Effect of chemical disinfectants on the transverse strength of heat-polymerized acrylic resins submitted to mechanical and chemical polishing

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Statement of problem. Immersion in chemical solutions used for cleansing and disinfecting prostheses can decrease the strength of denture base resins, making them more prone to fracture during use.

Purpose. The purpose of this study was to assess the effect of immersion in different chemical disinfectants for varying time periods on the transverse strength of 3 mechanically or chemically polished heat-polymerized acrylic resins.

Material and methods. A total of 630 rectangular specimens (65 × 10 × 3 mm), 210 per resin (Clássico, Lucitone 550, and QC-20), were fabricated. One side of each specimen was not polished and the other was either mechanically (n=300) or chemically (n=300) polished, and immersed for 10, 20, 30, 45, or 60 minutes in either 1%, 2.5%, or 5.25% sodium hypochlorite or 2% glutaraldehyde. Mechanically polished (n=15) and chemically polished (n=15) control specimens were immersed only in distilled water. The transverse strength (N/mm^2) was tested for failure in a universal testing machine, at a crosshead speed of 5 mm/min. Data were statistically analyzed using 2-way ANOVA and Student *t* test. Multiple comparisons were performed using Tukey and Scheffé tests (α=.05).

Results. There was significant difference ($P<.01$) between types of polishing, with chemical polishing resulting in lower transverse strength. ANOVA identified significant differences ($P<.01$) in strength between mechanically polished Lucitone 550 and QC-20, and among all 3 chemically polished resins. No significant differences were observed between resins submitted to both types of polishing or between different immersion periods (10 to 60 minutes), disinfectants, or interaction.

Conclusions. Lucitone 550 resin presented the greatest transverse strength values with both types of polishing. Among the mechanically and chemically polished specimens, transverse strength was not affected after immersion in the disinfectants for the immersion periods tested (10 to 60 minutes). Chemically polished control and experimental (immersed in all solutions) QC-20 specimens showed significant differences in transverse strength values. (J Prosthet Dent 2004;92:382-8.)

CLINICAL IMPLICATIONS

There is concern that immersion in certain chemical solutions, such as sodium hypochlorite and alkaline glutaraldehyde, often used for cleansing and disinfection of prostheses, may undermine the strength and structure of denture base resins. The findings of this in vitro study demonstrated that immersion for up to 60 minutes in 1%, 2.5%, and 5.25% sodium hypochlorite and 2% alkaline glutaraldehyde did not affect the transverse strength of the heat-polymerized acrylic resins evaluated. Lower transverse strength values were recorded for chemically polished specimens.

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. Likewise, prostheses in contact with oral tissues, saliva, and blood, when removed from patients' mouths at the various stages of trial and insertion, 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 exposing professionals and patients to disease. To eliminate cross-contamination, all prostheses and dental appliances should be

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Table I. Heat-polymerized acrylic resins

Acrylic resins	Principle ingredients: Polymer	Principle ingredients: Monomer	Manufacturer
Lucitone 550	Copolymer (methyl-n-butyl) methacrylate, benzoyl peroxide, mineral dyes	Methylmethacrylate, ethyleneglycol, dimethacrylate, hydroquinone	Dentsply International, York, Pa
Clássico	Polymethylmethacrylate, ethylacrylate, benzoyl peroxide, organic pigments	Methylmethacrylate, topanol stabilizer	Clássico Ind. e Com, São Paulo, Brazil.
QC-20	Copolymer (methyl-n- butyl) methacrylate, benzoyl peroxide, mineral dyes	Methylmethacrylate, ethyleneglycol, dimethacrylate, N,N dimethyl-p-toluidine, hydroquinone methyl ether	Dentsply International

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,[11,15] denture base thickness,[15] patient factors,[15] type of polishing, and action of chemical agents. Polishing may be accomplished either by conventional mechanical procedures, including the use of abrasive pastes with rotating felt cones and rag wheels, or by chemical procedures consisting of immersion in a monomer-based polishing fluid. The latter methods produce a coating on the resin that imparts a smooth shiny surface to the prosthesis.

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.[16] Therefore, the goal of this in vitro study was to assess the effect of immersion in different chemical disinfectants for varying time periods on the transverse strength of 3 heat-polymerized acrylic resins submitted to mechanical or chemical polishing. The first null hypothesis tested was that there is no difference between the transverse strength of acrylic resin specimens submitted to mechanical or chemical polishing. The second null hypothesis was that there is no difference in the transverse strength of the 3 resin brands submitted to mechanical or chemical polishing, after immersion in disinfecting solutions using different agents and different immersion times.

MATERIAL AND METHODS

This in vitro study evaluated the transverse strength of 3 commercial brands of heat-polymerized acrylic resin submitted to mechanical or chemical polishing and to chemical disinfection using 4 different agents and varying immersion periods. The resins analyzed consisted of 2 brands of acrylic resin used worldwide (Lucitone 550 and QC-20) and 1 brand used extensively in Brazil (Clássico).

Specimen preparation

Teflon (DuPont, Wilmington, Del) rectangles measuring $65 \times 10 \times 3$ mm (ISO 1567 Standard)[17] 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 (Cel-Lac; SS White Artigos Dentários, Rio de Janeiro, Brazil). The monomer and polymer of the heat-polymerized acrylic resins, Clássico, Lucitone 550, and QC-20, were proportioned, mixed, packed, and pressed into the mold following manufacturers' instructions (Table I). Lucitone 550 and Clássico are conventional heat-polymerized resins. QC-20 is a dual-polymerizing acrylic resin which uses thermal and chemical activators and is classified as a quick-polymerizing resin.

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 630 specimens were fabricated, 210 from each brand of resin. In the experimental group (n=600), 100 specimens from each resin were mechanically polished

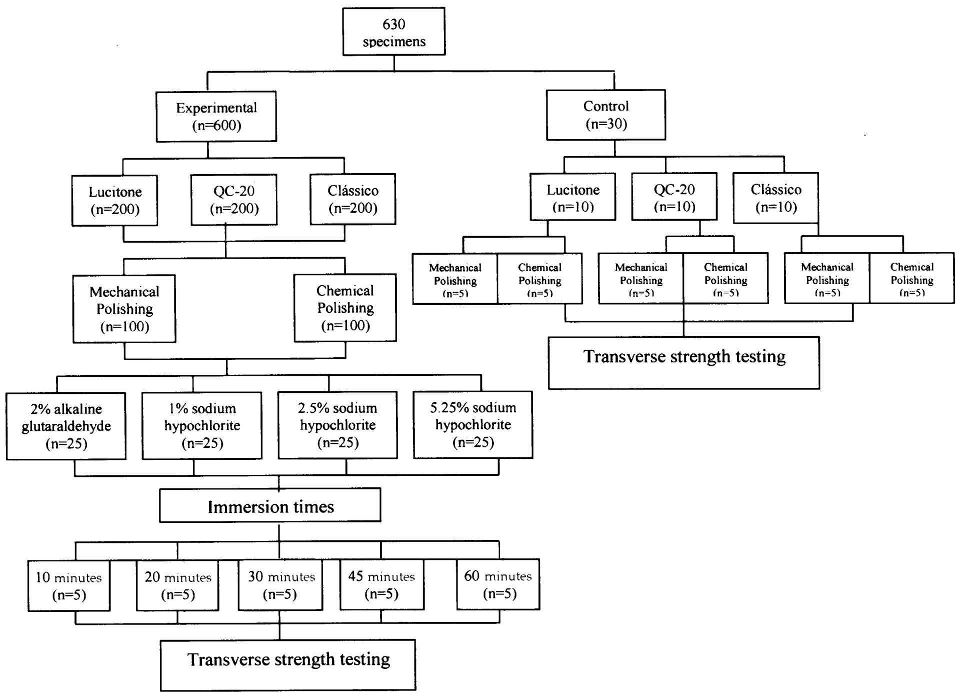

Fig. 1. Flow chart of sample grouping and specimen distribution.

and 100 were chemically polished. In the control group (n=30), mechanically polished (n=15) and chemically polished (n=15) specimens were immersed only in distilled water. Sample grouping and specimen distribution are illustrated in Figure 1. Flash and excess acrylic resin were removed by trimming the edges with tungsten steel burs (#1508; Edenta AG, Hauptstrasse, Switzerland) using a handpiece at low speed, and with additional hand smoothing using #320-grit silicon carbide paper (Norton Industria e Comércio Ltda, Guarulhos, Brazil). Specimens were then treated according to the following protocol: 1 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.

The mechanically polished specimens were polished using a lathe (SS White Artigos Dentários, Rio de Janeiro, Brazil) with a rag wheel and polishing pastes (pumice and water, followed by zinc oxide and water). Specimens submitted to chemical polishing were processed in a chemical polishing machine (PQ 9000; Equipamentos para Laboratórios Termotron Ltda, Piracicaba, Brazil) by soaking in a methyl methacrylate–based solution (Poli-Quim; Artigos Odontológicos Clássico, Sao Paulo, Brazil) heated to approximately 80°C for 10 seconds and then placed on a glass plate to dry. All specimens were stored in distilled water, at room temperature, for 7 days before disinfection and transverse strength testing.

Disinfection methods

To determine the effect of chemical disinfectants on the transverse strength, specimens (n=25) from each resin brand were immersed in 1 of the following chemical disinfectants: 1%, 2.5%, or 5.25% sodium hypochlorite (Rirex; Indústria Farmacêutica Rioquímica, São José do Rio Preto, Brazil) or 2% alkaline glutaraldehyde (Glutaron II; Indústria Farmacêutica Rioquímica). 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,[3,4,18-22] and glutaraldehyde is recommended for cleansing of partial removable prosthetic dentures containing metal.[5-8,22-24] The specimens of each brand of resin, submitted to either polishing procedure, were immersed in the chemical disinfectant solutions for 10, 20, 30, 45, or 60 minutes. This schedule was based on the minimum of 10 minutes required to achieve disinfection[5,6,21-23,25,26] and the 10- and 15-minute increments represented consecutive immersions. Five specimens were used for each resin brand, type of polishing, disinfecting agent, and immersion time. After immersion, the resin specimens were removed from the chemical solutions, thoroughly washed in running water, dried with absorbent paper, and tested for transverse strength. Control specimens from each resin brand (n=10) were submitted to either mechanical (n=5) or chemical polishing (n=5) but were not immersed in the disinfectants. After polishing, the specimens tested as controls were kept in distilled water until transverse strength testing (Fig. 1).

Transverse strength testing

Prior to transverse strength testing, the width and thickness of each specimen were measured with a digital pachymeter (Model SC-6; Mitutoyo Sul America Ltda, Suzano, Brazil) 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. Since width and thickness were factors assessed for determining transverse strength, only the resin specimens with slight variations in size (up to 0.3 mm) were included in the study. Those with greater variation in size (>0.3 mm) were discarded from the sample, so as not to interfere with the transverse strength calculation. New specimens were fabricated for discarded specimens.

The transverse strengths of the specimens were determined using a 3-point bending testing device in a universal testing machine (Model MEM 2000; EMIC Equipamentos e Sistemas de Ensaio, São José dos Pinhais, Brazil). 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. The values were recorded in kgf and converted into N (1 N = 9.81 kgf). Transverse strength was computed using the following equation[6,7,17,27-29]:

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

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)
d = thickness of the specimen (mm)

Preliminary statistical analysis showed that the sample distribution was normal and homogeneous, thereby allowing the use of parametric tests. The Student *t* test was used to compare both types of polishing procedures (mechanical and chemical). To compare the mean transverse strengths recorded for the tested resins with both types of polishing, 1-way analysis of variance was performed. To identify differences among the means, Tukey and Scheffé statistical tests were used. In order to clearly present the results and the significant differences, transverse strength data were gathered in 6 main groups, corresponding to each type of resin with mechanical or chemical polishing. To identify any significant differences between the transverse strength values recorded for the experimental conditions, 2-way analysis of variance was applied to the mechanically and chemically polished groups separately, using, for each group, a factorial design with disinfectants (2% alkaline glutaraldehyde and 1%, 2.5%, and 5.25% sodium hypochlorite) and immersion times (10, 20, 30, 45, and 60 minutes) as independent variables. The Student *t* test (α=.05) was used to compare the transverse strength values of the control groups from each commercial brand of resin, either mechanically or chemically polished, and immersed in each of the disinfecting solutions.

Table II. Mean transverse strengths of acrylic resin specimens submitted to chemical and mechanical polishing (N/mm^2)

	Polishing	
Heat-polymerized acrylic resins	Mechanical	Chemical
Lucitone 550	97.89 a (±10.62)	97.76 c (±11.15)
Clássico	96.78 ab (±9.05)	83.32 d (±9.34)
QC-20	94.77 b (±9.45)	92.29 e (±10.35)
	Tukey/Scheffé 2.96	Tukey 3.13

Different letters indicate statistically different means (P<.05).

RESULTS

The Student *t* test revealed significant difference (P<.01) between types of polishing, with mechanical polishing (96.48 N/mm^2 ± 9.67) yielding higher transverse strength means than chemical polishing (91.12 N/mm^2 ± 9.67). One-way analysis of variance of the mechanically or chemically polished specimens revealed significant difference (P<.01) among the resins for both types of polishing. Multiple comparisons by Tukey and Scheffé tests for mechanical polishing and Tukey test for chemical polishing showed significant differences among the means recorded for the 3 resin materials, with Lucitone 550 yielding the highest overall transverse strength (Table II). Two-way analysis of variance for mechanically and chemically polished specimens did not identify significant differences among individual factors (immersion times and disinfectants) or interaction effects. The mean values for individual factors and for the control group, with both types of polishing, are shown in Tables III through VI. The Student *t* test identified a significant difference between the chemically polished QC-20 resin control group values and the group immersed in 1% sodium hypochlorite (P<.01). For the chemically polished Lucitone 550 specimens, the Student *t* test showed a significant difference between the control group and the group immersed in glutaraldehyde (P<.01) and between the controls and the groups immersed in 2.5% hypochlorite (P<.05) and 5.25% hypochlorite (P<.05). In the chemically polished QC-20 specimens, the Student *t* test identified

Table III. Mean transverse strengths and standard deviations for the mechanically polished specimens submitted to different immersion times (N/mm^2).

Immersion period (min)	Heat-polymerized acrylic resins		
	Lucitone 550	QC-20	Clássico
10	98.71 (±9.05)	96.58 (±10.89)	98.15 (±8.40)
20	100.18 (±7.23)	92.20 (±10.16)	96.34 (±10.81)
30	98.33 (±8.26)	95.01 (±8.35)	96.37 (±10.01)
45	95.97 (±11.99)	91.26 (±8.73)	96.27 (±11.16)
60	95.73 (±12.74)	93.77 (±9.58)	93.73 (±7.44)

Table IV. Mean transverse strengths and standard deviations for mechanically polished control specimens and mechanically polished specimens immersed in different disinfecting solutions (N/mm^2)

Disinfectants	Heat-polymerized acrylic resins		
	Lucitone 550	QC-20	Clássico
control	98.41 (± 13.49)	99.79 (± 7.08)	99.80 (± 4.81)
2% glutaraldehyde	99.08 (± 9.68)	96.83 (±9.67)	96.46 (±9.85)
1% hypochlorite	98.25 (±10.39)	92.42** (±9.78)	97.87 (±8.39)
2.5% hypochlorite	99.97 (±10.76)	94.35 (±8.62)	96.13 (±9.60)
5.25% hypochlorite	94.24 (±11.20)	95.47 (±9.65)	96.65 (±8.63)

**Significant at $P<.05$ compared to control.

Table V. Mean transverse strengths and standard deviations for chemically polished specimens submitted to different immersion times (N/mm^2)

Immersion period (min)	Heat-polymerized acrylic resins		
	Lucitone 550	QC-20	Clássico
10	96.18 (±9.69)	87.15 (±10.28)	80.92 (±9.57)
20	97.68 (±9.48)	90.53 (±9.58)	80.28 (±6.18)
30	95.54 (±11.07)	92.44 (±5.56)	84.11 (±8.73)
45	95.52 (±13.09)	90.93 (±11.67)	85.98 (±9.37)
60	95.19 (±11.75)	88.38 (±6.23)	85.03 (±13.44)

Table VI. Mean transverse strengths and standard deviations for chemically polished control specimens and chemically polished experimental specimens immersed in different solutions (N/mm^2)

Disinfectants	Heat-polymerized acrylic resins		
	Lucitone 550	QC-20	Clássico
control	106.45 (±7.99)	104.34 (±8.07)	83.56 (±6.68)
2% glutaraldehyde	96.16* (±9.87)	92.75* (±10.46)	81.80 (±7.42)
1% hypochlorite	101.42 (±12.37)	90.90* (±10.23)	85.54 (±9.54)
2.5% hypochlorite	97.30** (±10.96)	93.88* (±9.74)	81.96 (±10.44)
5.25% hypochlorite	96.16** (±10.98)	91.65* (±11.18)	83.96 (±9.62)

*Significant at $P<.01$ compared to control.
**Significant at $P<.05$ compared to control.

significant differences ($P<.01$) between the control group and each of the disinfecting solutions employed.

DISCUSSION

The present study compared mean transverse strengths recorded for heat-polymerized resin specimens submitted to either type of polishing and further subjected to immersion in different chemical disinfectants for different immersion periods (experimental group) or distilled water (control). The first null hypothesis was rejected because of the differences found in transverse strength of acrylic resin specimens submitted to mechanical or chemical polishing. The second null hypothesis was accepted because there were no differences in the transverse strength of the 3 resin brands submitted to mechanical or chemical polishing after immersion in disinfecting solutions using different agents and different immersion times.

Lower transverse strength values were reported for chemically polished specimens, whereas mechanically polished specimens demonstrated significantly higher transverse strengths, emphasizing the observation that chemical polishing may adversely affect resin strength and structure. After polymerization of the polishing fluid (usually a methyl methacrylate monomer–based solution) a pellicle is formed on the denture surface, providing a glossy exterior. Although this pellicle reduces water absorption, the monomer that penetrates the resin matrix into the internal porosities but is not polymerized may result in increased levels of residual monomer, because the unpolymerized monomer may not be easily released due to the presence of a polymerized pellicle. Sadamori et al[30] indicated that the residual monomer content in heat-polymerized acrylic resins is very resistant to removal by immersion in water. Furthermore, the authors reported that the presence of a biofilm layer on the surface of the material may act as a physical barrier blocking diffusion of the residual monomer, because this monomer is promptly leached into the superficial layers but remains enclosed by long polymer chains in the internal layers of the resin. The residual monomer may act as a plasticizer[11,13] that, when present in high levels, may negatively interfere with the mechanical properties[31] of the resin. Consequently, this may increase the chances of permanent deformation of the structure submitted to a load.[15]

This study demonstrated significant differences among the resins for the groups submitted to either mechanical or chemical polishing. For the mechanically polished heat-polymerized acrylic resins, Lucitone 550 yielded the highest overall transverse strength. QC-20 specimens had significantly less transverse strength than Lucitone 550. Clássico specimens presented lower strength values than Lucitone 550 and higher values than QC-20, but the differences were not statistically significant. The differences in chain formation and composition, primarily due to different plasticizers, may explain the different transverse strength values recorded for the materials.[12] The higher transverse strength of Lucitone 550 may be related to its higher molecular weight values as reported by Shen et al.[32] The investigation of the intrinsic structures of the resins was not one of the goals of the present study, however, and the factors responsible for this observation are unknown. QC-20 resin presents some characteristics of a chemically activated denture base resin because its polymerization is a result of both chemical and thermal activation. Therefore, QC-20 may exhibit a higher amount of residual monomer, because residual monomer content of heat-polymerized denture base polymers has been found to be considerably lower than that of autopolymerized denture base polymers.[33]

Comparing the specimens submitted to chemical polishing, it was noted that Lucitone 550 yielded the highest transverse strength values, while Clássico resin yielded values much lower than Lucitone 550 and QC-20. A possible explanation is that Clássico resin may retain a greater amount of unreacted monomers after chemical polishing, because, as previously stated, these unreacted monomers act as plasticizers, decreasing the mechanical properties of the resins.[13]

The analyses of variance of the resin groups submitted to mechanical and chemical polishing revealed no alteration of the resins' transverse strength after immersion in the chemical disinfectants for the different immersion periods tested. For the specimens submitted to mechanical polishing, this outcome may be attributed to the diminished diffusion surface. According to Vallittu,[34] the reduction of residual monomer released from polished test specimens may be caused by the diminished diffusion surface rather than by reduction of the monomer content inside the test specimens. On the other hand, for chemically polished specimens, the superficial pellicle formed after polishing may prevent water sorption.

Considering the immersion periods tested (10 to 60 minutes), no significant differences were observed among the transverse strength means recorded. These outcomes are in agreement with Shen et al,[5] who reported that a period of immersion up to 12 hours or the type of disinfectant (phenol-buffered 2% alkaline glutaraldehyde) did not affect the transverse strength of the specimens. Accordingly, Asad et al[6] found that the modulus of rupture and elasticity of a resin with 6% cross-linkage remained unchanged following 7-day immersion in disinfectant solutions. The 4 disinfecting solutions evaluated in this study yielded the same degree of alteration on the transverse strength in mechanically or chemically polished specimens. The results from this study are in agreement with Polyzois et al,[7] who concluded that the transverse strength was not affected by the type of solution and the periods of immersion in the chemical solutions.

Also, the results of this study showed that mechanically polished QC-20 specimens were significantly different from the control specimens and those immersed in 1% sodium hypochlorite. Chemically polished Lucitone 550 and QC-20 specimens in the control group presented high transverse strength values, and significant differences were observed between control specimens and those immersed in disinfectants. Likewise, Robinson and McCabe[19] also observed differences in the transverse strength recorded for control specimens (immersed in water) and experimental specimens (immersed in cleansing solutions, such as sodium hypochlorite). Although the transverse strengths of these resins were affected by immersion in the tested chemical disinfectants (times = 10 minutes to 60 minutes) compared to control specimens, the means recorded after disinfection were within the acceptable range established by the ISO 1567 standard (55 N/mm^2 in water immersion).[17]

The authors speculate that immersion of chemically polished resin specimens in the disinfectants for different time periods may have led to dissolution of the superficial pellicle, thereby allowing the disinfectants to diffuse into the resin matrix. Because the chemical agents used in this study are aqueous-based solutions, it may be assumed that they had a plasticizing effect on the resin matrix, thus decreasing resin strength.

Anusavice[35] reported that polymethyl methacrylate absorbs relatively low amounts of water when immersed in aqueous medium. Even so, water may lead to deleterious effects on mechanical properties, because water molecules interfere with the polymer chains and act as a plasticizer. Because this study did not aim to investigate the structure or the presence of residual monomer in the acrylic resins evaluated after chemical and mechanical polishing, it is not possible to affirm whether or how these factors affected the transverse strength results. Therefore, further investigation is required to assess the structure and release of residual monomer from resins submitted to both types of polishing, as well as clinical trials to corroborate the outcomes obtained. The effect of such disinfecting agents on other properties and characteristics of denture base resins, such as color changes, should also be evaluated.

CONCLUSION

Based on the results from this study, the following conclusions were drawn:

1. Chemical polishing resulted in significantly lower transverse strength values than mechanical polishing ($P<.01$).
2. Lucitone 550 resin demonstrated the highest overall transverse strength for the materials tested. It was significantly stronger than QC-20 and Clássico, with either type of polishing ($P<.01$).
3. The 3 acrylic resins, either mechanically or chemically polished, did not demonstrate significant changes in transverse strength during immersion in the disinfecting solutions tested, regardless of time of immersion.
4. Among the mechanically polished specimens, the transverse strength was affected only in QC-20 specimens following immersion in 1% sodium hypochlorite, when compared to control specimens.
5. For the chemically polished specimens, Lucitone 550 and QC-20 demonstrated significant changes in transverse strength following immersion in the disinfectants when compared to the control specimens.

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