Comparison of compressive strength between two mini implants :An in vitro study

Miss Anchisa Weerasubpong

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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วัตถุประสงค์: เพื่อศึกษาและประเมินความแตกต่างของแรงอัดเชิงสถิตและ แรงอัดเชิงพลศาสตร์ระหว่างรากเทียมขนาดเล็ก 2 ระบบ (RetenDent และ MS denture® system, OSSTEM)

วัสดุและวิธีการทดลอง: รากเทียมขนาดเล็กทั้งสองระบบถูกนำไปทดสอบแรงอัดเชิงสถิต การทดสอบแรงอัดเชิงสถิตจะให้แรงกดครั้งเดียวคงที่ในแนว 30 องศาต่อแนวแกนยาวของรากเทียมบนเครื่องทดสอบอเนกประสงค์จนกระทั่งเกิดการเสียรูปถาวร จากนั้นจะนำค่าเฉลี่ยของแรงอัดเชิงสถิตที่ได้ มาคำนวณหาค่าแรงที่จะใช้ในการทดสอบแรงอัดเชิงพลศาสตร์ โดยการทดสอบแรงอัดเชิงพลศาสตร์จะใช้แรงกระทำต่อเนื่องเป็นวัฏจักรและนับจำนวนครั้งของวัฏจักรที่ชิ้นงานทนได้ก่อนจะเกิดการเสียรูปอย่างถาวร และค่าแรงที่ชิ้นงานสามารถทนต่อแรงอัดได้ถึงห้าล้านวัฏจักร จะถูกกำหนดเป็นค่าทนแรงอัดพลศาสตร์ของวัสดุชิ้นนั้นๆ

ผลการศึกษา: RetenDent มีค่าความทนต่อแรงอัดเชิงสถิตอยู่ที่ 462.969 ± 16.73 N ซึ่งสูงกว่ารากเทียมขนาดเล็กของ OSSTEM ที่มีค่าความทนต่อแรงอัดเชิงสถิตอยู่ที่ 403.407 ± 25.55 N อย่างมีนัยยะสำคัญทางสถิติ ($p<0.001$) โดยรวมพบว่า RetenDent มีค่าเฉลี่ยของจำนวนวัฏจักรมากกว่า OSSTEMทุกค่า ยกเว้นที่ค่าแรง 320 N และค่าความทนแรงอัดเชิงพลศาสตร์ของ RetenDent และ OSSTEM ถูกกำหนดที่ 185N และ 140 N ตามลำดับ

สรุป: RetenDent มีค่าเฉลี่ยแรงอัดเชิงสถิตและแรงอัดเชิงพลศาสตร์สูงกว่า OSSTEM รากเทียมทั้งสองระบบมีค่าแรงอัดเชิงสถิตและแรงอัดเชิงพลศาสตร์สูงกว่าค่าแรงบดเคี้ยวสูงสุดของฟันปลอมยึดเหนี่ยวบนรากเทียม RetenDent มีคุณสมบัติที่น่าจะนำไปประยุกต์ใช้ในทางคลินิคต่อไปได้

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สาขาวิชา	ทันตกรรมบูรณะเพื่อความสวยงามและทันตกรรมรากเทียม	ลายมือชื่อนิสิต ....
ปีการศึกษา	2565	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
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KEYWORD: Mini-implants, Compressive strength, RetenDent, OSSTEM

Anchisa Weerasubpong : Comparison of compressive strength between two mini implants :An in vitro study. Advisor: Assoc. Prof. PRAVEJ SERICHETAPHONGSE, D.D.S., M.S. Co-advisor: WAREERATN CHENGPRAPAKORN, D.D.S., Ph.D.

Objective: To observe and evaluate the difference in static and dynamic loadings between two mini-implant systems (RetenDent and MS denture® system, OSSTEM).

Materials and Methods: Fifty mini-implant from two companies were included in the study. The compressive force was applied to the mini-implants at 30 degrees from its vertical axis. Ten specimens from each group were subjected to static load tests. Subsequently, five cyclic loadings were calculated from static compressive strength. These loads include 320N, 275N, 230N, 185N, and 140N. Three specimens from each group were randomly selected and tested at each loading condition. The Independent T- test was utilized to obtain the statistical differences of the static compressive strength, while descriptive statistics was utilized to compare the difference of dynamic loading between two mini-implant systems.

Results: The average static compressive strengths of RetenDent and OSSTEM mini-implants were 462.969 + 16.73 N and 403.407 + 25.55 N, respectively. Overall, RetenDent demonstrated a higher number of survived cycles except at 320N loading condition compared to OSSTEM. The fatigue limit of RetenDent and OSSTEM mini-implants was defined at 185N and 140N, respectively.

Conclusion: RetenDent has higher static and dynamic compressive strength compare to OSSTEM. Both RetenDent and OSSTEM's static and dynamic compressive strength were greater than maximum bite force of implant-retained overdenture. RetenDent mini-implants is likely to has capabilities in need for application in clinical practice to retain prostheses.

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Field of Study:	Esthetic Restorative and Implant Dentistry	Student's Signature ....
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Chapter I INTRODUCTION

Rational and background information

Thailand is one of many countries in the world entering an ageing society. The number of ageing populations has considerably grown in the past year as a result of better medical healthcare. The National Committee for the Elderly (NCE) reported that the number of Thai Elderly was 11 million out of 65.5 million in 2017 which accounting for 17% of the total population. This marked Thailand as the second ranked in aged society among ASEAN countries. Elderly people usually suffered from numerous systemic diseases and poor quality of life. Three measurements were used to determine quality of life including eyesight, hearing's ability and wearing of the denture. The survey reported that up to 23 percent of elderly were wearing denture. [1] Moreover, the National oral health Survey in the same year reported that the percentage of elderly who was totally edentulous in the age group 60-74 and 80-85 years were 8.7% and 31% respectively.[2] In addition, there is study reported that patient without teeth or having improper dental substitution tend to receive less nutrients and has a higher risk of becoming obese.[3] Numerous

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health problems can be developed including gastroesophageal reflux disease, noninsulin- dependent diabetes mellitus, hypertension, heart failure, chronic kidney disease and sleeping disorder. [4-9] Therefore, solution for edentulous problem is considered to be an important issue that should be managed.

Conventional denture has been standard method for replacing lost teeth in the past history. However, many undesired problems have been reported. Among these, pain or discomfort were the most frequent complaints. [10] Discomfort can occur since the first day of denture delivery and last for a long period if the proper treatment has not been given. Dentures may also affect speech's ability of the patient. With improper design and thickness, it could lead to the change in articulation. [11] Bone-support is considered to be crucial factor in the success of denture wearing especially in mandibular area. The mandibular denture usually has more problem when compared to maxillary denture owing to the smaller surface area coverage of the foundation tissues. [12] Lack of bone support resulted in ill-fitting denture's problem and consequently lead to oral lesions which could range from simple inflammation to oral cancer.[13]

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With aforementioned problems, other choices of treatment have been proposed. The options could be either implant retained overdenture or implant-supported fixed prosthesis. Selection of treatment depended on cost, patient oral's conditions and patient satisfaction. Studies reported that patient preferences in implant retained overdenture is higher when compared to fixed prosthesis due to easy cleaning and maintenance.[14, 15]

Overdenture has been applied in dental practice for many years. At first, only natural teeth and retained roots were used to assist with a denture. However, problems arising from dental caries and periodontal disease has weaken the successful outcome of the treatment. Thus, dental implant has been considered to assists a denture instead. [16] Available dental implants in today market are different in design, material, surface and also diameter. The diameter of implant can vary from 1.8 to 7 mm. The selection of implant's diameter depends on the amount of bone available in each patient. Severe atrophic of alveolar ridges are commonly happen after tooth loss, especially in patient who have been edentulous for a long time. [17-19] Reduced alveolar bone is usually a contraindication for standard implant placement,

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unless some procedures are performed such as ridge augmentation or sinus floor elevation. However, these procedures might be limited for elderly people due to their medical conditions. Therefore, small diameter implant or mini-implant has been developed to advocate for these special clinical situations.

Mini implant was normally fabricated with a smaller diameter and shorter length. Their diameter is usually less than 3 mm. The advantages of using mini dental implant over standard diameter implant including minimal invasive protocol, less bone damage and postoperative discomfort, avoiding of additional surgery and cost effectiveness. [20]

Despite several benefits of implant-retained prosthesis, study in Germany, Sweeden and Switzerland demonstrated that only 2-4% of edentulous patients were treated with implants.[21] The main limitation for implant treatment is a high pricing of the material. [22] Thailand's market for dental devices and materials are highly dependent on import products. With material itself and import protocol, the price of an implant placement could reach up to about 30,000-60,000 per single tooth in

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standard implant. This high price limited the treatment to certain group of population.

With abovementioned issues, researchers of Chulalongkorn University have been developing “RetenDent mini-implant” in hope to make Thai’s majority being accessible to an implant treatment. However, mechanical testing of the material must be performed prior to clinical application to ensure that the products is qualified enough to apply in the patients. Static and Dynamic compressive strength were tested following the guidelines of ISO 14801. OSSTEM mini dental implant was selected to be a comparative group in this study due to its popularity and similar characteristic. The aim of this study is to compare the effect of compressive load on two different dental mini-implant systems and to prove whether overdenture using RetenDent mini-implant is clinically usable in edentulous patient.

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Research question

Is there any difference in static and dynamic compressive strength between RetenDent mini dental implant and OSSTEM mini dental implant?

Study goals and objectives

This study was conducted to compare the difference in compressive strength in both static and dynamic testing between two mini dental implant system, to determine the resistance of the mini-implant to masticatory forces and to examine whether overdenture using RetenDent mini-implant is clinically usable in mandibular area.

Research hypothesis

Ho = There is no differences in static and dynamic compressive strength between RetenDent mini dental implant and OSSTEM mini dental implant.

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Ha = There is a difference in static and dynamic compressive strength between RetenDent mini dental implant and OSSTEM mini dental implant.

Test groups

Totally 50 mini dental implants from 2 companies (RetenDent and OSSSTEM)

- 20 mini-implants, 10 from each company for static compressive strength testing
- 30 mini-implants, 15 from each company for dynamic compressive strength testing

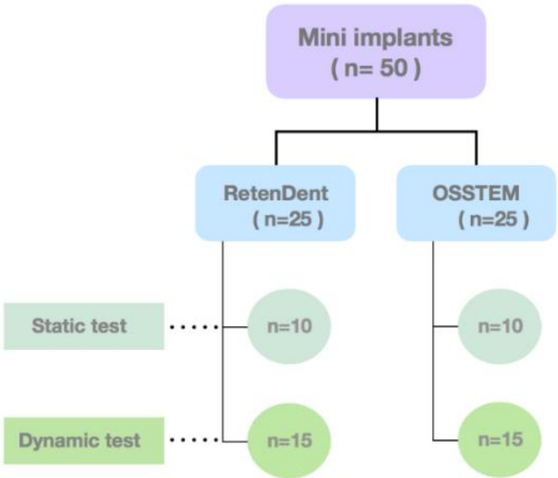

Figure 1 Test groups

Ethics

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Expected outcome

1. To demonstrate mini dental implant strength by means of compressive testing

2. RetenDent Mini dental implants are able to withstand the masticatory forces and qualify to clinical application in mandibular area

Conceptual framework

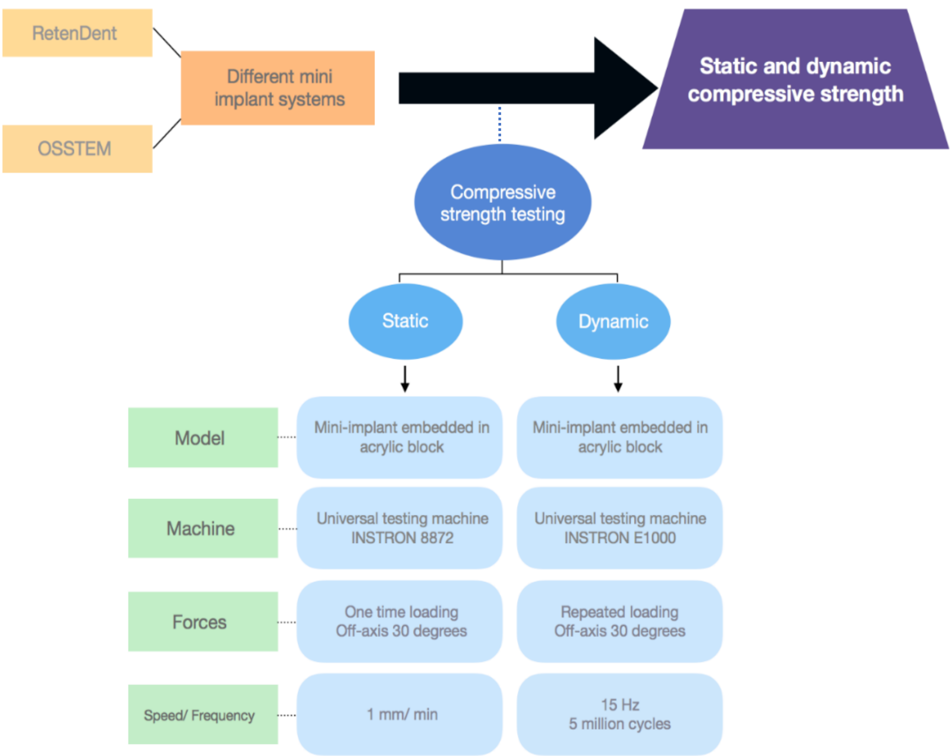

Figure 2 Conceptual framework

Chapter II REVIEW OF LITERATURES

Edentulous problems and solutions

Edentulism is the stage of having no teeth. Even the trend of edentulism is in the downturn, still it is considered to be an important issue that should be focused. Study reported the prevalence of edentulism is associated with several factors such as age, education, socio-economics conditions, oral health knowledge, and attitudes toward the dental care.[23] Edentulism is not only affect the general health of the patients, but also the quality of life as well. Study by Naik reported that lack of teeth leads to decreased self-esteem and a decline in psychosocial well-being. [24] On the contrary, with proper dental substitution, patients will have better oral appearance which consequently improve self-esteem, resulted in psychological well-being. [24, 25]

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Several methods have been applied for edentulism treatment. The most common one is conventional complete denture. The reason for its popularity is due to costs, short treatment time and acceptable esthetics and function outcomes. However, study by Perea reported that conventional complete dentures have a negative impact to the quality of life in elderly patients especially in the area of mandibular.[26] Also Huumonen reported that poor satisfaction of dentures strongly associated with poor denture stability. [27]

Denture stability is significantly associated with the height and width of the alveolar ridge. Resorbed ridges resulted in poor denture stability. Studies by Karaagaçlioglu reported that amount of mandibular height reduction is higher and the progression of bone resorption is faster in older than younger age group.[28] Thus, conventional complete denture is unlikely to be the most appropriate options for the treatment of edentulous problems in elderly patients.

Overdenture is a replacement of teeth retained by dental implants. Study demonstrated that mandibular denture is challenging since it has less retention and stability due to severe resorption of alveolar ridge. Thus, placement of implant to assist denture should be applied. [29] Overdenture demonstrated better psychosocial benefit over conventional denture because the dentures were stabilized by implants. Thus, the teeth can be placed in optimal esthetic positions without causing denture

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instability during the oral's muscles contraction. Overdenture also provided better functional benefits since it has an increased biting force. [30] Several studies reported patient has more satisfaction of overdenture wearing when compared to conventional denture. [31, 32] In addition, McGill consensus in 2002 proposed the concept of using two-implant overdenture with a supported evidence to prove that this concept should become the first choice of treatment for the edentulous mandible.[33] Mini implants have been introduced to use with overdenture. Systemic review demonstrated that mini implant overdenture has survival rate of 92.32% along with good patient's satisfaction.[34]

Dental mini implant

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Mini implants were first developed by Dr. Victor I. Sendax of New York in the early 1970s. It is an ultra-small 1-piece implant with a diameter of 1.8 mm. [35] At the beginning, the mini implant was designed as an interim restoration since it was expected to be easily removed. However, it was discovered during the removal process that the mini implant is strongly integrated to the bone. Histological studies later confirmed that mini implant provided successful osseointegration in light microscopic level. [19] Mini implants are fabricated from bio-compatible material, mostly Titanium, which is similar to standard diameter implant. [36] Its diameter ranged from 1.8-2.9 mm. Different from standard implant, mini implants usually fabricated in single solid screw piece, connected implant body and the abutment together, with a ball-shaped head for denture stabilization or a square prosthetic head for fixed applications.[37] Mini implants are exposed over the gingiva when they are placed while conventional implants are remained under the gums. [38] Mini implants were indicated to place in patient who has limited bone volume along with condition that additional surgical procedure cannot be performed due to medical's reason. However, there are some systemic diseases that even mini-implant cannot be applied such as clotting disorder, osteoporosis, metabolic bone disease and uncontrolled diabetes. In addition, patient with uncontrolled parafunctional habit such as severe bruxism or clenching also contraindicated. The advantages of mini-implant including minimal invasive protocol, shorter healing period and more

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affordable price. [17, 20, 38] On the other hand, their small diameter could lead to reduction in resistant to occlusal loading which resulted in implant fracture [38, 39]

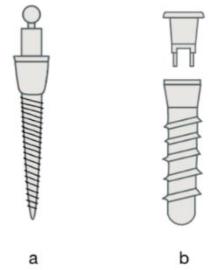

Figure 3 Mini-implant VS Standard implant

a : Mini-implant b : Standard Implant

	Standard implant	Mini implant
Characteristics	Hollow two pieces	Solid one piece
Diameter	More than 3 mm.	Less than 3 mm.
Bone volume	Need more bone available	Need less bone available
Strength	Higher strength	Lower strength
Protocol	More invasive	Less invasive
Complications	More postoperative discomfort	Less postoperative discomfort
Additional surgery	Bone graft or Sinus floor elevation	Avoiding of additional surgery
Costs	Higher price	Lower price

Table 1 Comparison between Standard implant and Mini-implant

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Dental implant materials

Implant material with modulus of elasticity similar to bone is preferable in order to achieved a uniform distribution of stress and to minimize the movement at implant and bone interface. Moreover, implant material should have high tensile and compressive strength to prevent fractures and increase functional stability. High yield strength and fatigue strength also preferred to prevent brittle fracture under cyclic loading. Surface roughness of implants increase the surface area of the implant to bone contact. Thus, improving cell attachment to the bone. [40] Biocompatibility is also a key factor for long term success of implants. Human's body did not accept every material; immune system might react to certain material. In order to minimize biological reaction, implants should be selected properly to reduce the negative biologic response while maintaining adequate function. Among these desired characteristics, titanium is bio-material that are acceptable and widely used. Titanium has a good record of its biocompatibility due to the formation of stable oxide layer on its surface. [41] The commercially pure titanium (cpTi) is classified into 4 grades which differ in their oxygen content. With its good properties make Titanium became

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material of choice for intraosseous applications. Other titanium containing products are also developed, Titanium alloys or Ti6Al4V are the Titanium that reacts with other elements such as silver, Al, Fe, Va and Zn to form alloys. This material is a combination of pure Titanium heated with elements Al, Va in certain concentrations and cooled. Titanium-zirconium alloy or known as Straumann Roxolid are Titanium zirconium alloys with 13%-17% zirconium (TiZr1317). It has superior mechanical properties such as increased in fatigue strength than pure titanium and it claims to be 50 percent stronger than typical titanium. Ceramics such as Zirconia are also considered to be use as an implant material. It provides good strength and physical properties such as minimum thermal and electrical conductivity. However, some characteristics of ceramics such as its brittleness are limited factor for its clinical application.[42]

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Mechanical properties of dental materials

Dental materials are always challenged by the change of oral's conditions. These included chemical, thermal and mechanical alteration. For mechanical property, it usually tested in both elastic and plastic deformation which demonstrated as stress-strain unit. Elastic deformation referred to reversible condition of material upon the force removal or known as elastic limit. While plastic deformation is an irreversible stage of material despite the force has been removed. Force that applied to material has 3 factors to be concerned including point of application, magnitude of force and the direction of force.

Stress is an internal resistance of material that withstand the external load applied on the material. It calculated by force per unit area. Their unit of measurement is in Megapascal. [43] Different in definition to stress, strain refer to the change of material in length per unit of its original length. Their unit of measurement is in percentage.

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$$\text{Stress}(\sigma) = \frac{F\ (N)}{A\ (m^2)}$$

$$\text{Strain}(\varepsilon) = \frac{\text{Change in length}\ (\Delta l)}{\text{Original length}\ (l_0)}$$

Stress can be classified according to direction of forces;

- Tensile stress : Stress that occur when 2 sides of forces are projected away in the opposite direction in a same straight line. It is a load that aim to stretch or elongate the material.
- Compressive stress : Stress that occur when 2 forces are projected toward each other in the same straight line. It is a load that aim to compress or shorten the material.
- Shear stress : Stress that occur when 2 forces are projected away in the parallel direction, but not in the same straight line.

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Figure 4 Types of Stress

Stress-strain curve

The stress–strain curve is a reliable evaluation of mechanical properties of dental material. The stress–strain curve is produced by plotting the applied stress on the axis and the elongation produced respond to it. If there is no permanent deformation occurs when relief the stress, it demonstrated the elasticity. From the start until a limit point, the deformation is called elastic deformation. In this point, the maximum stress of a material will resist without any permanent deformation. If continued applied load until it exceeded this point, irreversible deformation will occur. This resulted in plastic deformation. After this point, material will be failed. Thus, Ultimate strength which means to ability of material to withstand the load before it became failure referred to this point. [44]

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Ultimate strength is calculated by dividing the maximum loading by the original cross -sectional area of the tested material.

- Ultimate compressive strength referred to maximum stress that material can resist in compression.

• Ultimate tensile strength referred to maximum stress that material can resist in tension.

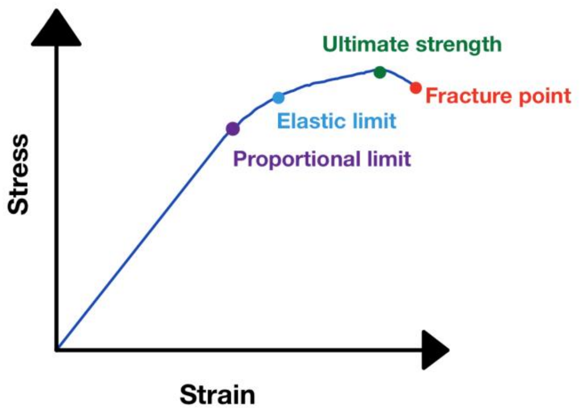

Figure 5 Stress-Strain curve

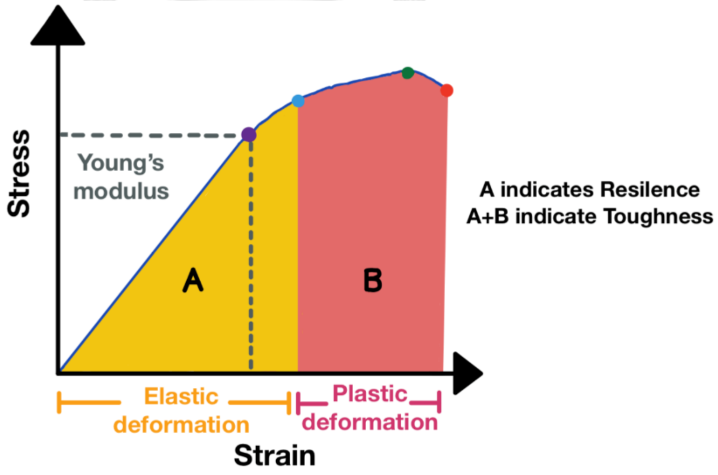

Figure 6 Stress-Strain curve and mechanical properties

From stress-strain curve, other properties of material can be determined including

• Young's modulus or elastic modulus

As stress-strain curve is constant proportionality until the proportional limit point. Thus, it can calculate the ratio of stress-strain curve within the elastic limit. This proportionality is defined as modulus of elasticity or Young's modulus. This value will measure the stiffness of material. The steeper the line, the higher modulus of the material which resulted in high rigidity of the material. [44]

• Resilience

Resilience refers to amount of energy required to deform the material to its proportional limit It calculated from area under the elastic portion of the stress-strain curve. Material with a longer elastic area has higher resilience. [44]

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• Toughness

Toughness is the resistance of a material to the fracture. It is an area under the elastic and plastic portions of a stress-strain curve. [44]

Compressive strength testing

Compression test is a test which materials subjected to 2 opposing forces that loaded to material from opposite sides. It demonstrated the material's behavior including the modulus of elasticity, proportional limit, compressive yield point, compressive yield strength, and compressive strength. These properties are important to determine the material's ability to applied in specific situation. There are 2 types of compressive testing classified by type of applied force

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1. Static loading

The forces were applied only one time over the period of experiment.

2. Dynamic loading

The forces were repeated loading over the period of the experiment.

Both compressive testing should be done following the ISO 14801 guidelines in order to get the standard testing method.

ISO 14801 guidelines

This guideline is to test the endoosseous dental implants by means of dynamic loadings. However, it can be applied to the static tests as well since several studies which tested static loads of dental implant also use the same schematic set up as ISO 14801 guidelines. The regulations for straight endooseeous dental implant testing are as followed;

- Specimen holder : The embedding material must have the young modulus higher than 3 GPa.

- Loading member : Loading member must be hemispherical plane contact surface and the center area of the loading member must be placed in point contact manners to the central longitudinal axis of the tested endooseeous dental implant.

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- Load application : The clamping device shall clamp the position of the specimen at 11mm distance from the center of hemisphere loading to the clamping plane and central longitudinal axis of the tested endooseeous dental implnt should be at the angle of 30 degrees to the direction of the testing machine.

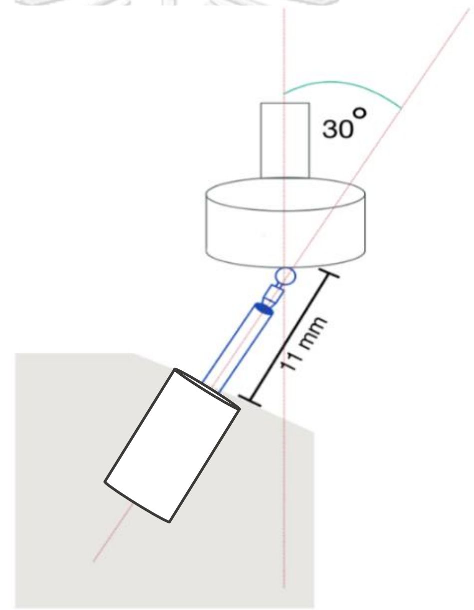

Figure 7 Schematic of test set up

For static load test, load will be applied once until permanent deformation occurred. The results are written in stress-strain curve.

For dynamic load, if the testing is conducted at frequencies less than 2 Hz, testing must be conducted at 2 million cycles, if the frequencies are more than 2 Hz, testing must be conducted to five million cycles. At least 4 loads should be tested and 2 or preferably 3 specimens should be tested for each loading conditions.

The results should be written in load-cyclic diagram. The load that at least 3 specimens are survived the entire cycles are considered as success.[45]

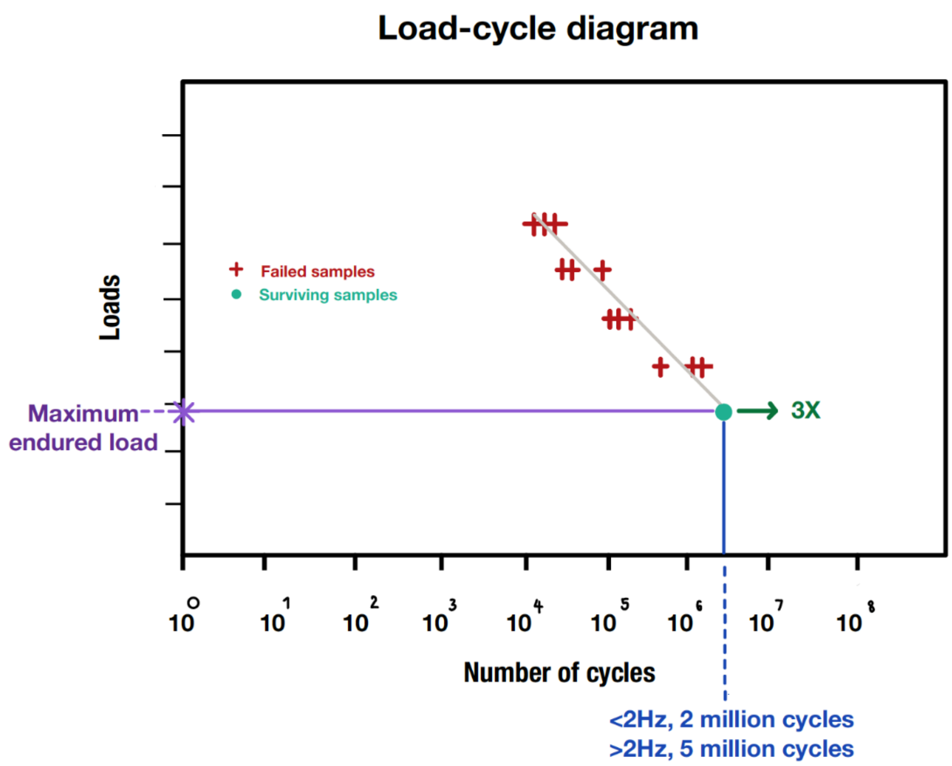

Figure 8 Load-cycle diagram

Chapter III MATERIALS AND METHODS

Research design

This study is an experimental, quantitative, cross-sectional study.

PICO

Population : Mini implants from 2 companies

Intervention : Static and dynamic compressive strength testing

Comparison : Two different mini-implant systems

Outcome : Compressive strength of each mini-implants

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Research study equipments

Sample selection : 50 Mini dental implants

1. 25 RetenDent mini dental implants

2. 25 OSSTEM mini dental implants

Both groups will be further subdivided into 2 groups for

1. Static compressive strength testing - 10 samples for each group

2. Dynamic compressive strength testing – 15 samples for each group

Test lot	Manufacturer	Implant	Lot no.
1	RetenDent mini-implant for overdenture (Chulalongkorn’s product)	∅ 2.5mm/12mm, cylindrical ball shape	L190320
2	MS denture® type implant (OSSTEM)	∅ 2.5mm/11.5mm, cylindrical ball shape	FMN19F031

Table 2 Mini-implant and components used in the current study

Specimen preparation : Cylindrical acrylic block from SIVA ANGKUN CO.,Ltd.

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Figure 9 Cylindrical acrylic block

Compressive strength testing :

1. Servo Hydraulic System, INSTRON 8872 for static compressive strength testing

2. Fatigue tester, INSTRON E1000 for dynamic compressive strength testing

Figure 10 Universal testing machine

Left: INSTRON 8872 Right: Instron E1000

SEM and EDS analysis : Scanning Electron Microscope (SEM) and Energy Dispersive Analysis (EDS) Quanta250, FEI, USA

Data collection and interpretation :

1. Merlin software for static compressive strength testing

2. Waveform software for dynamic compressive strength testing

Research methadology

All instruments, materials, and testing procedures in this study were done following the criteria and guidelines of ISO14801: 2016(E). [45]

Specimen preparation

All specimens were vertically embedded in acrylic blocks (SIVA ANGKUN Co.,Ltd.) following the insertion torque of the manufacturer's recommendation. The distance from the loading point to the level of embedding acrylic supporting the mini-implants was standardized at 11 mm. All specimens were subsequently transferred to the specimen holder that secured the position of each sample at an angle of 30 degrees from its vertical axis.

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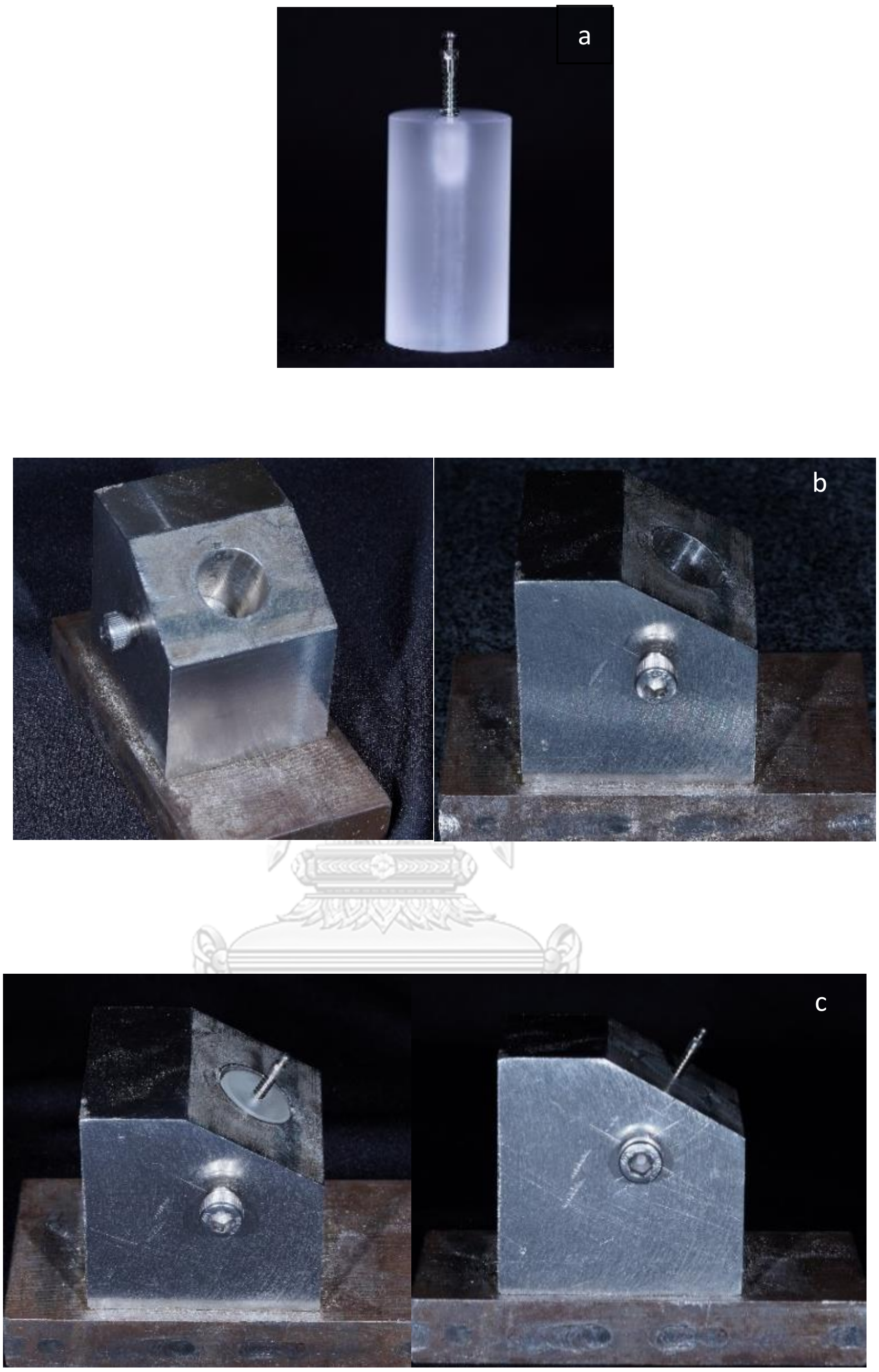

Figure 11 Specimen preparation

a : Mini-implant mounted in acrylic block b : Steel cradle c : Acrylic block secured in steel cradle ready for the compressive strength testing

Static compressive test

Twenty specimens, ten from each group, were randomized and subjected to test for static compressive strength. The static test was performed by Universal Testing Machine (Servo Hydraulic System, INSTRON 8872). The compression load was applied to each specimen by a unidirectional vertical platform through a hemispherical loading member with 1mm/min speed until permanent deformation occurred. Failure was defined as a fracture of the implant body. Data were recorded in the extension of mini-implants in relation to compressive load per second and plotted on a graph. The top peak of the graph, which referred to the maximum compressive strength, was recorded for each sample. Merlin software was used to collect and interpret the data.

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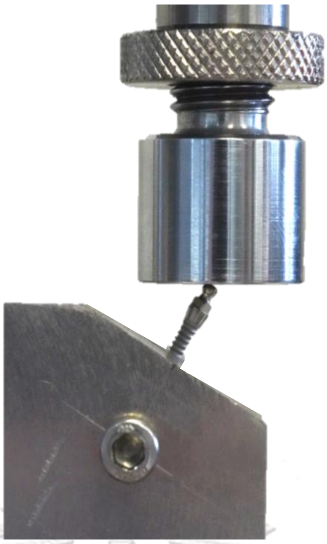

Figure 12 Static compressive strength testing

Fatigue compressive test

Thirty specimens, fifteen from each company, were placed in the same manner with the static testing. The fatigue test was performed in accordance with the guidelines of ISO14801:2016(E) by Universal Testing Machine, INSTRON E1000. Half of the maximum static compressive strength was selected as the first tested load, followed by two ranges of step width (10% of the estimated maximum endured load) above and below. These loads include 320N, 275N, 230N, 185N, and 140N. Three specimens were tested at each loading condition and subsequently

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calculated for the average number of survived cycles. The load was pulsated with a sine wave at the frequency of 15 Hz. The amplitude was set at half of the difference between the maximum and the minimum loads. Data were collected and interpreted by Waveform software. The load that reached five million cycles without deformation was defined as the fatigue limit.

SEM and ESD analysis

Scanning Electron Microscope (SEM) and Energy Dispersive Analysis (EDS) (Quanta250, FEI, USA) were used for further analysis of the morphological and chemical characteristics of the mini-implants, respectively. Samples from each group were observed through SEM at two locations including head and body of the mini-implants. The acceleration high voltage (HV) was set at 20 kV. Representative photos were taken at magnifications of 50 and 1,000. Then the EDS analyses were performed to examine the compositions of both samples. The analyses were randomly performed at three different areas for each sample and demonstrate the results in peak height intensities.

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Statistical analysis

Statistical Package for Social Sciences (SPSS) software was used for the statistical analysis. Shapiro-Wilk test was performed to validate the normality of the distribution of the data. An Independent t-test was utilized to investigate the statistical difference of the static compressive strength between the two mini-implant systems, while descriptive statistics was utilized for dynamic compressive strength testing. A P-value below 0.01 was considered as significance in all comparisons.

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Chapter IV RESULTS

Static compressive test

The results are as shown in Table 3. The average static compressive strengths of RetenDent mini-implants and OSSTEM mini-implants were 462.97 + 16.73 N and 403.41 + 25.55 N, respectively. RetenDent mini-implants demonstrated statistically higher compressive strength when compared to OSSTEM mini-implants at the significant level of 0.01. Example of specimens with permanent deformation after undergoing static tests are as shown below.

	1	2	3	4	5	6	7	8	9	10	Mean	SD	P-value
RetenDent	481.8	452.59	475.15	452.55	477.93	474.25	464.82	460.74	464.79	425.07	462.97	16.73	<0.001
OSSTEM	377.61	413.48	419.33	400.42	350.46	392.06	427.73	432.57	423.94	396.47	403.41	25.55	

Table 3 Mean values and standard deviations of static compressive strength(unit:N)

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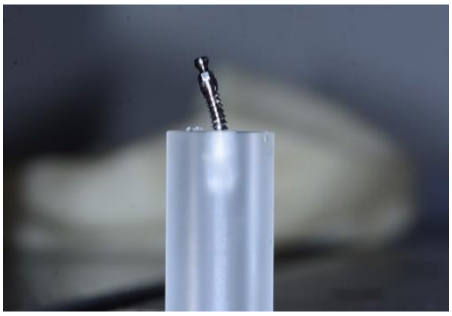

Figure 13 Sample after static compression test

On the right side a : RetenDent b : OSSTEM

Fatigue compressive test

The average number of survived cycles was calculated from three specimens in each loading condition. The results are as shown in Table below. RetenDent mini-implants demonstrated a higher number of survived cycles at loading conditions of 275N, 230N, 185N, and 140N. However, at 320N, OSSTEM showed a slightly higher number of survived cycles. The data were plotted in the load-cycle diagram for comparison according to ISO 14801 guidelines. (Fig. 14). The fatigue limits of RetenDent and OSSTEM mini-implants were 185N and 140N, respectively.

	Load (N)	RetenDent 1 (cycles)	RetenDent 2 (cycles)	RetenDent 3 (cycles)	Average (cycles)
1st	320	2,804	3,540	3,925	3,423
2nd	275	11,324	7,691	7,722	8,912
3rd	230	20,048	37,323	109,751	55,707
4th	185	5,000,000	5,000,000	5,000,000	5,000,000
5th	140	5,000,000	5,000,000	5,000,000	5,000,000

Table 4 Number of survived cycles of RetenDent

	Load (N)	OSSTEM 1 (cycles)	OSSTEM 2 (cycles)	OSSTEM 3 (cycles)	Average (cycles)
1st	320	3,265	3,759	4,068	3,697
2nd	275	5,080	4,911	6,070	5,354
3rd	230	7,140	10,884	9,585	9,203
4th	185	20,991	19,471	17,231	19,231
5th	140	5,000,000	5,000,000	5,000,000	5,000,000

Table 5 Number of survived cycles of OSSTEM

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	320N	275N	230N	185N	140N
RetenDent	3,423	8,912	55,707	5,000,000	5,000,000
OSSTEM	3,697	5,354	9,203	19,231	5,000,000

Table 6 Average number of survived cycles of RetenDent and OSSTEM

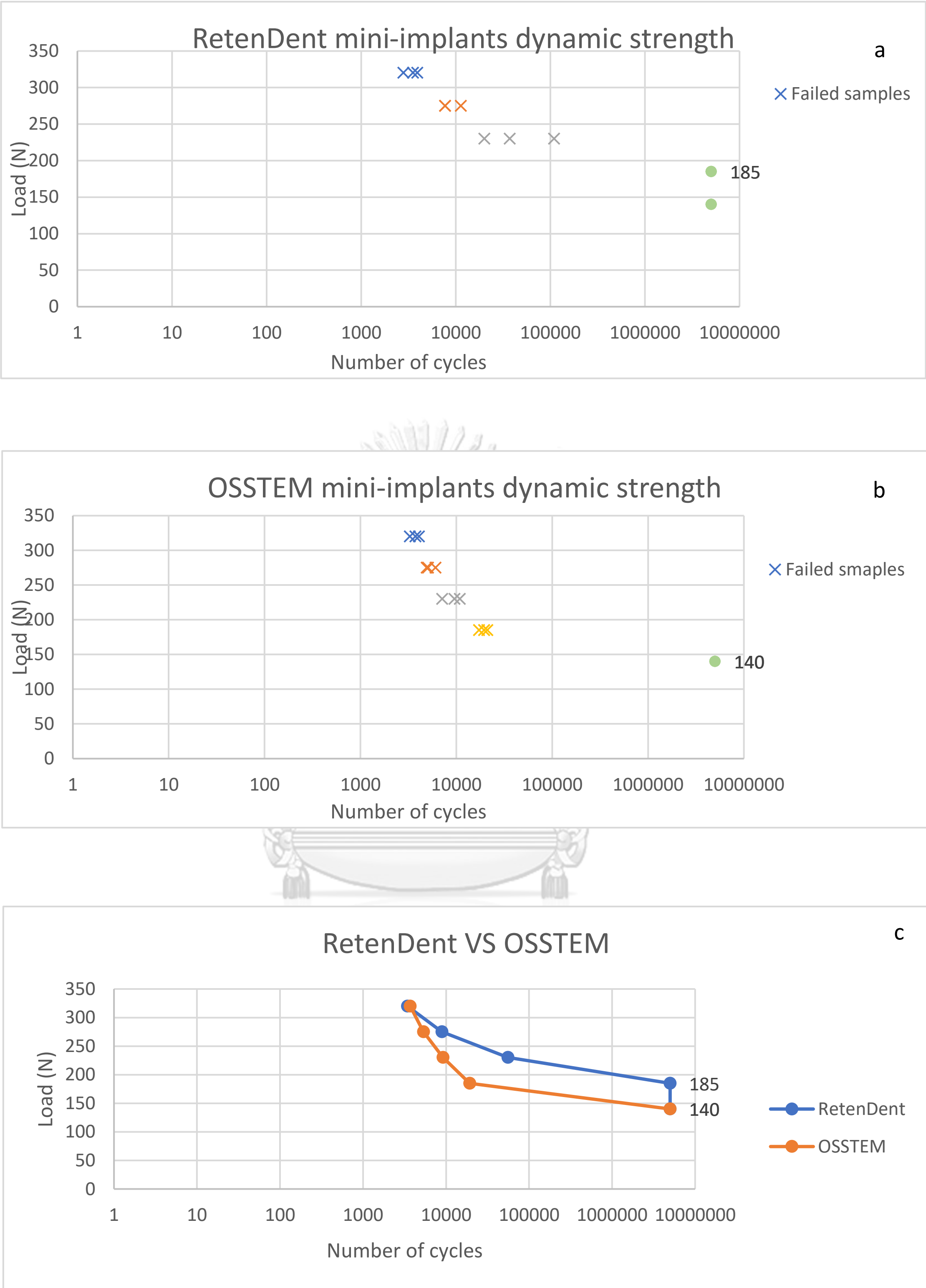

Figure 14 Load-cycle diagram of the results

a : RetenDent b : OSSTEM c : RetenDent VS OSSTEM

SEM and EDS analysis

The SEM images of the mini-implants are shown in Figure 15. At the head of the mini-implants, it showed a homogenous smooth mechanical surface, while the body of the mini-implants demonstrated the irregular roughness which is the results from surface modification in order to enhance osseointegration process of the mini-implants. Moreover, the picture also demonstrated different thread designs between the two mini-implants systems. RetenDent's thread design is similar to reverse buttress shape while OSSTEM's is similar to regular buttress thread shape. EDS spectra of both samples which were measured at 3 different locations are shown in Figure 16. Both samples demonstrated similar results as Ti represented the major components of the materials. The results also revealed the presence of Aluminium (Al) and Vanadium (V) with the same intensity.

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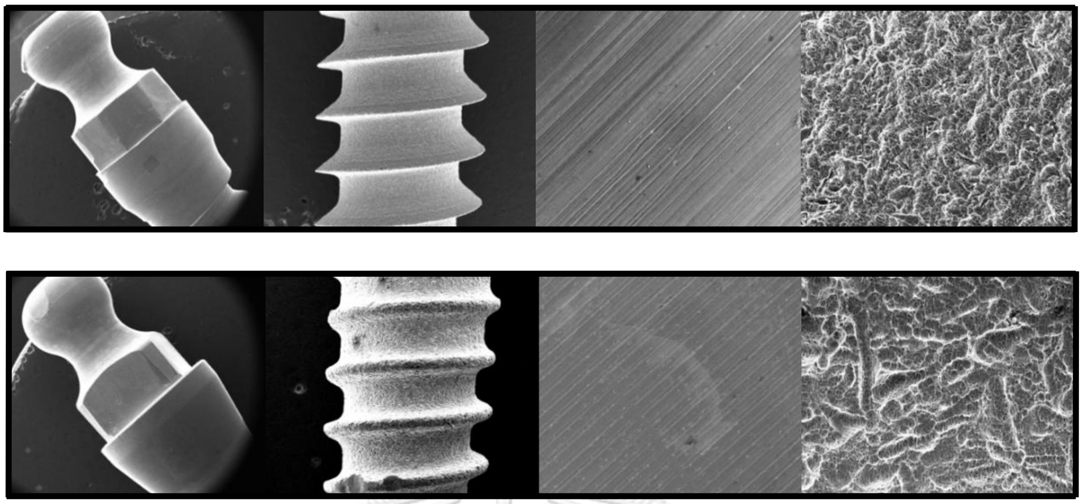

Figure 15 Images obtained by scanning electron microscopy

Top : RetenDent Below : OSSTEM From left to right: Head 50x, Body50x, Head 1000x, Body 1000x

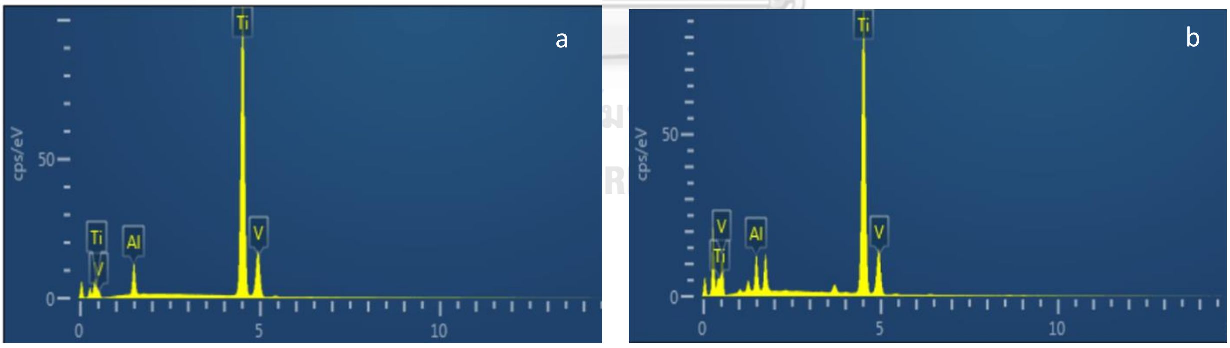

Figure 16 Energy dispersive spectroscopy spectra obtained by chemical analysis

A : RetenDent b : OSSTEM

Chapter V DISCUSSION

Several studies reported that denture wearer preferences in overdenture were higher when compared to the conventional complete denture and fixed prosthesis due to better denture stability, easy cleaning, and maintenance. [14, 15] However, severe atrophy of the alveolar ridges of patients is a contraindication for standard implant placement. Standard implant (two-piece) protocol requires at least 6 millimeters buccolingual width dimension of the alveolar process. This specific buccolingual dimension is rarely found in the edentulous patients, especially in the lower jaw. Therefore, the mini-implant overdenture (one-piece) is recommended to replace the standard implant. The mini-implants of 2.5 mm in diameter requires only 4.5 mm of bone thickness which is normally available in the lower jaw. Moreover, this one-piece design provides a better strength compared to the standard hollow implants.

OSSTEM mini-implant products were selected to be the benchmarked mechanical properties since several studies reported that OSSTEM mini-implants were successful in clinical application and demonstrated high patient satisfaction.[46,

[47] Static and dynamic compressive strengths were selected as a representative for the mechanical testing and the testing method were done following the guideline of ISO14801: Dynamic loading test for endoosseous dental implant in order to obtain the standard outcomes.

The result demonstrated that the mean static compressive strength of RetenDent mini-implants was 462.97 N, which was statistically higher when compared with that of the OSSTEM mini-implants (403.41N) at the significant level of 0.01. The compressive fatigue testing is the simulation of daily functions and is accepted as the foremost and suitable test strategy to get the information closet to the clinical circumstance. In this study, five loads were selected to compare the number of cycles between these two mini-implants, including 320N, 275N, 230N, 185N, and 140N. These loads were selected as 230N representing half of the maximum static compressive strength of the material, and 45N was determined as the step width of the maximum load. The specimens were positioned at a 30-degree off-axis which simulated clinically severe single tooth bending.[48] Literature review shows that adults have a chewing frequency of around 2700 times a day, which is equal to 10 million times per year.[49] However, chewing cycles are not always active in normal oral conditions. According to ISO14801, five million cycles are considered as a standard for cyclic testing. The results demonstrated that both RetenDent and OSSTEM mini-implants showed similar results in that the number of survived cycles were increased with decreasing level of load. RetenDent mini-implants showed a higher number of survived cycles when compared with OSSTEM mini-implants at the same loading condition. Only at 320N that OSSTEM did demonstrate a slightly higher number of survived cycles. The reason for this is the collar size of the mini-implants. The collar is located in the transitional area between the fixture and the head of mini-implant. The diameter of collar usually wider than the body part in order to provide a seal for the osteotomy. This wider collar will enhance the surface area and reduces the stress at the crestal area of the bone.[50] In addition, wide collar provides more bulk material which may improve the implant's resistance to failure. OSSTEM has a larger collar which is around 3.2 mm when compared with RetenDent, which has a collar size of around 2.8mm. This collar part receives the load and transfers it to the body.

At 320N, the 2.8 mm collar size cannot withstand the load. As a result, it fractured at the lower number of cycles than OSSTEM.

Analyzed through EDS, both mini-implants demonstrated the presence of Vanadium (V) and Aluminum (Al) elements suggesting that Ti6Al4V is the alloy material of both mini-implant systems. Moreover, the manufacturer of RetenDent mini-implant claims that the alloy material of the products is Ti6Al4V ELI (grade23) following the ASTM F 136 Titanium specification.[51] Two types of Titanium that are commonly used in the implant dentistry are cpTi4 and Ti-6Al-4V. Several studies reported that Ti-6Al-4V was a preferable material for mini-implants since it provided superior mechanical properties when compared with cpTi4. [52, 53] However, some studies reported the risk of toxicity from Vanadium in the Ti-6Al-4V alloy and the mismatch of the elastic modulus between the implant and the bones.[54, 55] Thus, modification of titanium alloy compositions with extra low interstitials (ELI) has been developed. The Ti6Al4V ELI contains lower levels of interstitials, which results in better mechanical and thermal properties. These properties include fracture and corrosion resistance, wear, and cryogenic properties.[56]

Comparing the results with a study by Heo et al., which tested mini-implants from Dentis, Daegu, Korea.The diameter of the mini-implant was 2.5 mm and the length was 13 mm. The test method was similar to this study. The results demonstrated that the maximum static compressive strength was 149 ± 6.1 N.[57] Dentis was made of cpTi4. Thus, it yielded a lower compressive strength value when compared with Ti6Al4V and Ti6Al4VELI material at the same diameter and tested conditions. The fatigue limit of Dentis was analyzed at 60N, which accounted for around 40 percent of its maximum static compressive strength. This percentage is comparative to RetenDent. OSSTEM's mean static load is around 403N, and its fatigue load is limit to around 140N. This accounts for around 35 percent of its maximum compressive strength. However, the large range of the step width must be considered, as the load between the ranges could be the definite fatigue limit of the materials.

In this study, both mini-implants of each system were embedded in the acrylic blocks with standardization of 11 mm distance between the supporting point and the loading point, resulting in an equal moment arm (lxsin30) of 5.5 mm.

Retendent’s length is 12mm while OSSTEM is 11.5mm. Study by Alshenaiber tested three different length of mini-implants with same diameter (2.4mm) including 13mm, 10mm and 8.5 mm length to prove whether the length of mini-implants affect the resistance in failure. The result demonstrated that there was no effect of the length on the failure of the mini-implants following overloading.[58]

Another different factors between these two mini-implant systems are the thread shape and design. Study by Lee et al reported that different types of thread had no effect on the compressive strength of the material. On the other hand, different thread shape and depth could affect the stress distribution and primary stability.[59] Study by Oswal et al. found that Minimum Von Mises stresses were seen with the reverse buttress thread design at the cortical bone.[60] Study by Ahmad et al. also reported that the reverse buttress had a favorable outcome as it provides better stability and increases the ability of osseointegration process. [61] Surface treatment is another factor that has an effect on osseointegration. According to manufacturer’s information, both RetenDent and OSSTEM were treated by Sandblasted and acid etching (SA) technique. Elkhaweldi et al. reported that SA had a higher survival rate compared to Resorbable blasting media (RBM) method, especially in the area of poor quality of bone.[62] Study by Im et al. also reported that the initial stability of SA was higher than RBM, but not statistically different.[63]

The most concerning problem for the mini-implants is their mechanical properties to withstand the force since several studies reported a high risk of fracture in the reduced diameter of the implants.[64, 65] The maximum bite force is usually used as an indicator to evaluate oral cavity function. Several factors have an effect on this value, including gender, age, periodontal and dental status. Study reported that completely edentulous patients had reduced masticatory force up to only 20 %–40 % of that of healthy dentate persons.[66] This is due to decreased muscle activity as older people tend to have weak neuromuscular control.[67] Type of prostheses play very important role in the bite force. Study by Manzon reported the highest bite force was found in natural full dentition followed by implant retained overdenture, natural teeth occlude to complete denture, complete denture occlude to complete denture and edentulous in both arch, respectively.[68] Study by Rismanchian investigate the maximum bite force in left and right side of patient with conventional maxillary denture occlude to mandibular implant- retained overdenture on 2 implants placed in canine region. The measurement area is at the first molar region. The results demonstrate the mean maximum bite force for each side is around 119.84 N.[69] Compared with this study's results, both RetenDent and OSSTEM's static and dynamic compressive strength are greater than this value. Therefore, it's come to conclusion that RetenDent mini-implants have comparable qualifications to the OSSTEM mini-implants and likely to has capabilities in need for application in clinical practice to retain prostheses.

Limitations

This study was an in-vitro study. It cannot simulate the actual intraoral environment. The load was applied only in a single direction. Temperature and humidity were not similar to the actual clinical situation. Future studies might consider artificial saliva baths and thermocycling.

Chapter VI CONCLUSION

RetenDent mini-implants are statistically higher in static compressive strength compared with OSSTEM mini-implants. RetenDent has a higher dynamic compressive strength than OSSTEM and also has a higher number of survived cycles in all loading conditions except at 320N loads. Both RetenDent and OSSTEM's static and dynamic compressive strength were greater than maximum bite force of implant-retained overdenture. RetenDent mini-implants have comparable qualifications to the OSSTEM mini-implants and likely to has capabilities in need for application in clinical practice.

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