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Evaluation of the effect of tobacco leaf (*Nicotiana tabacum L.*) denture cleaning paste on surface roughness and colour change of thermoplastic nylon

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Abstract

Thermoplastic nylon is an alternative denture base for patients allergic to residual monomers. The research results prove that 75% tobacco leaf extract (TLE) is fungistatic on thermoplastic nylon. This study evaluates the roughness and colour of thermoplastic nylon plates brushed with TLE paste. The post-test-only control group was designed to test changes in surface roughness, and the pre-post-test control group was designed to test colour changes in thermoplastic nylon plates (TNP). The sample group measuring the roughness and colour change of TNP consisted of the electrically brushed control group (K1), the electrically brushed placebo paste group (K2), and the electrically brushed 75% TLE paste group. (K3). We brushed for 23.5 minutes to test surface roughness and 3.90 minutes to test colour changes. The sample shape is a TNP 60x10x2.5 mm for testing surface roughness and 10x10x2.5 mm for testing colour changes with a colour reader. The research results were analyzed using the Kolmogorov-Smirnov and Levene tests, followed by a parametric one-way ANOVA with a significance level of 0.05. Results: There were no differences in surface roughness and colour changes in TNP after brushing with 75% tobacco leaf extract ($p>0.05$). The use of 75% TLE paste has no effect in increasing the surface roughness of TNP below the threshold value of 0.2 μm and does not have a significant impact on changing the colour of TNP with a value of $\Delta E \leq 3.70$.

Keywords: Tobacco leaf extract (*Nicotiana tabacum* L); Denture cleaning paste; Thermoplastic nylon

1. Introduction

Cleaning dentures is a necessary step to prevent cross-contamination and maintain oral health. Denture stomatitis is an oral disease that commonly occurs in denture wearers. Candida albicans is an opportunistic fungal species that causes denture stomatitis (DS). Epidemiological studies show that the prevalence of DS is relatively high. There were 83 wearers of removable dentures, 95% of whom had clinical symptoms of suspected denture stomatitis [1]. To prevent denture stomatitis, denture wearers must diligently clean their dentures. Various methods for cleaning dentures can be mechanical, chemical, or a combination. The research by Naini et al. (2022, in press) found that tobacco leaf extracts, in the form of an effervescent paste (Nicotiana tabacum L.), were 75% effective in inhibiting C. albicans. on heat-cured acrylic resin plates due to the activity of bioactive compounds, namely polyphenols. Apart from that, flavonoids, tannins, and saponins are also active substances that can inhibit the fungus C. albicans [2].

The lack of mechanical cleaning action from the chemicals it contains is a weakness in cleaning dentures soaked in effervescent tablets, so it is recommended to brush dentures [3]. Noviyanti's research shows that mechanical cleaning of dentures by brushing the teeth is more effective at removing plaque, requires less time, and requires less contact with the denture [4]. Chemical cleaning requires long soaking times and, if used continuously, can affect the properties of acrylic resin, such as colour, hardness, and surface roughness. Therefore, mechanical cleaning is required in addition to soaking by brushing the denture with a paste.

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Thermoplastic nylon, as a base for removable dentures, offers greater flexibility and is considered more aesthetically pleasing than acrylic resin [5]. Thermoplastic nylon can also be an alternative denture base material for patients allergic to residual monomer, as it contains almost no residual monomer. Apart from that, thermoplastic nylon is also recommended for growing patients, patients with special needs, and geriatric patients, as well as for temporary dentures after implant placement [6]. Thermoplastic nylon used as a denture base provides excellent aesthetics and comfort and adapts to the constant movement and flexibility of the partial edentulous ridge. Denture cleaners should not change the physical or mechanical properties of the denture base material. However, using denture cleaners can lead to water absorption, changes in surface roughness, and discolouration.

The surface roughness of thermoplastic nylon is due to its low melting point, which makes polishing more difficult. The roughness of the denture base surface can facilitate the buildup of plaque and oral microorganisms that cause denture stomatitis. The ideal denture base surface roughness is 0.2 μm [7]. Colour changes can occur due to intrinsic factors and extrinsic factors. Extrinsic factors include staining by adhesion or dye penetration due to exogenous exposure to the oral cavity, such as tea, coffee, and denture cleaners [2].

Based on the problems above, the researcher wanted to know the possible effects of roughness and colour changes in thermoplastic nylon after brushing with Tobacco leaf extract (TLE) paste 75% as a denture cleanser for 23.5 minutes for the surface roughness test and 3.90 minutes for the colour change test due to differences in the area of the test plate. This usage is equivalent to wearing dentures with mechanical cleaning for one year. This study aimed to evaluate the roughness and discolouration of the thermoplastic nylon denture base, which remained acceptable to denture wearers after 1 year of brushing with tobacco leaf extract denture cleaning paste.

2. Material and methods

The research design is an experimental laboratory study with a pre-posttest control group. The manufacture of thermoplastic nylon plates is located at the Dental Technology Laboratory, Faculty of Dentistry, University of Jember, the manufacture of paste of tobacco leaf extract (Nicotiana tabacum L.) is located in the Bioscience laboratory of the Dental Hospital Universitas Jember and the Pharmacy Laboratory of the Universitas Jember, the measurement of surface roughness in the Materials Laboratory of the Faculty Engineering Universitas Jember, and measure of colour change are located at the Food Analysis Laboratory at the Jember State Polytechnic.

The research samples for the surface roughness test were divided into three groups as follows: Group 1: thermoplastic nylon plates brushed with electric teeth but no paste for 23.5 minutes (15 specimens) as a control group (K1), Group 2: thermoplastic nylon plates brushed with electric teeth with placebo paste (K2) for 23.5 minutes (15 specimens), and Group 3: thermoplastic nylon plates brushed with electric teeth with 75% tobacco leaf extract toothpaste (K3) for 2.35 minutes (15 specimens). The sample shape for the thermoplastic nylon plate was 60 x 10 x 2.5 mm for the acrylic surface roughness test. Measurements are carried out using a surface roughness tester.

Colour change test research samples are divided into three groups as follows: group 1: thermoplastic nylon plates were brushed with electric teeth but did not use paste as a control group(K1) for 3.90 minutes (15 samples); group 2: thermoplastic nylon plates were electric tooth brushed with placebo paste (K2) for 3,90 minutes (15 samples) and group 3: thermoplastic nylon plates brushed with electric teeth with 75% tobacco leaf extract toothpaste (K3) for 3,90 minutes (15 samples). The sample shape is a thermoplastic nylon plate measuring 10 x 10 x 2.5 mm for the acrylic colour change test, and measurements are carried out using a colour reader.

2.1. Making 75% Tobacco Leaf Extract

6 kg of tobacco leaves were taken. The tobacco is then dried in an oven at 50°C for 24 hours. The dried tobacco is then blended into a powder. The resulting powder was filtered through a 16-mesh sieve. After the filtering process, the next step is maceration of the tobacco leaves with a 96% ethanol solvent (1:4 m/v). The maceration process lasted three days until a blackish-brown colour was formed.[8] The soaking is then filtered, and the filtrate is taken. The filtrate obtained was then concentrated using a rotary evaporator, resulting in a greenish-brown nylon thermoplastic plate.

2.2. Making Paste 75% Tobacco Leaf Extract

The way to make placebo paste is to mix all the placebo ingredients consisting of calcium carbonate (29%), magnesium carbonate (26%), propylene glycol (8%), glycerin (6%), TEA (4%), distilled water (25%), and oleum methane piperitae (2%) in a mortar and pestle, then stir all the ingredients until homogeneous paste forms. A placebo paste weighing 100 grams was placed in a closed container to prevent drying. To make a 75% tobacco leaf cleaning paste, mix 75 grams of placebo paste with 75 grams of tobacco leaf extract, stirring until a homogeneous paste forms.

2.3. Making Thermoplastic Nylon Plates

The thermoplastic nylon plate is a flexible resin, acrylonitrile. The master model was made with 45 pieces measuring 60 x 10 x 2.5 mm and 45 pieces measuring 10 x 10 x 2.5 mm, and the sprue was made from red wax. The master model and sprue are inserted into the mould space and disposed of overnight by boiling. The mould space is insulated with a separator, and then thermoplastic nylon, melted at 280^0C in the cartridge, is injected. Apply pressure using a hydraulic bench press at 6-8 bars for 5 minutes, then polish. Making thermoplastic nylon plates measuring 60 x 10 x 2.5 mm for testing the surface roughness of thermoplastic nylon and measuring 10 x 10 x 2.5 mm for testing acrylic colour changes (ADA Specification no. 12).

2.4. Mechanical Cleaning with Tobacco Leaf Extract Cleaning Paste

Tobacco leaf cleaning paste is weighed at 3 mg. The thermoplastic nylon plate was brushed on the stained area with an electric toothbrush and cleaning paste for one minute, then rinsed with running water. Repeat the procedure until a total time of 23.5 minutes is reached, with 3.90 minutes per test group.

2.5. Surface Roughness Testing

Surface roughness measurements can be carried out using a surface roughness tester or profilometer with an accuracy of 0.01 μm, namely by measuring the movement signal of a stylus moving along a straight line on the surface, which serves as an indicator of the surface roughness of the test object. The first step is to place the specimen on a flat plane. The sample is measured three times at different points by placing the stylus at the end of the sample, which has been marked with a distance to form a parallel line; then, activating the tool, the test equipment monitor will display the surface roughness value of the specimen. Surface roughness measurements are carried out using the average method, in which roughness is measured at three points, and the results are averaged. The average value is then used as the surface roughness value [9].

2.6. Colour Change Measurement

Colour change measurement can be done with a colour reader or densitometer. The two tools differ in their service principles: the colour reader uses colour-difference measurements based on light reflected from the sample surface, while the densitometer measures the intensity of light absorbed by an object. The measurement result is a value in L, a, b. Comparing the value of the measurement results before and after treatment. In this study, the colour change was measured using a colour reader and then calculated using the formula:

$$\Delta E_{ab} = \sqrt{(L2 - L1)^2 + (a2 - a1)^2 + (b2 - b1)^2}$$

ΔE :	colour change value
L :	dark/light colour on a scale of 0 (black) to 100 (white)
a :	red/green colour
b :	blue/yellow colour
L1, a1, b1 :	Before brushing
L2, a2, b2 :	After brushing

2.7. Statistical Analysis

The research results were carried out by the Kolmogorov-Smirnov and Levene tests, followed by the parametric one-way ANOVA test with a significance level of 0.05

3. Results and discussion

The highest average surface roughness value was found in the group of thermoplastic nylon plates brushed with 75% tobacco leaf extract paste (K3), namely 0.176 μm, followed by the group brushed with placebo paste (K2), 0.172 μm and the lowest average surface roughness value was found in the group that touched without paste (K1), namely 0.171 μm. (Table 1).

Table 1 The average surface roughness value in the group of thermoplastic nylon plates (μm)

Group	Average surface roughness (μm)	Standard Deviation
K1	0.171	0.06
K2	0.172	0.02
K3	0.176	0.03

The normality test results for the surface roughness of thermoplastic nylon plates in each group were not significant ($p > 0.05$). The significance value of K1 is 0.172, K2 is 0.077, and K3 is 0.079. The homogeneity test results for all treatment groups were 0.165 ($p > 0.05$). The results of the One-Way Analysis of Variance test show a significance value of 0.935 ($p>0.05$). These results indicate no significant difference in surface roughness across the treatment groups.

The highest average value of colour change was found in the group of thermoplastic nylon plates that were brushed using 75% tobacco leaf extract paste, namely 2.73, followed by the group that was brushed with placebo paste, namely 2.56, and the lowest average value of colour change was in the group that was brushed without paste, namely 2.48 (Table 2).

Table 2 Average value of colour changes in the group of thermoplastic nylon plates

Group	Value of colour change (ΔE)	Standard Deviation
K1	2.48	0.47
K2	2.56	0.34
K3	2.73	0.39

The normality test results for colour changes on the surface of thermoplastic nylon plates in each group were not significant ($p > 0.05$). The significance value of K1 is 0.20, K2 is 0.07, and K3 is 0.09. The homogeneity test results for all treatment groups showed a p-value of 0.314 ($p > 0.05$). The results of the One-Way Analysis of Variance show a significance value of 0.256 ($p > 0.05$). These results indicate no significant difference in surface roughness across the treatment groups.

3.1. Surface roughness of the thermoplastic nylon plate after brushing with 75% tobacco leaf extract paste

This research focuses on testing the physical properties of thermoplastic nylon, namely surface roughness and colour changes, after brushing using denture toothpaste made from 75% tobacco leaf extract. These two physical properties, based on thermoplastic nylon, have almost no porosity compared to the heat-cured acrylic resin denture base material. Thermoplastic nylon porosity can be caused by overheating or uneven pressure during polymerization. Porosity is caused by the influx of air during injection moulding. Air that is not released will have bubbles on the surface of thermoplastic nylon [10]. This research hypothesises that using denture toothpaste containing 75% tobacco leaf extract does not alter the surface roughness of thermoplastic nylon materials. This is certainly different from heat-cured acrylic resins, which tend to have high microporosity; as reported in previous research, the surface roughness of heat-cured acrylic resins was higher [11].

Based on the average surface roughness value of thermoplastic nylon after brushing, Table 1 shows variations in surface roughness values in each sample group. The highest average surface roughness value was found in the thermoplastic nylon plate group, which was brushed with 75% tobacco leaf extract (K3) paste, namely 0.176 μm, followed by the group which was brushed with placebo paste (K2), which was 0.172 μm, and the average The lowest average surface roughness value was found in the group that brushed without paste (K1), namely 0.171 μm. The results of the One-Way ANOVA analysis show a p-value of 0.935 (>0.05), indicating that there was no significant difference in surface roughness among the groups after brushing with water, placebo paste, and 75% tobacco leaf extract paste.

On average, surface roughness increased on thermoplastic nylon plates after brushing with 75% tobacco leaf extract paste (K3) compared to without paste (K1). This can be caused by contact between the thermoplastic nylon plate and the chemical compound in tobacco leaves, namely phenol. When phenol comes into contact with the denture base, it causes chemical damage to the surface. Chemical damage roughens the surface of the thermoplastic nylon plate, leading to cracks and reduced strength [12].

Phenol is a chemical from the aromatic hydrocarbon group that can penetrate the microporosity of resin-based denture bases and dissolve them. Phenolic compounds have acidic properties because they release H^+ ions from their hydroxyl groups. This is proven by reacting the two materials with NaOH. This dissolution decreases hardness, resulting in reduced physical properties. The phenol content in tobacco leaves can cause damage and penetration of phenolic compounds into the surface of the thermoplastic nylon base. Resin monomers can escape, causing polymer degradation due to H^+ ions from the acid. The polymer degradation that occurs alters the physical properties of thermoplastic nylon. The acidic nature of this phenolic compound may change the surface roughness of the denture base.

Surface roughness is defined as irregularities or high or low surfaces of a denture base. Based on the results of this research, it is known that the surface roughness value of thermoplastic nylon, after coating with 75% tobacco leaf extract, shows 0.176; this result is still below the threshold value for the ideal or acceptable denture base surface roughness in the oral cavity, namely 0 .2 μm [13]. This is also supported by the research of Hamanaka et al. [14], which shows that the threshold surface roughness of thermoplastic nylon after pulsed treatment is 1.70 ± 0.40 μm. The difference in the average value of surface roughness in the placebo paste group (K2), which was higher than that of the 75% tobacco leaf extract paste group, could be caused by the composition of the placebo material, which consisted of calcium carbonate (29%), magnesium carbonate (26%), and propylene glycol. (8%), glycerin (6%), TEA (4%), distilled water (25%), and oleum menthae piperithae (2%).

The paste material in this study contains calcium carbonate, which acts as an abrasive to remove plaque and has polishing properties, helping prevent plaque accumulation. Abrasive materials are insoluble minerals that help remove biofilm on the tooth surface, remove stains and debris/microorganisms, and provide a whitening effect [15]. However, abrasive materials also have disadvantages, namely that they can increase surface porosity or surface roughness. Making a paste of 75% tobacco leaf extract has a composition of 75% tobacco leaf extract: paste ingredients, namely 3:1. When making placebo pasta (K2), it has a composition of 100% of the paste ingredients. Based on this, the use of 75% tobacco leaf extract paste does not increase the surface roughness of the thermoplastic nylon plate, so it does not affect the physical properties of the thermoplastic nylon.

3.2. Colour change of the thermoplastic nylon plate after brushing with 75% tobacco leaf extract paste

Colour stability is the ability of the surface layer or the pigment to withstand environmental degradation. Colour stability is one of the properties of a denture base that is highly emphasized in achieving good aesthetic value, so it is essential to maintain it. Colour stability is also a crucial clinical characteristic of denture base materials, as it can influence a material's colour change. Changes can be caused by two factors: intrinsic factors, including the acrylic resin material itself, which may be due to its nature, chemical structure, or the monomers used. In contrast, extrinsic factors are stains caused by the absorption of colouring materials from exogenous sources such as tea, coffee, and other drinks. Light, natural colouring agent and denture cleaning agent [16]. This research focuses on mechanical cleaning methods, specifically brushing with a paste of 75% tobacco leaf extract.

Based on the average colour change value of thermoplastic nylon after brushing, Table 2 shows variations in colour change within each sample group. The highest average colour change value was observed in the group of thermoplastic nylon plates brushed with 75% tobacco leaf extract paste (K3), namely 2.73, followed by the group brushed with placebo paste (K2), namely 2.56. and the lowest average surface roughness value was in the group that brushed without paste (K1), namely 2.48.

The results of the One-Way ANOVA analysis show a p-value of 0.256 (>0.05), indicating that the groups did not differ significantly in surface roughness of the thermoplastic nylon plate after brushing with water, placebo paste, or 75% tobacco leaf extract paste. On average, there was an increase in colour changes on thermoplastic nylon plates after brushing with 75% tobacco leaf extract paste (K3) compared to without paste (K1). This can be caused by tobacco leaves, which contain phenolic compounds (flavonoids), alkaloids (nicotine), saponins (steroids), and essential oils (terpenoids) [17]. When phenolic compounds come into contact with thermoplastic nylon, they can penetrate the material and damage polymer chain bonds, resulting in a decrease in physical and mechanical properties, including colour change [18]. The ester group that reacts with phenol will cause the H+ ion in the phenol to bind with the OH- ion released from the ester group, so that the phenol group will bond with RCO from the ester group [2].

Hydrogen ions (H+) in large quantities can reduce surface tension so that diffusion occurs into the polymer chain in the ester group and causes the polymer chain bonds to become unstable, causing a lot of space between the polymer matrix, which makes it easier for bonds to occur between the elements contained in tobacco leaves and polymer matrix so that the polymer chains in the ester groups will be disrupted and separated. Disrupted and isolated polymer chains can increase the discoloration of thermoplastic nylon.

In this research, variations in the average colour change in thermoplastic nylon resin are attributed to several factors, namely sample size, sample microporosity, and contact time. The larger the sample size, the greater the physical changes that can occur in the material. The presence of microporosity determines the attachment of colour particles to porous areas. This is also supported by the diffusion theory, namely the tendency of fluids to fill the available cavities. The greater the porosity, the more fluid is absorbed through diffusion.

The colour change in thermoplastic nylon brushed without paste is thought to be caused by the breaking of chemical bonds in the nylon resin due to water diffusion. This reaction is believed to increase the clarity of thermoplastic nylon, thereby affecting colour stability. Besides that, it can also be caused by abrasive materials (calcium carbonate), with 29% in the placebo paste and 75% in the tobacco leaf extract paste. Abrasive materials are insoluble minerals that can increase surface porosity in thermoplastic nylon resin. The increase in colour changes on thermoplastic nylon plates brushed with 75% tobacco leaf extract may be due to the phenol content, which increases surface porosity and can lead to mass loss and greater water absorption, resulting in more pronounced colour changes. Phenol compounds penetrate the material and damage the polymer chain bonds, resulting in colour changes. This is the same as previous research, which used tobacco leaf extract containing phenolic compounds in an acrylic resin [19].

The colour change value in in vitro research is clinically acceptable if $\Delta E \leq 3.70$, whereas in in vivo research, it is acceptable if $\Delta E \leq 6.80$.[19] This research is an in vitro laboratory study, with the highest colour change value of 2.73 ($\Delta E \leq 3.70$) across all treatment groups, indicating that the colour change in all groups is still acceptable. The low colour change in thermoplastic nylon is also supported by its lower surface microporosity.

4. Conclusion

Paste 75% tobacco leaf extract (Nicotiana tabacum L.) has no effect in increasing the surface roughness of thermoplastic nylon plates after brushing, with the surface roughness value of thermoplastic nylon plates being below the threshold value for surface roughness of materials that can be used in the oral cavity, namely 0.2 μm. Paste containing 75% tobacco leaf extract (Nicotiana tabacum L.) does not affect the colour change of thermoplastic nylon plates after brushing, with $\Delta E \leq 3.70$, so the colour change remains below the acceptable threshold for a denture base material.

Compliance with ethical standards

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Disclosure of Conflict of interest

The authors report no conflict of interest.

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