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The Evaluation of the Dietary Habits Influence on the Microhardness of Gingiva-Coloured Composite and Acrylic Denture Base Materials

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Abstract

Purpose: The study investigated the impact of dietary habits, specifically soda, milk kefir, water kefir, almond milk, and distilled water (control) consumption, on the microhardness of gingiva-coloured composite and acrylic denture bases. **Methods:** Materials included gingiva-coloured composite (Fusion Universal G1), acrylic (Imicryl), and subdivided Procryla group. Subgroups comprised 15 and 30-minute heat polymerized (Pro15, Pro30), and 1 wt% (Pro1Z) and 3 wt% (Pro3Z) zirconium added groups. Immersed in beverages for 1, 7, and 14 days, pH and microhardness were assessed. SEM examined random samples. Statistical analysis used repeated measures ANOVA, and post hoc tests ($p < 0.05$). **Results:** The gingiva-coloured composites displayed noteworthy time-associated microhardness changes ($p < 0.05$), while Procryla1Z, Procryla30, Imicryl, and Procryla3Z groups showed non-significant shifts ($p > 0.05$). Despite variable pH levels in beverages, no substantial group interaction effects were observed ($p > 0.05$). Initial microhardness rankings shifted after a 14-day immersion. **Conclusions:** Gingiva-coloured composite exhibited the highest microhardness pre- and post-immersion, followed by Procryla30 and Imicryl groups.

Keywords

Gingiva-Coloured Composite, Acrylic, Denture Base Materials, Hybrid Prosthesis, Microhardness, Beverages

1. Introduction

Denture base materials, including gingiva-coloured composite and acrylic resin,

are widely used in dental prosthetics due to their ease of use, ease of repair, biocompatibility, and cost-effectiveness [1]. Acrylic resin was introduced in 1937 and has remained important as a base material, denture linings, rebases, maxillofacial dentures, orthodontic dentures, temporary crowns, splints for surgical procedures in prosthetic practice ever since. Gingiva-coloured composites are another type of material used for denture bases and implant-supported hybrid prostheses. The mechanical properties of these materials, such as microhardness, are crucial for their clinical performance [2]. Proper functioning and longevity of dental prostheses depend on the maintenance of these mechanical properties, as they can influence the material's wear resistance, fracture toughness, and resistance to deformation under stress [3].

The acrylic resin has some drawbacks. Poor strength, which causes a large number of denture repairs each year, is a major shortcoming. An allergic reaction to acrylic resin is also a common problem. This issue has been addressed by modifications of resin denture bases proposed to improve the mechanical properties. In research, it has been suggested to add zirconia nanoparticles (NPs) to improve the mechanical properties of acrylic resins. The incorporation of zirconia NPs into acrylic resins has been reported to increase microhardness. It can also have an antifungal effect and play a protective role in patients susceptible to fungal infections. On the other hand, one study found an insignificant increase in the microhardness of acrylics with zirconia nanoparticles added, and it was reported that the surface roughness did not change significantly [1] [4].

Several factors, including dietary habits, may affect the mechanical properties of these materials, leading to reduced durability and the need for frequent replacements [5]. Patients' dietary habits can significantly impact the performance of dental prostheses, as various foods and beverages may have different pH levels, erosive potential, and mechanical effects on dental materials [6].

Soda drinks, milk kefir, water kefir, and almond milk are popular beverages worldwide. Soda drinks are known for their high sugar content and acidity, which can contribute to tooth erosion and negatively impact dental materials [7]. Kefir is a fermented milk drink rich in probiotics, minerals, and vitamins, and has been reported to have potential oral health benefits [8]. Water kefir is a fermented beverage made from water, sugar, and kefir grains which also contains probiotics and beneficial nutrients, though it lacks the dairy component found in traditional kefir [9] [10]. Almond milk is a popular plant-based alternative to milk of animal origin, often consumed by those with lactose intolerance or following vegan diets. It has been suggested that almond milk may have a lower erosive potential compared to other beverages due to its neutral pH and lower sugar content [11].

Previous studies have demonstrated that these beverages have various effects on dental materials. For instance, soda consumption has been associated with increased surface roughness and decreased microhardness of dental materials [12]. Similarly, kefir and water kefir consumption have shown some protective effects on tooth enamel, potentially due to their buffering capacity and antibac-

terial properties [13]. These beverages have distinct properties, such as acidity, sugar content, and microbial composition, which may influence the integrity and performance of dental materials, as well as bacterial adhesion on their surfaces [14] [15].

However, research on the impact of these beverages on denture base materials, such as composite and acrylic resin, is limited.

Therefore, this study aims to evaluate the influence of these dietary habits, specifically the consumption of distilled water as control, soda, milk kefir, water kefir, and almond milk, on the microhardness of composite and acrylic denture base materials. Understanding the effects of these dietary habits on denture base materials may provide valuable information for dental professionals to guide their patients in making informed decisions regarding their dietary choices, ultimately maintaining the durability and performance of dental prostheses.

2. Materials and Methods

2.1. Sample Preparation

A power analysis was performed using G * Power software (G * Power 3.1.9.4. version, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) to determine the appropriate sample size. According to the G*Power analysis, a total sample size of 90 specimens (15 specimens per group) was deemed adequate to achieve statistically significant results for comparisons among the six groups. The power analysis was conducted based on a priori assumptions, including an effect size of 0.25, an alpha level of 0.05, and a power of 0.80.

The study groups were as follows:

1) Composite group (Fusion Universal G1, Belgium)

2) Acrylic group—Imicryl (Imicryl, Türkiye)

3) Acrylic group—Procryla (Procryla, Germany)

3a) Pressure-moulded Procryla—15 minutes (Procryla15) (Pro15)

3b) Pressure-moulded Procryla—30 minutes (Procryla30) (Pro30)

3c) Procryla with 1z zirconia (Pro1Z) (1%)

3d) Procryla with 3z zirconia (Pro3Z) (3%)

Wax dies of 10 mm diameter and 2 mm thickness were created to fabricate acrylic disc samples. These dies were coated with a separating medium, flasked, and embedded in type III dental stone (Elite Arti Fast, Zhermack, Italy). Post setting, the dies were removed with hot water, leaving cavities mirroring their dimensions. A mixture was combined with a monomer, packed into the cavities, and polymerized in a pressure pot at 2.5 bar, at 100˚C for 30 minutes for Imicryl, Procryla30, Procryla1Z and Procryla3Z and for 15 minutes for Procryla15 groups.

(Zirconia addition in the polymer mixture, which is normally prepared by adding 21 g of powder and 10 ml of monomer, was prepared by using 0.2 g of powder and 0.7 g of powder to obtain 1% and 3% by weight.)

Upon cooling, the samples were extracted from the flasks and cleared of any

residual stone particles. Subsequently, the samples underwent refinement through the elimination of superfluous resin with a tungsten carbide bur, followed by polishing with wet silicon carbide papers of assorted grit levels (600, 800, 1000, 1200, and 2000). Any samples exhibiting imperfections, such as internal or external porosities, warpage, altered dimensions, fractured edges, or surface flaws, were excluded from the investigation.

The remaining samples were meticulously re-evaluated at three distinct points using a high-precision digital caliper (Mitutoyo Corp, Tokyo, Japan) to confirm their dimensions' accuracy. Ultimately, the samples were stored in distilled water maintained at a temperature of 37˚C for a duration of 24 hours.

The composite samples (Fusion Universal G1, PrevestDentPro, Belgium) were placed in silicone molds with a 10 × 2 mm cavity and polymerized for 40 minutes. The other surfaces of the demolded samples were subjected to additional polymerization for 40 minutes.

After the polymerization was completed, medium and fine polishers were used for 15 seconds at 7500 - 12,000/min speed to complete the polishing process.

2.2. Immersion Procedure

The specimens were immersed in the respective beverages for each group (distilled water, milk kefir, water kefir, soda, and almond milk) for 1, 7 and 14 days at 4˚C, with the solutions refreshed daily. The distilled water group served as the control group.

2.3. Milk Kefir and Water Kefir Production

Milk kefir and water kefir are probiotic beverages fermented in different growth medium. Product-specific grains and solutions were used for both beverages. Pasteurised milk to which milk kefir grains were added was left to ferment at room temperature at 25˚C for 24 hours, while a solution containing water kefir grains and 5% sugar was kept at 25˚C for 24 hours to obtain probiotic drinks [16]. The first step for almond milk production is to soak raw almonds in water for 24 hours. The next day, the almonds, whose shells were removed, were first crushed in a blender and then the milk part was extracted in a blender by adding boiled and cooled water at a ratio of 1:1 (w/v). The obtained product was filtered through a clean cloth bag to produce almond milk [17]. Since product characteristics can change in a short time, both drinks were prepared daily. The beverages added to the samples were changed daily. All samples used in the study were kept at +4˚C, since the drinks rapidly deteriorate at room temperature.

2.4. Microhardness Testing

The microhardness of the samples was evaluated utilizing a Vickers hardness testing apparatus (HMV 2 version 1.23, Shimadzu, Japan). Each sample's surface was subjected to a 100 g load via a diamond indenter for a period of 15 seconds.

Triple indentations were performed on each sample, and a mean value was subsequently computed. The microhardness values were denoted in terms of the Vickers Hardness Number (VHN).

2.5. Sample Preparation for Scanning Electron Microscopy

One sample from each group was randomized and coated with gold for scanning electron microscopy (SEM) imaging (Fei Quanta Feg 250 model scanning electron microscope with 20 kV voltage, LFD and CBS detector, low vacuum mode, Netherlands).

3. Statistical Analysis

Analytical processing of data was undertaken using IBM SPSS Statistics version 26 (Armonk, New York, USA), employing repeated measures (ANOVA) for comparing the average microhardness values across the different groups. Post-hoc Tukey's tests were executed to discern significant disparities among individual groups. A p-value less than 0.05 was deemed to indicate statistical significance.

4. Results

In this study, the microhardness values of gingiva-coloured composite (Fusion Universal G1), Procryla15, Procryla30, Imicryl, Procryla1Z, and Procryla3Z material groups were measured in various liquid environments (distilled water (control), soda, almond milk, water kefir, and milk kefir) and at different time intervals (1 day, 7 days, 14 days) using a repeated measures ANOVA test at a significance level of $p < 0.05$.

The outcomes of the 2-way ANOVA, which explored the effect of groups, beverage solutions, and time factors on all dependent variables, are showcased in Table 1. A notable interaction ($p < 0.05$) was discerned between groups regarding the time factor. Fluctuations in microhardness were predominantly driven by this time factor ($p < 0.001$). In relation to the beverage solution factor, no interaction ($p > 0.05$) was observed between the groups.

Table 1. Two-way ANOVA table of groups, beverage solutions and time factor.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	1657.778	1.403	1181.739	42.868	0.000
Time * groups	1251.199	1.403	891.911	32.355	0.000
Time * Solutions	183.313	5.611	32.669	1.185	0.320
Error (Time)	3248.388	117.838	27.567		

According to the ANOVA test results, statistically significant differences were found in the microhardness values of the groups measured at different time intervals (Table 2) (Figure 1). In the Composite group, the microhardness values

increased at 7 and 14 days and were statistically significant ($p < 0.05$), while in the Procryla1Z, Procryla30 and Imicryl groups, the microhardness values decreased at 7 and 14 days, but this decrease was not statistically significant ($p > 0.05$). Procryla3Z group's microhardness values increased at 7 and 14 days and were not statistically significant ($p > 0.05$). While initially the microhardness values were found as Composite > Pro30 > Imicryl > Pro1Z > Pro15 = Pro3Z, the change in microhardness values after 14 days was as Composite > Pro30 = Imicryl > Pro15 = Pro1Z = Pro3Z.

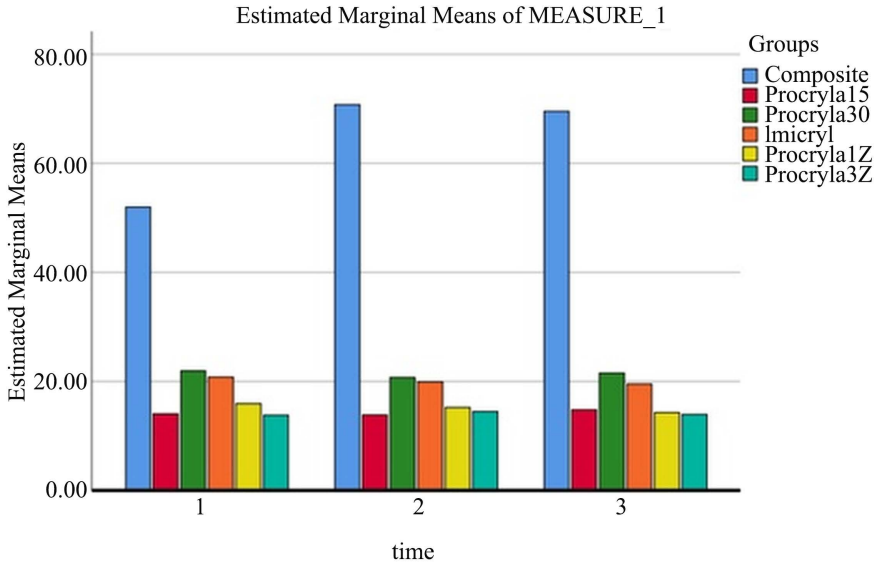

Figure 1. Microhardness graph of the groups waiting in beverage solutions on days 1, 7, and 14. 1, Groups waiting in beverage solutions on day 1; 2, Groups waiting in beverage solutions on the 2nd, 7th day; 3, Groups waiting in beverage solutions on the 3rd, 14th day.

Table 2. Microhardness mean and standard deviation (SD) for each material group according to the tested solutions within each time period.

Groups	Initial		7 days microhardness		14 days microhardness	
	Mean	Sd	Mean	Sd	Mean	Sd
Composite	51.97	2.80 ^{E,a}	70.77	11.84 ^{C,b}	69.55	8.65 ^{C,b}
Procryla15	14.07	0.38 ^{A,a}	13.85	1.10 ^{A,a}	14.81	1.51 ^{A,a}
Procryla30	21.93	0.27 ^{D,a}	20.73	2.20 ^{B,a}	21.54	0.87 ^{B,a}
Imicryl	20.80	0.25 ^{C,a}	19.91	2.38 ^{B,a}	19.51	2.65 ^{B,a}
Procryla1Z	15.93	0.13 ^{B,a}	15.23	1.41 ^{A,a}	14.29	0.91 ^{A,a}
Procryla3Z	13.80	0.30 ^{A,a}	14.45	1.77 ^{A,a}	13.96	0.83 ^{A,a}
Total	23.08	13.41 ^{a}	25.82	20.98 ^{b}	25.61	20.30 ^{b}

Mean values of microhardness accompanied by identical letters are not significantly disparate. Capital letters are used for vertical comparisons, while lowercase letters are employed for horizontal comparisons.

Poor strength, which causes a large number of denture repairs each year, is a major shortcoming. An allergic reaction to acrylic resin is also a common problem. This issue has been addressed by modifications of resin denture bases proposed to improve the mechanical properties. In research, it has been suggested to add zirconia nanoparticles (NPs) to improve the mechanical properties of acrylic resins. The incorporation of zirconia NPs into acrylic resins has been reported to increase microhardness. It can also have an antifungal effect and play a protective role in patients susceptible to fungal infections. On the other hand, one study found an insignificant increase in the microhardness of acrylics with zirconia nanoparticles added, and it was reported that the surface roughness did not change significantly

After the daily preparation of the beverage solutions in which the dental material groups were kept, pH measurements were also recorded (Table 3). The pH values of distilled water (7.01) were neutral, and almond milk (6.56) were slightly acidic or close to neutral, while soda (5.63), milk kefir (4.28) and water kefir (3.72) were more acidic. The microhardness values of the groups slightly increased compared to the initial values, but this increase was found to be significant at day 7 in the soda group and at day 14 in the water kefir group ($p < 0.05$) (Table 3).

Table 3. Two-way repeated measures ANOVA for beverage solutions.

Solutions	Initial		7 days		14 days	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Distilled Water	23.08	13.72 ^{Aa}	23.42	15.25 ^{Aa}	24.54	17.37 ^{Aa}
Soda	23.08	13.72 ^{Aa}	28.61	25.89 ^{Bb}	27.23	23.74 ^{ABa,b}
Almond Milk	23.08	13.72 ^{Aa}	23.70	18.98 ^{Aa}	24.45	17.99 ^{Aa}
Water Kefir	23.08	13.72 ^{Aa}	26.43	20.93 ^{ABa,b}	26.23	20.54 ^{Bb}
Milk Kefir	23.08	13.72 ^{Aa}	26.95	24.15 ^{Bb}	25.59	23.25 ^{ABa,b}
Total	23.08	13.41 ^{Aa}	25.82	20.98 ^{Bb}	25.61	20.30 ^{Bb}

Mean values of microhardness accompanied by identical letters are not significantly disparate. Capital letters are used for vertical comparisons, while lowercase letters are employed for horizontal comparisons.

Scanning Electron Microscopy Results

One sample from each group was randomized and examined at 3000 magnification (Figures 2-7).

The increase in the microhardness values of the samples kept in distilled water and almond milk after 14 days was not found to be significant ($p > 0.05$), while the microhardness values of the samples kept in soda and milk kefir increased significantly on the 7th day ($p < 0.05$) and the microhardness values decreased on the 14th day and reached values close to the initial values. The microhardness values of the samples kept in water kefir decreased, but this decrease was found to be significant on the 14th day ($p < 0.05$) (Table 4) (Figure 8).

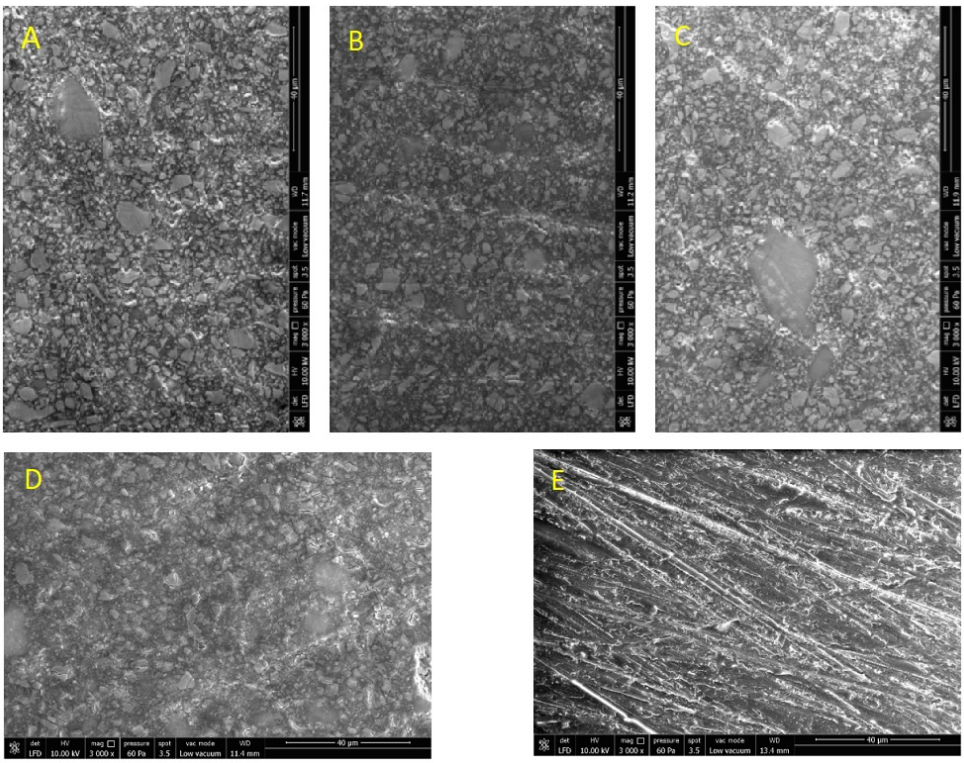

Figure 2. Scanning electron microscopy of the composite in different solutions for 14 days. (A) Distilled water, (B) Soda, (C) Almond milk, (D) Water kefir, (E) Milk kefir.

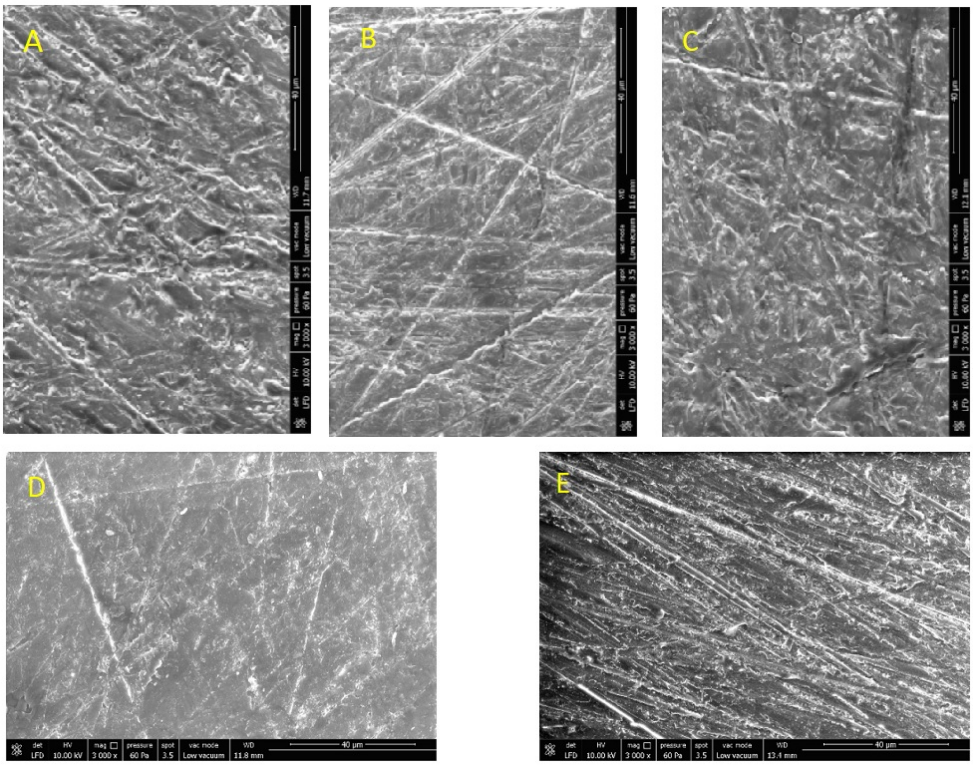

Figure 3. Scanning electron microscopy of the Procryla15 in different solutions for 14 days. (A) Distilled water, (B) Soda, (C) Almond milk, (D) Water kefir, (E) Milk kefir.

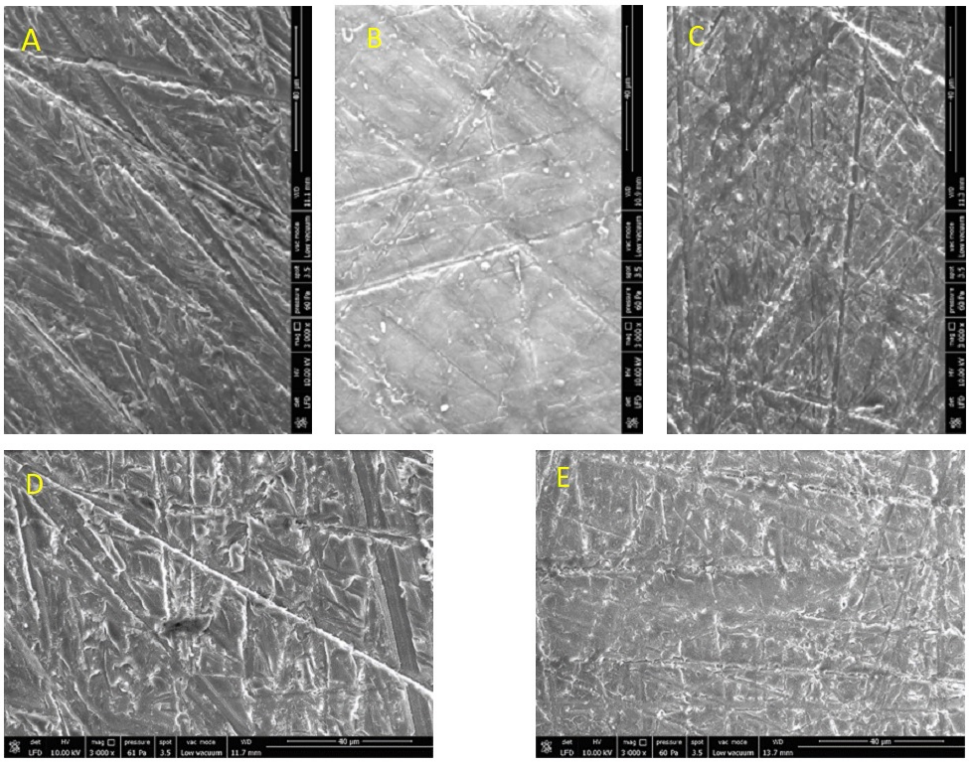

Figure 4. Scanning electron microscopy of the Procryla30 in different solutions for 14 days. (A) Distilled water, (B) Soda, (C) Almond milk, (D) Water kefir, (E) Milk kefir.

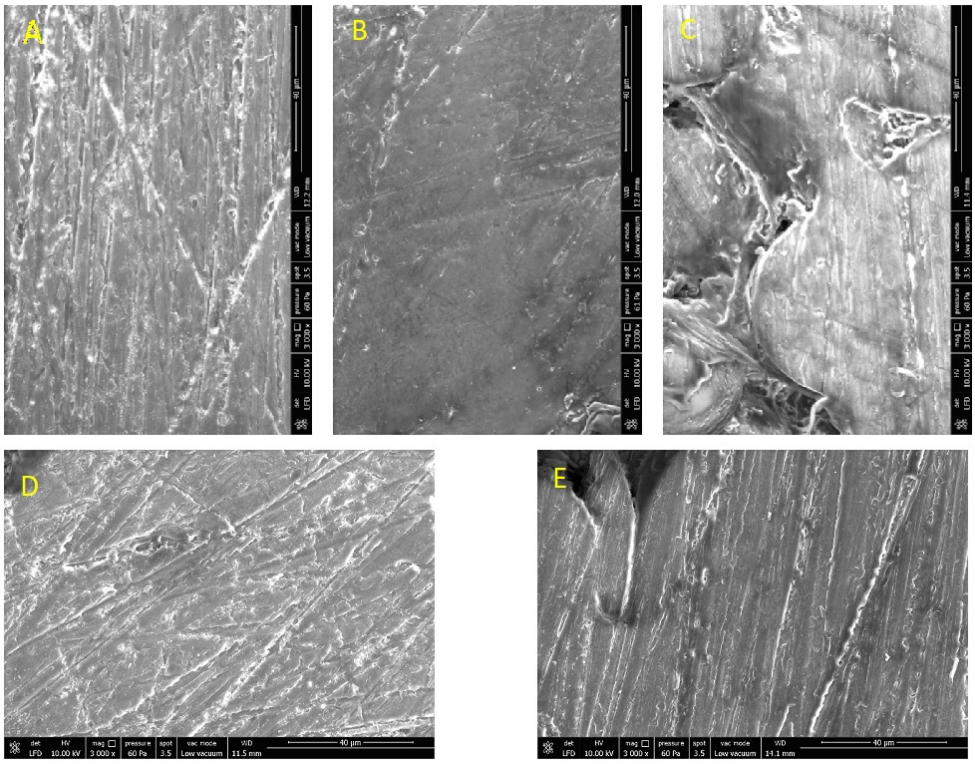

Figure 5. Scanning electron microscopy of the Imicryl in different solutions for 14 days. (A) Distilled water, (B) Soda, (C) Almond milk, (D) Water kefir, (E) Milk kefir.

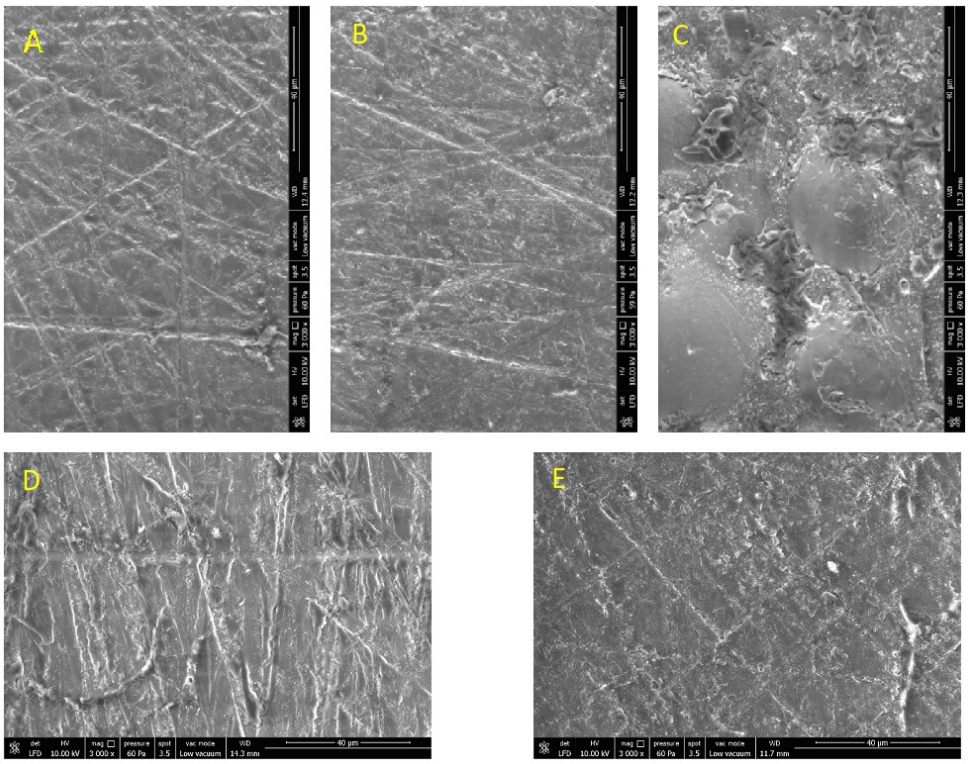

Figure 6. Scanning electron microscopy of the Procryla1Z in different solutions for 14 days. (A) Distilled water, (B) Soda, (C) Almond milk, (D) Water kefir, (E) Milk kefir.

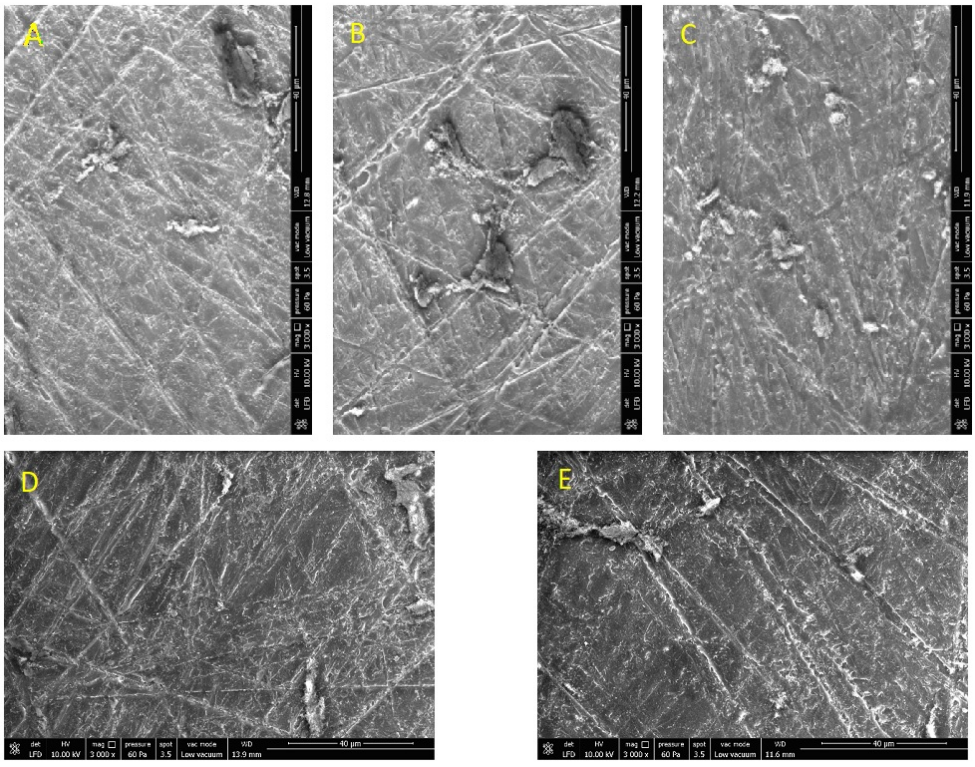

Figure 7. Scanning electron microscopy of the Procryla3Z in different solutions for 14 days. (A) Distilled water, (B) Soda, (C) Almond milk, (D) Water kefir, (E) Milk kefir.

Table 4. pH measurement values of beverage solutions according to days.

pH	Days													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Distilled water	6.92	6.86	7.00	6.83	7.06	7.01	7.09	7.07	7.06	7.03	7.06	7.03	7.07	7.00
Soda	5.63	5.64	5.66	5.77	5.82	5.62	5.62	5.68	5.69	5.54	5.54	5.54	5.60	5.49
Almond milk	6.89	6.83	6.83	6.90	6.81	6.48	6.32	6.36	6.35	6.36	6.45	6.39	6.41	6.43
Water kefir	4.98	3.80	3.56	3.85	3.50	3.54	3.60	3.78	3.71	3.47	3.55	3.54	3.61	3.59
Milk kefir	4.18	4.24	4.28	4.31	4.24	4.30	4.16	4.25	4.37	4.39	4.38	4.29	4.31	4.30

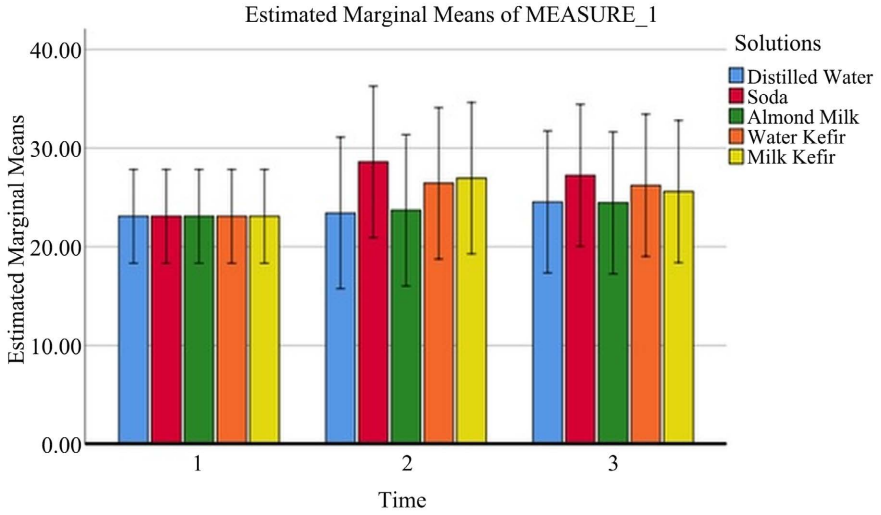

Figure 8. Microhardness graph of the groups waiting in beverage solutions on days 1, 7, and 14.

It was observed that zirconia nanoparticles added at 1 wt% were more uniformly and homogeneously distributed in the acrylic resin matrix. It is more evenly distributed in acrylic.

It can be said that in acrylics to which 3 wt% zirconia nanoparticles are added, zirconia particles are collected and agglomerated in the form of clusters. It is also observed that it forms large voids in the polymer matrix.

5. Discussion

The Vickers microhardness test operates on the premise of a material surface's capacity to resist the intrusion of a specified indenter over a determined duration under a certain load. While acrylic and composite resins remain current as base materials, recent perspectives propose that the addition of zirconia may augment their structural robustness. The hardness of these materials can be largely attributed to their fabrication process, as the conditions deployed for utilizing and polymerizing these substances in an industrial environment enhance their physical and mechanical characteristics [18].

In the investigation carried out by Aati *et al.* [19], considerable variances were observed in the microhardness readings of resins that were enhanced with 1%, 2%, 3%, 4%, and 5% ZrO_2, compared to the unmodified resin, subsequent to submersion in artificial saliva. Specifically, there was an absence of significant differentiation in microhardness between the unaltered resin and resins reinforced with 1%, 2%, 3%, and 4% ZrO_2. On the other hand, the resin supplemented with 5% ZrO_2 presented the maximum microhardness reading, while the lowest was noted for the unmodified resin. After being subjected to aging in artificial saliva, all samples displayed minor but noticeable increments in hardness, ranging from 0.007% to 0.062% in comparison to the original groups, except for the resin samples with a 3% ZrO_2 enhancement, which indicated a trivial reduction [19].

In parallel with this study, in our study, while there was a statistically significant difference in microhardness values as Composite > Pro30 > Imicryl > Pro1Z > Pro15 = Pro3Z at the beginning, the change in microhardness values after 14 days was as composite > Pro30 = Imicryl > Pro15 = Pro1Z = Pro3Z. There were slight increases in the microhardness values of the acrylic groups with 1 wt% and 3 wt% ZrO_2 at the end of the 15th day compared to the initial values. However, these increases were found to be statistically insignificant ($p > 0.05$).

The effect of filler weight percentages on the nanohardness of the initial samples was even more pronounced. It was reported that the initial nanohardness of all samples followed a positive development pattern with increasing weight percentage up to 3% zirconia addition, after which the nanohardness started to decrease gradually with the addition of 4% and 5% zirconia. In contrast to this study, our specimens initially had high microhardness values in the resin groups with no additions and resins with 1 wt% zirconia addition, while our specimens with 3 wt% zirconia addition had low microhardness values. The difference between them was also statistically significant ($p < 0.05$) [19].

Alhavaz *et al.* [20] reported that the addition of 2.5% zirconia nanoparticles to autopolymerized acrylic resins increased the surface hardness by 15.6% with a statistically significant difference, but the addition of 1% and 5% zirconia nanoparticles could not increase the surface hardness of autopolymerized acrylic resins. They stated that increasing the addition of nanofiller particles by weight weakened the adhesion between the nanoparticle and the matrix. It has been reported that the addition of nanoparticles at high concentrations causes agglomeration in the resin structure and creates defects. According to the researchers who argue that reinforcing resins with metal oxide nanoparticles can improve hardness, this improvement may be due to strong ionic interatomic bonds.

In their exploration of the impact of diverse solutions on acrylic teeth, Alubaidi and his associates [18] pointed out that acrylic exhibits a linear polymer chain structure, whereas all modified resins possess a cross-linked structure. They proposed that the ideal degree of cross-linking enhances the mechanical

properties of the acrylic resin. Their findings demonstrated that carbonated acidic beverages were the most potent solutions in diminishing the hardness of acrylic dental materials. This outcome can be ascribed to the acidic and basic composition of the carbonated beverage, instigating hydrolysis of Polymethyl methacrylate (PMMA). PMMA comprises an ester group, which is readily hydrolyzed to carboxylate and alcohol by the acidic and basic constituents. The initial stage of the reaction entails the oxygen atom of the carbonyl group binding to the proton (acidic hydrogen). During this phase, there is an enhancement in the electrophilicity of the carbon atom of the carbonyl group, resulting in an amplified binding of the nucleophile (H_2O). Subsequently, the alkoxy group separates to form carboxylic acid and alcohol. Citric juices, soda, and energy and sports drinks have a low acid composition, and their consumption only triggers minor and brief decreases in pH on the tooth surface.

Ashour Ahmad *et al.* [2] incorporated zirconia oxide nanofiller (1.5%, 3%, 5%, 7%) into heat-polymerized acrylic resin. The material's hardness increased proportionally with the concentration. This mechanical property enhancement is linked to the high interfacial shear strength between the nanofiller and resin due to protective cross-links. Additionally, nanofiller infusion boosts flexural strength, fracture toughness, and hardness as filler volume increases.

Damo *et al.* [21] reported that temperature increases the erosive potential of beverages. They recommend that the tested beverages should be taken at a cold temperature to reduce the negative effect on the materials. In our study, the beverages were stored at 4˚C and pH measurements were made. They reported that a possible explanation for the decrease in microhardness is the pH level of the tested beverages, which is thought to potentially erode tooth surfaces because it is below the critical pH for enamel hydroxyapatite crystal dissolution. The reason why a sports drink did not reduce microhardness despite having a pH of 2.6 and containing citric acid was attributed to the calcium content of the drink.

Denture base material hardness is crucial to ascertain since it signifies the polymeric matrix's resistance to degradation and denture longevity in the oral environment. An increased hardness reduces the risk of denture scratching, potentially weakening the denture and precipitating premature fractures under stress. These surface scratches could also escalate surface roughness, enabling plaque and pigment accumulation, thereby degrading the aesthetic appeal and appearance of the prosthesis.

In a study, conventional PMMA (Ivostar), double cross-linked PMMA (DCL), micro-filled composite resin (VivodentPE), and nanohybrid composite resin (PhonaresiII) samples were tested in artificial saliva, kefir, orange juice, and cola. Results indicated that PhonaresII samples had the highest average microhardness, while Ivostar samples had the lowest. Significant differences were observed in the microhardness data of samples aged in various liquids, yet the microhardness measurements of individual materials showed insignificant differences across solutions [8]. In parallel with this study, the microhardness values of the

composite samples were found to be higher in our study, and although the pH of the beverage solutions were different, no significant difference was found. Ruengrungsom *et al.* [22], concluded that dental materials can chemically interact with unreacted carboxylate groups on their surfaces, resulting in the absorption of Ca ions and a consequent increase in hardness. Therefore, the material's surface layer absorbed these ions, contributing to a notable hardness increase within merely seven hours of storage. In our study, similar to this study, it can be said that the probable reason for the increase in microhardness values in milk kefir and soda beverages on the 7th day was that the matrix of the dental materials we studied absorbed Ca ions and after reaching saturation, it showed values close to the initial values by establishing the ion balance.

Elhatery *et al.* [23], discovered a significant increase in high-impact acrylic resin hardness upon introducing 1% or 3% ZrO_2 nanoparticles, with the latter concentration providing a more substantial effect, irrespective of conventional or microwave treatment methods. This increase in hardness can be attributed to effective nanoparticle dispersion within the resin matrix and the filling of voids between polymeric chains. The average VHN (Vickers Hardness Number) values for samples modified with 1% and 3% nanoparticles ranged from 16.70 to 18.38. In contrast, Gad *et al.* [1] found negligible differences in hardness between resins with 0.5%, 1% nanoparticle additions, and the control group. However, they noted a significant hardness reduction in samples with over 1% nanoparticle concentration, with the lowest value in the 5% addition group.

Our research demonstrates that the presence of ZrO_2 nanoparticles modifies the surface hardness, and that the hardness decreases as ZrO_2 concentrations increase, in agreement with the researchers who observed a substantial difference between the averages at various concentrations.

Upon analysis of the SEM images, it was observed that the suitable incorporation of zirconia into the acrylic resin neither notably reduced the polymer matrix's cross-section nor induced void formation. However, the inclusion of 3 wt% zirconia led to a decrease in microhardness, with a pronounced reduction compared to the Procryla30 group. This decrease could be attributed to a reduced cross-section of the load-bearing polymer matrix, excessive filler particle-induced stress concentration, modifications in the resin's modulus of elasticity and crack propagation pattern, void formation from trapped air and moisture, incomplete filler wetting by the resin, and zirconia's disruptive role in maintaining polymer matrix integrity. Upon SEM examination, it was noticed that the 3 wt% zirconia loading resulted in substantial void formation within the acrylic resin matrix [24].

Our findings diverge from the majority of earlier investigations. In our research, the application of ZrO_2 as filler particles in heat polymerized acrylic resin did not achieve a homogeneous matrix fill; or it may not have uniformly dispersed within the matrix. Such discrepancies could stem from variances in the ZrO_2 percentage, filler size, and the specific type of acrylic resin employed.

Previous research has noted that temperature can influence the extent of surface structure dissolution in samples [25] [26]. Specifically, higher temperatures typically lead to a surge in the solubility and diffusion coefficient of ions in aqueous solutions into the material. Numerous study designs have utilized an incubator to submerge dental material samples at 37˚C, emulating the oral environment. In our investigation, acrylic and composite samples were exposed to varying solutions and stored at +4˚C and room temperature, potentially mitigating the impacts on the surface morphology of the materials. The study's in vitro design and simulated exposure duration are also recognized as limitations. This in vitro approach subjected the acrylic and composite samples to a set timeframe without considering factors such as the beverage consumption rate, mouth movements during swallowing, saliva neutralization, and saliva's remineralization potential. Consequently, the clinical extrapolation of these findings may vary. Other limitations include the fact that each sample was perfectly flat, but within the mouth, the samples were not flat but contained indentations, and that exactly the same points could not be measured before and after each sample [12].

6. Conclusion

Within the limitations of this study, gingiva-coloured composite was the material with the highest microhardness initially and after immersing in the beverage solutions. Composite groups were followed by Procryla30, and Imicryl, respectively. The lowest microhardness values were found between Procryla15, Procryla1Z and Procryla3Z. The results of this investigation indicate that adding 1% and 3% zirconia and decreasing the polymerization time decreased the microhardness values of the materials both initially and after immersing in beverage solutions.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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