THE OVERALL ESTHETIC ASSESSMENT OF ANTERIOR SINGLE-TOOTH IMPLANT RESTORATION: MODIFIED OBJECTIVE CRITERIA

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จุฬาลงกรณ์มหาวิทยาลัย
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บทคัดย่อและแฟ้มข้อมูลฉบับเต็มของวิทยานิพนธ์ตั้งแต่ปีการศึกษา 2554 ที่ให้บริการในคลังปัญญาจุฬาฯ (CUIR)
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นายพงศกร โกมุทผล

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาทันตกรรมบูรณะเพื่อความสวยงามและทันตกรรมรากเทียม
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Thesis Title	THE OVERALL ESTHETIC ASSESSMENT OF ANTERIOR SINGLE-TOOTH IMPLANT RESTORATION: MODIFIED OBJECTIVE CRITERIA
By	Mr. Pongsakorn Komutpol
Field of Study	Esthetic Restorative and Implant Dentistry
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พงศกร โกมุทผล : การประเมินความสวยงามโดยรวมของงานบูรณะฟันด้วยรากเทียมบริเวณฟันหน้าแบบหนึ่งซี่โดยการปรับเปลี่ยนเกณฑ์วัตถุพิสัย (THE OVERALL ESTHETIC ASSESSMENT OF ANTERIOR SINGLE-TOOTH IMPLANT RESTORATION: MODIFIED OBJECTIVE CRITERIA) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ทพ. ดร. อาทิพันธุ์ พิมพ์ขาวขำ, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ. ทพ. ดร. สุนทรา พันธ์มีเกียรติ, 123 หน้า.

วัตถุประสงค์: เพื่อศึกษาถึงความสัมพันธ์ของผลการประเมินด้านความสวยงามของงานบูรณะฟันด้วยรากเทียมแบบหนึ่งซี่โดยใช้เกณฑ์การประเมินพิงค์เอสเตติกสคอร์/ไวท์เอสเตติกสคอร์และเกณฑ์การประเมินแบบใหม่ที่มีการปรับแต่งวัตถุพิสัย

วัสดุและวิธีการทดลอง: การศึกษาย้อนหลังแบบตัดขวาง 5 ปีนี้ ได้รวบรวมคนไข้ที่มีการบูรณะฟันตัดกลางบนด้วยรากเทียมแบบหนึ่งซี่จำนวน 26 คนโดยคนไข้เหล่านี้ได้ถูกตรวจเชคสภาพรากเทียมซึ่งประกอบด้วยการบันทึกข้อมูลทั่วไป , ถ่ายภาพในช่องปาก , ถ่ายภาพรังสีรอบรากเทียมและถ่ายภาพรังสีสามมิติ หลังจากนั้นผู้ทำการทดสอบได้ประเมินความสวยงามของรากเทียมดังกล่าวโดยใช้เกณฑ์การประเมินพิงค์เอสเตติกสคอร์/ไวท์เอสเตติกสคอร์ และเกณฑ์การประเมินแบบใหม่ที่มีการปรับแต่งวัตถุพิสัย (ประกอบด้วยการประเมินเหงือก , ครอบฟันบนรากเทียม และสภาพกระดูกรอบรากเทียม) โดยใช้เวลาระหว่างการประเมินทั้งสอง 2 อาทิตย์ คะแนนความสวยงามของทั้งสองกลุ่มจะถูกนำมาวิเคราะห์โดยการจัดกลุ่มแบบเคมีนและใช้อะโนวาเพื่อประเมินความแตกต่างของค่าเฉลี่ยของคะแนนความสวยงาม โดยกำหนดให้ 0.05 เป็นระดับนัยสำคัญ

ผลการทดลอง: รากเทียมที่ถูกนำมาศึกษาอยู่ในสภาพที่ดี ค่าเฉลี่ยความสวยงามของกลุ่มที่ประเมินด้วยพิงค์เอสเตติกสคอร์/ไวท์เอสเตติกสคอร์มีค่า 15.7 ± 1.9 (คะแนนเต็ม 20) , ในขณะที่ค่าเฉลี่ยคะแนนจากกลุ่มประเมินแบบปรับแต่งวัตถุพิสัยมีค่าเท่ากับ 30.7 ± 3.9 นอกจากนี้การจัดกลุ่มเคมีนสามารถแบ่งกลุ่มรากเทียมออกได้เป็น 3 กลุ่ม ได้แก่ กลุ่มคะแนนดี , ปานกลางและผกผันโดยสามารถแบ่งเหงือกและสภาพกระดูกรอบรากเทียมออกได้อย่างมีนัยสำคัญ อย่างไรก็ตามคะแนนครอบฟันบนรากเทียมไม่สามารถแยกออกจากกันได้อย่างมีนัยสำคัญ

สรุปผลการทดลอง: การสอดแทรกการประเมินกระดูกรอบรากเทียมเข้าไปในการประเมินความสวยงามรอบรากเทียมสามารถแสดงผลลัพธ์ทางความสวยงามแตกต่างออกไปโดยกลุ่มผกผันนี้ควรอย่างยิ่งที่จะได้ทำการศึกษาต่อไปถึงความยั่งยืนคงทนของความสวยงามนี้

สาขาวิชา ทันตกรรมบูรณะเพื่อความสวยงามและทันตกรรมรากเทียม ลายมือชื่อนิสิต .....

ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

ปีการศึกษา 2560 ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

5775815632 : MAJOR ESTHETIC RESTORATIVE AND IMPLANT DENTISTRY
KEYWORDS: ANTERIOR IMPLANT RESTORATION / PERI-IMPLANT BONE / ESTHETIC EVALUATION / CBCT

PONGSAKORN KOMUTPOL: THE OVERALL ESTHETIC ASSESSMENT OF ANTERIOR SINGLE-TOOTH IMPLANT RESTORATION: MODIFIED OBJECTIVE CRITERIA. ADVISOR: ASSOC. PROF. ATIPHAN PIMKHAOKHAM, Ph.D., CO-ADVISOR: ASSOC. PROF. SOONTRA PANMEKIATE, Ph.D., 123 pp.

Objectives: The aim of this study was to observe the correlation of esthetic outcomes of single-tooth implant restoration when using Pink Esthetic Score/White Esthetic Score and the new modified assessment (Modified Objective Criteria; MOC)

Materials and Methods: This crossectional retrospective study, up to 5 years, recruited 26 patients who single implant in maxillary central incisor area was placed. All the implants were recalled. Demographic data, intraoral photograph, dental model, periapical radiograph and CBCT were taken. One examiner assessed the esthetic outcomes by using PES/WES and MOC (gingiva, prosthesis and bone foundation) with 2 weeks between each evaluation. The score of both groups were analyzed by using K-mean cluster analysis. ANOVA was used to observe the different mean score among clusters, which 0.05 was the significant level.

Results: All the recalled implants were found in healthy status. The mean PES/WES was 15.7 ± 1.9 (maximum possible = 20), whereas the mean MOC was 30.7 ± 3.9. The K-mean cluster analysis could categorized the data into 3 clusters namely excellent, medium and divergent cluster, which gingiva and bone foundation score could be significantly divided, however, prosthetic part could not.

Conclusions: Combining the bone assessment into esthetic evaluation could presented the esthetic outcome differently from previous routine. The divergent group should be further observed the sustainability of esthetic.

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

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CHAPTER I INTRODUCTION

Osseointegrated endosseous dental implant has been used and confirmed its success for long period of time. Many studies guarantee the success and survival rate of the dental implant therapy with almost more than 95% [1, 2]. Papaspyridakos et al. highlighted that despite the fact of predictable treatment ,innocuous materials and reliable success/ survival rate as well as marvelous versatile appliance, the various criteria for the dental implant have been questioned, employed and developed from time to time [3].

The criteria for assessing the success of single-tooth implant restoration (STIR) comprise many aspects such as osseointegrated level, etc. The osseointegration of dental implant is still the most main concern of achievement in implant dentistry. Because of increasing in high demands of treatment and the improved implant surface, the goal of success, which previously focused on implant survival, is shifting to the dental worker ability for mimicking a lifelike restorations with natural-looking soft

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tissues around the implant [3]. Moreover, the patients require not only improved function but also natural appearance [4].

The history of esthetic parameters of anterior dental-implant restoration has been proposed in various criteria. Begin with Papilla Index, which created by Jemt in 1997 [5], focuses on full of interproximal papilla. Eight years later, two new criteria were presented, Pink Esthetic Score (PES) [6] and Implant Crown Aesthetic Index [7]. PES mainly concerned to soft tissue around implant in many dimensions while the implant Crown Aesthetic index observed both dental prosthetic and gingival aspects. After that, Subjective esthetic score (SES) was developed by Evans and Chen [8]. This parameter evaluated vertical change in mucosal margin of restoration and soft tissue contour. Recently, the two esthetic objective measurements with scoring system, which are Pink Esthetic Score/ White Esthetic Score (PES/WES) and Esthetic Outcome Objective Score were announced in 2009. PES/WES, which developed by Belser et al [9], was modified from original PES [6] combining with the new created dental prosthetic scoring system, WES, whereas the Esthetic Outcome Objective Score evaluates the esthetic outcomes of oral rehabilitation for patients with tooth agenesis [10].

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Moreover, the existing criterion could only tell the esthetically visible part of the dental implant. If its underneath bone have been changed, the covering soft tissue will possibly change. According to the systematic review of the esthetic parameters in implant dentistry, there were many criteria would be mentioned in the next chapter [11].

In order to evaluate the underneath bone, Periapical radiograph was routinely used. However, the information from the periapical film including, periimplant lesion, and most of the information show only 2 dimensions which was mesiodistal and vertical dimension. There was still lack of buccolingual view ,which very important in term of labial bone support. Thus the cone beam computed tomography (CBCT) might plays an important role in evaluation of buccolingual bone around implant. Dental CBCT demonstrated many benefits in dental implant society such as preoperative analysis regarding specific anatomic considerations, site development for bone grafts, and computer-assisted treatment planning. Furthermore, CBCT was considered as an alternative imaging in cases where the future implant recipient site needs bone graft and conventional radiography cannot evaluate the true surrounding three-dimensional

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anatomical presentation [12]. Many researches have used CBCT as postoperative assessment including observing complication due to damage of neurovascular structure and labial bone alterations on maxillary anterior implants [13-16]. The post-operative underneath bone information have been proven to relate with the covering soft tissue and sustainably maintain the visible part of the dental implant.

Taken together with the esthetic parameter of anterior dental implant should be included not only the visible pink and white but also the underneath bone foundation around dental implant as well. Therefore, the combination of visible esthetic criteria and the success bone foundation criteria would be important and need for dental professions who play more attention in sustainable esthetic result of anterior dental implant.

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The aim of this study is to assess the esthetic outcome of single-tooth implant restoration by using modified objective criteria.

CHAPTER II REVIEW OF LITERATURES

Dental professions succeed in restoring one-missing tooth by replacing with osseointegrated endosseous dental implant for decades. To suitably serve the goal of this study, many literatures have been reviewed. All the reviewed studies could be categorized into four major aspects: gingival esthetic assessment, prosthetic-beauty evaluation, morphological bone measurement and effect of radiation dose from dental CBCT to human body.

2.1 Gingival esthetic assessment

During three decades, twelve soft tissue evaluations have been proposed with diversities in form and point of focus [11]: Papilla Index [5], papilla height classification system [17], Pink Esthetic Score [6], Implant Esthetic Score [18], Subjective aesthetic score [8], Modified Jemt Papilla Index [19], the index of Chang [20], the index of Levin [21], Implant Crown Aesthatic Index[7], the index of Rompen [22], Pink and White Esthetic Score [9] and Esthetic Outcome Objective score [10].

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2.1.1. Papilla Index [5]

This criteria was first launched by mean of proposing an index to clinically evaluate the degree of recession and regeneration of interproximal papilla which is adjacent to a STIR, and to test this proposed index in a pilot study for assessing the soft tissue at the time of crown insertion and during follow-up.

The criteria was designated five different levels in accordance with the amount of presented papilla. Reference line was defined at the highest point of the gingival curvature on the implant-restored tooth and it adjacent tooth (Figure 1). The score has 0-4, which was described following the Table 1.

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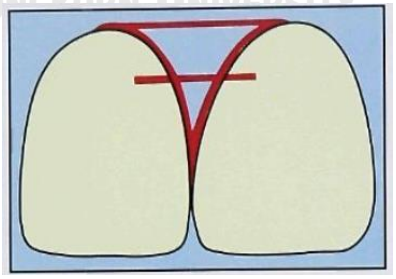
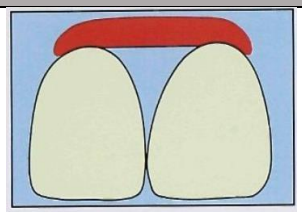
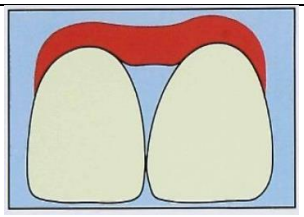
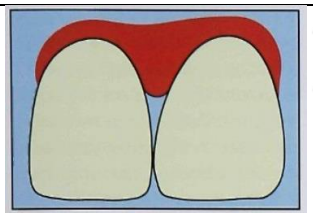
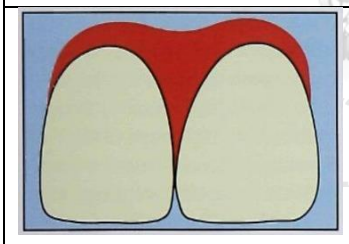
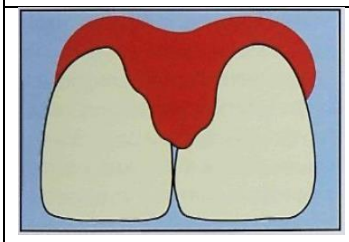


Figure 1 The reference line for evaluating the height of interdental papilla [5].

Table 1 Papilla Index [5].

Interdental papilla	score	Description
	0	- No papilla is presented - No indication of gingival curvature adjacent to the single-tooth implant restoratiion
	1	- Papilla is presented less than half of its height - A convex curvature of the soft tissue contour adjacent to the single- implant crown and the adjacent tooth is observed
	2	- At least half of the height of the papilla is presented, but not all the way up to the contact point between the teeth. Papilla is not completely in harmony with the adjacent papilla - Acceptable soft tissue contour is in harmony with adjacent teeth
	3	- The papilla is filled up the entire proximal space and is in good harmony with the adjacent papilla. - There is optimal soft tissue contour
	4	- The papillae are hyperplastic and cover too much of the single- implant restoration and/or the adjacent tooth. - The soft tissue contour is more or less irregular

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2.1.2. Papilla height classification system [17]

Nordland and Tarnow has proposed this classification which focusing on loss of papillary height. This criteria uses easily identifiable anatomical landmarks as references, and divides the degree of papillary loss into 3 classes (Table 2).

Table 2 The papilla height classification system.

Classification	Description
Normal	The interdental papilla fills embrasure space to the apical extent of the interdental contact point/area
Class I	The tip of the interdental papilla lies between the interdental contact point and the most coronal extent of the inter proximal CEJ (space present, but inter proximal CEJ is not visible)
Class II	The tip of the interdental papilla lies at or apical to the interproximal CEJ, but coronal to the apical extent of the facial CEJ (interproximal CEJ visible)
Class III	The tip of the interdental papilla lies level with or apical to the facial CEJ.

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2.1.3. Pink Esthetic Score [6]

PES was developed in 2005 with seven seperated variables. The criteria was objectively assessed the esthetic outcome of the soft tissues surrounding the dental implant restoration, designating some points that easily overlooked in a general assessment. PES values the quality of each factor by using a score of 2,1

or 0 which 2 was the best score while 0 was the worst, for a maximal possible score of 14. Except papilla, all variables were assessed by comparing to a reference tooth.

The method of that study was performed by using 30 intraoral photographs of single-tooth implants in the esthetic sensitive area of the maxilla (including first premolar area) (Figure 3). The photographs was twice magnified and printed together with the 7 following variables (Table 3).

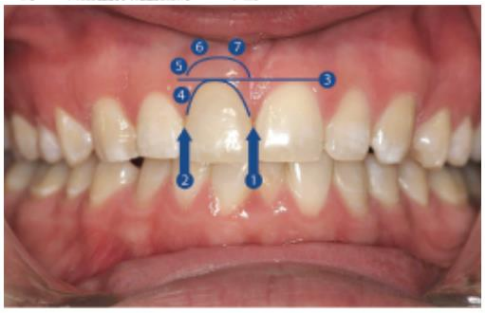

Figure 3 Pictorial view of pink esthetic score variables in the study of Furhauser et al.(6)

Table 3 The Pink Esthetic Score.

Variables		0	1	2
Mesial papilla	Shape vs. reference tooth	Absent	Incomplete	Complete
Distal papilla	Shape vs. reference tooth	Absent	Incomplete	Complete
Level of soft-tissue margin	Level vs. reference tooth	Major discrepancy >2 mm	Minor discrepancy 1–2 mm	No discrepancy <1 mm
Soft-tissue contour	Natural, matching reference tooth	Unnatural	Fairly natural	Natural
Alveolar process	Alveolar process deficiency	Obvious	Slight	None
Soft-tissue color	Color vs. reference tooth	Obvious difference	Moderate difference	No difference
Soft-tissue texture	Texture vs. reference tooth	Obvious difference	Moderate difference	No difference

2.1.4 Implant Esthetic Score [18]

This criteria was created for describing a new protocol of the implant placement. The mothod for using this evaluation can be performed by drawing a reference line (Figure 4) connecting the zenith of the teeth adjacent to the implant restoration ,then, evaluation the implant in accordance with Table 4.

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Figure 4 The reference line was a imaginary line drawn through the zenith of the CEJs of the adjacent teeth [18].

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Table 4 Implant Esthetic Score.

Variables	0	1	2
Presence and stability of the mesiodistal papilla	No papilla	Partially fill which esthetically acceptable in harmony with adjacent teeth	Total fill
Ridge stability buccopalatally	Width maintained	Width with ridge loss	
Texture of the peri-implant soft tissue	Complete loss of texture	Does not look like healthy tissue, but some texture still maintained	Looks like healthy gingival tissue around the natural teeth
Color of the peri-implant soft tissue	Completely different color from healthy tissue	Does not look like healthy tissue, but still esthetically acceptable	Looks like healthy gingival tissue around the natural teeth
Gingival contour	Evident asymmetry from the accept of patameters of scalloping	Signs of asymmetry but esthetically acceptable	Harmonious gingival contour

2.1.5. Subjective Esthetic Score (SES) [8]

By mean of reviewing the esthetic outcomes of immediate implant placement and define factors that may effect these results, Evan and Chen performed a retrospective study by collecting data of 42 patients with 47 immediate implants placement, which fullfilled their inclusion criteria, observing. Patients' photographs, assessing study models and evaluating radiographs and finally marking the esthetic results, which following Table 5

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Table 5 Subjective Esthetic Score as a part of esthetic evaluation of immediate implant placement.

Variables	Score	Description
Interdental papilla	Jemt's papilla index[5]	
Subjective evaluation score	**1**	Vertical buccal change was 0.5 mm or less and labial tissue fullness was in harmony with the adjacent teeth.
	2	Vertical buccal change was between 0.5 mm and 1 mm and the labial tissue fullness was in harmony.
	3	Vertical buccal change was between 1 and 1.5mm or if the labial tissue appears deficient in contour.
	4	Vertical buccal change was greater than 1.5 mm and a deficiency in labial tissue contour was noted.
Variables	**Score**	**Description**
Facio-lingual position	Reference line was drawn between the cervical buccal position of the adjacent teeth following the line of the arch	
	A	The buccal edge of the implant shoulder was at or buccal to the reference line
	B	The buccal edge of the implant shoulder was lingual to the reference line
Tissue biotype	Placing periodental probe into the labial gingival sulcus and catagorised as follows	
	thick	A periodontal probe could not be seen through the gingival tissue
	thin	A periodontal probe could be seen through the gingival tissue

The outcomes of the study, in term of SES, showed that 82% of the implant

restorations were satisfactory (score 1 and 2), with <1mm of buccal recession and normal labial tissue contour.

2.1.6. Modified Jemt Papilla Index [19]

This criteria was first publicised by Lars Schropp et al in 2008. fo reporting a 5-year follow-up of the outcomes of early and delayed placement of single-tooth implant restoration. An experienced prosthodontist was choosen to evaluate the clinical crown height and the interproximal papilla, at both mesial and distal aspect of the restoration, by using photographs. The examiner evaluated the gingival esthetic outcome, which focused on papilla fill. The level of the interdental papilla was catagorised into 4 levels (Table 6). In case of generalised gingival recession, the level of the distal papilla from the adjacent tooth was used as a reference line.

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Table 6 The Modified Jemt papilla index.

score	Description
0	No papilla or a negative papilla
1	Less than half of the height of the proximal area occupied by soft-tissue
2	At least half of the hetght of the proximal occupied by soft-tissue
3	Inter-proximal area completely occupied by soft-tissue

To perform an intraobsever reproducibilities, an examiner assessed the 2-year follow-up photographs twice within 6 weeks while the 5-year follow-up photographs were re-evaluated after 3 months comparing to baseline photograph. The results of the study implied that the intraobserver reproducibilities were 59% and 60%.

2.1.7 The index of Chang [20]

This esthetic criteria was first created as one part of clinical examination of that research, which want to make a comparative evaluation of crown and soft-tissue dimensions between STIR and its contralateral tooth. The assessment comprises two aspects : prosthetic dimensions and soft-tissue dimensions. Evaluation for soft-tissue aesthetic, Chang created as followed Table 7

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Table 7 The soft-tissue evaluation of Chang

Variables	Description
Width of keratinized mucosa	Clinical measurement
Thickness of mucosa	
Soft tissue margin level	
Papilla height	**Jemt papilla index** [5] by using intraoral photographs

With all the mentioned measurements, the author found that, in comparison to the contralateral natural tooth, the implant supported crown was longer, smaller in facio-lingual width, bordered by thicker mucosa, lower height of the distal papilla.

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2.1.8. The index of Levin [21]

To compare the traditional surgical survival and success criteria with different esthetic parameters in anterior maxillary single implant restoration. Levin et al. delicated their methodology by backward observing 52 STIRs, which located on upper central incisor and upper lateral incisor, 1-9 years. While the surgical success was defined on the level of marginal bone loss, The esthetic

success was developed by creating an esthetic assessment, examining with three independent dental professionals as showed on Table 8. The esthetic success was evakuated by the examiners' satisfaction and the esthetic criteria.

Table 8 Mucosal assessment of the index of Levin

Variables	Description
Interdental papilla shape	Papilla filled the entire proximal space and/or in good harmony with adjacent papilla.
Free gingival margin	Accurate form in harmony with adjacent teeth.
Attached gingival appearance	Occlusal- gingival height similar to neighboring teeth with stipple appearance.

After assessing the esthetic evaluation, Levin and colleagues defined the esthetic success by dividing in to 4 catagories:

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1. Failure: more than two esthetic parameters were unsatisfactory
2. Fairly good: two esthetic parameters were unsatisfactory
3. Good: one esthetic parameters was unsatidfactory
4. Perfect: all esthetic parameters were satisfactory

Esthetic sucess was defined as “Good” or “perfect ”, while esthetic failure was defined as “Fairly good” or “Failure”.

The results of the study showed that placing implant in the anterior has high surgical survival and success rate, as well as a high esthetic success rate. However, the high surgical success and survival rates can not predict the esthetic achievement.

2.1.9. Implant Crown Aesthetic Index [7]

The implant crown esthetic index was first proposed in 2005. The goal of that study was to developed and validated the index for evaluating the esthetic outcome of STIR and adjacent soft tissues. This index had nine variables (Table 9). Then, each variables were scored 0, 1, 2, 3, 4 or 5 as a penalty points. The penalty points were given to each variables if there was some mismatching to the desired outcome: one penalty point for minor deviation and five penalty points for major deviations.

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- 0 penalty points = excellent
- 1 or 2 penalty points = sarisfactory
- 3 or 4 penalty points = moderate
- 5 or more points = poor esthetics

Table 9 Soft tissue evaluation of the Implant Crown Aesthetic Index.

Variables	Description	Penalty points					
		0	1	2	3	4	5
Mesiodistal dimension of the crown	The dimension must be in harmony with the adjacent and contralateral tooth: grossly undercontoured, slightly undercontoured, no deviation, slightly overcontoured, grossly overcontoured.						
Position of the incisal edge of the crown	The position must be in harmony with the adjacent and contralateral tooth: grossly undercontoured, slightly undercontoured, no deviation, slightly overcontoured, grossly overcontoured.						
Labial convexity of the crown	Convexity of the labial surface of the crown must be in harmony with the adjacent and contralateral tooth: grossly undercontoured, slightly un- dercontoured, no deviation, slightly overcontoured, grossly overcontoured)						
Colour and translucency of the crown	Colour and translucency of the crown must be in harmony with the adjacent and contralateral tooth: gross mismatch, slight mismatch, no mismatch.						

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Variables	Description	Penalty points					
		0	1	2	3	4	5
Surface of the crown	Labial surface characteristics of the crown such as roughness and ridges must be in harmony with the adjacent and contralateral tooth: gross mismatch, slight mismatch, no mismatch.						
Position of mucosa in the proximal embrasures	The interdental papillae must be in their natural position: deviation of 1.5 mm or more, deviation less than 1.5 mm, no deviation						
Contour of the labial surface of the mucosa	The contour of the mucosa at the alveolar bone must be in harmony with the adjacent and contralateral tooth: grossly undercontoured, slightly undercontoured, no deviation, slightly overcontoured, grossly overcontoured.						
Color and surface of the labial mucosa	Color (redness) and surface characteristics (presence of attached mucosa) must be in harmony with the adjacent and contralateral tooth and must have a natural appearance: gross mismatch, slight mismatch, no mismatch.						

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The experiment was performed by preparing 24 slides of STIR which located in the esthetic region of the maxilla. Four examiners (two oral-maxillo facial surgeons and two prosthodontists) perfomed familiarisation with the index. The evaluation was done twice by each of examiner with 2 weeks interval.

The study concluded that The Implant Crown Aesthetic Index was an objective tool for evaluating aesthetics of implant-supported single crowns and the adjacent soft tissues. The evaluation which was carried out by one prosthodontist had the highest reliability.

2.1.10. The index of Rompen [22]

The criteria was created to evaluate the effect of a concave transmucosal profile on the vertical stability of soft tissues at the facial aspect of dental implants. Rompen et al designed their prospective study by placed fifty-four implants in esthet zone on 41 patients. With different stage approach (1-stage or 2-stage) and different abutment design (concave titanium or zirconia abutment), photographs were taken perpendicularly to the facial aspect of the artificial teeth at the time of crown placement, and at 1, 3, 6, 12, 18, and 24 months. The pictures were magnified and sunsequently analyzed by an independent examiner. Then, measuring the vertical changes in soft tissue levels: recession > 0.5 mm, recession $\leq$ 0.5 mm, stability (recession = 0), and

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vertical gain. After that, the definitive esthetic result was assessed subjectively (Table 10).

Table 10 The index of Rompen et al.

Variables	0 (bad)	1 (poor)	2 (satisfying)	3 (good)	4 (very good)	5 (excellent)
The soft tissue position and volume						
The color, shape, and texture of the definitive restoration						
The overall final outcomes						

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The outcomes showed 87% of the situations did not found the soft-tissue recession, and no greater than 0.5 mm recession was observed. The gingival level remained stable at 12, 18, and 24 months. The average esthetic result was rated as 4.5 (very good to excellent).

2.1.11. Pink and White Esthetic Score [9]

PES/WES was first mentioned as a tools for evaluating the esthetic outcomes of early implant placement. The study was designed as a crossectional retrospective study, which the period of time was 2-4 years. 45 implants were placed with early implant placement protocol on the anterior maxillary area. Selected patients were recalled as a routine annual program. After the routinely clinical examination, all the implants were photographs with digital camera, ensuring that the contralateral tooth was captured completely and symetrically (Figure 5). Moreover, a pair of study casts were fabricated for assisting the esthetic evaluation. Finally the PES/WES was used (Table 11).

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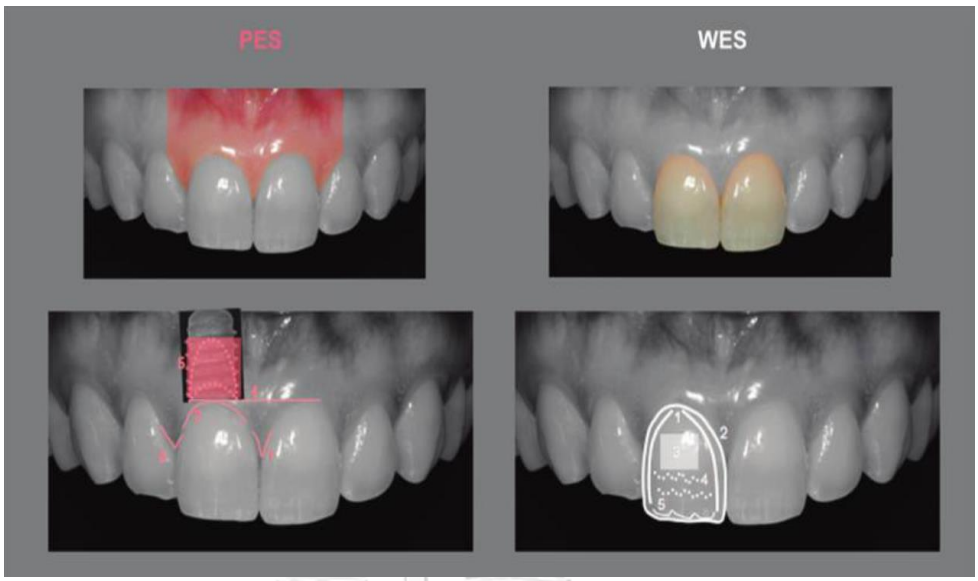

Figure 5 The location of each evaluated variables [9]

Table 11 The PES/WES.

Variables		score		
		0	1	2
PES	Mesial papilla	Absent	Incomplete	Complete
	Distal papilla	Absent	Incomplete	Complete
	Curvature of facial mucosa	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Level of facial mucosa	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Root convexity/soft tissue color and texture	Major Discrepancy	Minor Discrepancy	No Discrepancy
Maximum score of PES		10		

The results of the study showed that curvature of the facial mucosa and the level of facial mucosa had the highest mean score value, while the combined factors (root convexity, texture, and color) were the most difficult to get the high score.

The PES/WES criteria was seemed to be a gold standard of the esthetic evaluation in STIR. This criteria has been widely used and accepted by research community for assessing the esthetic outcomes of STIR in different placement and techniques [23-25].

2.1.12. Esthetic Outcome Objective score [10]

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With the goal of describing the objective measurement and subjective perception of oral rehabilitation in patients with tooth agenesis, the criteria was developed, which three concerned factors namely biological, technical and esthetic variables. Moreover, the Oral Health Impact Profile (OHIP) questionnaire was used to evaluate the patient-based outcomes. Six OHIP questions were subtracted to evaluate the patient-based esthetic outcomes.

In term of esthetic evaluation, The esthetic criteria comprises five variables: mucosal discoloration, crown morphology, crown color match, occlusal harmony, and papilla level. Each variable was evaluated by observing the quality of the outcome (Table 12)

Table 12 The esthetic outcomes objective score.

th	Description
Mucosal discoloration	4: metal visible 3: distinct grayish mucosal discoloration 2: light grayish mucosal discoloration 1: no discoloration
Crown morphology	Compared with contra-lateral tooth. If this was missing, to the "ideal" shape with regards to prominences, surface contours and structures, and the width and the height of the crown;
Crown color match	4: unacceptable 3: suboptimal and below the delivery standard 2: almost optimal but reconstruction differed from the natural tooth 1: optimal and indicated that it was not easy to distinguish the reconstruction from a natural tooth
Symmetry/Harmony	Evaluated according to the facial midline, tooth axis and smile line
Papilla level	**Modified Jemt Papilla Index**[19]

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This retrospective study collected data of 129 patients with tooth agenesis rehabilitated with implant- or tooth-supported reconstructions, and a control group of 58 patients. The observations were performed by one trained examiner, who was not involve in the treatment.

After analysing the experiment, the results of the research was shown that the implant-supported reconstructions povided better esthetic outcomes than the tooth-supported reconstructions, a positive but not significant correlation was observed between the professional and patient-based evaluations of esthetic outcomes.

2.2. Prosthetic-beauty evaluation

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Dental prosthesis was one of the main factors for achieving in esthetic dental implant. As the time goes by, various studies were publictised for assessing the tooth-mimic quality of the restoration on an implant such as the index of Chang et al, the index of Levin et al, the Implant Crown Aesthetic Index, the index of Rompen et al, PES/WES, Esthetic Outcomes Objective Score, and the guideline for the

assessment of clinial quality and professional performance proposed by the Californian Dental Association

2.2.1. The index of Chang [20]

According to the 2 aspects of this evaluation. The prosthetic dimension, which called crown form, was designated in accordance with Table 13.

Table 13 The prosthetic evaluation of Chang .

Variables	Description
Clinical crown length	Distance between the soft tissue margin and the incisal edge.
Width of the crown	The widest mesio-distal dimension of the crown.
Facio-lingual crown dimension	The distance between the facial and lingual aspect of the crown at the soft tissue margin.
Contact point position	The position of the apical extension of the contact point assesed from the imcisal edge and expressed as a percentage value of the clinical crown length.

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2.2.6. Esthetic Outcome Objective Score [10]

In term of esthetic evaluation, The esthetic criteria comprises five variables: mucosal discoloration, crown morphology, crown color matching, occlusal harmony, and papilla level. Each variable was rated by evaluating the quality of the outcome (Table 18).

Table 18 The esthetic outcomes objective score.

Variables	Description
Mucosal discoloration	4: metal visible 3: distinct grayish mucosal discoloration 2: light grayish mucosal discoloration 1: no discoloration
Crown morphology	Compared with contra-lateral tooth. If this was missing, to the "ideal" shape with regards to prominences, surface contours and structures, and the width and the height of the crown;
Crown color match	4: unacceptable 3: suboptimal and below the delivery standard 2: almost optimal but reconstruction differed from the natural tooth 1: optimal and indicated that it was not easy to distinguish the reconstruction from a natural tooth
Symmetry/Harmony	Evaluated according to the facial midline, tooth axis and smile line
Papilla level	**Modified Jemt Papilla Index**[19]

2.2.2. The index of Levin [21]

Levin et al. also created the reconstructive assessment as presented in Table 14.

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Table 14 Prosthetic assessment part of the index of Levin.

Variables	Description
Smile line	Harmony with the restoration

2.2.3. Implant Crown Esthetic Index [7]

The restorative evaluation of the index was defined in Table 15.

Table 15 Prosthetic evaluation of the Implant Crown Aesthetic Index.

Variables	Description	Penalty points					
		0	1	2	3	4	5
Mesiodistal dimension of the crown	The dimension must be in harmony with the adjacent and contralateral tooth: grossly undercontoured, slightly undercontoured, no deviation, slightly overcontoured, grossly overcontoured.						
Position of the incisal edge of the crown	The position must be in harmony with the adjacent and contralateral tooth: grossly undercontoured, slightly undercontoured, no deviation, slightly overcontoured, grossly overcontoured.						
Labial convexity of the crown	Convexity of the labial surface of the crown must be in harmony with the adjacent and contralateral tooth: grossly undercontoured, slightly un- dercontoured, no deviation, slightly overcontoured, grossly overcontoured)						

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Variables	Description	Penalty points					
		0	1	2	3	4	5
Colour and translucency of the crown	Colour and translucency of the crown must be in harmony with the adjacent and contralateral tooth: gross mismatch, slight mismatch, no mismatch.						
Surface of the crown	Labial surface characteristics of the crown such as roughness and ridges must be in harmony with the adjacent and contralateral tooth: gross mismatch, slight mismatch, no mismatch.						

2.2.4. The index of Rompen [22]

Despite the mucosal evaluation that be created, Rompen et al. simultaneously dedicated the prothetic evaluation (Table 16).

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Table 16 The index of Rompen.

Variables	0 (bad)	1 (poor)	2 (satisfying)	3 (good)	4 (very good)	5 (excellent)
The color, shape, and texture of the definitive restoration						
The overall final outcomes						

2.2.5. PES/WES [9]

In term of prosthetic assessment of this criteria, WES was proposed by defined 5 variables in accordance with Figure 4 and Table 17.

Table 17 The prosthetic assessment was defined as WES.

Variables		score		
		0	1	2
WES	**Tooth form**	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Tooth volume/outline	Major Discrepancy	Minor Discrepanc	No Discrepancy
	Color (hue/value)	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Surface texture	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Translucency	Major Discrepancy	Minor Discrepancy	No Discrepancy
Maximum score of WES		10		

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2.2.7. The modified guideline for the assessment of clinial quality and professional performance proposed by the Californian Dental Association [26]

This criteria was used as a parameter for assessing the quality of the restoration of De bryun's experiment. That study was designed as a prospective observations in order to describe the quality of implant supported reconstructions made by dentists previously inexperienced with implant prosthodontics and to assess alterations and complications from the visit of crown insertion to 3 years later.

The prosthetic evaluation was consist of 5 parts namely Overall coment, design, fit, occlusion/articulation and esthetics. Each of the variables would be rated as perfect, acceptable, to be corrected for prevention and to be redone.

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For esthetic part, each rating level was defined in accordance with Table19.

Table 19 esthetic evaluation in De bryun's modified criteria.

Rating	Description
Perfect	No mismatch in color/shade/translucency between crown and adjacent teeth. Lip fill and facial height are perfect. Natural appearance when the patient is smiling.
Acceptable	Mismatch in color/shade/translucency. Discoloration of acrylic teeth. Lip fill and facial height in harmony.
To be corrected for prevention	Esthetically disturbing mismatch in color/shade/translucency. Heavy discoloration and/or damage of acrylic teeth. Unharmonious lip fill and facial height
To be redone	Major esthetic disharmony on lip fill/facial height/color/shade/translucency

2.3. Morphological bone measurement: the importance and methodology

As we know that bone was a part of keys to success in creating the esthetic of the covering mucosal tissues [27] and presenting moderate association to each other [28]. This study had reviewed on peri-implant morphological bone measurement following these issues: Labial bone height measurement, Labial bone thickness measurement, proximal bone measurement, bucco-lingual position, distance between implant shoulder and the first visible implant contact to bone (DIB), and implant axis.

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2.3.1. Labial bone height

Buser et al. [27] claimed that there are two anatomic structures which importantly affect the esthetic of STIR in the anterior zone: the bone height of the alveolar crest in the interproximal areas and the height and thickness of the facial wall.

The labial bone height esthetically affects to the dental implant, which placed in the anterior area. Losing the facial marginal bone which is called bone dehiscence, can possibly show metal color of the underneath implant component.

Many researches have suggested that the marginal bone loss was a classical factor succeeding in implant treatment. To begin with Adell et al. [29], they recommended the mean bone loss for Branemark osseointegrated implants was 1.5 for the first year and followed by 0.1 mm annually. Moreover, Albrekson et al. [30] supported the previous criteria but presented in a slightly different number, which is less than 0.2 mm per year after the one year of service. Despite dental implant has been improved such as roughened–surface

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implants, platform switching and inward shifting of the connection microgap, the marginal bone remodeling still universally accept as being up to 2 mm during the first year of function, followed by a annual maximum bone loss 0.2 mm thereafter. However, the loss of peri-implant bone on platform-switched (PSW) implant was different. The mean bone loss of the PSW implant is approximately 0.6 mm in the first year of loading [31, 32] and up to 1.02 mm in 5-year follow up study [33]. These data suggested that the interproximal bone is preserved when using PSW implant is stable in the long term [34].

Measuring the marginal bone level can be performed by using dental CBCT. Miyamoto et al. [15] assessed the vertical bone loss in maxillary anterior dental implant by adjusting the focal planes of CBCT to the center of buccolingual aspect of the implant, then measuring from the implant platform to peak of alveolar ridge. Furthermore, Morimoto et al. [14] applied a positive and negative value to interpret the location of the bone comparing to the implant platform level (IPL), which the value was positive when the facial

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vertical bone level was above the IPL, and the value was negative for when the labial vertical bone was below the IPL (Figure 5).

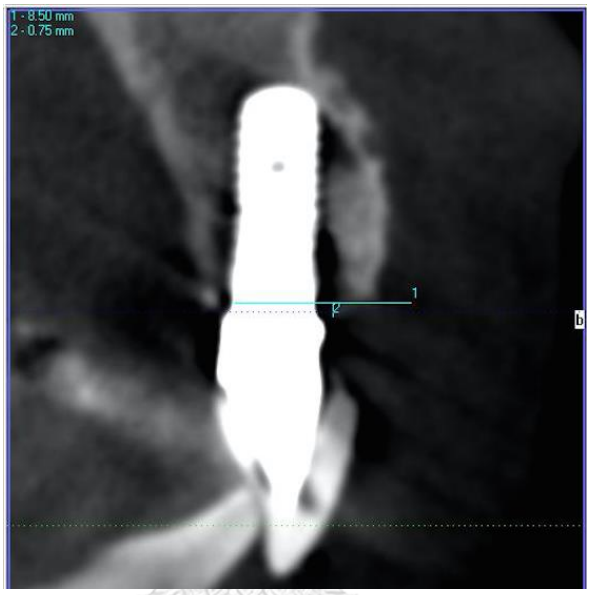

Figure 5 The labial bone height measured by CBCT.

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2.3.2. Labial bone thickness

Labial bone thickness was considered to be the one of anatomical structure which is a part for succeeding in implant treatment, especially in esthetic zone. The dimension of the facial bone wall have been observed for long time. The facial bone wall in most locations in all examined tooth sites

was less than or equal to 1 mm thickness and that close to 50% of sites had a bone wall thickness that was less than or equal to 0.5 mm [35]. Thin labial bone wall, which is less than 1 mm, was required contour augmentation for correcting the ridge architecture before or simultaneously implant placement [36].

Proper thickness of the labial wall has been proposed since 2000. The wall should be thickened 2 mm, preferably 4 mm [37]. If the bone is not available, the labial plate will be possibly lost, resulting in a high risk of soft-tissue recession [38].

The measurement of the labial bone thickness in anterior zone is usually evaluated at the widest part of the dental implant, which are implant shoulder or implant platform. The method was performed by using CBCT. Firstly, adjusting the focal planes of the machine to the center of the buccolingual aspect of the implant. Then, assessing the labial bone thickness perpendicular to the implant surface. The measurements are always done at more than one position along with implant figures such as at 0, 2, 4, 6, 8, 10,

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and 12 mm apical to the IPL [14] or 1.5 and 5.0 mm from the implant platform [15] (Figure 6).

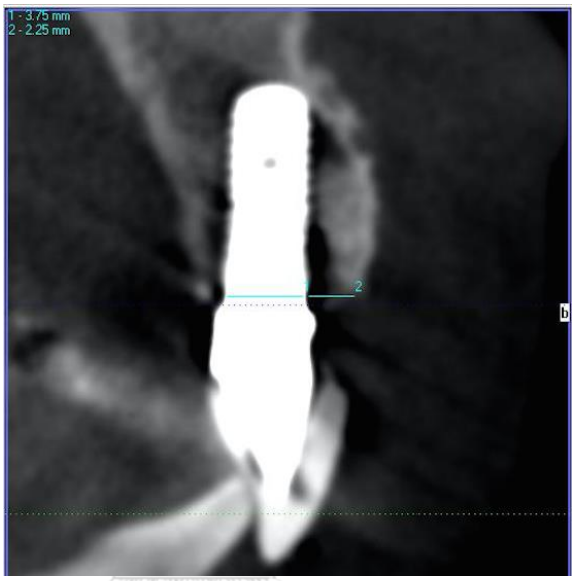

Figure 6 The labial bone thickness measured by CBCT.

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2.3.3. 3D-Implant position

Three-dimensional position of the dental implant when placed in bone: mesiodistal, orofaciall and apicocoronal are seemed to be the beginning of achievement in esthetic implant.

mesio-distal position

Using an implant shoulder as a reference plane, the proper mesiodistal distance to the adjacent root was now still controversy. Mostly, 1.5 mm apart from the root surface is suggested to be the appropriate distance when using platform-matching implant while platform-switched type was possible to be placed 1 mm from teeth while maintaining the bone level adjacent to the implant [34].

orofacial position

With regard to the orofacial dimension, it has been suggested that implant shoulder margin should be located at the ideal point of emergence [39, 40]. Placing too facially can lead to facial bone resorption, while placing too palatally must require an implant crown with a ridge-lap design

The proper orofacial position can be done by creating an imaginary line from the point of emergence of the adjacent teeth and observe the position of the implant. The shoulder of implant should be

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positioned about 1 mm palatal to the point of emergence at adjacent teeth and should not be placed more than 2 mm palatal to the line (Figure 7).

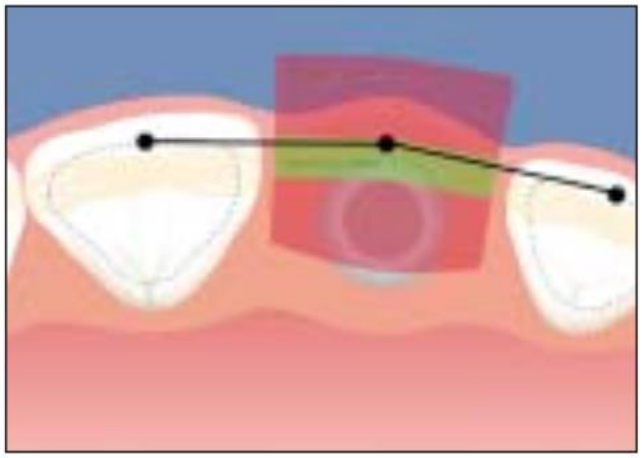

Figure 7 Proper orofacial position [27].

Apicocoronal position

Belser et al. mentioned the philosophy “as shallow as possible, as deep as necessary” for the apicocoronal proper position when placing implant in the anterior zone of the mouth. Placing too apically, more than 3 mm to the planed gingival margin, can result in facial bone resorption ,consequently the gingiva is recessed. In addition to excessively apical

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malposition, placing implant too coronally can lead to a visible metal margin and poor emergence profile.

ITI concensus meeting in 2000 claimed that the position of the implant shoulder should be estimated 2 mm. apical to the midfacial gingival margin of the planed restoration[41] or 2-3 mm to the imaginary line highlight from the midfacial of the CEJ of adjacent tooth without gingival recession. However, it is important to note that the CEJs of the adjacent teeth can be various, and must be taken in to consideration. Generally, lateral incisors are smaller and their CEJs is actually located more coronally than the central incisors or canines' CEJs [42](Figure 8).

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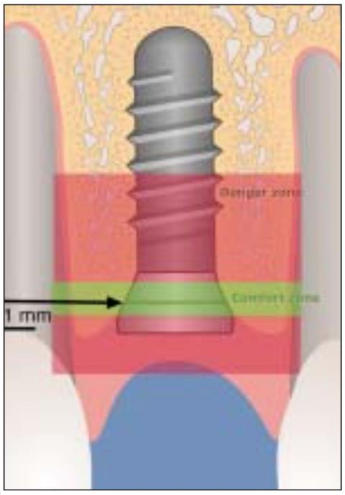

Figure 8 Proper apicocoronal position [27].

2.3.4. Proximal bone

Interproximal crestal bone at the root of an adjacent teeth is the key to success in fulfilling interdental papilla around STIR. Tarnow et al. found the suitable distance between two teeth and claimed that if the distance between the base of the contact point to the crest of bone was 5 mm or less, the papilla was fully presented almost 100% of the time, whereas the distance was 6 mm., the papilla was fully presented 56% and 27% for the distance of 7 mm [43]. Corresponding to implant and adjacent tooth, the ideal vertical distance should be 3-5 mm [44].

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2.3.5. Distance between implant shoulder and the first visible implant contact to bone (DIB)

Regarding to the stability of the dental implant, quantity of bone was unavoidably important. Marginal bone loss is able to affect not only the maintenance of the implant, but also the esthetic outcomes. To study the progress of the marginal bone loss, measuring the distance between implant shoulder and the first visible implant contact to bone is considered.

DIB was proposed in term of its usefulness in 1990 by Buser et al. [45] and has been used as a routine implant check up protocol. The method for measurement of DIB was clearly described in the study of Feloutzis et al. [46]. Periapcal rediograph was taken under long cone parallel technique. After that, measuring the DIB on both mesial and distal surface of the implant was done and the average value was calcualated consecuetively. The next step is modifying this value into the actual DIB by comparing between the actual length of the implant and the length which shown in the image. Finally, the real DIB was presented for the time of taking the image. Dental professions

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compare DIB between two images of the same implant, but taken in different time, for observing the vertical bone loss [47-50]. For platform-switching implant, DIB was recorded 0.6 mm in the first year of function, Moreover, Buser et al. did not found statistically significant difference of the DIB value between 5-year follow up and 9 year follow up cases. The difference approximately is 0.09 mm [48].

2.3.6. Implant axis

To maintain the labial soft-tissue level of the dental implant in aesthetic area, implant fixture angle, which called implant axis, is considered to be another essential factor [51]. Inappropriate implant selection and lack of surgical experience might lead to wrong-angulated implant placement which could cause a higher incidence of dehiscence and fenestration. Occurrance of fenestration was common even the implant was placed in the cingulum position [52]. The large fenestration can effect the loss of primary stability while

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the small is not but need greater cost and more time to correct the defect [53, 54].

2.4. Risks of radiation from dental CBCT to human body

Dental CBCT has been widely used in implant dentistry. While the machine becomes more popular in both dental and medical treatment, hazardous risks of increased amount of radiation, comparing to normal radiography, is concerned. In term of this controversial issue, there are some studies compare effective dose among dental CBCT in dentistry [55, 56]. They mentioned the effective dose of iCAT CBCT for scanning dento-alveolar region is 0.034 – 0.089 mSv which is equal or lesser than a complete full-mouth series conventional radiographs (D-speed film and round collimation) typically used in dentistry. Moreover, there are strong epidemiological references linking between the radiation and cancer induction which found no occur in dose below 100 mSv [57] and there is no any direct report of cancer as a result from dental imaging procedure [58].

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CHAPTER III RESEARCH METHODOLOGY

3.1. Research Questions

- Could a modified objective criteria comprise gingival, prosthetic, and bone foundation assessment be used to evaluate the esthetic of STIR?

3.2. Research Objectives

- To compare the esthetic outcome of STIR using modified objective criteria and the traditional compare objective criteria (PES/WES).

3.3. Statement of hypothesis

3.3.1. Null hypothesis

There is no statistically significant correlation between the traditional observation, which is PES/WES, and the new modified objective esthetic evaluation, which comprises gingival, prosthetic, and bone foundation.

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3.3.2. Alternative hypothesis

There is a statistically significant correlation between the traditional observation, which is PES/WES, and the new modified objective esthetic evaluation, which comprise gingival, prosthetic, and bone foundation.

3.4. Conceptual framework

According to all the reviewed knowledge and the aim of the study, which is modifying objective criteria using gingival, prosthetic and bone foundation assessment. Correlation to the traditional esthetic criteria (PES/WES) is the point of interest. The conceptual framework can be drawn Figure 9

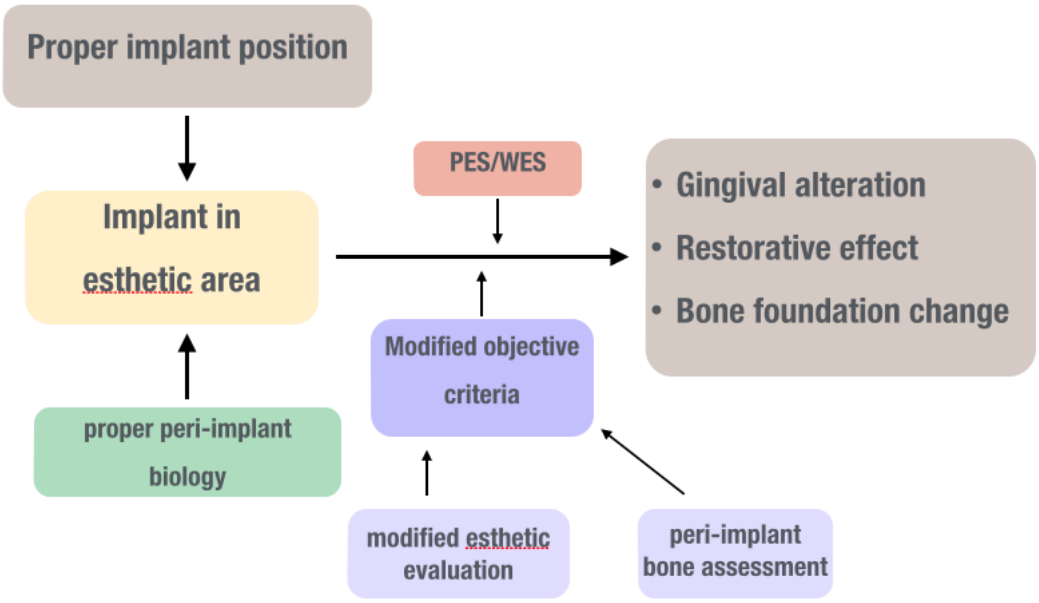

Figure 9 The conceptual framework of this study.

3.5. Keywords

- Dental implant
- Esthetic
- Evaluation
- Bone measurement
- Correlation

3.6. Type of study

Crossectional, retrospective study

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3.7. Research methodology

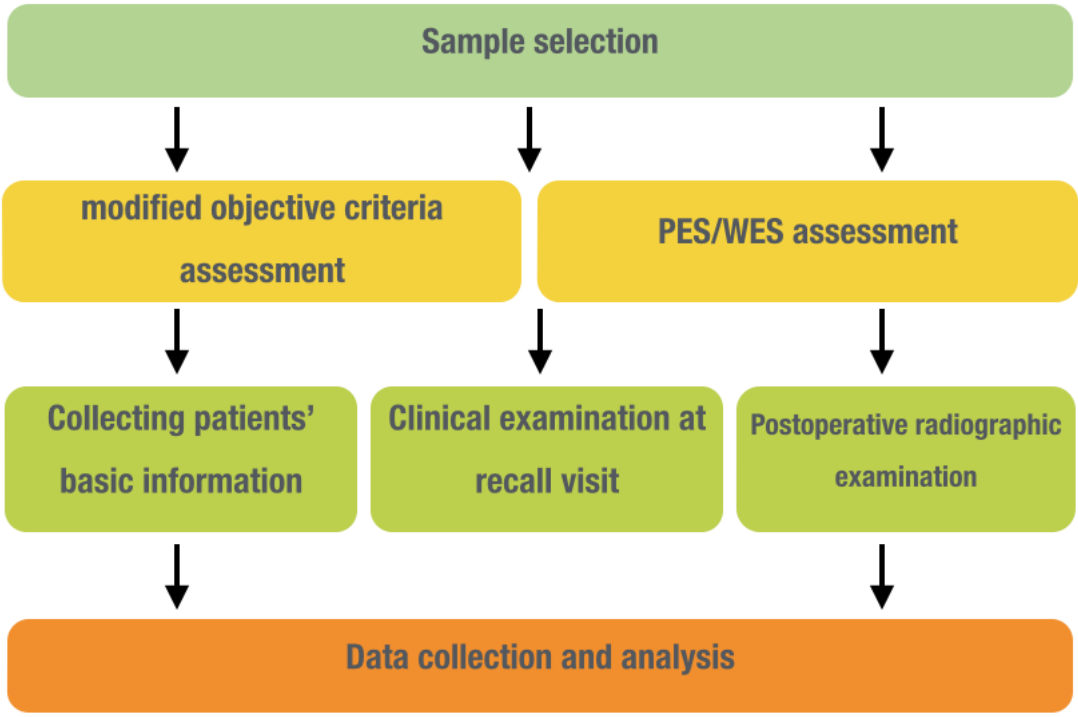

Figure 10 Research methodology.

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3.8. Materials and methods

3.8.1. Materials

- Participants

These samples are patients who have been treated with single-tooth implant restoration placed in anterior maxillary region, which focused on central incisor, at Chulalongkorn University between January

2005 to December 2014. All selected patiens will be excluded if they had only one factor of this exclusion criteria.

- The participant did not be treated with single-tooth implant restoration on a maxillary anterior zone after function at least 1 year up to 4 years
- The participant has large restoration on the adjacent tooth namely class IV cavity, diastema restoration, venner or crown. A small restoration, which was class III cavity, would not be excluded
- The participant has ridge lap implant restoration
- The remaining teeth has not be supported by posterior teeth
- The participant has uncontrolled systemic-disease
- The participant has active periodontitis
- The participant is a heavy smoker (> 10 cigarettes/day)

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- The implant did not have a bone augmentation procedure at the implant placement visit

- Examiner

An experienced dental student who following this inclusion criteria will be chosen.

- The examiner has been studying in year 2 to year 4 of post-graduated level at the Esthetic Restorative and Implant Dentistry program.
- The examiner has some experiences in using CBCT for measuring bone during implant treatment, which can be preoperative measurement or postoperative measurement.
- The examiner has an experience in restoring anterior tooth with fixed restoration. This fixed restoration can be either on natural tooth or on implant.

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- PES/WES evaluating form

The evaluating form comprised 2 main factors: soft tissue and prosthesis (Table 20).

Table 20 The traditional esthetic assessment, PES/WES.

Variables		score		
		0	1	2
PES	**Mesial papilla**	Absent	Incomplete	Complete
	Distal papilla	Absent	Incomplete	Complete
	Curvature of facial mucosa	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Level of facial mucosa	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Root convexity/soft tissue color and texture	Major Discrepancy	Minor Discrepancy	No Discrepancy
Total PES				
WES	**Tooth form**	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Tooth volume/outline	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Color (hue/value)	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Surface texture	Major Discrepancy	Minor Discrepancy	No Discrepancy
	Translucency	Major Discrepancy	Minor Discrepancy	No Discrepancy
Total WES				

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- Modified objective criteria evaluating form

The modified objective criteria was based on three components which synergetically establish the single-tooth implant restoration outcomes: bone morphology, gingiva and prosthesis. The underlying bone structure plays as an important role in the establishment of esthetic soft tissues in the anterior maxilla [27], whereas the prosthesis and its soft tissue are already known to be the main factors for creating a beautiful reconstruction in accordance with many aesthetic assessments which had been proposed [11]. To provide the criteria easier to understand, this study will name gingival esthetic quality, prosthetic esthetic quality, and bone-morphogenic quality as gingival assessment, prosthetic assessment and bone foundation assessment respectively (Figure 11).

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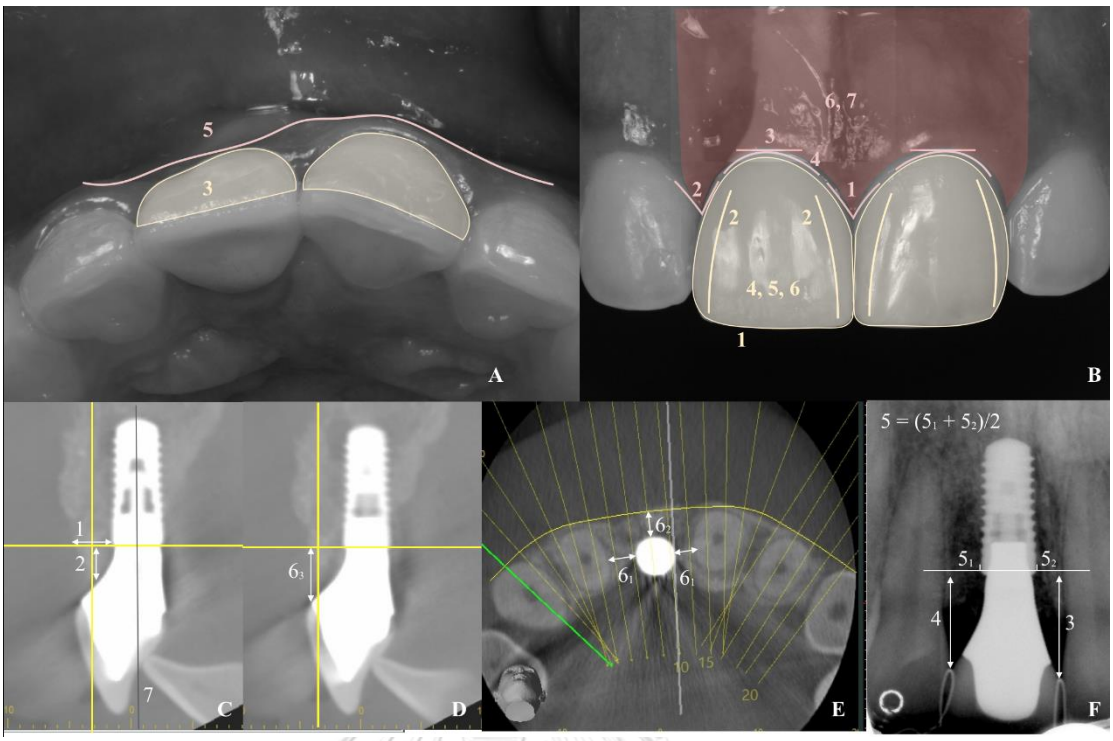

Figure 11 The 20 variables that be used in MOC (Gingival assessment: pink lebel, Prosthetic assessment: yellow lebel, bone foundation assessment: white lebel)

- Gingival assessment

To create gingival assessment of the modified objective criteria, six mucosal esthetic evaluations ands six mucosal and reconstructive esthetic evaluations had been reviewed. The gingival assessment was consist of seven variables: Mesial papilla, Distal papilla, soft tissue level, soft tissue contour, labial soft tissue convexity, color, and texture.

The score of 2, 1, or 0 are assigned to all seven of the gingival

parameters as presented in Table 21. The photographs and dental models would be presented to the examiner for scoring this part case by case.

Mesial and Distal papilla: scoring 2 when filled papilla was fully presented. 1 was marked for incomplete presence, and 0 was assigned for absence (Figure 11. 1B-pink, 2B-pink respectively).

Soft tissue level: scoring by comparing to the contralateral tooth. The score of 2 was marked when the identical vertical level was presented or less than 1 mm discrepancy. 1 would be marked when the 1-2 discrepancy was shown, and 0 would be marked when more than 2 mm discrepancy was presented (Figure 11. 3B-pink).

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Soft tissue contour: scoring by comparing to the contralateral tooth. The score of 2 would be marked when the symmetrical curve was presented, 1 would be marked when a slight symmetry was shown, and 0 would be marked when obvious asymmetry was found (Figure

11. 4B-pink).

Soft tissue convexity: using a dental model for evaluating this variable by comparing to the adjacent tooth in the occlusal view. The score of 2 would be marked when the harmonious convexity was presented, 1 would be marked when the fairly concave soft the soft tissue was shown, and 0 would be marked when the obviously concave of the soft tissue was presented (Figure 11. 5A-pink).

Soft tissue color: by comparing to the adjacent tooth from the photograph. The score of 2 would be marked when the identical appearance was presented, 1 would be marked when slight difference was shown, and 0 would be marked when the obvious difference was found (Figure 11. 6B-pink).

Soft tissue texture: by comparing to the adjacent tooth from the photograph. The score of 2 would be marked when the identical appearance was presented, 1 would be marked when slight difference

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was shown, and 0 would be marked when the obvious difference was found (Figure 11. 7B-pink).

Table 21 The gingival assessment of modified objective criteria.

Variables	reference	score		
		2	1	0
Mesial papilla fill	Adjacent tooth	Complete presence	Incomplete presence	Absence
Distal papilla fill	Adjacent tooth	Complete presence	Incomplete presence	Absence
Soft tissue level	Contralateral tooth	Discrepancy <1 mm	Discrepancy 1-2 mm	Discrepancy >2 mm
Soft tissue contour	Contralateral tooth	Symmetry	Fairly symmetry	Asymmetry
Soft tissue convexity	Adjacent tooth	Harmony	Slight harmony	No harmony
Soft tissue color	Adjacent tooth	No difference	Moderate difference	Obvious difference
texture	Adjacent tooth	No difference	Moderate difference	Obvious difference

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- Prosthetic assessment

To create a prosthetic assessment of this criteria, six mucosal and reconstructive evaluations and one reconstructive criteria were reviewed. The prosthetic assessment was consist of six variables: tooth shape/outline, tooth form, labial contour, color, texture, translucency and characteristics.

A score of 2, 1, or 0 was assigned to all the six of prosthetic parameters as presented in Table 22. The photographs and dental models would be presented to the examiners scoring this part case by case.

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Tooth shape and outline: observing the outline of the tooth comparing to the contralateral tooth by using a photograph. Identical appearance would be scored 2. Slightly unidentical appearance would be scored as 1, and obvious unidentical appearance would be scored as 0 (Figure 11. 1B-yellow).

Tooth form: evaluating the line angle of the restoration comparing to the contralateral tooth by using a photograph. Identical appearance would be scored 2. Slightly unidentical appearance would be scored as 1, and obvious unidentical appearance would be scored as 0 (Figure 11. 2B-yellow).

Labial contour: assessing the labial contour in both vertical and horizontal dimension by using a study model. Identical appearance would be scored 2. Slightly unidentical appearance would be scored as 1, and obvious unidentical appearance would be scored as 0 (Figure 11. 3A-yellow).

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Color: evaluating the color matching of the restoration comparing to the contralateral tooth by using a photograph. Identical appearance would be scored 2. Slightly unidentical appearance would be scored as 1, and obvious unidentical appearance would be scored as 0 (Figure 11. 4B-yellow).

Texture: observing the texture of the restoration comparing to the contralateral tooth by using both photograph combining with study model. Identical appearance would be scored 2. Slightly unidentical appearance would be scored as 1, and obvious unidentical appearance would be scored as 0 (Figure 5B-yellow).

Translucency and characteristics: assessing the translucency and characteristic which created on the restoration comparing to the contralateral tooth by using a photograph. Identical appearance would be scored 2. Slightly unidentical appearance would be scored as 1, and obvious unidentical appearance would be scored as 0 (Figure 6B-yellow).

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Table 22 The Prosthetic assessment of the modified objective criteria.

Variables	reference	score		
		2	1	0
Tooth shape/ outline	Contralateral tooth	Identical	Slightly unidentical	Obvious unidentical
Tooth form	Contralateral tooth	Identical	Slightly unidentical	Obvious unidentical
Labial contour	Contralateral tooth	Identical	Slightly unidentical	Obvious unidentical
Color	Contralateral tooth	Identical	Slightly unidentical	Obvious unidentical
Texture	Contralateral tooth	Identical	Slightly unidentical	Obvious unidentical
Translucency and characteristic	Contralateral tooth	Identical	Slightly unidentical	Obvious unidentical

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- Bone foundation assessment

This part can be evaluated by using periapical radiograph combining with CBCT. For CBCT measurement, the image will be rotated so that the vertical reference line bisected the implant in the faciopalatal direction according to the implant position on the arch form in the axial view. In the coronal view, the image will be rotated until

the implant's long axis was parallel to the vertical reference line. In the sagittal view, the image will be rotated so that the axis of the fixure parallel to the vertical line

After, adjusting patient's head position in the computer, Bone-score evaluation could be started. This score comprises 6 variables: Labial bone thickness, Labial bone height, Distance of base of contact point to bone (DCB): mesial, Distance of contact point to bone (DCB): Distal, Distance of crestal bone to the first visible bone-implant contact (DIB), Implant position (mesiodistal, orofacial, apicocoronal), and implant axis.

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Each variable was rated by 3 scores which were 2, 1, or 0. The value of the scores were dependent to the quality of the variable as presenting on Table 23.

Table 23 The Bone foundation assessment of modified objective criteria.

Variables	Reference	Score		
		2	1	0
Labial bone thickness	Implant platform	> 2	2 - 1	< 1
Labial bone height	Implant platform	< 0	0 - 2	> 2
DCB: Mesial	Distance between base of contact point to the connecting line of bone contact to adjacent root	< 5	5 - 7	> 7
DCB: Distal	Distance between base of contact point to the connecting line of bone contact to adjacent root	< 5	5 - 7	> 7
DIB: Mesial and distal	Distance between implant platform to the first bone-to implant contact	< 0.6	0.6 - 2.5	> 2.5
Implant position	Mesiodistal, orofacial, and apicocorona position correction	Correct all dimension	Correct 2 dimension	Correct 1 dimension or none
Implant axis	midsagittal view for the position and move plane for observing a sign fenestration	cingulum position, no fenestration	incisal position, no fenestraion	fenestration

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The method for measuring each variable of this part could divide into 2 groups: from periapical radiograph and from CBCT.

The variables, which are acquired from the routine periapical radiography, comprise DCB (mesial and distal) and DIB. All the STIRs would be captured under long cone parallel technique with XCP. Then,

DCB and DIB would be evaluated and recorded. The measured DCB data would be collected separately on mesial surface and distal surface, whereas the true DIB came from assessing on mesial surface and distal surface following with calculating an average.

In term of the DCB, the score of 2 would be marked when DCB was less than 5 mm, 1 would be marked when the DCB was in 5-7 mm, and 0 would be marked when the DCB was more than 7 mm (Figure 11. 3F, 4F).

Additionally, DIB woud be also scored as 2, 1, or 0. 2 would be marked when the distance was less than 0.6 mm. 1 would be marked when the distance was in the range of 0.6 - 2.5 mm, while the 0 would be marked when the distance was more than 2.5 mm (Figure 11. 5F).

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The data of the rest variables, which were labial bone thicknesss, labial bone height, implant position, implant axis and fenestration, would be collected by the CBCT. The measurement would be done under the following protocol.

Labial bone thickness: measuring from the outermost of the implant platform perpendicularly to the most outer surface of labial cortical wall. This point of measurement was defined as 0-mm point of measurement. The labial bone thickness in the study come from the average of labial bone thickness at 0, 2, 4, 6, 8, 10, 12-mm point of measurement along with the implant (or platform level, middle-length level and apical level). If dehiscence was found at any point of measurement, the labial bone thickness at that point will be equal to 0. 2 points would be marked when the average labial bone thickness was more than 2 mm. 1 point would be marked when the average labial bone thickness was less than 2 mm but more than 1 mm, and 0 point would be marked when the average labial bone thickness was less than 1 mm (Figure 11. 1C).

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Labial bone height: measuring from the uppermost of the implant platform to the uppermost of the peak of the labial wall. If the peak of the labial bone was located above the implant platform, the negative value (-)

would be given to that number. On the other hand, if the peak of the labial bone was located under the implant platform, the positive value (+) would be given to that number. 2 points would be marked when the labial bone height was less than 0, 1 point would be marked when the labial bone height was more than 0 but less than 2 mm, and 0 point would be marked when the labial bone thickness was more than 2 mm (Figure 11. 2C).

Implant position: the position of implant should be correctly located in all 3 dimensions

- Mesiodistal: measuring from the outermost of the implant platform to the outermost of the adjacent root in crossectional view at platform level.

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The assessment would be performed on both mesial and distal surface. 1.5 mm was the cut-off number that given to this evaluation. If the measured value was more than 1.5 mm on the both side of measurement, the position will be defined as “correct position”. While the measured value

was less than 1.5 mm on only one side of measurement , the positon would be immediately defined as “fault position” (Figure 11. 6_1E).

■ Orofacial: measuring from the outermost of the labial surface of the implant platform to the imaginary line connecting to the point of emergence of the adjacent tooth and the ideal point of emergence of the restoration in crossectional view. The range of 1-2 mm was the cut-off number that given to this evaluation. If the measured value was in the range, the position would be defined as “correct position”. In the other hand, the measured value was less than 1 mm or more than 2 mm would be defined as “fault position” (Figure 11. 6_2E).

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■ Apicocoronal: measuring from the middle point of implant platform to the imaginary line which drawn tangentially to the contralateral CEJ. The range of 2-3 mm was the cut-off number that given to this evaluation. If the measured value was in the range, the position would be defined as “correct position”. In the other hand, the measured value was less than 1

mm or more than 2 mm would be defined as “fault position” (Figure 11. 6_3E).

According to the 3 dimensional positions, 2 would be marked when the implant was correctly located in all dimensions, 1 would be marked when the implant was correctly located in 2 dimensions, and 0 would be marked when the implant was located in none or 1 correct position.

Implant axis: this variable could be measured by creating a line bisecting the implant in sagittal plane. If the line pass on the cingulum part of the restorative tooth, cingulum position would be defined. However, if the line pass on the incisal or labial portion of the restoration, incisal position and labial position would be defined respectively. For scoring this variable, 2 0would be marked when the implant shown its cingulum position without presenting of fenestration. 1 would be marked when the implant was placed in the incisal position

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but no sign of fenestration. Last but not least, 0 would be marked when the implant was placed to the labial position without a sign of fenestration or the implant was placed in any axis but presenting of fenestration (Figure 11. 7C-grey line).

- Irreversible Hydrocolloid (Jeltrate, Dentsply, China)
- Orthodontic stone (Sirius, Ultima, France)

3.8.2. Equipment

- Camera (Nikon D80, Nikon, Tokyo, Japan)
- Lense (AF Micro-Nikkor 105mm f/2.8D; Nikon, Japan)
- Dual point wireless flash (R1C1, Nikon)
- Stock Tray: upper and lower pieces
- Dental cone beam computed tomography (iCAT, Imaging Sciences International, USA)
- Intraoral radiography (Kodak 2200, Eastman Kodak Company, USA)
- Film holding instrument (XCP, Dentsply Rinn, USA)

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3.9. Conduct experiment

3.9.1. Ethical consideration

All patient data are collected following ethical approval from the Ethics Committee, the Faculty of Dentistry, Chulalongkorn University. (HREC-DCU 2015-082)

3.9.2. Sample preparation

- Patient preparation

All the patients, who pass the inclusion criteria, were recalled for evaluating the STIR. A regular maintenance protocol was followed.

- General oral examination was performed namely sex, age, present of parafunctional habit, smoking habit, type of osteotomy site, date of implant placement and loading, implant system, type of implant abutment, type of implant restoration, additional bone augmentation procedure, previous complication. Then periapical radiograph was taken and cone beam computed tomography was scanned as routine.

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- To assess the esthetic outcomes of the anterior single-tooth implant restoration, photographs were taken for recording the appearance of the prosthesis and the contralateral tooth.

- Then, maxillary and mandibular arch were impressed with irreversible hydrocolloid. After that, these negative impressions were poured with orthodontic stone to fabricate study models.

- Examiner preparation

The examiners who pass the inclusion criteria of the examination were practiced for using the both criteria by author. Moreover, the guideline for evaluating bone around implant by using CBCT will be published in order to assist the correct assessment (Appentix A).

- PES/WES vs modified objective criteria assessment

Firstly, intraobserver agreement would be inspected. Both of the evaluation would be similarly performed under the author observation. Each evaluation would be carried out twice in different week in order

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to reduce bias and ensure optimum reproducibility. If any variable are differently scored between the first and the second assessment, the examiner will reevaluate this variable again before making a decision.

After finish the reliability examination, the examiner performed the experiment with all recruited subjects. This time the samples were randomly swapped. Each evaluation must be done within 3 days. Interval time between the first criteria and the second criteria assessment was 2 weeks.

3.9. Data collection and statistical analysis

Data will be gathered by author, analyzed using statistical software (SPSS 20.0; SPSS, Chicago, IL, USA). Descriptive statistics means and standard deviation were calculated. Weighted Cohen's Kappa was used to measure the intraobserver agrreement and the kappa value was rated in accordance with Landis and Koh [59]. Finally, the score of ESC would be categorized by K-mean

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cluster analysis. ANOVA was used to observe the different mean score among groups of each factor, which 0.05 was the significant level of the study.

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CHAPER IV RESULTS

According to the inclusion criteria, 26 patients' data were used for the testing. All the subjects were 11 male and 14 female. The youngest patient in this study was 22 years old while the oldest one was 62 years old, an average age was 42 ± 12.496. Mean of observation period was 30.15 ± 18.78 months which 7 months was minimal and 69 months was maximum of implant usage. 14 implants were placed at tooth number 11 while the rest were placed at tooth number 21. 16 of all implants were used in Astratech system, the rest 11 of them were used in Straumann system (Table 24).

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Table 24 Initial descriptive information from entire recruited subjects.

Variables	Subjects (n=26)
Age (years)	42 ± 12.496 (22-62)
Gender	
Male	11
Female	15
Implant site	
Right central incisor	14
Left central incisor	12
Implant system	
Astratech	14
Straumann	12
Observation period (months)	30.15 ± 18.78 (7-69)

After the experiment accomplished, all these results could be observed. PES/WES of this study was 12-20, which show that all the implant of the study has above an acceptable reange. 16 was median and mode of these data, while a mean PES/WES was 15.88 ± 2.05. In term of MOC score, the score was between 24 and 36. 31 and 26 were median and mode of these group respectivel, whereas a mean score of MOC was 30.69 ± 3.92, and the median of the both criteria were 16 and 31.5 respectively (Table 25).

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Table 25 showed descriptive statistics between PES/WES and MOC

	Min	Max	Median	Mode	Mean	sd
PES	3	10	8	9	7.23	1.86
WES	7	10	9	8	8.65	0.98
PES/WES	12	20	16	16	15.88	2.05
Gingiva	5	14	12	12	11.34	2.26
Prosthesis	9	12	11	11	10.84	0.92
Bone	5	13	9.5	11	9.15	2.33
MOC	24	36	31	26	30.69	3.92

Regarding to intraobserver reliability as presented in appendix B. The result of this study showed moderate to almost perfect agreement (mean kappa score was 0.685 – 0.764)

Finally, when the MOC data was categorized by k-mean cluster analysis. 2-group clustering could separate only gingiva (Appendix C), while bone foundation score could be significantly separated in 3-group clustering with gingiva score was significantly separated also. Moreover, 4-group, 5-group and 6-group clustering could significantly separate gingiva and bone score as same as 3-group clustering (Appendix D, Appendix E and Appendix F respectively). Regard to Prosthesis score, this part could be separated significantly when the number of cluster was

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7(Appendix G). Although all parts of MOC could finally significantly separate in 7-group clustering, it was very hard to classify case in clinic. Therefore, 3-group clustering was the least possible clusters that could significantly separate gingiva and bone score with prosthesis score could not (Table 26).

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Table 26 Detailed PES/WES and MOC score of each subject in each cluster

	PES/WES			MOC				
Subject	PES	WES	Total(20)	GUM	Prosth	Bone	Total(40)	cluster
2	8	8	16	12	11	11	34	1
5	9	9	18	11	12	9	32	1
6	8	10	18	12	12	9	33	1
7	8	9	17	12	11	9	32	1
11	8	10	18	11	10	13	34	1
12	9	9	18	12	11	13	36	1
14	8	9	17	12	11	12	35	1
18	7	9	16	11	11	11	33	1
21	9	8	17	13	10	11	34	1
22	9	10	19	13	9	10	32	1
23	8	8	16	12	10	11	33	1
24	9	9	18	12	11	11	34	1
8	5	8	13	7	10	8	25	2
10	6	9	15	9	11	6	26	2
13	4	9	13	5	11	8	24	2
15	6	10	16	8	12	6	26	2
16	5	10	15	6	12	8	26	2
17	6	7	13	8	9	9	26	2
19	4	8	12	8	10	9	27	2
20	5	8	13	8	10	9	27	2
25	3	10	13	9	9	9	26	2
1	8	8	16	14	12	5	31	3
3	9	7	16	13	10	7	30	3
4	8	8	16	12	10	6	28	3
9	9	7	16	13	11	5	29	3
26	10	10	20	14	12	7	33	3

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Regarding to 3-groups clustering (Figure 12), the first group was excellent group, which the average gingival and bone score were 11.92 and 10.83

respectively. Total score of this group was 32 to 36 points (Figure 13). The second group was medium group, the average gingival and bone score were 7.56 and 8 respectively. Total score of this group was 24 to 27 points (Figure 14). Last but not least, the third group was divergent, which the average gingival and bone score were 13 and 6 respectively. Total score of this group were 29 to 33 points (Figure 15).

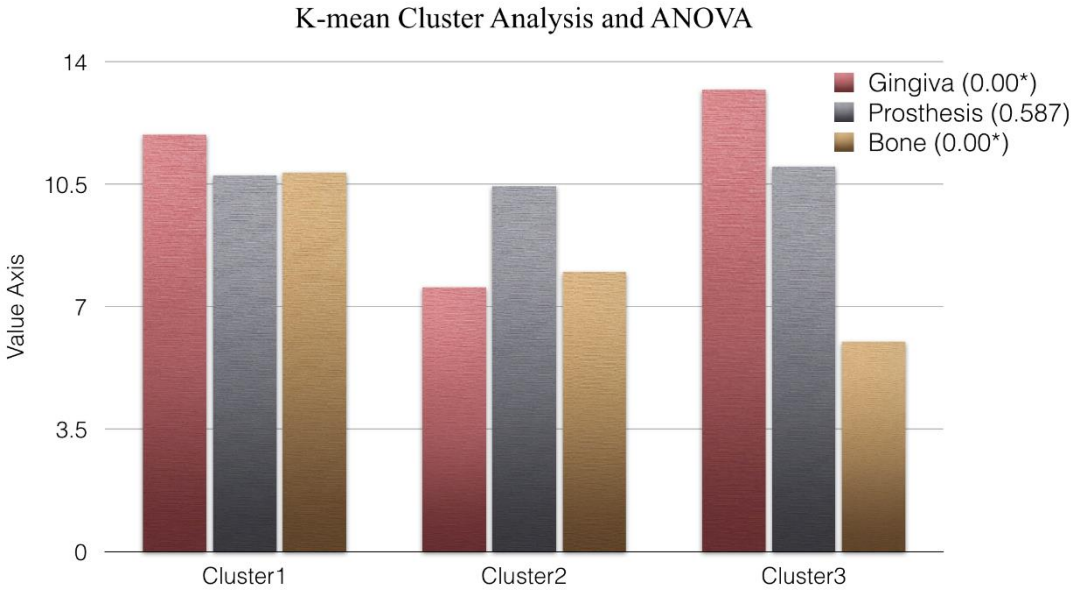

Figure 12 the score characteristic of each cluster after analysed by k-mean cluster

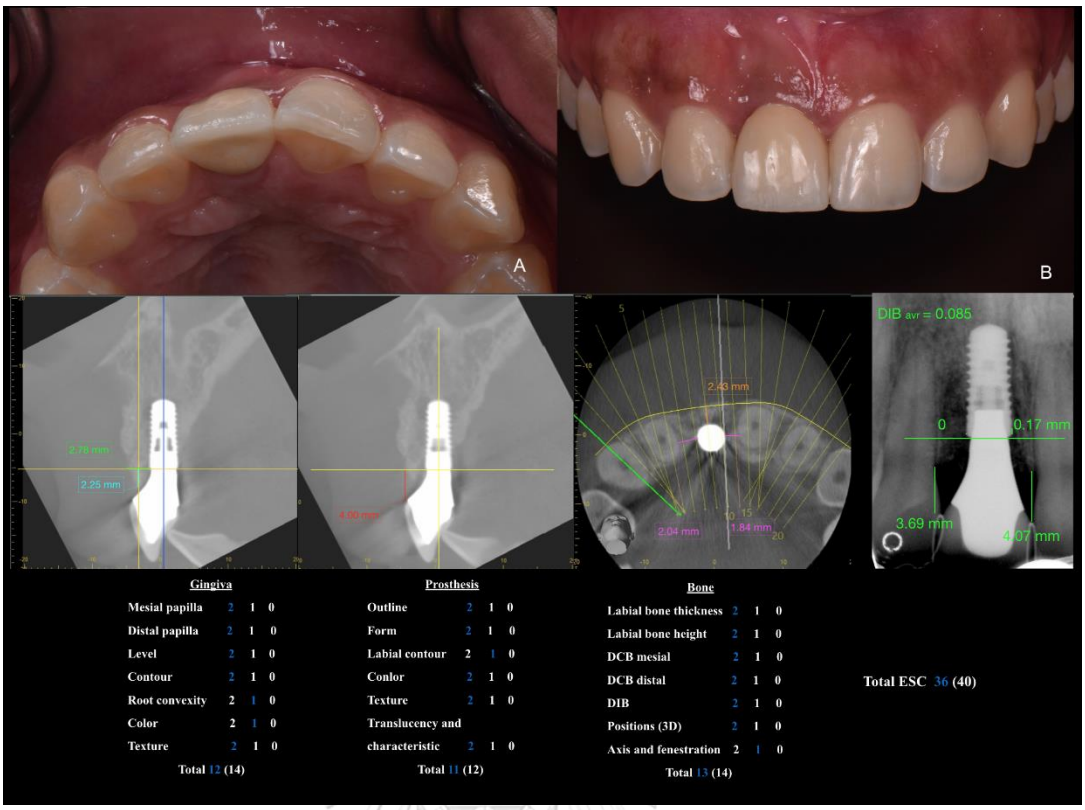

Figure 13 Example case of excellent group (cluster 1),

Case owner: Panita Sutisakpakdi, Master degree student,

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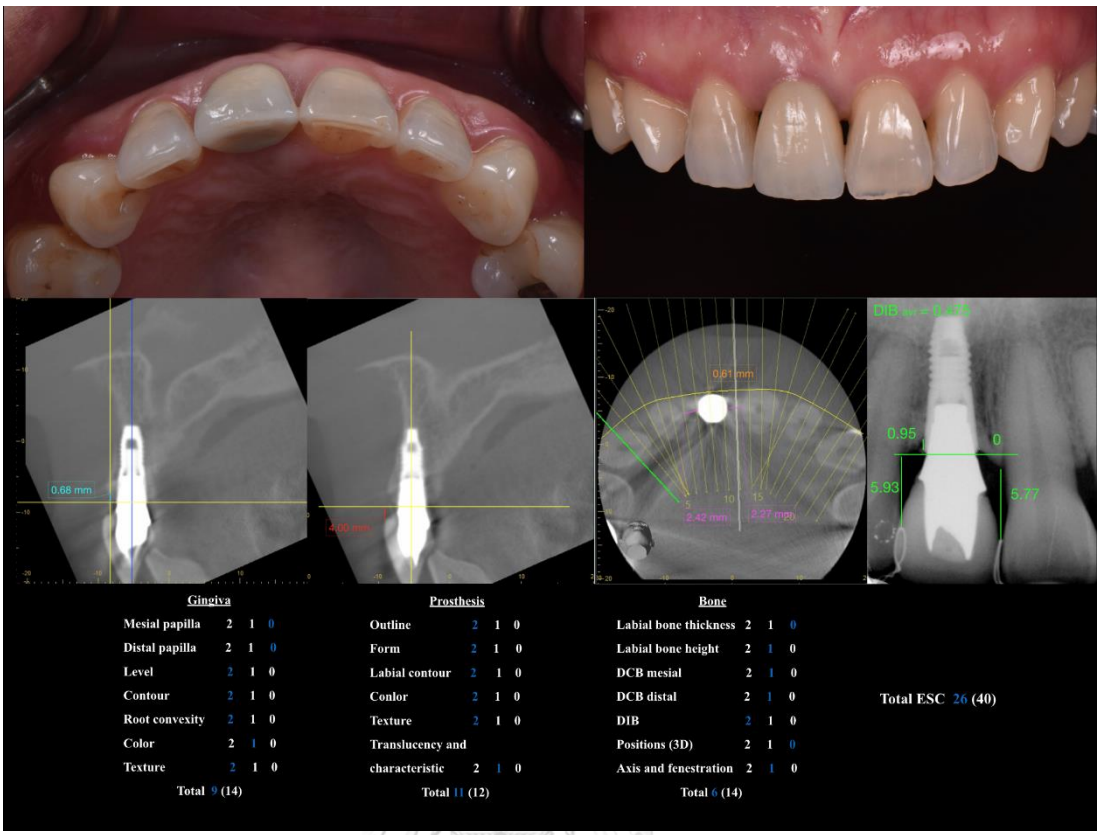

Figure 14 Example case of medium group (cluster 2),

Case owner: Chayanuch Angkaew, Master degree student,

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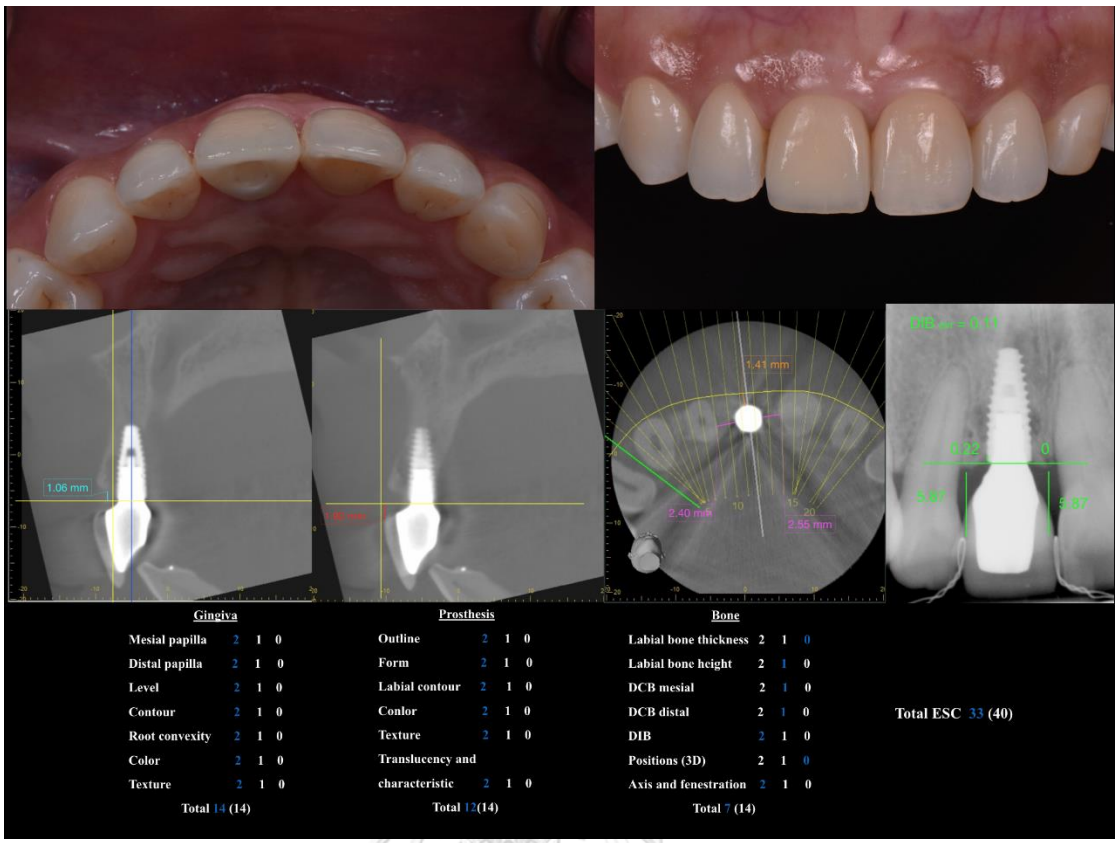

Figure 14 example case of divergent group (cluster 3)

Case owner: Nomjit Vidhayaphum, Master degree student,

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CHAPTER V DISCUSSIONS AND CONCLUSIONS

5.1 Discussions

This cross-sectional study mainly observed the correlation between the PES/WES criteria, which comprised gingival and prosthetic evaluation, and MOC, which created from 4 modifications from the well-known PES/WES. Firstly, gingival level assessment was changed to a measurable procedure. Secondly, the combined factor of PES, which were root convexity, texture and color, was separated independently. Adding bone-implant assessment as a part of the evaluation was the third modification. Fourth, labial contour parameter as applied to the new prosthetic evaluation. It was challenging to perform this kind of clinical trial because combining the holistic bone observation, as a part of postoperative esthetic implant evaluation, was never been done before. However, some interesting outcomes noticed.

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Since PES/WES was proposed to the implant society as a tool for evaluating the esthetic outcomes of STIR, This criteria was used in various scenario. The overall score of this criteria was found between 12-20 points with little amount of case from many studies showed the score below the acceptable threshold. Chayanuch and

colleagues observed the correlation between esthetic outcomes of STIR and their oral-health quality of life [60], The PES/WES score of the study was 16. While the study of Laren and colleagues [61] has PES/WES score 13.8 approximately. Moreover, Mangano and colleagues [62] presented their PES/WES score of immediately restored single implant in fresh and healed socket in 3-year follow up were 16.4 and 15.2 respectively. Resemble to our observation, the PES/WES score was 16 (median), which 3 of all cases has PES below 5 score but excellent in WES, which as same as the study of Critalli and colleagues [63]. This finding remind us that god prosthetic workflows could bring the compromised gingival architecture from STIR. Regard to MOC, the process of evaluating the implant was different and never be done before as mentioned in the previous paragraph. The authors design the method of this study by using same data of STIR that evaluated in PES/WES in order to get rid of the any bias of sample. Finally, the results of k-mean cluster could analyzed the data into 3 groups: excellent, medium and divergent.

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MOC score of 26 implants could be categorized into three group in accordance with k-mean cluster analysis, which is an unsupervised learning analysis. This number

of cluster came from the least possible that the authors could noticed the differences among group. 2 clusters could separate only gingival score. While, the 6 clusters could separate all gingival, prosthetic and bone score among groups significantly. However, detailed gingival and bone score would be difficult to interpret in this number of cluster and may lead reader confusing. Moreover, 6 cluster could imply the behavioral of prosthetic score that seemed to close to each other, which our study showed most of these score was high level comparing to other 2 parts. This high score of prosthesis was found in many study (Belser, Grutter, Vailati, Bornstein, Weber & Buser 2009, Cristalli, Marini, La Monaca, Sepe, Tonoli & Annibali 2015). Therefore, the author selected 3 clusters for seeing the correlation between ESC and PES/WES namely both-high group, both-medium group and divergent group.

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In the excellent group, the MOC score of the implant was 32-36 (Figure 13), while PES/WES was 16-20. While keeping in mind that MOC had a bone foundation evaluation part add on, high score of PES/WES with high score of MOC could imply that good or healthy surrounding bone of the implant may influence the esthetic outcome of the STIR. Some positive correlation of bone and gingiva appeared in many

of the bone factors such as labial bone thickness, labial bone height and implant position.

Regarding to labial bone thickness and height, Ventri and colleagues[64] study the 3-dimensional buccal bone anatomy and the esthetic outcome by using PES/WES and found that PES had a positive correlation to the thickness of the buccal bone at mesial and distal adjacent to the implant shoulder. Moreover, baseline buccal bone level correlated with gingival contour factor of the PES. Additionally, the sites without radiographically detectable buccal bone presented with 1 mm more apical mucosal level in comparison to the implant with intact buccal bone [65]. Resemble to our study, Buser et al. had shown the outcomes of their study [48], which observe the stability of guided bone regeneration procedure in anterior implant restoration in 5-9 year follow-up. They found that having labial bone wall in both thickness and height provide the stability of mucosal margin. However our finding showed some different results. There were 3 and 1 out of these 12 implant in this cluster got 0 score in labial bone thickness and height respectively. This different outcomes may resulted from the 0 score of MOC mean less than 1 mm of the bone, which lack of the bone was

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subset of this factor. Moreover, lacking of controlling the material of the operation such as artificial bone, or different the operators performing the implant treatment, even these operations were controlled by one experienced dentist, may affect the outcomes.

3D implant positions was accepted as the true factor for achieving in esthetic in the anterior implant restoration[27]. Recently, Furze and colleagues [66] placing implant with correct 3-dimensional implant positions and peri-implant tissue conditioning with temporary fixed prosthesis brought excellent esthetic outcome (PES/WES 16.7). In term of our study, 10 out of 12 from this cluster placed 3 dimensional correct, the rest was correct 2 dimensions.

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The second cluster of MOC, which called the medium group, showed the positive relation as the first cluster but compromised results. In this group, the range of the score was in 24-27. To compare this esthetic outcomes to PES/WES, this cluster was in 12-16 when evaluated by the criteria, which could be categorized as acceptable results. The compromised esthetic outcomes of both PES/WES and MOC could imply that something affecting bone around implant may influence gingival

esthetic outcome. Hita-Iglesias et al.[67] compared the survival rate of immediate implant between healthy and chronic apical lesion. They found that Implant survival rate were significant lower after immediate implant in chronic periapical disease comparing healthy socket. Regarding to the implant axis, Ramaglia and colleagues[68] proposed that Implant angulation associated with the vertical marginal bone resorption. Resorption in buccal area may be less intensive when the angulation of the implant trend toward to palatal area. Moreover, Furhauser et al claimed that Deviation of the implant shoulder and apex more than 0.8 mm would give a compromised esthetic score. The more deviate implant was, the more compromised PES. Additionally, the study of Nissapakultorn et al. found that implant fixture angle influenced the facial mucosal level. They found a significant correlation between the angulation of implant that showed the facial gingival level < 0.49 mm and ≥ 1 mm. in the other word, the more procline implant was placed, the more risk to gingival recession.

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Last but not least, divergent group was the group that showed a unique characteristic. While the gingival score showed the excellent outcomes (12-14), the

bone score was low (5-7) in accordance MOC evaluation. This phenomenon lead the total score of MOC seem to be almost excellent appearance (28-33), which better than the medium group. However, excellent outcomes (16-20) of this cluster showed when evaluating with PES/WES. The still-excellent PES/WES with seem-to-be excellent MOC questioned the authors why the low score of bone could bring the excellent outcome of gingiva. The contrast findings was found in some studies.

The first contrast findings was the PES and labial bone height. Ventri et al. [64] found that even PES correlate with the buccal bone thickness, it did not showed any correlation with bone dehiscence. Moreover, there were some studies found that despite the presence of bone dehiscence, healthy peri-implant conditions were present at the buccal aspect and no report of increased rates of biological complications [64, 65, 69]. In the other hand, if the patient could take care of their implant well, labial bone dehiscence may not affect the esthetic outcomes. Resemble to our study, all the implant that observed was found in healthy condition and the all samples showed satisfied oral hygiene.

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The second non-correlation was gingival level and the level of the labial bone. Noelken et al.[70] proposed that marginal bone level seemed to be stay still while PES, especially the soft tissue level parameters, improved during 2 years of observation, while den Hartog and colleagues found the marginal bone loss showed significantly different among different implant neck design, however, esthetic outcome (both PES/WES and ICAI) did not. Moreover, Nissapakultorn et al. [51] also showed that gingival recession has significant correlation with the distance from contact point to bone crest. They suggested that not only the proximal bone is important to keep the level of dental papilla, but bone at that site can keep labial gingival level. These recruited knowledges inspired us the gingival esthetic outcome could not always truly imply the topography of underneath bone.

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Regarding to the implant axis and fenestration, 4 out of 5 cases of this cluster got 1 or 0 in implant axis and fenestration, but got 2 in root convexity. Moreover, there were 2 and 3 out of 5 cases of this cluster got 1 or 0 in 3D implant position, but had high score of gingival part respectively. This might be attributed to the chance of showing fenestration defect in cingulum position [52, 71] and somehow the effect of

gingival biotype, the amount of attach gingiva or the effect of type of abutment to tissue integration may help the outcomes of this factor better. Further study about these outcomes should be needed.

5.2 Conclusions

With all the limitations of the study, the conclusions could be drawn. Combining the bone assessment into esthetic evaluation could present the esthetic outcome correlate but clearer to the PES/WES, which the divergent group should be further observed for the sustainability of esthetics

5.3 Clinical Implication

MOC could make the observer evaluated the single-tooth implant restoration completely in 3 parts, which were gingival, prosthesis and bone foundation, moreover it could prevent missing some important parameters when following up the case. Additionally, using MOC would provide the clearer outcomes on that restoration resulting in the observer would see which part of the implant having defect, good for observing the sustainability in implant esthetic outcomes and lead the dentist to more caring on the implant or make further beneficial treatment plan to the patient.

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APPENDIX

Appendix A. guideline for measuring surrounding bone in bone foundation part of MOC

Guideline for positioning head on CBCT image in the study of

"The Overall Assessment of Esthetic Around Single-tooth Implant Restoration: Modified Objective Criteria"

After obtaining a subject CBCT image, please make sure that the quality of the picture is good. Required object should be clearly observed with no noticeable movement. Adjust the clearance of the image so that the implant was obviously seen in fixture and abutment components by adjusting in "histogram window", in this picture WL and WW were adjusted to 3200 and 3000 respectively. After that, remove this window by click the histogram function at the right side of the screen.

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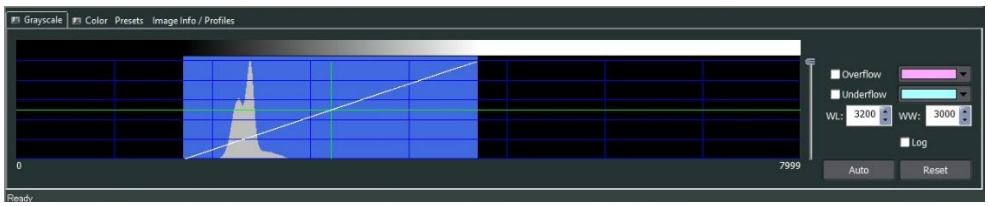

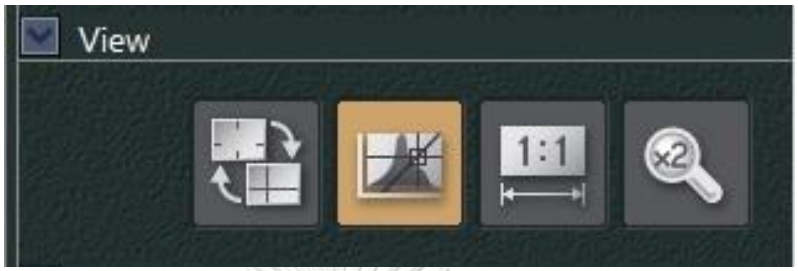

Head-position adjustment on CBCT image

1. Move a maxillary plane (red line) to the level of platform of the observed implant

2. Adjust head position in sagittal view by rotating the image so that the axis of the fixure parallel to the vertical line. Move the coronal plane (blue line) bisecting the implant sagitally.

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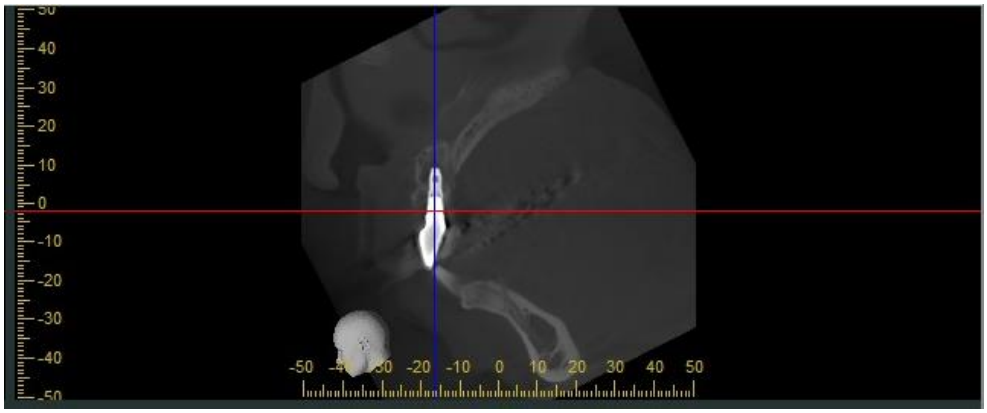
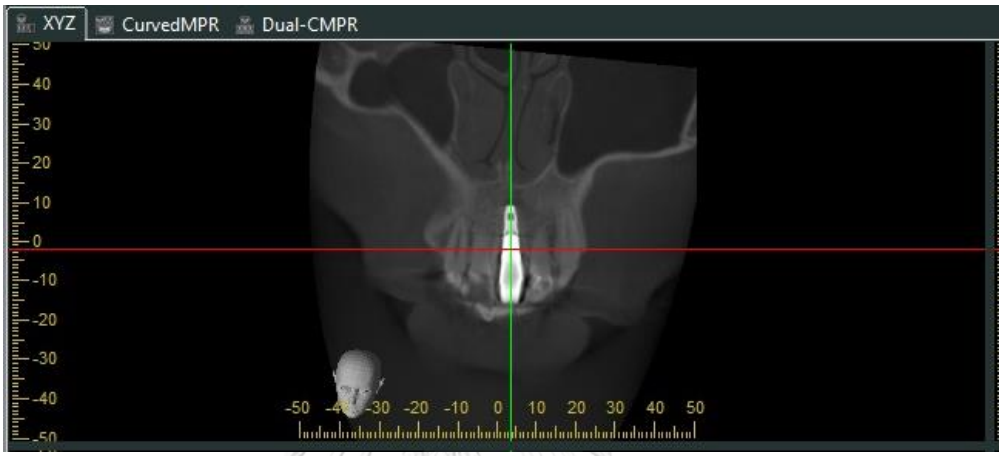
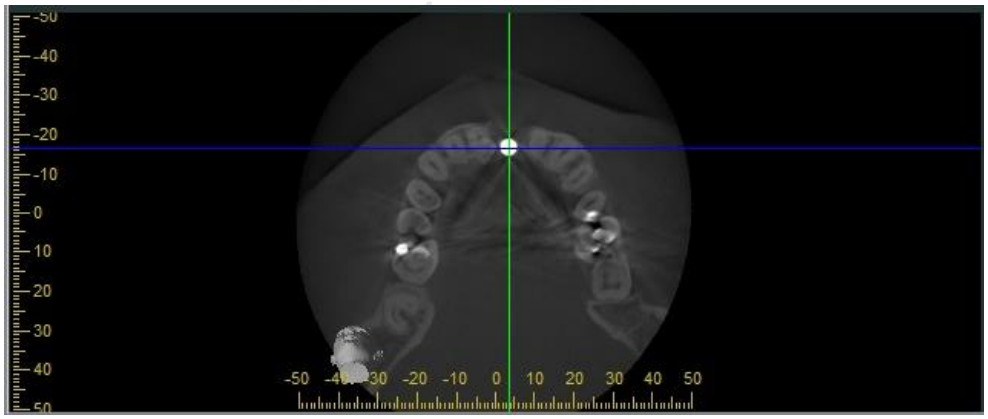


3. Coronally adjust the image by rotating the image so that the axis of the implant is parallel to the vertical line. The sagittal plane (green line) is moved bisecting the implant.

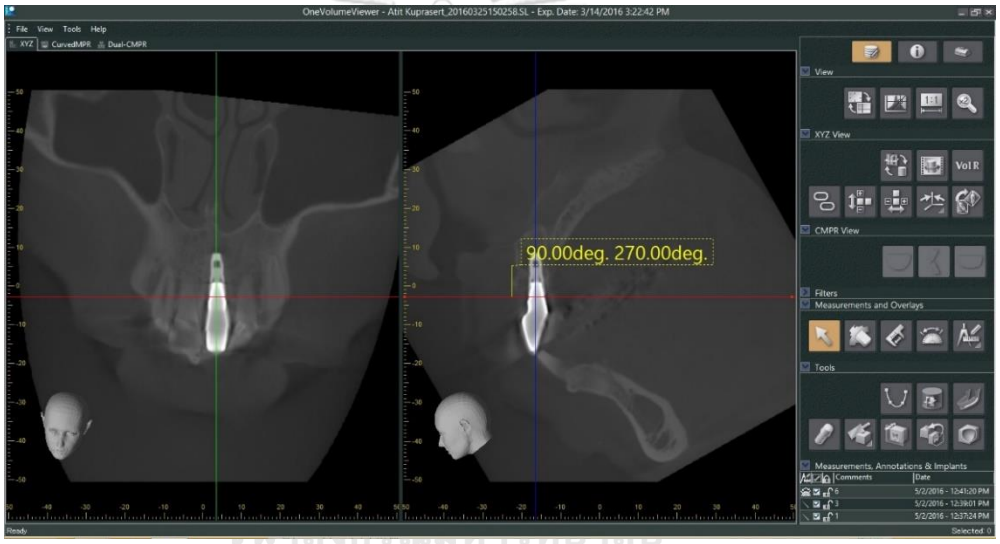


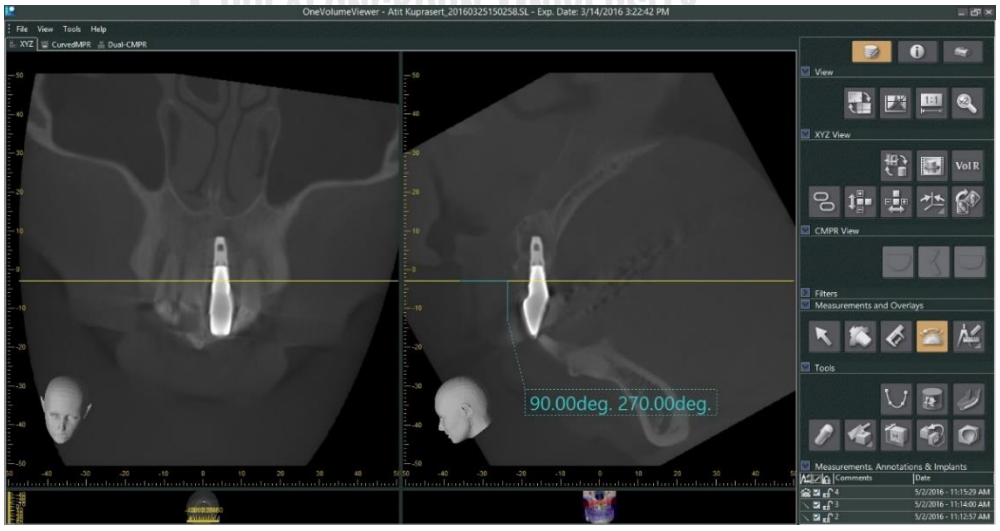
4. Rotate the arch form so that it showed symmetrical position between left and right side



5. Fully enlarge the sagittal view and coronal view, create one reference line at the platform level of each picture in accordance with the maxillary plane by using

“2D annotation” > “linear tool”(yellow line from the lower picture). Moreover, the 90-degree of reference angle is also created by using “measure angle” tool on the sagittal view (Draw the first line of the reference angle locating on the plat-form level reference line. After double click on the first line end point, the second line is drawn perpendicularly to the first line.)

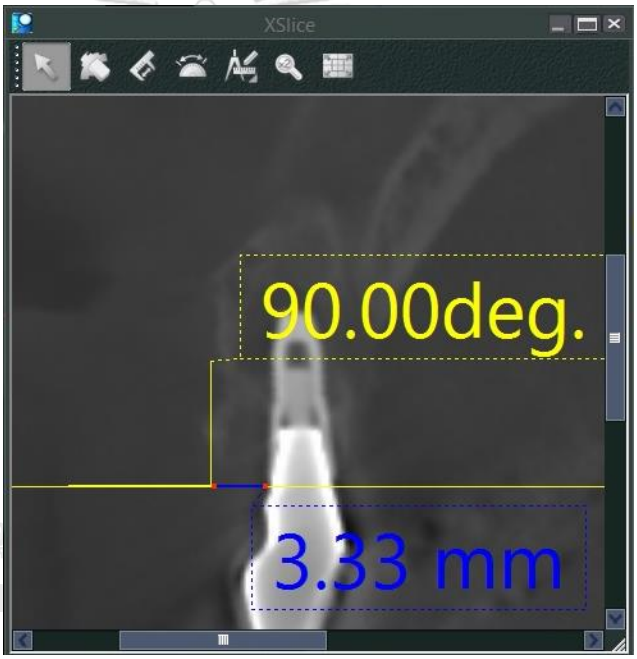




6. Evaluate the labial bone thickness by

    a. 200 times enlarge the picture in sagittal view

    b. Measuring from outermost of the implant platform perpendicularly to the most outer surface of labial cortical wall on the reference line by using "measure length"

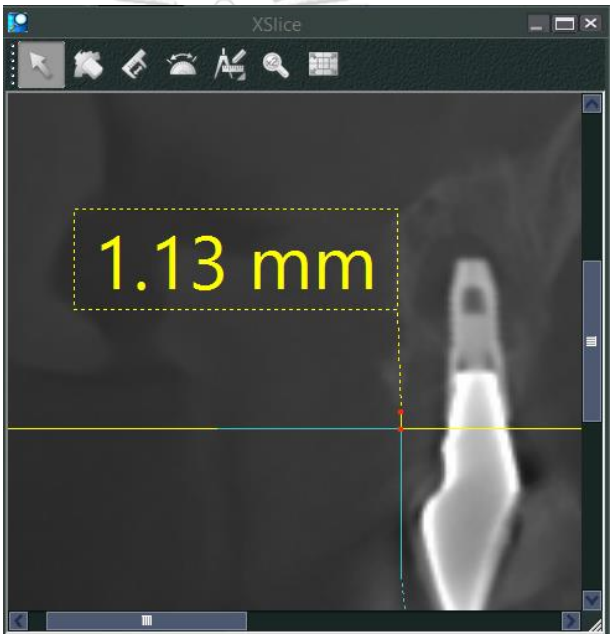


    c. If dehiscence is found at any point of measurement, the labial bone thickness at that point will be equal to 0

7. Evaluate the labial bone height by

    a. 200 times enlarge the picture in sagittal view

    b. Measuring the height of the labial bone by “measure length” and drawing a line from the platform-level reference line to the peak of the crest which parallel to the reference angle



    c. If the peak of the labial bone is located above the implant platform, the negative value (-) will be given to that number

    d. On the other hand, if the peak of the labial bone is located under the implant platform, the positive value (+) will be given to that number

8. Evaluate the implant axis by

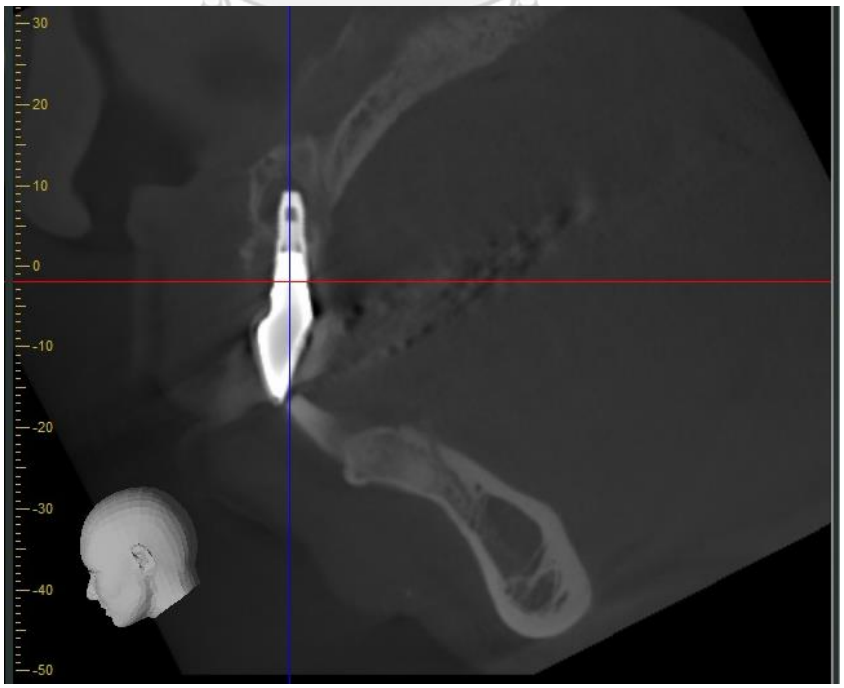
    a. Magnifying the picture to the full-screen display

    b. Draw a line which bisecting the implant in sagittal plane

    c. If the line pass the cingulum part of the restoration, cingulum position is defined.

    d. If the line pass the area of incisal 1/3 position, the incisal position will be defined.

    e. If the line pass the labial position of the restoration, labial position is defined.



9. Evaluate the 3D implant position by

- Magnify the crossectional picture to the full-screen display
- Evaluate the implant position following step by step

    a. Mesio-diatal position

        i. measuring the shortest distance from the outermost of the implant platform to the outermost of the adjacent root in crossectional view. The assessment will be performed on both mesial and distal surface

        ii. If the measured value is more than 1.5 mm on the both side of measurement, the position will be defined as “correct position”.

        iii. While the measured value is less than 1.5 mm on only one side of measurement , the positon will be immediately defined as “fault position”.

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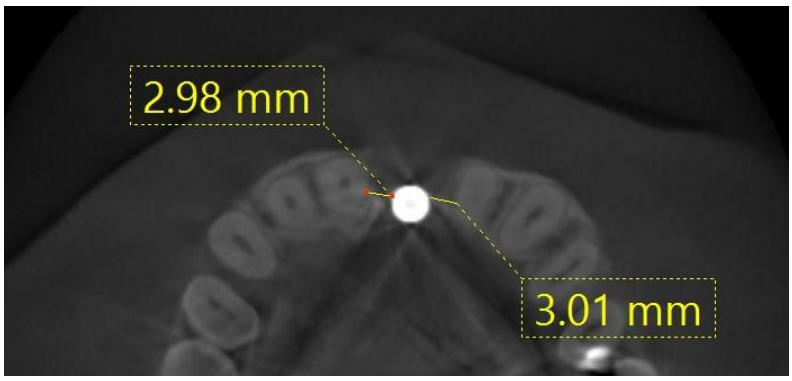

b. Oro-facial position

i. Click the CurveMPR display, and select curve tool to create the imaginary contour of the labial bone

ii. To construct the curve, at least five dots are defined at the most labial contour of the bone. All dots should be placed on the natural tooth to avoid a bias from labial contour definition on implant.

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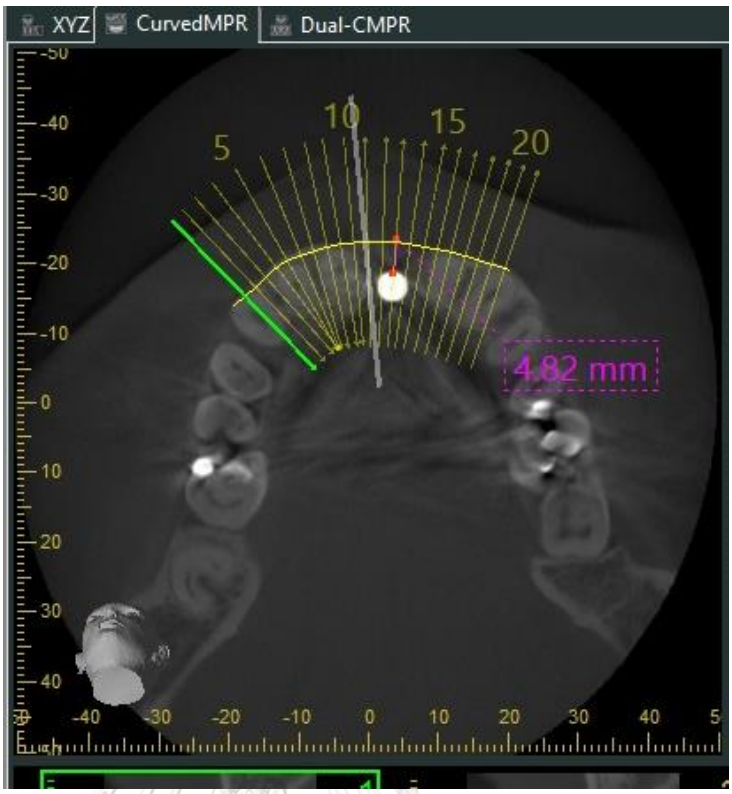
iii. Draw the shortest line from the outermost of the implant surface to the imaginary curve perpendicularly. The oro-facial distance will be defined

iv. If the distance is in 2mm – 3mm, the correct position will be defined.



c. apicocoroanl position

i. Select XYZ mode

ii. Move the sagittal plane on the coronal view distally for 1 mm in accordance with ruler

iii. Magnify the sagittal view to full-screen display 300 times

iv. Measuring the apico-coronal position by drawing a line from the uppermost and outermost point of the restoration to the

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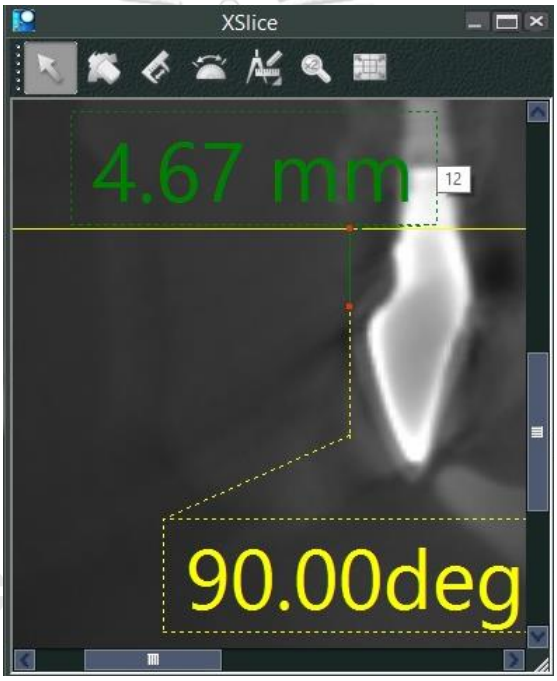
platform-level reference line perpendicularly and parallel to the reference angle

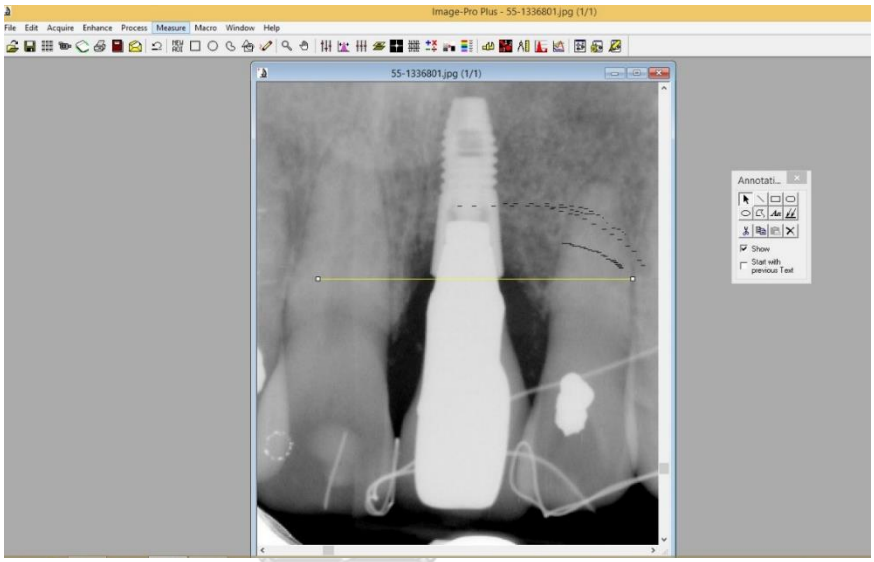
v. If the distance is appeared in 3-4 mm., the correct position will be defined. If the measured distance is less than 3 mm. or more than 4 mm , the position will be defined as “incorrect position”



10. Evaluate the distance between most-apical contact area to peak of crestal bone –DCB by using image pro program

a. Enlarge the image by click “zoom in” button, then, select 200 times zoom in

b. Create the reference line by using “Annotation”, then, select “linear tool”. After that move the line to the level of platform of the implant fixure.



c. Calibrate the size of the image by selecting “Measure” > “Spartial calibration” > define the unit as “mm” > select “Image” on the Pixels/Unit > define the length of the implant by drawing the line from the implant platform to the apical level of the implant fixure (This picture show 11 mm as the length of the implant.)

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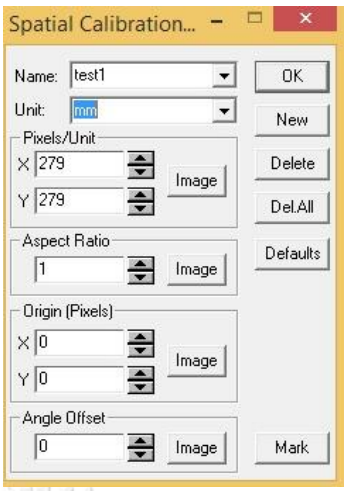

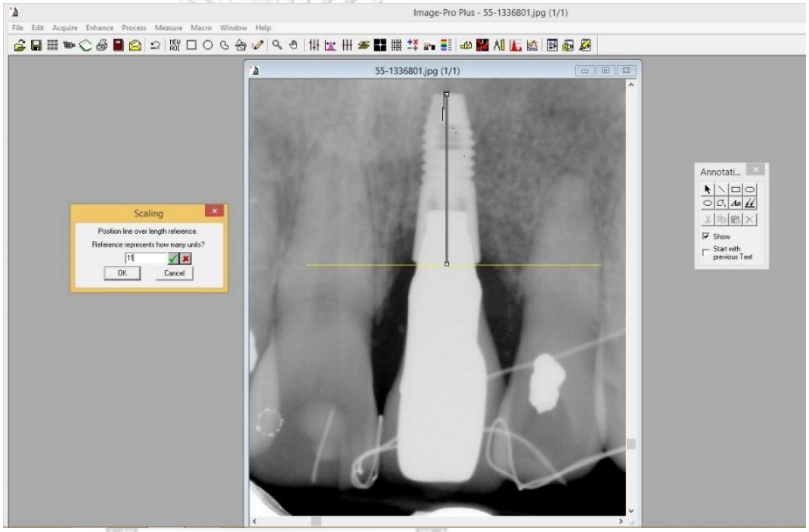

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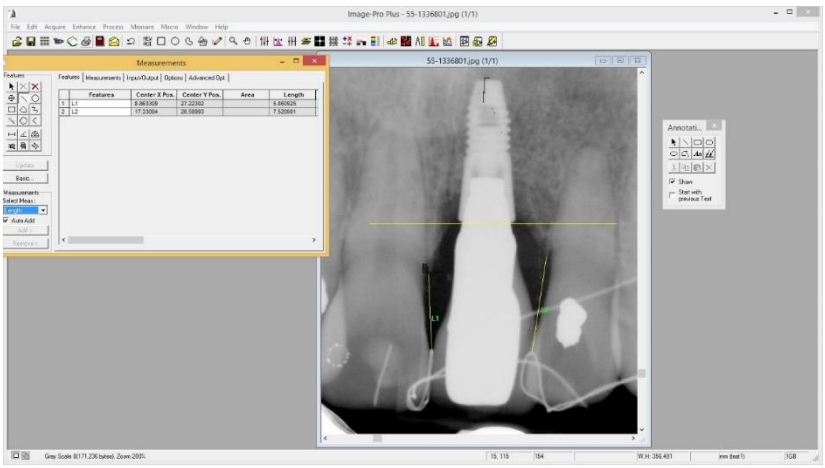
d. Draw a line from the most apical point of the wire embracing the contact area to the peak of the crestal bone by using “Measure” > “Measurement” > “linear tool”. That line is defined as DCB.



e. Measure DCB at the other side

11. Evaluate the distance between implant platform to first bone-to-implant contact-DIB

a. Move the reference line to the most upper of rough part of the fixure

b. Draw 2 lines from that reference line to the first bone-to-implant contact on both mesial and distal side

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c. DIB = $(DIB_{mesial} + DIB_{distal})/2$

Appendix B. intra-inter reliability observation

	Variables	Intra-examiner 1	Intra-examiner 2	Inter-examiner
PES/WES	Mesial papilla	0.645/0.001	0.737/0.000	0.527/ 0.004
	Distal papilla	1.000/0.000	0.845/0.000	0.857/0.000
	Curve of mucosa	0.629/0.015	0.675/0.015	0.629/0.015
	Level of mucosa	0.581/0.008	0.562/0.024	1.000/0.000
	Root convexity/ texture/ color	0.649/0.012	0.049/0.835	0.90/0.640
	Crown outline	0.639/0.021	1.000/0.000	0.581/0.021
	Crown form	0.755/0.005	0.806/0.003	0.755/0.005
	Crown color	0.649/0.012	0.69/0.013	0.519/0.033
	Crown texture	0.629/0.015	0.649/0.012	0.755/0.005
	Crown translucency and characteristic	0.675/0.015	1/0.000	0.698/0.008

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Appendix B. intra-inter reliability observation (continued)

		Variables	Intra-examiner 1	Intra-examiner 2	Inter-examiner
MOC	gingiva	Mesial papilla	0.655/0.001	0.621/0.002	0.636/0.002
		Distal papilla	0.621/0.002	1.000/0.000	0.857/0.000
		Curve of mucosa	0.606/0.002	0.845/0.000	0.819/0.000
		Level of mucosa	0.755/0.005	1.000/0.000	0.755/0.005
		Root convexity	0.859/0.000	0.857.0.001	0.729/0.001
		Texture	0.629/0.015	0.755/0.005	0.755/0.005
		Color	0.843/0.002	0.675/0.015	1.000/0.000
	prosthesis	crown outline	1.000/0.000	0.755/0.005	0.567/0.041
		Crown form	0.629/0.015	0.675/0.015	0.629/0.015
		Crown labial contour	1.000/0.000	0.567/0.041	0.629/0.015
		Crown color	0.698/0.008	0.683/0.009	0.541/0.048
		Crown texture	1.000/0.000	0.621/0.002	1.000/0.000
		Crown translucency and characteristic	0.831/0.002	0.536/0.016	1.000/0.000
	bone	Labial bone thickness	0.840/0.001	0.594/0.006	0.711/0.001
		Labial bone height	1.000/0.000	0.755/0.000	0.874/0.000
		DCB- mesial	0.717/0.003	0.735/0.001	0.723/0.002
		DCB- distal	0.602/0.005	0.610/0.005	0.625/0.002
		DIB	0.594/0.008	0.581/0.021	0.658/0.006
		Implant position	0.658/0.000	0.652/0.002	0.548/0.003
		Implant axis and fenestration	0.745/0.000	0.852/0.001	0.469/0.014

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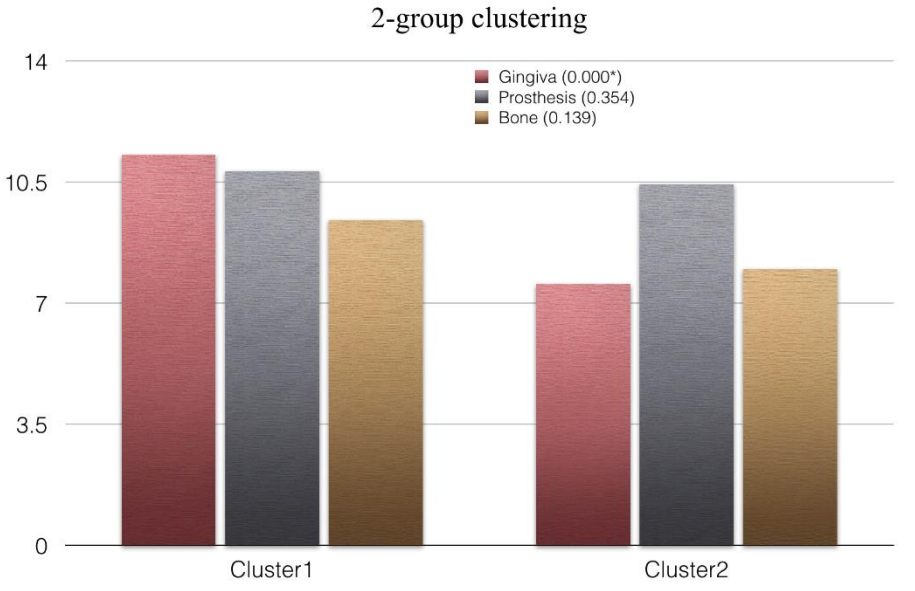
Appendix C. 2-group clustering result from K-mean cluster analysis

Final Cluster Centers

	Cluster	
	1	2
mocgum	12.29	7.56
mocprosth	10.82	10.44
mocbone	9.41	8.00

ANOVA

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
mocgum	132.133	1	1.156	24	114.270	.000
mocprosth	.846	1	.946	24	.894	.354
mocbone	11.729	1	5.005	24	2.343	.139



Appendix D. 4-group clustering result from K-mean cluster analysis

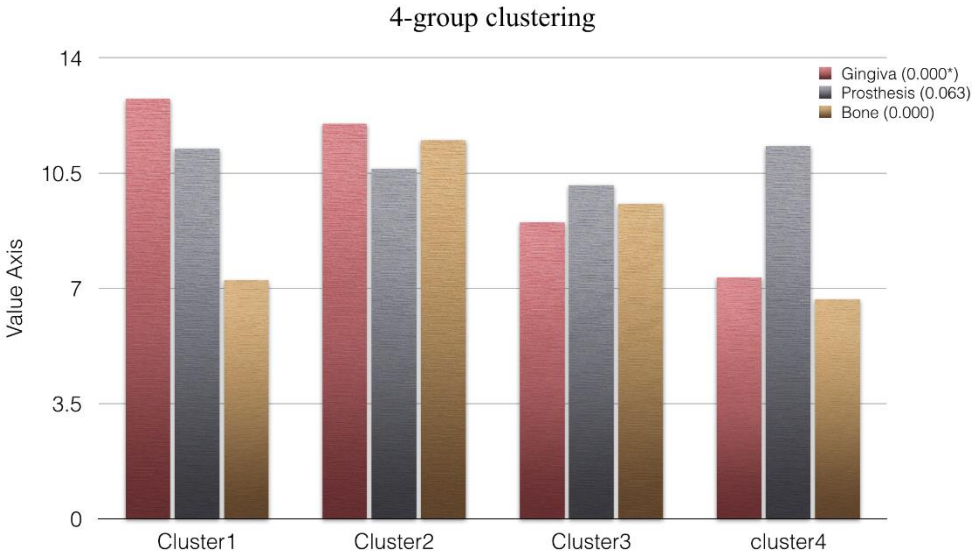
Final Cluster Centers

	Cluster			
	1	2	3	4
mocgum	12.75	12.00	9.00	7.33
mocprosth	11.25	10.63	10.14	11.33
mocbone	7.25	11.50	9.57	6.67

ANOVA

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
mocgum	33.496	3	1.189	22	28.162	.000
mocprosth	1.906	3	.677	22	2.814	.063
mocbone	30.924	3	1.449	22	21.340	.000

The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.



Appendix E. 5-group clustering result from K-mean cluster analysis

Final Cluster Centers

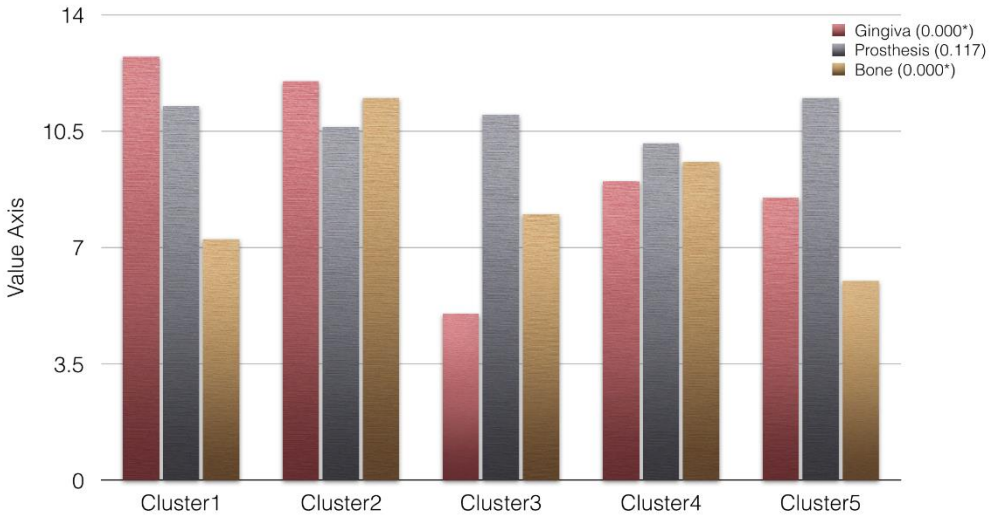
	Cluster				
	1	2	3	4	5
mocgum	12.75	12.00	5.00	9.00	8.50
mocprosth	11.25	10.63	11.00	10.14	11.50
mocbone	7.25	11.50	8.00	9.57	6.00

ANOVA

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
mocgum	27.163	4	.857	21	31.691	.000
mocprosth	1.471	4	.702	21	2.097	.117
mocbone	23.860	4	1.391	21	17.151	.000

The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.

5-group clustering



Appendix F. 6-group clustering result from K-mean cluster analysis

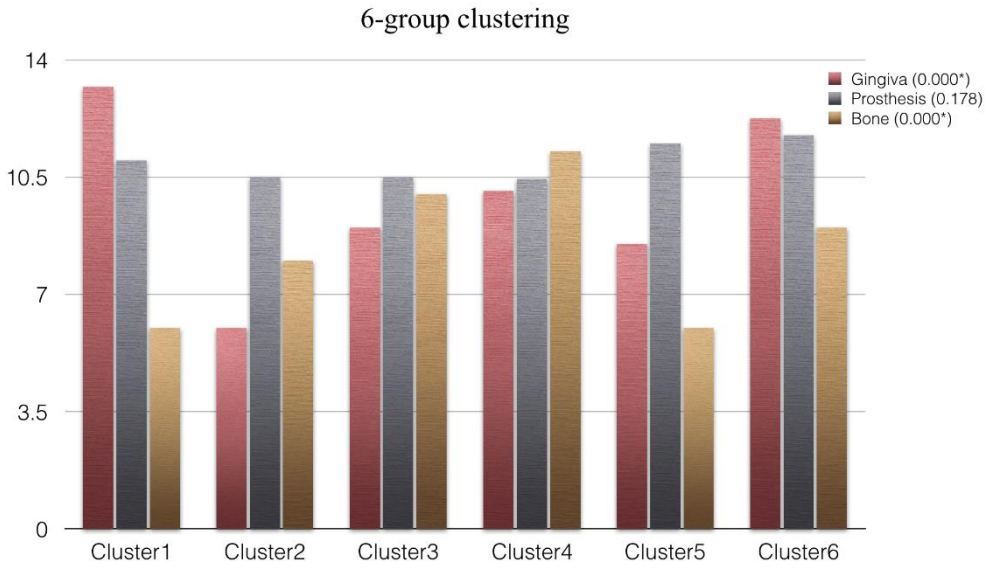
Final Cluster Centers

	Cluster					
	1	2	3	4	5	6
mocgum	13.20	6.00	9.00	12.09	8.50	12.25
mocprosth	11.00	10.50	10.50	10.45	11.50	11.75
mocbone	6.00	8.00	10.00	11.27	6.00	9.00

ANOVA

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
mocgum	22.185	5	.848	20	26.163	.000
mocprosth	1.281	5	.749	20	1.711	.178
mocbone	24.641	5	.609	20	40.455	.000

The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.



Appendix G. 7-group clustering result from K-mean cluster analysis

Final Cluster Centers

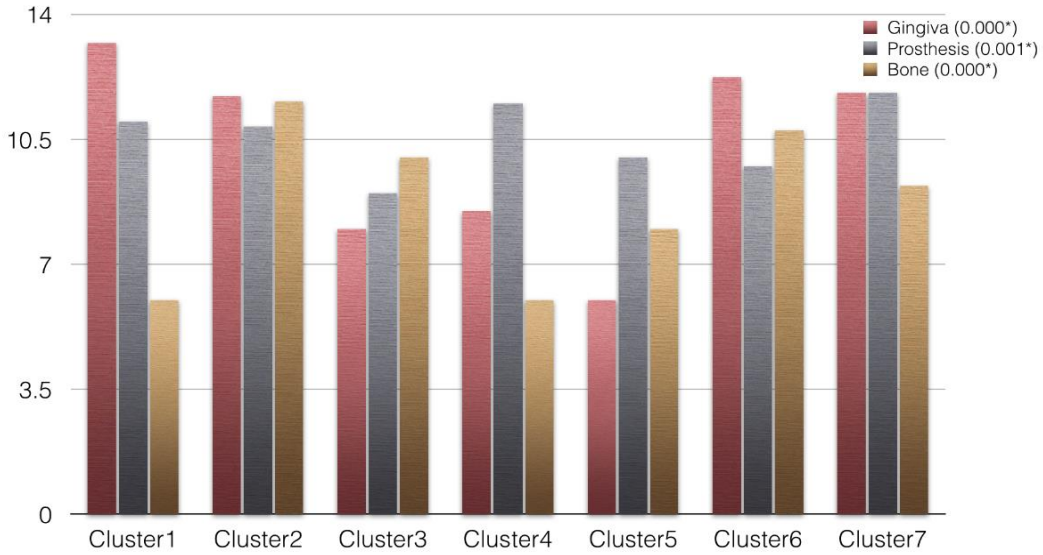
	Cluster						
	1	2	3	4	5	6	7
mocgum	13.20	11.71	8.00	8.50	6.00	12.75	11.80
mocprosth	11.00	10.86	9.00	11.50	10.50	9.75	11.80
mocbone	6.00	11.57	10.00	6.00	8.00	10.75	9.20

ANOVA

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
mocgum	18.601	6	.857	19	21.711	.000
mocprosth	2.330	6	.390	19	5.976	.001
mocbone	20.687	6	.593	19	34.893	.000

The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.

7-group clustering



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RESEARCH GRANT:

- The Graduated School of Chulalongkorn University, Bangkok, Thailand

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