The Effect of Eight Types of Denture Adhesives on Retention of Milled Denture Base Acrylic Resin

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Abstract

Objective: The retention of removable dentures is a primary concern for patients. Accordingly, this in vitro study aims to compare the retention strength of four commercial brands (eight formulations), offering cream type denture adhesives that can be brought in Thailand, on milled denture base acrylic resin.

Materials and methods: Eight milled acrylic resin molds were fabricated according to ISO10873:2021 and the retention strength 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)] were measured in each milled mold for ten times. All the data were analyzed independently by one-way analysis of variance (ANOVA) and post hoc test with a Least Significant Difference (LSD) multiple comparison test at a 95% level of significance.

Results: The study found statistically significant ($p < 0.05$) differences in mean retention strength between groups of denture adhesives. The Ft, O and P groups showed statistically significant ($p < 0.05$) differences to every other group. There was no significant difference between Fixodent groups (FxO, FxM, FxFS, FxBH and FxMH). The lowest and the highest retention strength were found in the Ft and the FxFS groups respectively.

Conclusions: According to ISO 10873:2021, the retention strength of denture adhesive should be more than 5 kPa. All tested adhesives have reached this threshold. All Fixodent groups have higher retention strength than Fittydent, Olivafix and Polident adhesives. There are no significant differences within the Fixodent group. Authors recommend Polident because it offers the best efficiency measured in kPa/THB or Fixodent Original because it offers the lowest cost per gram solution in the highest retention group.

Keywords: CAD/CAM, PMMA resin, Denture base, Tensile strength, Retention strength

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Introduction

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). 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 (2). It has been characterized as a substance used to make a denture attach to the oral mucosa through chemical and physical interactions in a glossary of prosthodontics terminology (3). 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 (4).

Wearers of dentures have utilized denture adhesives to improve retention (5-7), stability (5-7), oral health-related quality of life (QOL), masticatory efficiency and general health (8). According to ISO 10873:2021 (4), the denture adhesives are categorized into two type. Glue ypes 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 (5). While the particular ingredients in these denture adhesives may differ, they all include the same general elements that perform the same purpose (9). Among these, cream-types are the most recommended denture adhesives by dentists due to their ease of use (10,11). This is confirmed by Chowdhry, et al. and Kalra, et al., as they concluded that cream types were found to be more effective and retentive (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. 2008. used a novel gel-type denture adhesive to evaluate denture retention and ease of removal from the oral mucosa. They discovered that creams have a higher adhesion force than the gel, but the gel is simpler to remove from the oral mucosa than cream (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) (1). 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 (1,11,13,16,17). This can be explained by its higher viscosity and polyvinylacetate component,

which is a sticky and insoluble 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. Maximum tensile load (peak load dislodgement) measurements had been created in laboratories to search for retention forces (20). Retention of the denture could also be referred to as peak load-to-dislodgement, maximum tensile load (21), adhesion force (4), or retention force (20). The retention test was set up in laboratory to determine adhesion force of the denture adhesives. 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/m^2 (4).

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. Current adhesive characteristics are determined by a combination of chemical and physical factors; saliva increases the viscosity of the adhesive thus also increasing the force required to detach the prosthesis from the tissue surface (22).

Computer-aided design and computer-aided manufacturing (CAD-CAM) denture base fabricating is a subtractive process, and polymerization shrinkage is not an issue anymore (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 (9,11, 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 purpose 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.

Materials and methods

Sample preparation

Eight cream-type 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) were used in this study. Table 1-2 provides detailed information on the components of these materials

Table 1. Group in this study, the manufactures, denture adhesive ingredients of the eight groups of denture adhesives.

Group	Adhesives	Manufacture	Ingredients
Ft	Fittydent	Fittydent International GMBL, Pinkafeld, Austria	Sodium Carboxymethylcellulose, Polyvinylacetate, Alcohol, Paraffinum,Triacetin, Liquidum, Silica
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
FxM	Fixodent Microseal for Partials	Procter & Gamble Manufacturing Co., Ohio, USA	Paraffinum Liquidum, Calcium/Zinc PVM/MA Copolymer (35%), Cellulose Gum (20%), Petrolatum, Silica
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
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
FxMH	Fixodent Ultra Max Hold	Procter & Gamble Manufacturing Co., Ohio, USA	Calcium/Zinc, Mineral Oil, PVM/MA, Cellulose Gum, Petrolatum, Silica, Red 27 Lake
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.
O	Olivafix O	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

Table 2. The common components of denture adhesives are listed, along with their purpose (9).

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

Adhesive strength measurement

The adhesive strength test I (for type 1 class 2 adhesive) was measured according to ISO-10873:2021 recommended procedures (4). The study used a Class 2 denture adhesive to slightly overfill the hole of the sample holder, diameter 22.0 ± 1.0 mm and depth 0.5 ± 0.1 mm (Fig 1), flatten the surface, 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. The sample/sample holder assembly was removed and shaken once to remove any water that may have accumulated on the surface. The sample/sample holder assembly was placed on the adhesion test instrument's sample stand, with the load applied to the sample's center (Fig 2). Using milled acrylic resin with diameter 20.0 ± 0.5 mm (Fig 3) attached to the pressure sensitive shaft of the Universal Testing machine (Shimadzu, EZtest, Japan), a load was applied on the sample up to 10.0 ± 0.2 N at a cross-head speed of 5 mm/min. The load was held in place for 30 seconds, and then it was pulled in the opposite direction at a cross-head speed of 5 mm/min (Fig 4). The maximum force was detected and recorded by the pressure sensitive shaft and the adhesion strength was calculated as force per unit area. Each adhesive was tested ten times (instead of the five times required by ISO-10873:2021), with the average values being compared.

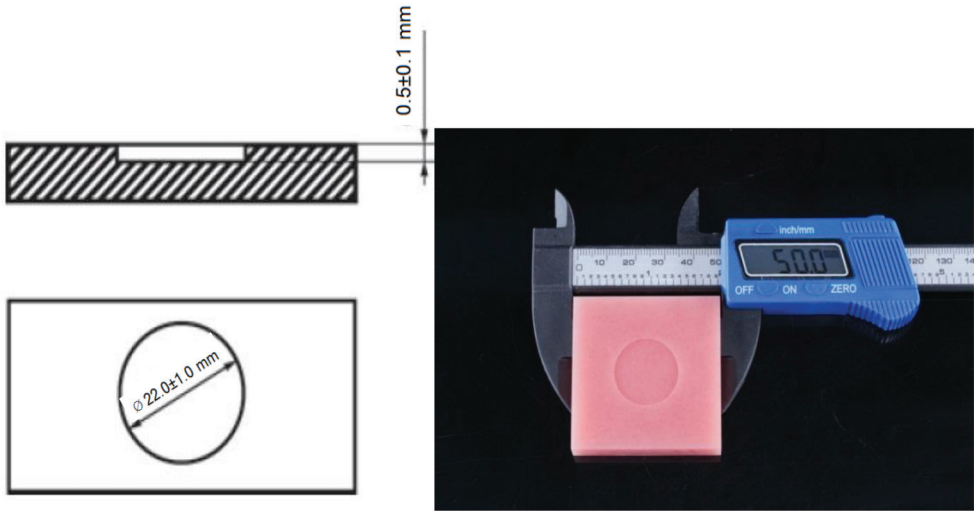

Fig 1. The sample holder made of 50.0 x 50.0 mm milled acrylic resin with a hole diameter of 22.0 ± 1.0 mm and a depth of 0.5 ± 0.1 mm.

Fig 2. 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.

Fig 3. 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.

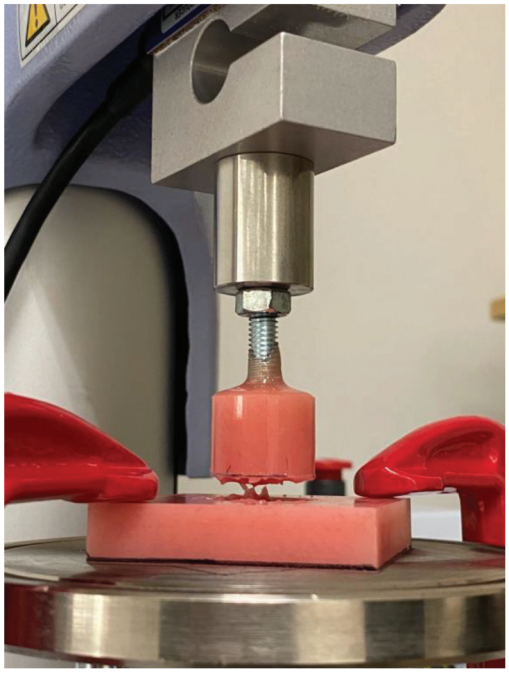

Fig 4. The pressure sensitive shaft was held with the load in place for 30 seconds, and then pulled in the opposite direction at a cross-head speed of 5 mm/min. The maximum tensile force was used for retention force testing.

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. 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).

Results

A total of 80 samples of eight formulations of denture adhesives were tested in this study. Figure 5 showed descriptive statistics of all eight groups. Ft showed the lowest mean retention strength (32.55 kPa), followed by O (44.86 kPa), P (66.29 kPa), FxO (77.92 kPa), FxM (80.51 kPa), FxMH (84.50 kPa), FxBH (88.40 kPa) and FxFS which showed the highest mean retention strength (90.56 kPa).

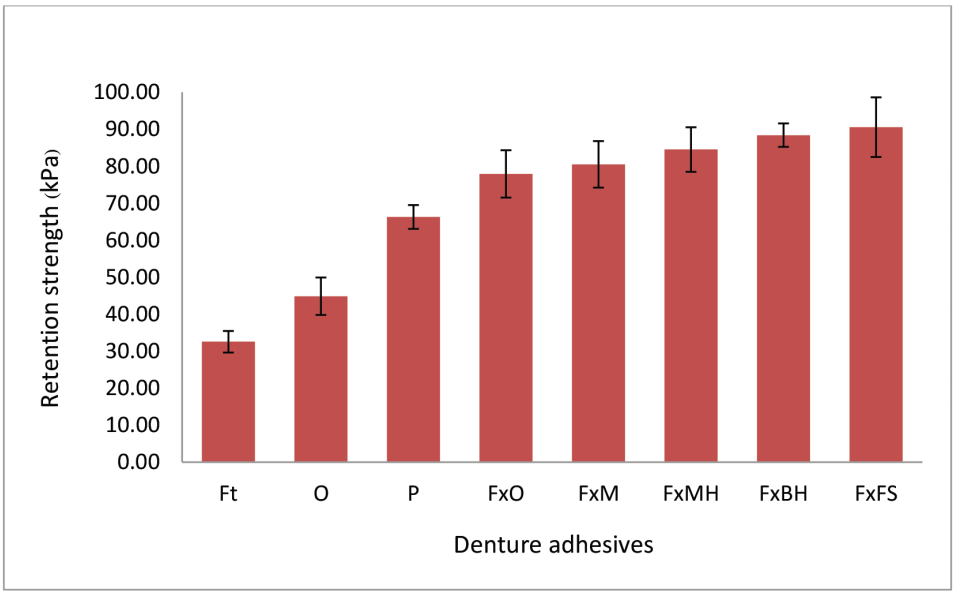

Fig 5. Retention strength (kPa) of denture adhesives [Fittydent (Ft), Olivafix (O), Polident (P), Fixodent Original (FxO), Fixodent Microseal for Partials (FxM), Fixodent Ultra Max Hold (FxMH), Fixodent Plus Best Hold (FxBH) and Fixodent PLUS Best Foodseal Technology (FxFS)]. Error bar indicates standard deviation.

Table 3 showed the one-way ANOVA statistics in which a statistical significance among all the eight groups ($p < 0.05$). To evaluate which group comparison yielded the statistical significance, a post hoc test (LSD test) was performed. Furthermore, table 4 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 5.

Table 3. Summary statistics of one way ANOVA.

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 4. 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 5. 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

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 (4).

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 (1). 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 (4).

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 (34). The major adhesive component (mostly alkyl vinyl ether-maleic anhydride-AVE-MA salts) is mucoadhesive, hydrophilic, and water-soluble, and expands when wet (34). 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 (35). 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 retention strength per 1 THB (kPa/THB) of each denture adhesive group was shown in Table 5. 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.

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.

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