that plays a role in screw joint stability.

Factors affecting the settling effect are the initial surface roughness, surface hardness, and magnitude of loading forces [14, 32]. The large loading external forces increase the settling effect. As when the screw joint is loaded, the contact surfaces become closer together and the screw is elongated. Finally, the settling effect becomes greater than the elastic elongation of the screw and the screw is loosened because there are no contact forces to hold the screw. [9, 14, 33] Several researches have been studied about the screw tightening to regain the preload.

Hack et al. reported that the preload at the initial time of tightening and loosening of the screw was less than at other times. Repeated screw tightening could reduce the friction between the contacting surfaces resulting in them becoming closer together and increasing the preload to prevent screw loosening [34].

Ding et al. recommended that the clinician should loosen the 2-piece SynOcta abutment after initial tightening and then retighten again to achieve a greater clamping force [35].

Tzenakis et al. also suggested that using a gold prosthetic screw from the try-in appointment might help obtain optimal preload during final torque at the insertion appointment [36].

In contrast, some publications have noted that the highest screw loosening resistance is produced when the screw is first tightened. The repeated closing-opening process was claimed to cause changes and opening torque failure on consecutive closing and opening cycles [37, 38]. They explained that repeating the tightening of the screws removes small irregularities on the contacting surfaces, which in turn reduces the friction at the surface and leads to lower preload [38].

However, there are 2 studies which outline methods for preventing the screw from loosening as following:

Saimos et al. recommended retightening the abutment 10 minutes after initial torque applications routinely [12].

Misch suggested tightening the screw to the recommended torque, then unloose screw after a few minutes and retighten it to the required torque once again. This approach causes a deformation at the thread interface, forming more secure union.

After more than 5 minutes, the screw may be tightened for a third time to reduce the screw rebound [11] . However, there is no research comparing the screw loosening resistance of these screw tightening methods.

6. Occlusal force

Occlusal force varies among patients. It is not well correlated with maximal strength of the masticatory muscle and is probably influenced by other factors such as growth, gender, type of food, occlusal function, restoration, pain threshold, sensitivity of mucosal and periodontal receptors, emotional status, and area of distribution force [39].

Occlusal force can be measured at different positions in the mouth. The highest occlusal force of the natural teeth occurs in the first and second molars with an average force of 565 N. The averages occlusal force in other areas are 288 N, 208 N, and 155 N in premolars, canines, and incisors, respectively [19].

Occlusal force is a significant risk factor in screw loosening, and the incidence of abutment screw loosening is influenced by the force factor. Lateral excursion acts as a joint-separating force that should be avoided [6]. There are several studies regarding occlusal force in implant-supported prostheses such as Mericske-Stern et al., who demonstrated 35 N - 350 N of occlusal force in implant supported prostheses [40]. Fontjin-Tekamp et al. reported 25 N - 170 N and 50 N - 400 N of occlusal force measured from implant-supported prostheses in the incisal and molar regions, respectively [41]. Morneburg and Poschel also revealed 220 N, 91 N, and 129 N of occlusal force in implant supported 3-unit fixed prostheses, anterior single implants, and posterior single implants, respectively. The occlusal force from implant-supported fixed prostheses occluded to the natural teeth was not different from those of natural teeth alone [42].

7. Fatigue testing

Fatigue is progressive, localized and permanent structural damage that occurs in a material subjected to repeated or fluctuated strains [43]. Fatigue testing is one of the methods for testing the mechanical properties of materials [44].

The fatigue testing of dental implants needs to closely imitate the complex oral environment [44]. Many researchers reported studies regarding the fatigue testing of implant abutment connections (Table 1).

Table 1 Studies regarding the fatigue testing of the implant-abutment connections.

Study	Loading	Direction of force
Bakaeen et al. (2001)[45]	60N	22° to the axis
Breeding et al. (1993)[46]	60N	15° to the axis
Khraisat (2002)[21]	100N	Perpendicular to the axis
Cribika et al. (2001)[47]	20-200N	Vertical to the t axis
Tsuge and Hagiwara (2009)[48]	0-100N	30 ° to the axis

Some previous studies used vertical loading whereas the other used off-axis loading. Generally, vertical-axis loading is greater than off-axis loading [49, 50]. However, ISO guidelines recommend that the axis of the implant should make a 30 degree angle with the loading direction of the testing machine.

In this study, the fatigue test was done at 60 N with a frequent rate of 80 cycles/ minute. The target of 1,000,000 repetitions was defined. The loading force was directed to the center of the abutment cap, which is at the 30 degree angle to the long axis of the implant.

CHAPTER III

Material and Method

Methodology

Thirty implants using in this study were 2 implant systems (Simple line II: Dentium company (Seoul, Korea) and CU dental implant: The development research and production of dental implants and accessories) (Table 2).

Table 2 The sample groups

Group	System	Method of screw tightening	Tightening torque (N-cm)	Sample size
1	CU dental implant	1	35	5
2		2	35	5
3		3	35	5
4	SimpleLine II	1	30	5
5		2	30	5
6		3	30	5

The 15 implants from Simple line II have a diameter of 4.8 mm. and a length of 14mm. (including polished surface) (Figure 7) and 15 implants from CU dental implant have a diameter of 4.3 mm. and a length of 14 mm. (including polished surface) (Figure 8)(Table 3).

Figure 7 The implant body from SimpleLine II

Figure 8 The implant body from CU dental implant

Table 3 The implant and abutment from 2 implant systems

Brand name	Manufacturer	Size	Abutment	Connection
CU dental implant	Development research and production of dental implant and accessories	4.3x14 mm.	Ø 4.3x10mm	Internal Hexagonal
Simple line II	dentium®	4.8x14 mm.	Ø4.8x7mm	Morse taper

1. <u>Implant body preparation</u>

The 30 transparent acrylic blocks size 2x2x2 cm. (Figure 9) were drilled at the center using the corresponding instruments of each implant system (Figure 10-11). The 30 implants were embedded in acrylic blocks at the level of platforms located 3 mm over and parallel to the blocks (Figure 12).

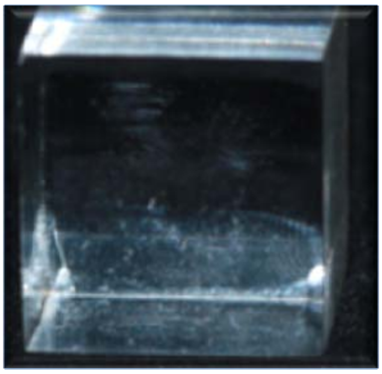

Figure 9 The acrylic block

Figure 10 The instrument of CU dental implant for acrylic block preparation

Figure 11 The instrument of SimpleLine II for acrylic block preparation.

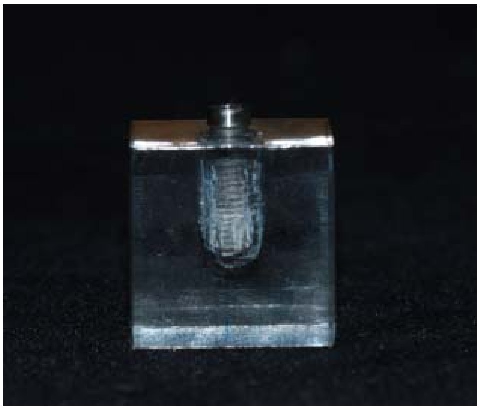

Figure 12 The implant body was embedded in the acrylic block.

2. sphrerical-end cap preparation

The 30 stainless steel spherical caps (Figure 13) designed by department of mechanical engineering, faculty of engineering, Chulalongkorn University had a hole at the center for tightening the screws. To compensate for different abutment height and width of each implant system, the spherical-end caps had the same diameter (8mm.) and height (8mm.).

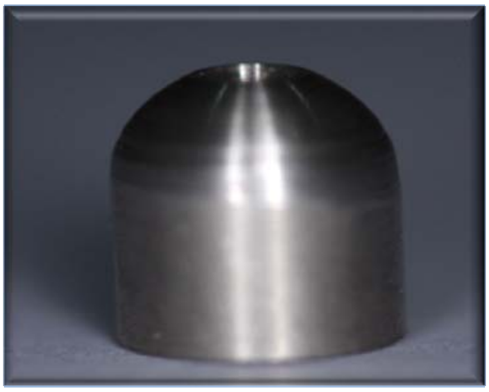

Figure 13 The stainless steel hemispherical caps

3. Abutment preparation

The abutments from Simple Line II (2-piece abutment Morse taper Syn Octa: figure 14) had a diameter of 4.8 mm and a length of 7mm while the abutments from CU dental implant had a diameter of 4.3 mm and a length 10 mm (2-piece abutment internal hexagon: Figure 15). The latter abutments were prepared in a length of 7 mm with a diamond disc to compensate for the different abutment height.

Figure 14 The abutment from SimpleLine II

Figure 15 The abutment from CU dental implant

4. Tightening the screw

The implant bodies, abutments, screws and spherical-end caps were randomly chosen from each system. Four components were 1 set. Randomly assign each set in to 6 groups (Table 4).

Table 4 The 4 components were assigned in 6 groups.

Group	Method	System
1	Method 1	CU dental implant
2	Method 2	
3	Method 3	
4	Method 4	SimpleLine II
5	Method 5	
6	Method 6	

*Each group n=5

After that, the screws of each were tightened with the labeling methods as following.

Method 1:

The screws were tightened to the torque according to the manufacturer's recommendation (CU dental implant: 35Ncm, SimpleLine II 30Ncm) (Figure 16).

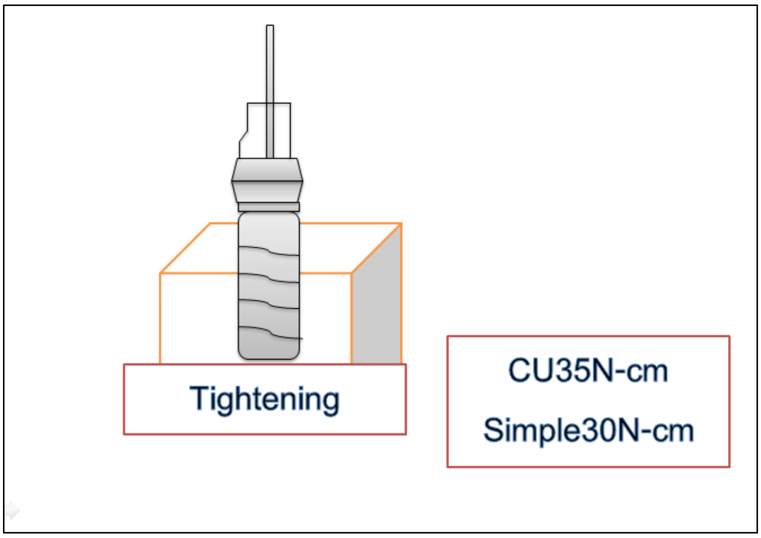

Figure 16 The diagram of method 1

Method 2:

The screws were tightened to the torque according to the manufacturer’s recommendations (CU dental implant: 35Ncm, SimpleLine II 30Ncm). After 10 minutes they were tightened to the same torque again (Figure 17).

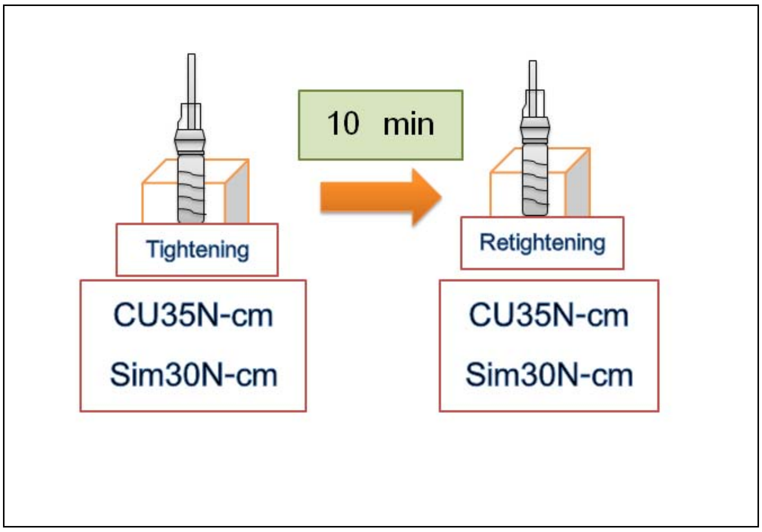

Figure 17 The diagram of method 2

Method 3:

The screws were tightened to the torque according to the manufacturer’s recommendations (CU dental implant: 35Ncm, SimpleLine II 30Ncm). After 3 minutes the screws were loosened and then tightened to the same torque again. After 10 minutes the screws were retightened to the same torque (Figure 18).

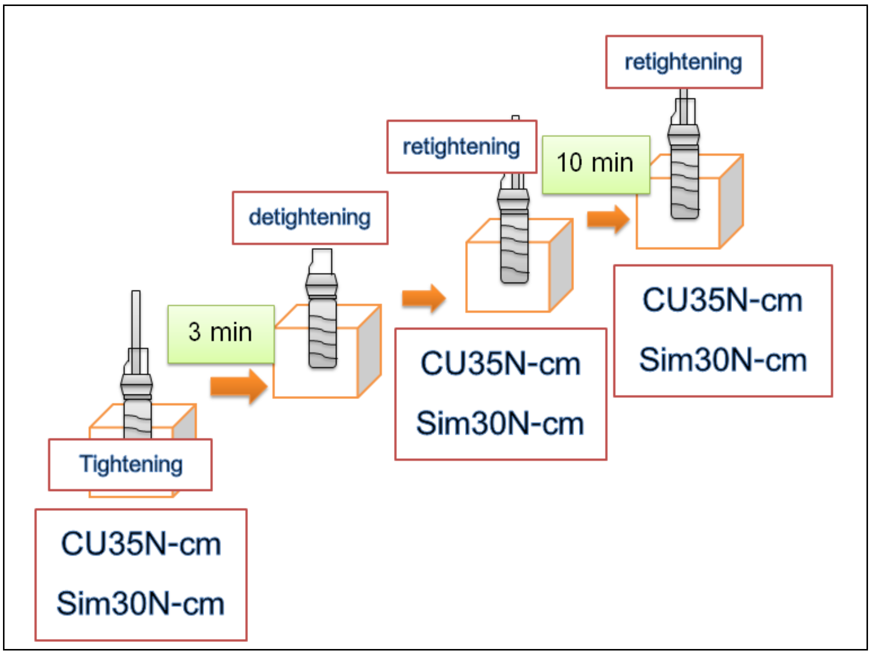

Figure 18 The diagram of method 3

The blocks were installed in the holder to prevent the rotation of the block when the screw was tightened. After the screw driver was fixed in the three jaw chuck of the Tonichi torque gauge (BTGCN-60) (Tokyu, Japan) (Figure 19, 20), the abutments were screwed into the corresponding implant (Figure 21). The torque gauge was used to apply reproducible force to each abutment screw.

Figure 19 The Tonichi torque guage

Figure 20 The screw driver was fixed in the three jaw chuck of the torque gauge.

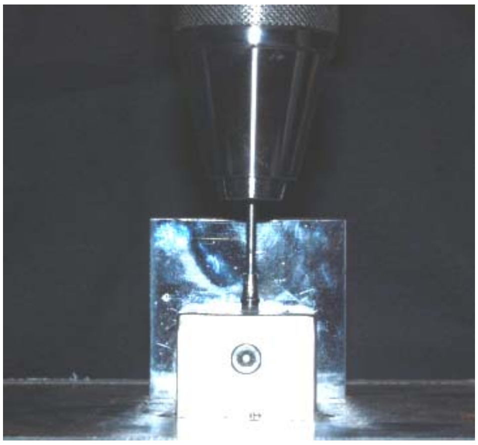

Figure 21 Tightening the screw

a. <u>cementation the caps</u>

1 scoop of zinc-phosphate cement power (Bosworth; Borsworth company, Illinois, USA) was mixed with the 5 drops of zinc-phosphate cement liquid in 90 seconds. Then the zinc-phosphate cement was painted on to the internal surface of each casting with a brush. Then the cement castings were seated with finger pressure for 10 seconds and removed the excess cement, followed by 5 kg of pressure for 12 minutes. The cement was allowed to set at room temperature 24 hours for final setting (Figure 22, 23)

Figure 22 The sample of SimpleLine II

Figure 23 The sample of CU dental implant

b. <u>fatigue test</u>

The samples were installed in the holding vice of the fatigue testing machine designed by the department of mechanical engineering, faculty of engineering, Chulalongkorn University. The fatigue test applied the load 60N at a rate of 80 times/minutes. A target of 1,000,000 times is defined. The location of force was at 30° to the long axis of the implant (Figure 24). The force travelled through the center of the cap that in line with the long axis of the implants. Inspection of the changes of the implant assemblies was performed every 10,000 cycles

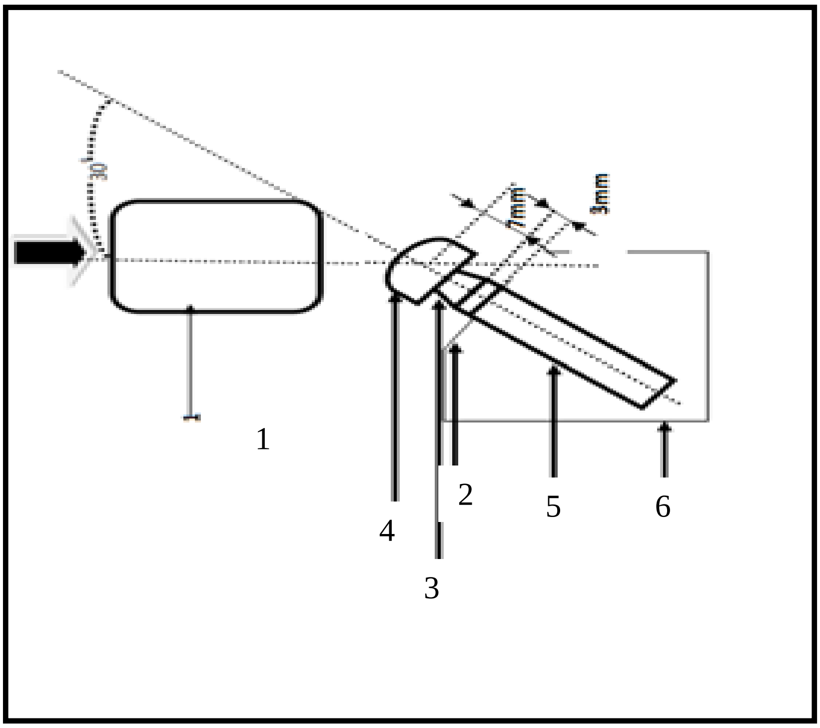

Figure 24 The fatigue testing diagram (1: Loading device, 2: Bone level, 3: Abutment, 4: Spherical-end cap, 5: Implant body, 6: Holding device)

c. Measurement of reverse torque value.

The blocks were installed in the holder. The screw driver was fixed in the three jaw chuck of the torque gauge. The torque gauge was used to measure the reverse torque value (Figure 25).

Figure 25 Detightening the screw.

d. Data analysis

The screw loosening resistance was expressed as the reverse torque value in percentage of the initial tightening torque according to the formula as following:

$$\frac{\text{The reverse torque value}}{\text{Initial tightening torque}} \text{ X } 100 = \text{Screw loosening resistance}$$

i. The normal distribution of screw loosening resistance was tested by the Shapiro- Wilk test.

ii. If the data was the normal distribution, the screw loosening resistance were analyzed by Two-way ANOVA.

iii. If the data was not the normal distribution, the screw loosening resistance were by Kruskal-Wallis and the Connover-Inmann test.

CHAPTER IV

Result

Shapiro- Wilk test showed that the data was not the normal distribution. The Kruskal-Wallis test and the Connover-Inmann test were used to compare the screw loosening resistance. The Kruskal-Wallis test showed the significantly different between screw loosening resistance of 6 group ($p<0.05$).

The mean, median and the standard deviation of the screw loosening resistance CU dental implant were showed in the Table 5. This system uses 35N-cm for the initial tightening torque. The means of screw loosening resistance in the method 1, 2 and 3 in were 51.08%, 69.54%, 70.23%, respectively. The screw loosening resistance in the method 1 were significantly lower than the method 2 and the method 3 ($p<0.05$). The screw loosening resistances occurred in the method 2 and method 3 were not significantly different ($p=0.26$) (Figure 26).

Table 5 The screw loosening resistance of CU dental Implant.

Method	Mean	Median	SD
Method1	51.08	51.42	1.50
Method2	69.54	69.14	1.20
Method3	70.23	70.00	1.15

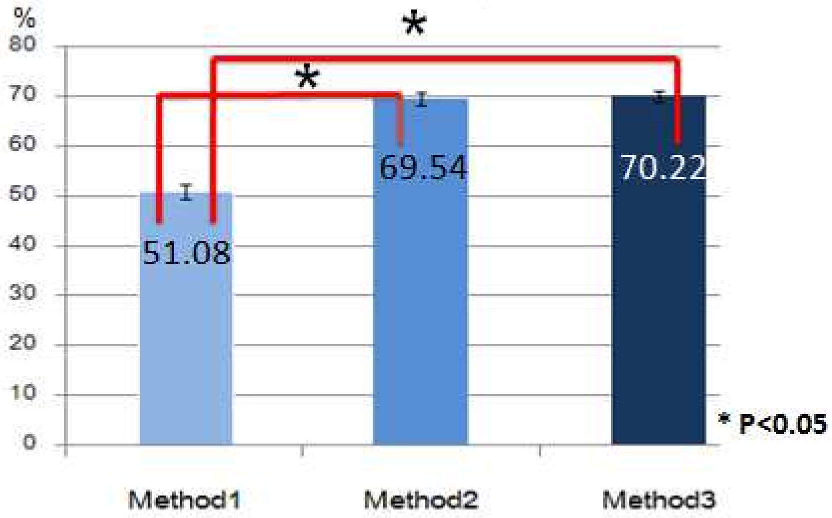

Figure 26 The screw loosening resistance in 3 methods of CU dental implant.

The screw loosening resistances of 3 screw tightening methods in the implant from SimpleLine II using 30 N-cm for the initial tightening torque were showed in the table 6. The means of the screw loosening resistance in the method 1, 2 and 3 were 57.00%, 74.33% and 73.13%, respectively (Table 6). The screw loosening resistance in the method 1 were significantly lower than the method 2 and the method 3 ($p<0.05$).The screw loosening resistances occurred in the method 2 and method3 are not significantly different ($p=0.22$) (Figure 27).

Table 6 The screw loosening resistance of SimpleLine II

Method	Mean	Median	SD
Method1	57.00	56.67	1.39
Method2	74.33	75.00	0.91
Method3	73.13	73.33	1.95

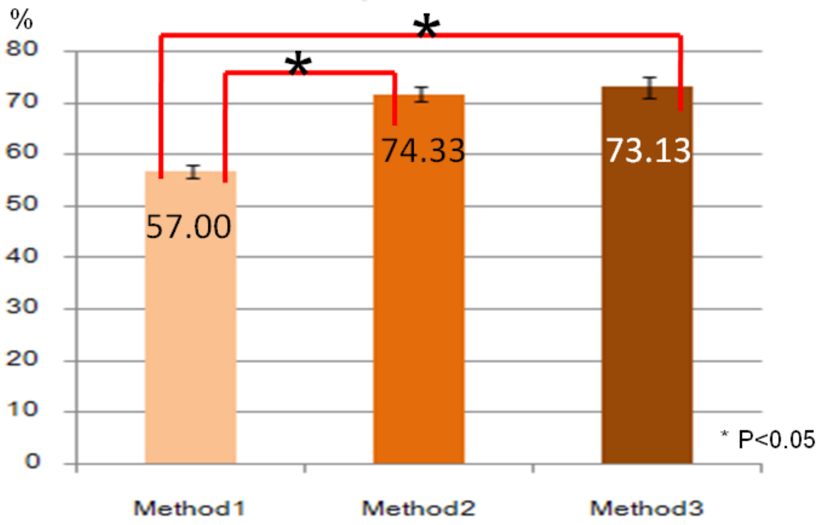

Figure 27 The screw loosening resistance in 3 methods of SimpleLine II.

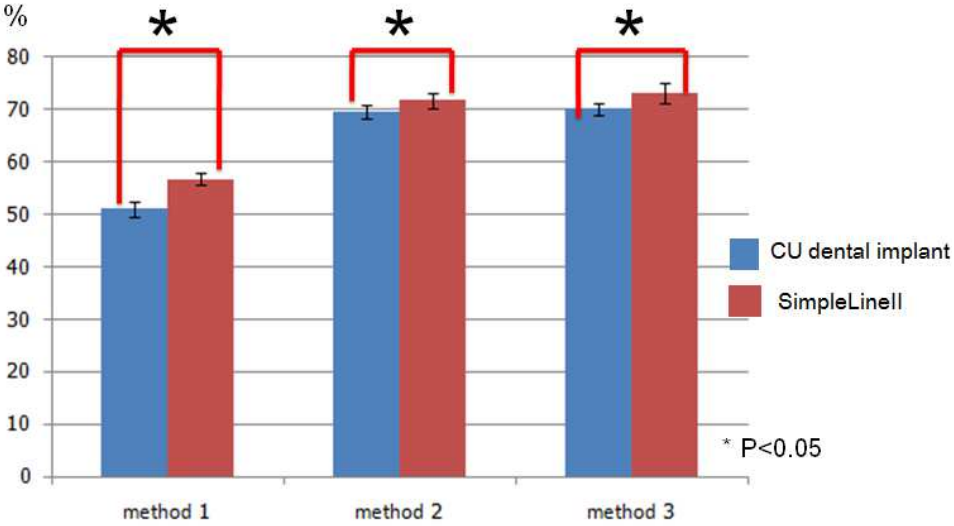

Figure 28 Comparison of the screw loosening resistance between 2 implant systems.

Figure 28 showed the comparison of the screw loosening resistance between 2 implant systems. In the method 1, the Conover-Inmann showed that the screw loosening resistance from SimpleLine II are significantly higher than those from the CU dental implant ($p<0.05$). Like the method 1, the screw loosening resistance from SimpleLine II are significantly higher than those from the CU dental implant in the method 2 and 3 ($p<0.05$)

CHAPTER V

Discussion

A limitation of this study is the small sample size of 5. However this is in compliance with the US Food and Drug Administration for fatigue testing of implants and abutments that recommended 5 or more testing samples [51].

There are several methods of measuring screw loosening resistance. Jaarda et al. used the elongation of the screw[52]. Dixon used the angle of rotation [10] .Karl used the strain [53]. This study used the reverse torque value measuring from the Tonichi torque gauge. Siamos et al. used the reverse torque value to compare the effect of screw retightening method. [12] Khraisat et al. used the reverse torque value to evaluate the effect of lateral cyclic loading [49]. This method was considered to be a gold standard for measuring screw loosening resistance and was used in several studies.

Since the implant systems used in this study have different tightening torque, the screw loosening resistance was expressed as reverse torque values in the percentage of the initial tightening torque. This approach makes it easy to compare between systems and is easy to compare with other research.

To limit the wear of the material after fatigue testing, hemispherical caps and the loading device of fatigue testing machine were fabricated with the same material that is the stainless. The caps were made by the milling machine, thus the fabricated caps were identical in size and shape.

In this study, the cement using to fix the hemispherical cap is the conventional Zinc-phosphate cement. This cement is widely used to fix the crown to the abutment. From the study of Khraisat et al. the cement could stand on 1,000,000 cycles of fatigue loading. However, the manufacturer’s instruction must be strictly followed during the mixing process [49].

The number of loading cycles applied in this study is followed the computation of Wiskott et al. The fatigue test should be performed for a minimum of 10^6 cycles [44].

This study is the laboratory research. Human oral environment and chewing process are not possible to completely simulate. However the position of the fatigue loading tip is at 30° to the long axis of the implant. This is similar to the condition occurred in the oral. From the study of Mericske-stem and Zarb, the 60N used in this study is in the range of occlusal force supported by the implant [54]. This loading value is higher than the occlusal force on the implant supported fixed patial denture reported by Haraldson et a[39]l. Bakaeen and Breeding used 58.8 N which similar to the load used in this study [45, 46]. Moreover, the 60N is the average axial load recommended by Kuczma et al. for using in the 24-hour fatigue testing [55].

To simulate the human chewing process, the force used in this study is the slow dynamic force. The loading force of the machine is produced by the movement of the spring pushing the press. The contraction of spring, which assumed to be constant, controlled the same loading force in every loading stroke [44].

An objective of employing 3 tightening methods used in this study was to clarify an optimal preload that can prevent screw loosening after fatigue loading. The result showed that screw tightening methods affected screw loosening resistance of both systems in the similar pattern. Method 1 presented the significantly lowest screw loosening resistance compared to methods 2 and 3 because the preload was lost due to the settling effect [7, 12]. This suggested that tightening the abutment screw only one time was not enough to prevent screw loosening. Siamos et al. stated that retightening screw after initial tightening was necessary to regain the preload which was lost from the settling effect [12]. Misch also confirmed that retightening acted to prevent screw rebound [11].

Method 2 differed from Method 3 in that, in the method 3, the screw was loosened after initial tightening. Micsh and Ding pointed out the importance of loosening the screw before retightening to bring the contact surfaces of the screw joint closer together. With this technique, the screw can obtain a more optimal seat and higher effective preload [11, 35] However, the screw loosening resistance after fatigue loading was not found in these studies.

The results of method 2 were not significantly different from those of method 3. Kim et al. showed that no more significant settling effect was observed in all sample groups after the second screw tightening. They explained that the fully settling effect was occurred in the second tightening [56]. The loosening screw after initial tightening did not affect the screw loosening resistance. From the result of this study, it was confirmed that the method of retightening without loosening the screw can be applied in both implant systems used in this study.

Because of the specific system of implants, the objective of this study is only to evaluate the screw loosening resistance between specific abutments and specific implant bodies. So, additional studies should be performed with other system of implants to confirm the results.

The implant-abutment connection of CU dental implant is an internal hexagon. Jariyawittayakul et al. recommended that the proper tightening torque value of this system was 35 N-cm [57]. As in the present study, they found that when screws were tightened only one time, the reverse torque value decreased 50 % from initial tightening torque after fatigue loading. However, the magnitude of applied torque is limited by the yield strength of the screw and the strength of the bone-implant interface [8].The result of this study shows that the reverse torque value could be increased by changing the screw tightening method.

The SimpleLine II is an 8-degee Morse taper with octagonal abutment. Several studies have been conducted on this implant-abutment connection. Sutter et al. demonstrated 124 % screw loosening resistance. They suggested that cold welding occurred in the Morse taper. Cold welding is a process that uses mechanical force or pressure to bring two metallic surfaces into contact, while considerable plastic deformation is taking place [58]. Some studies described screw loosening resistance in 80-90% range when the initial tightening torque was in the 30-40N-cm range. They explained that cold welding is only apparent when a tightening torque of 100 N-cm or more is applied. However, none of these studies measured the reverse torque values after fatigue testing [59].

In the present study, SimpleLine II system shows the screw loosening resistance 56.8% in the method 1(Table 2). This is more closer to the results of Cehreli et al. who demonstrated 64% screw loosening resistance after fatigue testing in an octagonal 2 piece- abutment Morse taper [24]. Ha et al. explained that cold welding could occur in the 2-piece abutment. This could be proved that the abutment could not be separated from implant body by hand pressure. However, screw in 2-piece abutment could loosen irrelevant to cold welding. [60].

However, when comparing screw loosening resistance between the 2 systems, screw loosening resistance from SimpleLine II system is still greater than those from the CU dental implant system in all methods. Tonella et al. showed that among the internal connections, the Morse taper demonstrated better stress distribution [61] . The Morse taper has a conical union between implant and abutment. In the conical abutment, the lateral force is resist by the taper design. The stress concentration is support by the contact area of the taper design [62]. This stress concentration is increased at the end of the contact surface where the implant is thicker. This provided more resistance to the force The screw is not only primarily resistant of the force [31].

CHAPTER VI

Conclusion

This study is the experimental study that has a purpose to evaluate the effect of screw tightening methods on screw loosening resistance. However, this study is only to understand the screw loosening resistance in specific implant systems. Notwithstanding the limitation of this study, the following may be concluded:

1. The method 1 showed the lowest screw loosening resistance significantly because the method 1 used the one-time screw tightening. This is not sufficient to compensate the preload lost from settling effect.

2. The screw loosening resistance from the method 2 and the method 3 were not significantly different because the screw retightening is necessary and one-time screw retightening is sufficient to compensate for preload loss from the settling effect in the process of screw tightening. Loosening the screw before retightening does not affect preload. Thus method 2 can be recommended for screw tightening method with both implant systems.

The screw loosening resistance of SimpleLine II is significantly higher than the screw loosening resistance of CU dental implant because SimpleLine II has a Morse taper connection which has a conical design supporting the force.

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Appendix

Descriptive analysis for screw loosening resistance in 2 implant systems

Descriptive

Group				Statistic	Std. Error
Resistance	CU method 1	Mean		51.0820	.67175
		95% Confidence Interval for Mean	Lower Bound	49.2169	
			Upper Bound	52.9471	
		5% Trimmed Mean		51.0917	
		Median		51.4200	
		Variance		2.256	
		Std. Deviation		1.50207	
		Minimum		49.14	
		Maximum		52.85	
		Range		3.71	
		Interquartile Range		2.85	
		Skewness		-.277	.913
		Kurtosis		-1.594	2.000
	CU method 2	Mean		69.5420	.53970
		95% Confidence Interval for Mean	Lower Bound	68.0436	
			Upper Bound	71.0404	
		5% Trimmed Mean		69.4911	
		Median		69.1400	

	Variance		1.456	
	Std. Deviation		1.20680	
	Minimum		68.57	
	Maximum		71.43	
	Range		2.86	
	Interquartile Range		2.15	
	Skewness		1.167	.913
	Kurtosis		.582	2.000
CU method 3	Mean		70.2280	.51522
	95% Confidence Interval for Mean	Lower Bound	68.7975	
		Upper Bound	71.6585	
	5% Trimmed Mean		70.2217	
	Median		70.0000	
	Variance		1.327	
	Std. Deviation		1.15207	
	Minimum		69.14	
	Maximum		71.43	
	Range		2.29	
	Interquartile Range		2.29	
	Skewness		.241	.913
	Kurtosis		-3.047	2.000
SimpleLine II	Mean		57.0000	.62272

	method 1	95% Confidence Interval for Mean	Lower Bound	55.2711	
			Upper Bound	58.7289	
		5% Trimmed Mean		57.0372	
		Median		56.6700	
		Variance		1.939	
		Std. Deviation		1.39244	
		Minimum		55.00	
		Maximum		58.33	
		Range		3.33	
		Interquartile Range		2.49	
		Skewness		-.520	.913
		Kurtosis		-.591	2.000
	SimpleLine II method 2	Mean		74.3320	.40906
		95% Confidence Interval for Mean	Lower Bound	73.1963	
			Upper Bound	75.4677	
		5% Trimmed Mean		74.3506	
		Median		75.0000	
		Variance		.837	
		Std. Deviation		.91470	
		Minimum		73.33	
		Maximum		75.00	

	Range		1.67	
	Interquartile Range		1.67	
	Skewness		-.609	.913
	Kurtosis		-3.333	2.000
SimpleLine II method 3	Mean		73.1340	.87226
	95% Confidence Interval for Mean	Lower Bound	70.7122	
		Upper Bound	75.5558	
	5% Trimmed Mean		73.1672	
	Median		73.3300	
	Variance		3.804	
	Std. Deviation		1.95044	
	Minimum		70.67	
	Maximum		75.00	
	Range		4.33	
	Interquartile Range		3.83	
	Skewness		-.286	.913
	Kurtosis		-2.325	2.000

Test of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
Resistance	.285	30	.000	.826	30	.000

a. Lilliefors Significance Correction

Statistic analysis of screw loosening resistance between 3 screw tightening methods in 2 implant systems.

Kruskal-Wallis test

Variables: CUmethod 1, CUmethod 2, CUmethod 3, SimpleLine method 1, SimpleLine method 2, SimpleLine method 3

Groups = 6

df = 5

Total observations = 30

T = 26.203871

P < 0.0001

Adjusted for ties:

T = 26.415429

P < 0.0001

Kruskal-Wallis: all pairwise comparisons (Conover-Inman)

Critical t (24 df) = 2.063899

CUmethod 1 and CUmethod 2 significant

(11.7 > 3.922312) P < 0.0001

CUmethod 1 and CUmethod 3 significant

(13.9 > 3.922312) P < 0.0001

CUmethod 1 and SimpleLine method 1 significant

(5 > 3.922312) P = 0.0146

CUmethod 1 and SimpleLine method 2 significant

(23.4 > 3.922312) P < 0.0001

CUmethod 1 and SimpleLine method 3 significant

(21 > 3.922312) P < 0.0001

CUmethod 2 and CUmethod 3 not significant

(2.2 > 3.922312) P = 0.2584

CUmethod 2 and SimpleLine method 1significant

(6.7 > 3.922312) P = 0.0017

CUmethod 2 and SimpleLine method 2 significant

(11.7 > 3.922312) P < 0.0001

CUmethod 2 and SimpleLine method 3 significant

(9.3 > 3.922312) P < 0.0001

CUmethod 3 and SimpleLine method 1 significant

(8.9 > 3.922312) P < 0.0001

CUmethod 3 and SimpleLine method 2 significant

(9.5 > 3.922312) P < 0.0001

CUmethod 3 and SimpleLine method 3 significant

(7.1 > 3.922312) P = 0.001

SimpleLine method 1 and SimpleLine method 2 significant

(18.4 > 3.922312) P < 0.0001

SimpleLine method 1 and SimpleLine method 3 significant

(16 > 3.922312) P < 0.0001

SimpleLine method 2 and SimpleLine method 3 not significant

(2.4 > 3.922312) P = 0.2188

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