COMPARISON OF THE ACCURACY BETWEEN DIGITAL AND CONVENTIONAL IMPRESSION IN DIFFERENT MULTIPLE IMPLANT ANGLES AT POSTERIOR MANDIBULAR REGION USING INNOVATION 3D SUPER IMPOSITION SOFTWARE PROGRAM; IN VITRO STUDY

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A Thesis Submitted in Partial Fulfillment of the Requirements
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การเปรียบเทียบความแม่นยำของรอยพิมพ์รากเทียม ที่ได้จากการพิมพ์ปากด้วยวิธีสแกนภาพในช่องปากกับการพิมพ์ปากด้วยวิธีทั่วไป จากโมเดลที่มีรากเทียมทำมุมต่างๆกันบริเวณฟันกรามล่าง โดยการใช้นวัตกรรมภาพสามมิติเชิงซ้อนในการวัดผลเปรียบเทียบ (การศึกษาในห้องปฏิบัติการ)

น.ส.อริสา หงษ์โสภา

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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อริสา หงษ์โสภา : การเปรียบเทียบความแม่นยำของรอยพิมพ์รากเทียม ที่ได้จากการพิมพ์ปากด้วยวิธีสแกนภาพในช่องปากกับการพิมพ์ปากด้วยวิธีทั่วไป จากโมเดลที่มีรากเทียมทำมุมต่างๆกันบริเวณฟันกรามล่าง โดยการใช้นวัตกรรมภาพสามมิติเชิงซ้อนในการวัดผลเปรียบเทียบ (การศึกษาในห้องปฏิบัติการ). (COMPARISON OF THE ACCURACY BETWEEN DIGITAL AND CONVENTIONAL IMPRESSION IN DIFFERENT MULTIPLE IMPLANT ANGLES AT POSTERIOR MANDIBULAR REGION USING INNOVATION 3D SUPER IMPOSITION SOFTWARE PROGRAM; IN VITRO STUDY) อ.ที่ปรึกษาหลัก : รศ.ทพ.ประเวศ เสรีเชษฐพงษ์, อ.ที่ปรึกษาร่วม : รศ.ทพ. ดร.อาทิพันธุ์ พิมพ์ขาวขำ

วัตถุประสงค์ : เพื่อวัดความแม่นยำเชิง 3 มิติของรอยพิมพ์รากฟันเทียมด้วยวิธีทั่วไปและ

วิธีสแกนภาพในช่องปากแบบดิจิทอล โดย เทียบกับโมเดลต้นแบบซึ่งมีการปักรากเทียมทั้งหมด 4 ตัวในมุมที่แตกต่างกัน

วิธีการศึกษา : โมเดลต้นแบบนำมาปักรากฟันเทียมทั้งหมด 4 ตัว โดยแต่ละตัวทำมุม 15 องศา ทางด้านกระพุ้งแก้ม, ด้านลิ้น, ด้านไกลกลาง, ด้านใกล้กลาง กับเส้นตั้งฉากของระนาบการสบฟัน ในตำแหน่งซี่ฟัน 36, 37, 46, และ 47 ตามลำดับ ในการทดลองจะมีการพิมพ์รากเทียม 15 ครั้ง ในแต่ละแบบ โดยวิธีดั้งเดิมจะนำไปเทปูน และวิธีดิจิทอลจะนำไปปริ้นท์เป็นโมเดลสามมิติ หลังจากนั้นนำชิ้นงานทั้งหมดซึ่งประกอบด้วย โมเดลต้นแบบ 1 ชิ้น โมเดลปูน และ ดิจิทอลโมเดล อย่างละ 15 ชิ้น ไปวัดความแม่นยำด้านระยะทางและมุมเชิง 3 มิติ ด้วยเครื่องวัดชิ้นงานละเอียด 3 มิติแบบเคลื่อนย้ายได้ร่วมกับโปรแกรมโพลีเวิร์ค โดยจะนำผลการวัดที่ได้จากรอยพิมพ์ทั้ง 2 ชนิด มาเทียบกับโมเดลต้นแบบ

ผลการศึกษา : จากการทดลองวัดความแม่นยำในด้านระยะทางของโมเดลต้นแบบในตำแหน่ง 37, 36, 46, และ 47 คือ 23.647, 31,984, 27.865, and 26.995 มม. ตามลำดับ ผลการวัดวิธีการพิมพ์รากเทียมแบบดั้งเดิม คือ 23.943, 32.137, 28.064, และ 27.172 มม.ในขณะที่ผลการพิมพ์รากเทียมแบบดิจิทัล คือ 23.592, 32.238, 27.798, และ 26.899 มม. ในการวัดมุมแบบ 3 มิติ พบว่าโมเดลต้นแบบ บริเวณตำแหน่งรากเทียมซี่ 37, 36, 46, และ 47 ได้ผลคือ 69.628, 78.445, 75.723, และ 78.579 องศา ผลการวัดวิธีการพิมพ์รากเทียมแบบดั้งเดิม คือ 71.076, 78.404, 75.968, และ 77.944 องศา ในขณะที่ผลการพิมพ์รากเทียมแบบดิจิทัล คือ 69.298, 78.351, 75.516, 78.746 องศา ในการทดสอบเชิงสถิติพบว่า การวัดความแม่นยำในด้านระยะทางของการพิมพ์รากเทียมแบบดิจิทอลมีความแตกต่างแบบมีนัยสำคัญในรากเทียมทั้ง 4 ตำแหน่ง ส่วนการวัดความแม่นยำในแง่ของ มุม 3 มิติ พบว่า การพิมพ์รากเทียมแบบดิจิทอลมีความแตกต่างแบบมีนัยสำคัญ บริเวณซี่ 37 (เอียง 15 องศา ด้านลิ้น) และซี่ 47 (เอียง 15 องศา ด้านใกล้กลาง)

สรุป : ในเคสรากเทียมทำมุม 15 องศา แตกต่างกันทั้งหมด 4 ตำแหน่ง พบว่าความแม่นยำของการพิมพ์รากเทียมแบบดิจิทอล สูงกว่า การพิมพ์รากเทียมแบบวิธีทั่วไปทั้งในแง่ของ ระยะทางและมุมเชิง 3 มิติ

สาขาวิชา	ทันตกรรมบูรณะเพื่อความสวยงามและทันตกรรมรากเทียม	ลายมือชื่อนิสิต ....
ปีการศึกษา	2561	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
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5975843332 : MAJOR ESTHETIC RESTORATIVE AND IMPLANT DENTISTRY

KEYWORD: Angulated implant, Impression, Conventional technique, Digital technique, Intra-oral scanner, Dimensional change

Arisa Hongsopa : COMPARISON OF THE ACCURACY BETWEEN DIGITAL AND CONVENTIONAL IMPRESSION IN DIFFERENT MULTIPLE IMPLANT ANGLES AT POSTERIOR MANDIBULAR REGION USING INNOVATION 3D SUPER IMPOSITION SOFTWARE PROGRAM; IN VITRO STUDY. Advisor: Assoc. Prof. PRAVEJ SERICHETAPHONGSE, DDS Co-advisor: Assoc. Prof. ATIPHAN PIMKHAOKHAM, DDS, Ph.D.

Statement of problem: This study aims to compare the accuracy of three-dimensional changes in position and angulation between digital and conventional impression techniques in different angulated implants at the mandibular partial edentulous area with the use of a mandibular partial edentulous reference model with 4 dental implants in different angulations (15 degrees buccally,lingually, mesially, and distally). Conventional and digital impression techniques were used for master model and fabricated 15 conventional master casts and 15 three dimensional printing models. Each scan body was connected with implant or analog to transfer implant positions. All of the master model, master casts, and printing models were scanned with articulating arm computer coordinating measuring machine and evaluated with Polywork software program. Dimensional change of positions and angulations ware calculated and statistically analyzed. Reference Model with 4 angulated implants showed the distance to reference at 23.647, 31.984, 27.865, and 26.995 mm at 37, 36, 46, and 47 area respectively. Conventional method showed distance of 23.943, 32.137, 28.064, and 27.172 mm at 37, 36, 46 and 47area sequentially. Digital method presented with 23.592, 32.238, 27.798, and 26.899 mm at 37, 36, 46, 47 areas consecutively as shown 37, 36, 46, 47 areas of 23.637, 31.984 mm. Angulation measurement presented in reference model were 69.628 at 37 area, 78.455 at 36 area, 75.723 at 46 area, and 78.579 at 47 area. Conventional method displayed angulation of 71.076, 78.404, 75.968, and 77.944 at 37,36, 46, and 47 areas respectively. Digital method exhibited 69.298 and 78.351 at 37and 36 implants, 75.516, and 78.746 in angulation of 46 and 47 implants in digital technique Within the limitation of this vitro study, partially digital impression technique by the 3Shape intraoral scanner with 3D printing models presented significantly superior accuracy of 3- dimensional distance and angulation to conventional one.

Conclusion : Angulated dental implants decreased the accuracy of the conventional approach. Both techniques were clinically acceptable to treat the patients. However, the digital technique is recommended to have more accuracy and decreased chair time. A digital impression of angulated implants was presented more accurate than conventional one in both of distance and angulation.

Field of Study:	Esthetic Restorative and Implant Dentistry	Student's Signature ....
Academic Year:	2018	Advisor's Signature ....
		Co-advisor's Signature ....

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Arisa Hongsopa

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CHAPTER I

INTRODUCTION

Rationale and Significance of the problem

In restorative implant dentistry, constant problems regarding communication between dentist and laboratory technician are found for example, shade selection, abutment selection and model accuracy etc. To create an accurate model for multiple implant restorations with conventional impression technique, dentist must select proper impression materials and techniques to obtain an accurate master model. Conventional impression technique in implant dentistry can be divided into two categories which are impression via impression post (open or closed tray) and direct impression from final abutment. Both techniques utilize elastomer impression material and models were made from dental stone. Errors can occur during each step of workflow process. The dimensional deformation of an elastomer impression material and expansion of dental stone can create an error for implant position of master cast. It results in the misfit of a final restoration especially in connected multiple implant units. With this conventional technique, dentist must know how to verify and correct the master model prior to send it to laboratory.

With advent of digital technology in restorative implant dentistry the workflow of fixed prosthodontic dentistry can be simplified and improved. These technologies are subjected to produce the most accurate models with reduction of workflow process compared to a conventional fashion. Digital workflow process starts with impression by intra-oral scanner to positioning implant fixtures using implant scan body. Data from scanner can be directly sent to laboratory for a final restoration fabrication or a master model printing. These technologies allow dentist to make an impression without any other materials used, no need to pour up the stone and reduce errors during a laboratory process. However, some errors had been reported from these technologies (1, 2).

For example, Intra oral scanner showed less accuracy in the arch curve especially at maxilla and mandibular anterior residual ridges. Also digital printing models from additive manufacturing technologies presented significant distortion at multiple implant position in horizontal dimension. Moreover, accuracy and precise restorations can be effected by several factors such as milling machine systems, coordinating software programs, and material selection (3, 4).

Therefore, to eliminate data compatibility in work flow with different machine, 3Shape intra-oral scanner system (opened system) has claimed to be absolutely precise accuracy, rapidly functional scanning system. The aim of this study is to compare the accuracy of master models with multiple implant positions and angulations situation produced from digital impression technique with conventional impression technique using innovation 3D superimposition software program.

Research Questions

: Does the digital implant impression presents more accuracy than conventional technique in different multiple implant angles at posterior mandibular region using innovation 3D super imposition software program?

Research Objective

: The purpose of this study was to measure and compare the accuracy in three dimension of working casts which made by using the digital and conventional impression techniques by comparing the distance and angulation relationship of implant positions in conventional and digital working cast to the reference model. Digital impressions were scanned by the 3Shape intra-oral scanner system and fabricated cast by digital printing machine. Whereas the conventional impressions were made with polyether impression material then poured up with a type IV stone. Then two different working cast were scanned and superimposed with reference model to determine dimensional change of implant which measure distance and angle deviation by articulating arm coordinating measuring machine.

Hypothesis

Null Hypothesis

: There would be no significant difference in three dimensional change of distance and angulation between conventional and digital dental implant impression techniques.

Alternative Hypothesis

: There would be significant difference in three dimensional change of distance and angulation between conventional and digital dental implant impression techniques.

Conceptual Framework

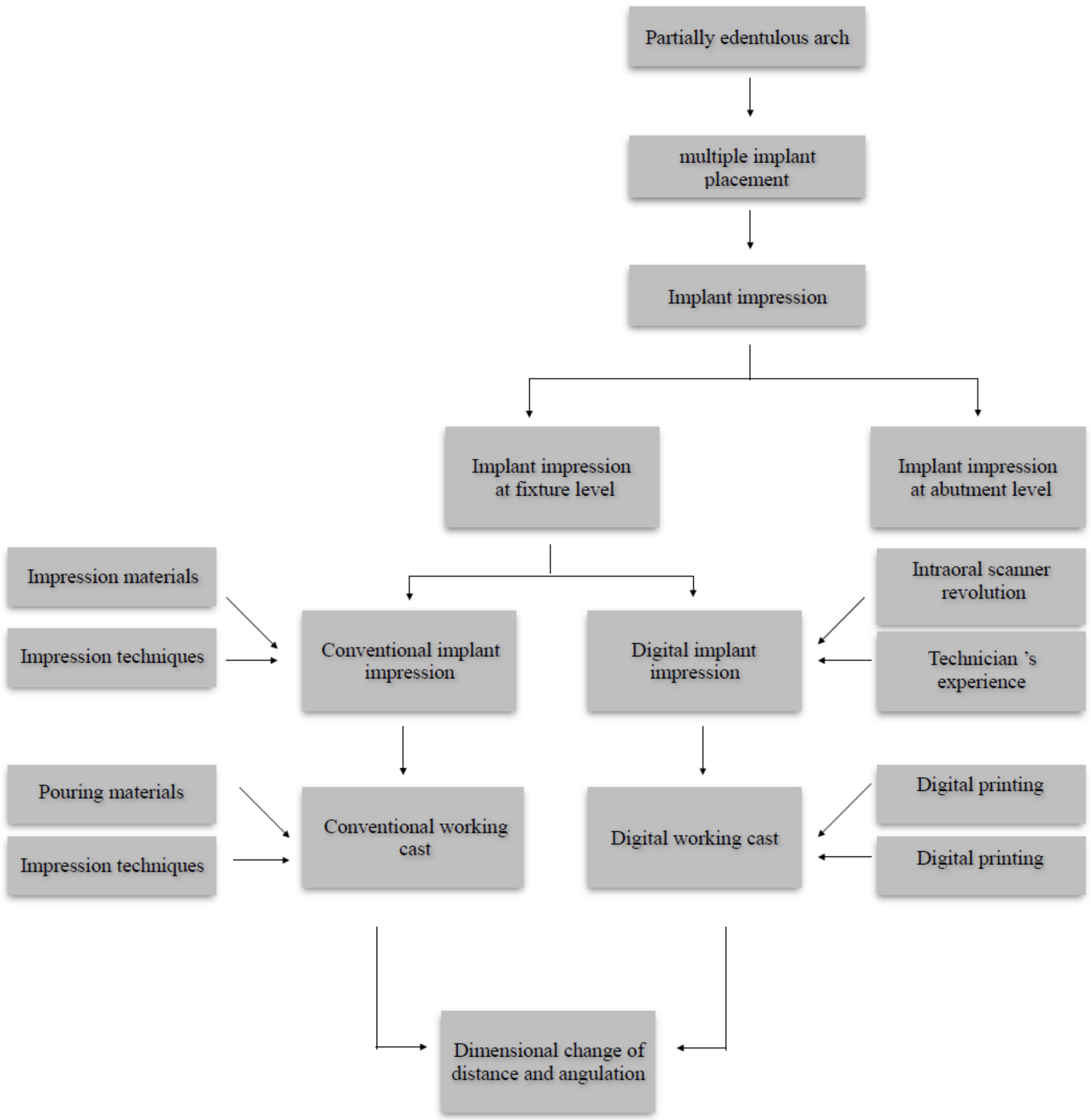


Figure 1 Diagram of Conceptual Framework

Keywords

: Angulated implant

: Impression

: Conventional technique

: Digital technique

: Intraoral scanner

: Dimensional change

Expected Benefit of the study

: The results achieved from this study will be beneficial for dentists to select the best and suitable implant impression methods especially in a case that requires multiple unit of dental implants, deviation of implant placement, laboratory communication or even limitation of time in order that the best outcome would be achieved.

CHAPTER II

REVIEW OF THE LITERATURES

The literatures in these following topics have been reviews.

: Passive fit of multiple implant restorations

: Angulated of implant fixtures

: Background of impression

: Conventional implant impression

: Impression materials

: Open-tray vs close-tray implant impression techniques

: Digital scanner implant impression

: Comparison of digital and conventional implant impression techniques

: Measurement of impression accuracy

Passive fit of multiple implant restorations

From the construction of multiple implant restorations, passive fit was one of the most fundamentally important factors that require in restorative insertion especially in multiple dental implant units which were affected to loading force pattern on the implant. Generally, natural teeth are available to move 25-100 and 56-108 um in axial and lateral direction (4, 5). This mobility was influenced to periodontal ligaments which presented only in natural teeth, that the reason why natural teeth could move under loading force. On the contrary, Dental implants performed without periodontal ligaments and ankylosed with bone, their motion showed as 3-5um and 10-50 um in axial and lateral movement sequently (4, 5). Thus, loading force on dental implants were directly transferred to the alveolar bone especially on alveolar crest (6). In case of non passive fit on implant, it presented internal stress whenever loading which was affected to interface between implant surface and bone contact that would lead to biological and mechanical complication (7) such as peri-implantitis, screw loosening and fracture of implant fixture (8). Moreover, pain, marginal bone loss, incompleted osteointegration would presented (9). From the previous study referred the result that the absolute passive fit was hardly to occur and happened achievement (10) but some researchers showed the acceptable misfit value had range between 22 to 100um and dentist would detect by tactile sense as 50-60 um (11, 12). Therefore, prosthetic part of dental implant restoration was absolutely required the accuracy of transfer implant position which depended on implant impression methods for the best prosthetic restoration.

Angulation of implant fixtures

Angulation of dental implant fixture during surgical procedure was one of a predictable factor due to bone anatomy and adjacent tooth structure (13). In multiple implant restorations with lack of parallelism, there were two options for restorative fabrication. First, a prefabricated angle abutment could be used to correct the fixture angulation , then dentists could deliver a final passive restoration as a cement retained restoration. Secondly, a double abutment technique has been introduced and used to correct the angulation of implant fixtures so that dentist delivered the final restoration as a screw retained restoration. In case of prosthetic work on implants were available to adapt and communicate to laboratory for best results of restoration however had to start from the impression which was the first important step of workflow. From previous data that showed some cases that had to place dental implant fixtures in angulation following bone anatomy, escaped adjacent tooth structure, or even in aesthetic consideration which were affected to the accuracy of impression work. Distortion after implant impression that showed 60% deformation because of elastomeric impression material (14). In 1992, the working cast was fabricated from impression with two different implant angulation 0 and 15 degree divergent vertically in both of transfer and pick-up technique. The result presented that pick-up technique more accuracy than transfer method and the less than 15 degree implant angulation showed more accuracy (15). Furthermore, in multiunit implant impression with 3, 4, or 5 dental implant units reported that whenever the more number of implants, the lesser accuracy of working cast after impression (16, 17). But in some research performed the results that 2, or 3 dental implants showed no significant difference implant accuracy as same as the angulation of implant at 5, 10, 15 convergence or divergence from each other were distortion similarly which was opposite to others said that more angulation from 0 to 25 degree vertically was able to create the decreasing accuracy of impression (17, 18, 19). However, the previous results of number of dental implants and implant angulation affected to the accuracy of impression which effected to working cast which presented most of the involved researches showed lesser accuracy but some of them performed no significant difference. Thus the determination of number of dental implants and angulation will be required more study.

Background of impression

The accuracy of impression was the mainly affected to the achievement of prosthetic outcome. There had a lot of factors influenced to the working cast accuracy, for example : selected materials of use, dentists' experiences, field of operation, moisture control, angulation of implant abutment or coping, impression technique and others which were resulted to the accuracy of working cast (20). Dental implant impression techniques were duplicated from prosthetic methods by modified transfer coping to represent the platform of implant and implant analog to capture implant position that were catagorized an impression by 2 main techniques which were conventional and digital one.

Conventional implant impression

Traditional implant impression was modified from prosthetic impression method but use implant transfer coping and implant analog to represent the implant position and platform. The ideal impression duplicated each case precisely to create the efficient working cast without or least distortion (21). They had many factors that affected to the ideal approach such as material selection, tray selection, impression technique, implant angulation, number of implant units, or even implant platform geometry (22). In term of dimensional stability of impression material should duplicate whole detail of working area, high tear strength, high elastic recovery, and accuracy.

Impression materials

In prosthetic restoration and implant treatment, polyether and polyvinyl siloxane (PVS) were the most selected choices to duplicate for conventional master cast (23). Both of them had quality of high accuracy, stable dimension, high elastic recovery, and adequate tear resistance. In some cases that were hard to control moisture, some researchers recommended polyether than polyvinyl siloxane because polyether was more hydrophilic and proper inadequate moisture control. It had more rigidity then presented less distortion and lower recovery from strain than PVS. But it was not suggested in significant undercut situation (24). Nevertheless, from a lot of studies concluded that both of polyether and PVS performed no significant difference in accuracy which were available to make and impression in elaborate work (17, 23, 25).

Open tray vs close tray implant impression techniques

Conventional implant impression are subdivided into 2 main techniques following by characteristic of tray as open and close tray methods. For close tray technique involved implant impression coping that impressed in oral cavity which transferred analog and implant impression coping were set back into the same position to prior model fabrication. For open tray technique used implant impression coping which were unscrewed and picked up together with impression that the reason why this technique was called in another name as picked up technique. From previous researches that compared both of close and open tray techniques in multiple implant units found more accuracy in open tray technique (15, 17, 26, 23, 27). But in case of implant placement such as single unit or less than 3 implants showed no significant different results (28, 29, 30).The average range difference presented between 10-60um which was various and wide value due to hardly estimate.

Digital scanner implant impression

In restorative dentistry, computer aided approach has been started since 1980s. Nowadays digital workflow is becoming increasingly prevalent used in medicine and dentistry. The last decade has seen the introduction of various intra oral scanning devices onto the dental market. Digital impression was claimed to simplify the impression procedure, reduced chair time and communicated comfortably between the clinician and lab technician (21). The use of digital implant impressions eliminates the need for use of traditional impression materials, making it potentially more comfortable for patients while potentially was decreased time of production and error from analogue techniques, according to manufacturers (31). Digital scanners were developed continuously which based on non contact reflective optical technologies represented by confocal microscopy, optical tomography, active and passive stereo-vision and phase shift principles (32). All of intra oral scanner systems use similar 3 principles as digitation, fusion, and optimisation which each manufacture still developed digital construction in 3 dimension as x, y, x coordinates. There had a lot of advantages of digital approach compared to conventional one which was able to reduce chair time, easily communicate with patients and technicians and more comfortable feeling of patients (21, 33). Digital approach were adapted in many kinds of dental work such as orthodontic record taking, bite registration record, monitoring of tooth wear, implant supported restoration or even prosthetic & dental implant impression (34, 35, 36). Nevertheless, the high accuracy of digital implant impression showed the good result but it still has limitation of digital approach which cannot scan through implant platform at bone level to soft tissue, thus digital method need digital scanning body or transmucosal component to reference implant position same as implant transfer coping and analog in conventional method.

Comparison of Conventional vs. Digital Impression Techniques

The ideal impression should be simple, reliable, accurate, comfortable for the patient and require minimal clinical time. Conventional impressions can be technique sensitive and can cause patient discomfort, while digital impressions require clinicians to master a new treatment modality. As digital impression technology is relatively new in its application to implant dentistry, published studies remain scarce. Only a small number of *i*n vitro studies have directly compared traditional impression procedures and digital impression approaches (21, 35). A recent study by Eliasson & Ortorp in 2012 compared the accuracy of implant analogue positions in casts using digital impressions of coded healing abutments (Encode) versus conventional implant-level impressions. The implant analogue centre point positions in 3-dimensions (x, y, z) were compared on the master and working casts using a laser measuring machine and it was concluded that both techniques resulted in slight inaccuracies of implant position (35.0-47.3μm for digital approach and 13.9-18.5μm for the conventional approach depending on the axis measured). Although the difference was found to be statistically significant ($p=0.01$) the authors could not conclude on the clinical significance, and ultimately observed that both techniques produced sufficiently accurate working casts for most clinical situations. Moreover also found that the digital impression approach using encode abutments resulted in casts that were less accurate compared to casts generated from either conventional close-tray or open-tray impressions; the mean difference of implant position relative to a reference point was 42-131μm using encode abutments and 22-74μm using conventional impressions (22). The authors asserted that further research is needed before clinical implications can be made from such data.

To date, no study has been published analyzing the accuracy of the Straumann Scanbody system for digital implant impressions to restore a partially edentulous arch with angulated implant fixture which printed as working casts either *in vivo* or *in vitro*. The manufacturer claims that the use of Straumann Scanbody digital implant impressions improves workflow and provides high quality digital implant impressions and casts while improving working time and overall cost. Straumann CARES Mono Scanbodies act as digital impression abutments and are placed intra orally in a similar fashion as traditional implant impression abutments. After removal of the implant healing abutment, the clinician connects the Scanbody directly to the implant using a mounting screw. After verification of proper fit and seating, the Scanbody can be scanned using a compatible intra oral scanner. The information captured with this scan creates a digital implant impression which is then used to create a dental cast on which to fabricate the desired prosthesis.

Measurements of Impression Accuracy

To evaluate the accuracy of Implant impression is still contradictory. One of the contributing factor to affect the agreement is the various process to evaluate implant impression and master master model accuracy From the systematic review showed trend of accuracy measurement from the past until nowadays, there are many machines and programs to evaluate such as confocal microscopy, optical tomography, active and passive stereo vision and phase shift principles , and computer coordinating measuring machine (CMM). Recently, computer coordinating measuring machine is absolutely presented high accuracy which could be detected the dimensional change and measurement error at least 50 micron but CMM was suitable for polygonal specimen to measure. The latest version of CMM as articulating arm computer coordinating measuring machine (ARM CMM) was developed to 3 dimensional measurement for free-form specimen using laser scanning in both of probing point and surface scanning as claimed just 0-20 microns machine measurement error that performed the least value of portable CMM nowadays.Furthermore, ARM CMM was movable and suitable for dental implant research due to not polygonal model, presented as free form and finely precise accurate measurement machine. Therefore, this machine was suggested to evaluate and measure both of distance and angulation in 3 dimension (32).

CHAPTER III

MATERIALS AND METHODS

Research design

This study an in vitro experimental study, which compared the accuracy of impression between conventional technique and digital one in multiple units of angulated implants.

Research methodology

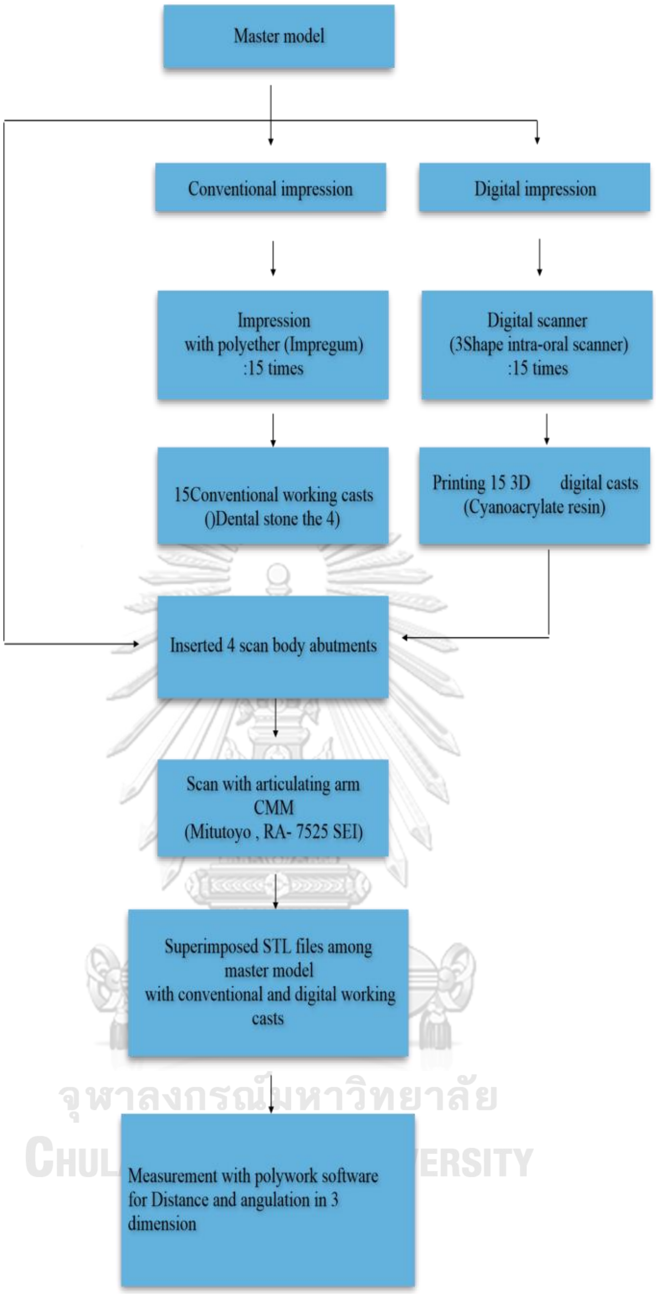


Figure 2 Diagram of research methodology

Sample size description

To date, no data has been published regarding the accuracy the specified digital implant impression techniques similar to this study, so sample size calculations and selection were based on pilot studies which selected 3 samples for each conventional and digital implant impression technique .

For the purpose of this study, the largest acceptable clinical difference in implant positioning in the working casts was set at 60-110 µm, as this approximates the minimum error than can be detected in a clinical setting (10, 22, 37). Based on pilot study, the objectives are measured 3 dimensional change of angulation and distance by articulating arm computer measuring machine compared to the master model which are presented the results in table1.

Table 1Mean and standard deviation value of 3 dimensional distance and angulation in 4 different angulated implants which compared 3 of each conventional and digital working casts to reference model in pilot study

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
ConeAng1	7	1.63	68.71	70.34	487.73	69.6757	.20462	.54138	.293	-.982	.794	.697	1.587
ConeAng2	7	1.73	66.75	68.48	471.13	67.3043	.20868	.55211	.305	1.964	.794	4.729	1.587
ConeAng3	7	1.90	80.54	82.44	566.86	80.9800	.25836	.68357	.467	2.108	.794	4.521	1.587
ConeAng4	7	2.26	70.19	72.45	499.69	71.3843	.28631	.75751	.574	.037	.794	.053	1.587
DisX1	7	.43	2.29	2.72	17.26	2.4656	.06784	.17948	.032	.372	.794	-2.072	1.587
DisY1	7	1.96	13.66	15.62	103.12	14.7316	.25998	.68785	.473	-.003	.794	-.276	1.587
DisZ1	7	5.61	23.65	29.26	181.59	25.9411	.72318	1.91336	3.661	.434	.794	.717	1.587
DisX2	7	1.32	21.51	22.83	156.77	22.3956	.17949	.47490	.226	-1.065	.794	1.083	1.587
DisY2	7	1.34	26.17	27.51	189.36	27.0509	.18994	.50254	.253	-1.138	.794	.012	1.587
DisZ2	7	3.68	20.06	23.73	155.32	22.1889	.49315	1.30475	1.702	-.704	.794	-.488	1.587
DisX3	7	1.08	9.30	10.38	68.78	9.8256	.13246	.35046	.123	.187	.794	.023	1.587
DisY3	7	.67	22.96	23.63	163.11	23.3014	.09454	.25012	.063	-.078	.794	-1.209	1.587
DisZ3	7	6.31	21.34	27.65	172.47	24.6390	.80534	2.13072	4.540	-.084	.794	-.488	1.587
DisX4	7	1.84	9.50	11.34	71.88	10.2687	.28465	.75312	.567	.377	.794	-2.025	1.587
DisY4	7	.84	22.08	22.92	157.82	22.5454	.10771	.28497	.081	-.702	.794	-.087	1.587
DisZ4	7	3.18	25.37	28.55	189.95	27.1350	.45478	1.20323	1.448	-.205	.794	-1.518	1.587
Valid N (listwise)	7												

The conventional and digital working cast evaluation technique standard deviation of our variable of interest, the mean vector magnitude error (VME) in three dimension between implants to reference point at a significance level (α) of 0.05 and power of 80%, with a standard deviation of outcome of each position, N 4Studies program was selected to calculate the sample size which is presented as a maximum sample size of 13 per group is required. Given that this is an estimate based on pilot study results. From the sample size value on the above estimated calculation, a final sample size selection for conventional and digital impression in this research are approximately 15 impression per group.

Materials

Table 2 Materials and equipments used in this study

Materials & equipments	Manufacturers	Size	Amounts
1. Mandibular partial edentulous arch model	X-761: Nissin, Kyoto Japan		1 Model
2. Dental implant fixtures	BLT : Straumann, Basel, Switzerland	Diameter 4.1mm Length 10 mm	4 Implants
3. Dental implant copings	Open tray type : Straumann, Basel, Switzerland	Diameter 4.1 mm	4 Pieces
4. Dental implant analogs	Open tray type : Straumann, Basel, Switzerland	Diameter 4.1 mm	4 Pieces
5. Digital scan body	RC type : Straumann, Basel, Switzerland	Diameter 4.1 mm	4 Pieces
6. Guided surgical stent	co-DiagnostiX : Straumann, Basel, Switzerland		1 Stent
7. Polyether	Impregum Penta Soft : 3M Espe, Saint Paul, USA		4 Tubes
8. Dental stone type IV	UtiRock premium stone type4 : UtiRock, Kentucky, USA		1 Box
9. Self-cured acrylic resin	COE Tray Plastic: GC, Tokyo, Japan		1 Box
10. Calibrated metal sphere balls	Sato, Tekkou, Japan	Diameter 10 mm	4 Balls

Apparatus

Table 3 Instruments used in this study

Instruments	Manufacturers
1. Intraoral digital scanner	D 900: 3Shape, Copenhagen, Denmark
2. Digital printing machine	ProMaker D35: PROADWAYS, Ostwald, France
3. Articulating arm computer coordinating measuring machine	RA- 7525 SEI: Mitutoyo
4. Resonance frequency analysis machine	RC type : Straumann, Basel, Switzerland
5. Mixing Machine	171971: Wassermann, Hamberg, Germany

Experimental groups and their details

This study selected reference model as mandibular partially edentulous arch composed with bone type 2 following Lekholm & Zarb classification which was lost of molar and second premolar teeth at both sides. 4 Angulated dental implants were placed buccally, lingually, distally and mesially 15 degree perpendicular to occlusal plan at 36, 37, 46, and 47 areas respectively. The position and angulation of implant placement were designed with digitally guided surgery programme (co-DiagnostiX: Straumann, Basel, Switzerland) to locate and control implant angulation precisely. After implant placement, 3 Calibrated metal sphere balls were installed at master model with acrylic resin to be the reference plan and points for an accuracy measurement with articulating arm computer coordinating measuring machine.

Methods

The procedures of Reference model fabrication

Figure 3 Step 1: Partially edentulous mandibular arch with lost of all molars and second premolars and composed of bone type 2 following Lekholm & Zarb classification was selected

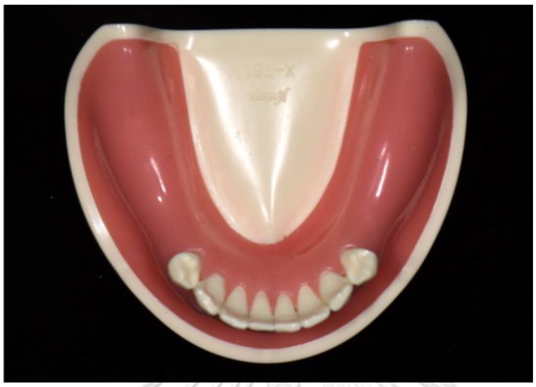


Figure 4 Step 2 :Planned 4 angulated implant positions by co-diagnostiX program by setting angle as 15 degree perpendicular to occlusal plan.

: 37 position (15 degree lingually), 36 position (15 degree buccally)

: 46 position (15 degree distally), 47 position (15 degree mesially)

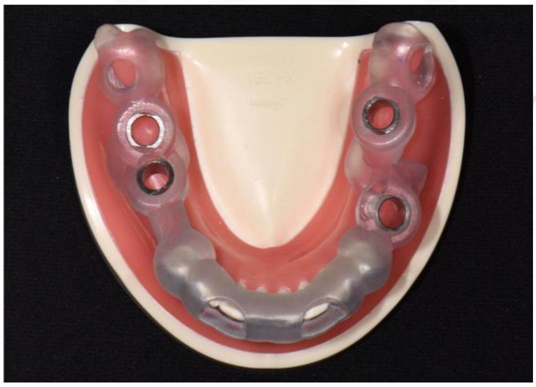


Figure 5 Step 3 : Placed dental implants at 4 positions following Straumann surgical guided surgery

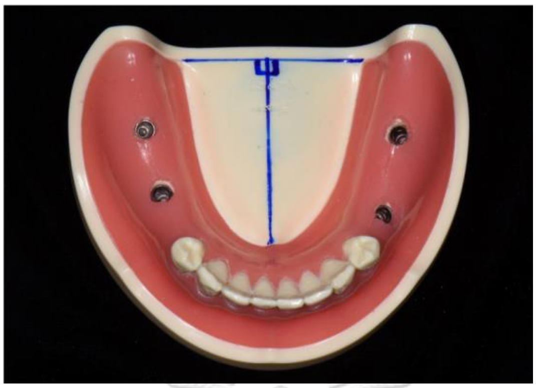


Figure 6 Step 4 : Drilled model with cylinder stone bur in 3mm depth to be the area of calibrated metal sphere balls.

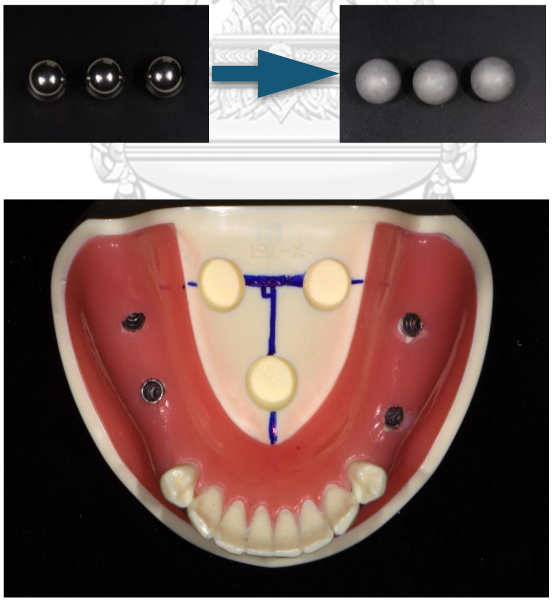
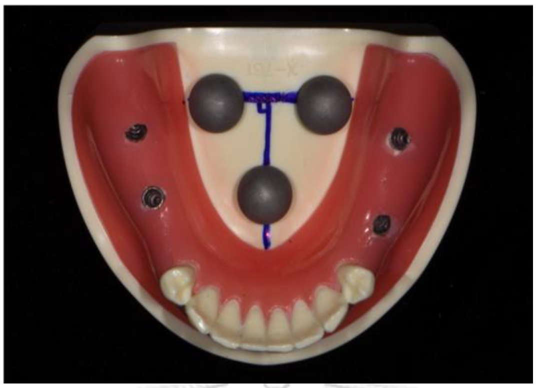


Figure 7 Step 5 : 3 Calibrated sphere balls were blasted with grain 30 microns to convert the shine surfaces to matte ones. After that, fixed sphere balls with self-cured acrylic resin.



Conventional impression methods and protocol of fabricated casts

Conventional implant impression was prepared with open-tray implant technique. Self-cured acrylic resin (COE Tray Plastic: GC, Tokyo, Japan) was used to fabricate individual tray with 2 punched holes for open access. Impression copings were inserted to implant fixtures tightly and properly checked by visual test and x-ray. Polyether (Impregum Penta Soft: 3M Espe, Saint Paul, USA) was utilized for impression taking of bone-level implant following manufacturer's instruction. After completely setting time for at least 6 minutes for impression material, the individual tray was removed from the reference model and waited 30 minutes to 2 hours until the material recovered from deformation. After that, transferred analogs were connected with impression copings and the working cast was fabricated using stone type IV (UniRock, Kentucky, USA) by mixing machine (171971: Wassermann, Hamberg, Germany). 15 Conventional implant impressions were performed by a single dentist for 15 conventional working casts.

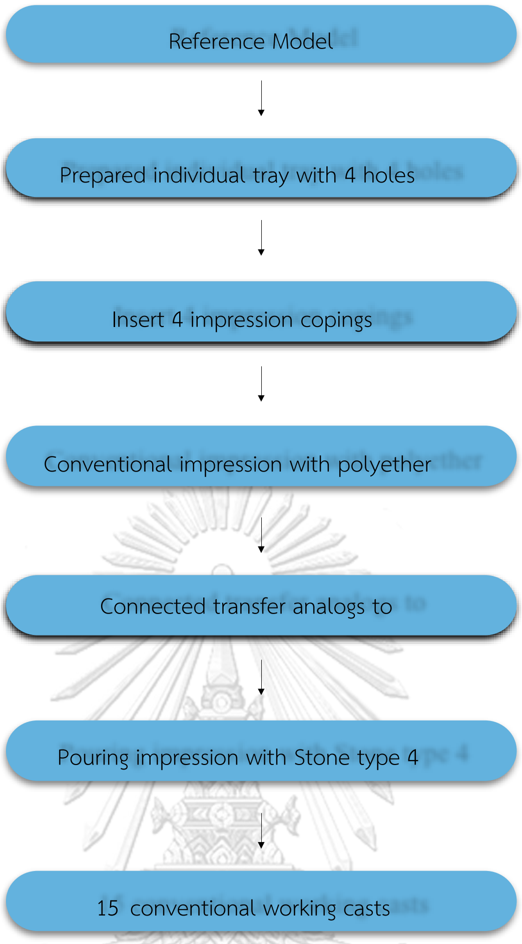


Figure 8 Diagram of Conventional impression methods and protocol of fabricated cast

Figure 9 Fabricating Conventional working cast from conventional impression technique.

Digital impression methods and protocol of fabricated casts

For digital implant impression methods, the reference model was inserted with a digital scan-body (RC: Straumann, Basel Switzerland) to the bone-level implant, then scanned by the intraoral scanner (D900: 3Shape, Copenhagen, Denmark), in which visual and tactile senses for proper seating were performed. After scanning, all documents were reported as STL files which were transferred and connected with the implant position in Straumann Library software program using point cloud technique to replicate the implant position correctly. After calculating the digital files, printed 3D models were fabricated using the printing machine (ProMaker D35: PROADWAYS, Ostwald, France). This process was repeated 15 times to achieve 15 3D printing models.

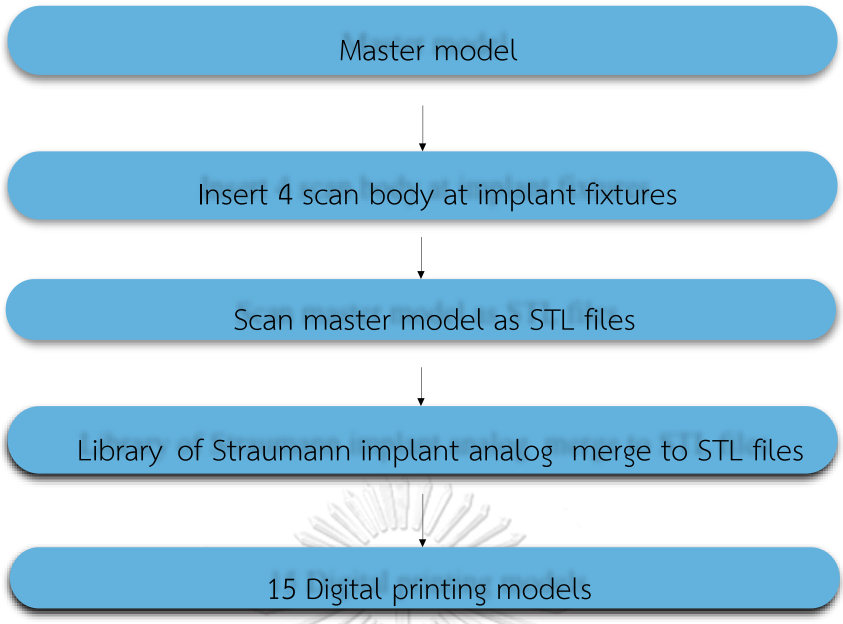


Figure 10 Diagram of digital impression methods and protocol of fabricated casts

Figure 11 Fabricating Digital working cast from digital impression technique

The measurement of compared dimensional change between master model and working casts

To compare the accuracy of digital and conventional techniques to reference model, articulating arm computer measuring machine was selected to scan whole reference model, conventional working casts, and digital printing cast. Results were calculated using a software program (PolyWorks: Hexagon, Stockholm, Sweden). Each dental implant was connected with cylinder digital scan-body (RC) to represented implant position and angulation as shown in Figure 12. Three center points of calibrated sphere ball no.1 (S1), no.2 (S2), and no.3 (S3) were set as a reference plan, reference point (ORG) was located at the center between S1 to S3, and ORG to S2 set as datum axis. After setting the reference plane and points, the highest point of cylinder digital scan-body at 37 and 36 implants were compared to ORG for distance. An axis of the cylinder scan-body compared to the reference plane was measured for angulation. To evaluate the 3-dimensional changes, the scanned files from each technique were superimposed with the reference model as shown in the polygonal color mapping.

Figure 12 Inserted Scanbody to all models and working casts to represent implant position and angulation

Figure 13 Step 1 : Whole specimens were scanned by ruby touch probe (diameter 3 mm) at 4 different angulated implant positions to represent the highest point of each implant abutment.

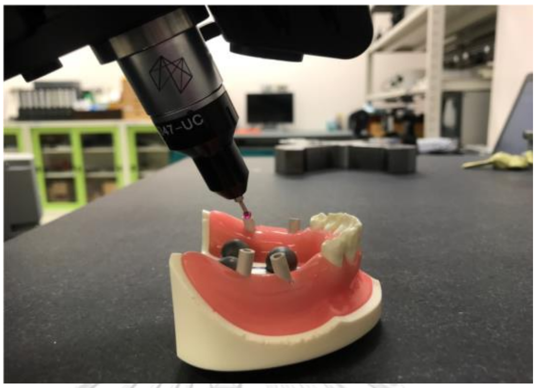


Figure 14 Surface scanning probe was scanned precisely all over vital substructure.

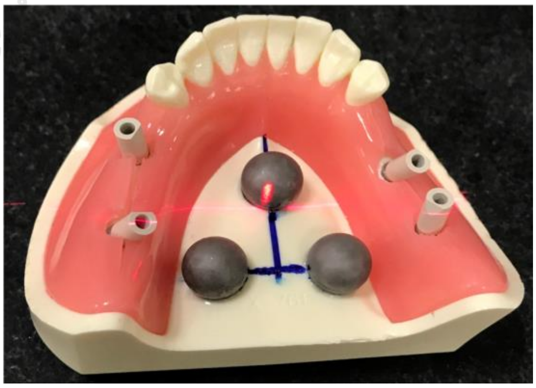
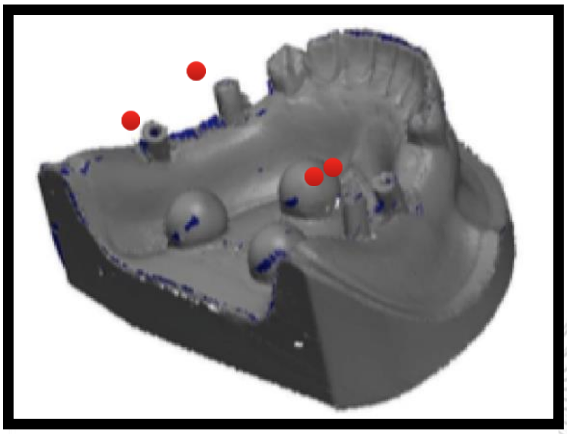
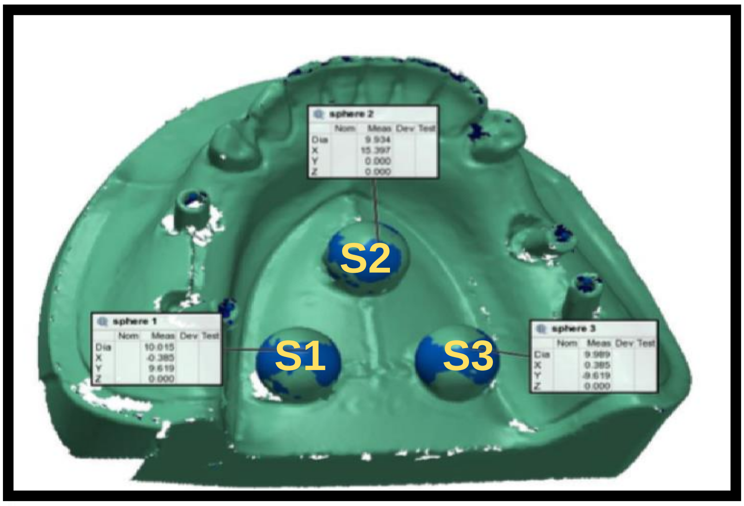


Figure 15 Step 3 : After laser scanning, the scanned models were evaluated the distinct quality especially at abutment and calibrated



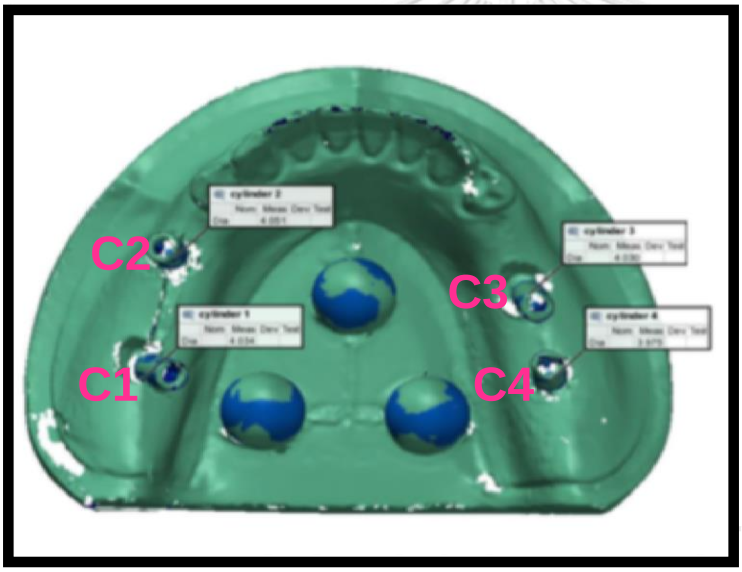
● = Highest point of abutment from ruby



S1 = Sphere ball no. 1

S2 = Sphere ball no. 2

S3 = Sphere ball no. 3



C1 = Cylinder abutment at 37 area

C2 = Cylinder abutment at 36 area

C3 = Cylinder abutment at 46 area

C4 = Cylinder abutment at 47 area

Figure 16 Step 4 : After scanning by articulating arm computer coordinating measuring machine, PolyWork software was selected to calculate the distance and angulation in 3 dimension. 3 Calibrated sphere balls (S1, S2, S3) were explored to locate the centre of balls and abutments (C1, C2, C3, C4) were evaluated their cylinder shape to present the axis of each implant by point cloud technique

Figure 17 Step 5 : Reference plan was set by connection of 3 centre points of each sphere ball.

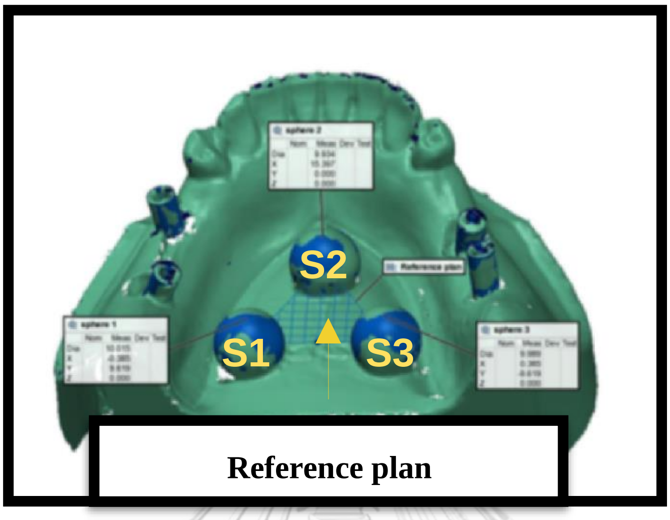


Figure 18 Step 6 : Reference point was created from centre position of distance between S1 to S3

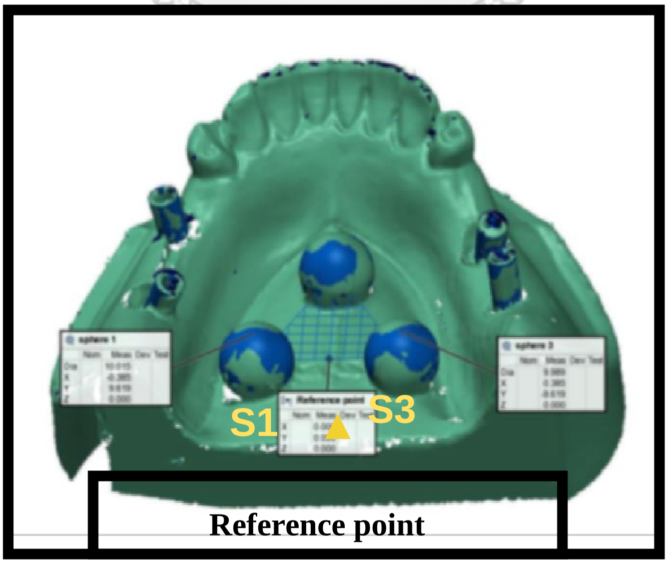


Figure 19 Step 7 : Datum axis (reference line) was the line from reference point to centre of S2.

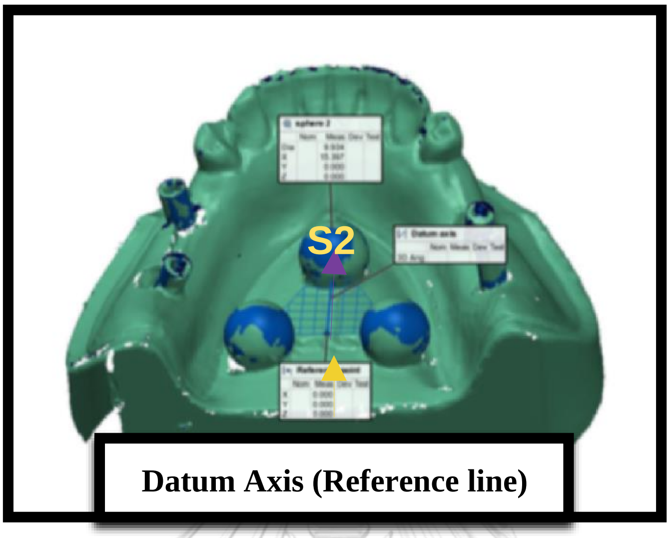


Figure 20 Step 8 : After setting reference plan, reference line, and reference point, Cartesian coordinate system was created X, Y, Z axis for reference position when compared 2 models with super-imposition.

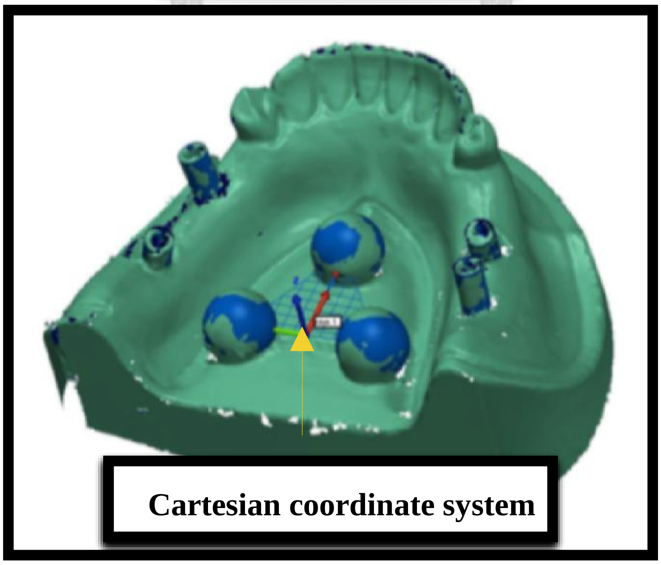


Figure 21 Step 9 : 3 dimensional distance measurement was calculated from reference point to the highest point of each implant abutment.

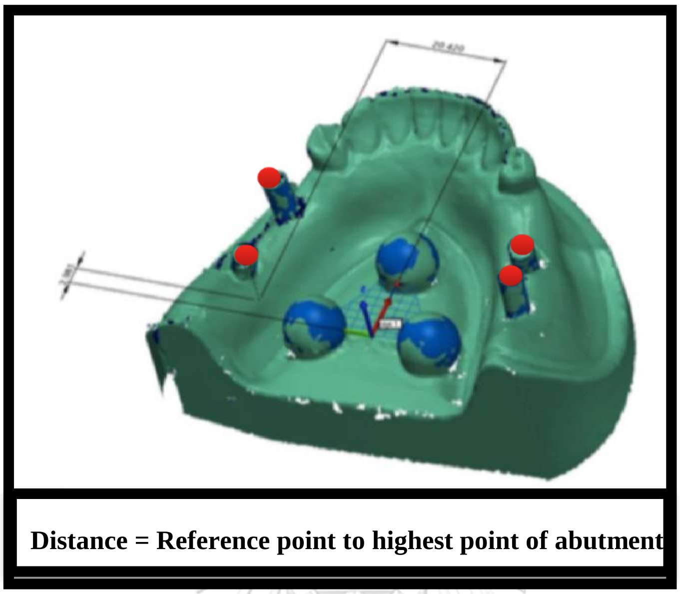
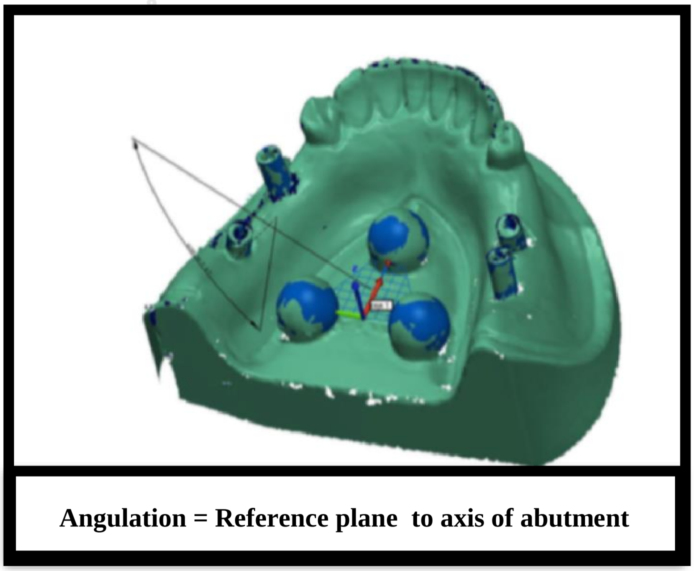


Figure 22 Step 10 : 3 dimensional angulation measurement was computed from reference plan to the axis of each implant abutment.



Data collection and analysis

The mean values and standard deviations of the data among each experimental group were analyzed by descriptive statistics, using statistical software (SPSS 16.0, SPSS, Chicago, IL, USA).The data was categorized the different in value of the distance and angle deviation in 3 dimension. The Kolmogorov-Smirnov test will be used to examine the data for normal distribution. To compare dimensional change between conventional and digital technique, paired-sample T test was used. Results will be considered to have statistically significant difference at p-value < 0.05.

CHAPTER IV
RESULTS

According to measurement of 3 dimensional distance and angulation of 4 different angulated implants at 36, 37, 46, and 47 areas by articulating arm computer coordinating measuring machine, the results presented as shown in below table 4, 5, 6, 7, 8, and 9 respectively.

Table 4 Mean value of 3 dimensional distance measurement of reference model at 36, 37, 46, and 47 areas by scanning with articulating arm computer coordinating measuring machine 5 times.

Sequence of reference model scanning	37 Implant (mm)	36 Implant (mm)	46 Implant (mm)	47 Implant (mm)
1st time	23.637	31.980	27.866	26.998
2nd time	23.634	31.988	27.865	26.994
3rd time	23.640	31.983	27.866	26.996
4th time	23.635	31.984	27.867	26.993
5th time	23.639	31.985	27.861	26.994
Mean Value	**23.637**	**31.984**	**27.865**	**26.995**

Table 5 Mean value of 3 dimensional angulation measurement of reference model at 36, 37, 46, and 47 areas by scanning with articulating arm computer coordinating measuring machine 5 times

Sequence of reference model scanning	37 Implant (degree)	36 Implant (degree)	46 Implant (degree)	47 Implant (degree)
1st time	69.626	78.456	75.722	78.580
2nd time	69.629	78.454	75.724	78.577
3rd time	69.630	78.458	75.723	78.579
4th time	69.628	78.455	75.725	78.578
5th time	69.627	78.452	75.721	78.581
Mean value	**69.628**	**78.455**	**75.723**	**78.579**

Table 6 Mean value of 3 dimensional distance measurement of conventional working casts at 36, 37, 46, and 47 areas by scanning with articulating arm computer coordinating measuring machine totally 15 casts

Distance measurement of Conventional cast	37 Implant (mm)	36 Implant (mm)	46 Implant (mm)	47 Implant (mm)
Model no. 1	23.637	32.010	27.865	26.995
Model no. 2	23.435	32.197	27.945	27.012
Model no. 3	23.790	32.454	27.969	26.894
Model no. 4	24.395	32.050	28.110	27.312
Model no. 5	23.970	31.894	28.013	27.099
Model no. 6	23.971	31.953	27.906	27.070
Model no. 7	24.034	32.699	27.992	27.171
Model no. 8	24.130	31.951	27.950	27.192
Model no. 9	24.033	32.018	27.997	27.177
Model no. 10	23.752	32.061	27.987	27.089
Model no. 11	24.102	32.079	27.976	27.237
Model no. 12	23.758	32.075	27.957	27.034
Model no. 13	24.030	33.713	27.923	27.083
Model no. 14	24.388	32.277	28.918	27.550
Model no. 15	23.715	32.140	28.455	27.664
Mean value	23.943	32.137	28.064	27.172

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Table 7: Mean value of 3 dimensional distance measurement of digital printing casts at 36, 37, 46, and 47 areas by scanning with articulating arm computer coordinating measuring machine totally 15 casts

Distance measurement of Digital printing cast	36 Implant (mm)	37 Implant (mm)	46 Implant (mm)	47 Implant (mm)
Model no. 1	23.475	32.198	27.962	26.812
Model no. 2	23.525	32.099	27.684	26.718
Model no. 3	23.872	32.461	27.892	27.077
Model no. 4	23.189	31.914	27.656	26.661
Model no. 5	23.447	31.846	27.607	26.675
Model no. 6	23.345	31.969	27.569	26.572
Model no. 7	23.538	31.860	27.879	27.128
Model no. 8	23.758	32.381	28.064	27.228
Model no. 9	23.551	32.097	27.752	26.887
Model no. 10	23.563	31.894	27.523	26.602
Model no. 11	23.730	32.339	28.049	26.844
Model no. 12	23.585	32.068	27.929	27.115
Model no. 13	24.082	32.350	28.039	26.943
Model no. 14	23.407	32.244	27.941	27.224
Model no. 15	23.820	32.333	27.418	27.001
Mean value	**23.592**	**32.238**	**27.798**	**26.899**

Table 8 Mean value of 3 dimensional angulation measurement of conventional working casts at 36, 37, 46, and 47 areas by scanning with articulating arm computer coordinating measuring machine totally 15 casts

Angulation measurement of Conventional cast	37 Implant (degree)	36 Implant (degree)	46 Implant (degree)	47 Implant (degree)
Model no. 1	71.144	77.744	75.549	78.185
Model no. 2	70.091	79.521	78.608	80.382
Model no. 3	73.858	78.828	78.758	76.937
Model no. 4	71.528	78.967	75.834	77.829
Model no. 5	71.413	79.156	75.469	78.140
Model no. 6	71.271	79.042	75.636	78.003
Model no. 7	72.061	78.474	76.122	78.354
Model no. 8	71.233	76.075	75.669	78.126
Model no. 9	70.327	78.282	75.505	77.638
Model no. 10	72.718	77.340	75.544	76.262
Model no. 11	70.279	78.345	75.586	77.458
Model no. 12	71.226	78.585	75.096	79.182
Model no. 13	71.472	78.144	75.886	78.018
Model no. 14	69.848	78.423	75.383	77.523
Model no. 15	67.720	79.139	74.876	77.118

Table 9 Mean value of 3 dimensional angulation measurement of digital printing casts at 36, 37, 46, and 47 areas by scanning with articulating arm computer coordinating measuring machine totally 15 casts

Angulation measurement of Digital printing cast	37 Implant (degree)	36Implant (degree)	46 Implant (degree)	47 Implant (degree)
Model no. 1	69.947	79.150	75.823	78.068
Model no. 2	69.160	79.168	74.534	78.609
Model no. 3	69.846	78.514	75.249	77.576
Model no. 4	68.353	78.208	76.174	79.035
Model no. 5	68.398	78.849	75.475	79.030
Model no. 6	69.011	78.885	75.467	78.893
Model no. 7	70.599	78.140	75.931	78.494
Model no. 8	69.390	77.741	75.515	79.078
Model no. 9	68.618	79.232	74.158	79.011
Model no. 10	69.195	79.726	75.442	78.961
Model no. 11	69.152	77.317	75.621	78.501
Model no. 12	69.096	78.299	75.904	79.637
Model no. 13	70.681	78.367	75.987	78.999
Model no. 14	69.383	77.837	76.011	78.679
Model no. 15	68.634	75.831	75.448	78.626
Mean value	**69.298**	**78.351**	**75.516**	**78.746**

Results of 3D distance measurement

Means and standard deviations of distances were calculated from lingually, buccally, distally, and mesially implant positions. Reference model showed distance of 23.647, 31.984, 27.865, and 26.995 mm at 37, 36, 46, and 47 area respectively. Conventional method showed distance of 23.943, 32.137, 28.064, and 27.172 mm at 37, 36, 46 and 47area sequentially. Digital method presented with 23.592, 32.238, 27.798, and 26.899 mm at 37, 36, 46, 47 areas consecutively as shown in table 10.

Table 10 Means and standard deviation values of distances of dental implant in lingual, buccal, distal, and mesial locations in three groups: reference model, conventional casts, digital printing model

Measurement	Implant position	Technique	Mean	SD
Distance (mm)	37 area (Ligually, D1)	Reference	23.637	0.000
		Conventional	23.943	0.265
		Digital	23.592	0.227
	36 area (Buccally, D2)	Reference	31.984	0.000
		Conventional	32.137	0.209
		Digital	32.238	0.459
	46 area (Distally, D3)	Reference	27.865	0.000
		Conventional	28.064	0.273
		Digital	27.798	0.210
	47 area (Mesially, D4)	Reference	26.995	0.000
		Conventional	27.172	0.206
		Digital	26.899	0.224

(Note: D1= distance of 37 implant, D2= distance of 36 implant, D3= distance of 46 implant, D4= distance of 47 implant)

Means and standard deviations of angulation were presented in reference model were 69.628 at 37 area, 78.455 at 36 area, 75.723 at 46 area, and 78.579 at 47 area.

Conventional method displayed angulation of 71.076, 78.404, 75.968, and 77.944 at 37,36, 46, and 47 areas respectively. Digital method exhibited 69.298 and 78.351 at 37and 36 implants, 75.516, and 78.746 in angulation of 46 and 47 implants as shown in table 11.

Table 11: Means and standard deviation values of angulations of dental implant in Lingual, buccal, distal and mesial locations in three groups: reference model, conventional casts, digital printing models

Measurement	Implant position	Technique	Mean	SD
Angulation (degree)	37 area (Ligually, A1)	Reference	69.628	0.000
		Conventional	71.076	1.384
		Digital	69.298	0.713
	36 area (Buccally, A2)	Reference	78.455	0.000
		Conventional	78.404	0.861
		Digital	78.351	0.951
	46 area (Distally, D3)	Reference	75.723	0.000
		Conventional	75.968	1.142
		Digital	75.516	0.549
	47 area (Mesially, D4)	Reference	78.579	0.000
		Conventional	77.944	0.957
		Digital	78.746	0.483

(Note: A1= angulation of 37 implant, A2= angulation of 36 implant, A3= angulation of 46 implant, A4= angulation of 47 implant)

According to 3 dimensional distance measurement, mean values of digital technique were closer to reference model compared with conventional one in all four angulated implants. From paired sample T test analysis, digital impression technique presented with significantly superior accuracy in whole buccally, lingually, measially, and distally-placed implant position in comparison to conventional technique (P < 0.05) as shown in table 12.

Table 12: Results of Paired-Sample T test for 3 dimensional distance error between conventional and digital technique compared to reference model

Compared Conventional vs digital Techniques	Conventional	Digital
D1	0.001	0.459
D2	0.013	0.050
D3	0.013	0.234
D4	0.005	0.120

Note : D1 = Distance of 37 implant (15 degrees Lingually-implant position)
: D2 = Distance of 36 implant (15 degrees buccally-implant position)
: D3 = Distance of 46 implant (15 degrees distally-implant position)
: D4 = Distance of 47 implant (15 degrees mesially-implant position)

In term of 3 dimensional angulation measurement, mean values of digital technique were closer to reference model compared with conventional one in four angulated implant positions. From paired sample T test analysis, digital impression technique presented with significantly superior accuracy in both of buccally and distally-placed implant position in comparison to conventional technique but insignificantly different results in lingually and mesially angulated implants ($P < 0.05$) as shown in table 13.

Table 13 Results of Paired-Sample T test for 3 dimentional angulation error between conventional and digital techniques compared to reference model

Compared Conventional vs digital Techniques	Conventional	Digital
A1	0.001	0.094
A2	0.823	0.678
A3	0.420	0.166
A4	0.022	0.200

Note : A1 = Angulation of 37 implant (15 degrees lingually-implant position)

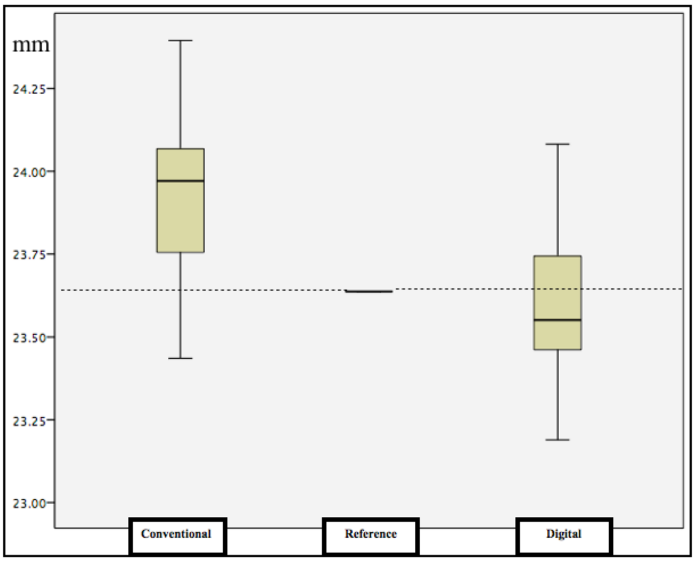
: A2 = Angulation of 36 implant (15 degrees buccally-implant position)

: A3 = Angulation of 46 implant (15 degrees distally-implant position)

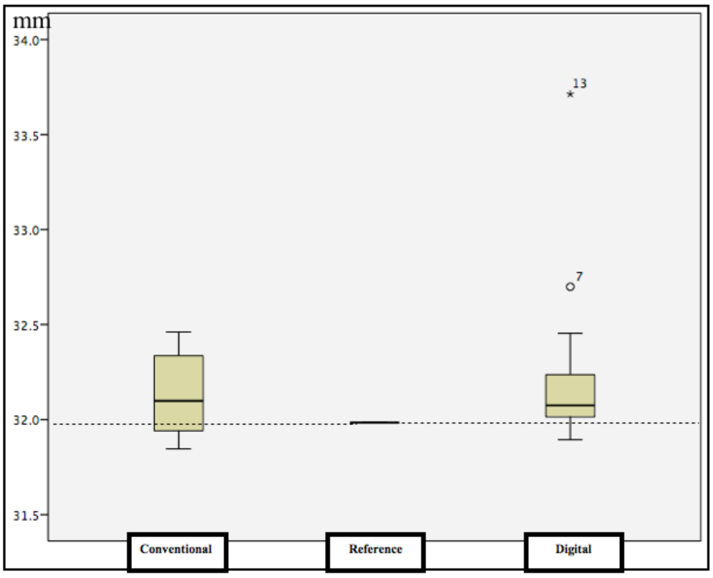
: A4 = Angulation of 47 implant (15 degrees mesially-implant position)

Figure 23 Box plot graph compared digital and conventional working cast to reference model of 3 dimensional distance measurement in 4 different angulated implant position

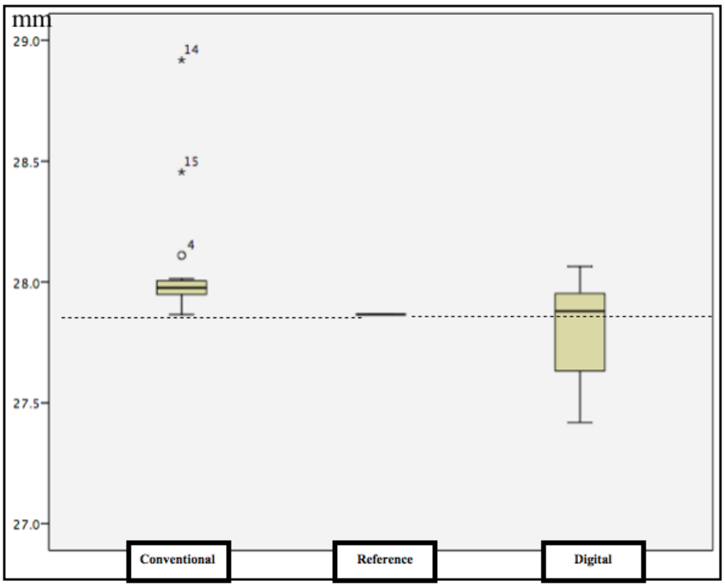
Implant position at 37 area (Lingually angulated position)



Implant position at 36 area (Bucally angulated position)



Implant position at 46 area (Distally angulated position)



Implant position at 47 area (Mesially angulated position)

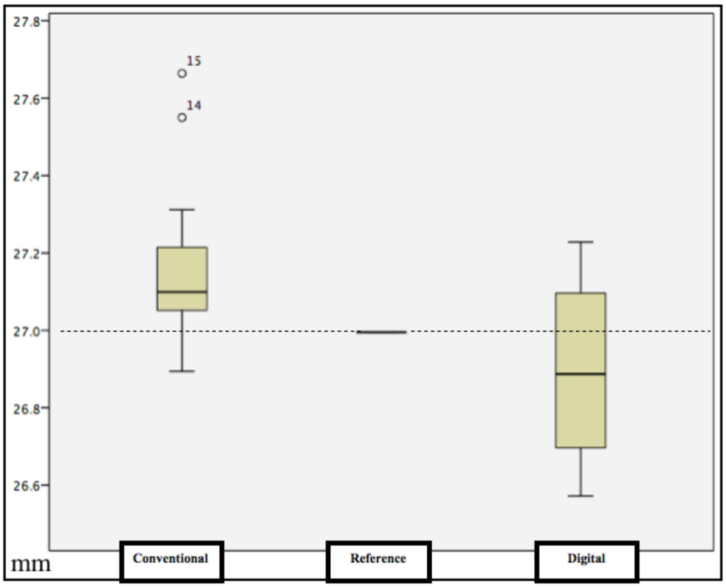
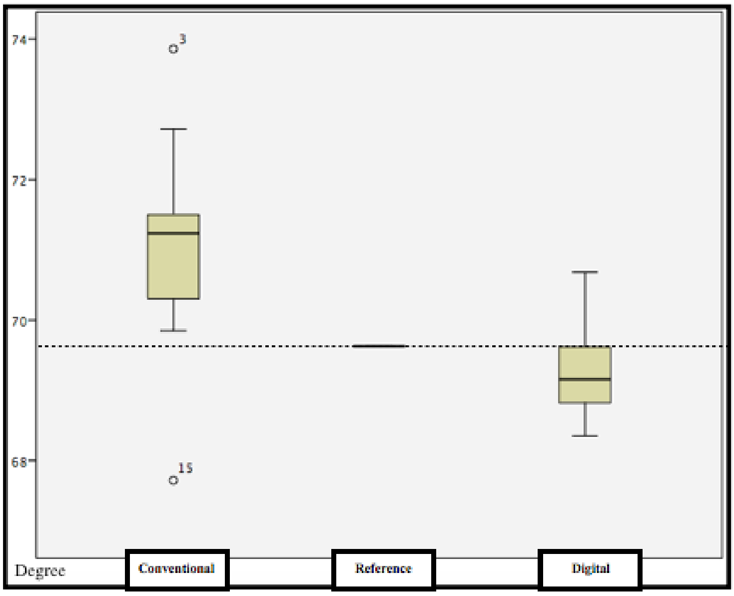
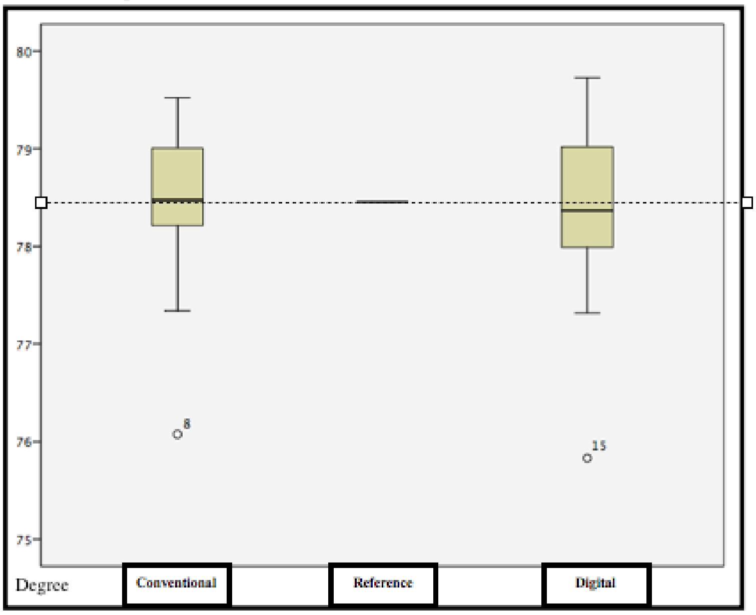


Figure 24 Box plot graph compared digital and conventional working cast to reference model of 3 dimensional angulation measurement in 4 different angulated implant position

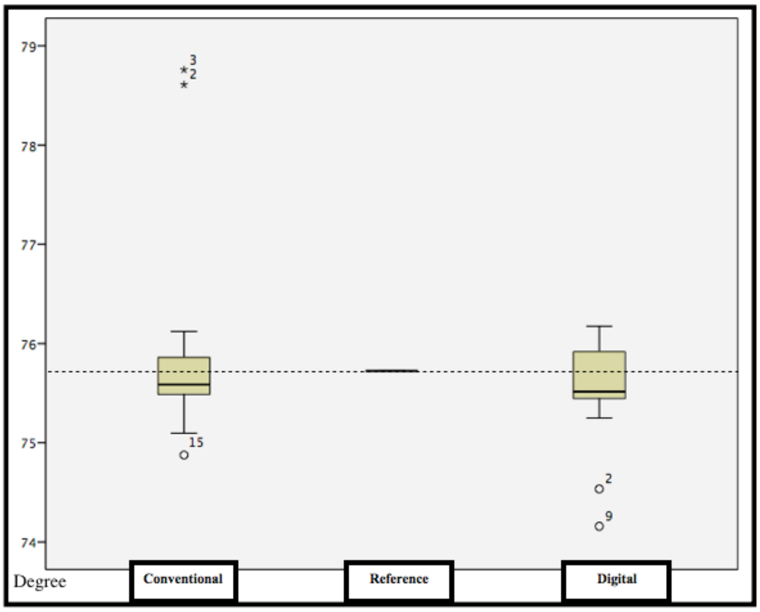
Implant position at 37 area (Lingually angulated position)



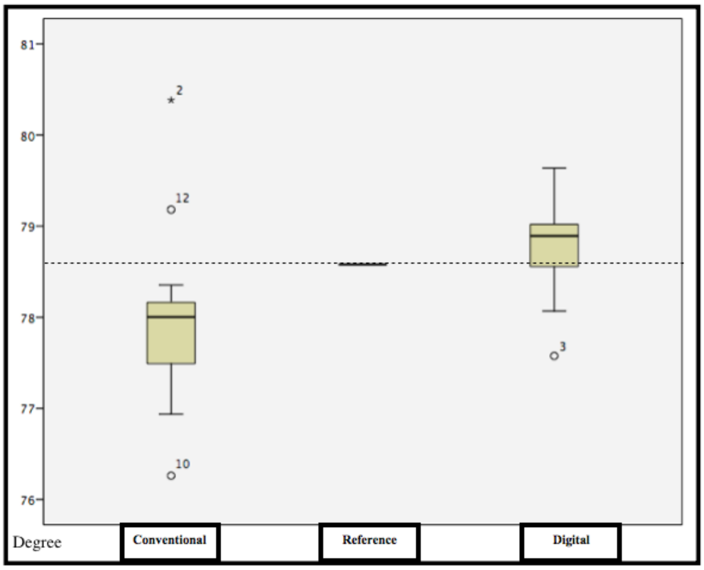
Implant position at 36 area (Bucally angulated position)



Implant position at 46 area (Distally angulated position)



Implant position at 47 area (Mesially angulated position)



CHAPTER V

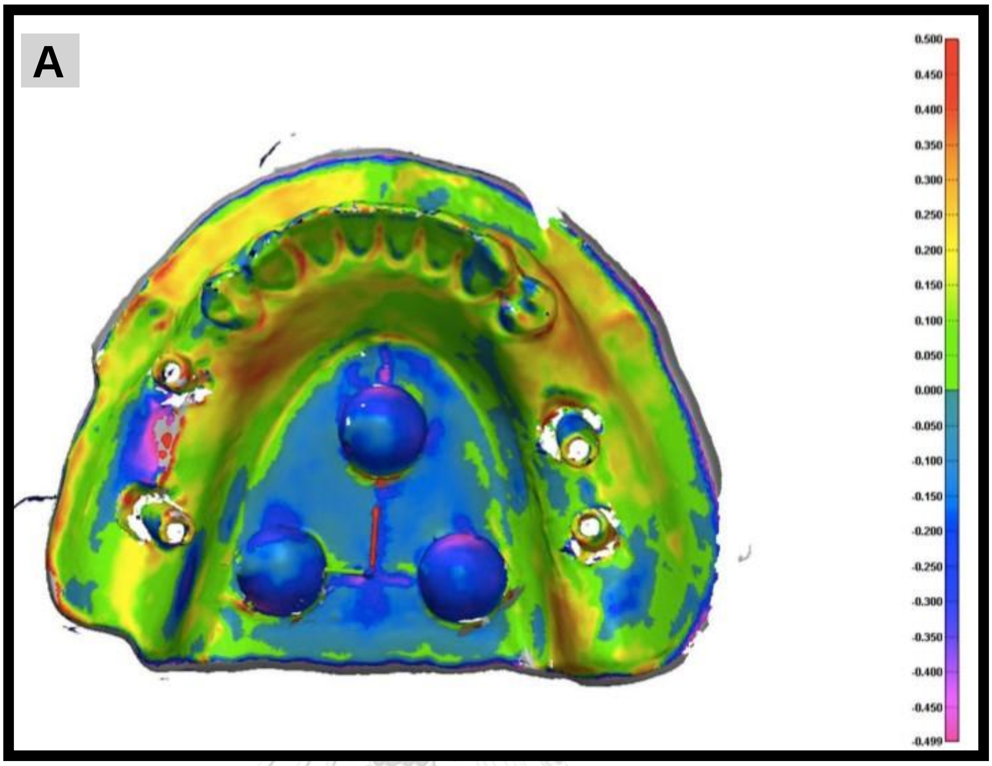
DISCUSSION AND CONCLUSION

Discussion

Digital computer-aided design started at 1950s, in restorative dentistry adapted to use first time to create restoration in 1980s and nowadays has been developed consecutively to apply on dental implantology. Previous studies had focused on conventional implant impression accuracy to minimize deviations in implant positions in transfer model which presented variations of experimental designs such as using transferred connection in different implant manufactures, comparison of impression materials, affection of multiple unit implant cases. There were some studies compared the accuracy between digital and conventional implant impression in single and multiple implant numbers and different angulation by measurement an accuracy such as computer software program or computer coordinating measuring machine but the data showed no one discovered 4 dental implant positions with 4 different angles and measured the error of dimensional change by articulating arm coordinating measuring machine which claimed the measurement machine error between 0 to 20 microns with high and effective precision instrument then was sensitive enough to detect differences between variables.

The intention of this in vitro study was to compare the accuracy of digital and conventional implant impression techniques by comparing the reference model to conventional working casts and digital printing casts. This study measured an accuracy in both of 3 dimensional distances and angulations in 4 different angulated implant positions with articulating arm computer measuring machine. According to distance measurement, the results presented digital printing casts more accurate than conventional working casts which were statistically significant difference ($P < 0.05$) in all 4 implant positions. Not only digital method showed superior accuracy to conventional one, but in terms of angulation measurement also performed the results that digital impression was more accuracy. Nevertheless, dental implant at 37 and 47 area which were located 15 degree to lingually and mesially not significant difference ($P < 0.05$). This study showed that angulation of implant placement affect accuracy of conventional impression technique similar to another study presented less accuracy in implant angulation between10 to 20 degrees as Choi study in 2007and performed significantly different in 10 and 30 degree in buccal and lingual angulation which was same results as Conradd study in 2007 that presented divergent or convergent implant had no significantly different in direction (15, 46). From the results as above, errors of conventional technique could possibly happened during any of the several steps, such as dimensional changes in materials, inaccurate repositioning of impression copings or analogs, and improper connection of components, or even design of this study. In case of materials, from previous study of Vigolo & Wee reported polyether was the best material for multiple abutment impression compared to polyvinyl siloxane but some study showed both of them were not significant difference but until now the clinical significance of polyether and polyvinyl siloxane distortion of the magnitude was absolutely unclear just the data of manufacturer's instruction showed the distortion percentage such as Impregum between 8.5-9 %. However, this study made impression over 4 angulated implant position, the density and duration of strain forces could occurred upon removal of impression which affect to permanent deformation of elastomeric impression materials, especially in multiple implant cases because of increasing difference angulation which were influence to accuracy in conventional technique (45). From the systematic review of performed that various results of evaluated splinting effect to decreasing and increasing distortion on multiple units of implant impression which splinting technique had influences at least 3-unit of implants (41). But other researchs presented conflicting conclusions: splinting shown no difference, splinting increased impression distortion, and splinting is importance. In case of multiple implant position with buccal inclination especially in maxilla at lingual angulation in lower arch was reported splinting technique be a factor as impression material deformation upon removal and not recommended. According to this study preferred open-tray technique for conventional impression because previous data showed more accuracy than closed-tray method in multiple implant units but limitation of this one in clinical situation was unsuitable for limited mouth opening patient and this technique still had to connect open- tray implant copings to transferred analogs that were possible to affect the misfit of each connection. In addition, dimensional change of dental stone has been reported. Dental stone type IV showed expansion rate between 0.07- 0.09% which UniRock manufacturer's instruction of conventional pouring materials claimed as 0.07% of expansion.

Digital method was available to produce 3D printing model without using impression material, eliminating the use of impression materials and dental stone. From this method also showed improved satisfaction of both patients and dentists (19, 35,42). Nevertheless, from the results of this study performed significantly superior accuracy compared to conventional one in both of angulation and distance measurement, digital approach still had some limitation. Distortion of polyurethane which was used in 3D printing and digital files transferred can affect the accuracy of 3D printing models. From super-imposition colour mapping performed slightly shrinkage between 0 to 100 microns in some undercut area. In the opposite way, conventional showed expansion in range 0-300 microns.


A
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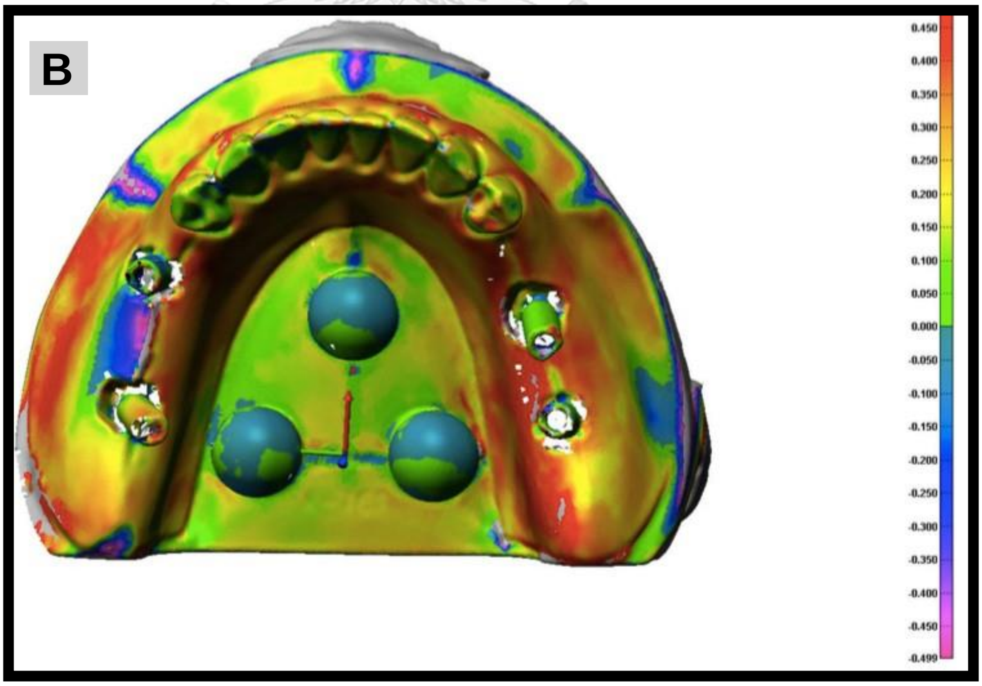
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-0.300
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-0.400
-0.450
-0.499

Figure 25 Super-imposition colour mapping

A. Super-imposed colour mapping between digital printing model with reference model

B. Super-imposed colour mapping between conventional working cast with reference model

In term of scan-body height, it could influence the accuracy of digital impression 10mm height of scan-body showed better accuracy than using 5 mm scan-body following by study of Ajioka in 2016 (32). In this study selected scan-body to represent abutment in cylinder shape due to a large number of stable reference points and easy scanning to set as a polygonal model in Polywork software program. the hight of selected scan-body was 10mm but it was affected by gingival hight so the 3Shape intra oral scanner could scanned only 6-8 mm from hight of abutment which could effect to an accuracy. Moreover, at the area of 37 and 47 implant position, which were long edentulous arch would be the large inter-implant distance in combination with lack of mucosal landmarks to serve as reference points effected to connect the photographs in the right position in 3Shape intra-oral scanner. Each scanner presented distance error in wide ranges depended upon many factors, such as the surface of scanning should not be shinning because of scattering effect no landmark of object and difficult location to access as undercut area beneath sphere balls in this research or distal aspect at molar teeth in clinical situation. As the research of Van der meer in 2012, performed the range7.2-126.8microns and angulation error in range 0.0069 to 0.6833 degrees by intra oral scanner that was quite a wide range (33).

At this moment, no clear guidelines are available on the acceptable thresholds for misfit between superstructures and implants. However, a passive fit of the superstructure should be the main goal to avoid mechanical and biologic complications. From previous study assessed a maximum lateral implant movement of 50microns. these results could be indicated that lateral implant movement due to a misfit that exceeds 50 microns will lead to a certain tension between the implant and the superstructure as claimed from Assuncao study in 2004. Furthermore, Franks study in 2014 displayed an acceptable distance error < 100 microns, angulation error

<0.4degrees (14, 34). In clinical situation, if followed reference data from study of Assuncao and Frank, both of conventional and digital impression techniques could be possible to treat patients which both of that presented acceptable distance and angulation error.

Conclusion

Within the limitation of this vitro study, partially digital impression technique by 3Shape intraoral scanner with 3D printing models presented significantly superior accuracy of three dimensional distances and angulations to definitive working cast from conventional one. Both techniques were clinically acceptable to treat the patients, but digital technique was highly recommended because of superior accuracy and effectively decreased chair time.

Limitation of This Study

No known limitation of this research

Suggested Further Studies

For further study, full edentulous arch is recommended to research an accuracy of digital impression maybe with increasing number of implants and scanning with different types of intraoral scanners.

Clinical Implication

Following the result of this study, both of digital and conventional implant impression techniques were clinically acceptable to treat the patients, but digital technique presented superior accuracy to conventional one and saved the chair tie.

Declaration of Conflicting Interest

The author declare that there is no conflict of interest

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