EFFECT OF FOUR TYPES OF DENTURE ADHESIVES ON RETENTION OF MILLED DENTURE BASE ACRYLIC RESIN

PAPATSARA VEERAPOL

Graduate School Srinakharinwirot University

2022

ผลของกาวติดฟันเทียมสี่ชนิดต่อการยึดติดบน
เรซินอะคริลิกฐานฟันเทียมชนิดขึ้นรูปด้วยการกลึง

ปภัทสรา วีระพล

ปริญญานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตร
วิทยาศาสตรมหาบัณฑิต สาขาวิชาทันตกรรมคลินิก
คณะทันตแพทยศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ
ปีการศึกษา 2565

EFFECT OF FOUR TYPES OF DENTURE ADHESIVES ON RETENTION OF MILLED DENTURE BASE ACRYLIC RESIN

PAPATSARA VEERAPOL

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of MASTER OF SCIENCE

(Clinical Dentistry)

Faculty of Dentistry, Srinakharinwirot University

2022

THE THESIS TITLED

EFFECT OF FOUR TYPES OF DENTURE ADHESIVES ON RETENTION OF MILLED DENTURE BASE ACRYLIC RESIN

BY

PAPATSARA VEERAPOL

HAS BEEN APPROVED BY THE GRADUATE SCHOOL IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE
IN CLINICAL DENTISTRY AT SRINAKHARINWIROT UNIVERSITY

(Assoc. Prof. Dr. Chatchai Ekpanyaskul, MD.)

Dean of Graduate School

ORAL DEFENSE COMMITTEE

.... Major-advisor

(Asst. Prof. Dr.Mali Palanuwech)

.... Chair

(Assoc. Prof. Dr.Niyom Thamronganskul)

.... Committee

(Dr.Nuttaphon Kittikundecha)

Title	EFFECT OF FOUR TYPES OF DENTURE ADHESIVES ON RETENTION OF MILLED DENTURE BASE ACRYLIC RESIN
Author	PAPATSARA VEERAPOL
Degree	MASTER OF SCIENCE
Academic Year	2022
Thesis Advisor	Assistant Professor Dr. Mali Palanuwech

As the population ages and tooth loss becomes more common, complete dentures become more essential. Therefore, the retention of removable dentures is a primary concern for many patients. As a result, denture wearers frequently use denture adhesives to enhance the functioning of full dentures. We examine the retention strength of four commercial brands (eight formulation) cream-type denture adhesives on milled denture base acrylic resin. Eight milled acrylic resin molds were created for this purpose in accordance with ISO 10873:2021, and ten times of the retention strength test of eight denture adhesives - Fittydent (Ft), Fixodent Original (FxO), Fixodent Microseal for Partials (FxM), Fixodent PLUS Best Foodseal Technology (FxFS), Fixodent Plus Best Hold (FxBH), Fixodent Ultra Max Hold (FxMH), Olivafix (O) and Polident (P). The analysis of variance (ANOVA) and LSD multiple comparison post hoc test were used to statistically evaluate the findings of the study at a 95% level of significance. There were statistically significant ($p < 0.05$) differences in mean retention strength between the groups of denture adhesives. The Ft, O and P groups had statistically significant ($p < 0.05$) differences to every other group. There was no significant difference between the Fixodent groups. The Ft and FxFS groups, respectively, had the lowest and highest retention strengths. There were no differences between any of the Fixodent groups and these adhesives had a greater retention strength than Ft, O, and P. The authors advised using P because it delivered maximum efficiency assessed in kPa/THB or FxO because it offered the lowest cost per gram of adhesive in the highest retention category.

Keyword : CAD/CAM, Retention strength, Denture adhesives, Milled denture base

ACKNOWLEDGEMENTS

Thank you to my supervisor, Asst. Prof. Dr. Mali Palanuwech, for your patience, guidance, and support. I have benefited greatly from your wealth of knowledge and meticulous editing. I am extremely grateful that you took me on as a student and continued to have faith in me over the years.

Thank you to my committee members, Assoc. Prof. Dr. Niyom Thamronganaskul and Dr. Nuttaphon Kittikundecha. Your encouraging words and thoughtful, detailed feedback have been very important to me.

Thank you for the great opportunities of the "70th year 70 scholarships SWU return to society" scholarship from Srinakarinwirot University and the research-support scholarship from the Faculty of Dentistry of Srinakarinwirot University.

Thank you to Wipavee Jenjittikul and Kanokporn Sukyanan, laboratory staff of the Faculty of Dentistry of Srinakarinwirot University, for all of the kind words and assistance you have provided.

Thank you to my parents, Prapas Weerapol and Kanokrat Weerapol, for your endless support. You have always stood behind me, and this was no exception. Thank you for all of your love and for always reminding me of the end goal. Thank you to my sister, Panatcha Weerapol, for guiding me in Master degree studies.

PAPATSARA VEERAPOL

TABLE OF CONTENTS

Page

ABSTRACT ..... D

ACKNOWLEDGEMENTS ..... E

TABLE OF CONTENTS ..... F

List of Tables ..... H

List of figures ..... J

CHAPTER 1 INTRODUCTION 1

1.1 Background 1

1.2 Research question 4

1.3 Objectives of the study 4

1.4 Scope of the study 4

1.4.1 Independent variables 4

1.4.2 Dependent variables 4

1.4.3 Controlled variables 4

1.5 Research hypothesis 4

1.6 Definitions of terms 5

1.6.1 Denture adhesive 5

1.6.1.1 Glue type denture adhesive 5

1.6.1.2 Liner type denture adhesive 5

1.6.2 Retention of dentures 5

1.6.3 Retention force 5

1.7 Significances of the study 5

CHAPTER 2 LITERATURE REVIEW 6
CHAPTER 3 RESEARCH METHODOLOGY 18
3.1 Materials preparation 18
3.2 Study design and method 22
3.3 Sample size 27
3.4 Data collection 27
3.5 Statistical analysis 29
CHAPTER 4 RESULT 30
CHAPTER 5 SUMMARY DISCUSSION AND SUGGESTION 35
Conclusions 35
Discussion 35
Suggestion 37
REFERENCES 37
APPENDIX 46
VITA 52

List of Tables

Page

Table 1 The common components of denture adhesives are listed, along with their purposes[1]. 8

Table 2 Group in this study, the manufactures, denture adhesive ingredients of the eight groups of denture adhesives and cost per gram (THB) 16

Table 3 Group in this study, the manufactures, denture adhesive ingredients of the eight groups of denture adhesives and cost per gram (THB) (Continued) 17

Table 4 Data table for the adhesion test of denture adhesives 28

Table 5 Mean surface roughness (Ra) in μm of all sample holders and cylinder-shape milled acrylic resin. 32

Table 6 Summary statistics of one way ANOVA of surface roughness (Ra) of sample holders and cylinder-shape milled acrylic resins 32

Table 7 Summary statistics of one way ANOVA of retention strength of denture adhesives 33

Table 8 Mean retention strengths and 95% confidence intervals of means with statistical summaries. 33

Table 9 Average Retention strength (kPa) of denture adhesives, cost of denture adhesives per gram (THB) and retention strength per 1 THB (price update on April 2022). 34

Table 10 Raw data of surface roughness (Ra) in μm of all sample holders milled acrylic resin 47

Table 11 Raw data of surface roughness (Ra) in μm of all cylinder-shape milled acrylic resin 47

Table 12 Correlation between mean of surface roughness (Ra) of cylinder-shape milled acrylic resin and mean of retention strength of denture adhesives (Pearson's correlation) 48

Table 13 Raw data of Retention strength (kPa) of denture adhesives 49

Table 14 Results of Least Significance Difference (LSD) post hoc comparisons test of denture adhesives retention strength (kPa) 50

Table 15 Results of Least Significance Difference (LSD) post hoc comparisons test of denture adhesives retention strength (kPa) (Continued) 51

Table 16 Results of Least Significance Difference (LSD) post hoc comparisons test of denture adhesives retention strength (kPa) (Continued) 52

List of figures

Page

Figure 1 – The sample holder made of 50.0 x 50.0 mm milled acrylic resin with a hole diameter of 22.0 ± 1.0 mm and a depth of 0.5 ± 0.1 mm.. 19

Figure 2 – Cylinder-shape milled acrylic resin, which was attached to pressure sensitive shaft of universal testing machine to detect compressive and tensile force, has a diameter of 20.0 ± 0.5 mm.. 19

Figure 3 – Universal testing machine (Shimadzu, Japan) 20

Figure 4 – Adhesion test instrument (Universal testing machine) layout 20

Figure 5 – Layout of adhesion test instrument 21

Figure 6 – Non-contact surface roughness tester (Alicona, UK)...................................... 21

Figure 7 – Surface roughness (Ra) testing of cylinder-shape milled acrylic resin........... 23

Figure 8 – Surface roughness (Ra) testing of sample holder. 23

Figure 9 – Made a hold in the cylinder-shape PMMA, preparing cylinder-shape PMMA for pressure sensitive shaft holding screw attachment. 24

Figure 10 – Attached cylinder-shape PMMA with pressure sensitive shaft holding screw with pink self-cure acrylic resin. 24

Figure 11 – Place sample holder in the center of the pressure sensitive shaft................ 25

Figure 12 – Two of C-clamps were used to fix sample holder in the correct place......... 25

Figure 13 – Move the pressure sensitive shaft down at a cross head speed of 5 mm/min 26

Figure 14 – The sample/sample holder assembly was placed on the adhesion test instrument's sample stand, with the load applied to the sample's center up to 10.0 ± 0.2 N at a cross-head speed of 5 mm/min.. 26

Figure 15 – The pressure sensitive shaft was held with the load in place for 30 seconds, and then pulled in the opposite direction at a cross-head speed of 5 mm/min. The maximum tensile force was used for retention force testing. 27

Figure 16 – The mean retention strength (kPa) with the error bar displayed the standard deviation of denture adhesives. The results of Least Significance Difference (LSD) post hoc comparisons were displayed as identical symbols, and the same identical symbols were not substantially different (P > 0.05). 34

CHAPTER 1
INTRODUCTION

1.1 Background

Dentists and the dentistry industry have tried for a long time to improve denture adherence by inventing a variety of "glues" with widely varying compositions and efficacy[1, 2]. Denture adhesives have been around since the late eighteenth century, although the American Dental Association first acknowledged them and characterized them in the literature in 1935[3]. In a definition of prosthodontics terms, it has been described as a material used to make a denture attach to the oral mucosa by chemical and physical interactions[4]. The International Organization for Standardization describes such adhesives as a dental agent is applied onto the intaglio surface (fitting surface) of a removable denture to temporarily enhance its retention to soft supporting tissue[5].

Wearers of dentures have utilized denture adhesives to improve stability [6-8], retention [6-8], masticatory efficiency, oral health-related quality of life (QOL) and general health[9]. According to ISO 10873:2021[5], the denture adhesives are categorized into two type. Glue types are water-soluble polymers, further classified into three classes based on form: powder, cream or sheet/tape. The other denture adhesive type consists of liner type adhesives which are non-aqueous forms. Accordingly, commercially-available denture adhesives are available in a variety of forms[6]. While the particular ingredients in these denture adhesives may differ, they all include the same general elements that perform the same purpose[1]. Due to their simplicity of application, dentists prefer cream-type denture adhesives over other types[10, 11]. Chowdhry, et al. and Kalra, et al., who came to the same conclusion that cream types were shown to be more effective and retentive, validate this.[12, 13].

Unsurprisingly, a variety of cream type denture adhesives are now marketed and there have been many studies on the retention efficacy between types of denture adhesive. For example, Sato, et al. evaluated denture retention and simplicity of removal from the oral mucosa using an unique gel-type denture adhesive. They found that gels are easier to remove from the oral mucosa than creams, despite the gel having a higher adhesion force[14]. In 2011, Manes, et al. studied the retention of three commercial cream type adhesive (Fittydent, Benfix and Supercorega) in removable complete mandibular dentures. The findings revealed that cream-type denture adhesives greatly improve denture retention, with Fittydent (1095.17 grams) topping the list, followed by Benfix (846.56 grams) and Supercorega (560.11 grams)[2]. In 2017, Yegin, et al. conducted an in vitro study about the retention force of denture adhesives for complete dentures, focusing on three commercial brands. Fittydent had the highest retention force (7.37 N) followed by Protefix (5.11 N), while the lowest retention was achieved by Corega (4.43 N). The adhesive strength of Fittydent and Protefix was rather strong, which might be related to their carboxymethylcellulose (CMC) component. CMC hydrates in the presence of water, resulting in ionic adhesion to dentures and mucosa[15]. Fittydent was shown to be the most effective, which is consistent with many other studies[2, 11, 13, 16, 17]. This can be explained by the component of polyvinylacetate, which has a higher viscosity and is a sticky and soluble substance[16]. According to Albaki, Fittydent's greatest adhesive strength value is attributed to its insoluble characteristics that protect the material from saliva or liquids[18]. Koppang, et al. similarly found that Fittydent exhibited higher retention force than Super Poli-Grip adhesives followed by Fixodent[19].

Retention was one of the most important requirements for both removable partial dentures and complete dentures. In order to investigate for retention forces, maximum tensile load (peak load dislodgement) measurements has been performed[20]. Retention of the denture could also be referred to as peak load-to-dislodgement, maximum tensile load[21], adhesion force[5], or retention force[20]. To measure the strength of the denture adhesives' adhesion, a laboratory retention test was set up. This laboratory design was fabricated to the standard testing with ISO 10873 that evaluates adhesion strength of denture adhesives. The International Organization for Standardization recommends the procedure to measure dental adhesive strength in ISO 10873:2021 and that denture adhesive strength should not be less than 5 kPa or 5000 N/m2 [5].

Shay reported the mechanism of action of adhesives in 1991, stating that in the presence of water, the materials expand 50 to 150 percent in volume, filling the gaps between the tissue and the prosthesis. Saliva increases the viscosity of the adhesive, increasing the effort needed to separate the prosthesis from the tissue surface and changing the characteristics of current adhesives, which are influenced by a combination of chemical and physical elements(22).

Polymerization shrinkage is no longer a problem since computer-aided design and computer-aided manufacturing (CAD-CAM) denture base fabrication is a subtractive process(23).

Because total tooth loss has grown among the elderly, the number of persons who wear full dentures will definitely increase as the senior population grows(24). Retention of removable dentures is a primary concern for a patient's first impression. There were many studies that compared the retention forces between different denture adhesives available in their respective countries, but there was no similar study in Thailand. Furthermore, milled denture base acrylic resin (the newest denture processing by CAD/CAM technology) showed higher retention than conventional dentures(25) but there is no study on comparing the retention strength of denture adhesives in milled denture. Moreover, although implant overdentures showed higher retention force than conventional dentures(26-30) and denture adhesives(13, 15-17, 20, 31), denture adhesive is still worthy of consideration due to low cost, non-surgical procedure, and higher retention force than conventional dentures(1, 11, 15, 32, 33). Therefore, the results of this study will be mainly used to update the literature on the retention strength of denture adhesives available in Thailand, which can be used as a clinical guideline to improve the quality of life of Thai people. In addition, it can be applied for usage in a wider context as well.

The objective of this in vitro study was to compare the retention strength, in milled denture base acrylic resin, of four commercial brands (eight formulations) offering cream type denture adhesives that can be bought in Thailand.

1.2 Research question

1. When used with milled denture base acrylic resin, do cream type denture adhesives have similar retention strengths?
2. Which cream-type denture adhesive, when used with milled denture base acrylic resin, has the maximum retention strength?

1.3 Objectives of the study

The objective of this study was to compare the retention strengths of four commercially available denture adhesives (eight formulations) with milled denture base acrylic resin.

1.4 Scope of the study

This study analyzes the retention strengths of four commercial brands (eight formulations) of cream-type denture adhesives that can be brought in Thailand with milled denture base acrylic resin through a laboratory experiment using an adhesion test[5].

1.4.1 Independent variables

Cream type denture adhesives are available from four commercial brands (eight formulations): Polident, Fixodent (five formulations), Olivafix, and Fittydent.

1.4.2 Dependent variables

Retention strengths (kPa) were measured using a universal testing machine and related software after tensile testing.

1.4.3 Controlled variables

The milled PMMA resin plates were passed with surface roughness testing. As part of a standardized methodology, the machine and software were calibrated.

1.5 Research hypothesis

Null hypothesis (H_0) = When used with milled denture base acrylic resin, denture adhesives are all equal in terms of adhesive strength.

Alternative hypothesis (H_1) = When used with milled denture base acrylic resin, denture adhesives differ in terms of adhesive strength.

1.6 Definitions of terms

1.6.1 Denture adhesive

A dental substance is applied to the intaglio surface (fitting surface) of a removable denture to increase its retention to soft supporting tissues for a limited time. Denture adhesives are divided into the following categories[5]:

1.6.1.1 Glue type denture adhesive

Water-soluble polymer is used as an adhesive ingredient in denture adhesive in powder, cream, sheet, or tape form.

Class 1: powder form;

Class 2: cream form;

Class 3: sheet or tape form.

1.6.1.2 Liner type denture adhesive

Denture adhesive in non-aqueous form

1.6.2 Retention of dentures

A property of a denture that secures it to the tissue basis and/or abutment teeth; resistance to movement of a denture away from its tissue basis, especially in the vertical direction[4].

1.6.3 Retention force

According to ISO 10873:2021, an adhesive strength test was conducted to determine the retention force. The force per unit area is used to calculate adhesive strength. When tested in accordance with IOS 10873, the adhesion strength must not be less than 5 kPa[5].

1.7 Significances of the study

Patient first impressions are affected by the retention of removable dentures. There were many studies that compared the retention strength between different denture adhesives available in their countries, except in Thailand. Therefore, the result of this study will be used to update the retention strength of denture adhesives available in Thailand, which can be used as a clinical guideline.

CHAPTER 2
LITERATURE REVIEW

Inadequate denture retention is a significant factor of patient satisfaction with using complete dentures[34]. Complete denture retention and stability in the oral cavity are influenced by a number of variables and intricate interactions, including accurate peripheral extensions of the denture base (determined by physiological movements), atmospheric pressure and the presence of a thin film of saliva (with acceptable viscosity) between the prosthesis and the tissues underneath the denture base. Denture retention may be disrupted if any of these factors are disturbed[35].

Following exodontia and denture placement, complete denture wearers who have RRR (residual ridge resorption) suffer from a chronic disease. RRR begins within 3–12 months of tooth extraction and lasts for the patient's entire life[36-38]. Denture retention and stability are compromised by alveolar ridge resorption, resulting in a loose and unusable denture for the patient[39]. Complete denture wearers require particular attention due to their compromised oral morphology, reduced adaptive capacity, and underlying health issues or medications that affect denture stability, all of which make it more difficult for them to effectively wear their prosthesis[40]. These patients may also be affected by aging, medicines, lower biting force, diminished neuromuscular control, changes in hard and soft tissues over time, and changes in saliva quality or quantity[41]. New techniques have been created to enhance the retention and fit of aging prosthetics when these physiological and biological changes make denture function more difficult. Among the procedures employed are denture adhesives, endosseous dental implants, and denture relining or rebasing[42].

Denture adhesives have been around since the late eighteenth century, although the American Dental Association first acknowledged them in the literature and characterized them in 1935[3]. A glossary of prosthodontics terminology describes it as a material used to make a denture adhere to the oral mucosa through physical and chemical interactions[4]. A dental agent applied on the intaglio surface (fitting surface) of a removable denture to temporarily enhance its retention to soft supporting tissues, as defined by the International Organization for Standardization[5].

Shay reported the mechanism of action of adhesives in 1991, stating that in the presence of water, the materials expand 50 to 150 percent in volume, filling the gaps between the tissue and the prosthesis. Saliva increases the viscosity of the adhesive, increasing the strength needed to separate the prosthesis from the tissue surface and changing the properties of current adhesives, which are influenced by a combination of physical and chemical factors[22].

Denture adhesives can be found in many different forms, including creams, strips, powders, and cushions. The cream-type denture adhesives are the most popular among them as they are simple to use[10, 11]. This is supported by Chowdhry et al. and Kalra et al., who came to the conclusion that cream type was more efficient and retentive[12, 13].

Denture adhesives available in a variety of forms, such as powders, liquids, creams, and pads or tapes. Even though the particular ingredients in commercially available denture adhesives may vary, they all contain the same fundamental components that serve the same function[1].

Table 1 The common components of denture adhesives are listed, along with their purposes[1].

Material	Purpose
Methyl vinyl ether-maleic anhydride copolymer	High molecular weight copolymers with adhesive and cohesive properties
Karaya gum	Thickener
Tragacanth	Water-soluble mixture of polysaccharides that absorbs water to become a gel
Acacia	Preservative
Pectin	Gelling agent
Gelatin	Gelling agent
Carboxymethylcellulose	Viscosity modifier/thickener
Mineral oil	Suspending and levigating agent
Antimicrobial agents (for example sodium borate, sodium tetraborate, ethanol, hexachlorophene)	Antimicrobial
Flavoring agents (for example wintergreen oil, peppermint oil)	Improves taste
Non-toxic additives	Wetting agents and plasticizers

The ideal denture adhesive should be designed in such a way that it is not hazardous to the patient's systemic or oral health (regardless of whether it is used for a short or long period of time). It enhances the functionality, stability, and retention of dentures. The patient or primary caregiver can easily apply and remove the device. It has an acceptable flavor, consistency, and scent (or none at all). The intaglio surface of the denture base is not changed or deteriorated. It maintains adhesive qualities for 8–12 hours, does not change the occlusion of the dentures, and is free of bacterial and fungal growth[1].

Several denture glue producers have endorsed and suggested particular techniques and guidelines for using denture adhesive on the denture base. The intaglio surface of the denture should be cleaned and dried. Then, in little increments, apply denture adhesive, each one about the size of a pea. Apply three pea-sized quantities of denture cream to the mandibular denture's edentulous ridge. Apply three to four increments of denture cream to the palatal of the maxillary denture's midline, posterior border and anterior ridge[1].

Denture adhesive usage grew more popular. In the US, 15% of denture wearers used adhesives in the 1980s, according to Shay[22] whereas 30% of denture wearers used or had used adhesives in 1990, according to Wilson et al[43]. Denture adhesive use among regular denture users is estimated by the industry to range from 15 to 33%[22]. The overall use of denture adhesives is rising along with the aging of the global population and the rise of edentulous people.

Retention was one of the most important requirements of both removable partial denture and complete denture. In order to investigate for retention forces, maximum tensile loads (peak load dislodgement) had been developed in laboratories[20]. Other phrases that could be used to describe the retention of the denture include peak load-to-dislodgement and maximal tensile load[21], adhesion force[5], or retention force[20]. To measure the adhesive strength of the denture, a retention was set up in the lab. This laboratory design was fabricated to the standard testing with ISO 10873 that evaluate adhesion force of denture adhesive. The International Organization for Standardization recommend the procedure to measure dental adhesive strength in ISO 10873:2021 and they recommended that denture adhesive strength should not less than 5 kPa or 5000 N/m^2[5].

The most crucial instrument for determining the retention force of denture adhesive was a universal testing machine and associated software[32]. In several investigations of the denture adhesive, the maximum vertical tensile strength was evaluated using the universal testing machine, which was considered as the gold standard[5, 19, 32, 44]. This study was performed using a universal testing machine in order to assess denture adhesive retention.

Burns et al. in 1995 proved how much retention was enough in two implant-supported overdentures in vivo to determine how much overdenture retention was sufficient to satisfy patients. Seventeen patients who had worn the conventional complete denture successfully switched to overdentures with a ball or magnet attachment. The questionnaire and the force gauge were used to monitor and record the subjective and objective retentions and stabilities. As a result, the recommended retention for conventional complete dentures was (190.55 ± 116.30 g), magnet attachments (479.12 ± 129.08 g) and overdentures with ball attachments (925.10 ± 134.18 g). The best score was 3, as well as the scores for each group's objective retentions were 2.98 ± 0.08 N for ball attachments, 2.49 ± 0.49 N for magnet attachments, and 1.33 ± 0.65 N for conventional complete denture. Therefore, ball attachments (925.10 ± 134.18 g) provided the highest level of patient satisfaction for overdenture retention[31]. In 1988, Setz et al.[45] also ran mechanical fatigue tests and assessed retention of numerous attachment systems. They compared their study and evaluations of the literature, and they made the assumption that a retention of about 20 N was adequate for an overdenture[46]. Despite the fact that satisfactory retention studies were rare, we could infer that 10 to 20 N exhibited acceptable retention for overdenture patients[26, 45]. According to Gupta et al., patients with resorbed ridges had an average retention of conventional mandibular complete denture bases of 56 g in the group with sublingual extension and 40 g in the group without sublingual extension[47].

There were many studies compare between denture adhesives and almost of them chose the group of without adhesive to be the control group. The effectiveness of three different denture adhesives (Super Corega, Fittydent, and Fixodent) in enhancing phonation in complete denture wearers was examined by Aziz et al[48]. They discovered a significant improvement in patients' articulation after application of the denture adhesives, both perceptually and acoustically, with the Fixodent denture adhesive providing the highest values.

Jian-Min HAN et al.[10] revealed that cream-type denture adhesives (Liodent Cream, Corect Cream, Poligrip S) had lower initial viscosity and stronger adhesive strength than powder-type adhesives (Poligrip Powder, New Faston, Zanfton) at 37°C for 0, 1, 10, 30, 60, 180, and 360 minutes. Poligrip S 103.38 ± 7.42 kPa, Corect Cream 132.50 ± 10.28 kPa, and Liodent Cream 109.84 ± 12.41 kPa were the adhesive strengths of cream type denture adhesives after 1 minute of immersion. The adhesive strengths of powder type denture adhesives were Poligrip Powder 79.82 ± 9.85 kPa, New Faston 65.43 ± 9.07 kPa and Zanfton 83.14 ± 6.81 kPa after one minute of immersion. The adhesive strengths of cream-type denture adhesives were Poligrip S 111.38 ± 3.86 kPa, Corect Cream 117.26 ± 9.20 kPa and Liodent Cream 126.48 ± 6.46 kPa after a 10-minute immersion time. The adhesive strengths of powder type denture adhesives were Poligrip Powder 90.75 ± 8.12 kPa, New Faston 83.26 ± 9.07 kPa and Zanfton 86.50 ± 7.37 kPa after a 10-minute immersion period. The ISO 10873-recommended techniques were used to evaluate the adhesive strength.

In an in vivo study, Yegin et al.[15] linked the influence of various denture adhesives on total denture retention. These researchers discovered that denture adhesive enhanced retention, that Fittydent was the most efficient denture adhesive, and that a digital dynamometer could be utilized to explore the in vivo study of denture adhesive retention in order to getprecise and accurate measurements. They reported that Fittydent (7.37 ± 1.81 N) had a greater dislodgment force than Protefix (5.11 ± 2.16 N), Corega (4.43 ± 1.86 N) adhesive creams, and the control group (4.29 ± 2.31 N). The findings were consistent with those of Ibraheem et al.,[32] who found that Fittydent (1024.2 g) adhesive paste was more successful than Protefix (825.9 g) and Corega (810.5 g) adhesive creams in enhancing retention of mandibular complete dentures. As a result, denture adhesives raise patient satisfaction.

In order to determine how the forces to induce denture displacement changed depending on where the force was applied along the saddle length, Quiney et al.[33] created an in vitro model based on an anatomically accurate cast of a clinical case and experimented with various amounts of adhesive (0.2 - 1 g). They also tested the tensile force using a universal testing machine. They found that there were significant differences in the effectiveness among several commercially available adhesive formulations and that the adhesive quantity had a significant impact on denture retention. The appropriate mass of Polygrip® denture glue for best retention is between 0.4 and 0.7 grams (0.6 g = 6.66 ± 0.68 N). When compared to the appropriate adhesive mass, too little (0.2 g = 4.41 ± 0.28 N) and too much adhesive might result in lesser retention forces. The maximum retention was shown in Fixodent neutral taste (about 11.0 N), followed by Polygrip® products (roughly 7.0 - 8.0 N), and lastly Boots Smile (approximately 5.0 N). Despite being advertised for different applications, there was no difference in retention between the two Polygrip® products due to similar compositions. When compared to Boots Smile, both Polygrip solutions showed stronger retention strengths.

In 2018, Ohno et al.[44] created a new denture adhesive for those with dry mouths and investigated its properties, such as ease of removal, retention force, and resistance to squeezing (through a syringe or tube). The retention force was assessed utilizing the ISO 10873:2010 test. They found that the newly created denture adhesive has sufficient retention force in both a severe dry mouth (water-free environment) and a moderate dry mouth (slightly wet environment), indicating that their new denture adhesive is appropriate for usage in dry mouth patients.

Numerous studies assessing the quality of life of patients revealed that implant overdentures were preferable to complete dentures[27, 28]. These findings supported the McGill Consensus of 2002, which indicated that two-implant mandibular overdentures rather than traditional full dentures be the first-line treatment option for edentulous mandibles[29]. The York Consensus Statement in 2009 also supported the use of two-implant mandibular overdentures as routine therapy for edentulous patients, reinforcing the same viewpoint[30]. It has been proven that dental implants have contributed to improving the stability and retention of dentures. Compared to conventional full dentures, an implant-supported overdenture enables more efficient chewing and reduced pain and suffering[27, 28].

In implant-supported overdentures, the attachment of the implants was important. A splinted group and an unsplinted group of attachments were identified. The unsplinted group (low-profile attachment) utilized a solitary stud (matrix and patrix) such as magnets, balls, and caps, as opposed to the splinted group (high-profile attachment), which required a rigid connecting bar and a retentive clip. More stability and retention were provided by the splinted group than the unsplinted group. The attachments were separated into two parts: implant and denture site. The housing and nylon insert that made up the denture site were crucial components for maintaining the overdenture. The attachment head and screw made up the implant site. In that system, the attachment head was often unique. Despite having various shapes and designs, the heads in each system served the same purpose as a retentive head[49-51].

The retention of implant-supported overdentures was widely discussed. High-profile attachments (bar and clip attachments) and low-profile attachments (ball attachments, cap attachments, and magnetic attachments), including Locator attachment[31, 46, 52-60] and Locator R-Tx attachment[20], were recommended for retention in several past investigations of the attachments.

Studies that examined bar and clip retention for a significant attachment. The quantity of clips can improve with overdenture retention. Greater retention was discovered for the Hader bar and clip with two clips (28.32 N) compared with just one clip (10.68 N)[61]. For a low-profile attachment, some studies evaluated retention of ERA attachments, Locator attachments, Equator attachments and Locator R-Tx attachment. Four different color-coded nylon inserts (white, orange, blue, and orange) were used in ERA attachments, an original type cap attachment, to evaluate retention. They calculated initial retention and retention after 5,500 cycles. Based on a daily average of five insertions and deletions, 5,500 cycles represented three years. All of the nylon inserts that were color-coded after 500 cycles quickly lost their retention (0.62 - 1.18 kg). After 1,500 cycles, retention was consistently lost by all of them. The outcome of wear was expected. There was no significantly different retention (0.25 – 0.35 kg) of all color-coded nylon inserts at the end of fatigue test[62]. The color-coded manufacturer's advice was used to explain three significantly different retentions for Locator attachments with three different colored nylon inserts (blue, pink, and white) in the next generation of cap attachment. However, the retention values of blue (3.83 N), pink (9.4 N), and white (12.39 N) were less than those recommended by the manufacturer of blue (6.66 N), pink (10.15 N), and white (22.2 N) respectively[63]. Comparing locator attachments to ERA attachments, all nylon inserts had their retention assessed. ERA attachment (12.87 ± 2.35 N) had a lower initial retention than Locator attachment (16.10 ± 6.17 N). Their initial retentions were unrelated to the manufacturer guidelines[55-57]. Equator and Locator, two innovative cap attachments, have been compared by certain authors. Equator attachments initially retained (16.38 N) almost the same amount as Locator attachments (17.02 N). Equators (69.74%) had a much greater loss of initial retention during the fatigue test than Locators (50.24%). After use, each system's geometry and design was impacted, especially when Equators' width and height were less than Locators®[31]. From baseline to 5,400 cycles, indicating a 3-year functional life, of mechanical fatigue test, by Lertsuriyakarn et al.[20] The retention force of the Locator R-Tx® changed from 19.24 ± 1.12 N to 10.70 ± 1.75 N and the Locator® changed from 19.95 ± 0.78 N to 11.65 ± 0.94 N. According to this investigation, the initial and terminal retention of the Locator R-Tx® and the Locator® after a fatigue test of 5,400 cycles did not differ significantly from one another. This study provided evidence that the Locator R-Tx®, a replacement innovation for the Locator®, might offer retention comparable to the Locator® due to its enhanced geometry and design.

Despite the implant overdentures has higher retention force than denture adhesive, but because it is lower cost, no surgical needed and has higher retention force than conventional denture. These are the reasons and significant of this study for Thai people.

Table 2 Group in this study, the manufactures, denture adhesive ingredients of the eight groups of denture adhesives and cost per gram (THB)

Group	Adhesives	Manufacture	Ingredients	Cost per gram (THB)
Ft	Fittydent	Fittydent International GMBL, Pinkafeld, Austria	Sodium Carboxymethylcellulose, Polyvinylacetate, Alcohol, Paraffinum,Triacetin, Liquidum, Silica	7.00
FxO	Fixodent Original	Procter & Gamble Manufacturing Co., Ohio, USA	Paraffinum Liquidum, Calcium/Zinc PVM/MA Copolymer (33%), Cellulose Gum (20%), Silica, Petrolatum, Menthyl Lactate, Aroma, Menthol, Limonene, CI 45410	8.30
FxM	Fixodent Microseal for Partials	Procter & Gamble Manufacturing Co., Ohio, USA	Paraffinum Liquidum, Calcium/Zinc PVM/MA Copolymer (35%), Cellulose Gum (20%), Petrolatum, Silica	11.00
FxFS	Fixodent PLUS Best Foodseal Technology	Procter & Gamble Manufacturing Co., Ohio, USA	Paraffinum Liquidum, Calcium/Zinc PVM/MA Copolymer (33%), Cellulose Gum (20%), Petrolatum, Silica, CI 45410, CI 15985	10.13
FxBH	Fixodent Plus Best Hold	Procter & Gamble Manufacturing Co., Ohio, USA	Paraffinum Liquidum, Calcium/Zinc PVM/MA Copolymer (33%), Cellulose Gum (20%), Petrolatum, Silica, CI 15985, CI 45410	10.75

Table 3 Group in this study, the manufactures, denture adhesive ingredients of the eight groups of denture adhesives and cost per gram (THB) (Continued)

Group	Adhesives	Manufacture	Ingredients	Cost per gram (THB)
FxMH	Fixodent Ultra Max Hold	Procter & Gamble Manufacturing Co., Ohio, USA	Calcium/Zinc, Mineral Oil, PVM/MA, Cellulose Gum, Petrolatum, Silica, Red 27 Lake	11.54
P	Polident	GlaxoSmithKline, Philadelphia, USA	Carboxymethylcellulose, Poly (Methylvinylether/Maleic Acid) Sodium-Calcium Mixed Partial Salt, Petrolatum, Mineral Oil, Spray Dried Peppermint, Spray Dried Spearmint, Propyl Hydrobenzoate, Erythrosine CI 45430.	4.75
O	Olivafix	Bonyf AG, Vaduz, Liechtenstein	Calcium/Sodium PVM/MA Copolymer, Cellulose Gum, Citrus Limon Peel Oil, Olea Europaea (Olive Fruit) Oil, Hydrogenated Soybean Oil, Trihydroxystearin, Menthol, Silica, Lecithin, Menthyl Lactate	4.98

CHAPTER 3
RESEARCH METHODOLOGY

There are 5 steps for this study.

Materials preparation

Study design and method

Sample size

Data collection

Statistical analysis

3.1 Materials preparation

1. Milled poly (methyl methacrylate) (PMMA) plate (Smile Cam Pressing Dental s.r.l., Rep. di San Marino)

    1. Sample holder, 50.0 x 50.0 mm milled poly (methyl methacrylate) (PMMA) plate with a hole diameter of 22.0 ± 1.0mm and a depth of 0.5 ± 0.1mm. See Figure 1.
    2. Cylinder-shape milled acrylic resin, round base milled PMMA with a diameter of 20.0 ± 0.5 mm. See Figure 2.

2. Four commercial brands (eight formulations) of cream-type denture adhesives See table 1-3.

    1. Fittydent
    2. Fixodent Original
    3. Fixodent Microseal for Partials
    4. Fixodent PLUS Best Foodseal Technology
    5. Fixodent Plus Best Hold
    6. Fixodent Ultra Max Hold
    7. Polident
    8. Olivafix

3. Universal testing machine (Shimadzu, Japan) See Figure 3-5

4. Non-contact surface roughness tester (Alicona, UK) See Figure 6

5. Water bath
6. Distilled water
7. Spatula
8. Pressure sensitive shaft holding screws
9. C-clamps
10. Self-cure acrylic resin (Pink UNIFASTTM Trad, GC)

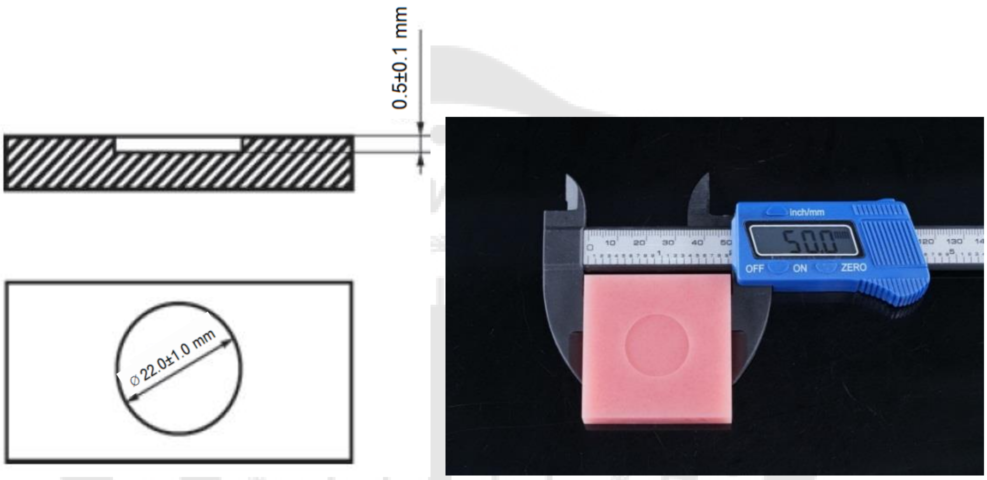
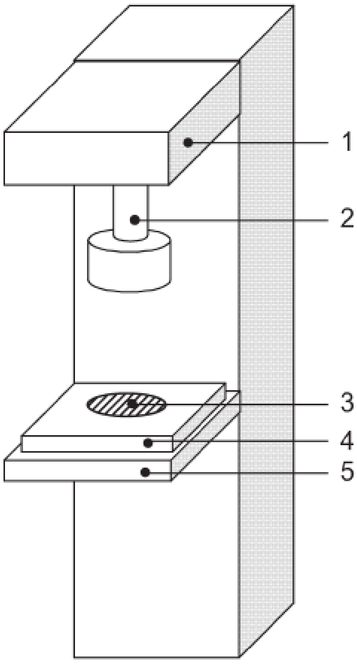


Figure 1 – The sample holder made of 50.0 x 50.0 mm milled acrylic resin with a hole diameter of 22.0 ± 1.0 mm and a depth of 0.5 ± 0.1 mm.

Figure 2 – Cylinder-shape milled acrylic resin, which was attached to pressure sensitive shaft of universal testing machine to detect compressive and tensile force, has a diameter of 20.0 ± 0.5 mm.

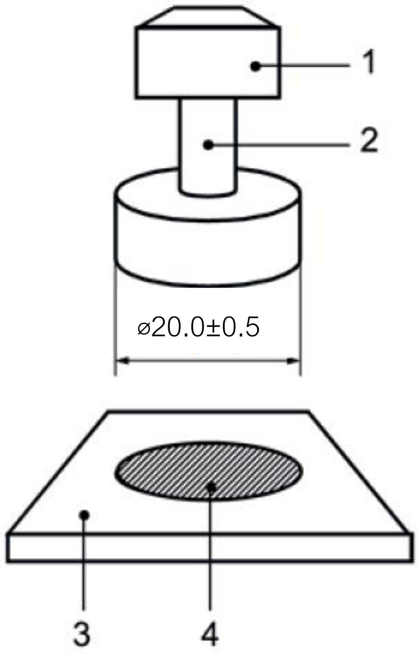
Figure 3 – Universal testing machine (Shimadzu, Japan)



Key

1. Load detecting part
2. Pressure sensitive shaft
3. Denture adhesive
4. Sample holder
5. Sample stand

Figure 4 – Adhesion test instrument (Universal testing machine) layout



Key

1. Load detector
2. Pressure sensitive shaft
3. Sample holder
4. Sample

Figure 5 – Layout of adhesion test instrument

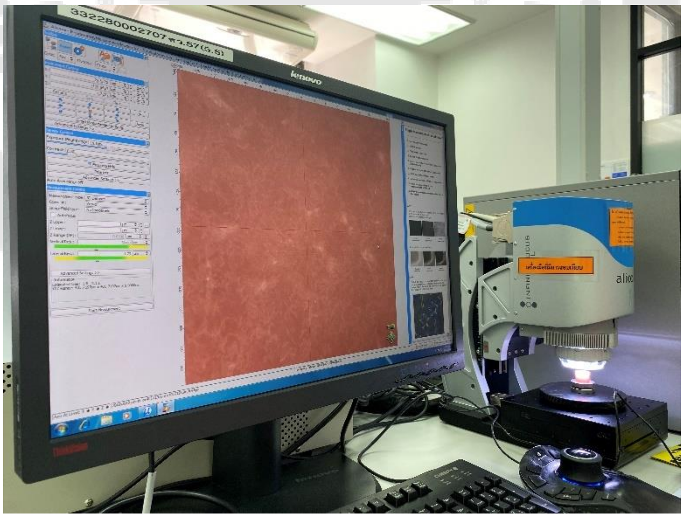


Figure 6 – Non-contact surface roughness tester (Alicona, UK)

3.2 Study design and method

1. Surface roughness (Ra) tested of all cylinder-shape milled acrylic resins and sample holders with non-contact surface roughness tester. See Figure 7-8.

2. Prepared cylinder-shape PMMA for pressure sensitive shaft holding screw attachment.

2.1 Made a hold in the cylinder-shape PMMA. See Figure 9.

2.2 Installed the holding screw at the pressure sensitive shaft and then moved it down until the holding screw was in the hold of cylinder-shape PMMA. Attached cylinder-shape PMMA with pressure sensitive shaft holding screw with pink self-cure acrylic resin. See Figure 10.

3. Evaluate retention strength of denture adhesives

To evaluate retention strength, the International Organization for Standardization (ISO 10873:2021) was conducted to an adhesive strength test[5].

Adhesion strength test I (for type 1 class 2 adhesive)

1. Use a Class 2 denture adhesive to slightly overfill the hole of the sample holder, flatten the surface with spatula in a circular spiral motion, and then immerse the sample/sample holder assembly in 300.0 ± 10.0 ml of water for 1 minute in a water bath maintained at 37.0 ± 2.0 °C.
2. Remove the sample/sample holder assembly and shake it once to remove any water that may have accumulated on the surface.
3. Place the sample/sample holder assembly on the adhesion test instrument's sample stand. See Figure 11.
4. Fix the sample holder in the correct place with two c-clamps then applied load to the sample's center. See Figure 12.
5. Move the pressure sensitive shaft down at a cross head speed of 5 mm/min and apply a load on the sample up to 10.0 ± 0.2 N. See Figure 13-14.

6. Hold the load in place for 30 seconds, and then pull it in the opposite direction at a cross-head speed of 5 mm/min. See figure 15.
7. Recording the maximum force detected by the pressure sensitive shaft and calculating the adhesion strength as force per unit area.
8. Each adhesive will be tested ten times, with the average values compared.

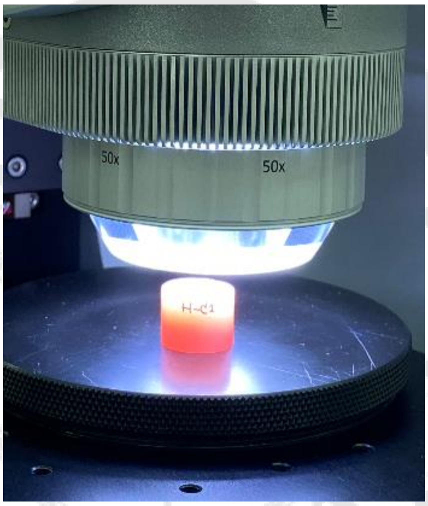


Figure 7 – Surface roughness (Ra) testing of cylinder-shape milled acrylic resin.

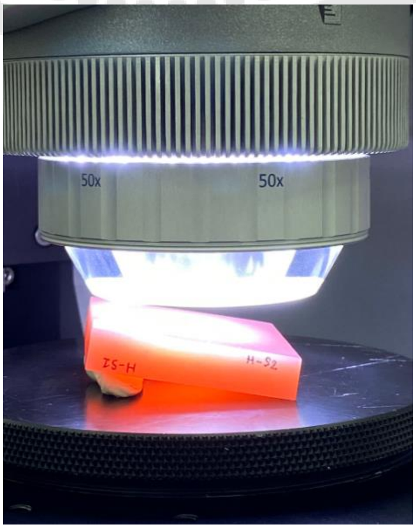


Figure 8 – Surface roughness (Ra) testing of sample holder.

Figure 9 – Made a hold in the cylinder-shape PMMA, preparing cylinder-shape PMMA for pressure sensitive shaft holding screw attachment.

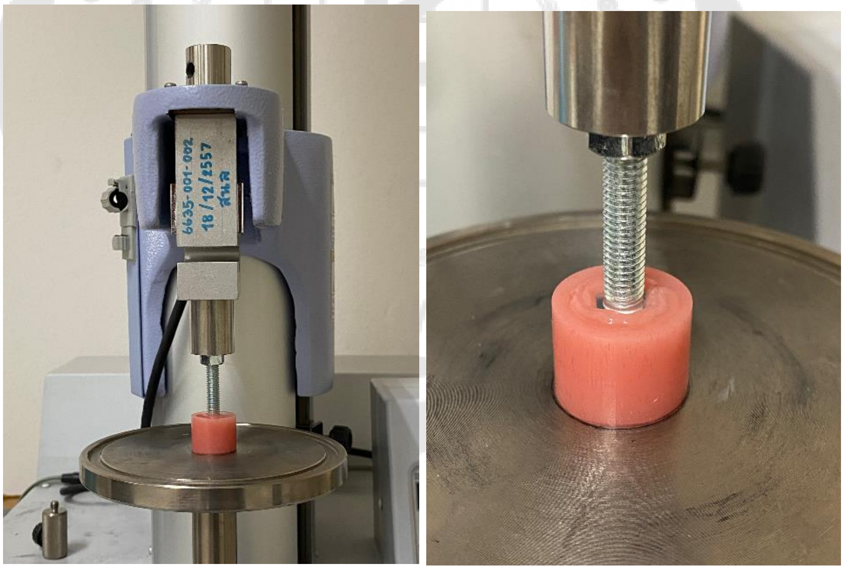


Figure 10 – Attached cylinder-shape PMMA with pressure sensitive shaft holding screw with pink self-cure acrylic resin.

Figure 11 – Place sample holder in the center of the pressure sensitive shaft.

Figure 12 – Two of C-clamps were used to fix sample holder in the correct place.

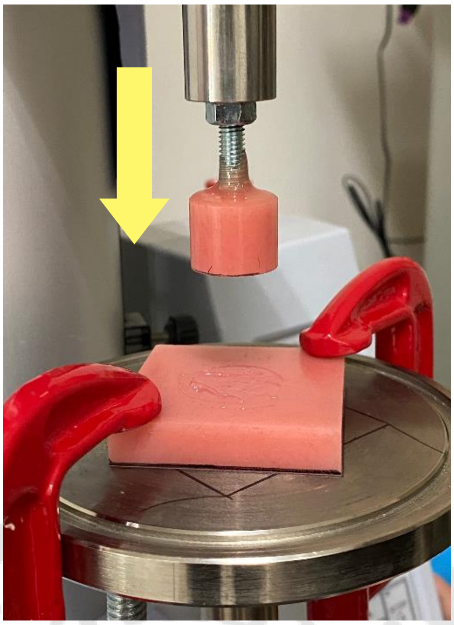


Figure 13 – Move the pressure sensitive shaft down at a cross head speed of 5 mm/min

Figure 14 – The sample/sample holder assembly was placed on the adhesion test instrument's sample stand, with the load applied to the sample's center up to 10.0 ± 0.2 N at a cross-head speed of 5 mm/min.

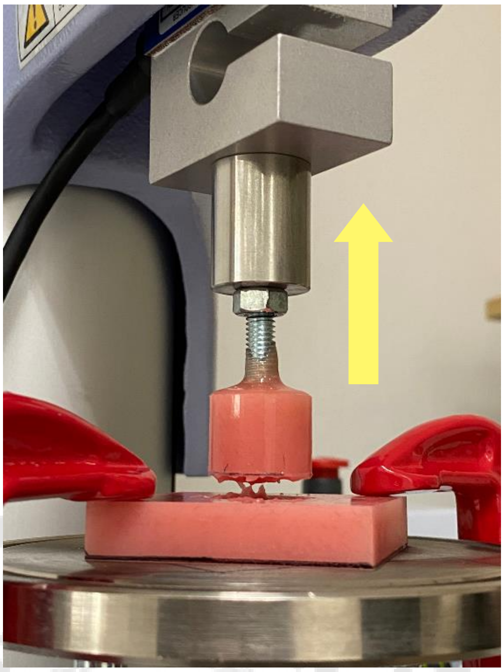


Figure 15 – The pressure sensitive shaft was held with the load in place for 30 seconds, and then pulled in the opposite direction at a cross-head speed of 5 mm/min. The maximum tensile force was used for retention force testing.

3.3 Sample size

In this investigation, we found a significant difference in the test's statistical power with 80 subjects (10 subjects per group) (G*Power 3.1.9.6; Department of Psychology, Christian-Albrechts-University, Kiel, Germany). The mean values will be compared. Eight cream type denture adhesive formulations will be tested.

3.4 Data collection

Adhesion strength (kPa) of each group were collected in the table 4.

Table 4 Data table for the adhesion test of denture adhesives

Code	Adhesion strength (kPa)													
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Average	Min	Max	Median	SD
Ft															
FxO															
FxM															
FxFS															
FxBH															
FxMH															
P															
O															

3.5 Statistical analysis

In this investigation, we found a significant difference in the test's statistical power with 80 subjects (10 subjects per group) (G*Power 3.1.9.6; Department of Psychology, Christian-Albrechts-University, Kiel, Germany). The normality of all data was confirmed using the Shapiro-Wilk normality test. One-way ANOVA analysis of variance was used for the comparison among the groups, followed by a pairwise comparison using Least Significance Difference (LSD) as a post hoc test. Pearson correlation tests were used to seek relationships between the surface roughness of milled acrylic resins and retention strength of denture adhesives. The significance level was set at $p < 0.05$. All analyses were computed with IBM SPSS Statistics for Windows (IBM SPSS Statistics 22, IBM Japan Corp., Tokyo, Japan).

CHAPTER 4
RESULT

To standardize of milled acrylic resin tested in this study, the surface roughness (Ra) test was performed by non-contact surface roughness tester in accordance with ISO 10873:2021 which should less than 2.00 μm[5]. All milled acrylic resins were passed by this standard, Table 5 showed mean surface roughness (Ra) of the tested milled acrylic resins that used for sample holders and cylinder-shape milled acrylic resins that used for attached to pressure sensitive shaft. The one-way ANOVA statistics in Table 6 showed that there was no statistical significance within any of the surface roughness (Ra) of the eight groups of milled acrylic resin sample holders ($p > 0.05$), but there was statistical significance within the eight groups of cylinder-shape milled acrylic resins ($p < 0.05$). According to Table 12, there was no statistically significant link between the mean surface roughness (Ra) of cylinder-shaped acrylic resins milled and the mean of retention strength of denture adhesives ($p > 0.05$).

A total of 80 samples of eight formulations of denture adhesives were tested in this study. Table 7 showed the one-way ANOVA statistics in which a statistical significance among all the eight groups of retention strength of denture adhesives ($p < 0.05$). To evaluate which group comparison yielded the statistical significance, a post hoc test (LSD test) was performed and showed in Table 14-16. The retention strength of Ft group was less than the others groups with statistically significant difference ($p < 0.05$). The retention strength of O group was higher than Ft group and lower than P, FxO, FxM, FxFs, FxBH and FxMH with statistically significant difference ($p < 0.05$). The retention strength of P group was higher than Ft and O group and lower than FxO, FxM, FxFs, FxBH and FxMH with statistically significant difference ($p < 0.05$). The retention strength of the Fixodent group was higher than Ft, O and P group and there were no statistically significant difference with in the Fixodent groups and the retention strength of FxO group was found to be the lowest, following by FxM, FxMH, fXBH and FxFS was the highest of the Fixodent group respectively.

Furthermore, table 8 showed mean retention strengths and 95% confidence intervals of means with statistical summaries of denture adhesive groups. The Fixodent groups (FxO, FxM, FxMH, FxBH and FxFS), were no significantly different. But Ft, O and P group were significantly different from the others groups. In addition, the retention strength per 1 THB (kPa/THB) of each denture adhesive group was shown in Table 9.

Figure 16 showed the mean retention strength (kPa) with the error bar displayed the standard deviation of denture adhesives. The retention strength of Fixodent groups (FxO, FxM, FxMH, FxBH, and FxFS) was not considerably different. However, the Ft, O, and P groups were considerably different from the other groups. The results of Least Significance Difference (LSD) post hoc comparisons were displayed as identical symbols, and the same identical symbols were not substantially different ($P > 0.05$).

Table 5 Mean surface roughness (Ra) in μm of all sample holders and cylinder-shape milled acrylic resin.

Milled acrylic resin groups	Mean of surface roughness (μm)	
	Sample holder	Cylinder-shape milled acrylic resin
Ft	0.4639	0.2550
O	0.5562	0.5162
P	0.7140	0.7565
FxO	0.5750	0.7575
FxM	0.6432	0.7558
FxMH	0.4084	0.7390
FxBH	0.5426	0.3741
FxFS	0.8438	0.7125

Table 6 Summary statistics of one way ANOVA of surface roughness (Ra) of sample holders and cylinder-shape milled acrylic resins

	Source of variation	Sum of Squares	df	Mean Square	F	p-value
Sample holder milled acrylic resin	Between Groups	0.405	7	0.058	1.474	0.245
	Within Groups	0.628	16	0.039		
	Total	1.033	23			
Cylinder-shape milled acrylic resin	Between Groups	0.842	7	0.120	16.405	< 0.001
	Within Groups	0.117	16	0.007		
	Total	0.960	23			

Table 7 Summary statistics of one way ANOVA of retention strength of denture adhesives

Source of variation	Sum of Squares	df	Mean Square	F	p-value
Between Groups	31889.847	7	4555.692	154.214	0.000
Within Groups	2126.974	72	29.541		
Total	34016.820	79			

Table 8 Mean retention strengths and 95% confidence intervals of means with statistical summaries.

Denture Adhesive group	Mean (95% CI of mean)
Ft	32.555 (30.472 – 34.638)
O	44.858 (41.236 – 48.480)
P	66.288 (63.984 – 68.592)
FxO [a]	77.922 (73.341 – 82.503)
FxM [ab]	80.509 (76.009 – 85.008)
FxMH [bc]	84.503 (80.192 – 55.814)
FxBH [cd]	88.402 (86.137 – 90.668)
FxFS [d]	90.559 (84.795 – 96.324)

Fittydent (Ft), Olivafix (O), Polident (P), Fixodent Original (FxO), Fixodent Microseal for Partials (FxM), Fixodent Ultra Max Hold (FxMH), Fixodent Plus Best Hold (FxBH) and Fixodent PLUS Best Foodseal Technology (FxFS).

*Results of Least Significance Difference (LSD) post hoc comparisons are shown as superscript letters, and values having same superscript letters were not significantly difference ($P > 0.05$).

Table 9 Average Retention strength (kPa) of denture adhesives, cost of denture adhesives per gram (THB) and retention strength per 1 THB (price update on April 2022).

Group	Average Retention strength (kPa)	Cost per gram (THB)	Retention strength per 1 THB (kPa/THB)
Ft	32.555	7.00	4.65
O	44.858	4.98	9.00
P	66.288	4.75	13.96
FxO	77.922	8.30	9.39
FxM	80.509	11.00	7.32
FxMH	84.503	11.54	7.32
FxBH	88.402	10.75	8.22
FxFS	90.559	10.13	8.94

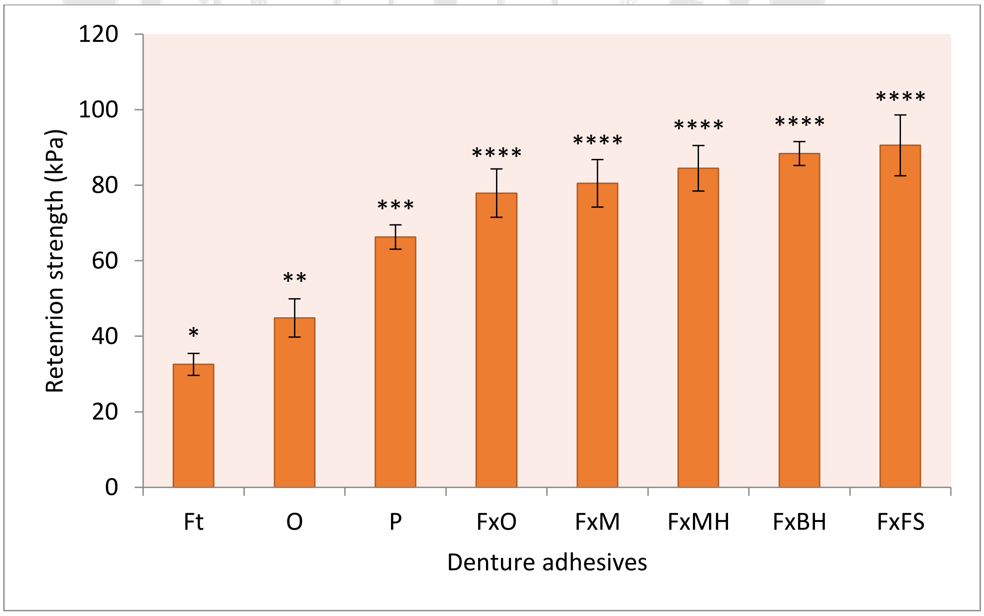


Figure 16 – The mean retention strength (kPa) with the error bar displayed the standard deviation of denture adhesives. The results of Least Significance Difference (LSD) post hoc comparisons were displayed as identical symbols, and the same identical symbols were not substantially different (P > 0.05).

CHAPTER 5
SUMMARY DISCUSSION AND SUGGESTION

Conclusions

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The results showed that all the tested denture adhesives, in milled dentures, have passed the minimum requirement of having a 5 kPa retention strength.
2. The lowest and the highest retention strength were found in Ft and FxFS groups respectively.
3. The Fixodent groups give a greater retention with milled denture base than the other groups and there are not significant differences within this group based on product brand.
4. Authors recommend P because of the highest kPa/THB and FxO because of the lowest cost per gram in the highest retention group.

Discussion

The null hypothesis that the denture adhesives are all the same in aspects of adhesive strength was rejected as some of them showed statistically significant differences. While all groups of the Fixodent denture adhesives showed not statistically significant difference, Ft, O and P group were found to be statistically different.

The International Organization for Standardization (ISO) 10873:2021 suggested that one should apply a load up to 10.0 ± 0.2 N, at cross-head speed of 5 mm/min, by the pressure sensitive shaft to the sample[5].

The retention strength of Fittydent in this study was 32.56 kPa, whereas Manes, et al. found that the highest retention force in clinical study of Fittydent on removable denture was 1095.00 N[2]. In addition, a clinical trial study of Ibraheem, et al. was found that the retention forces was increased with the use of the denture adhesives and the retentive force of Fittydent was 1024.20 N[32]. These previous studies showed retentive force (N) instead of retentive strength (kPa) which was calculated by dividing the force at dislodgment with the total surface area of each prepared sample. Therefore, our study shows more meaningful data which can be compared with minimum requirement of having a 5 kPa retention strength[5].

The mechanism of action of denture adhesives is 50-150% materials swelling from water absorption[22]. They increase the adhesive and cohesive characteristics as well as the viscosity of the medium between the denture and the basal seat, reducing spaces between the denture base and the basal seat[22]. A major adhesive component may be found in all types of adhesives (5-60% by weight), a water-insoluble component (20-70% by weight), viscosity index improvers (1-20% by weight), plasticizing agent (1-10% by weight), gallant agent (1-10% by weight), and taste and scent additions that may be medicinal and sensual[64]. The major adhesive component (mostly alkyl vinyl ether-maleic anhydride-AVE-MA salts) is mucoadhesive, hydrophilic, and water-soluble, and expands when wet[27]. Because it swells less than 10% in water, the water-insoluble component (primarily waxes, petrolatum, oils, silicone, PolyVinylAcetate) adds to the product's cohesiveness. The viscosity index improver (PolyMethylAcrylate, acrylic resins, PolyVinylChloride, nylon, polyesters) controls the product's overall viscosity, allowing it to act appropriately in the mouth as temperature changes. Plasticizing agents (polyols, glycerin, propylene glycol, xylitol) are water-insoluble and are employed to soften the product. Cohesive forces are increased by molecular cross-linking to further extend the action of the products (long-acting polymers), enhancing the total adhesive qualities of the materials and the resistance to denture removal[65].

There are two main parts of soluble denture adhesives, active and nonactive parts. The soluble group's active ingredient, which expands and turns viscous in the presence of saliva, is the basis for the mechanism of action. This substance fills the space between the denture surface and the gum tissue by typically swelling by 50-150 percent after being hydrated[22]. This ingredient typically consists of a blend of polymer salts with various rates of hydration. The active component is divided into two categories, short-term action and long-term action[66].

Short-term action polymer salts like carboxymethylcellulose (CMC) hydrate fast but lose their potency just as quickly. In the other hand, a long-acting polymer salt, like Polyvinylether Methyl Cellulose (PVM-MA), hydrates and activates and remains in the mouth longer than a short-acting salt, could last for six to twelve hours[66]. Over time, the addition of calcium salts and zinc has increased the effect of the active components[67].

Hypocupremia has been linked to excessive zinc intake. A well-established and getting becoming more acknowledged cause of hematologic and neurologic illness is copper deficiency. Myelopathy with or without peripheral neuropathy is one of the most typical neurologic signs of copper insufficiency. Motor neuron disease, peripheral neuropathy without myelopathy, and optic neuritis are fewer described and less obviously causally related with hypocupremia. Malabsorption, parenteral nutrition deficit, and gastrointestinal surgery are three causes of acquired copper deficiency. Hypocupremia may arise from long-term, excessive usage of denture creams containing zinc. Zinc concentrations of 17,283.65 μg/g were found in Fixodent Original[68].

From this study, all groups of Fixodent (FxO, FxM, FxMH, FxFS and FxBH) were of the highest retention strength group and no statistically significant differences could be observed between them because their ingredients were mostly the same. The calcium salt and zinc that make the Fixodent group different from the others are what give them their superior retention strength[67], otherwise zinc may cause hypocupremia[68].

The retention strength per 1 THB (kPa/THB) of each denture adhesive group was shown in Table 9. The P group had the greatest retention strength per 1 THB, followed by FxO, O, FxFS, FxBH, FxMH, FxM, and Ft group was the lowest.

Suggestion

The result of this study will be used to update the retention strength of denture adhesives available in Thailand, which can be used as a clinical guideline for Thai people.

REFERENCES

1. Duqum I, Powers KA, Cooper L, Felton D. Denture adhesive use in complete dentures: Clinical recommendations and review of the literature. Gen Dent. 2012;60(6):467-77; quiz p. 78-9. eng. Epub 2012/12/12.
2. Mañes JF, Selva EJ, De-Barutell A, Bouazza K. Comparison of the retention strengths of three complete denture adhesives: An in vivo study. Med Oral Patol Oral Cir Bucal. 2011;16(1):e132-6. eng. Epub 2010/06/08.
3. Grasso JE. Denture adhesives. Dent Clin North Am. 2004;48(3):721-33, vii. eng. Epub 2004/07/21.
4. The glossary of prosthodontic terms: Ninth edition. J Prosthet Dent. 2017;117(5s):e1-e105. eng. Epub 2017/04/19.
5. International organization for standardization. ISO 10873:2021(E)_Dentistry - Denture adhesives_. Geneva: ISO; 2021.
6. Manikantan N.S., Dhanya Balakrishnan, Manoj KA. Denture adhesives: A review. Int J Recent Sci Res. 2019;10(01):30267-9.
7. Hong G, Maeda T, Hamada T. The effect of denture adhesive on bite force until denture dislodgement using a gnathometer. Int Chin J Dent. 2010;10:41-5.
8. Kumar PR, Shajahan PA, Mathew J, Koruthu A, Aravind P, Ahammed MF. Denture adhesives in prosthodontics: An overview. J Int Oral Health. 2015;7(Suppl 1):93-5. eng. Epub 2015/08/01.
9. Nomura T, Murakami T, Shimoyama Y, Kobayashi T, Furuya J, Sasaki M, et al. Effects of denture adhesives on growth and morphological transformation of candida albicans. J Prosthodont Res. 2020;64(1):78-84. eng. Epub 2019/05/31.
10. Han JM, Hong G, Hayashida K, Maeda T, Murata H, Sasaki K. Influence of composition on the adhesive strength and initial viscosity of denture adhesives. Dent Mater J. 2014;33(1):98-103. eng. Epub 2014/02/05.

11. Koronis S, Pizatos E, Polyzois G, Lagouvardos P. Clinical evaluation of three denture cushion adhesives by complete denture wearers. Gerodontology. 2012;29(2):e161-9. eng. Epub 2010/11/19.
12. Chowdhry P, Phukela SS, Patil R, Yadav H. A study to evaluate the retentive ability of different denture adhesive materials: An in vitro study. J Indian Prosthodont Soc. 2010;10(3):176-81. eng. Epub 2011/09/03.
13. Kalra P, Nadiger R, Shah FK. An investigation into the effect of denture adhesives on incisal bite force of complete denture wearers using pressure transducers - a clinical study. J Adv Prosthodont. 2012;4(2):97-102. eng. Epub 2012/06/28.
14. Sato Y, Kaiba Y, Hayakawa I. Evaluation of denture retention and ease of removal from oral mucosa on a new gel-type denture adhesive. Nihon Hotetsu Shika Gakkai Zasshi. 2008;52(2):175-82. eng. Epub 2008/05/10.
15. Yegin E, Akpinar YZ, Yavuz T, Aslan MA. Effect of different denture adhesives on retention of complete dentures: An in vivo study. Journal of Adhesion Science and Technology. 2017;31(18):2044-52.
16. Panagiotouni E, Pissiotis A, Kapari D, Kaloyannides A. Retentive ability of various denture adhesive materials: An in vitro study. J Prosthet Dent. 1995;73(6):578-85. eng. Epub 1995/06/01.
17. Pachore NJ, Patel JR, Sethuraman R, Naveen YG. A comparative analysis of the effect of three types of denture adhesives on the retention of maxillary denture bases: An in vivo study. J Indian Prosthodont Soc. 2014;14(4):369-75. eng. Epub 2014/12/10.
18. Albaki MAA. Investigate the effect of three types of denture adhesives on the retention of a poorly fitting maxillary complete denture (clinical study). Mustansiria Dent J. 2007;4(1):1-9.
19. Koppang R, Berg E, Dahm S, Real C, Fløystrand F. A method for testing denture adhesives. J Prosthet Dent. 1995;73(5):486-91. eng. Epub 1995/05/01.
20. Lertsuriyakarn K, Palanuwech M. Comparison of retention between two implant attachment systems after fatigue test. J Dent Assoc Thai. 2020;70(3):216-29.

21. Varghese RM, Masri R, Driscoll CF, Romberg E. The effect of denture cleansing solutions on the retention of yellow hader clips: An in vitro study. J Prosthodont. 2007;16(3):165-71. eng. Epub 2007/06/22.

22. Shay K. Denture adhesives. Choosing the right powders and pastes. J Am Dent Assoc. 1991;122(1):70-6. eng. Epub 1991/01/01.

23. Steinmassl O, Dumfahrt H, Grunert I, Steinmassl PA. Cad/cam produces dentures with improved fit. Clin Oral Investig. 2018;22(8):2829-35. eng. Epub 2018/02/23.

24. Kassebaum NJ, Smith AGC, Bernabé E, Fleming TD, Reynolds AE, Vos T, et al. Global, regional, and national prevalence, incidence, and disability-adjusted life years for oral conditions for 195 countries, 1990-2015: A systematic analysis for the global burden of diseases, injuries, and risk factors. J Dent Res. 2017;96(4):380-7. eng. Epub 2017/08/10.

25. Goodacre BJ, Goodacre CJ, Baba NZ, Kattadiyil MT. Comparison of denture base adaptation between cad-cam and conventional fabrication techniques. J Prosthet Dent. 2016;116(2):249-56. eng. Epub 2016/04/27.

26. Burns DR, Unger JW, Elswick RK, Jr., Beck DA. Prospective clinical evaluation of mandibular implant overdentures: Part i--retention, stability, and tissue response. J Prosthet Dent. 1995;73(4):354-63. eng. Epub 1995/04/01.

27. Zhang L, Lyu C, Shang Z, Niu A, Liang X. Quality of life of implant-supported overdenture and conventional complete denture in restoring the edentulous mandible: A systematic review. Implant Dent. 2017;26(6):945-50. eng. Epub 2017/12/01.

28. Kutkut A, Bertoli E, Frazer R, Pinto-Sinai G, Fuentealba Hidalgo R, Studts J. A systematic review of studies comparing conventional complete denture and implant retained overdenture. J Prosthodont Res. 2018;62(1):1-9. eng. Epub 2017/07/02.

29. Feine JS, Carlsson GE, Awad MA, Chehade A, Duncan WJ, Gizani S, et al. The mcgill consensus statement on overdentures. Mandibular two-implant overdentures as

first choice standard of care for edentulous patients. Gerodontology. 2002;19(1):3-4. eng. Epub 2002/08/08.

30. Thomason JM, Feine J, Exley C, Moynihan P, Müller F, Naert I, et al. Mandibular two implant-supported overdentures as the first choice standard of care for edentulous patients--the york consensus statement. Br Dent J. 2009;207(4):185-6. eng. Epub 2009/08/22.

31. Mínguez-Tomás N, Alonso-Pérez-Barquero J, Fernández-Estevan L, Vicente-Escuder Á, Selva-Otaolaurruchi EJ. In vitro retention capacity of two overdenture attachment systems: Locator® and equator®. J Clin Exp Dent. 2018;10(7):e681-e6. eng. Epub 2018/07/31.

32. Ibraheem EMA, El-sisy AME. Comparing the effect of three denture adhesives on the retention of mandibular complete dentures for diabetic patients (randomized clinical trial). Bulletin of the National Research Centre. 2019;43(1):24.

33. Quiney D, Nishio Ayre W, Milward P. The effectiveness of adhesives on the retention of mandibular free end saddle partial dentures: An in vitro study. J Dent. 2017;62:64-71. eng. Epub 2017/05/21.

34. Fenlon MR, Sherriff M. An investigation of factors influencing patients' satisfaction with new complete dentures using structural equation modelling. J Dent. 2008;36(6):427-34. eng. Epub 2008/04/18.

35. Ştefănescu C-L, Zaharia A, Murineanu RM, Puşcaşu CG, Sachelarie L, Grigorian M. Flabby ridge, a challenge for making complete dentures. Applied Sciences. 2021;11(16):7386.

36. Atwood DA. Bone loss of edentulous alveolar ridges. J Periodontol. 1979;50(4 Spec No):11-21. eng. Epub 1979/04/01.

37. Atwood DA, Coy WA. Clinical, cephalometric, and densitometric study of reduction of residual ridges. J Prosthet Dent. 1971;26(3):280-95. eng. Epub 1971/09/01.

38. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: A mixed-longitudinal study covering 25 years. J Prosthet Dent. 1972;27(2):120-32. eng. Epub 1972/02/01.

39. McCartney JE. Prosthetic problems resulting from facial and intraoral changes in the edentulous patient. J Dent. 1981;9(1):71-83. eng. Epub 1981/03/01.

40. Atwood DA. Reduction of residual ridges: A major oral disease entity. J Prosthet Dent. 1971;26(3):266-79. eng. Epub 1971/09/01.

41. Felton DA. Edentulism and comorbid factors. J Prosthodont. 2009;18(2):88-96. eng. Epub 2009/03/04.

42. Sajjad M, Rahim S, Khan S. Comparison of efficiency of polymethylvinylether-maleic anhydride (pvm-ma) based denture adhesive and carboxymethyl cellulose (cc) based denture adhesive. 2020.

43. Wilson MJ, Watts DC. Denture adhesives: An in vitro evaluation. J dent res. 1990;69:970.

44. Ohno T, Itatsu R, Moriya M, Sato Y, Sumi Y. Evaluation of the physical properties of a newly developed denture adhesive for patients with dry mouth. J Prosthodont Res. 2019;63(2):157-61. eng. Epub 2018/12/12.

45. Setz I, Lee SH, Engel E. Retention of prefabricated attachments for implant stabilized overdentures in the edentulous mandible: An in vitro study. J Prosthet Dent. 1998;80(3):323-9. eng. Epub 1998/10/07.

46. Rabbani S, Juszczyk AS, Clark RK, Radford DR. Investigation of retentive force reduction and wear of the locator attachment system with different implant angulations. Int J Oral Maxillofac Implants. 2015;30(3):556-63. eng. Epub 2015/02/12.

47. Gupta DR, Luthra DRP, Gupta DS. A comparative analysis of retention of mandibular denture bases in patients with resorbed ridges with or without sublingual extension - an in vivo study. International Journal of Approximate Reasoning. 2016;4:1920-9.

48. Adel Aziz E, Adel Aziz A, Eldeen Ibrahim DE , Mohammed AAE. Comparative study between different denture adhesives in improving phonation in complete denture wearers. J Am Science. 2010;6(11):556-61.

49. Carlsson GE. Implant and root supported overdentures - a literature review and some data on bone loss in edentulous jaws. J Adv Prosthodont. 2014;6(4):245-52. eng. Epub 2014/09/02.

50. Warreth A, Byrne C, Alkadhimi AF, Woods E, Sultan A. Mandibular implant-supported overdentures: Attachment systems, and number and locations of implants--part ii. J Ir Dent Assoc. 2015;61(3):144-8. eng. Epub 2015/08/20.

51. Ahuja S, Cagna DR. Classification and management of restorative space in edentulous implant overdenture patients. J Prosthet Dent. 2011;105(5):332-7. eng. Epub 2011/05/03.

52. Aroso C, Silva AS, Ustrell R, Mendes JM, Braga AC, Berastegui E, et al. Effect of abutment angulation in the retention and durability of three overdenture attachment systems: An in vitro study. J Adv Prosthodont. 2016;8(1):21-9. eng. Epub 2016/03/08.

53. Kurtulus IL, Gurbulak AG. The in vitro comparison of the retention of an implant-supported stud attachment locator and straumann ball attachment at different angulations. Niger J Clin Pract. 2018;21(5):639-44. eng. Epub 2018/05/08.

54. Reda KM, El-Torky IR, El-Gendy MN. In vitro retention force measurement for three different attachment systems for implant-retained overdenture. J Indian Prosthodont Soc. 2016;16(4):380-5. eng. Epub 2016/10/18.

55. Rutkunas V, Mizutani H, Takahashi H. Evaluation of stable retentive properties of overdenture attachments. Stomatologija. 2005;7(4):115-20. eng. Epub 2006/02/28.

56. Rutkunas V, Mizutani H, Takahashi H. Influence of attachment wear on retention of mandibular overdenture. J Oral Rehabil. 2007;34(1):41-51. eng. Epub 2007/01/09.

57. Rutkunas V, Mizutani H, Takahashi H, Iwasaki N. Wear simulation effects on overdenture stud attachments. Dent Mater J. 2011;30(6):845-53. eng. Epub 2011/11/30.

58. Sultana N, Bartlett DW, Suleiman M. Retention of implant-supported overdentures at different implant angulations: Comparing locator and ball attachments. Clin Oral Implants Res. 2017;28(11):1406-10. eng. Epub 2017/02/14.

59. Türk PE, Geckili O, Türk Y, Günay V, Bilgin T. In vitro comparison of the retentive properties of ball and locator attachments for implant overdentures. Int J Oral Maxillofac Implants. 2014;29(5):1106-13. eng. Epub 2014/09/13.

60. Yilmaz B, Ozkir E, Johnston WM, McGlumphy E. Dislodgement force analysis of an overdenture attachment system. J Prosthet Dent. 2020;123(2):291-8. eng. Epub 2019/06/17.

61. Breeding LC, Dixon DL, Schmitt S. The effect of simulated function on the retention of bar-clip retained removable prostheses. J Prosthet Dent. 1996;75(5):570-3. eng. Epub 1996/05/01.

62. Gamborena JI, Hazelton LR, NaBadalung D, Brudvik J. Retention of era direct overdenture attachments before and after fatigue loading. Int J Prosthodont. 1997;10(2):123-30. eng. Epub 1997/03/01.

63. Alsabeeha N, Atieh M, Swain MV, Payne AG. Attachment systems for mandibular single-implant overdentures: An in vitro retention force investigation on different designs. Int J Prosthodont. 2010;23(2):160-6. eng. Epub 2010/03/23.

64. Polychronakis N, Sykaras N, Polyzois G, Lagouvardos P. Removal of denture adhesives from pmma and polyamide denture base materials. J Appl Oral Sci. 2021;29:e20200448. eng. Epub 2021/04/01.

65. AlRumaih HS, AlHelal A, Baba NZ, Goodacre CJ, Al-Qahtani A, Kattadiyil MT. Effects of denture adhesive on the retention of milled and heat-activated maxillary denture bases: A clinical study. J Prosthet Dent. 2018;120(3):361-6. eng. Epub 2018/03/20.

66. Silva J, Madrid Troconis C, Tirado Amador L. Saliva and alternative adhesive systems for complete dentures. 2013;25:208-18.

67. Nagaraj E, Kondody R, Kalambettu A, Vinnakota D, Hari J. Changing trends and clinical recommendations of denture adhesive in complete denture: A review. Journal of Dental Research and Review. 2021;8(3):228-32.

68. Nations SP, Boyer PJ, Love LA, Burritt MF, Butz JA, Wolfe GI, et al. Denture cream: An unusual source of excess zinc, leading to hypocupremia and neurologic disease. Neurology. 2008;71(9):639-43. eng. Epub 2008/06/06.

APPENDIX

Table 10 Raw data of surface roughness (Ra) in µm of all sample holders milled acrylic resin

Sample holder milled acrylic resin groups	Test 1	Test 2	Test 3	x̄
Ft	0.4877	0.4128	0.4912	0.4639
O	0.4698	0.3177	0.9376	0.5750
P	0.5517	1.0117	0.3663	0.6432
FxO	0.5439	0.8643	1.1232	0.8438
FxM	0.5339	0.5993	0.4945	0.5426
FxMH	0.3756	0.3824	0.4671	0.4084
FxBH	0.6867	0.7621	0.6931	0.7140
FxFS	0.6435	0.4964	0.5286	0.5562

Table 11 Raw data of surface roughness (Ra) in µm of all cylinder-shape milled acrylic resin

Cylinder-shape milled acrylic resin groups	Test 1	Test 2	Test 3	x̄
Ft	0.2394	0.2756	0.2500	0.2550
O	0.7604	0.7321	0.7801	0.7575
P	0.6424	0.7428	0.8822	0.7558
FxO	0.6849	0.7342	0.7183	0.7125
FxM	0.3621	0.3388	0.4213	0.3741
FxMH	0.9130	0.5585	0.7301	0.7339
FxBH	0.8019	0.7627	0.7048	0.7565
FxFS	0.6004	0.4332	0.5150	0.5162

Table 12 Correlation between mean of surface roughness (Ra) of cylinder-shape milled acrylic resin and mean of retention strength of denture adhesives (Pearson's correlation)

		Mean of surface roughness (Ra)	Mean of retention strength (kPa)
Mean of surface roughness (Ra)	Pearson Correlation	1	0.581
	Sig. (2-tailes)		0.131
	N	8	8
Mean of retention strength (kPa)	Pearson Correlation	0.581	1
	Sig. (2-tailes)	0.131	
	N	8	8

Table 13 Raw data of Retention strength (kPa) of denture adhesives

Code	Adhesion strength (kPa)														
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Average	Min	Max	Median	SD
Ft	29.603	35.014	32.070	26.340	35.332	31.910	35.810	31.910	34.298	33.263	32.555	26.340	35.810	32.666	2.9117
FxO	72.017	83.477	74.564	70.108	71.301	89.843	77.031	76.951	79.657	84.272	77.922	70.108	89.843	76.991	6.4037
FxM	74.007	79.339	71.063	85.386	93.583	83.556	82.920	78.543	78.145	78.543	80.508	71.063	93.583	78.941	6.2895
FxFS	95.970	104.565	81.408	92.389	86.501	77.190	88.888	99.074	90.161	89.445	90.559	77.190	104.565	89.803	8.0583
FxBH	84.511	93.583	85.943	85.864	91.593	89.843	87.058	92.150	87.774	85.705	88.402	84.511	93.583	87.416	3.1668
FxMH	80.771	78.702	93.424	80.930	76.315	89.684	87.933	89.047	78.622	89.604	84.503	76.315	93.424	84.431	6.0261
P	65.651	63.264	71.699	68.994	67.800	68.596	63.582	67.879	64.139	61.275	66.288	61.275	71.699	66.726	3.2209
O	49.895	48.701	44.006	42.733	54.192	44.882	39.789	43.688	44.245	36.446	44.858	36.446	54.192	44.126	5.0630

Table 14 Results of Least Significance Difference (LSD) post hoc comparisons test of denture adhesives retention strength (kPa)

Multiple Comparisons

Dependent Variable: Retention (kPa)

LSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Ft	FxO	-45.367100*	2.430691	.000	-50.21259	-40.52161
	FxM	-47.953500*	2.430691	.000	-52.79899	-43.10801
	FxFS	-58.004100*	2.430691	.000	-62.84959	-53.15861
	FxBH	-55.847400*	2.430691	.000	-60.69289	-51.00191
	FxMH	-51.948200*	2.430691	.000	-56.79369	-47.10271
	P	-33.732900*	2.430691	.000	-38.57839	-28.88741
	O	-12.302700*	2.430691	.000	-17.14819	-7.45721
FxO	Ft	45.367100*	2.430691	.000	40.52161	50.21259
	FxM	-2.586400	2.430691	.291	-7.43189	2.25909
	FxFS	-12.637000*	2.430691	.000	-17.48249	-7.79151
	FxBH	-10.480300*	2.430691	.000	-15.32579	-5.63481
	FxMH	-6.581100*	2.430691	.008	-11.42659	-1.73561
	P	11.634200*	2.430691	.000	6.78871	16.47969
	O	33.064400*	2.430691	.000	28.21891	37.90989
FxM	Ft	47.953500*	2.430691	.000	43.10801	52.79899
	FxO	2.586400	2.430691	.291	-2.25909	7.43189
	FxFS	-10.050600*	2.430691	.000	-14.89609	-5.20511
	FxBH	-7.893900*	2.430691	.002	-12.73939	-3.04841
	FxMH	-3.994700	2.430691	.105	-8.84019	.85079
	P	14.220600*	2.430691	.000	9.37511	19.06609
	O	35.650800*	2.430691	.000	30.80531	40.49629

Table 15 Results of Least Significance Difference (LSD) post hoc comparisons test of denture adhesives retention strength (kPa) (Continued)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
FxFS	Ft	58.004100*	2.430691	.000	53.15861	62.84959
	FxO	12.637000*	2.430691	.000	7.79151	17.48249
	FxM	10.050600*	2.430691	.000	5.20511	14.89609
	FxBH	2.156700	2.430691	.378	-2.68879	7.00219
	FxMH	6.055900*	2.430691	.015	1.21041	10.90139
	P	24.271200*	2.430691	.000	19.42571	29.11669
	O	45.701400*	2.430691	.000	40.85591	50.54689
FxBH	Ft	55.847400*	2.430691	.000	51.00191	60.69289
	FxO	10.480300*	2.430691	.000	5.63481	15.32579
	FxM	7.893900*	2.430691	.002	3.04841	12.73939
	FxFS	-2.156700	2.430691	.378	-7.00219	2.68879
	FxMH	3.899200	2.430691	.113	-.94629	8.74469
	P	22.114500*	2.430691	.000	17.26901	26.95999
	O	43.544700*	2.430691	.000	38.69921	48.39019
FxMH	Ft	51.948200*	2.430691	.000	47.10271	56.79369
	FxO	6.581100*	2.430691	.008	1.73561	11.42659
	FxM	3.994700	2.430691	.105	-.85079	8.84019
	FxFS	-6.055900*	2.430691	.015	-10.90139	-1.21041
	FxBH	-3.899200	2.430691	.113	-8.74469	.94629
	P	18.215300*	2.430691	.000	13.36981	23.06079
	O	39.645500*	2.430691	.000	34.80001	44.49099

Table 16 Results of Least Significance Difference (LSD) post hoc comparisons test of denture adhesives retention strength (kPa) (Continued)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
P	Ft	33.732900*	2.430691	.000	28.88741	38.57839
	FxO	-11.634200*	2.430691	.000	-16.47969	-6.78871
	FxM	-14.220600*	2.430691	.000	-19.06609	-9.37511
	FxFS	-24.271200*	2.430691	.000	-29.11669	-19.42571
	FxBH	-22.114500*	2.430691	.000	-26.95999	-17.26901
	FxMH	-18.215300*	2.430691	.000	-23.06079	-13.36981
	O	21.430200*	2.430691	.000	16.58471	26.27569
O	Ft	12.302700*	2.430691	.000	7.45721	17.14819
	FxO	-33.064400*	2.430691	.000	-37.90989	-28.21891
	FxM	-35.650800*	2.430691	.000	-40.49629	-30.80531
	FxFS	-45.701400*	2.430691	.000	-50.54689	-40.85591
	FxBH	-43.544700*	2.430691	.000	-48.39019	-38.69921
	FxMH	-39.645500*	2.430691	.000	-44.49099	-34.80001
	P	-21.430200*	2.430691	.000	-26.27569	-16.58471

*. The mean difference is significant at the 0.05 level.

VITA

NAME	Papatsara Veerapol
DATE OF BIRTH	31 December 1988
PLACE OF BIRTH	Thailand
INSTITUTIONS ATTENDED	2012 Doctor of Dental Surgery from Chulalongkorn University
HOME ADDRESS	Bangkok, Thailand