

Flexural strength of relined denture base using different thickness of self-cured relining material

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Objectives: To evaluate the flexural strength of a heat-cured denture base polymer relined with different thickness of self-cured relining materials.

Materials and methods: Two different thickness ratios (1.5:1.5 and 2:1) of one heat-cured denture base polymer (ProBase Hot) to three self-cured hard relining materials (Kooliner PEMA, Tokuyama Rebase II PEMA and Unifast Trad PMM) were examined. Three point bending flexural test was applied on the relined specimens (64mm × 10mm × 3mm) and on intact specimens of similar dimension with 3, 2 and 1.5 mm thickness. Each specimen was immersed in 37±1°C distilled water for 43±2 hours prior to relining and testing. Statistical analysis was performed using one-way ANOVA and Tukey's HSD post-hoc test ($\alpha = 0.05$).

Results: There were significant differences in flexural strength among denture base relined with different materials, in both thickness ratios. The specimens relined with Unifast Trad possessed the highest flexural strengths (60.77 ± 5.88 MPa), while those relined using Tokuyama Rebase II displayed the lowest strength (40.55 ± 1.04 MPa). No significant differences were found when ProBase Hot was relined with different thickness (1.5mm and 1mm) of Tokuyama Rebase II (40.55 ± 1.04 MPa and 44.25 ± 1.79 MPa), Kooliner (45.80 ± 2.25 MPa and 50.20 ± 2.95 MPa), and Unifast Trad (60.77 ± 5.88 MPa and 60.77 ± 5.88 MPa).

Conclusions: Self-cured hard relining materials have an effect on the flexural strength of relined denture base. Flexural strength of denture base relined with PMMA is higher than that relined with PEMA. Different thickness ratio of denture relining polymer had no effect on the flexural strength of relined denture base.

Key words: denture base polymer, flexural strength, relining denture base, thickness ratio

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Introduction

Existing removable prostheses dentures become loose over the period of time because of the continuous progressive alveolar bone resorption and bone remodeling of edentulous ridge [1-3]. In addition, the processing of alveolar bone resorption may compromise the adaptation of a dental prosthesis in some areas of the oral mucosa. The poor-fitting denture will move to any

direction resulted in mucosal trauma, contribute to compromised function and rapid residual ridge reduction [4-6]. For this reason, denture must be evaluated periodically. Denture relining material could be used to recover the existing prosthesis adaptation to the patient's oral mucosa by the technique which performed directly in the patient's mouth (with auto-polymerizing resin) or indirect technique in a laboratory (with heat-polymerizing resin). Direct relining of denture base is carried out

with the auto-polymerizing acrylic resin to improve the fit of denture base and maintaining the prosthesis- tissue relationship [7]. Generally, removable prosthesis made of poly (methyl methacrylate) (PMMA), which has reliable with resins containing MMA. Some studies reported that acrylic monomers with different chemical compositions presented lower bond strength of PMMA denture base polymer [8-10]. The widely use of the materials to relined denture is an acrylic resin polymer that similar to the original denture base material. An important property of denture relined materials is adequate mechanical strength [11,12].

Over the last two decades, there were many numbers of studies [11-19]. have been investigated the effect of relining materials on flexural strength of denture base by using different types of relining materials. Measurement the flexural strength of denture base material is always taken through flexural test and using a three point bending test, specimen was bend under one loading nose [11-19].

Some studies have demonstrated the flexural strength of relined denture bases lower than the intact denture base and significantly decreased flexural strength of denture base after relining [11,14-16]. However the information that showed flexural strength value of relined denture base by using the different thickness ratio of relining material to existing denture base are still limited.

Objective of this present study was to evaluate the flexural strength of heat-cured denture base when relined using three self-cured hard relining materials with 2 thickness ratios.

Materials and Methods

One heat-cured denture base polymer and three self-cured hard relining materials were used in this investigation. The manufacturers, fabrication process, mixing proportions of powder to liquid,

mixing and working time, and curing procedures of these materials are listed in Table 1.

Four different size of the metal molds (64.5 mm × 10.5 mm × 3.5 mm , 64.5 mm × 10.5 mm × 2.5 mm, 64.5 mm × 10.5 mm × 2 mm and 64.1 mm × 10.1 mm × 3 mm) were used and mounted with dental stone type III into the dental flasks. Three different thickness of intact specimens of ProBase Hot(Ivoclar Vivadent, Schaan, Liechtenstein), Tokuyama Rebase II (Tokuyama Dental , Tokyo, Japan), Kooliner (GC America Inc., IL, USA) and Unifast Trad (GC Corporation, Tokyo, Japan) in size of 64 mm × 10 mm × 3 mm, 64 mm × 10 mm × 2 mm and 64 mm × 10 mm × 1.5 mm were fabricated by using the metal mold size 64.5 mm × 10.5 mm × 3.5 mm, 64.5 mm × 10.5 mm × 2.5 mm and 64.5 × 10.5 × 2 mm, respectively. The intact specimens were served as control groups (n=3). All materials were manipulated according to the manufacturers. After polymerization, each specimens was polished with standard metallographic paper number p500, p1000, p1200 to make all surfaces of specimen smooth before testing. Then all those specimens were immersed in 37 ± 1°C distilled water for 43 ± 2 hours before testing the flexural strength.

Thirty-six specimens in the size of 64 mm × 10 mm × 2 mm and the another thirty-six specimens in the size of 64 mm × 10 mm × 1.5 mm of ProBase Hot were fabricated from stainless steel molds with cavity 64.5 mm × 10.5 mm × 2.5 mm and 64.5 mm × 10.5 mm × 2 mm, respectively. Each thirty-six denture base specimens was divided into three sub-groups (n=12). Each sub-group specimens was prepared for relining with three different self-cured hard relining materials. After polymerization, the specimens were wet polished with p500 grinding paper to obtain the desired dimension. The superior surface of specimen which to be relined was polished with p120 grinding paper to create retention for the relining materials. Six groups of denture base specimens were immersed in 37 ± 1°C distilled water for 43 ±

Table 1. Materials used in this investigation

Material	Manufacturer	Processing procedure	Powder-liquid ratio	Mixing time	Working time	Curing procedure
ProBase Hot (PMMA)	Ivoclar Vivadent Schaan, Lichtenstein	Heat-cured compression molding	2.25g : 1ml	10 mins. (including time for leaving mixture to become dough stage)	20 mins.	Standard procedure (recommended procedure). Place mold in cool water, heat up 100 °C and boil it for 45 minutes.
Tokuyama Rebase II Fast (PEMA)	Tokuyama Dental Corporation, Tokyo, Japan	Self-cured	2.4g : 1ml	5-10 seconds	20 -60 seconds	Apply adhesive to the surface of denture. Mix powder into liquid and then apply the mixture on denture surface. It will be set in 6-8 minutes. Then Prepare Tokuyama Resin Hardener II and immerse the relined denture for 3 minutes.
Kooliner (PEMA)	GC America Inc, IL, USA	Self-cured	2.5ml : 1ml	No more than 30 seconds	1-2 mins.	Mix powder into liquid slowly and then spread the mixture over the area to be relined, wait about 10 mins until it set.
Unifast Trad (PMMA)	GC Corporation, Tokyo, Japan	Self-cured	1g : 0.5ml	10-15 seconds	2 mins	Mix powder into liquid and then apply the mixture on denture surface. Then wait until it reaches setting time.

2 hours. After water storage, each specimens was placed into the metal mold with a cavity 64.1mm×10.1mm×3mm in dimensions, relined with hard relining material to made 3mm thickness specimen. Each self-cured hard relining materials (Tokuyama Rebase II, Kooliner and Unifast Trad) was mixed according to the manufacturer's instruction. The mixture of each relining materials

was applied to the superior surface of ProBase Hot which polished with p120 grinding paper. Then, each relined specimens was polished with 500, 1000, and 1200 grinding paper on the grinding machine to get smooth surfaces. The dimension of relined specimens were 64mm×10mm×3 mm. The relined specimens were stored in 37±1°C distilled water for 43 ± 2 hours

before testing.

Flexural strength testing was carried out by applying a three-point bending test in a Universal testing machine (Model EZ-S, SHIMADZU, Japan, Load Cell<500N). Each specimen was taken from the distilled water, measured with a digital caliper (Mitutoyo, Japan) to verified the dimension, then immediately placed on the flexural test supporters which immersed in 37 ± 1 °C water bath. The testing was designed by placing the surface of the ProBase Hot face down to receive the tensile stress as showed in Figure 1. A vertical load was applied at the midpoint of each specimen at a crosshead speed of 5mm per minute on a load test machine until the specimen break down. The highest load at the time of specimen break down was recorded in the computer program and used equation below to calculate the value of flexural strength.

$$\sigma = \frac{3FL}{2bh^2}$$

σ was the flexural strength of specimen (MPa). F was maximum load exerted on the specimen at the time of fracture (N), L was the distance between two supports (mm), h was the

height of specimen measured immediately prior to water storage (mm) and b was the width of specimen measured immediately prior to water storage (mm).

The statistical analysis was done by SPSS for windows version 16.0. Normality of the data was determined by the Shapiro-Wilk test. The homogeneity of variances was carried out by using Levene's test. One-way analysis of variances (ANOVA) was applied to analyze all data at $\alpha = 0.05$. Tukey's HSD post-hoc test was used for comparing the mean of flexural strength of each relined groups at $\alpha = 0.05$.

Results

The mean and standard deviation values of flexural strength of six relined groups (n=12) are presented in Table 2. Flexural strength of all control groups (n=3) are showed in Table 3.

Data distribution of all groups were normal ($p>0.05$). Therefore, One-way ANOVA was utilized to detect the effect of differences in thickness ratio and relining materials on the flexural strength of relined denture base. There was significant difference in flexural strength among six relined

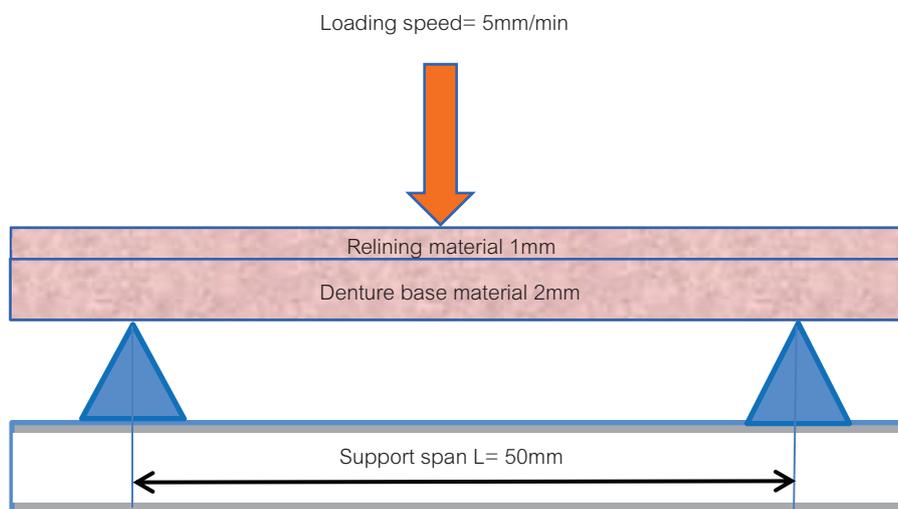


Figure 1. Configuration of three point bending test for 2:1 thickness ratio relined specimen

groups ($p < 0.05$). Tukey's comparison test revealed that the flexural strength of three relined materials were significantly different ($p < 0.05$). There were no significant differences for different thickness of ProBase Hot (1.5mm and 2mm) when relined with different thickness (1.5mm and 1mm) of Tokuyama Rebase II (40.55 ± 1.04 MPa and 44.25 ± 1.79 MPa), Kooliner (45.80 ± 2.25 MPa and 50.20 ± 2.95 MPa), and Unifast Trad (60.77 ± 5.88 MPa and 60.77 ± 5.88 MPa) as presented in Table 2 and Figure 2. The relined group with Unifast Trad possessed the highest flexural strengths (60.77 ± 5.88 MPa), while Tokuyama Rebase II displayed the lowest strength ($40.55 \pm$

1.04 MPa) as shown in Table 2.

Discussion

The strength of relined denture base polymer depended on the strength of both denture base polymer and relining material, and the bonding strength between denture base and relining material [11]. Many commercial self-cured hard relining materials have been investigated and claimed for their superior physico- mechanical properties [20-22], including their bond strength to acrylic resin denture base [8,23,24]. Nowadays,

Table 2. Means and standard deviations of flexural strength of six relined groups (n=12)

Relined Group	Flexural Strength (MPa)
	Means \pm SD
ProBase Hot 1.5mm + Tokuyama Rebase II 1.5mm	40.55 ± 1.04^a
ProBase Hot 2mm + Tokuyama Rebase II 1mm	$44.25 \pm 1.79^{a,b}$
ProBase Hot 1.5mm + Kooliner 1.5mm	$45.80 \pm 2.25^{b,c}$
ProBase Hot 2mm + Kooliner 1mm	50.20 ± 2.95^c
ProBase Hot 1.5mm + Unifast Trad 1.5mm	60.77 ± 5.88^d
ProBase Hot 2mm + Unifast Trad 1mm	60.77 ± 5.88^d

Means with superscript of the same letter indicate no significant difference ($p > 0.05$)

Table 3. Flexural strength of all control groups (n=3)

Materials	Thickness (mm)	Flexural Strength (MPa)
		Means \pm SD
ProBase Hot (PMMA)	3	72.00 ± 2.80
	2	65.39 ± 5.04
	1.5	54.51 ± 2.28
Unifast Trad (PMMA)	3	53.08 ± 1.85
	2	50.61 ± 1.91
	1.5	43.86 ± 1.59
Kooliner (PEMA)	3	30.94 ± 2.10
	2	23.05 ± 2.88
	1.5	10.74 ± 1.05
Tokuyama Rebase II (PEMA)	3	29.95 ± 1.14
	2	24.97 ± 0.52
	1.5	19.02 ± 1.85

a newly developed elastic and resilient relining resin, which consists of non-MMA-based monomers, generates less heat during polymerization and produces less irritation to oral mucosa when compared to conventional relining materials. [14,25] In this study, the flexural strength of relined denture base was investigated by using three brands of self-cured hard relining material commercially available in Thailand. They were Tokuyama Rebase II, Kooliner and Unifast Trad to reline on one brand of heat-cured acrylic resin denture base, ProBase Hot. Previous study reported that Tokuyama Rebase II presented lower heat generation and higher flexural strength than its predecessor, Tokuso Rebase [26]. Kooliner is a self-cured hard relining material with lower polymerization temperature than other autopolymerizing acrylic resin, can be used more favorable to direct relining denture base in patient's mouth [22,27-29]. Unifast Trad is a hard relining material with a fast setting time (3min). It is difficult to manipulate in patient with tissue undercut. And the polymerizing state of Unifast Trad produced heat that might be irritate to the oral mucosa.

Results from table 2 showed the flexural strengths of ProBase Hot relined with Unifast Trad

were higher than those of Probase Hot relined with Kooliner and Tokuyama Rebase. A possible explanation for this phenomenon is the higher ability of ProBase Hot to bond to Unifast Trad than to Kooliner and Tokuyama Rebase II. ProBase Hot is a high cross-linked polymer composed of Poly (methyl methacrylate) (PMMA) as the powder and methyl methacrylate (MMA) as the liquid. Unifast Trad is also a high cross-linked polymer which its composition was similar to ProBase Hot. Probably to the fact that Unifast Trad is more structurally compatible to ProBase Hot (both Polymethyl methacrylate based) than Kooliner and Tokuyama Rebase II (Polyethyl methacrylate with non-monomer based). High bond strengths of relined denture base were obtained when relining material chemically similar to the denture base. [30-32] Minami H et al. suggested that greater cross- linking occurred between base material consist of similar composition, so similarly for PMMA denture polymer, higher bond strength was reported with MMA-based resin as compared to non-MMA-based resin [31]. The manipulation procedure in this study, Unifast Trad presented higher temperature during polymerization than other two relining materials. Unifast Trad was the

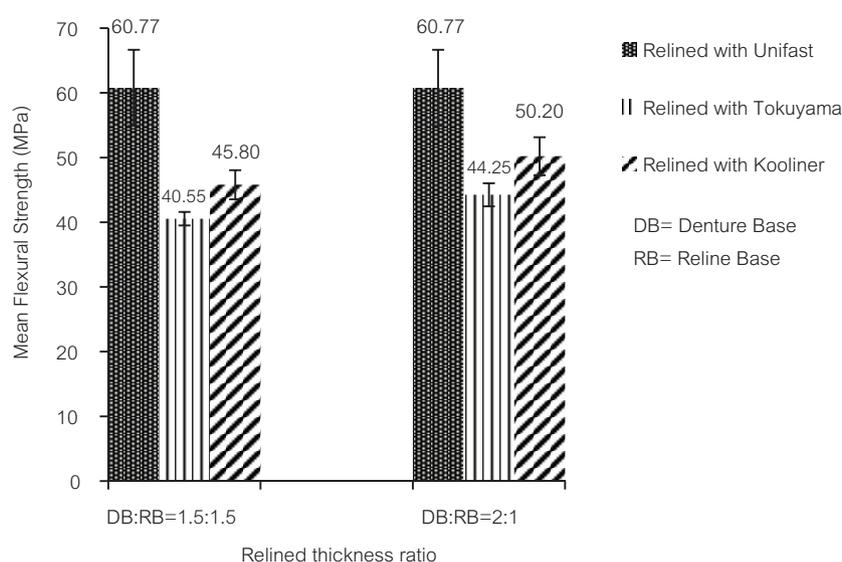


Figure 2. Flexural strength of relined denture base specimens in both thickness ratios

only one PMMA relining material; the rest were PEMAs. The previous studied on hard relining denture base reported that PMMA resins process stronger exothermic heat reactions than PEMA [33]. This result was the same as the other vitro studies on autopolymerizing resin used for direct fabrication of interim restorations [34]. The high temperature of Unifast Trad during reline on ProBase Hot might increase diffusion rate of relining material into the base polymer resulting in good bond strength. Adhesive failure was displayed for all relined specimen in the Kooliner groups (Figure 3). The phenomenon of de-bonding surface of Kooliner to denture base polymer revealed in this study is similar to some previous studies [10,30,35,36]. Adhesive bonding of relined denture base depends on the penetration of polymerizable monomer of relining material into the denture base network [21]. For self-cured hard relining material, higher molecular mass of isobutyl methacrylate (IBMA) monomer might have limited the monomer penetration to denture base [21,23,31]. Kooliner is one of the self-cured hard relining material consist of IBMA. The failure bond strength of Kooliner to denture base could cause the low flexural strength of relined denture base.

Methyl methacrylate monomer (MMA), ethyl acetate (EA) and acetone (AC) are primer and

adhesives provided by manufacturers to use as chemical agents for surface treatment of denture base polymer before relining procedure [37-40]. Tokuyama adhesive was applied on ProBase Hot specimen surface before relining with Tokuyama Rebase II. The composition of Tokuyama adhesive consists of 47% ethyl acetate (EA) and 47% acetone (AC) However, the effect of EA and AC that contained in Tokuyama has not been well established. The difference between the chemical composition ProBase Hot denture base resin and Tokuyama Rebase II Fast denture reline may leads to absence chemical interaction between them, and this seems to be the main reason for the bond failure observed in relined specimen (Figure 4). Thus, the result of this experiment suggest to study how to improve bond strength of Tokuyama adhesive and the proper management of denture base surface before relining procedure.

The present study revealed that 3mm thick intact denture base showed higher flexural strength (72.00 ± 2.80 MPa) than all relined denture base groups (40.55 ± 1.04 MPa to 60.77 ± 5.88 MPa). Many studies also reported that the flexural strength of relined denture base was lower than intact denture base [14,41-43]. The reason of decreasing in flexural strength of the relined denture base could be mainly related to the



Figure 3. De-bonding of Kooliner from ProBase Hot after flexural strength test



Figure 4. De-bonding of Tokuyama Rebasell from ProBase Hot after flexural strength test

adhesive failure under load between the relining and the denture base material or from the low strength of relining material. We clearly knew that a relined denture base consists of two different materials with an interface between them and resulting in creation a composite laminate structure. If the composite interface structure is weak, then delamination will be occurred during function [44]. A weak bond will decrease the flexural strength of the relined denture base [8,11]. It may be probably explained by molecular interaction of active site between two surfaces. The active site of denture base to be relined was occupied by the previous curing material, while the added relining material has fully activated active sites. As a result, the compatibility between the two resins is incompetent which leads to weakening of the molecular interaction between the two resins, consequently decreasing the mechanical properties of the relined denture base [45]. This result is in agreement with Baily who reported that the cross linkage between the existing denture base and the new reline resin was not as complete as the initial polymerization process [46].

This current study investigated the flexural strength of two different thickness ratio of denture base to reline material (1.5:1.5 and 2:1). The result displayed that the different thickness ratio of denture base to relining materials had no significant effect on flexural strength of the relined denture base. This result is in agreement with the study of Hatim et al which concluded that there were no significances of relining thickness (0.5mm, 1mm, and 1.5mm) on the flexural strength of denture base polymer [47].

Conclusion

Within the limitations of this study, it can be concluded that;

1. Different thickness ratios of denture base

to relining materials had no significant effect on flexural strength of the relined denture base.

2. Different self-cured hard relining material had significant effect on the flexural strength of the relined denture base.

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Ethical approval: None (Laboratory study)

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