

Surface roughness of denture bases after immersion in fishcake vinegar solution

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Abstract. Fishcake is a common food in Palembang city and is usually eaten with fishcake vinegar sauce. Fishcake vinegar solution contains acetic acid and chloride and fluoride ions, all of which cause surface roughness on the denture base material. The objective of this study was to analyze the effect of fishcake vinegar solution on the surface roughness of heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy denture bases. This laboratory-based experimental study was performed on heat-cured acrylic resins, thermoplastic nylon specimen plates formed in 15 x 10 x 1 mm shapes, and cobalt-chromium alloy specimens in cylinder forms with a 7.7 mm diameter and 17.5-mm height. Each group consisted of 10 pieces. Each specimen was immersed in a fishcake vinegar solution at 37 °C for 4 days. The surface roughness was measured using a profilometer before and after immersion. Statistical analyses showed significant ($p < 0.05$) changes in heat-cured acrylic resin, thermoplastic nylon, and the cobalt chromium alloy plates after immersion in a fishcake vinegar solution for 4 days. Fishcake vinegar solution affects the surface roughness of heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy plates after a 4-day immersion period. The greatest surface roughness change occurred in the thermoplastic nylon plate, while the lowest change occurred in the cobalt-chromium alloy.

1. Introduction

Tooth loss can be caused by several factors, such as caries, periodontal disease, and trauma. Replacing missing teeth is an important patient need for both aesthetic restorations and masticatory functions. There are many treatment options for replacing missing teeth, such as removable partial dentures, fixed dentures, and implant-supported dentures. Three types of removable partial dentures are commonly fabricated in Indonesia. Removable partial dentures typically have denture base materials comprised of metal frameworks, acrylic, or flexible dentures (thermoplastic nylon) [1-3]. There are various kinds of traditional foods in Indonesia, such as pickles and fishcake, which contain vinegar. The acid in fishcake vinegar can cause erosion of the tooth surface, which can lead to tooth loss. This condition is common in young patients in the Palembang society. Based on a previous study, from 1,156 people who had been examined, 1,005 people had eaten fishcake vinegar solution. This solution is made from brown sugar, salt, dried shrimp, and garlic. Fishcake vinegar solution contains high levels of calcium, phosphate, and fluorine. Moreover, fishcake vinegar solution also contains acetic acid, derived from vinegar, and chloride ions from salt [4-6]. The presence of acetic acid and chloride and fluoride ions in fishcake vinegar solution can affect not only the teeth, but also the material characteristics of the denture base [5].



The habit of consuming drinks that contain an acid may cause damage to acrylic resin dentures [7]. Acrylic resin dentures immersed in an apple cider vinegar solution, which contains chlorogenic acid, will undergo chemical changes that affect the mechanical properties of the acrylic resin [8]. Coffee is an acidic beverage with a pH of 3.0 to 5.0, and has erosive properties. The acidity in coffee, derived from chlorogenic acid, can lead to erosion in thermoplastic nylon dentures. Furthermore, the surface roughness increases on thermoplastic nylon materials after immersion in Robusta coffee for 3 days [9]. In addition to acid-containing beverages, toothpaste pH can also cause damage to dentures. A previous study has shown that both the pH concentration and the fluoride contained in toothpaste could release metal ions on the alloy surface and promote the breakdown of the chromium oxide passive layer [10]. Dentures with a rough surface promote bacterial colonization and plaque accumulation, as well as the attachment of *Candida albicans*. The clinically acceptable limit for surface roughness is 0.2 μm . If the surface roughness is greater than 0.2 μm , dental plaque development will occur [11].

Previous research has shown that acrylic resin and thermoplastic nylon may undergo changes due to an acidic solution [7-9]. Cobalt-chromium alloy can also experience the release of ions as a result of pH levels and fluoride concentration. However, a study to observe the effects of fishcake vinegar on the surface roughness of denture bases has not been done. The preliminary study for this research was conducted to determine the timing of surface roughness changes on three types of denture base materials after being immersed in a fishcake vinegar solution. The results of the preliminary study showed that, on the first and second day, surface roughness changes had not occurred in the heat-cured acrylic resin, thermoplastic nylon, and cobalt chromium alloy. On the third day, while surface roughness changes occurred on the heat cured acrylic resin and thermoplastic nylon, no changes occurred on the cobalt-chromium alloy. On the fourth day, surface roughness changes occurred in the heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy groups. Therefore, this study aimed to evaluate the effect of fishcake vinegar solution on surface roughness in heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy.

2. Materials and Methods

This research was a laboratory-based experimental study conducted in the laboratory of Research and Development of Dental Materials, Faculty of Dentistry, Universitas Indonesia. The specimens for this research were heat-cured acrylic resin plates, thermoplastic nylon plates, and cobalt-chromium alloy cylinders. The heat-cured acrylic resin and thermoplastic nylon plates were 15 mm in length, 10 mm in width, and 1 mm thick [12]. The cobalt-chromium alloy cylinders were 7.7 mm in diameter and 17.5 mm in height. Each group consisted of 10 specimens. All specimens were measured using a surface roughness profilometer before being immersed in the fishcake vinegar solution. The pH of the fishcake vinegar solution was 5.34 and was measured using a pH meter. The specimens were immersed in a fishcake vinegar solution at 37 °C for 4 days [13]. Every 24 hours, the fishcake vinegar solution was replaced. Each specimen was cleaned using an ultrasonic cleaner in distilled water for 5 minutes and then dried. The surface roughness of each specimen was then measured using a profilometer. All data were collected for statistical analyses using SPSS V.20.

3. Results and Discussion

3.1 Results

The results show that the greatest surface roughness change occurred in the thermoplastic nylon, while the smallest change occurred in the cobalt-chromium alloy after immersion in fishcake vinegar solution for 4 days (table 1). The data distribution of heat-cured acrylic resin and thermoplastic nylon group were not normal; therefore, it was analyzed their data using nonparametric Wilcoxon tests. The data distribution of cobalt-chromium alloy was normally distributed. Therefore, it was analyzed this data using parametric paired t-tests. Based on the results of the Wilcoxon tests, the heat-cured acrylic resin p value was 0.004 and the thermoplastic nylon p value was 0.005. These results indicate there were significant differences between the surface roughness values for the heat-cured acrylic resin and the thermoplastic nylon before and after being immersed in the fishcake vinegar solution for 4 days.

The paired parametric t-tests on cobalt-chromium alloy specimens showed a p value of 0.000. Thus, there was a significant difference in surface roughness between the cobalt chromium alloy before and after immersion in the fishcake vinegar solution.

Table 1. The surface roughness (Ra) of heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy before and after immersion in a fishcake vinegar solution for 4 days

Specimen type	Mean Ra immersion (μm)		Mean difference (μm) \pm SD	p -value
	Before	After		
Heat-cured acrylic resin	0.09	0.18	0.09 ± 0.01	0.004*
Thermoplastic nylon	0.09	0.20	0.11 ± 0.01	0.005*
Cobalt-chromium alloy	0.23	0.27	0.04 ± 0.01	0.000**

*Wilcoxon tests; **Paired t-test

Table 2. The surface roughness difference of heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy specimens after being immersed in a fishcake vinegar solution for 4 days

The surface roughness difference (μm)	Median (min-max)	p -value
Heat-cured acrylic resin	0.08 (0.08-0.11)	< 0.001
Thermoplastic nylon	0.09 (0.08-0.10)	
Cobalt-chromium alloy	0.18 (0.16-0.21)	

Kruskal-Wallis tests

Numeric comparative tests were conducted using Kruskal-Wallis tests on heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy specimens because the data were not normally distributed (table 2). Mann-Whitney post hoc tests were used to determine differences between the groups. Kruskal-Wallis tests showed a p value of 0.000. Because the p value was < 0.05 , it could be concluded there were significant differences in surface roughness between at least two groups. With regard to the Mann-Whitney post hoc tests, the heat-cured acrylic resin compared with the thermoplastic nylon had a $p = 0.000$; the heat-cured acrylic resin compared to cobalt chromium alloy had a $p = 0.000$; and the thermoplastic nylon compared to the cobalt chromium alloy had a $p = 0.000$. The Mann-Whitney post hoc tests showed a $p < 0.001$ for the heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy. Therefore, it there were significant differences in surface roughness between the heat cured acrylic resin and thermoplastic nylon, the heat-cured acrylic resin and the cobalt chromium alloy, and the thermoplastic nylon with the cobalt-chromium alloy after immersion in fishcake vinegar solution for 4 days.

3.2 Discussion

This research was a laboratory-based experimental study aimed to determine changes in the denture base surface roughness caused by a fishcake vinegar solution. There were three types of denture bases used in this study including a heat-cured acrylic resin, a thermoplastic nylon, and a cobalt-chromium alloy, all of which are commonly used as denture base materials [1]. There is a tradition among the Palembang people to consume fishcake and fishcake vinegar solution. Children between 11 to 12 years of age in Palembang consume fishcake more than twice a day (breakfast, snack at school, and evening). A one-time fishcake consumption will cause an acid exposure for 40 minutes, so it will cause 200 minutes of acid exposure if consumed 5 times a day [6]. After the measurements, the pH of the fishcake vinegar solution was obtained and was approximately 5.35. The fishcake vinegar solution was replaced every 24 hours because pH reductions occurred after 24 hours and the pH became 5.01. The aim of a fishcake vinegar solution replacement was to maintain a stable pH.

According to Rahal *et al.*, the surface roughness is an important factor because rough denture surfaces can cause an accumulation of microorganisms that affect oral health [14]. The surface roughness was measured before and after immersion in a fishcake vinegar solution using a profilometer tool to determine surface roughness changes caused by the immersion. The three groups in this study were immersed in a fishcake vinegar solution for 4 days. The 4-day immersion time was selected following the results of a preliminary study. In the preliminary study, the surface roughness of a heat-cured acrylic resin and a thermoplastic nylon plate started to change after being immersed in a fishcake vinegar solution for 3 days. On the fourth day, the surface roughness increased in the heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy specimens. The 4-day immersion time was equivalent to 144 meals a day, or 48 days, a figure obtained from $(4 \text{ days} \times 24 \text{ hours} \times 60 \text{ minutes}) / (3 \text{ meals} \times 40 \text{ minutes})$. This immersion time calculation was in accordance with a previous study [6].

From the present study, it can be concluded that there was a significant difference in the mean surface roughness before and after immersion in a fishcake vinegar solution for 4 days for the heat-cured acrylic resin and the nylon thermoplastic group. The increased value of surface roughness in the heat-cured acrylic resin and thermoplastic nylon groups in this study were caused by a chemical degradation of the polymers. These changes were due to the influence of the low pH in the fishcake vinegar solution, a chemical bonding of the polymer structure, and the ability to absorb the fluid. The heat-cured acrylic resin and thermoplastic nylon material had properties that could absorb liquids. In turn, this caused hydrolysis of the polymer chains in an aqueous environment resulting in an unstable polymer. The results of this study were relevant to the “corrosive wear” theory, which states that an acid solution is corrosive, so it may lead to chemical degradation [15].

In this study, there was a significant difference in surface roughness changes in the heat cured acrylic resin plate due to the acetic acid in the fishcake vinegar solution. These results agreed with research conducted by Elyana in which heat-cured acrylic resin was immersed in a green tea solution with a pH of 4–6. This resulted in an increased surface roughness in heat-cured acrylic resin after immersion for 4 days. However, in the green tea solution, the surface roughness of heat-cured acrylic resin occurred because of the acid content of catechins [16]. When the acid solution reacts with the acrylic resin, it causes chemical changes, such as cross-linking agent glycol dimethacrylate solubility. During the polymerization reaction, the carbon bonds of the methyl methacrylate monomers will react with glycol dimethacrylate to form polymer matrix. These bonds can be degraded by water absorption when the acrylic resin is used. The excess H^+ ions from the acid cause degradation of the polymer bonds, so some of the acrylic resin monomer will release and be accompanied by a glycol dimethacrylate release [5,17]. In this study, there were significant differences in surface roughness for the thermoplastic nylon, which was caused by the acetic acid contained in the fishcake vinegar solution. This research supported a previous study by Kuandinata, which investigated the thermoplastic nylon surface roughness after immersion in Robusta coffee, which is acidic with a pH of 3.0 to 5.0. This previous study showed that the thermoplastic nylon surface roughness changes were due to the acid, but in the Robusta coffee, the acidity is caused by chlorogenate acid [9].

The biggest change in surface roughness occurred in the thermoplastic nylon since it has a higher ability to absorb liquids. Thermoplastic nylon has a fiber that easily absorbs water so it has hygroscopic properties that enable it to absorb water molecules from the environment. The water absorption that occurs in the thermoplastic nylon is caused by the high hydrophilic properties of the amide, which is composed of the polyamide resin main chain, so the increased water absorption is comparable with the amide chain concentration on the acrylic resin [18]. In addition, its light molecular weight, its linear polymer chain, and its polymer structure with minimal thermoplastic nylon crystalline structure, cause high fluid absorption. In previous studies, it caused a higher polymer degradation, so the surface roughness changes in thermoplastic nylon are the highest [2,5,16]. The cobalt-chromium alloy specimens, after being immersed in a fishcake vinegar solution for 4 days, showed significant differences in mean surface roughness values before and after immersion. The results of this research show that the changes in surface roughness in the cobalt-chromium alloy

specimens were caused by halide ions, such as fluoride and chloride, contained in the fishcake vinegar solution. These ions can interfere with the thin oxide layer in the cobalt-chromium alloy. The amount of fluoride ions in the fishcake vinegar solution is derived from palm sugar, garlic, and dried shrimp, while the chloride ions are derived from the salt. In addition, the effect of the acidic pH, from the acetic acid in fishcake vinegar solution, causes an increase in the cobalt-chromium alloy surface roughness. In this research, the surface roughness changes in the cobalt-chromium alloy were relatively small. This was due to the acetic acid in the fishcake vinegar solution, which is classified as a weak acid group, so the changes only happened on the metal surface area (tarnish). The results of this research support previous findings by Ichwani that showed a strong acid solution provides a greater impact on corrosion compared with a weak acid [19].

This study showed that the changes in heat-cured acrylic resin surface roughness were smaller than in the thermoplastic nylon because the heat-cured acrylic resin has hydrophilic properties, but the ability of heat-cured acrylic resin to absorb fluid is less than with thermoplastic nylon. The heat-cured acrylic resin has a greater molecular weight, cross-link bond, and crystalline polymer structure, which is higher than the thermoplastic nylon. The cross-link bonds on the polymer chains increase the molecular polymer weight, so the hardness, strength, and its resistance to solvents are also increased. Crystalline structures act as cross-link bonds to lower the solubility [5,18]. One weakness of this study was the different thicknesses of the cobalt-chromium alloy specimens compared with the heat-cured acrylic resin and thermoplastic nylon. This difference caused a lack of uniformity of the immersed surfaces in the fishcake vinegar solution, due to differences in acidity exposure. The thickness uniformity was caused by not cutting the cobalt-chromium alloy specimens. The cutting of the cobalt-chromium alloy specimens could lead to material fatigue. Material fatigue caused by the friction between the cutting tool and the specimen results in permanent damage of the specimen [20]. Moreover, because the immersion time was only 4 days, the surface roughness changes that occur after 4 days were not observed in this research.

4. Conclusion

The findings from this study suggest that a fishcake vinegar solution can affect the surface roughness of heat-cured acrylic resin, thermoplastic nylon, and cobalt-chromium alloy after a 4-day immersion period. The highest surface roughness changes occurred in the thermoplastic nylon plate after being immersed in a fishcake vinegar solution for 4 days, while the smallest surface roughness changes occurred in the cobalt-chromium alloy.

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