Retention force and wear characteristic of ball and O-ring attachment in Chulalongkorn mini-implant overdenture system.

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A Thesis Submitted in Partial Fulfillment of the Requirements
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แรงในการยึดอยู่และลักษณะการสึกของระบบการยึดฟันเทียมคร่อมรากเทียมชนิดบอลร่วมกับยางโอ
ริง โดยจุฬาลงกรณ์มหาวิทยาลัย

นายธนกร ทิมขำ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Thesis Title	Retention force and wear characteristic of ball and O-ring attachment in Chulalongkorn mini-implant overdenture system.
By	Mr. Thanakorn Thimkam
Field of Study	Esthetic Restorative and Implant Dentistry
Thesis Advisor	Associate Professor PRAVEJ SERICHETAPHONGSE

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ธนกร ทิมขำ : แรงในการยึดอยู่และลักษณะการสึกของระบบการยึดฟันเทียมคร่อมรากเทียมชนิดบอลร่วมกับยางโอริง โดยจุฬาลงกรณ์มหาวิทยาลัย. (Retention force and wear characteristic of ball and O-ring attachment in Chulalongkorn mini-implant overdenture system.) อ.ที่ปรึกษาหลัก : รศ. ทพ.ประเวศ เสรีเชษฐพงษ์

งานวิจัยนี้มีจุดประสงค์เพื่อศึกษาแรงในการยึดอยู่และลักษณะการสึกของระบบการยึดฟันเทียมคร่อมรากเทียมชนิดบอลร่วมกับยางโอริงรีเทนเดนท์(RetenDent) ที่พัฒนาโดยจุฬาลงกรณ์มหาวิทยาลัยเมื่อผ่านการทดสอบความล้าจากการใส่-ถอด โดยใช้ระบบการยึดฟันเทียมคร่อมรากเทียมขนาดเล็กชนิด MS denture® (ออสเทมส์) และ รีเทนเดนท์ (จุฬาลงกรณ์มหาวิทยาลัย) มาผ่านการจำลองการใส่-ถอดโดยเครื่องทดสอบยูนิเวอร์แซล (E1000, อินสตรอน) ทั้งหมด 5500 รอบ ที่ความถี่ 1 รอบต่อวินาที เพื่อจำลองการใส่และถอดฟันปลอมคร่อมรากเทียมจำนวน 3 ครั้งต่อวัน เป็นเวลา 5 ปี การวัดแรงในการยึดอยู่ได้จากการดึงโอริงแยกจากหลักยึดโดยใช้เครื่องทดสอบยูนิเวอร์แซล (EZ-SX, ชิมัตสึ) ทำการวัดทั้งหมด 6 ครั้ง ที่ก่อนการทดสอบความล้า และหลังจากการจำลองการใส่-ถอดแต่ละปีที่ 1100, 2200, 3300, 4400 และ 5500 รอบ ลักษณะการสึกบนโอริงและหลักยึดรูปบอลศึกษาภายใต้กล้องจุลทรรศน์สเตอริโอ (SZ61, โอลิมปัส) โดยเปรียบเทียบระหว่างก่อนการทดสอบความล้าและหลังจาก 5500 รอบ ผลการทดลองแสดงให้เห็นค่าเฉลี่ยของแรงในการยึดอยู่ในทั้งสองกลุ่มไม่แตกต่างกันอย่างมีนัยสำคัญ กลุ่มรีเทนเดนท์มีค่าเฉลี่ย 6.65N และในกลุ่มออสเทมส์มีค่าเฉลี่ย 6.84N อย่างไรก็ตามการทดสอบในทางสถิติแสดงว่าปฏิสัมพันธ์ระหว่างรอบในการทดสอบความล้าและระบบการยึดอยู่นั้นส่งผลต่อแรงในการยึดอยู่อย่างมีนัยสำคัญ โดยแจกแจงได้ว่ากลุ่มรีเทนเดนท์มีแรงในการยึดอยู่ก่อนการทดสอบ (10.96N) และหลังจาก 1100 รอบ (8.73N) สูงกว่ากลุ่มออสเทมส์ (6.50N และ 6.66N) อย่างมีนัยสำคัญ แต่ทั้งสองกลุ่มไม่แตกต่างกันอย่างมีนัยสำคัญที่ 2200 รอบ และหลังจาก 3300, 4400 และ 5500 รอบ กลุ่มออสเทมส์ (6.86N, 7.06N, 6.997N) มีแรงในการยึดอยู่สูงกว่ากลุ่มรีเทนเดนท์ (5.04N, 4.49N, 3.88N) อย่างมีนัยสำคัญ ภายใต้กล้องจุลทรรศน์สเตอริโอไม่พบการสึกบนหลักยึดของทั้งสองกลุ่มจากการส่องด้วยกล้องจุลทรรศน์แบบสเตอริโอ โดยสรุประบบการยึดฟันเทียมคร่อมรากเทียมขนาดเล็ก MS denture® (ออสเทมส์) และรีเทนเดนท์ ให้แรงการยึดอยู่เฉลี่ยที่ไม่แตกต่างกันอย่างมีนัยสำคัญหลังการจำลองการใส่ถอดเป็นเวลา 5 ปี ทั้งสองกลุ่มให้ค่าที่สูงกว่าค่าแนะนำขั้นต่ำสำหรับฟันเทียมคร่อมรากเทียม โดยกลุ่มรีเทนเดนท์ให้แรงยึดที่มากกว่าในช่วงแรกอย่างมีนัยสำคัญ และไม่พบการสึกบนหลักยึดภายใต้จุลทรรศน์แบบสเตอริโอหลังการจำลองการถอดใส่ 5500 รอบ

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Thanakorn Thimkam : Retention force and wear characteristic of ball and O-ring attachment in Chulalongkorn mini-implant overdenture system.. Advisor: Assoc. Prof. PRAVEJ SERICHETAPHONGSE

The purpose of this experimental study was to evaluate wear characteristics and retention force of the RetenDent mini-implant overdenture system (Chulalongkorn product) after the insertion-removal fatigue test. One-piece mini-implants attachment system for overdenture, Osstem MS denture® type implant (OSSTEM, Germany GmbH), and RetenDent mini-implant were tested. All samples were subjected to repeated insertion and removal fatigue cycles by the universal testing machine (E1000, INSTRON Instrument, England). Subjected fatigue cycles were 5500 with 1.00Hz frequency to mimic a 5-year insertion and removal three times per day. The retention force was measured by separating the O-ring from the abutment and recorded with the universal tester (EZ-SX, SHIMADZU, Japan). The retention force was measured six times, at baseline and the end of 1100, 2200, 3300, 4400, and 5500 cycles. These represent each year of use. After fatiguing, the O-rings and mini-implant ball abutments were examined with a stereomicroscope (SZ61 OLYMPUS, Japan) and compared to baseline. The result showed a mean retention force of 6.65N for the RetenDent group and 6.84N for the Osstem group, which were not statistically different. The two attachment systems had no significant effect on retention force. However, the fatigue cycles alone and the interaction between the attachment system and fatigue cycles had significant effects on retention force. The RetenDent group's retention was significantly higher at baseline (10.96N) and after 1,100 cycles (8.73N) compared to the Osstem group (6.50N and 6.66N). There was no statistical difference at 2200 cycles. The Osstem group's retention became significantly higher after 3300, 4400, and 5500 cycles (6.86N, 7.06N, 6.997N) compared to the RetenDent group (5.04N, 4.49N, 3.88N). In conclusion, the RetenDent and the MS denture® mini-implant attachment system provided a similar 5-year average retention force at higher than the minimum recommended for overdenture. The RetenDent group had significantly higher retention forces at the first two-point of measure. There was no wear on the ball abutment of both groups under the stereomicroscope after 5,500 fatigue cycles.

Field of Study:	Esthetic Restorative and Implant Dentistry	Student's Signature ....
Academic Year:	2020	Advisor's Signature ....

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Thanakorn Thimkam

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Introduction

Background and Rationale

The Thai community had been steadily transitioning to an elderly society. As reported in 2017, the Thai elderly population was 11 million from a total of 65.5 million Thais. This was approximately 17% of the total population, ranking second among all ASEAN member countries and projected to be more than 26.6% of the total population in 2030.(1, 2) A survey in Thailand during 2017 had found 8.7% of 60-74 years old and 31% of 80-85 years old had total edentulism. It had shown that only 23% of the elderly population were wearing a denture. This number was lower than the past surveys in 2007 and 2011.(Fig. 1)(1)

YEAR	60-69 years old	70-79 years old	80 + years old	TOTAL
2007*	39.0	35.5	28.6	36.0
2011	20.5	27.8	29.0	23.7
2017	19.9	26.9	28.0	23.0

*Remarks: In 2007, only those with less than 20 natural teeth

Source: Analysis of Data from the Survey of Older Persons in Thailand: 2002, 2007, 2011, 2017 (weighted)

Figure 1 Percentages of elderly wearing dentures by age: 2007-2017(1)

Complete edentulism and tooth loss have been correlated to a multitude of systemic comorbid conditions. Also, edentulous patients are at risk of reduced nutritional intake and increased risk of obesity.(3) In Thailand, the royal complete denture project had shown positive impacts on the Thai elderly's quality of life and their oral health.(4) Prosthetic options for patients presented with complete edentulous ridge include a conventional complete denture, implant-supported prosthesis, and implant-retained prosthesis. These options differ in terms of cost, maintenance, denture stability and retention, and patient satisfaction toward the denture. Interestingly, some patients have had difficulty adapting to conventional dentures, even with proper tissue support and good denture quality.(5, 6) On the other hand, implant-retained or implant-supported prostheses lessen the requirement of the patient's muscular control development for denture adaptation. Thus, positively affect their quality of life.(7-9) Implant-retained prosthesis such as implant-overdenture is a great alternative with relatively lower cost compared to an implant-supported fixed denture.(10) Several studies have reported the advantages of implant-overdenture over conventional tissue-borne complete denture. These include better retention particularly in the edentulous mandible, good functional ability, and less ridge resorption rate.(7, 8, 11) In terms of patient-based analysis, implant-overdentures give better patient satisfaction with a predictable outcome.(9, 12) Furthermore, the McGill consensus in 2002 suggested that two-implant overdenture is the first choice of treatment for the edentulous mandible.(13)

There have been uses of mini-implants to support the overdenture as an alternative to standard diameter implants. A mini-implant is a rigid, non-hollow implant with less than a 3mm diameter. The mini-implant surgical technique is simple and quick with a high success rate compared to standard-size implants.(14, 15) A meta-analysis of randomized controlled trials had shown that mini-implants provided good patient satisfaction compared to standard diameter implants when used for implant-retained overdentures.(16, 17) Another systemic review also concluded that mandibular mini-implant retained overdentures are predictable regarding implant survival, marginal bone resorption, and patient satisfaction.(18, 19) Mini-implants used with overdenture can further lower the total cost of the treatment and applicable in patients with narrower ridges. However, the most common complication is the loss of attachment retentive ability over time. This is due to wear and deformation of ball abutment and O-ring through the patient's insertion-removal routine.(20) Maintenance of the attachment system as changing the O-ring or replacing wore abutment will contribute to the long-term cost of the prosthesis. More importantly, abutment wear in mini-implants will result in the need for fixture replacement surgery.

The RetenDent mini-implant overdenture system developed by Chulalongkorn university aims to provide an attachment complex with good wear resistance, to be more accessible, with a lower cost to Thais in need of complete denture. This experimental study's objective was to evaluate wear characteristics and retention force of the RetenDent mini-implant overdenture system after the insertion-removal fatigue test.

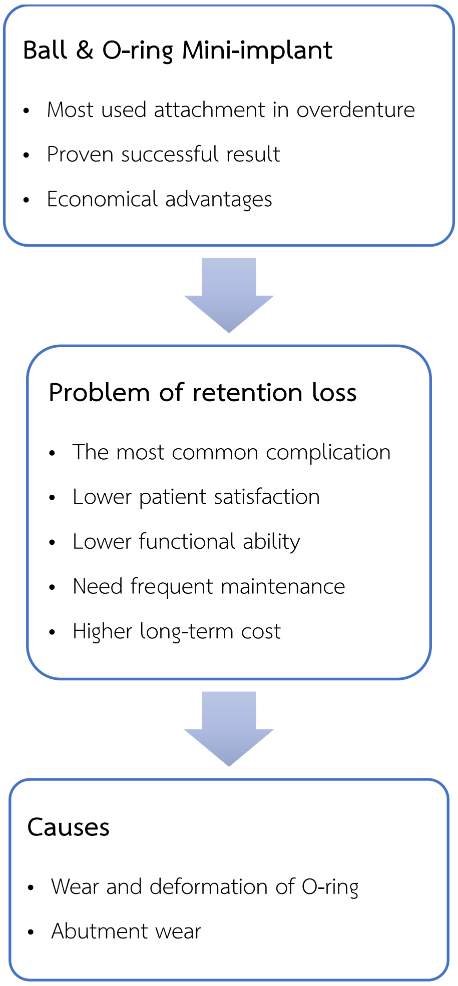


Figure 2 Ball & O-ring attachment and its complication

Research question

Is there a difference in wear characteristics and retention force between two different ball and O-ring attachment systems after the insertion-removal fatigue test?

Objectives

1. Evaluate retention force between two different ball and O-ring attachment systems after the insertion-removal fatigue test.
2. Evaluate wear characteristics between two different ball and O-ring attachment systems after the insertion-removal fatigue test.

Hypotheses

There is no difference in retention force between two different ball and O-ring attachment systems after the insertion-removal fatigue test.

There is no difference in wear characteristics between two different ball and O-ring attachment systems after the insertion-removal fatigue test.

Expected Outcome

The RetenDent, Chulalongkorn mini-implant attachment system seeks to provide an alternative to dentists and patients in treating edentulism. This study would compare the performance in vitro to the available and widely used commercial product. The study would allow the possibility of a more affordable, readily available, and potentially better wear resistance attachment system.

Literature Review

Elderly edentulism patients without treatment are at the risk of exposing to further frail conditions. Reasons for the lack of treatment include affordability and difficulty in adapting to dentures. Implant-retained overdenture is proven to be a solution to the problem. The development of attachment with good wear resistance will improve the long-term success and lower the maintenance cost for the patient.

Edentulism

Edentulism does not only decrease the masticatory function of the individual but also affects their overall health negatively. The study of adults from 50 middle to low-income countries in 2016 had shown edentulism to be significantly associated with depression and poor self-rated health.(21) The resorbed alveolar complex will negatively affect the appearance of the patient’s soft tissue profile. The reduced masticatory function from tooth loss also leads to malnutrition.(22-24) A study by De Marchi et al. expresses that edentulism, which was not rehabilitated with a set of complete dentures were linked with triple the risk of malnutrition when compared to partially dentate patients.(25) Following that, a lower intake of necessary nutrition contributes to frailty, morbidity, and mortality in older people.(26, 27) A systemic review by David A. Felton concluded that reduced, but not replaced dentition was found to increase the risk of mortality. This was later supported by the systematic review in 2019, which showed a higher number of deceased edentulous patients without denture compared to denture wearer over a long follow-up period.(28) Treatment with optimal removable prostheses may help protect patients against some types of comorbid disease conditions.(3, 24)

Implant overdenture

The implant-overdenture has been a validated treatment of choice for edentulous patients. Conventional mandibular denture retention and stability is very difficult in severely resorbed ridges unless implant overdenture is applied.(29) A crossstudy research by Burns D. R. et al. showed clear superiority of implant-overdentures over conventional mandibular denture. Patients in the study were also found to have better soft tissue response after switching to overdenture.(8) Retreatment of edentulous patients with mandibular implant overdentures provided significantly better oral health-related quality of life than fabricating new conventional dentures.(12) The patient-based evaluation also supports this treatment concept with higher satisfaction and consistent, predictable outcome.(9) McGill consensus since 2002 proposed the evidence to support that two-implant overdenture should become the first choice of treatment for the edentulous mandible.(13, 29) The introduction of mini-implants in use with overdenture had proven to be a successful alternative to normal diameter implants. Narrow diameter implant(NDI) can be classified into 3 categories; Category 1 is the mini-implants (implant diameter <3.0 mm), Category 2 (implant diameter 3–3.25 mm) and Category 3 (implant diameters 3.3–3.5 mm).(30) A systemic review of 1,273 patients with mini-implant overdenture has shown a 92.32% mini-implant survival rate. All studies from the review verified an increase in satisfaction and quality of life after rehabilitation treatment with mini dental implants.(31)

Attachment system

The attachment system for overdentures can be categorized into three groups bar, stud, and magnet attachment.(32) Engquist et al. found that individual attachments are easily applied in many situations compared to bar attachments.(33) The most commonly used anchorage system for overdenture retained by one-piece mini-implants is the ball and O-ring attachment.(31, 34) Ball attachment also introduces less technical complications and repairs than bars.(35) O-rings are commonly made of an elastomer, for example, nitrile rubber or polyurethane.(36) Desirable advantage of the O-ring attachment is a reduced stress distribution on the implants. O-ring has true rotational freedom which functions as a stress breaker.(37) O-ring attachments were found to provide better stability and retention than magnetic attachments.(8) These advantages contribute to good patient satisfaction. However, the most common mechanical complication in cases of implant-overdenture is the loss of retention.(20, 32) This has been known to cause by wear and deformation of the attachment component over time.(38-41) In the case of ball attachment, the point of failure is the O-ring part which wears during insertion and removal of the overdenture.(38-43) These activities, over time decrease retentive ability as well as lower patient satisfaction.(44)

Retention force

Studies indicated that a 5 to 7N retention force is enough to support and stabilize implant overdentures.(45) While the minimum retention force sufficient for implant-overdenture with stud attachments is thought to be 5N.(46) There have been studies considering the effect of simulated function or cyclic loading on the changes of retention force. The insertion and removal simulation of 5,500 cycles was done to mimic 5 years expected usage of the denture.(38, 40, 41) Another study's method was 2,500 cycles for 2-year insertion and removal (3-4 times per day).(47) A systematic review of multiple in vitro studies shown reduction or total loss of retention force across the majority of attachment systems after cyclic loading.(32) Finally, in vitro study by Chaves et al. concluded that insertion-removal cycles led to a retention loss of 24%, whereas masticatory cycles did not influence retention.(48)

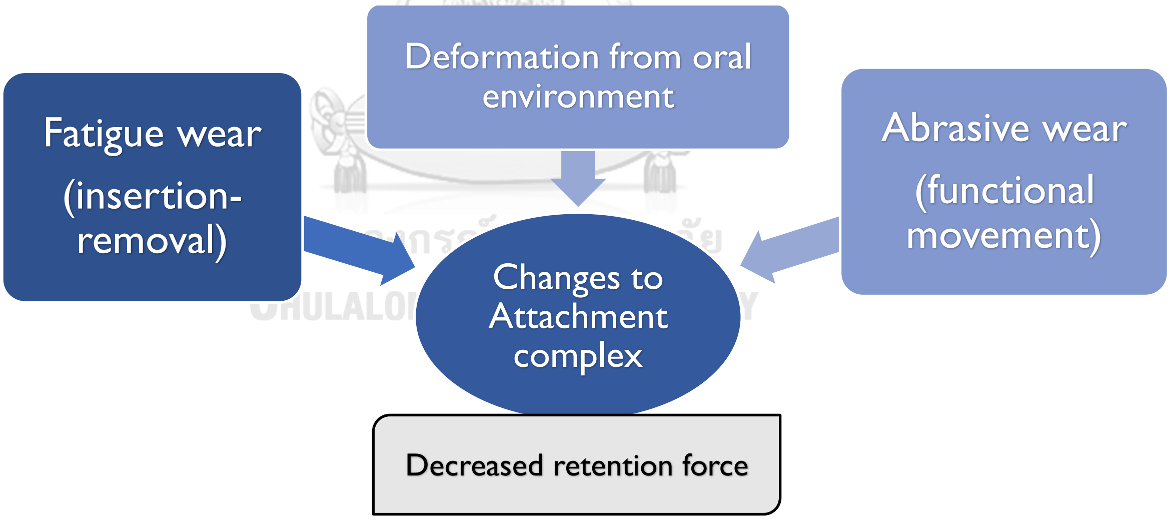
RetenDent's carbon-coated abutment

Other than dental implants, titanium alloy is also used for joint prostheses in the medical field. The wear in titanium alloy causes tissue inflammation from its metal debris and ions. A class of amorphous carbon that shares some properties of diamonds called DLC (Diamond-like carbon), was introduced to modify the surface of these prostheses.(49) This coating was studied to greatly increase titanium alloy wear resistance up to 3 folds.(50) DLC film was successfully tested to prevent implant-abutment screw loosing.(51) According to an in vitro experiment, DLC coated abutment screw helps maintain the abutment torque after cyclic loading.(52) Besides, studies on DLC coating on titanium and titanium alloy implant surface has shown to be biocompatible for hard and soft tissue; DLC coating did not alter bacterial adhesion.(53, 54)

Osstem MS denture® type implant

The Osstem MS denture® mini-implant (OSSTEM, Seoul, South Korea) is selected to be compared to Chulalongkorn's product (RetenDent) in this study. Osstem mini-implant system is a Korean product widely used in Thailand with the U.S. FDA's approval and the EU quality certification CE. They are relatively affordable and have great clinical validations and yearly clinical publications. A study has found the MS mini-implants to have good clinical prosthetic effects even in immediate loading cases.(55) Osstem MS mini-implant ball abutment is a bare machined titanium surface in contrast to DLC coated RetenDent abutment.

Conceptual framework



Material and method

Sample selection

One-piece mini-implants fixtures for overdenture, MS denture® type implant (OSSTEM, Germany GmbH), and RetenDent mini-implant for overdenture (Chulalongkorn's product) were tested. The samples were designated as the OS group (MS denture®) and the RD group (RetenDent). Sample size calculation performed with G*Power program version 3.1.9.7. Input data was obtained from a similar experimental study with power $(1-\beta) = 0.95$ and $\alpha = 0.05$.(38) The sample size determined was 10 per group.

Fatigue test

All samples were subjected to repeated insertion and removal fatigue cycles by the universal testing machine (E1000, INSTRON Instrument, England). Matrix and O-ring complexes were fixed to the upper member of the machine while implant fixtures were fixed to the lower member of the machine (Fig.3-5). The lower member stayed stationary while the upper member of the machine moved vertically. The fatigue frequency is 1.00Hz, for a total of 5500 cycles to mimic 5 years insertion and removal three times per day.

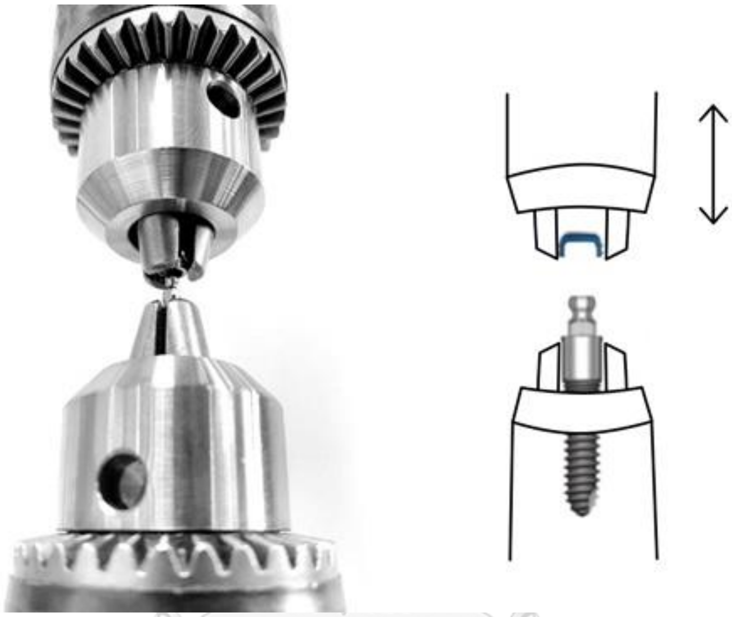


Figure 3 The testing apparatus

(Left: The sample was mounted in the universal testing machine, right: Diagram of the apparatus with an arrow showing the movement of the machine)

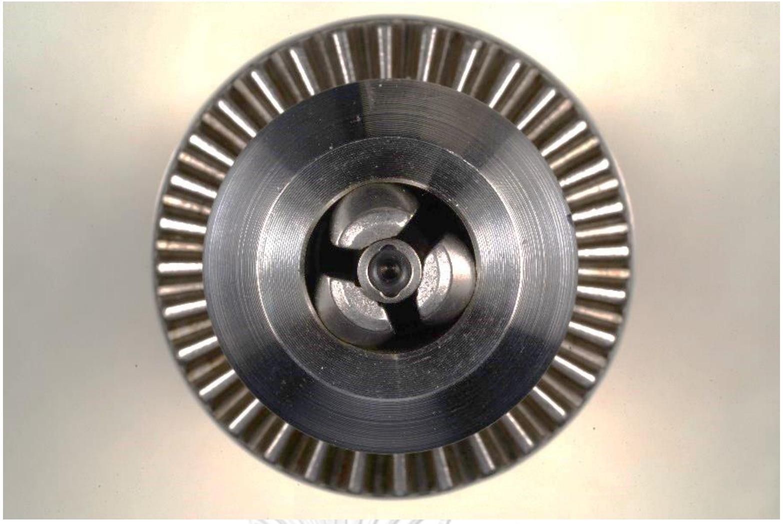


Figure 4 O-ring and its housing mounted in the testing apparatus

Figure 5 Mini-implant abutment mounted in the testing apparatus

Retention force measurement

The retention force was determined by separating the O-ring from the abutment. The force was performed and monitored by the universal tester (EZ-SX, SHIMADZU, Japan), and the test speed was 50mm/min. The retention force was measured six times, at baseline and the end of 1100, 2200, 3300, 4400, and 5500 fatigue cycles. These had intended to represent 1, 2, 3, 4, and 5 years of denture usage, respectively.

Stereomicroscope imaging

Stereomicroscope images of the mini-implant ball abutments and O-rings were taken before cyclic fatigue (SZ 61 OLYMPUS, Japan). After 5500 cyclic fatiguing, the samples were examined by a stereomicroscope again.

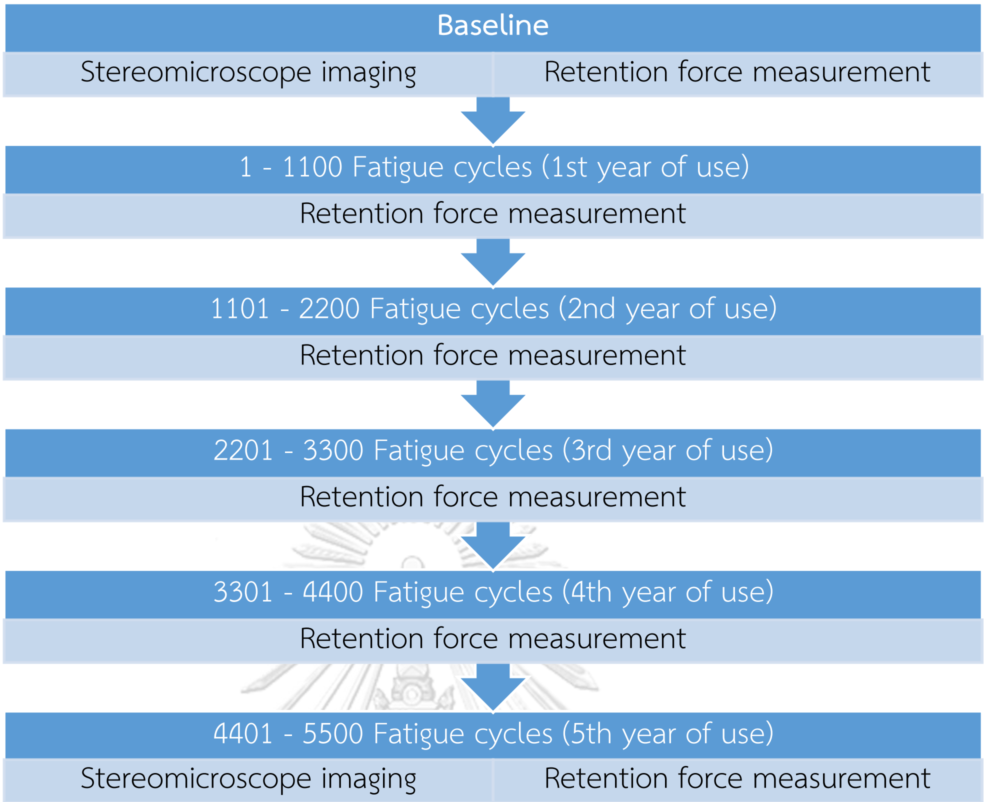


Figure 6 Flowchart of the testing process for all samples

Data analysis

The normal distribution of data collected was checked and confirmed with the Kolmogorov-Smirnov test. Mixed-Model Factorial ANOVA was performed to evaluate the effect of the attachment system and cyclic fatigue on retention force. Retention forces measured from the two attachment groups were compared by independent samples T-test. The comparison of retention force within the group was done with repeated ANOVA and followed with Bonferroni post hoc analysis. All analyses were performed at α=0.05. Data were calculated with the SPSS Statistics 22. The qualitative comparison was used for the evaluation of stereomicroscope images.

Results

Retention force

The independent variables, attachment system, and cyclic fatigue were two potential factors affecting the retention force. Their effects and interaction were calculated by Mixed-Model Factorial ANOVA. The results in Table 1 showed cyclic fatigue alone and the interaction between the attachment system and cyclic fatigue have significant effects impacting the retention force. In contrast, the effect from the attachment system alone was insignificant. The mean retention forces of RD and OS groups recorded are shown in Table 2.

Table 1 Mixed-Model Factorial ANOVA

Effects	Sum of Squares	df	Mean Squares	F	Sig.
Cyclic fatigue	162.480	2.256	72.026	27.828	0.000
Cyclic fatigue x Attachment system	218.127	2.256	96.694	37.359	0.000
Attachment system	1.118	1	1.118	0.329	0.573

Retention forces between the two groups at each fatigue cycle were compared by independent samples *T*-test (Table 3). The RD group showed significantly higher retention forces when comparing to the OS group at baseline (*P*=.000) and 1100 cycles (*P*=.002). At 2200 cycles, there was no statistical difference between the attachment groups (*P*=.750). At 3300, 4400, and 5500 cycles, the OS group retention force was higher than RD group statistically (*P*=.002, .000, .000)

Table 2 Mean retention force in total (N)

Attachment system	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
RD	6.65	.24	6.146	7.146
OS	6.84	.24	6.339	7.339

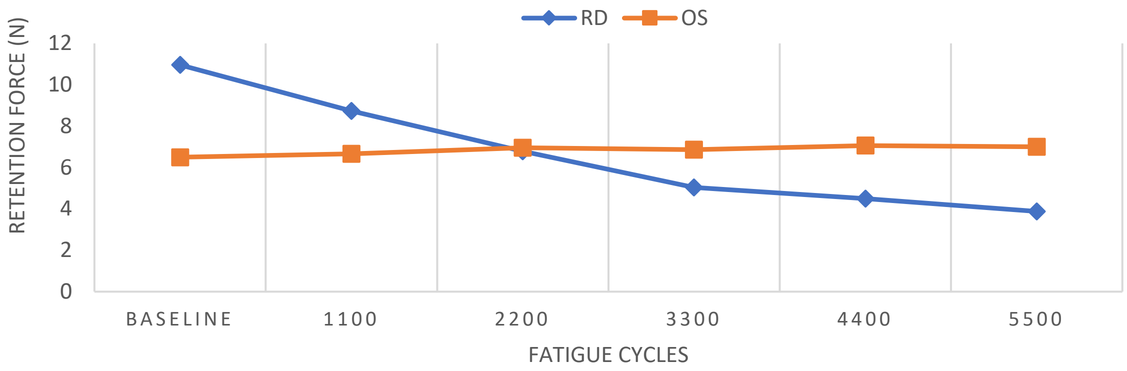
There was no statistical difference between groups.

Table 3 Retention force for each fatigue cycles (N)

Attachment system	Retention force in newton after cycles count (±SD)					
	Baseline	1100	2200	3300	4400	5500
RD	10.96±1.78[a]	8.73±1.23[b]	6.78±1.34[c]	5.04±1.19[cd]	4.49±1.26[de]	3.88±1.44[e]
OS	6.50±0.88[a]	6.66±1.27[a]	6.96±1.16[a]	6.86±1.07[a]	7.06±0.997[a]	6.997±1.02[a]
Comparison between groups (P-value)	.000	.002	.750	.002	.000	.000

The significant difference within the same attachment system was showed as different lowercase letters. (α=0.05)

FIGURE 2: MEAN RETENTION FORCE FOR EACH FATIGUE CYCLES (N)

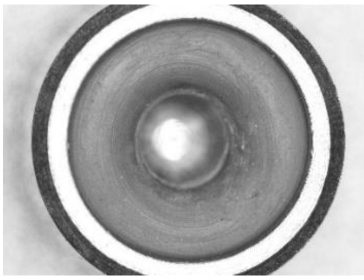


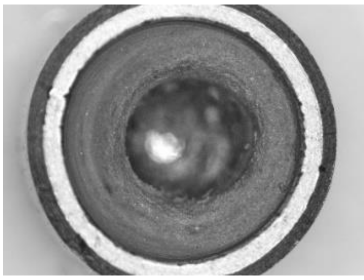
The pairwise comparison within the same attachment system is also shown in Table 3. The retention force of the RD group when comparing the baseline to 1100 and 1100 to 2200 decreased significantly. However, statistical significance was not found when comparing 2200 to 3300, 3300 to 4400, and 4400 to 5500 cycles. In the OS group, the retention force was not statistically different between all fatigue cycles. The changes in retention of the two groups were demonstrated in figure 2.

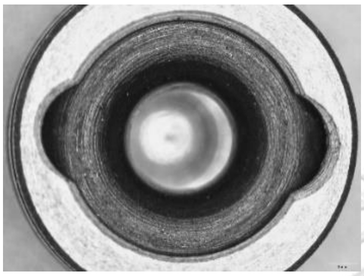
Stereomicroscope images

The stereomicroscope images of the O-ring in Fig.5 express material loss and changes for both groups after 5,500 cycles. The RD group exhibited surface roughness and material loss around the internal surface of the O-rings. In contrast, the OS group showed surface roughness and material loss on the upper surface of the O-rings. The ball abutment images of both groups indicated no wear in the stereomicroscope. (Fig.6)

Figure 7 Stereomicroscope images of O-rings


RD (baseline)


RD (5500)


OS (baseline)

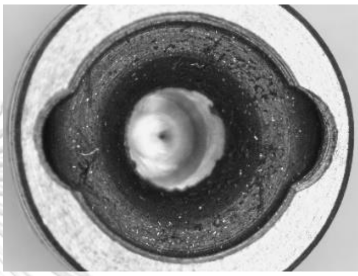

OS (5500)

Figure 8 Stereomicroscope images of abutments


RD (baseline)


RD (5500)


OS (baseline)


OS (5500)

Discussion

The mini-implant overdenture has proven to be a long-term successful treatment option for edentulous patients.(31) RetenDent product developed with Chulalongkorn university is aiming to be a great alternative with global standard, performance, and quality while being more affordable to Thais.

The result from mixed ANOVA shows that the attachment systems had no statistical effect on retention force. This corresponds with the similarity of overall mean retention force after 5500 fatigue cycles, which is 6.65±0.24N for the RD group and 6.84±0.24N for the OS group. The required retention for implant-overdenture had been studied with a variety of attachment types and methods. Pigozzo et al. had considered the minimum recommended retention force for 2-implant overdenture to be 5N-7N.(45) Lehmann had considered a minimum of 5N for overdenture stability from their study.(46) However, the retention from this study was recorded from only a single mini-implant. A study had found that two-implant overdenture gives more than double the retention force of a single implant overdenture.(56) The recorded retention force in this study is comparable to previous studies. Leung and Preiskel measured the retention of 12 commercially available stud-type attachments. Retentive forces varied between 3N to 15N. Most of the attachments (8 of 12) exhibited forces between 6N to 9N. The fatigue test was not performed in their study.(57) Besimo and Guarneri reported initial retention force of six brands of stud attachments were between 4.4N to 9.1N. The fatigue test was concluded to be sufficient for implant-retained overdentures in the long term.(58) Another study from Abou-Ayash et al. found a newly delivered attachment retention force ranged from 3.7±1.1N to 4.0±1.7N is sufficient for overdenture retention (MDI, condent GmbH, Germany). This value fell over time and can be re-establish by O-ring replacement.(34)

Patient satisfaction in overdenture cases greatly depends on the retentive ability of the attachment system, to stabilize the underlying denture.(59) The RD group in this test showed significantly higher retention forces compared to the OS groups at the first two years simulated. The RD group also had significant retention force change during the 0-2200 cycles. The past study showed that ball and O-ring attachment could lose its retention significantly in the first 1,500 cycles, with up to 75% retention lost after

5,500 cycles.(60) In contrast, the OS group had significantly lower initial retention and 1100 cycles and held up better after 3300 cycles. Some attachment systems could express the same retention force stability for ball and O-ring after 5,500 fatigue cycles.(61) This result coincides with the significant interaction of cyclic fatigue and attachment system effect calculated from Mixed-Model Factorial ANOVA. However, despite the RD group changes in retention force, the importance of retention force would not be about the mean retention force after 5 years usage, rather the two to three years retention since the insertion of O-ring. This is because in overdenture cases, regardless of attachment type, recall visits to reevaluate the denture and O-ring replacement are required, along with routine maintenance to achieve long-term success.(62) The O-ring replacement is a relatively easy, quick, and cheap operation. The replacement will also immediately restore the high overdenture retention for the patient. The RD group that performed better at the simulated first two years would be beneficial. The higher overdenture retention in the RD group would result in the aforementioned higher patient satisfaction.

The difference in wear characteristics of the attachment systems studied could be a result of variation in abutment design, O-ring material, and its dimension. The O-ring of the RD group has higher hardness (80±5 Shore A) with a smaller internal diameter, which contributed to the higher initial retention force. Nonetheless, the microscope finding after 5500 fatigue cycles showed no visible wear presented on the RD abutment. There have been reports of significant ball abutments wear in both in-vitro study and clinical situation.(63, 64) This would be a consequential complication for one-piece mini-implants, as the treatment would require a removal surgery and re-implantation procedure. In the RD group, a diamond-like coating (DLC) was implemented on the abutments with the aim to improves the wear resistance properties of the abutment.(50) The RD group's coated ball attachment would allow more rigid attachment such as PEEK material to be coupled in future development, thus provide better retention with a longer lifetime.

An additional finding in this study is regarding the abutment O-ring and housing design. Due to the dimensional differences of Ball abutment and O-ring between OS and RD groups, the OS samples experience O-ring dislodgement several times during fatigue cycling (Fig. 7). The O-ring was re-inserted, and the test continued. The housing of the RD group is larger than the OS group (Fig. 8). This was a design decision to improve housing retention in overdentures. A study showed that complications leading to housing replacements were common (26.9%) and were very costly for their patients.(62)

Figure 9 The O-ring dislodgement
(arrow) was presented during the test only in OS group.

Figure 10 The O-ring housings
(Left: RD group, right: OS group) have design differences.

In the present study, only controlled vertical movements were performed to simulate the insertion and removal of overdentures. This action is the major factor causing retentive force reduction in overdentures. This experiment allows a controlled in-vitro comparison between the two systems. This also gave a possibility of relative comparisons to other studies because of the testing method similarity. Other clinical factors and oral environment would further impact the wear characteristic of the attachment. For example, masticatory functions were not taken into account. However, several studies indicated simulated mastication had no effect, rather insertion-removal cycles cause a reduction in retention forces.(42, 48) Saliva was proven to provide lubrication, lessen attachment wear.(65) The variety of temperature changes and chemicals in diets could also have an effect on the O-ring. Clinically, the attachments may wear differently for these reasons. Additionally, the angulation of implants would affect the retentive ability of the system clinically. Therefore, further study and clinical trials should be considered. Regardless of the overall similarity in the mean retention force of the two systems, the operator and patients should also take the long-term maintenance cost, availability, and technical difficulty into account when choosing an overdenture system.

Conclusion

The mean retention force from 5 years fatigue cycles is 6.65±0.24N for the RetenDent system and 6.84±0.24N MS denture® system. They were not statistically different, and both were higher than the minimum recommended retention force for overdenture. The RetenDent system showed significantly higher retention force at baseline and 1100 cycles than the MS denture®. The higher initial retention force of RetenDent in the first simulated two years of use is more appropriate for overdenture cases. However, the MS denture® system showed better retention stability. There was no wear on the ball abutments of both groups under the stereomicroscope after 5,500 fatigue cycles.

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