Effect of Aging Process on Physical Properties of Denture Lining Materials

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Abstract

This experimental study examined the physical properties including of surface roughness, tensile bond strength and viscoelastic behavior of denture lining materials, namely Dynamic Impression Liner (DIL), Peripheral resin II (Peri-resin II) and conventional lining material (Tokuso).
DIL, Peri-resin II and Tokuso specimens were prepared according to the manufacturer's instructions. Viscoelasticity test were performed amplitude sweep and thixotropy test by using oscillatory shear method. In addition, the surface roughness and tensile bond strength were investigated. The sample specimens of each denture lining materials were divided into 3 groups (n=5) according to accelerated aging cycles (0, 1000 and 2000). The number of cycles simulated short and prolonged clinical use. The average and standard deviations were calculated for each group, results were submitted to independent T test and one-way ANOVA, significant differences were compared by Turkey ($\alpha = 0.05$).

The results were found that DIL has more thixotropy than Peri-resin II. Tensile bond strength of DIL at 0, 1000 and 2000 thermocycling cycles not differ from Peri-resin II significantly ($p>0.05$). Surface roughness of DIL at 2000 thermocycling cycles was higher than Tokuso and Peri-resin II respectively. In case of tensile bond strength of DIL at 0 and 1000, 1000 and 2000 thermocycling cycles were increased significantly ($p<0.05$). Surface roughness of DIL at 0, 1000 and 2000 thermocycling cycles were increased significantly ($p<0.05$). Surface roughness of Peri-resin II at 0 and 1000 thermocycling cycles were increased not significantly ($p>0.05$).

DIL, novel soft denture liner, has thixotropy property more than Peri-resin II therefore it suitable for irritated lesion. Peri-resin II, novel peripheral border molding material, has surface roughness lower than conventional peripheral border molding material (Tokuso) used in dental clinic. After 2 years using soft denture liners, it will decline the physical properties.

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Introduction

Denture substitutions are necessary for partial or complete edentulous patients. It will rehabilitate both esthetic and chewing ability. Edentulous ridges normally resorb rapidly in the first 6 months to 2 years following extraction then slow down but continues unto death.[1]

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Because of the removable dentures depend on the residual ridge for support, retention, stability, comfort, function and esthetics.[2-4] If the ridge is gradually changing in size and shape over time, dentures become unstable and require re-do or at least reline to restore esthetic and function.[5] The relining procedure is suitable in the selected cases to get the good adaptation of denture base to the changing resorbed residual ridge.[6,7]

The material is applied on the tissue-surface of the denture, perform better adaptation of the denture base to the supported ridge. These materials can be either hard or soft type which are needed in some cases that the patient's residual ridge cannot tolerate to chewing force. So, the relining material acts as cushion effect prevent tissue trauma of the ridge. However, each material has indications and limitations to be considered in each case.

There are vary commercial brands of soft lining materials, but mostly still get trouble while handling or fail to meet the requirements during function.[8] For example, water sorption and solubility, color stability,[9] low tensile and tear strength,[10] rough surface and decrease bonding ability to the denture base. The companies tried to develop and launched some new materials. One of these soft lining materials, called "Dynamic Impression Lining material (DIL)", acts as tissue conditioner during 1 week after application then gradually becomes hard. So, the material has dynamic change until it set in form and thickness that help the patient feel more comfortable. This character offers comfortable feeling to the patient who wear denture especially the person which has fragile residual ridge. During 1 week that the material still in soft and "dynamic" change due to functional force, the shape and thickness of the material will be adapted. Then finally set to become hard within 2 weeks. So, the complete relining surface will present smoother and reduce chance for bacterial adherence. The DIL material will be fully polymerized after 2 weeks. Moreover, there's another material used for border molding, called "Peripheral Resin II (Peri-resin II)", the novel denture border molding material with special character that suitable for handling. The property of material called thixotropic will help the operator to apply the material on the border and shaping by fingers easily. The denture lining material has good viscoelastic property, easy for handling and application onto the denture's border by hand.[11]

However, there's no information of these materials after long function. Whether they may change the physical properties when compare with the conventional lining material. This present research will study on two new materials in comparison with conventional relining material (Tokuso). The properties including of surface roughness, tensile bond strength and viscoelastic behavior will be examined. For surface roughness and tensile bond strength also test with thermocycling to simulate the condition after long function.[12-14]

Materials and methods

Viscoelastic behavior

DIL, Peri-resin II and Tokuso was mixed using ratio according to the manufacturers;
DIL: pour powder into the company's measuring cup 3 portions then add monomer 2.5 milliliters. Peri-resin II: use powder 2 portions in the company's measuring cup and monomer 1 milliliters. Tokuso: mixing ration is powder 2 gram and monomer 1 milliliters.

The mixing materials were brought into rheometer (Hhaake Mars modular advanced rheometer system, sweden). Analyze the viscoelastic behavior by oscillatory shear method with amplitude sweep in 0.2 to 100 strain, 1 Hertz, 25°C. The result of linear viscoelastic range (LVR) and parameters such as storage modulus (G'), loss modulus (G") and damping factor were collected. Also, the test for thixotropic property was performed at 1 Hertz, 25°C and 1% strain.

Surface roughness

All of three materials were mixed in the ratio according to the manufacturers. Pour the mixing material into the metal mold. After the material set, cut into rectangle shape 15x25x2.5 millimeters. (Figure 1).

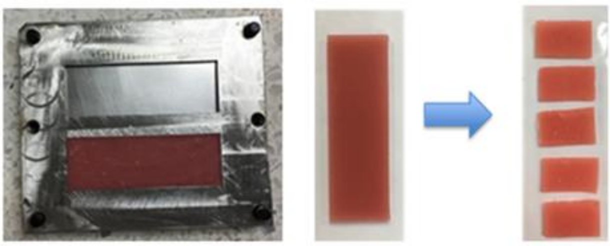

Figure 1. Mold and specimen preparation for surface roughness testing.

The specimens were put in thermocycling machine (HWB332R Institute of technology, Bangkok, Thailand) at 5±1 °C and 55±1°C (30 seconds) for 0, 1000 and 2000 cycles. Randomized pick-up 5 pieces from 15 pieces of the specimens (each material). The test for surface roughness was performed using surface roughness testing machine (TalyScan 150; Taylor Hobson Ltd., Leicester, England). The machine was set to point pressure at 1 millinewton (100 milligram), range 10 millimeters, speed 3000 micrometers/second, cut-off at 0.8 millimeters. The profile result was collected 3 times per piece at controlled temperature (below 25°C).

Tensile bond strength

Acrylic resin specimen, heat-polymerized acrylic resin (Triplex Hot®; Ivoclar Vivadent, Liechtenstein) was used. Mixed 23 gram of powder and 10 milliliters of monomer to dough stage then applied the material into metal mold 6x6x30 millimeters. The process of trial pack was done and placed the mold in boiling water for polymerization. The acrylic resin specimen was cut into 6x6x12 millimeters and trimmed one-end to match the clamp of testing machine (Shimadzu Corporation, Kyoto, Japan). Put the acrylic resin back into metal mold so the space was left at the middle between 2 pieces of acrylic 6x6x6 millimeters (Model BK3 MKll, Burgess Power Tools Ltd., Sapcote, UK). The prepared area to bond with each relining material was applied with primer due to the company's recommendation.

Relining material, all of three materials were mixed in the ratio according to the manufacturers. Pour the mixing material into the metal mold (prepared area). Closed the mold then wait for the material to set. (Figure 2).

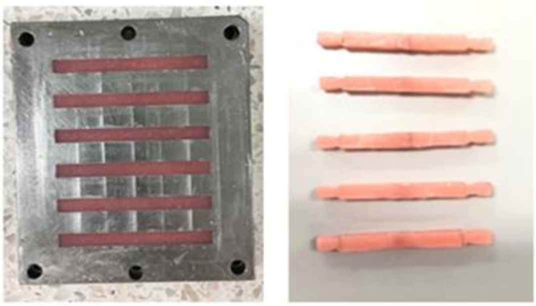

Figure 2. Mold and specimen preparation for tensile bond strength testing.

The specimens were put in thermocycling machine at 5±1 °C and 55±1°C for 0, 1000 and 2000 cycles. Randomized pick-up 5 pieces from 15 pieces of the specimens (each material). The test for tensile bond strength was performed using universal testing machine. The tensile force 500 Newton and speed 5 millimeters/minute was set.

Statistical analysis

Following data collection, statistical analysis was carried out by SPSS (SPSS for Windows, version 22.0 IBM Company, USA). The average and standard deviations were calculated for each group, results were submitted to independent t-test and one-way ANOVA, significant differences were compared by Turkey (α= 0.05).

Results

Viscoelastic property

DIL has elastic response when strain is changed. It shows widest LVR. Tokuso has narrowest LVR. From the data, DIL has lowest storage modulus while Tokuso has highest storage modulus. However, Peri-resin II has higher storage modulus than DIL but lower than Tokuso. Also, Perio-resin II has narrower LVR than DIL but wider than Tokuso. (Figure 3A).

The relationship of loss modulus and strain amplitude; DIL shows widest LVR and lowest loss modulus. Tokuso has narrowest LVR and highest loss modulus. Then comparing storage modulus versus loss modulus of each material reveals that Peri-resin II and Tokuso have storage modulus and loss modulus in about the same value. While DIL has storage modulus lower than loss modulus. (Figure 3B).

Determine damping factor relate to strain amplitude; the value of damping factor of each material supports the modulus properties which stated in the result. Damping factor of Tokuso is the lowest one, while DIL is the highest value. (Figure 3C).

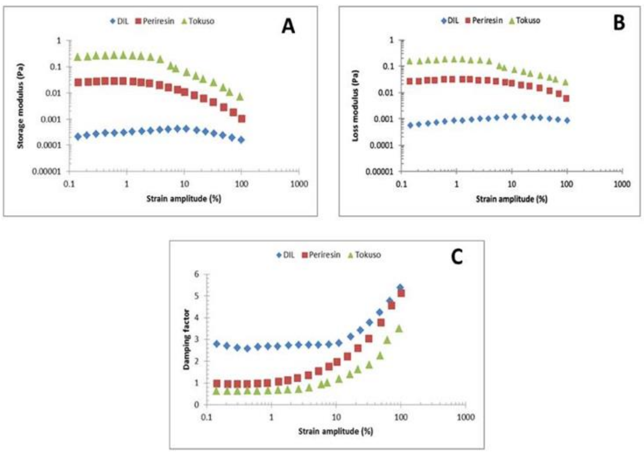

Figure 3. Shows relationship between storage modulus and strain amplitude (3A), relationship between loss modulus and strain amplitude (3B), relationship between damping factor and strain amplitude (3C).

All of these three materials demonstrated thixotropic property. The viscosity decreases during increasing shear rate. Moreover, the data of DIL shows the same value during increase and decrease shear rate. (Figure 4).

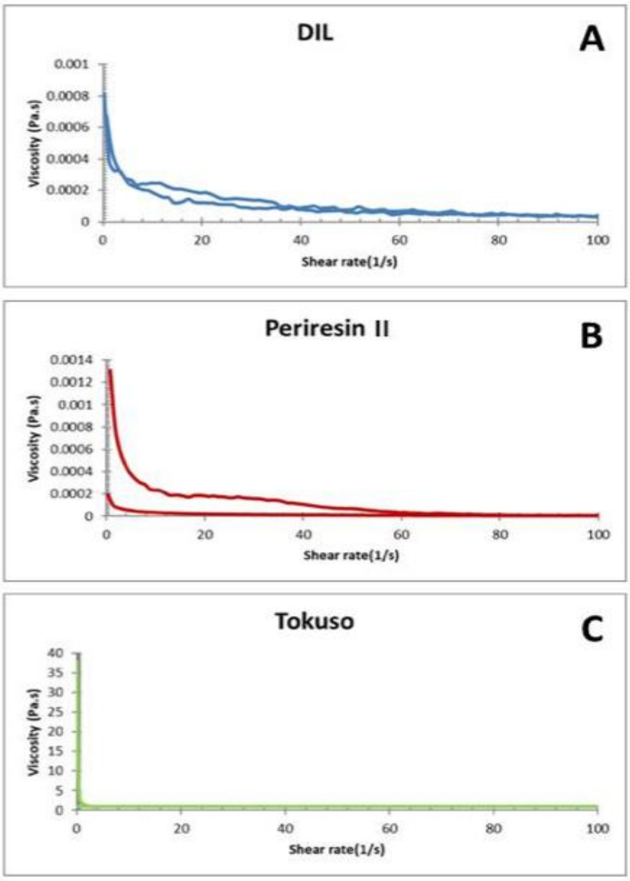

Figure 4. Shows relationship between Viscosity and Shear rate of DIL (4A), relationship between Viscosity and Shear rate of Peri-resin II (4B), relationship between Viscosity and Shear rate of Tokuso (4C).

Surface roughness

The DIL specimens after thermocycling procedure show increase in surface roughness at 0, 1000 and 2000 cycles significantly (p<0.05). Surface roughness of Peri-resin II specimens compare between baseline (0 cycle) and 1000 cycles shows no significant difference (p>0.05). While compare surface roughness of Peri-resin II between 0 and 2000 cycles, and also between 1000 and 2000 cycles shows increasing of surface roughness significantly (p<0.05). The same results are found in Tokuso; surface roughness of Tokuso specimens compare between baseline (0 cycle) and 1000 cycles shows no significant difference (p>0.05). While compare surface roughness of Tokuso between 0 and 2000 cycles, and also between 1000 and 2000 cycles shows increasing of surface roughness significantly (p<0.05).

The study compares surface roughness at baseline (0 cycle) and 1000 cycles among DIL, Peri-resin II and Tokuso found that surface roughness of DIL is higher than Peri-resin II and Tokuso significantly (p<0.05). However, surface roughness of Peri-resin II and Tokuso are not significant difference (p>0.05). Comparing of surface roughness after 2000 cycles thermocycling among DIL, Peri-resin II and Tokuso, the data shows significant difference (p<0.05). (Figure 5).

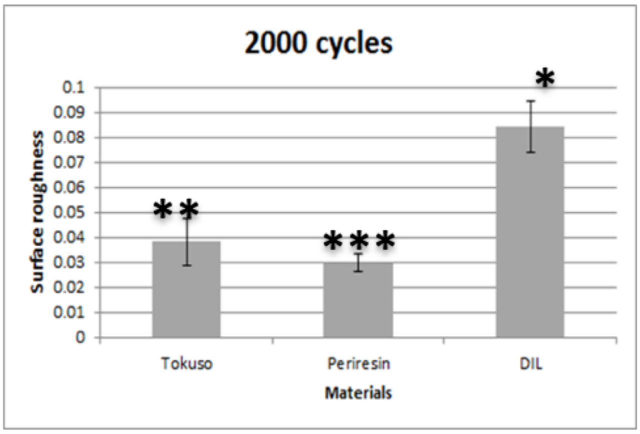

Figure 5. Shows surface roughness of the materials after thermocycling 2000 cycles.

Tensile bond strength

The tensile bond strength of DIL compare between baseline (0 cycle) and 1000 cycles shows no significant difference (p>0.05). When compare between 0 and 2000 cycles, and also between 1000 and 2000 cycles shows increasing of tensile bond strength significantly (p<0.05). For Peri-resin II, compare between 0 and 1000 cycles shows no significant difference (p>0.05). When compare between 0 and 2000 cycles, and also between 1000 and 2000 cycles shows decreasing of tensile bond strength significantly (p<0.05).

Then the study compares among these materials, tensile bond strength at baseline (0 cycle), 1000 and 2000 cycles between DIL and Peri-resin II shows no significant difference (p>0.05).

Discussion

This experimental study evaluated surface roughness, tensile bond strength and viscoelastic behavior of denture lining materials, namely DIL, Peri-resin II and Tokuso. The result of this study found significant differences between the physical properties (surface roughness, tensile bond strength and viscoelastic behavior) of each material.

DIL has elastic response when change the strain, while Tokuso has plastic behavior. The storage modulus of DIL is the lowest among three materials and Tokuso is the highest one. This can be interpreted that Tokuso has entanglement of molecules more than DIL. Peri-resin II has response to strain in the middle between DIL and Tokuso. The relationship of storage modulus and strain amplitude revealed that DIL has the ability of flow more than Peri-resin II and Tokuso. All of three materials have thixotropic property which means the viscosity will be decreased while increasing of shear rate.

The thermocycling procedure in this research was set as 0 (no treat), 1000 and 2000 cycles which represented the use of denture at 0, 1 and 2 years. When compare within the material, DIL has changed in surface roughness significantly every time periods (p<0.05). Peri-resin II and Tokuso changed surface roughness significantly between 0 and after 2000 cycles. The test of surface roughness compared among DIL, Peri-resin II and Tokuso revealed that at 0, 1000 and 2000 cycles, surface roughness of DIL was significant difference from Peri-resin II and Tokuso. When compare at 2000 cycles, all of three materials were significant difference. The surface roughness of DIL at 2000 cycles was highest, follow by Tokuso then Peri-resin II. Even though in a review paper found that thermal cycling did not change the surface roughness of PMMA (p>0.001).[15] No significant differences were found between the control and 15,000 cycles, the control and 30,000 cycles, or 15,000 and 30,000 cycles in any of the denture resins. But the values of mean surface roughness of materials can be noted that there were increasing in small number.[15]

Comparing of tensile bond strength before and after thermocycling process, DIL and Peri-resin II were decreased significantly (p<0.05). So, application of these materials more than 2 years can result in dislodge or peel off the relining material from denture base. Comparing tensile bond strength between DIL and Peri-resin II found that no significant difference at 0, 1000 and 2000 cycles. While Tokuso could not test for tensile bond strength because of the material set as hard as acrylic resin, so Tokuso was unable to peel off from denture base. The result in this present study was conformed the article review that thermocycling resulted in decrease in bond strength of silicone-based liner.[14,16-18] Also support by a study stated that thermocycling had a deleterious effect on bonding strength of lining materials to denture base. Surface treatment with ethyl acetate increased the surface roughness of acrylic denture base and improved the shear bond strength of acrylic.[19] Another method to facilitate the ability of bonding strength was revealed in an article that sand papering the surface of the heat polymerized denture base resin or preparing holes on the surface of the denture base increases the bond strength of the soft liner.[20-22]

Conclusion

Within limitations of the present experimental, we found that: 1) DIL is a soft lining material with thixotropic property that flow better than Peri-resin II. This material is suitable for application in case of fragile residual ridge or traumatic tissue. 2) Peri-resin II can be used as a lining material especially around the border of denture. Due to the lower surface roughness compare to the conventional material (Tokuso). 3) These soft lining materials will decrease in physical properties after 2 years.

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Declaration of Interest

The authors declare no potential conflicts of interest with the materials involved in this study.

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