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ORIGINAL ARTICLE

EFFECTIVENESS OF COMMERCIALLY AVAILABLE DENTURE ADHESIVES ON RETENTION OF MANDIBULAR COMPLETE DENTURE IN RESORBED MANDIBULAR RIDGE: AN *IN VITRO* STUDY

Efectividad de los adhesivos disponibles comercialmente sobre la retención de prótesis removibles completas mandibulares en el reborde mandibular reabsorbido: un estudio *in vitro.*

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ABSTRACT

Background: Denture adhesives are alternatives used to improve retention, stability, comfort and satisfaction in patients with complete dentures. Evidence on the effectiveness of denture adhesives on resorbed mandibular ridges is scarce. Among the many commercially available denture adhesives, the ideal material for the severely resorbed mandibular ridge remains in dispute. **Objective:** The aim of this study was to evaluate the effectiveness of different quantities of four commercially available denture adhesives on the retention of mandibular complete dentures in severely resorbed ridges.

Materials and Methods: A resorbed edentulous mandibular ridge model was manufactured in acrylic resin. A denture base was made and three loops were attached to it. Four commercially available denture adhesives (Fixodent, Perlie White, Fiftydent and Polident) were tested in amounts of 0.2 g, 0.4 g, 0.6 g, 0.8 g and 1.0 g. The acrylic resin model was evenly moistened with 1 ml of water and a weighted amount of adhesive material was applied to the denture base. The universal testing machine engaged the loops fixed on the denture base and applied the vertical displacement force. The maximum vertical displacement force values were recorded for each denture adhesive material at different amounts. Statistical calculation was performed using Kruskal Wallis with Bonferroni post hoc correction.

Results: Statistically significant differences were observed in the mean values of the vertical displacement force for adhesive amounts of 0.2 g, 0.4 g, 0.6 g and 1.0 g ($p<0.05$) between the four adhesive materials tested. Statistically significant differences were observed when four denture adhesives were compared to each other in different amounts ($p<0.05$). Statistically significant differences were observed between different amounts for each of four denture adhesives ($p<0.05$).

Conclusions: Among the four materials tested, Polident showed greater effectiveness at 0.6 g and 0.8 g, Fittydent at 0.6 g, 0.8 g and 1 g, Fixodent at 0.4 g and 0.6 g and Perlie White at 1 g and 0.8g quantity to resist vertical displacement. forces on the severely resorbed mandibular crest. Using an appropriate amount of denture adhesive allows for proper retention of the denture; Replacement of this adhesive is necessary once a day.

Keywords: *Denture retention; Alveolar ridge; Mandible; Adhesives; Effectiveness; Denture, complete.*

RESUMEN

Introducción: Los adhesivos para prótesis dentales son alternativas utilizadas para mejorar la retención, la estabilidad, la comodidad y la satisfacción en los pacientes con prótesis completas. La evidencia sobre la efectividad de los adhesivos para prótesis dentales en los rebordes mandibulares reabsorbidos es escasa. Entre los muchos adhesivos para prótesis dentales disponibles comercialmente, sigue estando en disputa cuál es el material ideal para el reborde mandibular severamente reabsorbido. **Objetivo:** El objetivo de este estudio fue evaluar la efectividad de diferentes cantidades de cuatro adhesivos para prótesis dentales disponibles comercialmente sobre la retención de prótesis dentales completas mandibulares en reborde mandibular reabsorbido severamente.

Materiales y Métodos: Se fabricó un modelo de reborde mandibular edéntulo reabsorbido en resina acrílica. Se hizo una base para la prótesis y se le colocaron tres bucles. Se probaron cuatro adhesivos para dentaduras postizas disponibles comercialmente (Fixodent, Perlie White, Fiftydent y Polident) en cantidades de 0,2 g, 0,4 g, 0,6 g, 0,8 g y 1,0 g. El modelo de resina acrílica se humedeció uniformemente con 1 ml de agua y se aplicó la cantidad correspondiente de material adhesivo sobre la base de la dentadura. La máquina de prueba universal enganchó los bucles fijados en la base de la dentadura postiza y aplicó la fuerza de desplazamiento vertical. Se registraron los valores máximos de fuerza de desplazamiento vertical para cada material adhesivo para dentaduras postizas en diferentes cantidades. El cálculo estadístico se realizó utilizando Kruskal Wallis con corrección post hoc de Bonferroni.

Resultado: Se observaron diferencias estadísticamente significativas en los valores medios de la fuerza de desplazamiento vertical para cantidades de 0,2 g, 0,4 g, 0,6 g y 1,0 g ($p<0,05$) entre los cuatro materiales adhesivos para prótesis dentales probados. Se observaron diferencias estadísticamente significativas cuando se compararon cuatro adhesivos para prótesis dentales entre sí en diferentes cantidades ($p<0,05$). Se observaron diferencias estadísticamente significativas entre diferentes cantidades en los cuatro adhesivos para prótesis ($p<0,05$).

Conclusión: De los cuatro materiales probados, Polident mostró mayor efectividad a 0,6 g y 0,8 g, Fittydent a 0,6 g, 0,8 g y 1 g, Fixodent a 0,4 g y 0,6 g y Perlie White a 1 g y 0,8 g para resistir fuerzas de desplazamiento vertical en la cresta mandibular severamente reabsorbida. El uso de una cantidad adecuada de adhesivo para dentaduras postizas permite una retención adecuada de la dentadura postiza; El reemplazo de este adhesivo es necesario una vez al día.

Palabras Clave: *Retención de dentadura; Cresta alveolar; Mandíbula; Adhesivos; Efectividad; Dentadura completa.*

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INTRODUCTION

Severe mandibular ridge resorption often results in discomfort and dissatisfaction with the mandibular denture owing to loss of retention and stability. Residual ridge resorption can either be a normal physiological or pathological process with a multifactorial etiology.[1] A combination of metabolic, mechanical, and anatomical factors plays a significant role in determining the rate at which the resorption occurs.[2] A recent systematic review reported that placement of four-implant supported overdenture prosthesis can lower the rate of residual ridge resorption compared to two-implant overdenture treatment and conventional complete denture prosthesis.[3] However, with the recent global increase in edentulous aging population, conventional complete dentures remain as the forefront treatment option in most developing and third world nation owing to financial constraints.[4] Such situations have led to usage and prescription of denture adhesives to improve mandibular denture retention and stability and increase the patient's confidence in wearing dentures.[5]

Denture adhesives are commercially available as cream, wafers or powder form for application on the impression surface of the denture. Generally, they are made up of synthetic and natural water-soluble polymers, antibacterial agents, preservatives, fillers, wetting agents and flavoring agents.[6] Sometimes alginates or other polysaccharides are added in these formulations. Generally, polymers hydrate when they come into contact with saliva. This increases their volume which helps to fill the voids between the denture and mucosal tissues and the difference in viscosity between the hydrated polymer and saliva helps to increase the denture's retention.[7,8] The synthetic polymers also form molecular cross-links which increase the cohesive forces within the adhesive material.[7,8] Recent improved denture adhesive formulations contain salts, e.g. sodium polyacrylic acid, which may be cross-linked with other polyvalent ions when in contact with water.

Many manufacturers produce and market denture adhesives, each with different recommendations of quantity for use. Several studies have been published in literature regarding the clinical effectiveness of various denture adhesives in improving the denture retention, masticatory function and psychological comfort of the complete denture patients.[9-11]

Grasso *et al.,*[12] studied the effect of denture adhesive on retention of mandibular and maxillary dentures at 0-, 2- and 4-hour period using Fixodent denture adhesive. They reported that the adhesive significantly reduced movement of the maxillary and mandibular dentures during both chewing and biting; and the improvement occurred immediately post-application of the adhesive and was maintained up to four hours of follow-up.[12] However, Duqum *et al.,*[13] systematically reviewed the advantages and disadvantages of denture adhesive use among complete denture patients in 38 studies and highlighted the lack of standardized guidelines for proper use, application, and removal of denture adhesives. Although most published studies provide data on effectiveness of denture adhesive on well-formed ridges, there is certainly a dearth of studies focusing on the effectiveness of denture adhesive on resorbed mandibular ridges.

Knowing the effectiveness of denture adhesives and its required quantity for use among the commercially available products would help the dental clinicians in recommending the appropriate denture adhesive in severely resorbed ridge cases to improve the retention of the denture and thereby improving the quality of life of these patients. So, the aim of this study

was to test the effectiveness of four commer-cially available denture adhesives in different quantities in retaining mandibular complete denture of a severely resorbed mandibular ridge. Therefore, the null hypotheses are set where the quantity of denture adhesive will not affect the retention of mandibular denture; the commercially available denture adhesives will make no significant difference to the retention of mandibular denture.

MATERIALS AND METHODS

Ethical clearance (SEGiEC/SR/FOD/34/2020-2021) was obtained from the Internal Ethical Committee from university before the start of the study.

Fabrication of resorbed mandibular ridge model

A complete clinical examination of a completely edentulous patient was performed. The residual ridge was classified as Type IV resorbed ridge according to American college of prosthodontics (residual vertical bone height of 10 mm or less measured at the least vertical height of the mandible). Preliminary impression was made using stock tray and impression compound (Pyrax, Impression compound). Primary cast was fabricated, and a custom tray was made.

Custom tray was border molded using a low-fusing compound (Kemdent) and definitive impressions were made using zinc oxide eugenol impression paste (SS White). The impression was poured with type IV dental stone to obtain a master cast. The master model was duplicated using silicone (Kemsil Duplicating Silicone) and duplicating flask. Duplicating silicone is an addition cured system commercially available as base and catalyst. The master model was placed in the center of the duplicating flask. Equal parts of base and catalyst were mixed to obtain a homogenous mixture.

It was poured into the flask to fill it completely and allowed to set for 5 minutes. The master model was removed from the flask. The silicone mold was inspected for any voids and was found satisfactory. Self-cure acrylic resin (DPI, Self-cure powder and liquid) was used to make an acrylic model. Polymer and monomer were mixed following the manufacturer's instructions and poured into the mold. The silicone mold was placed over the vibrator for 2 minutes to remove air bubbles, and then allowed to set. The acrylic model was removed from the mold. It was trimmed and finished using acrylic finishing burs (Shofu, Acrylic Contouring & Finishing Kit HP), and finally polished with pumice slurry. This acrylic model avoided wear-related issues arising from repeated testing and cleaning protocols (Figure 1). The mandibular denture base was constructed from heat cured acrylic resin: A layer of modeling wax (Metrowax, No.2 Stretch Toughened Dental Modelling Wax) was adapted over the master cast up to the desired extension to form the denture base and excess was removed.

The waxed-up cast was invested in a dental flask using dental plaster. After dewaxing, heat cure acrylic resin (DPI, Heat cure resin) was manipulated and packed in the dough stage. The dental flask was kept in a curing unit (72°C per 12 hours) for polymerization. The denture base was finished and polished (Shofu, Acrylic Contouring & Finishing Kit HP). Three displacement loops were placed, one on the anterior region and two on the right and left posterior region (Figure 1B). These loops helped to engage the denture base to the testing machine through which the displacing force was applied.

Vertical Displacement Test

The vertical displacement test was conducted according to International Standard Organization ISO 10873:2021. To assess the vertical displacement, a universal testing machine (Victor WAW 100E) was used to apply a vertical displacement force at a cross-head speed of 5 mm/min. The vertical displacement force was

applied to the denture base through rigid steel wires connected to the displacement loop. Rigid steel wires ensured negligible elastic deformation when loading the denture base. In this experiment the force was applied at the anterior and posterior region simultaneously.

Vertical displacement was assessed for 5 different experimental groups; the control (without adhesive) and four different commercially available adhesives (Table 1). To simulate the oral environment, 1 mL of water was applied evenly on the denture bearing surface of the acrylic cast model prior to applying the denture adhesive. Each denture adhesive was tested for quantities of 0.2, 0.4, 0.6, 0.8 and 1.0 g. The denture adhesive mass was weighed to ensure the quantity being tested (Figure 3A). The denture base was coated with the measured quantity of denture adhesive according to the manufacturer's instructions (Figure 1D). and pressed into place with even pressure for 10 seconds by the same operator each time.

The adhesive was then left for 5 minutes before applying the vertical displacement force. For the control group the baseplate and cast were soaked in water for 10 min and an additional 1 mL of water was applied to the edentulous ridge area prior to firmly attaching the denture base into place and loading. The model was secured in the universal testing machine and vertical displacement force was applied by engaging the loops that were attached to the denture base (Figure 1E). The force values that were displayed on the testing machine screen were recorded. The test was repeated 3 times for all the four test materials in different quantities (0.2, 0.4, 0.6, 0.8 and 1.0 g).

Statistical analysis

The test values were entered in a Microsoft Excel (Microsoft Corp., Redmond, WA) spreadsheet for statistical analysis. The statistical analysis was performed using the statistical software SPSS for Windows, version 22 (SPSS Inc, Chicago, IL). The Kruskal Wallis test with post hoc Bonferroni correction was conducted to compare the vertical force displacement values for four denture adhesive materials. Statistical significance level was set ($p<0.05$).

RESULTS

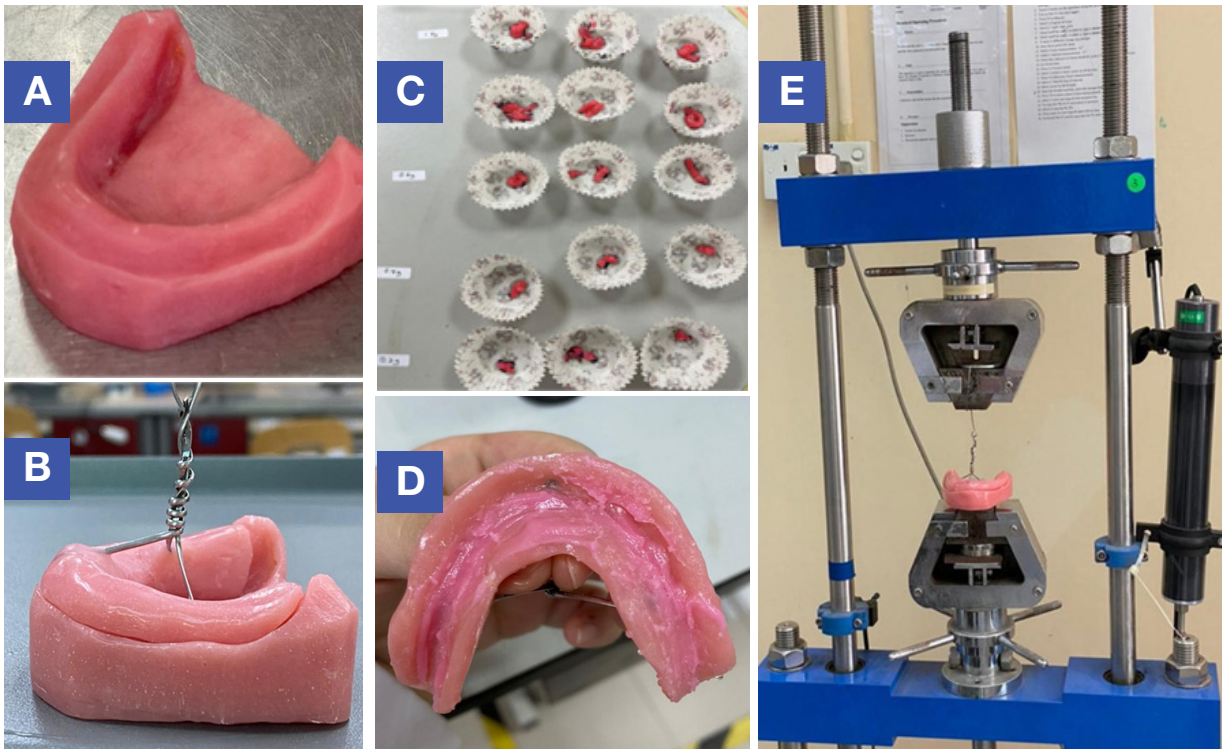
Table 2 shows the Kruskal Wallis test comparing the mean vertical displacement force values at quantities of 0.2g, 0.4g, 0.6g, 0.8g and 1g among four denture adhesives. Statistically significant differences were observed ($p<0.05$) at all tested quantities of denture adhesives except at 0.8g.

Table 3 shows the results of pair wise comparison of mean vertical displacement force values among the four denture adhesives in different quantities. Significant differences were observed for Fixodent at quantities of 0.2g and 0.4g compared to others. At 0.6g, Polident and Fittydent matched Fixodent. Conversely, at 1g, statistically significant differences were observed for Fittydent and Perlie White.

Table 4 shows results of Kruskal Wallis test comparing the mean vertical displacement force values of each denture adhesive in different quantities. Statistically significant differences were observed ($p<0.05$) for each tested denture adhesive when compared between different quantities.

Table 5 showed results of pair wise comparison of the mean vertical displacement force values for each denture adhesive in different quantities. Statistically significant differences were observed for Polident at quantities of 0.8g and 0.6g than other quantities. Similarly, statistically significant

Figure 1. Experimental setup utilized in this study.



A. Edentulous mandibular acrylic model.
B. Mandibular denture base with three displacement loops.
C. Cleaning the outside of the implant-abutment set with a sterile swab containing chlorhexidine gluconate 0.12%.
D. Denture adhesive applied on the denture base following manufacturer's instruction.
E. Edentulous acrylic model secured in the testing machine for vertical displacement force test.

differences were noted for Fittydent at quantities of 1g, 0.6g and 0.8g, for Fixodent at quantities of 0.6g and 0.4g and for Perlie White at quantities of 1g and 0.8g when compared to other quantities.

On analysis, there was a significant difference in the retention of mandibular complete dentures between four commercially available denture adhesives at all amounts except at 0.8 g (Table 2). On pairwise comparisons, Fixodent exhibited greater adhesiveness compared to others at 0.2g and 0.4g. At 0.6g, Polident and Fittydent exhibited equal adhesiveness as Fixodent. But, at 1g, Fittydent and Perlie White exhibited greater adhesiveness than other adhesives. (Table 3)

There was also a significant difference in the retention of mandibular complete dentures between different amounts in all four denture adhesives (Table 4). On pairwise comparisons, 0.8g and 0.6g amounts of Polident exhibited greater adhesiveness compared to others.
Regarding Fittydent, 1g, 0.6g and 0.8g of amounts exhibited greater adhesiveness compared to others.
For Fixodent, 0.6g and 0.4g of quantity exhibited greater adhesiveness compared to others. Regarding Perlie White, 1g and 0.8 g showed greater adhesiveness compared to others (Table 5)

Table 1. Characteristics of the denture adhesives used in the present study.

Denture adhesive Details brand name	Composition	Manufacturer's Recommended Dosage	Manufacturer's
Polident	Sodium Bicarbonate, Citric Acid, Potassium Caroate (Potassium Monopersulfate), Sodium Carbonate, Sodium Carbonate Peroxide, TAED, Sodium Benzoate, PEG-180, Sodium Lauryl Sulfate, VP/VA Copolymer, Aroma, Subtilisin, Cellulose Gum, CI 42090, CI 73015, CI 19140.	For full dentures, not more than 6 strips or about 3 inches in total length.	Stafford- Miller (Ireland) Limited, Waterford, Ireland
Fittydent	Polyvinyl Acetate, Sodium Carboxymethyl cellulose, methylcellulose, Alcohol, Triacetin, Paraffinum Liquidum, Silica.	short strips	Fittydent International, Vienna, Austria
Fixodent	Calcium/Zinc PVM/MA, Mineral Oil, Petrolatum, Cellulose Gum, Silica, Flavor, Sodium Saccharin, Yellow 6 Lake, Red 27 Lake.	short strips	Procter and Gamble Cincinnati, OH
Pearlie White, Singapore	Cellulose Gum, Calcium/Sodium PVM/MA Copolymer, Paraffinum Liquidum, Petrolatum, Aroma, CI 45430.	Short strips	Corlison, Singapore

Table 2. Kruskal Wallis test comparing the mean vertical displacement force values among the four denture adhesives at varying amounts.

Mass	Denture adhesive (n=3)	Mean (N)	Standard Deviation (N)	*p*-value*
0.2 g	Polident	11.6667	2.8867	0.000*
	Fittydent	6.6667	2.8867	
	Fixodent	20.0000	0.0000	
	Perlie White	5.0000	0.0000	
0.4 g	Polident	15.0000	0.0000	0.001*
	Fittydent	13.3333	2.8867	
	Fixodent	21.6667	2.8867	
	Perlie White	10.0000	.0000	
0.6 g	Polident	18.3333	2.8867	0.024*
	Fittydent	18.3333	2.8867	
	Fixodent	25.0000	5.0000	
	Perlie White	13.3333	2.8867	
0.8 g	Polident	23.3333	2.8867	0.052
	Fittydent	16.6667	2.8867	
	Fixodent	16.6667	2.8867	
	Perlie White	16.6667	2.8867	
1 g	Polident	10.0000	0.0000	0.001*
	Fittydent	23.3333	2.8867	
	Fixodent	13.3333	2.8867	
	Perlie White	18.3333	2.8867	

*: Statistical Significance $p<0.05$

Table 3. Pair wise comparison of mean vertical displacement force values among different amounts of four denture adhesives.

Dependent Variable	Denture adhesive *versus* Denture adhesive		Mean Difference (N)	*Sig.*
0.2 g	Polident	Fittydent	5.0000	0.067
	Polident	Fixodent	-8.3333*	0.005
	Polident	Perlie White	6.6666*	0.017
	Fittydent	Fixodent	-13.3333*	0.000
	Fittydent	Perlie White	1.6666	0.754
	Fixodent	Perlie White	15.0000*	0.000
0.4 g	Polident	Fittydent	1.6666	0.754
	Polident	Fixodent	-6.6666*	0.017
	Polident	Perlie White	5.0000	0.067
	Fittydent	Fixodent	-8.3333*	0.005
	Fittydent	Perlie White	3.3333	0.264
	Fixodent	Perlie White	11.6666*	0.001
0.6 g	Polident	Fittydent	.0000	1.000
	Polident	Fixodent	-6.6666	0.175
	Polident	Perlie White	5.0000	0.369
	Fittydent	Fixodent	-6.6666	0.175
	Fittydent	Perlie White	5.0000	0.369
	Fixodent	Perlie White	11.6666*	0.016
1 g	Polident	Fittydent	-13.333*	0.001
	Polident	Fixodent	-3.3333	0.414
	Polident	Perlie White	-8.3333*	0.015
	Fittydent	Fixodent	10.0000*	0.005
	Fittydent	Perlie White	5.0000	0.144
	Fixodent	Perlie White	-5.0000	0.144

***:** Statistical Significance $p<0.05$

Table 4. Kruskal Wallis test comparing the mean vertical displacement force values for each denture adhesive used at varying amounts.

Adhesive (n=3)	Thickness	Mean (N)	Standard Deviation (N)	*p*-value
Polident	0.2 g	11.6667	2.8867	0.000*
	0.4 g	15.0000	0.0000	
	0.6 g	18.3333	2.8867	
	0.8 g	23.3333	2.8867	
	1 g	10.0000	0.0000	
Fittydent	0.2 g	6.6667	2.8867	0.000*
	0.4 g	13.3333	2.8867	
	0.6 g	18.3333	2.8867	
	0.8 g	16.6667	2.8867	
	1 g	23.3333	2.8867	
Fixodent	0.2 g	20.0000	0.0000	0.010*
	0.4 g	21.6667	2.8867	
	0.6 g	25.0000	5.0000	
	0.8 g	16.6667	2.8867	
	1 g	13.3333	2.8867	
Perlie White	0.2 g	5.0000	0.0000	0.000*
	0.4 g	10.0000	0.0000	
	0.6 g	13.3333	2.8867	
	0.8 g	16.6667	2.8867	
	1 g	18.3333	2.8867	

Table 5. Pair wise comparison of the mean vertical displacement force values for each denture adhesive used in different amounts.

Dependent Variable	Denture adhesive *versus* Denture adhesive		Mean Difference (N)	*Sig.*
Polident	0.2 g	0.4 g	-3.3333	0.411
	0.2 g	0.6 g	-6.6666*	0.029
	0.2 g	0.8 g	-11.666*	0.001
	0.2 g	1.0 g	1.6666	0.886
	0.4 g	0.6 g	-3.3333	0.411
	0.4 g	0.8 g	-8.3333*	0.007
	0.4 g	1.0 g	5.0000	0.117
	0.6 g	0.8 g	-5.0000	0.117
	0.6 g	1.0 g	8.3333*	0.007
	0.8 g	1.0 g	13.3333*	0.000
Fittydent	0.2 g	0.4 g	-6.6666	0.102
	0.2 g	0.6 g	-11.6666*	0.004
	0.2 g	0.8 g	-10.0000*	0.012
	0.2 g	1.0 g	-16.6666*	0.000
	0.4 g	0.6 g	-5.0000	0.283
	0.4 g	0.8 g	-3.3333	0.633
	0.4 g	1.0 g	-10.0000*	0.012
	0.6 g	0.8 g	1.6666	0.950
	0.6 g	1.0 g	-5.0000	0.283
	0.8 g	1.0 g	-6.6666	0.102
Fixodent	0.2 g	0.4 g	-1.6666	0.964
	0.2 g	0.6 g	-5.0000	0.359
	0.2 g	0.8 g	3.3333	0.702
	0.2 g	1.0 g	6.6666	0.148
	0.4 g	0.6 g	-3.3333	0.702
	0.4 g	0.8 g	5.0000	0.359
	0.4 g	1.0 g	8.3333	0.055
	0.6 g	0.8 g	8.3333	0.055
	0.6 g	1.0 g	11.6666*	0.008
	0.8 g	1.0 g	3.3333	0.702
Perlie White	0.2 g	0.4 g	-5.0000	0.117
	0.2 g	0.6 g	-8.3333*	0.007
	0.2 g	0.8 g	-11.6666*	0.001
	0.2 g	1.0 g	-13.3333*	0.000
	0.4 g	0.6 g	-3.3333	0.411
	0.4 g	0.8 g	-6.6666*	0.029
	0.4 g	1.0 g	-8.3333*	0.007
	0.6 g	0.8 g	-3.3333	0.411
	0.6 g	1.0 g	-5.0000	0.117
	0.8 g	1.0 g	-1.6666	0.886

*: Statistical Significance $p<0.05$

DISCUSSION

The drive for this study originated from Quiney *et al.,*[14] whose findings highlighted the significant role of adhesive quantity in augmenting denture retention. They suggested that adjusting the amount of adhesive could notably enhance re_ tention in distal extension cases with removable partial dentures (RPD). This study aimed to expand on Quiney *et al.,*[14] work by applying their novel quantitative model to completely edentulous and resorbed mandibular ridges. Our study rejected the null hypotheses, revealing substantial differences among denture adhesive materials when used in quantities of 0.2, 0.4, 0.6, and 1.0 grams.

Previous studies[14-17] comparing com-mercially available denture adhesives have consistently positioned Fixodent as superior to others in terms of retentive properties. Quiney *et al.,*[14] specifically examined Polygrip ultra, Polygrip partial, Fixodent, and Bootsmile, concluding that Fixodent provided superior retention, particularly in mandibular free-end saddle partial dentures within the quantities of 0.2 to 1.0 g range. Our study, focusing on completely edentulous scenarios, echoed these findings, showcasing Fixodent's superior efficiency at quantities of 0.2 and 0.4 grams compared to other materials, albeit with a slight deviation in the optimal adhesive quantity range.

Our results also correlate with an in vitro study conducted by Kore *et al.,*[15] who assessed the tensile bond strength of various denture adhesives over different time intervals, identifying Fixodent as one of the materials with the highest strength. Furthermore, an *in vivo* study by Shamsolketabi et al.,16 focusing on the effect of Fixodent denture adhesive in complete dentures among patients with varied levels of alveolar ridge resorption, found no statistical differences between mild, moderate, and severely resorbed ridge groups.

Literature has noted that composition of the denture adhesive plays an important role in the retentive property of the denture.[7,8] Sodium carboxymethyl cellulose and synthetic poly-mers such as polyethylene oxide, acrylamides, acetic polyvinyl are the key active ingredients that provide the adhesive property.

Most cream-based denture adhesives employ either carboxymethyl cellulose (CMC) or methoxy ethylene maleic anhydride copolymer (PVM-MA) as active ingredients. Some manufacturers, however, use both together as active ingredients to achieve superior adhesive properties. Han *et al.,*[18] demonstrated that CMC has an initial higher adhesive strength than PVM-MA but due to higher solubility it dissolves quickly and loses its effectiveness within a relatively short period. PVM-MA is less soluble, so it lasts for longer duration.[18]

Samples that combined both CMC and PVM-MA not only had higher initial adhesive strength, but also had a longer duration of effectiveness.18 In our present study, all four denture adhesives incorporated both CMC and synthetic copolymers as active ingredients. Despite this similarity, variations in adhesive strength were evident among the tested adhesives. These differences in effectiveness among the four adhesives could not be disregarded.

Quiney *et al.,*[14] in his study indicated that the superior efficiency of Fixodent could be attributed to its composition, which includes si-lica, a component that may alter the viscosity of the gel and reduce moisture, ultimately increasing frictional forces between the saddle and the mucosa. Silica comes in two primary types based on its interaction with water: hydrophilic and hydrophobic. Hydrophilic silica exhibits an affinity for water molecules, promoting better dispersion and potentially enhancing moisture retention. Conversely, hydrophobic silica, due to its altered surface properties, repels water, which

can contribute to reduced moisture content in the adhesive.[19] These distinctions in surface properties significantly impact the adhesive's behavior and its efficacy in providing enhanced friction and retention between th

e denture and oral tissues.[19] The choice of silica type in denture adhesives is pivotal, influencing their performance within the oral cavity. Upon examining the composition of adhesive materials in the current study, silica emerged as a constituent in two adhesive products: Fixodent and Fittydent. While Fittydent exhibited lower efficiency at quantities of 0.2 and 0.4 grams, it surprisingly demonstrated superior effectiveness at 0.1 grams. This finding is similar to previous studies by Koppang *et al.,*[20] Koronis *et al.,*[21] and Manes *et al.,*[22] all of which favored Fittydent as the most preferred adhesive, consistently yielding optimal results over time.

Zinc is a common ingredient added in the denture adhesive to enhance the adhesive property. It is also known to reduce inflammation, bacteria, and plaque accumulation, but its deficiency in the elderly can lead to immune dysfunction and can contribute to risk and progression of Alzheimer's disease.[23] Prolonged excessive use of denture adhesives has resulted in zinc toxicity among the denture wearers. López-García *et al.,*[24] compared the cytotoxicity of six commercially available denture adhesives on human gingival cells and reported that denture adhesives containing zinc in their composition could be responsible of the decrease of cell viability, reactive oxygen species production, aberrant cell morphology, and induction of apoptosis and cell death.

Overuse of denture adhesive have reported to cause copper deficiency as excess zinc prevents absorption of copper from the gut.[25,26] In turn copper deficiency can result in bone marrow suppression and neurological dysfunction.[27] These complications associated with overuse of denture adhesive are as a result of improper guidance or instructions from the clinicians to denture patients regarding the usage.

The manufacturer's instructions for dosage and use vary for each commercially available product. Since instructions regarding the dosage are unclear in most products and it is seemingly difficult for clinicians to follow. Recent denture adhesive products are reported to be manufactured without zinc and claiming to be safer however recommending appropriate dosage for effective usage is every clinicians responsibility for implementing safe health care practices among geriatric patients.

The inherent *in vitro* design of this study stands as a notable limitation, as the outcomes might not fully represent the complexities of the biological oral environment. Denture adhesives are formulated to interact with saliva in the patient's mouth, benefiting from constant moisture and body temperature. The use of water to simulate hydration in this experiment may have altered the adhesive behavior, potentially impacting the observed results. Moreover, conducting the experiment at room temperature rather than at body temperature, as encountered in the oral cavity, could have influenced the effectiveness of the denture adhesives. These deviations from the oral environment's physiological conditions underline the need for caution in directly extrapolating these findings to real-world clinical scenarios. In addition to the previously mentioned constraints, it's crucial to highlight the limitations associated with assessing adhesives solely on acrylic surfaces, which inherently differ from the properties of soft oral tissues. This discrepancy in surface characteristics might not fully represent oral environment adhesion dynamics.

Moreover, the absence of consideration for various physiological variables, such as muscle movements within the oral cavity, presents

another limitation. These unaccounted-for factors hinder the direct extrapolation of study results to clinical applications. Addressing these limitations underscores the need for future research to encompass a broader spectrum of variables, including evaluations on soft oral tissues and consideration of physiological dynamics, to provide more accurate and clinically applicable insights into denture adhesive performance.

It is notable that despite the abundant evidence in the literature highlighting the potential overuse of denture adhesive, there remains a striking absence of clinical research dedicated to this critical aspect. Future investigations should prioritize well-designed prospective studies aimed at evaluating the clinical implications of prescribing varied dosages of commercially available denture adhesives. This imperative research would shed light on the practical efficiency and appropriate usage of these products in clinical settings.

CONCLUSION

Within the limitations of the present study, the following conclusion can be drawn:

1. There was a significant difference in the retention of mandibular complete dentures between four commercially available denture adhesives at 0.2, 0.4, 0.6 and 1g of mass.

2. Greater adhesiveness was exhibited by Polident at 0.6g and 0.8g, Fittydent at 0.6g, 0.8g and 1g, Fixodent at 0.4g and 0.6g and Perlie White at 1g and 0.8g of adhesive mass.

3. These results may better inform clinicians on best practice and may be beneficial to complete denture patients with severely resorbed mandibular ridge.

CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Study was approved by the SEGi University Ethics Committee, Authorization's number/code: SEGiEC/SR/FOD/2018-19/10

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PEER REVIEW

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