Effect of Chemical Disinfectants and Repair Materials on the Transverse Strength of Repaired Heat-Polymerized Acrylic Resin

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Purpose: **The purpose of this study was to evaluate both the effects of immersion in different chemical disinfectant solutions and the type of repair material on the transverse strength of repaired heat-polymerized acrylic resin.**

Materials and Methods**: A total of 110 rectangular specimens (65 × 10 × 3 mm) of heat-polymerized acrylic resin (Triplex) were fabricated. After polymerization, the specimens were polished, then stored in distilled water at 37°C for 1 week. The specimens were divided into 11 groups (n = 10) coded A to K. Specimens of Group A remained intact (control). The specimens of Groups C to F and Groups H to K were immersed in the following chemical disinfectant solutions (1%, 2.5%, and 5.25% sodium hypochlorite and 2% glutaraldehyde, respectively) for 10 minutes. The specimens of all groups except those of Group A were sectioned in the middle to create 10 mm gaps and repaired with the same resin (Groups B to F) and autopolymerizing acrylic resin (Groups G to K). The specimens of Groups C to F and Groups H to K were again immersed in the disinfectant solutions in the same sequence. The transverse strength (N/mm^2) was tested for failure in a universal testing machine, at a crosshead speed of 5 mm/min. Two-way analysis of variance (ANOVA) was performed to evaluate the effects of both the disinfectant solutions and repair materials on the transverse strength of repaired specimens. All data were statistically analyzed using one-way analysis of variance followed by Tukey's test at 95% confidence level.**

Results**: The repaired specimens treated with/without disinfectant solutions showed similar ($p > 0.05$) transverse strength values. No differences ($p > 0.05$) were detected among the repaired specimens either with heat-polymerized or autopolymerizing acrylic resins. The intact specimens showed transverse strength values (86.9 ± 11.8) significantly higher ($p < 0.05$) than the values of the repaired specimens.**

Conclusions**: Among the repaired specimens, transverse strength was not affected after immersion in the disinfectants for the immersion period tested (10 min). The repair material, either heat-polymerized or autopolymerizing acrylic resin, had no effect on the transverse strength of the repaired acrylic resin specimens.**

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INDEX WORDS: repair strength, disinfectants, heat-polymerized acrylic resin, autopolymerizing acrylic resin

DENTISTS, AUXILIARY personnel, and dental laboratory technicians may be exposed to a wide variety of harmful microorganisms daily. Potential sources of transmission of infectious diseases from patients to dental technicians include impressions, impression trays, and gypsum casts. Similarly, prostheses in contact with oral tissues, saliva, and blood, when removed from patients' mouths at the various stages of repairing procedures, may be contaminated by pathogenic organisms, which can be transmitted through direct contact or through the aerosol raised during trimming, finishing, and/or polishing procedures. Opportunistic bacteria with varying levels of pathogenicity may be spread and disseminated in the air, leading to cross-infection and exposure

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Accepted June 6, 2005.

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1059-941X/06

doi: 10.1111/j.1532-849X.2006.00131.x

of professionals and patients to disease. To eliminate cross-contamination, all prostheses and dental appliances should be properly disinfected in both the dental office and laboratory and before being inserted intraorally.[1]

The commonly used chemical agents for disinfection of prostheses are chlorine, iodophors, and aldehyde compounds;[1-4] however, several studies have emphasized that some disinfectants may adversely affect the physical properties of denture base resins.[5-8] Immersion in certain cleansing and disinfecting solutions may, for example, decrease the transverse strength and hardness, degrade the surface appearance of the resins,[5] and cause corrosion of metal surfaces of removable prosthetic devices. The transverse strength of acrylic resins depends on several factors, such as polymer molecular weight,[9] polymer bead size,[10] residual monomer level,[9,11] plasticizer composition,[9,12] amounts of cross-linking agents,[13,14] internal porosity of the polymer matrix,[11] denture base thickness,[15] type of polishing, and action of chemical agents.

Acrylic resin complete dentures are susceptible to fracture after periods of clinical use.[16] The repair of the fractured prostheses can be accomplished using acrylic resins that are light-polymerized,[17] autopolymerized,[18,19] or heat-polymerized.[20] The repair material of choice depends on the following factors: length of time required for making the repair, transverse strength obtained with the repair material, and degree to which dimensional accuracy is maintained during the repair.[21]

Despite the high frequency of denture fracture, there is surprisingly little data about the effects of chemical disinfectants on the repaired prostheses. Therefore, the aim of this in vitro study was to evaluate both the effects of immersion in different chemical disinfectant solutions and the type of repair material on the transverse strength of repaired heat-polymerized acrylic resin.

Materials and Methods

Specimen Preparation

Teflon rectangles measuring 65 × 10 × 3 mm (ISO 1567 Standard)[22] were invested in flasks with dental stone. After the setting of the stone, the flasks were opened, and the Teflon rectangles were removed, leaving rectangular-shaped cavities in the stone, used as matrices for the fabrication of heat-polymerized acrylic resin specimens.

The dental stone was lubricated with a thin layer of acrylic separating film (Isolmajor, Major, Italy). The monomer and polymer of the heat-polymerized acrylic resin (Triplex, Ivoclar Vivadent, Schaan, Liechtenstein), were proportioned, mixed, packed, and pressed into the mold following the manufacturer's instructions.

After polymerization of the resin, the flasks were allowed to cool to room temperature before opening. The rectangular resin specimens were then deflasked. A total of 110 specimens were fabricated. Flash and excess acrylic resin were removed by trimming the edges with tungsten steel burs using a handpiece at low speed, and with additional hand smoothing using #320-grit silicon carbide paper. Specimens were then treated according to the following protocol: one side of the acrylic resin rectangle was hand-polished with a #320-grit silicon carbide paper using water as a coolant, and the other side was sequentially polished with #320-, 400-, and 600-grit silicon carbide papers. The purpose of this approach was to obtain in the same specimen an intaglio surface and a highly smooth surface, thus simulating both sides of a complete denture. All specimens were stored in distilled water at 37°C, for 1 week before immersion in the chemical disinfectants, repair procedure, and transverse strength testing.

Disinfection Methods and Repairing Procedures

The specimens were divided into 11 groups (n = 10) coded A to K. Specimens of Group A remained intact (control). The specimens of Groups C to F and Groups H to K were respectively immersed in the following chemical disinfectants [1%, 2.5%, and 5.25% sodium hypochlorite (Quneex, Saudi Industrial Detergents Co, Dammam, Saudi Arabia) and 2% glutaraldehyde (Protectal, Spimaco, Al-Qassim Pharmaceutical Plant, Saudi Arabia)] for 10 minutes. The rationale for selecting these agents was based on the fact that sodium hypochlorite is accepted by the American Dental Association for the cleansing and disinfection of complete and nonmetal partial removable dentures,[3,4,23-27] and glutaraldehyde is recommended for cleansing of partial removable prosthetic dentures containing metal.[5-8,27-29] After immersion, the resin specimens were removed from the chemical solutions, thoroughly washed in running water, and dried with absorbent paper. The specimens of all groups except those of Group A were sectioned in the middle using a double-sided diamond disc. The freshly cut ends of the two pieces of each specimen were ground to a butt joint with 600-grit silicon carbide papers until 10 mm of the total length of the specimen was removed. Once polished and cleaned, the specimens were returned and positioned to the same

preparation mold in such a way that a 10 mm gap existed between the two sections of the specimen. The same heat-polymerized acrylic resin was used for repairing the specimens of Groups B to F, while autopolymerizing acrylic resin (Triplex) was used for repairing the specimens of Groups G to K. These materials were mixed and added to the gap in a free flowing stage, thus filling the space between the sections. The joint space was slightly overfilled to allow for polymerization shrinkage and finishing. After the repair procedures, the specimens of Groups C to F and Groups H to K were again immersed in the disinfectant solutions in the same sequence.

Transverse Strength Testing

Prior to transverse strength testing, the width and thickness of each specimen were measured with a digital caliper (Fowler Tools & Instruments, Boston, MA) with measuring accuracy of ±0.1 mm. This procedure was necessary because after the trimming and polishing procedures the original size of each specimen was altered.

The transverse strengths of the specimens were determined using a 3-point bending testing device in a universal testing machine (Instron, Model TM 5565, Canton, MA). The device consisted of a loading wedge and a pair of adjustable supporting wedges placed 50 mm apart. The specimens were centered on the device in such way that the loading wedge, set to travel at a crosshead speed of 5 mm/min, engaged the center of the upper surface of the specimens. Specimens were loaded until fracture occurred. Transverse strength was calculated using the following equation:[6,7,22,29-32]

$$S = 3PI/2bd^2$$

Where: S = transverse strength (N/mm^2), P = load at fracture (N), I = distance between the supporting wedges (mm), b = width of the specimen (mm), and d = thickness of the specimen (mm). In addition, the nature of the failure was noted as adhesive, cohesive, or mixed.

Preliminary statistical analysis showed that the sample distribution was normal and homogeneous, thereby allowing the use of parametric tests. Two-way analysis of variance (ANOVA) was used to test for differences among the groups. To compare the mean transverse strengths recorded for the intact and repaired specimens, one-way analysis of variance was performed followed by Tukey's test at 95% confidence level.

Results

A 2-way ANOVA (Table 1) showed that disinfectant solution was not detected as source of variation with p value of 0.271. The other factor (repair material) was detected as a source of variation with a p value of 0.004.

The mean values for the transverse strength of intact and repaired specimens treated with/without different disinfectant solutions are presented in Table 2. The intact specimens showed transverse strength significantly higher ($p < 0.05$) than repaired specimens. No differences ($p > 0.05$) were detected among the groups with repaired specimens. The repaired specimens treated with/without disinfectant solutions showed similar ($p > 0.05$) transverse strength values.

The percentage of strength of the intact specimens and the type and frequency of failures for repaired specimens are presented in Table 3. The specimens revealed three types of failures: adhesive (interface), cohesive (only at the repair material), and mixed (interface and repair material). Mixed failure was the most common type of failure. Only two repaired specimens showed a pure adhesive failure.

Discussion

To prevent bacterial cross-contamination among denture patients all dental prostheses must be disinfected on entering and again on leaving the laboratory.[4] The objective of immersing a denture base in a disinfectant solution is to inactivate infectious viruses and bacteria. Furthermore, the

Table 1. Results of 2-Way Analysis of Variance (ANOVA)

Source of Variation	*Df*	*SS*	*MS*	*F Ratio*	*p Value*
Repair Material	1	1324.9	1324.9	9.2	0.004*
Disinfectant	4	769.9	192.5	1.3	0.271
Repair material × disinfectant	4	367.6	91.9	.64	0.636
Error	40	5731.3	143.3		
Total	49	8193.6			

*Significant at the level of $p < 0.05$.

Table 2. Mean Transverse Strengths (MPa) and Standard Deviations for Intact and Repaired Specimens

Groups	*Repair Material*	*Disinfectant Solutions*	*Mean and Standard Deviations**
Group A	—	—	86.9 ± 11.8^{a}
Group B	heat-polymerized	—	62.3 ± 16.5^{b}
Group C	heat-polymerized	1% sodium hypochlorite	60.0 ± 14.0^{b}
Group D	heat-polymerized	2.5% sodium hypochlorite	60.7 ± 8.2^{b}
Group E	heat-polymerized	5.25% sodium hypochlorite	62.7 ± 17.2^{b}
Group F	heat-polymerized	2% glutaraldehyde	63.4 ± 14.3^{b}
Group G	Autopolymerizing	—	57.9 ± 11.3^{b}
Group H	Autopolymerizing	1% sodium hypochlorite	54.9 ± 10.7^{b}
Group I	Autopolymerizing	2.5% sodium hypochlorite	55.9 ± 6.3^{b}
Group J	Autopolymerizing	5.25% sodium hypochlorite	52.6 ± 4.4^{b}
Group K	Autopolymerizing	2% glutaraldehyde	54.9 ± 9.5^{b}

*Groups with the same superscript letter were not significantly different according to post-hoc Tukey test companions ($p > 0.05$), while Group A with the different superscript letter was significantly different ($p < 0.05$).

disinfectants should be effective without damaging the denture materials.

Considering that the overall longevity of a dental prosthesis also depends on the physical properties of the denture base resin,[12] and that denture base polymers may fail clinically due to flexural fatigue, the assessment of the transverse strength of acrylic resins has been reported to be a reliable method to estimate resin behavior under different experimental conditions.[33]

The current work was undertaken to determine whether significant changes in the transverse strength of repaired heat-polymerized acrylic resin occur after immersion in chemical disinfection solutions. The results demonstrated that the flexural strength was not significantly affected by exposure in any of the four types of immersion disinfectant solutions (Table 2). There is no published data showing the effect of disinfectant solutions on the transverse strength of repaired acrylic resin; however, the results of the present study are consistent with those of Orsi and Andrade[34] who studied the effect of immersion in different chemical disinfectants for varying time periods on the transverse strength of three mechanically or chemically polished heat-polymerized acrylic resins.

Table 3. Percentage of Strength of Intact Specimens (Group A) and Failure Types

Groups	*Percentage of Strength of Intact Specimens (Group A)*	*Mode of Failure*		
		Adhesive	*Cohesive*	*Mixed*
Group A	—		—	—
Group B	72		3	7
Group C	69		4	6
Group D	70		5	5
Group E	71		4	6
Group F	73		2	8
Group G	67		5	5
Group H	63		6	4
Group I	64	1	2	7
Group J	61		5	5
Group K	63	1	4	5

Ma et al[27] observed that the use of sodium hypochlorite disinfectant produced color changes for four of the five resins studied, which indicated the bleaching action of the disinfectant. Soaking trials involving the use of denture cleansers applied to heat-and-cold curing acrylic resin have indicated that both materials were whitened by hot hypochlorite and by hot alkaline peroxide solutions.[24] This indicated that the temperature of the immersion solutions played an important role in the bleaching effect. When whitening occurred, the specimens also suffered a reduction in flexural strength. In the current study, the flexural strength of the acrylic resins was not affected by immersion in these solutions. This could be related to the fact that the specimens were soaked in sodium hypochlorite and glutaraldehyde at room temperature.

The absence of any significant change in flexural strength of repaired specimens after immersion in the disinfectants could be attributable to the fact that the immersion solutions used do not contain chemicals that may cause dissolution or crazing of the resins, such as alcohol and phenol.

Furthermore, the heat-polymerized resin evaluated contains cross-linking agent, which has been used widely in the manufacture of acrylic denture teeth to increase their resistance to solvents and surface stresses.[35]

Lower transverse strength values were reported for repaired specimens, whereas intact specimens demonstrated significantly higher transverse strengths, emphasizing the observation that the repairing procedure may adversely affect resin strength and structure.

The results of the present study are consistent with those of Rached et al[36] who evaluated the transverse repair strength of a conventional heat-polymerized and a microwave-polymerized acrylic resin that were repaired with these same resins and with an autopolymerizing acrylic resin. They found that autopolymerizing resin had a repair strength similar to those found for the conventional heat- and microwave-polymerized materials.

The repair strength of heat-polymerized materials ranges from 75%[18] to 80%[19] of the original material. Although the conventional material demonstrates superior strength, this material requires a significant amount of working time due to necessary packing and flasking procedures, and also presents the added risk of denture distortion by heat.[37] The repair strength of autopolymerizing acrylic resins have been shown to be approximately 60%[19,38] to 65%[18] of the original material, which is lower than strengths achieved with heat-polymerized acrylic resins. In the present study, the repair strength of heat-polymerized resin ranges from 69% to 73% of the original material. The repair strength of autopolymerizing resin ranges from 61% to 67% of the original material. Differences in material composition and experimental protocols may explain this finding.

The failures observed were of the mixed type similar to those found by Rached et al.[36] The pure cohesive fractures occurred only at the repair material regardless of the type of the material; these results are consistent with those of Harrison and Stansburry.[39] Although there is a high incidence of mixed fractures in the present study, the occurrence of only two pure adhesive failures indicates the overall acceptable good bond strengths were achieved especially for the autopolymerizing acrylic resin.

As the flexural strength of the acrylic resin remained unaffected, it seems that all immersion solutions evaluated in this study could be safely applied in everyday practice for the disinfection of dentures before repairing procedures. However, a denture base, during its service life, may be exposed several times to disinfecting solutions due to repeated fractures. Therefore, the effects of long-term immersion in the disinfectant solution on the transverse strength of the denture base materials are topics for future investigation. Further studies are also indicated to determine the effect of these solutions on the surface characteristics of the materials.

Conclusions

Within the limitation of the current study, the following conclusions were drawn:

1. Among the repaired specimens, transverse strength was not affected by the chemical disinfectant solutions used in this study.
2. Repair materials did not significantly ($p > 0.05$) affect the transverse strength of repaired heat-polymerized acrylic resin.
3. Repaired specimens exhibited significantly lower transverse strength than the intact specimens.

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