In-vitro study of the fracture resistance of denture base resin with resilient reline material

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Purpose: This study aimed to analyze the fracture resistance of denture base resins relined with either a conventional rigid resin or a new resilient resin.
Materials and Methods: Two types of test plates were fabricated by relining the base resin (Acron) with a conventional rigid resin (Tokuso Rebase, TR) or a newly developed relining resin (Tokuyama Rebase II, RII). The specimens were divided into three groups (n=10) according to the number of thermo-cycles applied (0, 15,000, and 30,000), and were subjected to three-point flexural test. Mean flexural strength, elastic modulus, and the destruction energy of each group were statistically analyzed by one-way analysis of variance with Fisher's PLSD at α=0.05.
Results: RII showed higher flexural strength than TR, and the difference reached in the 30,000 thermo-cycling group ($p<0.05$). TR showed significant reduction of elastic modulus after 30,000 thermo-cycling ($p<0.05$). On the other hand, RII showed no significant difference between the elastic modulus before and after thermo-cycling ($p>0.05$), though the elastic modulus of RII is lower than that of TR. The destruction energy of TR was significantly less than that of RII ($p<0.05$) after thermo-cycling.
Conclusion: The results of this study demonstrated that a new relining resin, Tokuyama Rebase II, provides higher elasticity, resilience, and durability than Tokuso Rebase. Destruction energy was indicated to express comprehensive proof strength against mechanical force and serve as an effective parameter in the evaluation of relining materials used for repair and adjustment of fractured or poor-fit denture bases.
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Key Words: denture base resin, destruction energy, reline material.

Introduction

Direct denture base relining is a useful method for repairing fractured or poor-fit denture bases for edentulous patients. This method has some advantages such as simple procedure and reduced work time at chair side. In particular, 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 resins.[1-3]

Further, the new relining resin has higher long-term durability than the soft silicon materials used for dynamic impression taking or tissue conditioning. In case of direct relining, perfect adherence at the interface between the base resin and relining resin is critical to prevent the relining resin from debonding in the process of fatigue and deterioration. With an aim to improve the bonding strength between the denture base resin and relining materials, studies on mechanical or chemical surface modification of denture base resin have been reported.[4-12]

On the other hand, little is known about the durability of relined or adhered base resin during long-term use, in terms of not only the bonding strength at the interface but also the mechanical property (flexural strength) of the relined denture base resin. One of the reasons is the fact that a different test method or evaluation standard is applied according to the mechanical property of the material, thus no test method or standard to facilitate direct comparison of the performance of rigid and resilient resins is available. Despite a higher fracture resistance compared with conventional rigid relining materials and denture base resins, the newly developed resilient relining resin shows a clearly lower value when evaluated by flexural test. This indicates that the test methods meeting the current development level of rigid relining material have not yet been established.

The purpose of this study was to analyze the mechanical durability of heat-cured denture base resin samples relined with either a conventional rigid or a new resilient materials, and to discuss an effective method of analysis of relining materials.

Materials and Methods

In this study, the bending strength of relined denture base resins before and after thermo-cycling was evaluated through measurement of bending strength. Materials used in this study included a heat-polymerizing denture base resin and two types of non-MMA-based autopolymerizing acrylic resins, both distributed as relining material (Table 1).

Table 1. Materials investigated.

	Curing type	Brand name	Manufacturer	Batch number	Code
Base	Heat curing	Acron	GC Corp., Tokyo, Japan	P, 181042; Liq, 0303181	Acron
Reline	Auto-curing	Tokuso Rebase	Tokuyama Dental, Tokyo, Japan	P, 35663; Liq, 180103	TR
Reline	Auto-curing	Tokuyama Rebase II	Tokuyama Dental, Tokyo, Japan	P, SA150; Liq, 340	RII

The denture base resin, Acron, was prepared by mixing the powder and the liquid, and the mixture then packed in a flask (30x30x2.5 mm). A total of 12 denture base resin pieces were heat-polymerized at 70˚C for 90 minutes, followed by 30 minutes in 95˚C water. After 12 hours the resin pieces were removed from the flask and ground to form 2.0 mm thick pieces using 600-grit silicon carbide paper under water irrigation.

The relined denture base resin specimens (30x30x4 mm) were prepared by direct bonding a 2 mm thick relining resin (TR or RII) to a 2 mm thick base resin (Acron) according to the manufacturer's instruction (monomer to polymer ratio of 1.6 g/1.0 g) as shown in Fig. 1. Five specimens (4x4x30 mm) were prepared from each plate with a diamond disk (Isomet, Buehler Ltd., Lake Bluff, IL, USA). The specimens were divided randomly into three thermo-cycling groups (n=10). The specimens of the first group were placed in distilled water at 37˚C for 24 hours without thermo-cycling to serve as the control group. The specimens in the second group were subjected to thermal cycling for 15,000 cycles between 5 and 60˚C water bath with a 1-minute dwell time at each temperature. The third group was subjected to 30,000 thermo-cycles.

A three-point loading test was performed using a universal testing machine (AGS500, Shimadzu Corp., Kyoto, Japan) at a crosshead speed of 1 mm/minute and a span length of 20 mm. The specimen was mounted to the testing machine with the base resin side up as shown in Fig. 2 so that the base resin and relining resin were respectively exposed to compression and tensile force. Flexural strengths (σ) and elastic modulus (E) were calculated based on the results of the three-point loading test as follows (ISO 178):

$$\sigma = 3/2 \cdot LF/WT^2 \qquad E = L^3/4WT^3 \cdot F/Y$$

where, L, span length (mm); F, loading force (N); W, width of specimen (mm); T, thickness of specimen (mm); and Y, displacement under the loading force (mm). Integral calculus from the starting point of loading to the breaking point of the loading-deformation curve was used to express the destruction energy (the enclosed area in Fig. 3). Mean flexural strength, flexural modulus and the destruction energy of each group were statistically analyzed by one-way analysis of variance (ANOVA) at α=0.05. Significant differences between the groups were further analyzed using Fisher's PLSD with significance level of α=0.05.

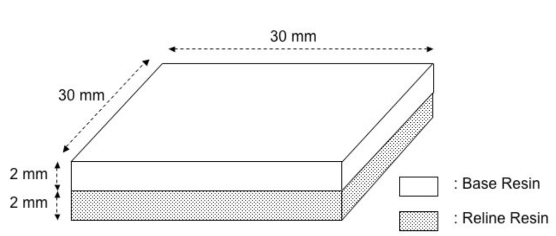

Fig. 1. The size of relining resin plate.

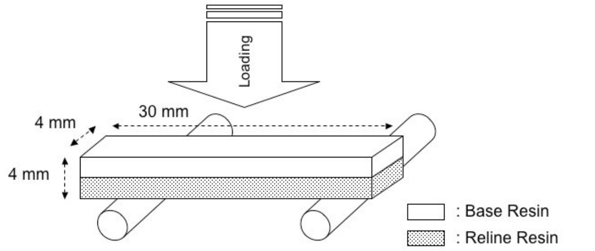

Fig. 2. Specimen set up for three-point loading test.

Results

Flexural strength

The mean flexural strength and the standard deviation are shown in Fig. 4. In the control group, TR showed higher flexural strength than RII, though the difference was not statistically significant (TR, 103.1±15.9 MPa; RII, 94.4±6.7 MPa). In the case of the group subjected to 15,000 thermo-cycles, RII showed higher flexural strength than TR (TR, 75.4±7.4 MPa; RII, 84.8±15.2 MPa), and the difference reached a statistically significant level in the 30,000 thermo-cycling group (TR, 47.9±7.4 MPa; RII, 65.6±10.3 MPa) ($p<0.05$)

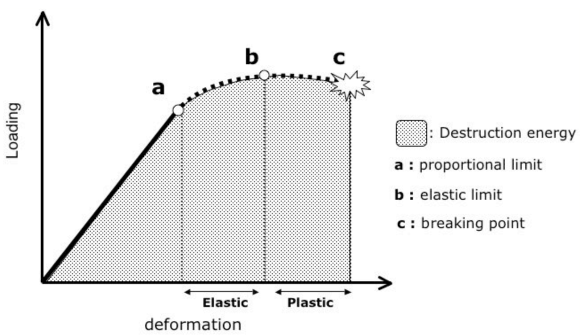

Fig. 3. The schema of loading-deformation line.

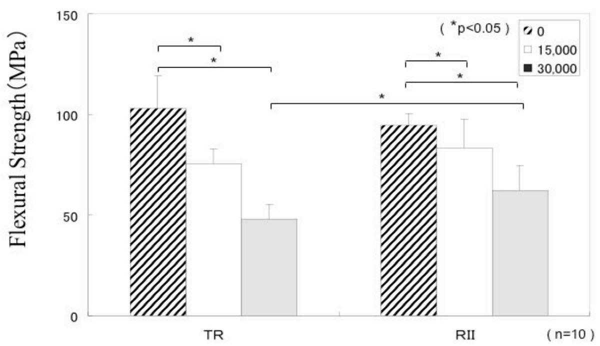

Fig. 4. Flexural strengths of relined denture base resin.

Elastic modulus

The mean elastic modulus and standard deviation calculated from the stress-strain curve are shown in Fig. 5. TR showed significant reduction of elastic modulus after 30,000 thermo-cycling ($p<0.05$). On the other hand, RII showed no significant difference between the elastic modulus before and after thermo-cycling ($p>0.05$), though the elastic modulus of RII is lower than that of TR.

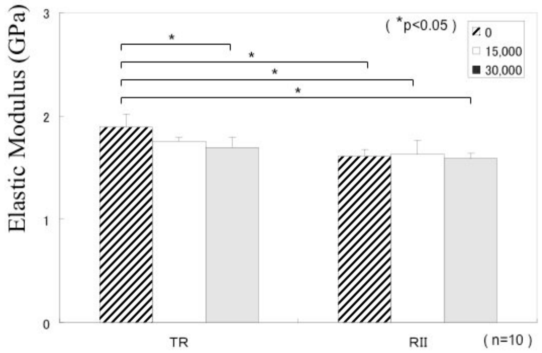

Fig. 5. Elastic moduli of relined denture base resin.

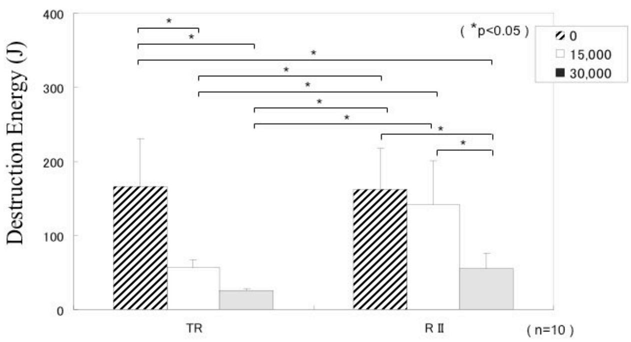

Fig. 6. Destruction energies of relined denture base resin.

Destruction energy

The mean destruction energy and the standard deviation are shown in Fig. 6. There was no significant difference in the destruction energy before thermo-cycling between TR (147.3±73.7 J) and RII (161.6±56.2 J) ($p>0.05$). After thermo-cycling tests of 15,000 cycles (TR, 56.6±11.0 J; RII, 135.2±69.8 J) and 30,000 cycles (TR, 26.1±5.2 J; RII: 55.5±20.4 J), the destruction energy of TR was significantly less than that of RII ($p<0.05$).

Discussion

Test method

In the bending test, one side of a specimen receives compressive force and the other side of the same specimen is exposed to tensile force depending on the loading direction of the machine. Therefore, when testing a specimen consisting of two materials having different physical properties, the direction of mounting the specimen in the machine may affect the test result. In other words, the flexural strength of a specimen measured by placing the base resin layer to the tensile force side and relining resin layer to the compression force side cannot be interpreted as identical to the result measured by placing the specimen in the opposite direction. They are values measured under different test conditions.

In a study using hard relining resins, Mori et al.[13] reported that no significant difference was found in the values measured by changing the mounting direction of the same specimen. In the case of elastic and resilient hard relining resins used in this study, however, it was assumed that data would vary according to the loading direction. In order to collect data in an environment similar to actual clinical conditions, the bending tests in this study were conducted by setting all the specimens with the relining resin layer and base resin layer respectively positioned to the tensile and compressive force sides to reflect the reality that a denture base consists of a base resin on the outer surface and relining resin on the inner surface. As a result, no debonding of relining resin from base resin occurred during the loading tests and stable data was collected.

Evaluation method (flexural strength, elastic modulus and destruction energy)

Generally, complete fracture of denture base resin occurs as a result of excessive elastic and plastic deformation caused by mechanical loading as shown in Fig. 3. Conventionally, the destruction point on the stress-strain curve has been used as the parameter to evaluate the mechanical toughness of denture base resins. However, the destruction point is not the perfect criterion of evaluation from a clinical viewpoint because the denture fit is lost once plastic deformation occurs. A poor-fit denture cannot be used any more even if it is not completely fractured.

There are reports that used the proportional limit, or the point on the stress-strain diagram where the curve becomes nonlinear, for the evaluation of flexural strength of materials.[10,13] However, no elastic transformation is taken into account in the proportional limit. The newly developed hard relining resin is provided with characteristics such as elasticity and resilience and can serve as shock absorbent against dynamic mechanical forces. The proportional limit is not useful enough to evaluate the advantages provided by these unique features. Further, there is no definitive border between the elastic and plastic transformation on the stress-strain curve.

In contrast, the destruction energy used in this study can express not only the mechanical toughness of a material but also other characteristics such as comprehensive proof strength against external mechanical forces. In this study, destruction energy was indicated as an effective parameter to evaluate the relining materials used for repair of fractured or poor-fit denture bases.

Measurement results

The results of this study indicated that flexural stress at the destruction point was higher in the specimen with conventional relining material than the specimen with elastic and resilient relining material. However, evaluation based on destruction energy produced opposite results and indicated that the specimens relined with RII were more flexible against mechanical forces and harder to fracture.

In general, the loading test by thermo-cycling is affected by complex factors such as mechanical and chemical loads. For example, temperature changes lead to changes in thermal expansion rate, resulting in a mechanical load generated at the bonding interface or inside the specimen. Specimens placed in a water bath for a long period of time are subject to chemical loading due to hydrolysis. The complex load in thermo-cycling tests can serve as an indicator of long-term prognosis in short-term in-vitro studies.

Relining materials are different from base resins used for permanent dentures in terms of the intended application and service life. In particular, the direct use of relining materials is limited to the repair of fractured dentures or readjustment of dentures whose fit was lost due to changes in oral conditions such as tooth loss or gingival mucosa. Accordingly, the dentures repaired or readjusted with the relining resin are only for temporary use for several months until the new permanent denture is fabricated. On the other hand, clinical problems such as staining and/or debonding at the interface have been experienced quite frequently.

In this study, both relining materials tested showed clear deterioration of physical property data after thermo-cycling, which indicated the possibility of deterioration of the base resin and/or relining materials themselves. There is also a high possibility that the deterioration of the bonding mechanism at the bonding interface affects the strength of the entire structure. The fact that the deterioration after thermo-cycling was less in RII than in TR suggests the possibility that the improvement of the bonding agent in RII was one of the factors of this phenomenon.

The magnitude of compression displacement of oral mucosa under denture base varies from patient to patient, and clinicians must make efforts to meet the clinical conditions of each patient in daily practice, including the choice of relining material, i.e. hard or elastic, best suited for the patient's requirements. However, the selection of these materials is currently determined empirically by clinicians. Advanced approaches for material selection, including the establishment of guidelines for selection of relining materials satisfying the conditions of oral mucosa, are anticipated.

The results of this study demonstrated that a new relining resin, Tokuyama Rebase II, provides higher elasticity, resilience, and durability than Tokuso Rebase. Destruction energy was indicated to express comprehensive proof strength against mechanical force and serve as an effective parameter in the evaluation of relining materials used for repair and adjustment of fractured or poor-fit denture bases.

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