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Evaluation of the Effect of Brushing on Vickers Microhardness of Acrylic Denture Base Resins Polymerized by Different Techniques

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ABSTRACT

Objectives: To prevent the negative effects of brushing on the microhardness of the acrylic resin, different polymerization techniques may be taken into consideration while choosing the denture base material. This study's objective was to assess how brushing affected the Vickers microhardness of acrylic denture base resins polymerized using various methods.

Materials and Methods: From each acrylic resin (Integra and FuturaJet), 100 disk-shaped specimens (15 mm in diameter and 2 mm thick) were created. A total of five distinct polymerization processes—the traditional water-bath method, short and long autoclave polymerization, injection-molding polymerization, and auto-polymerization—were examined (n=20). An automatic brushing machine was used to imitate brushing on half of the specimens, applying 54 000 brush strokes each specimen. All specimens were then subjected to a Vickers hardness test with a 300-g force for 15 s. Data analysis was done using the Mann-Whitney U test, Kruskal-Wallis test, and Dunn's post-hoc test; statistical significance was set at p<0.05.

Results: In all polymerization methods, a statistically significant difference was seen between the control and brushing groups. The autopolymerized acrylic resin group substantially had lower microhardness values than the control and brushing groups' short, long autoclave, and water bath-polymerized resins.

Conclusions: The microhardness of acrylic denture base resins should be taken into consideration when considering polymerization procedures because the autopolymerization method may have certain drawbacks in terms of preventing negative effects of brushing on the microhardness.

Key words: Denture Bases, Polymerization, Hardness Tests.

Farklı Tekniklerle Polimerize Edilen Akrilik Protez Kaide Rezinlerinin Vickers Mikrosertliğine Fırçalamanın Etkisinin Değerlendirilmesi

Süreç

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ÖZ

Amaç: Protez kaide materyali seçiminde, fırçalamanın akrilik rezinin mikrosertliği üzerindeki olumsuz etkilerinden kaçınmak için farklı polimerizasyon teknikleri dikkate alınabilir. Bu çalışmanın amacı, farklı tekniklerle polimerize edilen akrilik protez kaide rezinlerinin Vickers mikrosertliği üzerindeki fırçalama etkisinin değerlendirilmesidir.

Gereç ve Yöntemler: Her bir akrilik rezinden (Integra ve FuturaJet) 100 adet disk şeklinde örnek (15 mm çap ve 2 mm kalınlık) üretildi. Geleneksel su banyosu polimerizasyonu, kısa ve uzun otoklav polimerizasyonu, enjeksiyon kalıplama polimerizasyonu ve oto-polimerizasyon olmak üzere 5 farklı polimerizasyon tekniği test edildi (n=20). Örneklerin yarısı, her numune için 54 000 fırça darbesi kullanılarak otomatik bir fırçalama makinesinde simüle edilmiş fırçalamaya tabi tutuldu. Tüm örnekler daha sonra 15 saniye boyunca 300 g yük ile Vickers sertlik testine tabi tutuldu. Sertlik verilerinin analizi için Mann-Whitney U testi ve Kruskal-Wallis testi ve ardından Dunn's post-hoc testi uygulandı, sonuçlar p<0,05 için istatistiksel olarak anlamlıydı.

Bulgular: Tüm polimerizasyon tekniklerinde kontrol ve fırçalama grupları arasında istatistiksel olarak anlamlı bir fark bulundu. Otopolimerize akrilik rezin grubu, kontrol ve fırçalama gruplarında su banyosu, kısa ve uzun otoklav polimerize rezin gruplarına göre anlamlı derecede daha düşük mikrosertlik değerleri gösterdi.

Sonuçlar: Otopolimerizasyon tekniği, fırçalamanın mikrosertlik üzerindeki olumsuz etkilerinden kaçınmak için bazı dezavantajlara sahip olabilir, bu nedenle polimerizasyon teknikleri belirlenirken, akrilik protez kaide rezinlerinin mikrosertliği açısından düşünülmelidir.

Anahtar Kelimeler: Protez Kaideleri, Polimerizasyon, Sağlamlık Testleri.

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Introduction

Denture wearers must maintain adequate denture hygiene because it helps control oral and systemic infections, especially in elderly and immune-compromised patients with decreased salivary flow rates, and it inhibits biofilm collection on the inner surfaces of complete dentures.[1,2] It was discovered that biofilm colonization and denture stomatitis are related.[3,4] In order to prevent oral and systemic disorders in edentulous individuals, thorough denture cleaning is crucial.

Complete dentures can be cleaned by mechanical, chemical, and combined methods. Chemical cleaning with hypochlorite, peroxides, enzymes and acids corrodes the metal components of the dentures, spoils the acrylic resin components, causes color changes and increased surface roughness.[5] In one study, it was reported that brushing and denture cleansers were more effective than placebo in reducing the amount of plaque and the microbial load on the plaque on the complete denture base.[6] The mechanical removal of organic debris and stains with brushing with the use of a toothbrush, dentifrice and water is a simple, inexpensive and effective technique commonly used by denture wearers.[3,7] However, it may cause the wear of the denture base or denture lining materials.[8] Many factors, including the abrasiveness of the dentifrice, the hardness of the bristles, brushing method, frequency, and strength, as well as the microhardness of the acrylic resins used in the denture foundation, might affect surface alterations that may happen from brushing.[9] In tests to ascertain how the brushes interact with the substrates, brushing with water may be advised to control for these factors.[8]

The most used acrylic material for denture bases is polymethyl methacrylate (PMMA). To overcome its poor mechanical qualities, numerous approaches have been tried.[10] To reduce residual monomer production, conventional denture base acrylic resins are polymerized in a lengthy hot water bath. The entire dentures, however, have undergone a few alterations as a result of this process, including internal stress development, dimensional changes brought on by polymerization shrinkage, and internal porosities brought on by monomer dissolution.[10] The fracture resistance of the denture base materials may be reduced by these chemical changes. Different polymerization or molding methods, including autoclave polymerization, dry polymerization, and injection molding, have been tested to reduce the problems associated with polymerization methods.[14]

By permitting the creation of denture bases that withstand the stresses from occlusion, mechanical denture cleaning, and abrasion, the hardness of acrylic resins is a critical component that extends the longevity of complete dentures.[15] Different hardness tests have been utilized to forecast in vitro wear behavior[16] and the elastic modulus[17] of dental materials. Rigid polymer hardness can be accurately assessed using the Vickers microhardness test. This test is based on a material's surface resistance to point penetration under a specified load.[18] The measurement of hardness has been used to forecast dental material deterioration.[16]

There are still few studies examining the impact of various polymerization processes on the microhardness characteristics of PMMA denture base resin and the change in of hardness values dependent on daily care.[8,9,11,12,19] It would appear crucial to assess both the abrasion resistance of various denture base resins polymerized using various processes as well as the impact of brushing acrylic resins with water on their microhardness. Therefore, the purpose of this study was to determine how brushing affected the Vickers microhardness of denture base resins polymerized using various polymerization methods. The first null hypothesis stated that brushing would not have an impact on the microhardness of the acrylic resin materials used. The second null hypothesis was that the microhardness of the acrylic resin materials would not be impacted by the polymerization processes.

Material and Methods

The Clinical Research Ethics Committee of Afyonkarahisar Health Sciences University granted its approval for this study (Date/ID Number: 04.03.2022/122). Table 1 lists the denture base resins used for this study. Working molds were created from stainless steel master dies with dimensions of 15 mm in diameter and 2 mm in thickness, from which 100 disk-shaped specimens were produced. The samples (n=20) were put through the paces using standard water baths, short and long autoclave polymerization, injection molding, and autopolimerization methods. According to references from previous studies, the sample size was determined.[19,20]

The specimens were fabricated with following polymerization techniques. For standard water-bath polymerization, conventional PMMA resin was prepared in accordance with the manufacturer's recommended powder to liquid ratio, and the specimens were then polymerized in a water bath at 70°C for 90 minutes before being heated to 100°C for 30 minutes.

In order to polymerize materials in an autoclave (Ar-El Group SAN, Greece), samples were either put through a short cycle at 60°C for 30 minutes, followed by 10 minutes at 130°C, or a long cycle at 60°C for 30 minutes, followed by 20 minutes at 130°C.

Models were maintained under constant pressure during the injection-molding polymerization process using specialized cap and pressure equipment. Vibration was used to combine pre-dosed acrylic capsules for five minutes. The cap assembly was submerged in tap water for 20 minutes after the mixture had been poured into the cap under 6 bar pressure for 35 minutes of polymerization. The pressure device was then taken off, and the cap was left to soak in tap water for an additional ten minutes.

For autopolymerization, the mixed material was pressed directly into the mold. Then, it was placed in a pressure chamber containing water at 40°C at 2 bar pressure for 15 minutes.

Since it is known that porosity will adversely affect the hardness values, it was ensured that there was no porosity in any of the specimens.[21] After the polymerization processes, all specimens were removed from the molds. A skilled dental technician hand-polished all specimens using a laboratory polishing lathe machine (Reno, Roberson Machine Company) at 1500 rpm for 2 minutes each. Then, all specimens were kept in distilled water at 37°C for 48 hours.

Half of the specimens (n=10) had a linear brushing abrasion movement that involved a total of 54 000 strokes (forward and back), which is equivalent to three years of brushing.[8] According to ISO/DTS 145691, the brushing operation was carried out on a mechanical cross brushing equipment (Esetron MF-100, MOD Dental, Turkey).[22] The machine covered 3.8 cm at a speed of 356 rpm while brushing six specimens at once at a weight of 200 g. Only distilled water that was 23±3°C was used for the brushing. The type of toothbrush (Colgate professional soft, Colgate-Palmolive, Brazil) used had flexibility, uniform length, rounded ends, and smooth bristles. Brushes were replaced with new ones at each interval of 18 000 strokes. The specimens that were not subjected to brushing were immersed in distilled water at 23 ± 3°C. After being dried by air and cleaned with distilled water, each sample was put into a microhardness tester.

With a 300-g load applied for 15 seconds, the microhardness of all specimens was measured using a Vicker's Hardness Tester (Shimadzu HMV-M3, Japan). Each specimen was subjected to three measurements, each taken at a fixed distance from the center, with the third measurement serving as the arithmetic mean. At x40 magnification, Vickers indenter marks on the specimens were examined. The formula below was used to compute the Vickers hardness values (HV):

$$HV = 1.854\left(\frac{F}{D^2}\right)$$

with *F* is the applied load (measured in kgf) and D^2 is the area of the indentation (measured in mm^2).

Using SPSS 20.0 software (IBM, IL), the microhardness data were analyzed using the Mann-Whitney U test, Kruskal-Wallis test, and Dunn's post-hoc test ($p<0.05$).

Table 1. Composition of acrylic resins tested in this study

Commercial Brand	Manufacturer	Polymerization technique	Composition
Integra	BG Dental, Ankara, Turkiye	Water bath heat polymerization	Powder: polymethyl methacrylate, catalyst, pigments Liquid: methyl methacrylate, dimethacrylate
Integra	BG Dental, Ankara, Turkiye	Autoclave polymerization (short cycle)	Powder: polymethyl methacrylate, catalyst, pigments Liquid: methyl methacrylate, dimethacrylate
Integra	BG Dental, Ankara, Turkiye	Autoclave polymerization (long cycle)	Powder: polymethyl methacrylate, catalyst, pigments Liquid: methyl methacrylate, dimethacrylate
FuturaJet	Schütz- Dental GmbH Rosbach, Germany	Injection molding polymerization	Powder: polymethyl methacrylate, copolymerand catalyst Liquid: mixture of MMA stab, dimethacrylate and copolymer
Integra	BG Dental, Ankara, Turkiye	Autopolymerization	Powder: Polymethyl methacrylate Liquid: methyl methacrylate, N,N dimethyl p-toluidine

Table 2. Vickers microhardness – mean and standard deviation (SD) and median values

Polymerization technique	Control group Mean ± SD Median	Brushing group Mean ± SD Median
Water bath	47.83±2.39 A a 48.89	39.32 ± 5.90 B a 38.11
Short autoclave	45.49±3.63 B a 47.05	38.55 ± 4.25A a 38.56
Long autoclave	53.25±3.38 A a 50.36	47.40 ± 2.69 B a 47.26
Injection molding	37.92 ± 2.52 B a b 36.51	34.80 ± 2.24 A a b 34.74
Autopolymerized	21.89 ± 1.10 A b 21.23	19.15 ± 2.34 B b 20.10

*****Means followed by a distinct capital letter in the line and lower-case letter in the column differ statistically according to Dunn's post-hoc test ($p < 0.05$).

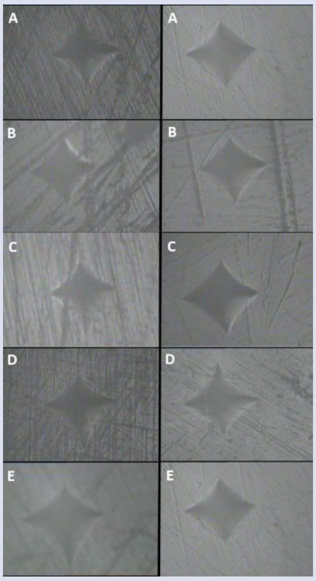

Figure 1: Traces formed in the Vickers microhardness test of the control (left) and brushing (right) groups. A. Conventional water-bath polymerization, B. Short autoclave polymerization, C. Long autoclave polymerization, D. Injection-molding polymerization, E. Auto-polymerization.

Results

The mean values and standard deviation of the Vickers microhardness of the examined acrylic resins are displayed in Table 2.

Auto-polymerized acrylic resin displayed significantly lower microhardness values than water bath, short and long autoclave polymerized resins in the control and brushing groups ($p < 0.05$). There is no significant difference between autopolymerization and injection molding ($p>0.05$). Regardless of brushing, long autoclave polymerized resin displayed higher microhardness values than those produced by injection molding and auto-polymerization ($p < 0.05$).

When comparing the control and brushing groups, it was possible to see that brushing had a negative impact on the Vickers microhardness of the acrylic resins (Figure 1). In all polymerization methods, a statistically significant difference was seen between the control and brushing groups ($p < 0.05$).

Discussion

In this study, the microhardness of denture base resins polymerized using various polymerization processes was assessed in relation to the impact of brushing with water. Acrylic resin specimens' microhardness was impacted by the brushing process. In all groups, microhardness values were reduced with brushing; in the water bath group, this reduction rate was around 18%, and in the autopolymerized group, it was approximately 12.5%. These findings demonstrated the rejection of the first null hypothesis of this study.

There was a 40% difference between the highest and lowest microhardness values for both the control and brushing groups when polymerization procedures were investigated. According to the results of the current study, which showed that the auto-polymerized acrylic resin had the lowest microhardness values, it was determined that specimens made using the auto-polymerization approach might wear out more quickly than those made using the other techniques. The high concentration of residual monomer left over after autopolymerization operations, which acts as a plasticizer, may be the cause of the current study's findings.[23,24] The evaluated acrylic materials' microhardness was strongly influenced by the polymerization processes used. The second null hypothesis was therefore disproved. Another study produced results that were similar to this one.[10] Anusavice and Phillips[18] claimed that autopolymerization results in a lower degree of polymerization than heat polymerization.

Acrylic resin used in injection molding had lower microhardness values than acrylic resin used in water baths. In a study, two varieties of acrylics polymerized using water-bath and injection-molding processes were examined for hardness and surface roughness. They came to the conclusion that both had similar levels of hardness and surface roughness, which was at odds with the findings of the present study.[25] The varied types of acrylic used in the water baths may be the cause of the variations in results. Another finding from this study showed that the microhardness of the two autoclave polymerization cycles (long and short) and water bath polymerization procedures did not significantly differ from one another. These findings were consistent with those of Abdulwahhab.[26] In a recent study, it was found that extended autoclave polymerization produced materials with higher hardness values than short autoclave polymerization and water-bath polymerization.[27] In the aforementioned study, autoclave polymerization under pressure sped up the initial polymerization by increasing the steam's temperature and the monomer's boiling point. This discrepancy in the result with the current study may be explained by a decrease in the residual monomer content.

In order for patients who wear dentures to be able to wear them for an extended period of time, it is important to properly clean and care for the prosthesis at home to get rid of food particles, salivary mucus layer, and plaque deposits. Cleaning techniques are typically utilized for this purpose by washing with soap or brushing with dentifrice.[28] In earlier studies on the subject, it has been claimed that the denture base is harmed by the number of abrasives in toothpaste and/or different soaps or cleansers used at home.[28,29] These findings led to the goal of eradicating the damaging effects of chemical solutions on acrylic surfaces and demonstrating the relationship between mechanical cleaning and abrasion using simply water brushing.

The clinical life of the denture base material and the oral health of the tissues in contact with the prosthesis and the ability to perform adequate mechanical cleaning have a parallel effect.[30] In previous studies evaluating wear caused by brushing, different types of brushes and dentifrices were used as abrasives.[8,19,31] There are significant differences in the results of these studies due to the use of dentifrices containing different concentrations of different abrasive particles, making it difficult to compare the available data with each other. In the current study, a soft-bristled toothbrush was used because it is inexpensive, accessible to most patients and of high quality. Brushing with distilled water has been shown to cause minimal wear and minimal mass loss to the brushed substrate.[31] This study aimed to isolate the effect of brushes and dentifrices by analyzing the effect of brushing method with distilled water on the wear resistance of acrylic resins polymerized by different techniques.

In order to prevent loss of smoothness, to lessen aesthetic issues like plaque retention and discoloration, and to provide dentures with a longer serviceable life that will be more resistant to damage, the hardness of the acrylic resin used to make dentures for the elderly has been increased.[10] Clinicians should be aware that they can handle this circumstance using various polymerization techniques when creating dentures to address these issues. Regardless of the polymerization methods used, the microhardness values of the studied denture base materials declined during brushing. These findings suggest that complete denture wearers should be made aware that the fracture resistance of the denture may diminish even if they regularly clean it with a brush and water. In order to achieve long-term success, clinicians may be recommended to steer clear of autopolymerization and injection molding polymerization techniques, according to the study's therapeutic implications.

The limitations of this study include the use of in vitro tests rather than clinical trials and the evaluation of just two of the numerous denture base resins on the market. Additional research may focus on chemical and combination cleaning techniques, specialized denture brushes and dentifrices, or denture cleaning solutions in addition to mechanical cleaning. To continue the search for the best polymerization method for creating denture prosthetics, additional study using various mechanical testing and extended brushing times is required. Clinicians will learn more as a result of additional research on methods to improve the polymethyl methacrylate denture base material's wear resistance.

Conclusions

This study's findings could lead to the following conclusion:

1. In all groups, the microhardness values declined as the brushing process progressed.
2. The microhardness of acrylic resin specimens was influenced by the polymerization process.
3. The specimens produced from autopolimerized denture base acrylic resin had the lowest microhardness values.

Conflicts of Interest Statement

The authors declared that there is no conflict of interest.

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