Original Article

pISSN, eISSN 0125-5614
M Dent J 2017; 37 (1) : 37-45

Effect of three repairing materials on the flexural strength of repaired heat-cured acrylic resin denture base material

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Objectives: To investigate the effect of different materials and repairing techniques on the flexural strength of heat-cured acrylic denture bases.

Materials and methods: Seventy-five specimens of Probase Hot with rectangular shape (63x10x3mm.) were processed according to manufacturer's instruction. Only three specimens were intact, the remaining was further divided into two main groups (n=36) by repairing using small gap (2/10mm) and big gap (9/17mm). In each group, three brands of repairing materials Kooliner (GC America Inc), Tokuyama Rebase Fast II (Tokuyama Co., Ltd, Tokyo, Japan), and Unifast Trad Pink (GC America Inc) were used to fill in the gap (n=12). Prior to testing, all specimens were immersed in distilled water at 37°C for 43±2h. The flexural strength of intact and repaired specimens was calculated using three-point bending test with Shimadzu Universal Testing Machine. Two-way ANOVA was used to analyze the data at α=0.05. Simple effect test was also used to identify a significant difference of pairs.

Results: There was an effect of materials and repairing techniques on the flexural strength of acrylic denture bases. Unifast Trad Pink showed the highest repair strength among all materials, while repair using larger gap displayed higher repair strength than that with smaller gap. However, there was no significant difference in term of repairing technique in the group repaired with Tokuyama Rebase Fast II. The flexural strength of all repaired specimens was lower than that of intact specimens.

Key words: Autopolymerizing resin, denture base materials, flexural strength, repairing techniques, repairing materials, three-point bending test

How to cite: Kay SC, Kanchanavasita W, Wonglamsam A. Effect of three repairing materials on the flexural strength of repaired heat-cured acrylic resin denture base material. M Dent J 2017; 37: 37-45.

Introduction

For those who lost their teeth either partially or completely, they may require some kinds of removable prosthesis such removable partial denture and complete denture. A recognizable and well-known material to fabricate these types of dental prosthesis is polymethylmethacrylate (PMMA) [1]. Even though, long term service of denture base has been reported previously [2,3], but they are not quite stable. They changed overtime because of various degree of alveolar bone resorption, poor management of occlusal force, which result in being loose. Even worse, they were broken as a consequence of poor processing or denture wearers themselves. Another reason is low fracture strength of acrylic denture base. Some literature reported that denture fracture happened twice as more frequent in maxillary as in mandibular prosthesis [4,5]. Therefore repairing is a good solution for treatment or even it is indicated if there were slight modifications and the denture was still in good condition; because making a new denture is time-consuming and costly. By repairing, denture

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Received : 16 December 2016 Accepted : 8 March 2017

base could return back to be closely adapted with underlying tissue and help patient to function properly. Moreover, repairing materials have to fulfill some requirements: reasonable strength, color stability, rapid, dimensional stability, and cost-effectiveness.

Repairing denture base could be accomplished either directly or indirectly; or either temporary or definitive. The indirect method, the denture has to be delivered to laboratory for further processing, being time-consuming and costing are all its disadvantages. The direct method, unlike the indirect one, using an autopolymerizing acrylic resin which is easy and inexpensive but negative effects are unpleasant smell, bad taste and soft tissue irritation due to its monomers [6-8]. Therefore chair-side repairing materials with alternative monomer could overcome all these shortcomings. There are many material used for chair-side repairing and their physical and mechanical properties vary according their chemical compositions.

In repairing modality, some defect parts of PMMA denture base will be replaced by other materials, resulting in two materials that may be different in compositions. Some studies reported that different compositions in acrylic denture base would alter mechanical property of PMMA [9,10]. They vary from 95% with autopolymerizing resin to 34%-44% with relined materials in term of bonding strength [10]. Poor bonding at this interface will result in microleakage facilitating bacterial adhesion, staining, or even worse, delamination [11]. According to Mustafa [12], molecules of some materials used in relining denture base cannot penetrate into swollen layers of denture base due to its bigger size. Therefore the materials which have similar compositions both physically and chemically may increase bonding strength at the interface of repairing materials and PMMA denture base.

Materials and methods

Materials used in this study are presented in Table 1.

Table 1 materials used in this study

Product	Polymer	Monomer	Manufacturer	Powder/liquid Ratio	Polymerization condition
Kooliner® (repair material) (Figure 3.1)	Polyethyl methacrylate	Isobutyl methacrylate	GC America Inc	2.1 g/ 1.5 ml	10 min at environmental temperature
Unifast trad Pink® (repair material) (Figure 3.2)	PMMA	MMA	GC AMERICA INC	1 g/ 0.5 ml	Manipulation should be finished before 2 min.
Tokuyama rebase fast® (repair material) (Figure 3.3)	Polyethyl methacrylate	MAOP, 1,6-HDMA	Tokuyama Co., Ltd, Tokyo, Japan	2.056 g/1 ml	5.5 min at environmental temperature
Probase Hot® (denture base material) (Figure 3.4)	PMMA	MMA	Ivoclar, vivadent Liechtenstein	23.4 g/ 10 ml	Heat polymerized for 7 hrs at 70°c and 1 hr at 100°c

1. Specimen preparation

To obtain an acquired shape a rectangular bar made of stainless steel with a dimension 64mm x 11mm x 4mm, was fabricated. With a sandwich technique, the metal pattern will be invested in dental stone type 4, using denture processing Hanau flask. Then specimens was prepared and mixed according to the manufacturer's instruction with powder/liquid ratio 24.3g/10ml. Until becoming dough, the resin was poured into the stone mould. Lower half of the flask was covered with polyethen sheet and upper half was joined face to face with upper flask. The flask was placed under bench press for 10min to remove excess acrylic resin. This process was repeated until there is no excess resin coming. The flask was fixed with knots and rings, and placed in water bath at 70°C for 90min and heated up 100°C for 30min. After polymerization, the flask was bench cooled at environmental temperature for 30min and under running water for 15min prior to resin removal from the flask. The 400 grit sand paper was used to remove irregularity at the edge of the bar and then the bar was stored in distilled water at 37°C for 43±2h. After water storage, specimen dimension will be verified with a digital caliper (Mitutoyo, Japan). The total amount is 75 specimens.

2. Repair specimen preparation

Three specimens of acrylic denture base materials remained intact. The rest was divided into 6 groups, 12 specimens per each, were prepared by the following:

- Three groups of the specimens had a convergent 45° bevel with a space at the upper edges and lower edges 10mm and 2mm respectively according to the mold design.
- Other three groups were done by the same procedures but the space of upper edges is 17mm, and that of lower edges is 9mm.

The repaired surface was polished with 240 grit sand paper and stored in distilled water at 37°C at 43±2h. Then the repairing was carried out by placing the specimens into the same (64mm x 11mm x 4mm) gypsum mould and the repairing materials was mixed (10 specimens per group) accordingly and placed into the space in the mould. To simulate clinical reality, the mould was placed in water bath at 37°C for 10min. Prior to testing, the specimens was polished with 600 and 1000 grit sand paper(during the polishing procedure, a 64mm x 11mm x 4mm was polished into a 63mm x 10mm x 3mm) and immersed in distilled water at 37°c for 43±2h.

3. Intact repair specimen preparation

The same stainless steel mold with the same dimension was used again. The process was repeated as in specimen preparation. Then repair material was packed according to manufacturer's instruction in Table 1. After polymerization, the specimen was polished with 400, 600, and 1000 grit sandpapers respectively. Subsequently, repair specimens were immersed in distilled water at 37°C for 43±2h before flexural testing. The total specimens are 9, 3 per each group.

4. Flexural strength testing

All specimens were broken under flexural strength testing jig by using Instron universal testing machine with a three-point bending at the cross speed 5mm/min. The distance from the specimens to support was 50mm. The fracture force was recorded in Newtons (N). The flexural strength of each specimen was calculated (MPa) using the formula: $FS = 3\ FL/2bh^2$, where FS is the flexural strength, F the maximum load before fracture or at the proportional limit, L the distance between the supports (50 mm), b the width of the specimen (mm), and h is the thickness of the specimen (mm).

Modes of failure identification

After the specimens were broken, they were inspected by naked eyes to identify the mode of failure. There were 3 types of mode of failure: cohesive, adhesive, and mix types of

failure. Cohesive failure occurred when there was a fracture at either PMMA or repairing materials. Adhesive failure occurred when there was a fracture at the interface between PMMA and repairing materials. At last, mix types of failure occurred when there was a combination of those two materials (Figure 1, 2, 3).

5. Statistical analysis

Shapiro-Wilk test and Levene's test was used to determine the normality of data distribution and equality of variance for each group. Two-way ANOVA was used to analyze all the data at α=0.05, and Turkey's test was used to compare between groups.

Results

The data of all groups were normally distributed. Therefore, two-way ANOVA was utilized to find the significant difference among them. There was significant difference for repairing techniques ($P < .05$), repairing materials ($P < .05$), and interaction among them as well ($P < .05$).

The mean and standard deviation values of flexural strength of controlled and experimental groups are summarized in Table 2.

The failure modes of all specimens in all groups were presented in Table 3. With accomplishment of statistical analyses, the result

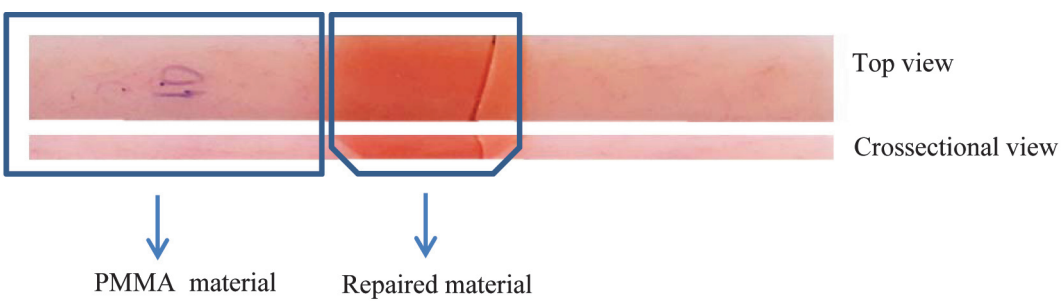

Figure 1 Illustration of cohesive failure in which fracture occurred at repairing material.

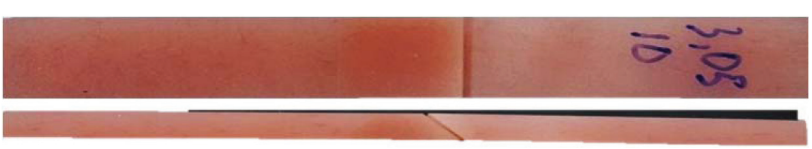

Figure 2 Illustration of adhesive failure in which fracture occurred at the interface

Figure 3 Illustration of mix type of failure in which fracture occurred in both repairing material and the interface.

revealed that there was significant difference among the three materials (Unifast pink, Tokuyama rebase fast II, and Kooliner) used to repair PMMA specimen (Probase hot). The Unifast pink, exhibited the highest flexural strength, followed by Tokuyama and Kooliner was the least one. However, the flexural strength value of all repairing materials was still lower than that of pure PMMA (controlled group).

In addition, gap size had also an effect on flexural strength of Probase hot repaired with Unifast pink and Kooliner. The big gap mean displayed higher than the small one. The only exception was seen for Tokuyama rebase fast II whose flexural strength mean of both big and small gap were about similar.

As can be seen in the Table 3, there were three different modes of failure among the three materials. The failure mode of Kooliner was all adhesive. In contrast, there was a combination of modes of failure for the other two materials, excepting that no cohesive failure occurred in both small and big gap sizes of Probase hot repaired with Unifast pink.

Table 2 Mean and standard deviation value of flexural strength of controlled and experimental groups

Treatment groups		Materials							
		PMMA		Unifast Pink		Tokuyama rebase fast II		Kooliner	
		Mean (MPa)	Sd (MPa)	Mean (MPa)	Sd (MPa)	Mean (MPa)	Sd (MPa)	Mean (MPa)	Sd (MPa)
Controlled groups (n=3)		77.63	7.83	52.63	2.49	35.24	0.45	37.86	2.31
Experimental groups (n=24)	Small gap (2/10mm) * (n=12)	n/a	n/a	32.80	4.10	18.97	3.25	9.97	1.99
	Big gap (9/17mm) ** (n=12)	n/a	n/a	41.40	4.79	19.89	2.78	13.78	2.47

*upper width is of 2mm. and lower width is of 10mm.

**upper width is of 9mm. and lower width is of 17mm.

Table 3 Failure modes of all groups of specimens

Gaps	Materials(repaired)								
	Unifast Pink (n=24)			Tokuyama rebase fast II (n=24)			Kooliner (n=24)		
	Cohesive	Adhesive	Mix	Cohesive	Adhesive	Mix	Cohesive	Adhesive	Mix
Small	0% (0)	83.33% (10)	16.67% (2)	0% (0)	91.66% (11)	8.34% (1)	0% (0)	100% (12)	0% (0)
Big	0% (0)	75% (9)	25% (3)	16.67% (2)	83.33% (10)	0% (0)	0% (0)	100% (12)	0% (0)

Discussion

Unifast Trad Pink (GC America Inc), Tokuyama rebase fast (Tokuyama Co., Ltd, Tokyo, Japan), Kooliner (GC America Inc) were selected and all materials are autopolymerized. They were chosen to find out which materials would provide better strength in repairing with Probase Hot (Ivoclar, vivadent, Liechtenstein) as heat-cured polymerized denture base material. All materials chosen in this study are chemically-cured resin because they provided more superior strength and faster compared to other types of resin according to previous studies [17,19]. Even though there was a study [20] reported that using microwave polymerized resin to repair offers better strength but the disadvantage is to need more extra equipment (microwave system).

In this experiment, the result revealed that Unifast Trad Pink showed the most superior repair strength among all materials. However their repair strength value (narrow width 32.80MPa, broad width 41.40MPa) were still lower than those of intact specimen itself and original strength PMMA, 52.63MPa and 77.63MPa respectively. This finding was in agreement with two studies [13,23] that reported that strength of PMMA repaired with autopolymerized resin was of 60% to 65% of the intact material. In contrast, some authors [15,24,25] gave the opposite statement that their repair strength was about similar. This could be explained that a chemical substance had been used to treat cutting surface PMMA prior to perform the repairing.

Moreover, during testing in this group (Unifast Trad Pink), none of the specimens was fractured cohesively. Adhesive failure occurred predominantly, ten specimens (83.33%) and nine specimens (75%) from small gap and big gap respectively. This indicates that the weakest point was at the interface between repair resin and PMMA denture base material. This happened because of two reasons. First, there were no additional neither chemical nor mechanical means used in this repair except 45 degree bevel of repaired surface of PMMA to expand surface contact. Second, during polymerization of self-cured resin whose an initiator system causes a low degree of conversion [21].

Kooliner was the material which displayed lowest bond strength with denture base specimen. This poor bond strength between PMMA and Kooliner was even more clarified by the fact that all specimens were broken at the interface, purely adhesive. Bunch J et al [7] also detected the same result although Kooliner was used as a reline material. In comparison to the strength of its intact specimens (37.86MPa), its repair strength mean with Probase Hot is of 26.33% (9.97MPa) and 36.39% (13.78MPa) with the small gap and big gap accordingly. The difference in molecular structure and composition probably was an answer to this result. For Tokuyama rebase fast II, though the flexural strength of control specimens was slightly lower than that of Kooliner but its repair strength was higher than Kooliner. Both Tokuyama rebase fast and Kooliner are relined resins but their chemical compositions are different. The monomer of Tokuyama rebase fast is Methacryloyloxyethyl propionate (MAOP) and 1.6- Hexanediol dimenthacrylate (1.6-HDMA). That of Kooliner is isobutyl methacrylate (IBMA). A literature [26] reported molecular weight of MMA, IBMA, and 1.6 HDMA is 100.12, 142.20, and 254.33 respectively. It was suggested that [18] adhesive mechanism of autopolymerizing resin with the denture base materials occurred through two phenomenon penetration and diffusion. Therefore lower molecular weight would facilitate a stronger bonding of repair resin and denture base material. Unifast Triad Pink contains MMA as a monomer resulting to higher repair strength than the other two as the result demonstrated. Regarding to higher molecular weight of Kooliner than Tokuyama rebase fast, yet content of residual monomer after

polymerization of Kooliner was superior than that of Tokuyama according to a former study [27]. The residual monomer, caused by low degree of conversion, played role as a plasticizer which would be a negative effect on mechanical property of denture base material [27,28].

Statistically, there was a significant difference, in term of repair gap, occurred in the group PMMA repaired with Unifast Trad Pink and Kooliner but not with Tokuyama. Repair width of resin base material could be considered as a contributing factor to the stress concentration in repaired part. It was reported in the literature [13] that rate of deflection was decreased by 20% if the gap space was 1.5mm compared to 3mm. Even though Beyli and von Fraunhofer [14] recommended that repair space should not be more than 3mm but they found that there was no significant different of flexural strength means from 1-5mm gap. The reason was to minimize color difference between repaired and denture base materials. Unlikely, by this experiment, bigger gap was found to be stronger than smaller gap. These two different findings might be probably explained by two reasons. Firstly, the large gap used in this experiment was 10mm and that of Beyli was 5mm. Secondly, surface joint of this study was 45 degree bevel and the previous study used butt joint. Thean et al [29] stated that repair space wider than 3mm might be responsible for pure cohesive failure. However, this current study found that among all groups with wider gap there was no cohesive failure occurred except two specimens repaired with Tokuyama. This outcome was supported by Rached et al [20] who demonstrated that cohesive fracture was less likely to happen with 10mm gap repair. Similarly, the same author Rached et al reported that with improvement at the interface of repaired and denture base materials by chemical treatment, none of the specimens fractured in the repaired material (cohesive type). Plus, another study [30] performed a 3-mm gap repairing with autopolymerizing resin and the cutting surface also was treated by the same chemical substance as in previous study [20]. The result showed that all the specimens were broken purely cohesive.

Surface contact is one of the factors involved in mechanism of adhesion. The more the surface contact area the more the adhesion will be improved. In this study, the selected surface design for repairing was 45° bevel. An author [16] claimed that surface contact area for butt joint, 45° bevel, and rounded joint are 50 mm^2, 72 mm^2, and 78.5 mm^2 respectively. To verify this, Ward et al [22] conducted a study to compare bonding strength of these three surface designs. He found that the butt joint surface displayed lower value than other two and there was no significant different between 45° bevel and rounded joint. As being clinically convenient and homogeneity of fabricating all specimens, 45° bevel has been selected.

Intact specimens of Tokuyama rebase fast and Kooliner were not fractured during 3-point bending testing. As this happened, at certain point the load to cause specimens failed did not increase while the deflection increased continuously resulting in specimen slipping from support bar. To prevent this from happening, testing was observed and stopped at the point when the load stopped rising. According to ASTM D790-02, for those specimens which did not break during testing, strain up to 5% will be used to calculate the flexural strength. By calculation using strain up to 5%, the deflection on the graph was about 7mm. Only Tokuyama rebase fast intact specimens which showed deflection more than 7mm on the graph. Therefore this rule applied only in this group.

Limitation of this in vitro study was lack of aging process and thermo-cycling test. Moreover, the three point bending test rather than actual complicated masticatory force was used and the configuration of specimens used in this study did not reflect the real shape of denture. All these feed-backs limit the ability of this study to predict

the success of materials and techniques in the real clinical situation. Therefore, further research should focus more on the simulation of complexity of functional force in the mouth with actual shape of denture; and the aging and thermo-cycling test should be included as well.

Acknowledgement

I would like to thank my advisor and co-advisors for their contribution in this study.

Funding: None
Competing interests: None
Ethical approval: None

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