



REPAIR STRENGTH OF HYPOALLERGENIC DENTURE BASE MATERIALS

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Statement of problem. Hypoallergenic denture base materials are commonly used for patients with allergic reactions to polymethyl methacrylate (PMMA) denture base materials. The goal for repaired fractured dentures fabricated from hypoallergenic denture base materials is to restore the dentures to their original strength.

Purpose. The purpose of this in vitro study was to investigate the flexural properties of 7 hypoallergenic denture base materials after repair compared with a conventional PMMA-based heat-polymerizing resin.

Material and methods. Specimens ($n=5$) of the following hypoallergenic denture base materials with differing polymerization modes: Eclipse base material, Luxene, Microbase, Polyan, Puran HC, Alldent Sinomer, and The.r.mo.Free, were repaired with Versyo.com as well as the respective repair systems for 4 of the tested materials. A heat-polymerized acrylic resin (Paladon 65) was repaired using autopolymerizing acrylic resin (Palapress), which served as the control. Flexural strengths (MPa) and flexural moduli (MPa) were assessed before and after repair of each material, according to ISO 1567. The data were analyzed with repeated measures 2-way and 3-way ANOVA, 1-way ANOVA, and Bonferroni-Dunn's multiple comparisons post hoc analysis, or with the paired t test ($\alpha=.05$).

Results. Flexural strengths and flexural moduli of both repair methods (repair according to manufacturer's instructions or repair with Versyo.com) for all materials were significantly lower than those of the intact specimens ($P<.001$). Alldent Sinomer and The.r.mo.Free repaired with Versyo.com showed flexural strengths comparable to the intact material. The flexural modulus of Puran HC, Alldent Sinomer, and The.r.mo.Free repaired with Versyo.com did not differ significantly from the original, nonrepaired material. No significant differences were noted between the flexural strength ($P=.616$) and the flexural modulus ($P=.138$) values regarding the 2 repair methods of the respective materials. None of the repaired hypoallergenic denture base materials demonstrated significantly higher flexural strengths than repaired Paladon 65. Flexural strengths of repaired Puran HC and Alldent Sinomer were significantly lower than those of repaired Paladon 65 specimens ($P<.001$). Flexural moduli of repaired Puran HC, Alldent Sinomer, and The.r.mo.Free showed a significant decrease compared to the repaired Paladon 65 specimens ($P<.001$). Eclipse and Luxene passed the flexural property requirements of ISO 1567 before and after repair.

Conclusions. No significant influence of the repair systems was found, but the flexural properties of the repaired materials differed significantly with respect to the tested acrylic resins. (J Prosthet Dent 2008;100:292-301)

CLINICAL IMPLICATIONS

This study suggests that flexural properties of Versyo.com were adequate as a universal repair material for the tested hypoallergenic denture base materials.

The number of patients with allergies is increasing, and, as a consequence, dentists are confronted with more patients reporting allergic re-

actions to polymethyl methacrylate (PMMA) denture base materials.^{1,2} Though the prevalence of contact allergies to acrylic resins remains

unclear, the use of a hypoallergenic denture base material for patients susceptible to allergic reactions and requiring a removable prosthesis is

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desirable. Adverse reactions may be induced by residual methyl methacrylate monomer (MMA). Therefore, MMA has been replaced by presumably hypoallergenic resins, such as diurethane dimethacrylate, polyurethane, polyethylenterephthalate, and polybutylenterephthalate, or the content of the residual monomer has been reduced.³⁻⁵

The fracture of acrylic resin prostheses occurs frequently in dental practice.⁶⁻⁸ Prosthesis fracture is primarily caused by fatigue of the base material during function and mastication or is caused by dropping the prosthesis. In addition, watersorption in the oral environment weakens the denture base material. Furthermore, the adaptation of the prosthesis deteriorates over time due to resorption of the alveolar ridge.^{7,9-11}

The goal of denture repair is to restore the denture to its original strength.^{7,12,13} Previous studies have shown that the repair strength of various denture repair resins exhibited a dramatic decrease when compared to the original strength of the denture.^{6,7,12,14,15} Repair strength of the denture depends on the laboratory procedures (width of gap, beveling of the fractured surfaces) and on the characteristics of the denture repair resin used (cohesive strength and adhesive strength to the denture base material).¹⁶ The resistance of the repaired denture base materials to fracture is affected by the fracture strength as well as the fracture toughness.¹⁷⁻¹⁹ Various methods have been suggested to test the flexural properties of denture bases.²⁰⁻³⁰ Testing of the flexural strength and flexural modulus of denture base materials according to ISO 1567 is well accepted.³¹⁻³⁶

The purpose of this in vitro study was to evaluate the flexural strengths and flexural moduli of 7 hypoallergenic denture base materials compared to a conventional heat-polymerized PMMA material before and after repair using a universal hypoallergenic repair material or the repair material of the respective base materials,

if available. The research hypothesis was that hypoallergenic denture base materials could be repaired and exhibit the same flexural properties as the intact materials, and that a hypoallergenic light-polymerizing repair material would provide comparable results to the respective repair systems recommended by the manufacturers.

MATERIAL AND METHODS

The evaluated denture base resins and repair materials are listed in Table I. A heat-polymerizing acrylic resin, Paladon 65, was repaired using autopolymerizing acrylic resin, Palapress, and served as the control. Sixty specimens were tested twice in groups of 5 specimens each. First, the intact specimens were tested, and then the repaired specimens were tested. The specimens were fabricated and the flexural strengths as well as flexural moduli of the denture base materials were tested according to ISO 1567.^{31,32}

Specimen plates of each material, 65 × 40 × 5 mm, were fabricated from 2 different mixes of the materials. The materials were prepared following the manufacturers' instructions. Each plate was cut lengthwise into 3 equal strips, 10 mm wide, with a precision saw (IsoMet; Buehler Ltd, Lake Bluff, Ill). The strips were ground to the required length, width, and height of 64 mm × 10 mm ± 0.2 mm × 3.3 mm ± 0.2 mm with an automatic grinding and polishing unit (Phoenix Beta; Buehler Ltd) under water cooling, using water-resistant metallographic grinding paper (500 FEPA; Buehler Ltd) with a grain size of 30 µm. Specimens were fabricated under constant environmental conditions (23 ± 2°C room temperature, 50 ± 10% relative humidity).

The specimens were evaluated for porosity. Specimens which appeared porous were remade. The width and height of each specimen were measured and recorded. The specimens of Eclipse base material, Puran HC, and Alldent Sinomer, which were to be re-

paired with the corresponding repair materials Eclipse, Puran CC, and Alldent Sinomer N, were indexed in plaster (Moldano; Heraeus Kulzer, Hanau, Germany). A plaster (Alabastergips I; Wiegmann Dental GmbH, Bonn, Germany) index was fabricated for all hypoallergenic denture base materials to assist in repairing the specimens with Versyo.com as well as for repair of Microbase with Microbase repair material and repair of Paladon 65 with Palapress.

The specimens were stored in 37 ± 1°C warm water for 50 ± 2 hours prior to flexural testing. The 3-point bending test was performed using a servohydraulic universal testing machine (Type 1445; Zwick GmbH, Ulm, Germany). The specimen strips were removed from water storage and the flat surface was immediately placed on the supports of the flexural testing device immersed in a water bath adjusted to 37 ± 1°C by a low-temperature thermostat (RC 20 CS; Lauda, Lauda-Koenigshofen, Germany). The flexural testing device consisted of a central loading plunger as well as 2 polished cylindrical supports, 3.2 mm in diameter and 10.5 mm long, arranged parallel to each other. The distance between the centers of the supports was 50 ± 0.1 mm. The force was applied perpendicular to the center of the specimen strips. The load was applied to the repaired area of the specimens from the direction from which repaired maxillary complete dentures are affected in situ (facing the smaller gap side of the repaired specimen, as described in the preparation of specimens below).¹⁶ The specimens were continuously loaded at a crosshead speed of 5 mm/min. The recording of results ended when the specimens fractured. The maximum force (N) upon fracture was recorded. The flexural strength (σ) was calculated from the equation^{31,32}:

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

where F is the maximum load (N) exerted on the specimen, l is the distance (mm) between the supports, b is the width (mm) of the specimen

TABLE I. Denture base and repair materials evaluated

Denture Base	Polymerization Mode	Composition	Repair Material	Polymerization Mode	Composition	Manufacturer
Eclipse Base Material	light	urethane-based oligomers	Eclipse Base Material	light	urethane-based oligomers	DeguDent GmbH, Hanau, Germany
Luxene	heat	polyvinyl copolymer, prepolymerized acrylate monomer	–	–	–	Astron Dental, Lake Zurich, Ill
Microbase	microwave	highly cross-linked polyurethane	Microbase repair material	light	polyurethane	DeguDent GmbH
Polyan	thermoplastic	modified methyl methacrylate	–	–	–	Polyapress GmbH, Altkirchen, Germany
Puran HC	heat	polyurethane dimethacrylate, oligomers	Puran CC	auto	urethane-based oligomers	Novodent, Eschen, Liechtenstein
Alldent Sinomer	heat	acrylic polymers of methyl methacrylate, urethane, acrylate-based oligomers	Alldent Sinomer N	auto	urethane-based oligomers	Novodent
The.r.mo.Free	thermoplastic	polymethyl methacrylate based	–	–	–	Pressing Dental, San Marino, Italy
			Versyo.com	light	cross-linked organic matrix, dimethacrylate	Heraeus Kulzer, Hanau, Germany
Paladon 65 (control group)	heat	polymethyl methacrylate	Palapress (control group)	auto	polymethyl methacrylate	Heraeus Kulzer

measured prior to water storage, and h is the height (mm) of the specimen measured prior to water storage.^{31,32}

According to ISO 1567, the minimum flexural strength of denture base materials of Type 1, Type 3, Type 4, and Type 5 (heat-polymerized polymers, thermoplastic blank or powder, light-polymerized materials, and microwave-polymerized materials, re-

spectively) should not be less than 65 MPa.^{31,32} If results obtained for at least 4 out of 5 specimens comply with this requirement, the material passes. If 1 or 2 of the specimens comply with the requirement, the material fails. If 3 of the specimens comply with ISO 1567,^{31,32} 6 new specimens must be prepared and the test repeated. If at least 5 of the second series of speci-

mens comply with the requirements, the material passes.

Flexural modulus was calculated from the flexural strength tests. Additionally, the deflection of the specimens (mm) and the corresponding forces (N) were determined. The flexural modulus (E) was calculated from the equation^{31,32}:

$$E = \frac{F_1 l^3}{4bh^3d}$$

where F_i is the load (N) at a convenient point in the straight-line portion of the trace, d is the deflection (mm) at load F_i , l is the distance (mm) between the supports, b is the width (mm) of the specimens measured prior to water storage, and h is the height (mm) of the specimen prior to water storage.^{31,32}

If at least 4 of the results met the requirements for the flexural strength on the first series, the flexural modulus was calculated for each of the 5 specimens. If a second series was tested for the flexural strength, the flexural modulus for 5 out of the 6 specimens was calculated. According to ISO 1567, the minimum flexural modulus of denture base materials of Type 1, Type 3, Type 4, and Type 5 should not be less than 2000 MPa. The requirements are fulfilled if at least 4 out of 5 results exceed 2000 MPa. If at least 3 of the specimens do not comply with the requirement, the material fails. If 3 of the flexural modulus results comply with the requirements, 6 new specimens should be prepared. If at least 5 results of the second series comply with the requirement, the material passes.

Then the fractured specimens were repaired according to the following test design. Eclipse base material, Microbase, Puran HC, and Alldent Sinomer were repaired using the recommended repair method for their respective systems. The manufacturers of Luxene, Polyan, and The.r.mo. Free recommended no repair materials. Versyo.com was to be tested to determine its suitability for the repair of hypoallergenic denture base materials lacking a repair system; therefore, each hypoallergenic denture base material was repaired using Versyo.com. The conventional heat-polymerizing PMMA-containing material, Paladon 65, was repaired with Palapress (control group, Table I).

For the Versyo.com repair system, the fracture gap was prepared to a distance of 3 mm between the 2 surfaces using a diamond rotary cutting instrument (ISO 806 104 263524 060;

Komet, Lemgo, Germany). Specimen preparation was performed without pressure to avoid thermal effects on the materials. In addition, manufacturers' instructions were strictly followed for the repair systems offered for 4 of the tested products. A gap of 3 mm for the other denture base materials was prepared using a diamond rotary cutting instrument or a carbide rotary cutting instrument (ISO 500 104 274220 060; Komet), as recommended in the literature, forming a 45-degree bevel of the fractured surfaces of both fragments, exactly as for the Versyo.com repair.^{15,16}

The plaster indices were stored in water for 10 minutes before use. The respective specimen fragments were replaced into the index and the gap between them was prepared using the various repair materials. A surplus of repair material was used to completely fill the gap. After polymerization, the repair material surplus was removed using metallographic grinding paper (1200 FEPA; Buehler Ltd) under water cooling. The width and height of each specimen were measured and recorded. The repaired specimens were again stored in water (37°C) for 50 ± 2 hours. The 3-point bending test was performed in the same manner as described previously. Flexural strengths and flexural moduli were calculated.

The mean values of flexural strengths and flexural moduli for those groups which were either repaired according to manufacturer's instructions or repaired with Versyo.com were analyzed by 2-way repeated measures analysis of variance (ANOVA), with repair (intact, repaired) as the repeated-measure factor and denture base material as the between-group factor, using statistical software (StatView 5.0; SAS Institute, Cary, NC). Statistical analyses of the groups which were repaired according to manufacturer's instructions and repaired with Versyo.com were performed with repeated measures 3-way ANOVA for denture base materials by repair methods (between-group factors) and by repairs (repaired versus

intact specimens, repeated) to evaluate interaction effects between these variables ($\alpha=.05$). A 1-way ANOVA and Bonferroni-Dunn's multiple comparisons post hoc analyses of the flexural strengths and flexural moduli were conducted for the original and the repaired groups, respectively ($\alpha=.05$). Additionally, test groups of each material before and after repair (according to the manufacturers' instructions and with Versyo.com) were individually compared using paired t tests ($\alpha=.05$).

RESULTS

Two-way (Tables II through V) and 3-way (Tables VI and VII) repeated measures ANOVA revealed that the between-group main effect for denture base material and the repeated-measure factor repair (repaired versus intact specimens) were significant ($P<.001$). The denture base material-by-repair interaction had a significant effect on the flexural properties ($P<.001$), indicating that flexural strengths and flexural moduli of repaired versus intact specimens differed according to denture base material (Tables II through VII). Repair methods (repair according to manufacturer's instructions or repair with Versyo.com) and the interactions "denture base material × repair method," "repair (repeated) × repair method," and "repair (repeated) × denture base material × repair method" showed no significant effect on the repair strength (Tables VI and VII). Therefore, neither the repair method in combination with different denture base materials nor the repair method in combination with the repair (repaired versus intact specimens) had a significant effect on the flexural strengths and flexural moduli.

Bonferroni-Dunn's post hoc analysis showed statistical differences in flexural strength and flexural modulus between different denture base materials (Tables VIII and IX). Flexural strengths of intact specimens of Eclipse and Luxene demonstrated sig-

TABLE II. Two-way repeated measures ANOVA for intact Eclipse, Microbase, Puran HC, Alldent Sinomer, and Paladon 65, as well as for these materials repaired according to manufacturers' instructions (flexural strength)

	<i>df</i>	Sum of Squares	Mean Square	F	<i>P</i>
Denture base material	4	7519	1880	67.8	<.001
Subject (group)	20	555	28		
Category for repair (repeated)	1	3080	3080	234.2	<.001
Category for repair (repeated) × denture base material	4	553	138	10.5	<.001
Category for repair (repeated) × subject (group)	20	263	13		

P<.05 indicates significant difference

TABLE III. Two-way repeated measures ANOVA for intact Eclipse, Luxene, Microbase, Polyan, Puran HC, Alldent Sinomer, and The.r.mo.Free, as well as for these materials repaired with Versyo.com (flexural strength)

	<i>df</i>	Sum of Squares	Mean Square	F	<i>P</i>
Denture base material	6	13327	2221	44.9	<.001
Subject (group)	28	1385	49		
Category for repair (repeated)	1	4054	4054	94.8	<.001
Category for repair (repeated) × denture base material	6	2426	404	9.5	<.001
Category for repair (repeated) × subject (group)	28	1198	43		

P<.05 indicates significant difference

TABLE IV. Two-way repeated measures ANOVA for intact Eclipse, Microbase, Puran HC, Alldent Sinomer, and Paladon 65, as well as for these materials repaired according to manufacturers' instructions (flexural modulus)

	<i>df</i>	Sum of Squares	Mean Square	F	<i>P</i>
Denture base material	4	3796407	949102	110.3	<.001
Subject (group)	20	172049	8602		
Category for repair (repeated)	1	534102	534102	77.8	<.001
Category for repair (repeated) × denture base material	4	141287	35322	5.1	.005
Category for repair (repeated) × subject (group)	20	137338	6867		

P<.05 indicates significant difference

TABLE V. Two-way repeated measures ANOVA for intact Eclipse, Luxene, Microbase, Polyan, Puran HC, All-dent Sinomer, and The.r.mo.Free, as well as for these materials repaired with Versyo.com (flexural modulus)

	<i>df</i>	Sum of Squares	Mean Square	F	<i>P</i>
Denture base material	6	4928553	821426	100.6	<.001
Subject (group)	28	228741	8169		
Category for repair (repeated)	1	274589	274589	53.9	<.001
Category for repair (repeated) × denture base material	6	462834	77139	15.1	<.001
Category for repair (repeated) × subject (group)	28	142591	5093		

P<.05 indicates significant difference

TABLE VI. Three-way repeated measures ANOVA for intact Eclipse, Microbase, Puran HC, and All-dent Sinomer, as well as for these materials repaired according to manufacturers' instructions or repaired with Versyo.com (flexural strength)

	<i>df</i>	Sum of Squares	Mean Square	F	<i>P</i>
Denture base material	3	16620	5540	118	<.001
Repair method	1	12	12	0.3	.616
Denture base material × repair method	3	64	21	0.5	.716
Subject (group)	32	1501	47		
Category for repair (repeated)	1	7262	7262	236.2	<.001
Category for repair (repeated) × denture base material	3	731	244	7.9	<.001
Category for repair (repeated) × repair method	1	24	24	0.8	.380
Category for repair (repeated) × denture base material × repair method	3	41	14	0.4	.721
Category for repair (repeated) × subject (group)	32	984	31		

P<.05 indicates significant difference

TABLE VII. Three-way repeated measures ANOVA for intact Eclipse, Microbase, Puran HC, and Alldent Sinomer, as well as for these materials repaired according to manufacturers' instructions or repaired with Versyo.com (flexural modulus)

	<i>df</i>	Sum of Squares	Mean Square	F	<i>P</i>
Denture base material	3	6637890	2212630	203	<.001
Repair method	1	25280	25280	2.3	.138
Denture base material × repair method	3	63463	21154	1.9	.143
Subject (group)	32	348783	10899		
Category for repair (repeated)	1	633057	633057	91.2	<.001
Category for repair (repeated) × denture base material	3	366731	122244	17.6	<.001
Category for repair (repeated) × repair method	1	22954	22954	3.3	.078
Category for repair (repeated) × denture base material × repair method	3	36554	12815	1.8	.176
Category for repair (repeated) × subject (group)	32	222072	6940		

P<.05 indicates significant difference

TABLE VIII. Mean flexural strength and standard deviations before and after repair. ISO 1567 requirement for flexural strength is at least 65 MPa for denture base materials

	Flexural Strength (MPa)							
	Repair According to Manufacturer's Instructions				Repair with Versyo.com			
	Before Repair		After Repair		Before Repair		After Repair	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Eclipse	106 ^{ab}	3	81 ^f	10	108 ^a	3	83 ^f	8
Luxene	–	–	–	–	97 ^b	2	73 ^{fg}	8
Microbase	77 ^c	5	60 ^{gh}	4	77 ^c	9	55 ^{hij}	9
Polyan	–	–	–	–	80 ^c	1	69 ^{fgh}	3
Puran HC	70 ^{cd}	2	51 ⁱ	5	72 ^c	1	47 ⁱ	9
Alldent Sinomer	65 ^d	3	55 ^{hi}	3	62 ^{deA}	10	53 ^{iA}	3
The.r.mo.Free	–	–	–	–	53 ^e	8	62 ^{ghi}	2
Paladon 65 (control)	77 ^c	1	71 ^{fgi}	2	–	–	–	–

Groups with same superscripted lowercase letters in column (before repair and after repair, respectively) or uppercase letters in row are not significantly different (*P*>.05).

TABLE IX. Mean flexural modulus and standard deviations before and after repair. ISO 1567 requirement for flexural modulus is at least 2000 MPa for denture base materials

Denture Base Material	Flexural Modulus (MPa)							
	Repair According to Manufacturer's Instructions				Repair with Versyo.com			
	Before Repair		After Repair		Before Repair		After Repair	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Eclipse	2319 ^a	64	2054 ^e	215	2310 ^{ab}	101	1998 ^{ef}	64
Luxene	–	–	–	–	2245 ^{ab}	54	2000 ^{ef}	87
Microbase	2130 ^{bc}	115	1753 ^{gh}	38	2151 ^{abc}	185	1888 ^{efg}	91
Polyan	–	–	–	–	2031 ^c	25	1853 ^{fg}	48
Puran HC	1492 ^d	31	1410 ⁱ	51	1505 ^{dA}	32	1597 ^{hiA}	80
Alldent Sinomer	1586 ^d	29	1467 ⁱ	64	1572 ^{dB}	31	1488 ^{iB}	63
The.r.mo.Free	–	–	–	–	1470 ^d	95	1592 ^{hi}	38
Paladon 65 (control)	2002 ^c	15	1815 ^{fg}	59	–	–	–	–

Groups with same superscripted lowercase letters in column (before repair and after repair, respectively) or uppercase letters in row are not significantly different ($P>.05$).

nificantly higher values and Alldent Sinomer and The.r.mo.Free had significantly lower results than Paladon 65 ($P<.001$) (Table VIII). Flexural moduli of the intact specimens of Eclipse and Luxene demonstrated significantly higher values compared to Paladon 65, whereas for Puran HC, Alldent Sinomer, and The.r.mo.Free, significantly lower results were obtained than for the control group ($P<.001$) (Table IX).

Flexural strengths and flexural moduli of the denture base materials repaired according to the manufacturer's instructions were not significantly different from specimens repaired with Versyo.com (Tables VI, VII, and VIII). Puran HC and Alldent Sinomer repaired according to the manufacturer's instructions or repaired with Versyo.com showed significantly lower flexural strengths than the control group (Paladon 65 repaired with Palapress, $P<.001$). Flexural strengths after repair of the other hypoallergenic base materials

were not significantly different from the control group. Flexural moduli after repair were significantly improved for Eclipse with Eclipse base material compared to Paladon 65/Palapress, and significantly lower for Puran HC, Alldent Sinomer, and The.r.mo.Free ($P<.001$) (Table IX).

Paired t tests revealed that flexural strengths of both repair methods (repair according to manufacturer's instructions or repair with Versyo.com) for all materials decreased significantly compared to the intact specimens ($P=.001 - P=.021$), except for Alldent Sinomer with Versyo.com and The.r.mo.Free with Versyo.com (Table VIII). Accordingly, the flexural moduli of both repair methods for all materials showed a significant decrease compared to the intact specimens ($P<.001 - P=.046$), whereas for The.r.mo.Free repaired with Versyo.com, significantly higher values were obtained than for the intact material ($P=.011$) (Table IX). No significant differences were found for Puran HC

and Alldent Sinomer repaired with Versyo.com compared to the intact specimens.

Eclipse, Luxene, Microbase, Polyan, and Paladon 65 fulfilled the requirements of ISO 1567 with respect to both the flexural strength of 65 MPa and flexural modulus of 2000 MPa for the intact material (Tables VIII and XI). The.r.mo.Free failed with respect to both requirements, whereas Puran HC and Alldent Sinomer failed with respect to the required flexural modulus.

After repair, Eclipse with Eclipse base material as well as Eclipse, Luxene, and Polyan with Versyo.com, and Paladon 65 with Palapress (control group), exhibited the required flexural strength according to ISO 1567.^{31,32} Yet only Eclipse with both repair methods (repair according to manufacturer's instructions or repair with Versyo.com) and Luxene repaired with Versyo.com passed the flexural modulus standard.

DISCUSSION

Based on the results, the hypothesis that the repair methods for the hypoallergenic denture base materials restore the flexural strength and flexural modulus of the original material was not accepted, except for The.r.mo.Free. The hypothesis that the light-polymerizing hypoallergenic repair material Versyo.com provides results comparable to the respective manufacturer-recommended repair systems was accepted. It was also shown that Versyo.com is suitable for the repair of hypoallergenic denture base materials which lack a repair system.

Studies revealed that the success of the repair procedure depends on the width of the gap and the preparation of the fractured surfaces.^{15,16} In the present investigation, the fracture gap, with a distance of 3 mm between the 2 fragments, was prepared as recommended in the literature, forming a 45-degree bevel of the fractured surfaces of both fragments.^{15,16} Ward et al¹⁵ advised a 45-degree bevel or rounded joint rather than a butt joint of the repair surfaces to improve the fracture strength.

Test groups with intact Eclipse, Luxene, Microbase, Polyan, and Paladon 65 specimens fulfilled the requirements of ISO 1567 for both flexural strength and flexural modulus. The.r.mo.Free neither fulfilled the requirements of ISO 1567 for the flexural strength nor for the flexural modulus. Rolleke et al³⁶ examined the mechanical properties of denture base materials according to ISO 1567 as well. The investigation revealed that the denture base materials Microbase, Paladon 65, Polyan, Promysan (Pedrazzini Dentaltechnologie, Munich, Germany), and Alldent Sinomer passed the requirements of ISO 1567 regarding flexural strength. Only Alldent Sinomer did not reach the required values for the flexural modulus. These results are in agreement with the results of the present study.

Repaired Eclipse and Luxene spec-

imens met the ISO 1567 requirements with respect to flexural strength as well as flexural modulus. However, the flexural modulus of the PMMA material of the control group (Paladon 65/Palapress) did not meet the requirements. Flexural strengths and flexural moduli of Microbase and Polyan were not significantly different from the control group. The finding of reduced flexural strength and flexural modulus after repair of the denture base is in agreement with several studies.^{6,7,12,14,15,16} Studies revealed that repair of denture base materials reduced flexural strengths to 22-58%,¹² or to 36-65%,⁹ of the intact materials. In the present study, flexural strengths of the repaired specimens were 72-91% of the strengths of intact materials; this finding was in agreement with the maximum estimated repair strength of 75-85% reported in previous studies.^{7,13-15,24} Therefore, the repair strengths of the hypoallergenic base materials achieved the level of repaired conventional denture base materials, except for Puran HC, Alldent Sinomer, and The.r.mo.Free.

No significant differences between the 2 repair methods (repair according to manufacturer's instructions or repair with Versyo.com) were found with respect to the flexural properties. The superior repair material, Eclipse base material, was light polymerizing. The other light-polymerizing material, Microbase repair material, presented a flexural strength and flexural modulus that did not differ significantly from the control group, whereas both autopolymerizing repair materials, Puran CC and Alldent Sinomer N, demonstrated significantly lower flexural strengths and flexural moduli compared to the control group. Contrary to this finding, Dar-Odeh et al⁶ reported similar values in transverse strength for autopolymerizing, heat-polymerized, and light-polymerized resin materials after repair. Andreopoulos et al¹² also found lower flexural properties for light-polymerized repair materials compared to those of autopolymerizing resin. Additionally,

Polyzois et al⁷ reported greater repair strengths for autopolymerizing acrylic resin compared to heat-polymerizing acrylic resin. From the results of the present study, light-polymerized materials seem to be promising for repair, but the differing results of Versyo.com with the various denture base materials demonstrated that both the repair material and the strength of the denture base material itself are important in determining the flexural properties of the repair. Flexural strength of The.r.mo.Free repaired with Versyo.com was significantly higher than the strength of the intact material. Yet the results for the flexural moduli of the intact and the repaired materials Alldent Sinomer, Puran HC, and The.r.mo.Free were below the requirements of ISO 1567.^{31,32} Nevertheless, it was shown that Versyo.com, based on a cross-linked organic matrix, could be used with other types of material, such as urethane-based oligomers. Therefore, Versyo.com was found to be a suitable repair material for the tested hypoallergenic denture base materials, which lack a repair system.

The present study involved a limited analysis of mechanical properties for the denture base materials used. Further investigations regarding other properties of these materials are mandatory. To overcome the limitations of the in vitro tests, repaired denture base materials must be evaluated intraorally.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. Only 4 of the investigated hypoallergenic denture base materials (Eclipse, Luxene, Microbase, and Polyan) as well as Paladon 65 passed requirements of ISO 1567 for flexural strength as well as flexural modulus.
2. As a result of the significant decrease in flexural strengths and flexural modulus of the various materials after repair, only Luxene and Eclipse

still fulfilled the requirements of ISO 1567, whereas Paladon 65 repaired with Polyapress (control group) passed only the required value for flexural strength, and its flexural modulus was significantly lower than the flexural moduli of Luxene and Eclipse.

3. Versyo.com demonstrated flexural strength and flexural modulus comparable to the respective repair systems recommended by the manufacturers.

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