FACTORS AFFECTING SOFT TISSUE RECESSION AROUND ANTERIOR MAXILLARY SINGLE-TOOTH IMPLANTS

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ปัจจัยที่มีผลต่อการร่นของเหงือกรอบรากเทียมแบบหนึ่งชิ้นบริเวณฟันหน้าบน

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Thesis Title	FACTORS AFFECTING SOFT TISSUE RECESSION AROUND ANTERIOR MAXILLARY SINGLE-TOOTH IMPLANTS
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สุปรีดา สุภานันตชาติ: ปัจจัยที่มีผลต่อการร่นของเหงือกรอบรากเทียมแบบหนึ่งซี่บริเวณฟันหน้าบน (FACTORS AFFECTING SOFT TISSUE RECESSION AROUND ANTERIOR MAXILLARY SINGLE-TOOTH IMPLANTS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: อ.ทญ.ดร.กนกวรรณ นิสภกุลธร, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: อ.ทญ.อรอนงค์ ศิลโกเศศศักดิ์, 67 หน้า.

ที่มาและความสำคัญ การเกิดเหงือกร่นรอบรากเทียมมีความสำคัญยิ่งต่อความสวยงามโดยเฉพาะบริเวณฟันหน้า การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาถึงปัจจัยต่างๆที่มีผลต่อการร่นของขอบเหงือกด้านใบหน้าและการร่นของเหงือกสามเหลี่ยมระหว่างฟัน บริเวณรากเทียมฟันหน้าบน

วัสดุและวิธีการ ทำการศึกษาในฟันรากเทียมแบบหนึ่งซี่จำนวนทั้งสิ้น 40 ตัว โดยประเมินถึงปัจจัยที่คาดว่าน่าจะมีผลต่อการเกิดเหงือกร่นรอบรากเทียม ซึ่งได้จากการเก็บข้อมูลทางคลินิก แบบจำลองศึกษา ภาพถ่ายรังสีรอบปลายราก และภาพถ่ายรังสีส่วนตัดอาศัยคอมพิวเตอร์ (computerized tomograms) และทำการวิเคราะห์เชิงสถิติโดยการทดสอบ Fisher's exact การวิเคราะห์ความแปรปรวน และการวิเคราะห์การถดถอยโลจิสติกแบบตัวแปรทวิ เพื่อทราบถึงอิทธิพลของแต่ละตัวแปรต่อการมีเหงือกร่นรอบรากเทียม

ผลการศึกษา รากเทียมส่วนใหญ่คิดเป็น ร้อยละ 75 ของรากเทียมที่พบในกลุ่มตัวอย่างได้รับการฝังในตำแหน่งฟันตัดบนซี่กลาง ค่าเฉลี่ยของระยะการร่นของขอบเหงือกด้านใบหน้ามีค่าเท่ากับ 0.5 ± 0.9 มิลลิเมตร และพบว่าร้อยละ 89.2 ของกลุ่มตัวอย่างมีเหงือกสามเหลี่ยมระหว่างฟันเติมเต็มช่องว่างระหว่างฟันมากกว่าครึ่งหนึ่งของความสูงของช่องว่างดังกล่าว หลายปัจจัยส่งอิทธิพลต่อการเพิ่มความเสี่ยงในการเกิดขอบเหงือกร่นทางด้านใบหน้าอย่างมีนัยสำคัญทางสถิติ ซึ่งได้แก่ การมีเนื้อเยื่อเหงือกชนิดบาง (thin biotype) มุมในการฝังรากเทียมที่แคบลง ระดับของสันกระดูกเบ้าฟันด้านใบหน้าที่มากขึ้น ระยะจากจุดสัมผัส (contact point) ถึงสันกระดูกระหว่างฟัน ส่วนแท่นของรากเทียม (implant platform) และจุดแรกที่รากเทียมสัมผัสกับกระดูกเบ้าฟัน (implant bone) ที่เพิ่มมากขึ้น โดยที่การมีเนื้อเยื่อเหงือกชนิดบางนั้นเป็นปัจจัยที่ส่งผลมากที่สุดต่อการร่นของขอบเหงือกด้านใบหน้า ในขณะที่ความเสี่ยงในการเกิดการร่นของเหงือกสามเหลี่ยมระหว่างฟันได้รับอิทธิพลจากเพียงปัจจัยเดียว คือ ระยะจากจุดสัมผัสถึงสันกระดูกระหว่างฟัน

สรุป ปัจจัยหลักที่มีผลต่อการร่นของเหงือกสามเหลี่ยมระหว่างฟันบริเวณรากเทียม คือ ระดับความสูงของสันกระดูกระหว่างฟันของฟันธรรมชาติข้างเคียง ในขณะที่การร่นของขอบเหงือกด้านใบหน้านั้นได้รับอิทธิพลจากหลากหลายปัจจัย ซึ่งได้แก่ ชนิดของเนื้อเยื่อเหงือกรอบรากเทียม (peri-implant biotype) ระดับของสันกระดูกเบ้าฟันด้านใบหน้า มุมในการฝังรากเทียม ระดับความสูงของสันกระดูกระหว่างฟัน ระดับความลึกในการฝังรากเทียม และตำแหน่งที่รากเทียมสัมผัสกับกระดูกเบ้าฟัน การศึกษาตามแผนแบบติดตามผลไปข้างหน้าในระยะยาวเพิ่มเติม จะสามารถให้ข้อมูลเกี่ยวกับปัจจัยต่างๆเหล่านี้ในแง่ของการเป็นปัจจัยเสี่ยงของการเกิดเหงือกร่นรอบรากเทียมได้ดียิ่งขึ้น

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SUPREDA SUPHANANTACHAT: FACTORS AFFECTING SOFT TISSUE RECESSION AROUND ANTERIOR MAXILLARY SINGLE-TOOTH IMPLANTS. THESIS PRINCIPAL ADVISOR: KANOKWAN NISAPAKULTORN, PhD., THESIS COADVISOR: ONANONG SILKOSESSAK, DDS., MSc., 67 pp.

Background: Peri-implant soft tissue recession is a major esthetic concern for the anterior implants. The aim of this study was to determine factors that affected the facial marginal recession and papillary recession around single-tooth implants in the anterior maxilla.

Methods: Forty single-tooth implants in the anterior maxilla were studied. Variables possibly associated with soft tissue recession were obtained from clinical measurements, study models, peri-apical radiographs, and computerized tomograms. The Fisher's exact test, analysis of variance, and binary logistic regression analysis were used to determine the influence of each factor on facial marginal recession and papillary recession.

Results: The majority of the implants (75%) replaced the upper central incisors. The mean facial marginal recession was 0.5 ± 0.9 mm. Eighty-nine percents of the implants had more than half of papilla fill. Facial marginal recession was influenced by many factors. Increased risk of facial marginal recession was significantly associated with thin peri-implant biotype, proclined implant fixture angle, more apical level of facial bone crest, increased distance from contact point to bone crest, contact point to platform, and contact point to implant bone. Thin biotype was the most significant factor in determining the presence of facial marginal recession. Increased distance from contact point to bone crest was the only factor significantly associated with increased risk for papillary recession.

Conclusions: Papillary recession around single-tooth implants in the anterior maxilla was mainly influenced by the interproximal bone crest level of the adjacent tooth. Facial marginal recession, on the other hand, was affected by multiple factors including, the peri-implant biotype, the facial bone crest level, the implant fixture angle, the interproximal bone crest level, the depth of implant platform, and the level of first bone to implant contact.

Department : Periodontology	Student's Signature :
Field of Study : Periodontics	Principal Advisor's Signature :
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CHAPTER I

INTRODUCTION

Background and significance

Dental implants have become a standard of care for tooth replacement. Long term studies demonstrated high survival rate and success rate of dental implants. For anterior maxillary implants, besides the functional predictability, esthetic becomes an important success criteria. Together with the esthetic demand of patients and the complexity of the pre-existing anatomy after tooth extraction, the predictable and esthetic acceptable treatment plan becomes essential for the clinicians. Successful implant esthetics required high quality implant restorations as well as gingival architecture that harmonized with the adjacent natural teeth.

The harmonization of gingival margin along with intact papillae is the major concern for dental implant restoration in esthetic zone. A mean marginal recession of 0.6-1.5 mm around dental implants has been reported (Cardaropoli et al., 2006; Kan et al., 2003a; Oates et al., 2002; Small and Tarnow, 2000). The majority of recession (80%) occurred on the buccal aspect with the mean recession of 0.88 mm and more pronounced in maxillary teeth especially during the first 3 months following abutment

connection surgery (Small and Tarnow, 2000). Furthermore, while the lingual site of the mandible showed the most recession at 6 months which remained stable up to 2 years, the facial site of maxilla showed significantly increased recession between 6 months to 2 years (Bengazi et al., 1996).

Peri-implant soft tissue recession, a serious esthetic complication, could be influenced by various factors. The most important factor that determines the soft tissue profile is the underlying alveolar bone. Unfortunately, bone resorption is a common sequela after tooth loss. This undesirable process was affected by the remodeling of alveolar bone which is critical in the first 3-6 months post-extraction, as well as the surgical trauma at the time of implant surgery (Botticelli et al., 2004; Cardaropoli et al., 2006). Previous study showed that the mean facial recession seemed to correspond with the amount of bone remodeling after abutment connection surgery (Cardaropoli et al., 2006). Likewise, a close relationship between the presence or absence of the interproximal papilla and the height of interproximal crest has been reported in many studies. In natural tooth, Tarnow et al. found that increasing the distance from contact point to proximal bone crest will significantly increase a chance of papillary recession (Tarnow et al., 1992). For single tooth implants, similar trends were also observed (Choquet et al., 2001; Gastaldo et al., 2004; Lops et al., 2008; Palmer et al., 2007; Ryser

et al., 2005). However, few studies provided proper statistical analyses of these relationships.

Soft tissue recession appeared to be an unavoidable consequence after tooth loss and implant surgery. To preserve the restricted amount of hard and soft tissue, the precise position of implant is particularly necessary. In bucco-lingual position, 2-mm of facial bone thickness was recommended to be left after implant placement to avoid future recession (Spray et al., 2000). Three times more recession was also observed when implants shoulder positioned at or buccal to a reference line drawn between the cervical margins of adjacent teeth (Evans and Chen, 2008). Therefore, the thickness of facial bone is critical to prevent future bone dehiscence and marginal recession.

The apico-coronal position or depth of implant placement may also be important in determining the stability of the peri-implant mucosa. More apical location of implants may result in thicker soft tissue height and deeper probing depth which serves as a reservoir for periodontal pathogens (Mombelli et al., 1987). Presence of these pathogens may lead to an increase risk of peri-implant bone resorption and mucosal recession. Another factor that may affect the soft tissue recession around implants is the implant angulation. An attempt to place an implant in sites with limited amount of alveolar bone may lead to improper axial angulation of implant. Too procline implant

position may lead to facial bone loss and future recession. At present, this relationship has not been explored.

Mesio-distal positioning of implants has been shown to influence the height of interproximal bone crest and papillae (Buser et al., 2004). To maintain the interproximal bone peak and papillae, the horizontal distance of 1.5-4.0 mm between the implant platform and adjacent teeth was suggested (Gastaldo et al., 2004; Grunder et al., 2005; Lops et al., 2008). However, some studies did not find the relationship between the presence of papillae and this horizontal distance (Palmer et al., 2007; Ryser et al., 2005). Therefore, the significance of the inter implant-tooth distance and the papillary recession is still controversial.

Besides the implant position, other factors including gingival biotype and facial bone crest has been suggested to influence the peri-implant soft tissue recession (Kois, 2001; Zetu and Wang, 2005). The gingival biotype was related to the tooth shape and the underlying bone thickness. A thick gingival biotype was frequently associated with square-shape tooth morphology and thicker underlying bone. In contrast, a thin gingival biotype was commonly associated with triangular-shape tooth morphology and thinner underlying bone. A thin biotype appeared to be more prone to recession in response to trauma and bacteria than a thick biotype. Facial bone crest is the bone the supported

the facial gingiva. Studies on the facial bone crest level around dental implants were limited. Kan et al. determined the facial crest level around anterior maxillary implants by bone sounding. They found that the average facial crest level was 3.6 ± 0.9 mm from the gingival margin. However, the relationship between the facial crest level and facial marginal recession has not been verified.

A number of factors appeared to influence the presence of soft tissue recession around dental implants. While some factors were well-studied, many factors were still controversial or have not been explored. The aim of this retrospective study was to broadly determine factors that may influence the facial marginal recession as well as papillary recession around single-tooth implant in the anterior maxilla.

Objective

To determine factors that affected soft tissue recession around anterior maxillary single-tooth implants.

Hypothesis

Soft tissue recession around single-tooth anterior maxillary implants was affected by peri-implant bone level, implant position, and soft tissue biotype.

Field of Research

This is a clinical study with the cross-sectional analytical study design.

Limitation of Research

Due to the cross-sectional nature of the study, only the association between different factors and soft tissue recession can be drawn. However, this information will be useful for further evaluation in prospective study design.

Application and Expectation of Research

This study was the first to determine the influence of facial bone crest level and the implant angulation on peri-implant soft tissue recession. In addition, other factors possibly affected peri-implant soft tissue recession as reported in the literature review were further evaluated. This will give useful information to understand the possible causes and nature of soft tissue recession around anterior maxillary implants.

CHAPTER II

LITERATURE REVIEW

Dental implants have become a standard of care for tooth replacement. Long term studies demonstrated high survival rate and success rate of dental implants. A systematic review that included prospective longitudinal studies with follow-up periods of at least 5 years showed that the survival rate for various types of implant restorations ranged from 91-97% whereas the success rate, as determined by the loss of crestal bone less than 2.5 mm, ranged from 86-96% (Berglundh et al., 2002). While tooth replacement with dental implants is predictable in term of function, achieving successful implant esthetics, especially in the anterior maxilla, is challenging. Besides the objective criteria judged by the clinician, the patient-based treatment outcome became the most important justified criteria of success (Zarb and Albrektsson, 1998). Successful implant esthetics required high quality implant restorations as well as gingival architecture that harmonized with the adjacent natural teeth.

Peri-implant soft tissue recession is a major implant esthetic complication. The most important factor that determines the soft tissue height is the underlying alveolar bone. In 1986, Oschenbein described the normal osseous contour as “positive architecture” which referred to the condition that the osseous crest has a scallop

contour that followed the outline of the cemento-enamel junction, and the position of the interproximal bone is more coronal than the radicular bone (Oschenbein, 1986). This osseous contour provided that foundation for the overlying gingiva and mucosa. Unfortunately, bone resorption is a common sequela after tooth loss. Approximately 50% reduction of the facial-lingual dimension and slight loss of the vertical height (0.2-0.6 mm) of the alveolar ridge has been reported (Botticelli et al., 2004). The major part of this remodeling took place during the first 3-6 months following tooth extraction. Surgical trauma at time of implant surgery also caused additional bone loss. Cardaropoli et al. determined changes of bone dimension following single tooth implant surgery in the maxillary region. They showed a mean loss of 0.7-1.3 mm of bone height at the facial and lingual aspect of the implant and a reduction of 0.4 mm of the labial bone thickness between the time of implant placement and abutment connection surgery. This bone remodeling corresponds with the mean labial recession of 0.6 mm (Cardaropoli et al., 2006). Therefore, soft tissue recession appeared to be an unavoidable consequence after tooth loss and implant surgery.

Facial marginal recession

Marginal mucosal recession is common esthetic complications. A mean marginal recession of 0.6-1.5 mm around dental implants have been reported

(Cardaropoli et al., 2006; Kan et al., 2003a; Oates et al., 2002; Small and Tarnow, 2000). Small and Tarnow measured the changes in soft tissue level over 1 year. The study included 65 implants in 11 patients that required full arch, partial arch and single tooth replacement. They found that soft tissue recession occurred in most of the implant restorations during the first 3 months following abutment connection surgery. The majority of recession (80%) occurred on the buccal aspect with the mean recession of 0.88 mm and more pronounced in maxillary teeth (Small and Tarnow, 2000). Bengazi et al. performed a 2-year longitudinal study to evaluate changes in the soft tissue margin. Approximately half of the implants were placed in edentulous jaws. They found that the mucosal recession mainly took place during the first six months. Anterior implants showed higher recession than posterior implants. The lingual site of the mandible showed the most recession at 6 months which remained stable up to 2 years. In contrast, the facial site of maxilla showed significantly increased recession between 6 months to 2 years. In addition, sites with a non-keratinized mucosa showed higher recession than sites with keratinized mucosa (Bengazi et al., 1996). Oates et al. studied the mucosal recession in maxillary and mandibular anterior implants over 2 years. They found the mean recession of 0.6 mm with 60% of the implants showed recession 1 mm or more (Oates et al., 2002). Jemt et al. retrospectively examined the study casts of 23 patients who received single implant restorations in the anterior maxilla for an average of 15 years. They found that the implant clinical crowns were an average

0.6 ± 1.04 mm longer than the contralateral teeth. Seventeen percent of the implant crowns showed recession ≥1 mm. In addition, the teeth adjacent to single implant restoration presented a higher recession than teeth in the untreated area (Jemt et al., 2006).

In natural tooth, the bone crest level is a critical determinant for marginal gingival recession. Kan et al. determined the bone crest level in 45 maxillary anterior single implant crowns by bone sounding. The average depth of bone at midfacial was 3.6 ± 0.9 mm. This dimension was greater in the thick biotype (3.8 ± 0.9 mm) than the thin biotype (3.4 ± 0.9 mm) (Kan et al., 2003b). This mean facial dimension of the peri-implant mucosa was slightly greater than the histologic dimensions of the dentogingival complex of the natural tooth as reported by Gargiulo et al. (2.73 mm) (Gargiulo et al., 1961). However, it is comparable to the histometric dimensions reported for dental implants (Berglundh and Lindhe, 1996). Although the facial bone crest level in relation to the mucosal margin was known, the information on the relationship between the bone crest level and the marginal recession around dental implants is lacking. This may be due to the difficulty in determining the facial bone crest level non-invasively.

Facial bone thickness is critical to prevent future bone dehiscence and marginal recession. Facial bone thickness is related to the bucco-lingual position of the tooth.

Teeth positioned too far facially often resulted in thin facial bone and were more prone to marginal recession. In contrast, teeth positioned too far lingually resulted in thick facial bone and more coronal gingval margin (Andlin-Sobocki and Bodin, 1993). Similar findings were also observed in dental implants. Evan and Chen found that the bucco-lingual position of the implant shoulder was a highly significant factor in determining buccal marginal tissue recession. Implants with a shoulder positioned at or buccal to a line drawn between the cervical margins of adjacent teeth demonstrated three times more recession than implants with a shoulder positioned lingual to this line (1.8 mm vs 0.6 mm) (Evans and Chen, 2008). Spray measured the change of facial crestal bone height between implant insertion and uncovering. They observed a mean vertical bone loss of 0.7 mm at time of uncovering. The facial vertical resorption was more pronounced when the facial bone thickness was decreased. As the facial bone thickness approached 1.8 mm, vertical bone loss decreased significantly. Therefore, they proposed that a 2-mm of facial bone thickness should be left after implant placement to avoid future recession (Spray et al., 2000).

Although it has been suggested that facial bone crest level and thickness was important factors that influenced marginal recession around dental implants, no direct relationships were demonstrated. Limited studies on this aspect were possibly due to the difficulty to obtain measurements of facial bone crest level and thickness non-

invasively. The level and thickness of facial bone crest can be determined clinically by surgical exposure or bone sounding. Surgical exposure provided accurate measurements but can only perform in conjunction with the implant surgery. The surgical measurement was not possible following implant restorations. Bone sounding is an alternative to surgical exposure. With local anesthesia, bone sounding can be used to measure the bone crest level after implant restorations. However, the contour of the restorations may hinder the accurate measurement. The computerized tomography provides three-dimension information of hard tissues. Therefore, it can be a useful tool to allow non-invasive measurements of facial bone crest level and thickness.

The apico-coronal position or depth of implant placement may also be important in determining the stability of the peri-implant mucosa. More apical location of implants may result in thicker soft tissue height and deeper probing depth. It was well documented that periodontal pathogens such as *Porphyromonas gingivalis* were frequently found at peri-implant sites with deep probing depth (Mombelli et al., 1987). Presence of these pathogens may lead to an increase risk of peri-implant bone resorption and mucosal recession. In addition, unnecessary bone loss frequently occurred with the implant positioned too far apically. The effect of saucerization

appeared to play this role (Buser et al., 2004; Hartman and Cochran, 2004; Hermann et al., 2000; Hermann et al., 1997).

Persistent gingival inflammation from bacterial plaque is another cause of peri-implant bone loss and soft tissue recession. Fransson et al. showed that implants having progressive bone loss had many clinical signs of peri-implant soft tissue inflammation, including high mean plaque score, suppuration on probing, bleeding on probing, and probing pocket depth ≥6 mm. In addition, they reported a significant association between soft tissue recession and progressive bone loss with an odds ratio of 4.6 (95% CI = 2.9-7.3) (Fransson et al., 2008). On the other hand, the successful implant with healthy peri-implant soft tissue can be obtained by providing an adequate oral hygiene (Adell et al., 1981). Throughout the 3-year observation period, Johnson and Persson showed that stable probing depth and bone height around dental implants as well as the high survival rate of 98.7% can be obtained from the patients who achieved the high standard of oral hygiene (Johnson and Persson, 2000).

Interproximal papillary recession

The interproximal recession has been a focus of attention in many studies. In natural teeth, the height of interdental papilla appeared to be influenced by the location of the contact point of the tooth and the level of proximal bone crest. Tarnow et al. found that when the distance from the contact point to the proximal bone crest was ≤5 mm, the papilla was present 98% of the times, while at 6 mm it dropped to 56%, and at 7 mm it was present only 27% of the times (Tarnow et al., 1992). For single tooth implants, similar trends were observed (Choquet et al., 2001; Gastaldo et al., 2004; Lops et al., 2008). However, for two adjacent implants, the chance for the presence of interproximal papilla was significantly diminished as the mean height of papillary tissue was only 3.4 mm (Tarnow et al., 2003). Therefore, the clinician should proceed with caution when placing two adjacent implants in the esthetic zone. Mesio-distal positioning of implants also has shown to influence the height of interproximal bone crest and papilla (Buser et al., 2004). Tarnow et al. found that when the distance between 2-adjacent implant platforms was greater than 3 mm, less crestal bone loss was observed compared to those with ≤3 mm distance (Tarnow et al., 2000). Similarly, the chance of papillary recession seemed to be increased when the inter implant-tooth distance was decreased (Gastaldo et al., 2004; Lops et al., 2008; Romeo et al., 2008). Lops et al. found the significant relationship between the presence of the interproximal

papilla and the inter implant-tooth distance. With the distance of 3-4 mm, the interproximal papilla was present 84.2% of the time (Lops et al., 2008). In contrast, Ryser et al. found no correlation between the horizontal distance from the implant junction to the CEJ of the adjacent tooth and the Jemt's papilla score (Ryser et al., 2005). In addition, Palmer et al. also demonstrated that the inter implant-tooth distance had no impact on the interproximal papilla (Palmer et al., 2007). Therefore, the relationship between the implant-tooth distance and the papillary recession was still controversial.

Other factors besides the bone level may also be involved in the presence and absence of the interproximal papilla. Tooth morphology has been shown to influence the location of the contact point and the dimension of interproximal space (Kois, 2001; Zetu and Wang, 2005). The tooth with triangular shape has a more coronal contact point and a larger interproximal dimension whereas the tooth with square shape has a more apical contact point and a smaller interproximal dimension. Therefore, the complete fill of interproximal papilla may be more difficult to achieve in the triangular-shape tooth than the square-shape tooth. The gingival biotype was also related to the tooth morphology and the bone thickness. The gingival biotype was divided into a thick and a thin biotype. A thick gingival biotype was frequently associated with square-shape tooth morphology and thicker underlying bone. This type of tissue was more

resistant to recession and often resulted in pocket formation in the presence of the bacteria insult. In contrast, a thin gingival biotype was frequently associated with triangular-shape tooth morphology and thinner underlying bone. This type of tissue was more prone to recession in response to trauma and bacterial plaque.

Patient satisfaction on anterior maxillary implants

The patient's esthetic satisfaction is an important criterion for implant success in esthetic zone. However, few studies have addressed this aspect when evaluating the implant success outcome. Implant esthetics can be rated in a subjective and an objective manner. In the subjective method, questionnaires are commonly used (Chang et al., 1999a; Chang et al., 1999b; De Rouck et al., 2008; Levi et al., 2003; Moberg et al., 1999; Palmer et al., 2007; Vermylen et al., 2003; Wannfors and Smedberg, 1999). The judgment of favorable implant esthetics appeared to be different between patients and clinicians. Patients were more likely to give higher satisfaction scores than clinicians (Chang et al., 1999a; den Hartog et al., 2008; Gibbard and Zarb, 2002; Palmer et al., 2007). Chang et al. compared patients' and prosthodontists' judgment of esthetic outcome of maxillary anterior single-tooth implant restorations. They found that the clinician's satisfaction was influenced by multiple factors, including surrounding soft tissue appearance, crown form, contact point position, and crown

color. In contrast, no single factor was found to significantly influence the patient's satisfaction (Chang et al., 1999a). Besides the esthetic standpoint, the dental implant therapy has been shown to improve the patient's quality of life (Cibirka et al., 1997). Therefore, lifestyle-related factors, such as comfort when chewing or biting, speaking, confidence when smiling, and cost, may also be of concern for the patient to justify the outcome of therapy.

In conclusion, successful anterior maxillary implants require not only the functional predictability, but also the optimal esthetic satisfaction met by both clinicians and patients. The harmonization of gingival margin along with intact papillae is the major concern for dental implant restoration in the esthetic zone. Thorough understanding of factors that influence the peri-implant soft tissue recession is necessary for clinicians to prevent this undesirable complication and to enhance the long-term stability of the peri-implant mucosa.

CHAPTER III

MATERIALS AND METHODS

Study samples

The study protocol was approved by the ethic committee of the Faculty of Dentistry, Chulalongkorn University. Informed consent was obtained from all subjects. The list of patients who received dental implant treatment at the Faculty of Dentistry, Chulalongkorn University between the year 1999-2008 was reviewed. The patients who met the following criteria were invited to participate in the study: 1) had a single-tooth implant in the anterior maxilla; 2) had a natural contralateral tooth; and 3) the implant was restored and in function for at least 6 months. Forty patients agreed to participate in the study and 40 single-tooth implants were included for analysis.

Clinical measurements

The following clinical parameters of an implant and the contralateral tooth were examined and recorded: 1) probing depth (PD), recorded in millimeters with a UNC-15 periodontal probe at mid-facial and proximal sites; 2) soft tissue biotype, categorized into thick or thin biotype. A periodontal probe was placed into the facial aspect of the

gingiva. The biotype was categorized as thin if the outline of the probe can be seen through the gingiva, and as thick if the outline of the probe cannot be seen (Kan et al., 2003); and 3) dental plaque, recorded as presence or absence of dental plaque on the facial aspect of the implant.

Radiographic measurements

Periapical radiographs were taken with the parallel technique using film holders (Rinn XCP, Dentsply, IL, USA) and sized 2, D speed films (Ultra-speed, Kodak, USA). Prior to the exposure, a 0.25 mm orthodontic wire was placed apical to each contact point and tightened to demarcate the position of the contact point on the radiograph. The films were developed using an automated processor (Dent-X Excel, NY, USA) under controlled condition recommended by the manufacturer. The radiographs were digitized at a resolution of 1,000 dpi, stored as TIFF-format, and examined using commercially available software (Adobe Photoshop CS3 extended version 10.0, Adobe System Inc., USA). The following parameters were measured from the digitized images: 1) the distance from the contact point to the interproximal bone crest of the adjacent tooth (CP-BC); 2) the distance from the contact point to the implant platform (CP-P); 3) the distance from the contact point to the first bone to implant contact (CP-IB); and

4) the distance between the implant and adjacent tooth at the platform level (ITD). Vertical measurements were made parallel to the long axis of the implant fixture whereas horizontal measurements were made perpendicular to the long axis of the fixture (Fig.1). The measurements were made in pixels and converted to millimeters by calibrating with a known length.

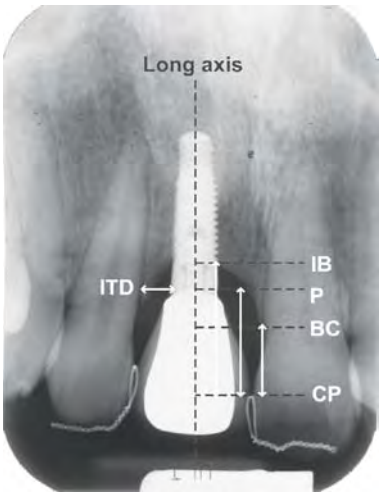

Figure 1. Periapical radiograph showing the reference points and measured distances. CP-contact point; BC-bone crest, P-implant platform, IB- implant bone, ITD-inter implant-tooth distance.

Computerized tomograms (CT) were acquired using a dental CT unit (CBMercuRay, Hitachi, Japan) with I-mode (implant mode providing 10 cm diameter field of view (FOV) and 0.2 mm image resolution) and standard parameters (120 kVp, 15 mA, 9 sec). The patients were positioned with the occlusal plane parallel to the floor. Image reconstruction was performed corresponding to axis of the implant as adjusted axial plane and cross-sectional view (Fig.2a, b).

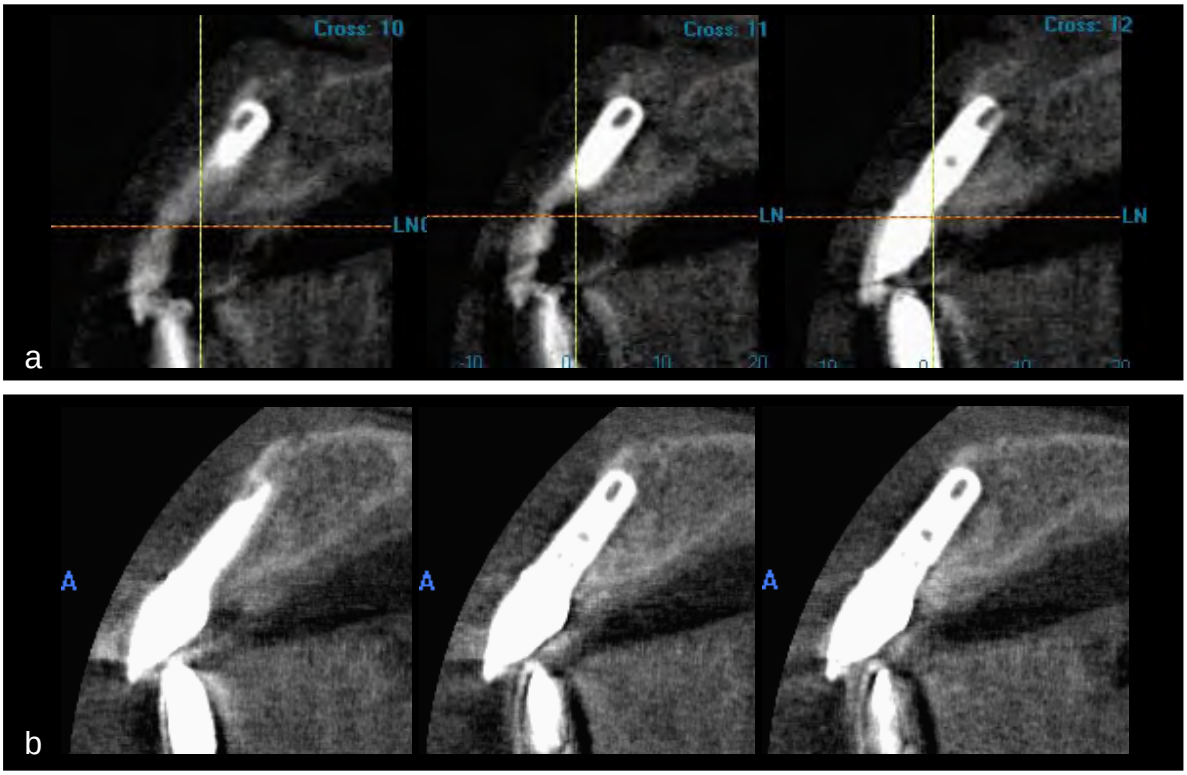

Figure 2. (a) 3-continuous slices of the original cross-sectional view showed the plane that was not parallel to the implant long axis. (b) 3-continuous slices of the adjusted cross-sectional view which demonstrated the correct axis of the implant fixture.

Image analysis was performed using CBWork (version 2.12, Hitachi, Japan) and Image-J software (version 1.410, NIH, USA). The following parameters were assessed: 1) facial bone crest level; 2) facial bone crest thickness; 3) implant fixture angle; and 4) bucco-lingual implant position. The facial bone crest level/ thickness and the implant fixture angle were measured from a selected cross-sectional slice of the middle of the implant fixture (Fig.3a). The facial bone crest level was defined as the distance from the facial gingival margin to the facial bone crest. The computerized tomography which allowed the detection of facial bone crest did not show the soft tissue margin. Therefore, the location of facial bone crest in reference to the gingival margin was determined indirectly. First, the incisal edge was marked (A). Then, the facial gingival margin was located (B). The distance from A to B was equal to the clinical crown length measured from the study model. The computer software displayed the distance between two points (A-B) as we located the gingival margin which facilitated the precise marking. Once the gingival margin was determined, the distance from the facial gingival margin to the facial bone crest was measured (B-C). The thickness of the facial bone was measured at 0.5 mm apical to the bone crest. A profile line was drawn 0.5 mm apical to the bone crest and perpendicular to the long axis of the implant fixture. The radiographic density along the profile line was displayed as a histogram profile (Fig.3b). The bony outline of the facial crest was determined from the histogram and the

thickness of the facial bone crest was measured (x). The implant fixture angle was measured in degree with reference to the occlusal plane.

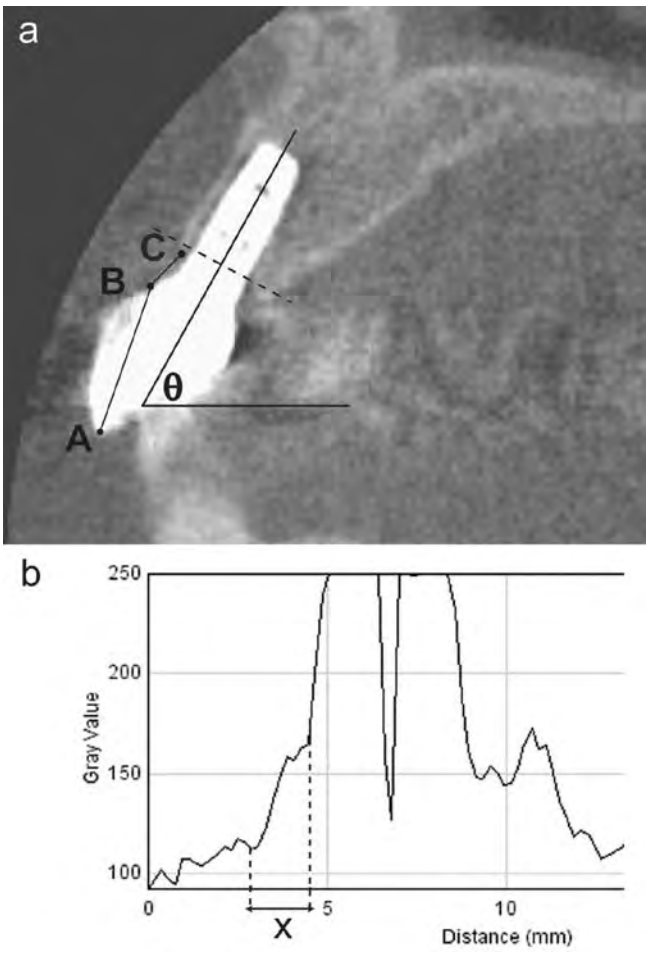

Figure 3. (a) Mid-facial cross-sectional CT slice showing the facial crest level (B-C), profile line (dash line), and implant fixture angle (θ). (b) Histogram profile showing the thickness of facial bone crest (x). A = incisal edge; B = facial gingival margin; C = facial bone crest; A-B = clinical crown height; B-C = facial bone crest level.

The bucco-lingual position of the implant platform was determined in relation to the cervical contour of the adjacent teeth. Two axial slices, one at the level of implant platform, another at the cervical level of the adjacent teeth, were selected (Fig.4a, b). Both slices were superimposed using commercially available software (Adobe Photoshop CS3 extended version 10.0, Adobe System Inc., USA). A reference line connecting the mesio-buccal line angle and disto-buccal line angle of two adjacent crowns was drawn (Fig.4c). The implant was considered buccal position when the buccal border of the platform was at or buccal to the reference line. The implant was considered lingual position when the buccal border of the platform was lingual to this line.

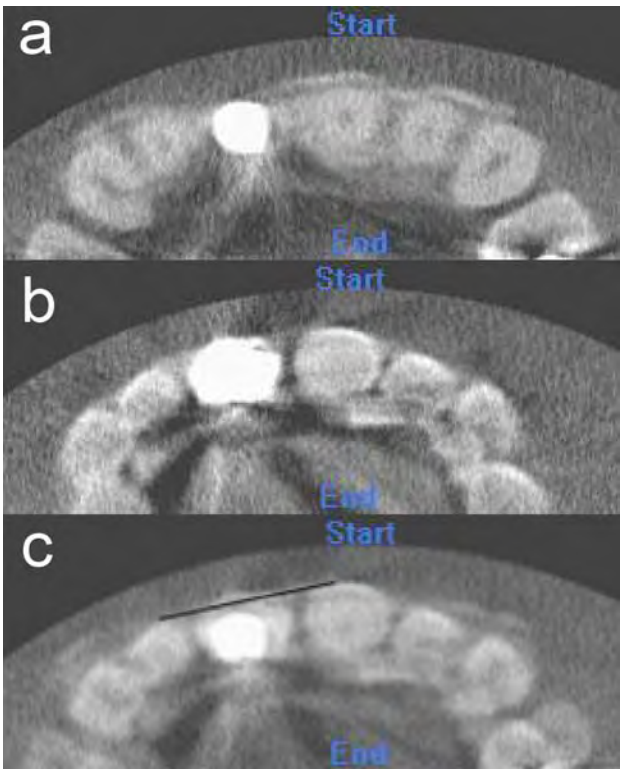

Figure 4. Determination of the bucco-lingual position of the implant using two axial CT slices. (a) Axial CT slice at the implant platform level. (b) Axial CT slice at the cervical level of the adjacent teeth. (c) Superimposition of both slices. A reference line connecting the mesio-buccal line angle and disto-buccal line angle of two adjacent crowns was drawn. This implant was considered lingual position.

Presence of facial marginal recession

The clinical crown height of an implant and the contralateral tooth were measured from the study model using the digimatic caliper (Mitutoyo, Japan) measured to the closet 0.1 mm. Facial marginal recession was calculated by subtracting the clinical crown height of an implant from the contralateral tooth. For binary logistic regression analysis, the marginal recession was considered “presence” if the clinical crown height of an implant was ≥1 mm longer than that of the contralateral tooth. The marginal recession was considered “absence” if the clinical crown height of an implant was <1 mm longer than that of the contralateral tooth.

Presence of papillary recession

Digital clinical photographs were used to evaluate papillary recession. The photographs were taken at a 1:1 magnification perpendicular to the buccal surface of the single-tooth implant crown, using a Nikon D80 digital camera with macro lens and ring flash. The interproximal papilla was scored using an index described by Jemt (Jemt, 1997). The score was rated as followed: score 0-no papilla was present; score 1-less than half of the papilla was present; score 2-half or more of papilla present; score 3- complete fill of papilla (Fig.5a-c). A total of 74 papillae were available for

evaluation. Six papillae without contact points were excluded. For binary logistic regression analysis, the papillary recession was considered “presence” when the assigned Jemt score was 0 or 1 and “absence” when the assigned Jemt score was 2 or 3.

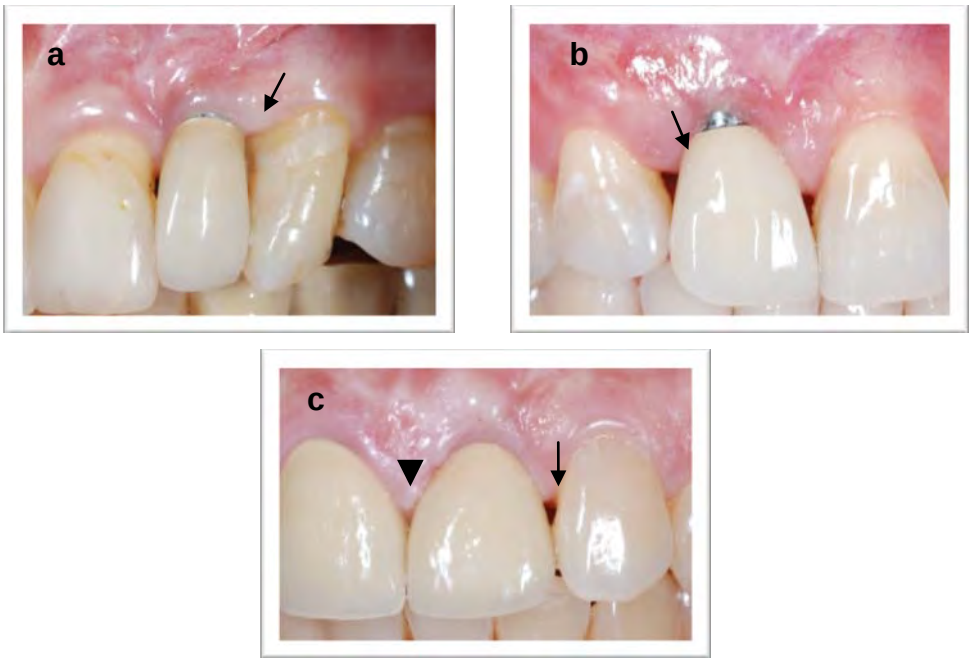

Figure 5. Determination of the papilla score using clinical photographs. (a) The arrow showed Jemt’s papilla score 0. (b) The arrow showed Jemt’s papilla score 1. (c) The arrow and arrowhead demonstrated Jemt’s papilla score 2 and 3, respectively.

Assessment of patient satisfaction

A Thai-language questionnaire composed of 8 questions was used to assess the patient satisfaction using visual analog scale (VAS). The questions were categorized into 2 groups, esthetic-related variables (4 questions) and lifestyle-related variables (4 questions). For esthetic-related variables, the patients were asked about their satisfaction with harmonization of gingival margin, crown shape, crown color, and overall esthetic satisfaction. For lifestyle-related variables, the patients were asked about their satisfaction with implants in term of confidence when smiling, comfort when chewing or biting, speaking well, and worth for the expense. The patients were asked to mark their assessment on a 100-mm line having end phrases “not satisfied at all” on the left and “very satisfied” on the right. The distance from the left end of the VAS to the mark made by the patient was measured to the nearest millimeter and reported as a percentage. The patients completed the questionnaire at the time of participation.

Statistical analysis

Commercially available statistical software (SPSS version 14.0, SPSS Inc., USA) was used to analyze the data. The descriptive analysis of data was presented as frequency and mean ± standard deviation (S.D.). The Fisher’s exact test was used to

analyze the association between two categorical data. For continuous data, the analysis of variance (ANOVA) was utilized to compare means among different groups of variables. Multiple comparisons were performed by Tukey's test or Tamhane's T2 test depending on the homogeneity of variance. The influence of each independent variable on the presence of facial marginal recession and papillary recession was analyzed using binary logistic regression analysis. The data were presented as the odds ratios (OR) with 95% confidence intervals (CI). The association between the presence of marginal/ papillary recession and the VAS score assessed by patients was analyzed by independent sample T-test or Mann Whitney U test depended on the characteristic of the sample's distribution. Statistical differences with a p-value < 0.05 were considered significant.

CHAPTER IV

RESULTS

A total of 40 patients with 40 single-tooth implants in the anterior maxilla were included in the study. All implants were in functioned between 6-68 months (mean ± S.D.; 27.18 ± 15.3 months) after completed restoration. The characteristics of the study group were shown in Table 1. The mean age of the patients at time of implant placement was 45.2 ± 13.9 years. The majority of implants (75%) were located at central incisors. Presence of facial marginal recession (≥1 mm) was observed in 35% of the cases whereas papillary recession (Jemt score 0 and 1) was shown in 10.8% of the study samples. Dental plaque was present in 67.5% of the subjects. There were 17.5% of subjects with thin peri-implant biotype and 20% with buccal position of the implant platform.

Table 1. Characteristics of the study group.

	N	%
Number of patients	40	100
Number of implants	40	100
Male/ Female	18/22	45/55
Implant location		
Central incisor	30	75
Lateral incisor	8	20
Canine	2	5
Facial marginal recession		
Presence/ Absence	14/26	35/65
Papillary recession		
Presence/ Absence	8/66	10.8/89.2
Dental plaque		
Presence/ Absence	27/13	67.5/32.5
Peri-implant biotype		
Thin/ Thick	7/33	17.5/82.5
Implant position		
Buccal/ Lingual	8/32	20/80

To identify factors that possibly affected the peri-implant mucosal recession, a number of parameters were measured and analyzed. The mean ± S.D. and range of these measurements were presented in Table 2.

Table 2. Measurements used for analysis.

Variables	Mean ± S.D.	Range
Facial marginal recession (mm)	0.5 ± 0.9	-1.0 - 2.9
Facial bone crest level (mm)	4.8 ± 3.2	1.8 - 13.7
Facial bone crest thickness (mm)	1.2 ± 0.6	0.4 - 2.8
Implant fixture angle (degree)	58.1 ± 7.9	39.6 -75.3
Mid-facial probing depth (mm)	2.6 ± 1.0	1.0 - 7.0
Proximal probing depth (mm)	3.3 ± 0.9	2.0 - 7.0
Contact point to bone crest (CP-BC) (mm)	5.1 ± 1.1	2.9 - 9.0
Contact point to platform (CP-P) (mm)	6.7 ± 1.8	3.3 - 10.6
Contact point to implant bone (CP-IB) (mm)	8.8 ± 1.9	3.7 - 13.1
Inter implant-tooth distance (ITD) (mm)	2.7 ± 1.1	0.4 - 5.2

The association between each variable and papilla index score was shown in Table 3 and 4. Categorical variables including facial marginal recession, dental plaque, peri-implant biotype, and implant position were not significantly associated with the papilla score. Among continuous variables, the distance between contact point to bone crest was the only factor significantly associated with the papilla score. The contact point to bone crest distance of the papilla score of 0 was significantly greater than those of the papilla score of 2 and 3.

Table 3. The association between categorical variables and papilla index.

Jemt index score	0	1	2	3	*p*-value[†]
Number of papillae	3	5	39	27	-
Facial marginal recession					
Presence/ Absence	2/1	2/3	12/27	9/18	0.66
(%)	(66.7/ 33.3)	(40/60)	(30.8/69.2)	(33.3/66.7)	
Dental plaque					
Presence/ Absence	1/2	2/3	25/14	21/6	0.17
(%)	(33.3/66.7)	(40/60)	(64.1/35.9)	(77.8/22.2)	
Peri-implant biotype					
Thin/ Thick	2/1	1/4	6/33	4/23	0.18
(%)	(66.7/33.3)	(20/80)	(15.4/84.6)	(14.8/85.2)	
Implant position					
Buccal/ Lingual	0/3	1/4	8/31	7/20	0.95
(%)	(0/100)	(20/80)	(20.5/79.5)	(25.9/74.1)	

[†] Fisher's exact test

Table 4. The association between continuous variables (mean ± S.D.) and papilla index.

Jemt index score	0	1	2	3
Proximal probing depth (mm)	2.7 ± 0.6	3.5 ± 0.4	3.4 ± 0.9	3.3 ± 1.1
Contact point to bone crest (mm) †	7.4 ± 1.7	5.5 ±0.9	5.1 ± 1.0	4.7 ± 0.9
Contact point to platform (mm)	7.8 ± 2.2	6.3 ± 0.9	7.0 ± 1.8	6.3 ± 1.8
Contact point to implant bone (mm)	9.7 ± 3.3	9.0 ± 0.9	9.0 ± 1.8	8.3 ± 2.0
Inter implant-tooth distance (mm)	1.8 ± 1.4	2.9 ± 1.2	2.9 ± 1.0	2.6 ± 1.0
Facial crest level (mm)	3.1 ± 0.7	5.5 ± 4.0	4.1 ± 2.3	6.0 ± 4.0
Facial crest thickness (mm)	1.4 ± 0.5	1.3 ± 0.8	1.2 ± 0.6	1.2 ± 0.6
Implant fixture angle (degree)	58.3 ± 5.3	58.5 ± 8.4	60.3 ± 7.6	55.4 ± 7.3

† Tukey's test for multiple comparisons.

** $p < 0.01$, *** $p < 0.001$.

The association between each variable and facial marginal recession was shown in Table 5 and 6. Facial marginal recession was categorized into 3 groups: <0.49 mm, 0.5-0.99 mm, and ≥1.00 mm. Peri-implant biotype was significantly associated with facial marginal recession whereas dental plaque and implant position were not. There were significantly differences in the implant fixture angle, the distance from contact point to bone crest, contact point to platform, as well as contact point to implant bone among different facial marginal recession group. However, we did not observe significant difference in the facial probing depth, facial crest level, facial crest thickness and inter implant-tooth distance among different facial marginal recession group.

Table 5. The association between categorical variables and facial marginal recession.

Facial marginal recession (mm)	<0.49	0.50-0.99	≥1.00	*p*-value[†]
Number of implants	19	7	14	-
Dental plaque				
Presence/ Absence	14/5	4/3	9/5	0.74
(%)	(73.7/26.3)	(51.7/42.9)	(64.3/35.7)	
Peri-implant biotype				
Thin/ Thick	1/18	0/7	6/8	0.01*
(%)	(5.3/94.7)	(0/100)	(42.9/57.1)	
Implant position				
Buccal/ Lingual	3/16	2/5	3/11	0.87
(%)	(15.8/84.2)	(28.6/71.4)	(21.4/78.6)	

[†] Fisher's exact test.

* $p < 0.05$.

Table 6. The association between continuous variables (mean ± S.D.) and facial marginal recession.

Facial marginal recession (mm)	<0.49	0.50-0.99	≥1.00
Facial probing depth (mm)	2.8 ± 1.2	2.4 ± 0.8	2.4 ± 0.9
Facial crest level (mm)	3.7 ± 1.3	4.4 ± 3.4	6.6 ± 4.2
Facial crest thickness (mm)	1.3 ± 0.7	1.2 ± 0.6	1.1 ± 0.4
Implant fixture angle (degree) †	61.1 ± 6.2	58.5 ± 6.5	53.7 ± 8.9
			*
Contact point to bone crest (mm) †	4.6 ± 0.8	5.1 ± 1.0	5.7 ± 1.0
			**
Contact point to platform (mm) †	6.1 ± 1.7	6.3 ± 1.4	7.9 ± 1.2
			**
			*
Contact point to implant bone (mm) ‡	8.0 ± 2.0	8.8 ± 0.6	9.9 ± 1.2
			**
Inter implant-tooth distance (mm)	2.7 ± 0.8	2.5 ± 0.5	3.0 ± 0.6

† Tukey's test, ‡ Tamhane's T2 test for multiple comparisons.

* $p < 0.05$, ** $p < 0.01$.

Binary logistic regression analysis was further used to determine the effect of each variable on the presence/ absence of facial marginal recession as well as the presence/ absence of papillary recession. Facial marginal recession was considered "presence" when recession was ≥1 mm. Papillary recession was considered "presence" when Jemt papilla score was 0 and 1. The odds ratios and 95% confidence intervals for the risk of facial marginal recession and papillary recession was shown in Table 7. Facial marginal recession was influenced by multiple factors. Increased risk of facial marginal recession was significantly associated with thin peri-implant biotype, increased facial bone crest level, increased distance form contact point to bone crest, contact point to platform, and contact point to implant bone. Conversely, increased implant fixture angle was associated with decreased risk for marginal recession. Thin biotype was the most significant factor in determining the presence of facial marginal recession. In contrast, the distance from contact point to bone crest was the only factor significantly associated with the risk for papillary recession.

Table 7. The odds ratios and 95% confidence intervals for the risk of facial marginal recession and papillary recession.

Variables	Facial marginal recession		Papillary recession	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Thin peri-implant biotype	18.8 (2.0-180.0)	0.01*	4.0 (1.0-16.7)	0.06
Buccal position of implant	2.3 (0.5-10.1)	0.26	1.3 (0.3-5.7)	0.70
Facial bone crest level (mm)	1.3 (1.0-1.7)	0.03*	1.0 (0.8-1.2)	0.81
Facial bone crest thickness (mm)	0.5 (0.1-1.8)	0.29	1.5 (0.5-4.7)	0.48
Implant fixture angle (degree)	0.9 (0.8-0.99)	0.02*	1.0 (0.9-1.1)	0.94
Contact point to bone crest (mm)	3.4 (1.3-8.8)	0.01*	2.9 (1.3-6.3)	0.007*
Contact point to platform (mm)	2.3 (1.3-4.2)	0.005*	1.0 (0.7-1.6)	0.84
Contact point to implant bone (mm)	2.4 (1.2-4.7)	0.01*	1.2 (0.8-1.8)	0.46
Inter implant-tooth distance (mm)	2.4 (0.8-7.1)	0.13	0.8 (0.4-1.6)	0.52

* $p<0.05$.

The patients' satisfaction on the dental implants was shown in Table 8. The average VAS score of all 8 variables was 80.5%. For esthetic–related variables, the patients showed high overall esthetic satisfaction (84.5%), and high satisfaction on crown shape and color. However, their satisfaction on the harmonization of gingival margin was relatively low (67.4%). For lifestyle–related variables, high satisfaction scores were shown for all except for the comfort when chewing or biting (71%). Overall, the patient thought that the dental implant treatment was worth the expense with the highest satisfaction score of 88.9%.

Table 8. The VAS scores for esthetic-related variables (1-4) and lifestyle-related variables (5-8) assessed by patients.

Variables	Mean ± S.D. (%)	Range (%)
1. Harmonization of gingival margin	67.4 ± 27.1	0-100
2. Crown color	80.8 ± 18.5	44.0-100
3. Crown shape	82.9 ± 16.9	45.0-100
4. Satisfaction with esthetic	84.5 ± 13.6	44.0-100
5. Confidence when smiling	79.8 ± 18.7	38.5-100
6. Comfort when chewing or biting	71.0 ± 25.1	6.0-100
7. Speak well	87.3 ± 15.0	44.0-100
8. Worth for the expense	88.9 ± 16.6	21.0-100

Finally, we examined whether the presence of facial marginal recession (≥1 mm) or papillary recession (Jemt papilla score 0 and 1) affected the VAS score assessed by patients. The data were shown in Table 9. We found that the presence of marginal or papillary recession had no significant effect on patients' VAS scores for all variables, excepted for satisfaction when speaking which found to be significantly impacted by being presence of papillary recession (p=0.01).

Table 9. Association between the presence of marginal/ papillary recession and the average VAS scores assessed by patients.

Variables	Facial marginal recession	Papillary recession
	p-value	*p*-value
Harmonization of gingival margin †	0.95	0.11
Crown color †	0.32	0.59
Crown shape †	0.35	0.14
Satisfaction with esthetic †	0.31	0.60
Confidence when smiling †	0.54	0.67
Comfort when chewing or biting	0.19 †	0.26 ‡
Speak well ‡	0.55	0.01*
Worth for the expense ‡	0.91	0.07

† Independent samples T-test, ‡ Mann-Whitney U test.

* p<0.05.

CHAPTER V

DISCUSSION

Peri-implant soft tissue recession is a major esthetic complication, especially in the anterior maxilla. The present study showed that facial marginal recession and papillary recession around anterior single-tooth implants was influenced by multiple factors. Using logistic regression analysis, we showed that the distance form contact point to alveolar bone crest of the adjacent tooth was a significant factor that influenced the presence of papillary recession (OR=2.9; 95% CI=1.3-6.3). As the distance from contact point to bone crest increased, the risk of papillary recession increased. This finding was in agreement with other studies (Choquet et al., 2001; Palmer et al., 2007; Ryser et al., 2005). The complete papilla fill has been observed when the distance from contact point to bone crest was less than 5 mm. In our study, the group with complete papilla filled had a mean distance from contact point to bone crest of 4.7 ± 0.9 mm. This finding emphasized the need to maintain the crestal bone of the adjacent teeth to maintain the papilla.

Several studies showed that the inter-implant and inter implant-tooth distance was an importance factor which influenced the presence or absence of interproximal papilla (Lops et al., 2008; Romeo et al., 2008; Tarnow et al., 2000). The importance of

this horizontal distance was first suggested by Tarnow (Tarnow et al., 2000). They found that the average crestal bone loss between two adjacent implants placed >3 mm apart was 0.45 mm whereas the crestal loss for two adjacent implants placed ≤3 mm apart was 1.04 mm. Therefore, it was concluded that reduced crestal bone height may affect inter-implant papilla fill and a minimum distance of 3 mm was recommended to retain crestal bone height. Studies of single-tooth implants showed that the interproximal papilla was significantly present when the implant-tooth distance was 3-4 mm (Lops et al., 2008; Romeo et al., 2008). Therefore, they recommended interproximal space dimensions of 3-4 mm between an implant and the adjacent tooth. Our study and others, however, did not observe the effect of inter implant-tooth distance on papillary recession (Palmer et al., 2007; Ryser et al., 2005). This horizontal distance may be more critical for papilla fill in case of two adjacent implants than a single-tooth implant.

Soft tissue biotype was used to describe the thickness of gingiva in a bucco-lingual dimension. Studies showed that the mucosal thickness at implants was twice thicker than that of natural teeth (2-2.2 vs 1-1.1 mm) (Cardaropoli et al., 2006; Chang et al., 1999b). Hence, the prevalence of thin biotype around implants is likely to be less than that of natural teeth. In our study samples, thin biotype was observed in 17.5% of implants, as compared to 45% of adjacent natural teeth. All implants with thin biotype also had thin gingival biotype of adjacent natural teeth (data not shown). Romeo et al.

studied 48 single-tooth implants (Romeo et al., 2008). They showed that complete fill of interproximal papilla was significantly correlated with thick peri-implant biotype. We observed higher proportion of subjects with thin biotype in groups with lower papilla score (Table 3). However, the association between thin peri-implant biotype and papillary recession did not reach statistical significance (OR=4.0; 95% CI=1.0-16.7) in logistic regression analysis. The small number of subjects with thin biotype may contribute to the finding.

We showed that the presence of facial marginal recession was affected by multiple factors including peri-implant biotype, facial bone crest level, implant fixture angle, the distance from contact point to bone crest, contact point to platform, and contact point to implant bone. We observed a mean facial marginal recession of 0.5 ± 0.9 mm. This was within the range reported by other studies (Cardaropoli et al., 2006; Chang et al., 1999b; Evans and Chen, 2008; Jemt et al., 2006; Priest, 2003). Peri-implant biotype has been shown to influence the facial marginal recession. Evan and Chen found that thin peri-implant biotype sites showed greater recession than thick biotype sites (mean 1 vs 0.7 mm) (Evans and Chen, 2008). The difference was not statistically significant. In addition, sites with thin tissue biotype had a higher frequency of recession of ≥1mm compared to thick sites (48.5% vs 33.3%). In our study, peri-implant biotype was significantly associated with facial marginal recession

(Table 5). Moreover, logistic regression analysis showed that peri-implant biotype was a major factor that influenced facial marginal recession (OR=18.8; 95% CI=2.0-180.0). The mean facial recession at thin biotype sites was also significantly greater than at thick sites (1.4 ± 0.8 vs 0.4 ± 0.7 mm, $p<0.001$) (data not shown). Therefore, sites with thin tissue biotype should be regarded as having a greater risk of facial marginal tissue recession when compared with thick sites.

Soft tissue topography was determined by the underlying osseous architecture. The position of facial soft tissue margin may therefore be influenced by the facial bone crest level and thickness. The present study showed that facial marginal recession around single-tooth implants was significantly affected by the facial crest level, but not the facial crest thickness. Clinically, the level and thickness of facial bone crest can be determined by surgical exposure or bone sounding. Surgical exposure provided accurate measurements but can only perform in conjunction with the implant surgery. The surgical measurement was not possible following implant restorations.
Bone sounding is an alternative to surgical exposure. With local anesthesia, bone sounding can be used to measure the bone crest level after implant restorations. However, the contour of the restorations may hinder the accurate measurement.
The present study used the computerized tomography to determine the facial bone crest level and thickness. This method is non-invasive and allows measurements after

implant restorations. The density profile was used to allow objective determination of facial crest thickness. Kan et al. identified the bone crest of maxillary anterior implants by sounding through the peri-implant sulcus (Kan et al., 2003). The mean facial crest level measured from facial gingival margin to bone crest was 3.6 ± 0.9 mm. Clinical data regarding the peri-implant probing depth and mean facial marginal recession were not reported. Our study showed a mean facial probing depth of 2.6 ± 1.0 mm, facial recession of 0.5 ± 0.9 mm, and facial crest level of 4.8 ± 3.2 mm. The discrepancy of the crest level may be due to different methods used to determine the crest level and different characteristic of the study groups.

Facial bone thickness has been shown to influence the vertical resorption of the facial crest (Spray et al., 2000). This may in turn have an effect on facial marginal recession. Spray et al. measured facial bone thickness with a caliper at 0.5 mm from the crest (Spray et al., 2000). The mean facial bone thickness was 1.7 mm at time of implant insertion. A mean facial crestal bone loss of 0.7 mm was observed between the time of implant insertion and uncovering. The facial crestal resorption was less pronounced as the facial bone thickness increased. They recommended that a facial bone thickness of 1.8 mm should be left at time of implant insertion to avoid crestal loss. The mean facial crest thickness in our study was 1.2 ± 0.6 mm which may reflect the thin bone dimension of the anterior maxilla. We showed that the mean facial crest thickness

decreased as the degree of facial recession increased. However, the association between facial crest thickness and facial recession was not statistically significant (Table 6 and 7). To our knowledge, this study was the first to evaluate the effect of facial crest level and thickness on facial mucosal recession around dental implants.

Bucco-lingual position of the implant has been shown to be a significant factor in determining the degree of facial marginal recession. Evan and Chen retrospectively studied 47 single-tooth implants in the anterior and premolar region (Evans and Chen, 2008). They found that implants with a shoulder position at or buccal to a line drawn between the cervical margins of adjacent teeth demonstrated three times more recession than implants with a shoulder position lingual to this line. Buser et al. recommended that the implant shoulder should be placed 1-2 mm lingual to the emergence of the adjacent teeth to ensure maintenance of an adequate width of buccal bone and stable mucosa over the buccal implant surface (Buser et al., 2004). In our study, the buccal position of implants was not significantly associated with the risk of facial recession. The study by Evan and Chen used immediate placement whereas ours used delayed placement protocol. Whether different placement protocol contributed to the different finding was unknown. More studies are needed to clarify the influence of bucco-lingual implant position on facial recession.

We showed that the implant fixture angle was another factor that affected facial marginal recession. A group with facial recession <0.49 mm had a mean implant fixture angle of 61.1 degree whereas a group with facial recession ≥1 mm had a mean implant fixture angle of 53.7 degree. This difference was statistically significant (Table 6). Logistic regression analysis also showed that the implant fixture angle was inversely related to the degree of facial recession (OR=0.9; 95% CI=0.8-0.99). In other words, more proclined implant position significantly increased the risk of facial recession. Pronounced facial bone resorption is a common consequence after tooth extraction in the anterior maxilla. Implant placement based on the residual bone may result in a too proclined implant position and increased risk of facial recession. Therefore, good planning and performing necessary ridge augmentation procedure are important to achieve proper implant angulation.

The apico-coronal position or depth of implant placement has been suggested to be an important factor in determining the stability of peri-implant mucosa (Buser et al., 2004; Kois, 2001). We showed that as the implant platform located deeper, more facial marginal recession was observed. Increased distance form contact point to implant platform was strongly associated with the risk of facial marginal recession (OR=2.3; 95% CI=1.3-4.2). Deep implant placement may lead to thick soft tissue height and deep

probing depth. It was well documented that periodontal pathogens such as *Porphyromonas gingivalis* were frequently found at peri-implant sites with deep probing depth (Mombelli et al., 1987). Presence of these pathogens may lead to an increase risk of peri-implant bone resorption and mucosal recession.

The interproximal bone crest level and the level of first bone to implant contact were also associated with facial marginal recession. In this study, increased distance from contact point to bone crest as well as from contact point to implant bone significantly increased the risk for facial marginal recession with odds ratios of 3.4 and 2.4, respectively. It is interesting that the level of interproximal bone crest determined the risk for both facial and papillary recession whereas the level of first bone to implant contact determined the risk for facial marginal recession, but not the papillary recession. Therefore, keeping interproximal bone crest intact was critical for the stability of interproximal papilla and facial mucosa. In addition, maintaining bone level adjacent to implant fixtures was important to prevent facial marginal recession. We also determined whether there was any relationship between facial and papillary recession. We found that the presence or absence of facial marginal recession was not associated with papilla score. In other words, presence of facial marginal recession and papillary recession appeared to be independent.

The patients included in the present study showed high overall satisfaction (80.5%) on their implant restorations. The result was in agreement with previous studies which reported above 80% VAS score on the satisfaction with esthetic and function of single-tooth implant restorations (Chang et al., 1999a; Chang et al., 1999b; De Rouck et al., 2008; Wannfors and Smedberg, 1999). However, the satisfaction score for the harmonization of gingival margin was relatively low (67.4%). This may be due to the fact that one-third of the study subjects had the facial marginal recession ≥1 mm. Nonetheless, the presence of facial marginal recession alone did not appear to affect their overall satisfaction (Table 9). When lifestyle-related variables were evaluated, the patients gave the highest satisfaction score to the “worth for the expense” variable (88.9%). This implied that the patients perceived dental implant treatment as worthwhile although it costs higher than other methods of tooth replacement. The patients gave a relatively low VAS score for the “comfort when biting or chewing” variable (71%). Moberg et al. also observed the similar finding. Approximately one-third of their study subjects that received single-tooth maxillary implants reported that they avoided chewing and biting with their implants (Moberg et al., 1999). The patients should, therefore, be informed that implant restorations are not more prone to damage caused by normal diet than natural teeth or other type of restorations.

Moreover, we found that the presence of papillary recession was significantly affected on their satisfaction when speaking (p=0.01). Since patients who having papillary recession were less satisfied with their pronunciation compared to the group with intact papillae (73.5% vs 89.3%; data not shown). Levi et al. reported that "speech" problem was one of the significant factors that justified patients' satisfaction on overall dental implant treatment (Levi et al., 2003). The result from the present study emphasized the impact of having papillary recession at an implant site on the phonetic problem, which may affect the patient's quality of life.

Due to the cross-sectional nature of this study, there were several limitations. The degree of gingival recession was determined by comparing with the natural contralateral tooth. This may not reflect the true change of the gingival level of the implant. However, this measurement was still of clinical value since the patient and clinician's perception on gingival recession was usually based on the symmetry between the right and left side. In this study, each variable that possibly affected soft tissue recession was analyzed separately. However, it should be kept in mind that clinically these factors were inter-related. For example, an implant placed too far facially was often related with more proclined implant axis. This position may lead to the resorption of facial bone crest both horizontally and vertically with subsequent soft tissue

recession. The cross-sectional nature of the study only allowed us to determine the association between the proposed factors and soft tissue recession. A future prospective study is required to determine whether the factors associated with soft tissue recession in this study are true risk factors. In addition, a complex relationship between each factor may be resolved with a larger sample size.

In conclusion, the present study showed that papillary recession around single-tooth implants in the anterior maxilla was mainly influenced by the interproximal bone crest level of the adjacent tooth. Facial marginal recession, on the other hand, was affected by multiple factors including peri-implant biotype, facial bone crest level, implant fixture angle, the interproximal bone crest level, the depth of implant platform, and the level of first bone to implant contact. Overall, patients were highly satisfied with their single-tooth anterior maxillary implant therapy. However, future prospective studies are required to identify the relative risk of these factors.

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APPENDICES

Case record form

1. Clinical examination chart

Subject No. _____

Name_____ Age_____

H.N._____

Tel._____ Date_____

	#	14			13			12			11			21			22			23			24		
B	PD																								
L	PD																								

- PD (mm) = Probing depth (6 sites/tooth)

- Oral hygiene status:

  ☐ Presence of dental plaque ☐ Absence of dental plaque

- Gingival biotype: ☐ Thick ☐ Thin

- Average proximal PD of implant: _____mm

- Mid-facial PD of implant: _____mm

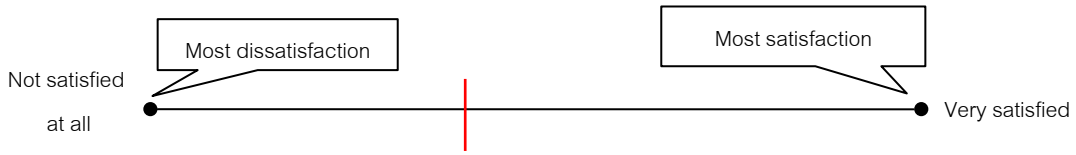
2. Patient's satisfaction with the appearance and function of the implant restorations

2.1 English version:

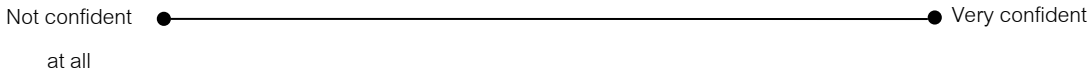
Subject No. _____

Please draw only one vertical line across the horizontal one to demonstrate your satisfaction as seen in an example.

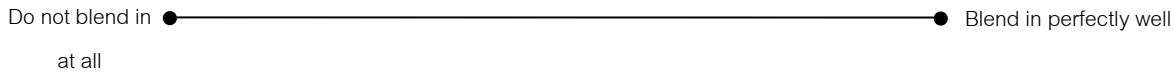
Example:



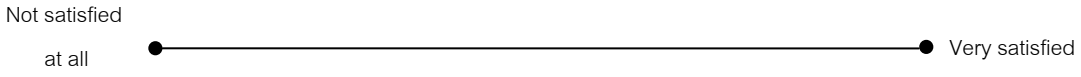
1. How confident do you feel about your smile?



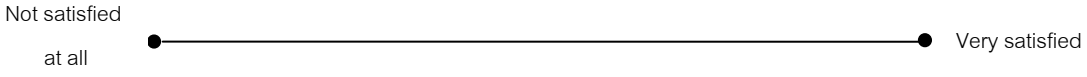
2. Do you think your gingival margin in your implant area blend in well with your nearby teeth or not?



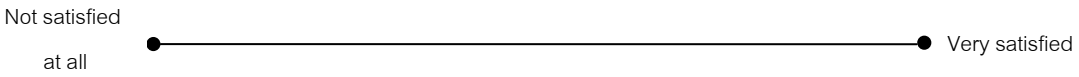
3. How much do you satisfy with the color of your implant crown?



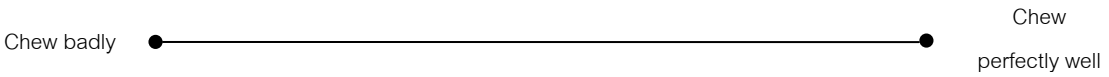
4. How much do you satisfy with the contour and shape of your implant crown?



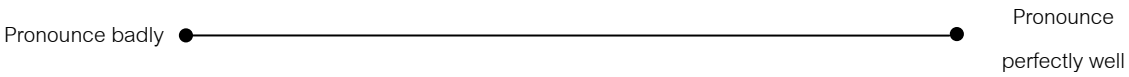
5. Overall, how much do you satisfy with your dental implant?



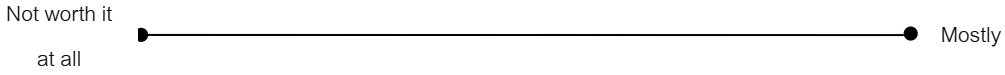
6. Can you use the implant tooth in chewing well or not?



7. Can you use the implant tooth in pronunciation well or not?



8. Do you think dental implant is worth your expense?



% Satisfaction = _____

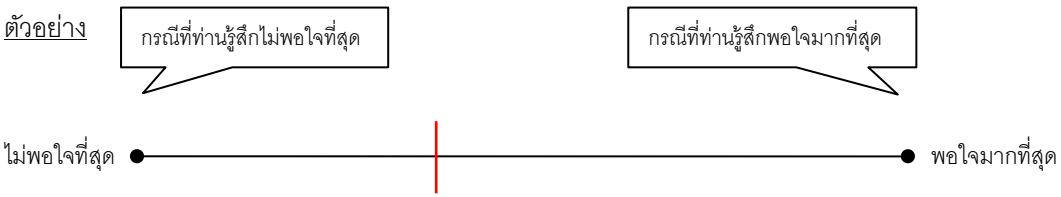
2.2 Thai version:

Subject No. _____

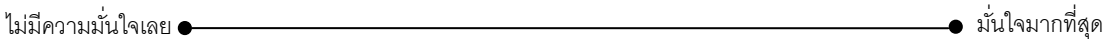
<u>แบบสอบถามประเมินระดับความพึงพอใจภายหลังการบูรณะฟันด้วยรากเทียมบริเวณฟันหน้าบน</u>

กรุณา<u>ขีดเส้นในแนวตั้ง</u>แสดงระดับความพึงพอใจ<u>เพียงเส้นเดียว</u>ลงบนเส้นตรงในแนวนอน ดังตัวอย่าง

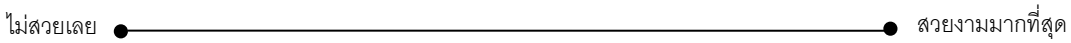
<u>ตัวอย่าง</u>



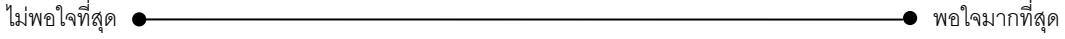
1. ท่านรู้สึกมีความมั่นใจในรอยยิ้มของท่านมากน้อยในระดับใด



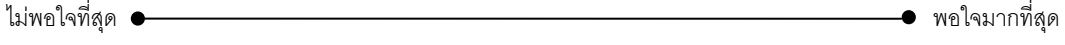
2. ท่านคิดว่าขอบเหงือกบริเวณรากเทียมมีความสวยงามกลมกลืนไปกับฟันข้างเคียงหรือไม่



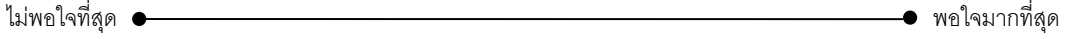
3. ท่านพอใจกับ “สีของครอบฟัน” บนรากเทียมในระดับใด



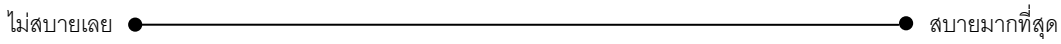
4. ท่านพอใจกับ “รูปร่างของครอบฟัน” บนรากเทียมในระดับใด



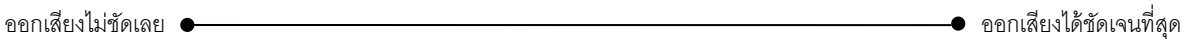
5. โดยภาพรวมแล้วท่านรู้สึกพอใจในความสวยงามของรากเทียมในระดับใด



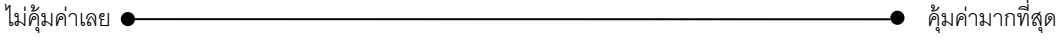
6. ท่านสามารถใช้ฟันที่บูรณะด้วยรากเทียมในการ “เคี้ยวหรือกัดอาหาร” ได้อย่างสบายหรือไม่



7. ท่านสามารถใช้ฟันที่บูรณะด้วยรากเทียมในการ “พูดออกเสียง” ได้ชัดเจนหรือไม่



8. ท่านคิดว่าการบูรณะฟันด้วยรากเทียมให้ประโยชน์คุ้มค่ากับค่าใช้จ่ายหรือไม่



% Satisfaction = _____

3. Data from clinical examination

Subject No. _____

Clinical variables	Grouping (implant site only)
Oral hygiene	☐ Plaque presence (1) ☐ Plaque absence (2)
Peri-implant biotype	☐ Thin (1) ☐ Thick (2)
Natural tooth biotype	☐ Thin (1) ☐ Thick (2)

4. Data from the study models

Subject No. _____

Clinical crown height (mm)	Measure 1	Measure 2	Measure 3	Average	Marginal recession (≥ 1 mm)
Implant #_____					☐ Presence (1) ☐ Absence (2)
Contralateral tooth #_____					

5. Data from the periapical radiographs

Subject No. _____

Distance (mm)	mesial	distal	average
Contact point to implant platform (CP-P)			
Contact point to bone crest (CP-BC)			
Contact point to implant bone (CP-IB)			

6. Data from the CT images

Subject No. _____

Facial bone thickness (mm) (0.5 mm from crest)	
Facial bone crest level (mm)	
Implant fixture angle (degree)	
Bucco-lingual implant position (buccal/lingual)	☐ Buccal position ☐ Lingual position

7. Data from chart record

Subject No. _____

- Type of implant
- Date of implant placement and details of surgical procedure
- Date of insertion of permanent restoration

เอกสารยินยอมเข้าร่วมการวิจัย (Consent Form)

การวิจัยเรื่อง
“ปัจจัยที่มีผลต่อการร่นของเหงือกรอบรากเทียมแบบหนึ่งชิ้นบริเวณฟันหน้าบน”

การมีเหงือกร่นในฟันหน้าที่ได้รับการบูรณะด้วยรากเทียมเป็นปัญหาที่สำคัญที่มีผลโดยตรงต่อความสวยงามของรากเทียม กลุ่มผู้วิจัยจึงได้ดำเนินการวิจัยนี้เพื่อศึกษาปัจจัยที่มีผลต่อการเกิดเหงือกร่นของรากเทียม โดยทำการตรวจวัดสภาพเหงือกรอบรากเทียม รวมทั้ง ทำการถ่ายภาพรังสีแบบ 3 มิติ เพื่อศึกษาระดับกระดูกรอบรากเทียม ความรู้จากการศึกษานี้จะช่วยให้เข้าใจปัจจัยที่มีผลต่อการเกิดเหงือกร่นของรากเทียมได้ดีขึ้น ซึ่งจะเป็นประโยชน์ในการป้องกันการเกิดเหงือกร่นรวมทั้งรักษาอาการเหงือกร่นของรากเทียมได้ ผู้เข้าร่วมวิจัยจะได้รับการตรวจสภาพเหงือกรอบรากเทียม ถ่ายภาพฟันหน้าที่ได้รับการบูรณะด้วยรากเทียม พิมพ์แบบจำลองฟัน และถ่ายภาพรังสีรอบปลายรากและคอมพิวเตอร์ 3 มิติ โดยไม่เสียค่าใช้จ่าย
ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัยอย่างละเอียด และมีความเข้าใจดีแล้ว ข้าพเจ้าเข้าร่วมโครงการวิจัยนี้โดยสมัครใจ ข้าพเจ้ามีสิทธิที่จะบอกเลิกการเข้าร่วมในโครงการวิจัยนี้เมื่อใดก็ได้และการบอกเลิกการเข้าร่วมการวิจัยนี้ จะไม่มีผลต่อการรักษาที่ข้าพเจ้าจะพึงได้รับต่อไป ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะเกี่ยวกับตัวข้าพเจ้าเป็นความลับ และจะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆ ที่เกี่ยวข้องกระทำได้เฉพาะกรณีจำเป็น ด้วยเหตุผลทางวิชาการเท่านั้น

ข้าพเจ้าได้อ่านข้อความข้างต้นแล้ว และมีความเข้าใจดีทุกประการ และได้ลงนามในใบยินยอมนี้ด้วยความเต็มใจ

ลงนาม.....ผู้ยินยอม
(.....)
ลงนาม.....พยาน
(.....)
ลงนาม.....พยาน
(.....)
ลงนาม.....หัวหน้าโครงการวิจัย
(.....ทญ.สุปรีดา..สุภนันตชาติ.....)
วันให้คำยินยอมเข้าร่วมวิจัย วันที่.....เดือน.....พ.ศ.....

BIOGRAPHY

Miss Supreda Suphanantachat was born on 22th of July 1982 in Bangkok City. She graduated the elementary and high school education from Patumwan Demonstration School, Bangkok. In 2006, she earned her Doctor of Dental Surgery degree with second class honor from Chulalongkorn University. She used to serve the government as a general dentist at Klaeng Hospital, Rayong in year 2006. Subsequently, she worked as a general dentist at Thammasat Chalermprakiat Hospital, Pathumthani. Presently, she practices in private dental clinics, Bangkok. At the same time, she attends the Master of Science Program in Periodontics, Department of Periodontology, Faculty of Dentistry, Chulalongkorn University in year 2007. She was granted 90th Anniversary of Chulalongkorn University Fund (Ratchadapiseksomphot Endowment Fund) for the Master degree's research.