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Comparison of Microhardness of Artificial Teeth with Different Contents After Waiting in Various Liquids

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ABSTRACT

Objectives: This study aimed to assess the long-term microhardness of different artificial teeth after waiting in liquids of various pH values.
Materials and Methods*:* Four different artificial teeth [conventional PMMA (Ivostar) as control group), double cross-linked PMMA(DCL), micro-filled composite resin(VivodentPE), nanohybrid composite resin (PhonaresiII)] were used for the study. After the samples fixed on acrylic blocks were immersed in distilled water at 37˚C for 24 hours, initial microhardness (T0) measurements were performed. Randomly selected samples from each group were immersed in liquids with different pH values (artificial saliva, kefir, orange juice, cola). Measurements repeated on the 7th day on the same samples were recorded as T1, and measurements repeated on the 14th day were recorded as T2. The data obtained were evaluated in the SPSS 22.0 program. Friedman and Kruskall Wallis tests were used to compare of the groups.
Results: While the highest initial microhardness averages were found in the Phonares II group, the lowest average belongs to the Ivostar group. Microhardness findings of all materials measured at different times were obtained in the order of T0>T1>T2. When the data of samples aged in different liquids are compared, significant differences are observed. When the microhardness measurements of a single material exposed in different solutions were compared, no difference was found between the solutions.
Conclusions*:* A decrease in microhardness of materials that are immersed in liquids with different pH values for a long time was observed, and the microhardness of the materials exposed to these solutions is adversely affected.

Keywords: Acidic Beverages, Artificial Teeth, Hybrid Materials, Microhardness, PMMA

Farklı İçeriklerdeki Yapay Dişlerin Sıvılarda Bekletildikten Sonraki Mikrosertliklerinin Karşılaştırılması

Süreç

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ÖZ

Amaç: Bu çalışmada amaç farklı yapay diş materyallerinin farklı pH değerlerindeki sıvılarda bekletildikten sonraki mikrosertliklerinin uzun dönem karşılaştırmasıdır.
Yöntem: Çalışma için 4 farklı yapay diş materyali [(kontrol grubu olarak konvansiyonel PMMA(Ivostar), çift çapraz bağlı PMMA (DCL), mikrodolduruculu kompozit rezin (VivodentPE) ve nanohibrit kompozit rezin(PhonaresiII)] kullanıldı. Akrilik bloklara sabitlenen örnekler 24 saat 37˚C de distile suda bekletildikten sonra başlangıç mikrosertlik(T0) ölçümleri yapıldı. Her gruptan rastgele seçilen örnekler farklı pH değerine sahip sıvılarda (yapay tükürük, kefir, portakal suyu ve kola) bekletildi. Aynı örnekler üzerinde 7. Günde tekrarlanan ölçümler T1, 14. günde tekrarlanan ölçümlerse T2 olarak kaydedildi. Elde edilen veriler SPSS 22.0 programında değerlendirildi. rupların karşılaştırmasında Friedman ve Wilcoxon testi kullanılırken, bağımsız grupların değerlendirmesinde Kruskall Wallis ve Mann Whitney U testi kullanıldı.
Bulgular: En yüksek başlangıç mikrosertlik ortalamalası PhonaresII grubunda bulunurken, en düşük ortalama Ivostar grubuna aittir. Tüm materyallerin farklı zamanlarda ölçülen mikrosertlik bulguları T0>T1>T2 sıralamasıyla elde edilmiştir. Farklı sıvılarda yaşlandırılan örneklere ait veriler karşılaştırıldığında anlamlı farklılıklar görülmektedir. Aynı zamanda farklı solüsyonlarda muamele edilen tek bir materyale ait mikrosertlik ölçümleri karşılaştırıldığında ise solüsyonlar arasında farklılık bulunmamıştır.
Sonuç*:* Farklı ph değerlerine sahip sıvılarda uzun dönem bekletilen materyallerin mikrosertliklerinde azalma görülmüştür ve bu solüsyonlara maruz kalan materyallerin mikrosertlikleri olumsuz yönde etkilenmektedir.

Anahtar Kelimeler: Asidik içecekler, yapay diş, hibrit materyaller, mikrosertlik, PMMA

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Introduction

Acrylic artificial teeth (PMMA) used in the treatment of total and partial edentolusness is used in many areas of dentistry due to their low water absorption, high durability, good optical properties, and acceptable dimensional stability.[1] Besides, the good connection with the denture base facilitates discoloration and hygiene maintenance. However, the prosthesis cannot resist parafunctional movements with low wear resistance over time and cannot maintain proper occlusal relationships, resulting in disruptions in closing relationships and loss of vertical dimension.[2]

With the developments in the field of polymer science, to overcome the negative properties of PMMA in the linear polymer structure, the structure of acrylic teeth is highly strengthened by using cross-linking agents (glycolmethacrylate and allylmethacrylate).[3] Cross-linked acrylic teeth, developed with the help of different polymer technologies, can be composed of blended polymer, interpenetrating polymer network (IPN), and double cross-linked (DCL=doublecrosslinked) structures. These developments it is aimed not only to increase the wear resistance but also to increase the structural durability against the formation of cracks in the structure.[4] Cross-links involved in the structures of acrylic teeth have also made them more resistant to organic solvents and heat.[5]

With the improvement in composite materials with higher wear resistance compared to conventional acrylic teeth, the area of use in artificial teeth has also expanded, and modified composite-containing acrylic teeth have been introduced to the market.[3,6] Micro-filled (MF) and nanohybrid composites (NHC) produced to improve the mechanical properties of conventional artificial teeth consist of urethane dimethacrylate (UDMA) matrix as well as PMMA clusters. The "hybrid" means that this composite is formed by the combination of fillers of different types and sizes. NHC contains highly cross-linked inorganic-filled macro filters and highly concentrated inorganic micro fillers[7]. The commercially available composite artificial resin tooth has different properties such as the shape of the filler, the amount of filler, the type of polymer, and the shape of the cross-links.[8] The increase in the amount of organic filler resulted in a decrease in the expansion coefficient and polymerization shrinkage, in addition to an increase in the wear resistance of the resin teeth.

Hardness, defined as the ability of a material to resist locally acting deformation, should be considered in conjunction with wear resistance and is often an indicator of the mechanical property of synthetic, synthetic material.[8,9]

Dental materials are exposed to long-term contact with many liquids in the oral environment, apart from saliva, depending on their consumption habits[10]. Therefore, nutritional habits and their effects on artificial teeth should be evaluated. Besides, when the literature was reviewed, no study was found on the hardness of acrylic and hybrid artificial teeth that evaluated liquids with different acidity in the long term. Therefore, we aimed to evaluate the hardness of artificial teeth immersed in liquids with different pH values in our study. The null hypothesis of our study was determined that liquids with different artificial teeth and pH values would not change the hardness value.

Materials and Methods

This in vitro study was conducted on four different resin materials and beverages (Table 1).Groups were performed according to chemical structure of artificial teeth as follows: GroupI; PMMA (Vivodent Ivostar), GroupII; DCL PMMA (Vivodent DCL), GroupIII; micro-filled composite resin (Vivodent PE), GroupIV; nano-hybrid composite resin (Vivodent Phonares II).

Table 1. Contents of artificial teeth and beverages used in the study

Materials	Components	Manufacturer
Artificial Teeth		
Ivostar	Polimetil metakrilat (PMMA)	Ivoclar Vivadent (Schaan, Lihtenştayn)
SR Vivodent DCL	Double cross-linked (DCL) PMMA	
SR Vivodent PE (İt)	Isosit Cross-linked inorganic micro-filled composite resin with PMMA pearls	
SR Phonares II	Nano Hybrid Composite Resin (UDMA + inorganic fillers + silanated silica prepolymer with inorganic filler + binder PMMA)	
Beverages		
Artificial Saliva	Carboxymethyl cellulose, Xylitol potassium chloride, calcium chloride, potassium sulphate, potassium thiocyanate, distilled ionized water	pH=6.93
Kefir (Ülker İçim, Bursa, Türkiye)	Pasteurized cow's milk, kefir culture	pH=4.5
Orange Juice (Coca-Cola İçecek A.Ş., Istanbul, Türkiye)	Orange juice with orange particles produced from concentrate (100%) water, flavors	pH=3.87
Cola (Coca-Cola İçecek A.Ş., Istanbul, Türkiye)	Water, sugar, CO_2, colorant, cola extract, caffeine, acidity regulator (phosphoric acid)	pH=2.53

The samples were embedded in condensation silicone impression material (Zetaplus, Zhermack, Badia Polesine, Italy) to create negative space with the help of disc-shaped wax with a thickness of 1 cm and a diameter of 2 cm for fixation. Molds were made with auto polymerizing acrylic resin (Panacryl Self Cure Acrylic, Rubydent, Istanbul, Türkiye) with created negative spaces.

The teeth were fixed in these molds by embedding their vestibule surfaces up and parallel to the plane. To facilitate the measurement processes and to standardize the measurement surfaces after the teeth are embedded in the acrylic molds, enamel level correction was made with a precision cutting device (Isomet 1000, Buehler, USA), and then surface treatment was applied with (600-800-1000) grit silicon carbide abrasive paper under permanent water cooling. Each tooth was numbered by writing the abbreviation of the group names on the lower surface of the acrylic bases with a water-proof pen.

After the prepared samples were immersed in distilled water for 24 hours, for microhardness tests, each sample group was prepared with standard metallographic sample preparation methods, and VHN hardness values were measured under 0.1kg-f load using a microhardness device with a diamond square pyramid tip with an apex angle of 136° (Shimadzu HMV-2/HMV-2T Micro Vickers Hardness Tester). The application time was determined as 15 seconds. All of the tests were performed according to ASTM C1327-15(2019) standards. In all hardness tests made, 3 measurements were taken from the specified surface of the samples by the same researcher (by M.Y.). Initial microhardness values were recorded as T0.

After the T0 measurements, all samples were placed in the containers to be used for the experiment, with the vestibule surfaces of the teeth up. The test containers were sufficiently filled with the specified beverages so that all surfaces of the samples were exposed to the liquid. During the test, the teeth were exposed to beverages for 18 hours every day and immersed in distilled water for 6 hours. The samples were kept in an oven (FN 400, Nüve, Türkiye) at a constant temperature of 37˚C throughout the experiment. Drinks were refreshed daily to prevent bacterial contamination throughout the study.

Microhardness measurements were repeated on the 7th (T1) and 14th (T2) days for the same samples. While the measurements were being made, each measurement was made 3 times from the same region of the samples and by the same researcher for the purpose of standardization.

Statistical Analysis

Statistical analysis was performed using computer statistical software (SPSS 22.0 for windows; SPSS Inc., Chicago, IL). After test of normality, nonparametric tests were used. The Friedman test and Wilcoxon tests were used to compare of the groups.

Results

Microhardness results and comparison results of the groups are given in Table 2. Microhardness averages for all groups were found in the order of T0>T1>T2. The initial microhardness (T0) averages decreased for all artificial dental materials compared to the findings after treatment with different liquids. This decrease was significant for all artificial teeth and different fluids ($p<0.05$). While the highest measured T0 value (34.75±0.89) belonged to PhonaresII material, the lowest microhardness value (22.70±0.57) was found for Ivostar material. The order of the microhardness results of the materials at T0, T1 and T2 times is Ph>DCL>PE>Ivostar.

When the T0, T1, and T2 data obtained from the same materials at different times are compared according to the solutions, the difference between all groups was statistically significant ($p<0.05$). In T0, T1, and T2 measurements, in Group I samples, there were differences between artificial saliva-orange juice, kefir-orange juice, orange juice-cola in intragroup comparisons for Ivostar material ($p<0.05$).

Table2. Comparison of initial, 7th and 14th day microhardness findings of different materials

	Beverages	GroupI (Median±Sd)	GroupII (Median±Sd)	GroupIII (Median±Sd)	GroupIV (Median±Sd)	p
T0	Artificial Saliva	$25.20\pm1.10^{A,a,b}$	$30.30\pm2.54^{A,a}$	24.55 ± 1.43^{A}	$31.30\pm1.81^{A,b}$	0.001*
	Kefir	$24.94\pm0.51^{B,C,a,b,c}$	$31.50\pm2.01^{B,a}$	$25.50\pm0.43^{b,c}$	$31,15\pm0,66^{B,C}$	0.001*
	Orange Juice	$22.70\pm0.57^{A,B,D,a,b,c}$	$28.00\pm1.60^{A,B,a,d,e}$	$25.50\pm1.80^{b,d,f}$	$31.95\pm1.22^{A,B,D,c,e,f}$	0.001*
	Cola	$25.53\pm0.75^{C,D,a,b}$	$29.70\pm1.99^{a,c,d}$	$24.05\pm1.68^{A,c,e}$	$34.75\pm0.89^{C,D,b,d}$	0.001*
		0.001*	0.006*	0.043*	0.001*	
T1	Artificial Saliva	$24.50\pm1.58^{A,a,b}$	$30.06\pm2.50^{A,B,a}$	23.55 ± 1.24^{A}	30.70 ± 2.27^{b}	0.001*
	Kefir	$23,80\pm0,70^{B,a,c}$	$30.45\pm2.67^{C,D,a}$	$23.50\pm0.90^{B,c}$	$29.70\pm0.88^{A,C}$	0.001*
	Orange Juice	$21.95\pm0.92\ ^{A,B,C,a,b,c}$	$26.35\pm1.81^{A,C,a,e}$	$24.95\pm1.09^{A,B,b,f}$	$31.65\pm0.77^{A,c,e,f}$	0.001*
	Cola	$24.05\pm0.73^{C,a,b}$	$27.20\pm1.04^{B,D,a,c}$	23.40 ± 1.79^{d}	$32.35\pm1.18^{C,b,c,d}$	0.001*
		0.003*	0.001*	0.009*	0.003*	
T2	Artificial Saliva	$24.29\pm2.37^{A,a}$	$29.88\pm2.78^{A,B,a,b}$	23.55 ± 1.24^{A}	30.41 ± 2.35^{b}	0.001*
	Kefir	$23.70\pm0.71^{B,a,c}$	$30.10\pm0,71^{C,D,a}$	23.42 ± 0.82^{c}	$29.30\pm0.96^{A,B}$	0.001*
	Orange Juice	$21.86\pm0.91^{A,B,C,a,b,c}$	$25.51\pm2.11^{A,C,a,e}$	$24.40\pm1.07^{A,b,f}$	$31.35\pm0.46^{A,c,e,f}$	0.001*
	Cola	$23.950.73^{C,a,b}$	$26.20\pm1.02^{BD,a,c,d}$	$22.95\pm1.74^{c,e}$	$31.85\pm1.26^{B,b,d,e}$	0.001*
		0.001*	0.004*	0.036*	0.014*	

*Statistically significance, p<0.05, Different capital letters represent the statistical difference between groups in the same column. Different lowercase letters represent the statistical difference between them

In the results of Group II (DCL) samples, while T0 values differ significantly between artificial saliva-orange juice and kefir-orange juice, and between artificial saliva-orange juice, artificial saliva-cola, kefir-orange juice, and kefir-cola in T1 and T2 measurements, it is insignificant in other groups.

In the comparison of Group III (Pe) data, T0 measurements differ between artificial saliva-cola, T1 measurements differ between artificial saliva-orange juice, kefir-orange juice, T2 measurements differ between artificial saliva-orange juice.

While Group IV materials (PhonaresII) were between artificial saliva-orange juice, kefir-orange juice, orange juice-cola, between artificial saliva- orange juice, kefir-orange juice for DCL, and artificial saliva-cola for Pe material ($p<0.05$), the differences between other groups were insignificant ($p>0.05$). While there was a difference in artificial saliva-orange juice, kefir-orange juice, kefir-cola, orange juice-cola groups in T0 data of Phonares II material, in kefir-orange juice, kefir-cola groups in T1 and T2 data, the difference in other groups was insignificant.

While the difference between kefir-orange juice and kefir-cola groups in T0, T1, and T2 measurements in the samples belonging to Group IV (Phonares II) was statistically significant, in addition to these groups, a significant difference was found between artificial saliva-orange juice, orange juice-cola liquids in T0 measurements ($p<0.05$), the difference in other groups was insignificant ($p>0.05$).

According to the comparison data for artificial saliva, kefir, orange juice, and cola liquids of different materials, T0, T1, and T2 data of Group I and Group II were significant for all fluids. While T0 and T1 findings were significant between Ivostar-PhonaresII in artificial saliva and colas, T2 data was significant for Ivostar-DCL in all fluids. There were differences between Ivostar-DCL, Ivostar-Pe, and Ivostar-Ph materials in terms of T0, T1, and T2 data in groups treated with orange juice.

Discussion

The null hypothesis that liquids with different pH values will not cause a change in the microhardness of artificial teeth was rejected in our study. The microhardness values of all artificial teeth decreased after waiting in various liquids. The mean initial microhardness values were found as PhonaresII> DCL>PE>Ivostar. It was concluded that the microhardness of artificial teeth with different features decreased significantly in liquids with different pH values.

In addition to complete and partial dentures, modified acrylic teeth with cross-links and composite resin teeth with micro and nanofillers are also used as an alternative to conventional acrylic teeth, which are mostly used in the construction of implant-supported hybrid prostheses.[8,11,12]

Acrylic polymers can absorb of absorbing water because of the polar properties of the resin molecules.[13] Water acting as a plasticizer reduces the hardness of the material through the formation of microcracks caused by the absorption/adsorption process.[14] As a result of this, the microhardness of materials decreases with exposure to beverages.

Microhardness is defined as the surface property of a material related to its resistance to local deformation. Besides, the hardness value is an indicator of the resistance of dental materials to wear during function.[15] It has been reported that Brinell and Rockwell hardness tests can be used mostly in metal alloys, and Vickers and Knoop hardness tests can be used to measure the hardness of all materials used in dentistry such as gold porcelain, composite resins, and cement. Therefore, we preferred to use the Vickers hardness test in our study.

Goiato *et al.*[16] obtained the result that the microhardness of the polymer, which they immersed in different beverage and cleaning solutions at different times, decreased the most in the cola solution. We concluded that the most changes on the microhardness data we obtained after starting and aging with liquids, similar to these findings, were in cola and orange juice. It was concluded that the microhardness results of the samples aged by immersed in liquids decreased in all artificial tooth groups.

Erosion in dentistry is a chronic condition seen with the loss of substance in hard tissues due to the effect of acids without a bacterial agent.[17] The associations of soda, energy drinks, and food materials with acidic potential with dental erosion are reported in studies.[18,19] Beverages with low pH value not only affect the natural tooth surfaces but also affect the surfaces of resin-containing restoration materials, accelerating their deterioration. Studies have shown that when resin-based restorative materials are immersed in environments with low pH values, the filling components in its structure are separated from the resin material, and degradation in the matrix content is observed.[22,23,24]

In a study in which resin-based restorative materials with different contents were immersed in liquids of different pH values for 7 and 14 days, and the surface roughness and color changes of the resin-based materials were examined by Güler *et al*.[23], samples were immersed in an acidic solution for 18 hours and distilled water for 6 hours. They stated that 14-day aging corresponds to 336 hours, and this aging process corresponds to approximately 13 years.[24] Considering that the mean duration of use of prosthetic rehabilitation is between 10-20 years, we think that the durations we have chosen in our study are acceptable.

Loyaga-Rendon *et al.* attributed the differences in surface hardness of artificial teeth to the presence of cross-links for acrylic resin teeth and the different filling particles and compositions for composite resin teeth.[4] However, no study has been found in the literature evaluating the effect of beverages with different pH values on the surface hardness of artificial teeth with different contents, such as nano filled composite resin, micro filled composite resin, which was newly developed in line with the developments in material technologies and started to be used routinely.

Ersu *et al*. compared the microhardness of artificial teeth (micro-filled composite (Orthosis), acrylic containing cross-links, and conventional acrylic) with different structures. In consequence of the study, the highest values were obtained in the composite artificial tooth group with micro-fill (31 kg/mm^2) and the lowest values in the conventional acrylic resin artificial teeth group (23 kg/mm^2).[25] In our study, when T0, T1, and T2 measurements were compared, they were found to belong to the highest microhardness group. After the NHC resin group, it is DCL>PE>Ivostar, respectively. The results of the researchers are similar with our data despite the differences in materials and methods.

Suzuki *et al*. compared the wear, microhardness, and surface roughness properties of artificial teeth (nano-composite, micro-filled composite, cross-linked acrylic resin, conventional acrylic resin) in four different structures. They concluded that nano-filled composite resin teeth are harder and have higher wear resistance than other teeth.[3] Although the materials and methods used are different, they support our results. The commercial differences in the teeth used and the difference in the application time and strength of the microhardness device used by the researchers for Knoop hardness may have affected the results numerically.

Ünal *et al*.[26] stated that microhardness of different restorative materials were affected gastric acid. They noticed that resin materials should be carefully selected in patients with gastric reflux. It is stated that the decrease in microhardness may be due to the loss of chemical and physical bonds as a result of water absorption and hydrolysis between the resin matrix and the filler particles.

The results obtained within the limitations of our study are that the microhardness of artificial teeth decreases after exposure to acidic beverages. However, it is assumed that cola and orange juice can cause potential changes in some properties of solutions over time, which can be considered a limitation of this study. In addition to this, methodological limitations for in vitro studies are inherent in the evaluation of microhardness and other properties. Therefore, future studies are needed to evaluate differences in a solution's ability to affect acrylic resin hardness over time.

Conclusions

The microhardness of materials can be affected by liquids with different pH values. Compared to conventional artificial teeth, the microhardness results of the new materials are better. Considering the nutritional habits of the patients, it can be recommended to treat patients with low pH consumption habits with new generation resin artificial teeth as an alternative to conventional materials.

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Conflict of Interests

Authors declare that no conflict of interests.

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