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THE POTENTIAL EFFECT OF AVOCADO SEED EXTRACT (PERSEA AMERICANA) AS A CORROSION INHIBITOR ON SURFACE CHARACTERISTIC OF ORTHODONTIC WIRES

POTENSI EKTRAK BIJI BUAH ALPUKAT (PESEA AMERICANA) SEBAGAI INHIBITOR KOROSI TERHADAP SIFAT PERMUKAAN KAWAT ORTODONTI

Original Research Article
Penelitian

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ABSTRACT

Background: *The surface roughness of orthodontic arch wires is an essential factor that affects the effectiveness of arch-guided tooth movement. Metal wires exposed to the oral cavity environment are susceptible to corrosion. The corrosion process cannot be stopped but can be inhibited using natural inhibitors that contain antioxidant compounds, such as tannins found in avocado seeds. Tannins in avocado seed extract can act as a corrosion inhibitor through two working mechanisms, a passive layer and an adsorption process.* ***Purpose:*** *The aim of this study was to examine the viability of avocado seed extract as a corrosion inhibitor on the surface characteristic of orthodontic wires. This research is an experimental laboratory research.* ***Method:*** *A total of 48 orthodontic wires (stainless steel, nickel titanium, and Titanium-Molybdenum Alloy (TMA)) were prepared and divided into control and treatment groups. The treatment groups were immersed in avocado seed extract at concentration of 1.5 g/L (T-1), 2 g//L (T-2) and 2.5 g/L (T-3) for 7 days with twice daily immersion of 1 minute each. A TR 220 surface roughness tester (ΔR_a) was used to evaluate surface characteristic. The data was analyzed using the one-way ANOVA test followed by post hoc LSD test with a significance value of p-value < 0.05.* ***Result:*** *The average surface roughness increased in all control groups except for stainless steel wire which did not show a significant difference with p-value = 0.716. Furthermore, the difference test between groups on each wire showed different results.* ***Conclusion:*** *Avocado seed extract is effective as a corrosion inhibitor for orthodontic wires.*

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ABSTRAK

Latar belakang: Kekasaran permukaan kawat ortodontik merupakan faktor penting dalam menentukan efektivitas gerakan gigi. Kawat dengen bahan logam yang terpapar ke lingkungan rongga mulut rentan terhadap korosi. Proses korosi tidak dapat dihentikan tetapi dapat dihambat dengan menggunakan bahan alami penghambat yang mengandung senyawa antioksidan, seperti tanin yang terkandung dalam biji alpukat. **Tujuan:** Penelitian ini bertujuan untuk untuk mengetahui potensi ekstrak biji alpukat sebagai penghambat korosi pada sifat permukaan kawat ortodontik. Penelitian ini merupakan penelitian eksperimental laboratorium. **Metode:** Jumlah sampelnya adalah 48 kawat ortodontik yang terdiri dari stainles steel, nikel titanium dan Titanium-Molybdenum Alloy (TMA), kemudian dibagi menjadi kontrol dan perlakuan kelompok perlakuan akan direndam dalam ekstrak 1,5 g/L (P-1), 2 g/L (P-2) dan 2,5 g/L (P-3) selama 7 hari dengan perendaman 2 kali sehari selama 1 menit. Uji kekasaran permukaan dengan mesin TR 220 digunakan untuk mengevaluasi rata-rata kekasaran (ΔR_a). Data dianalisis menggunakan uji *one-way* ANOVA dikuti dengan uji *post hoc* LSD dengan nilai signifikansi sebesar *p-value* < 0,05. **Hasil:** Kekasaran permukaan rata-rata meningkat di semua kontrol kelompok kecuali kawat stainles steel yang tidak menunjukkan perbedaan yang signifikan dengan nilai *p-value* = 0,716. Selanjutnya, uji beda antar kelompok pada setiap kawat menunjukkan hasil yang berbeda. **Kesimpulan:** Ekstrak biji alpukat dapat digunakan sebagai inhibitor korosi untuk kawat ortodonti.

Kata kunci:
Inhibitor korosi, Ekstrak biji buah alpukat, Kawat ortodonti, Kekasaran permukaan

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INTRODUCTION

The surface topography of orthodontic wires is a basic characteristic known to affect their mechanical properties, the biocompatibility and corrosion resistance. Increased surface roughness of orthodontic wires can influence the coefficient of friction, which in turn affects how effective sliding the biomechanics works and the efficiency of sliding mechanics and the overall effectiveness of orthodontic appliances (Ashique Abdulhameed *et al*., 2024).

Orthodontic wires provide force to move teeth back into the proper arch alignment, enabling proper occlusion (Arora *et al*., 2019). Several types of orthodontic wires that can be used in the orthodontic treatment, consist of Stainless Steel (SS), Nickel Titanium (NiTi), and Titanium-Molybdenum Alloy (TMA) wires (Nimeri *et al*., 2013). Stainless steel wires primarily consist of Fe ions at 71%. Nickel titanium wire has a composition of 55% nickel ions and 45% titanium ions, and TMA wire contains 77.8% titanium, 11.3% molybdenum, 6.6% zirconia, and 4.3% tin (Brantley and Eliades, 2011).

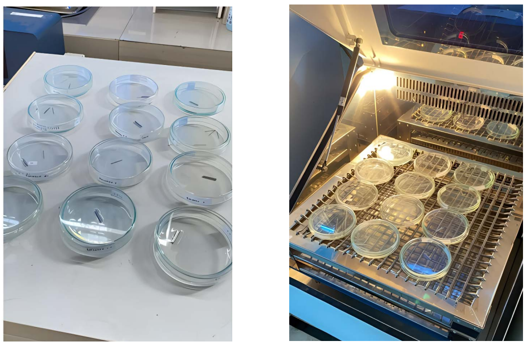
The mechanical properties of orthodontic wires are exceptionally critical since they greatly influence the viability of orthodontic treatment. Basic mechanical properties such as modulus of versatility, abdicate quality, and fracture toughness. Additionally, orthodontic wires must be resistant to corrosion (Zinelis *et al*., 2015). However, orthodontic treatment is a long-term procedure, orthodontic wires are potentially subject to ion release due to prolonged contact with saliva (Castro *et al*., 2015). In artificial saliva with pH 4 - 6, stainless steel and Ni-Ti wires are known to undergo pitting corrosion (Fatene *et al*., 2019). The consequence of corrosion on orthodontic wire affects its mechanical properties, specifically elastic modulus and yield strength. In addition, the roughness of the wire surface will cause greater friction between the bracket and the wire, which will reduce the sliding action and thus decrease the efficiency of tooth movement during treatment (Sheikh *et al*., 2015). Corrosion also affects the biocompatibility of the wire. Metal ions released into the oral environment will enter the body and can have health effects such as triggering type 4 hypersensitivity reactions in some patients (Uzer *et al*., 2016).

Saliva is an electrolyte liquid that facilities electrochemical reactions. In electrochemical reactions, oxidation occurs at the anode (metal surface), and reduction occurs at the cathode. H^+ ions in saliva. As a result, there is a release of ions in orthodontic wire as a sign of corrosion. The corrosive impact of the artificial saliva-based arrangements is due to the nearness of chloride ions. In environment with sufficient of chloride particles, pitting corrosion can occur, characterized by localized pits forming on the metal surface. This typically occurs in base metals protected by a thin, naturally formed oxide film (Rajendran *et al*., 2017).

Corrosion inhibitors are chemicals that when when applied in small amounts to metals can decrease corrosion without reacting with the encompassing environment. Corrosion inhibitors can come from extracts of natural materials that contain flavonoids, phenols, steroids, triterpenoids, and tannins with antioxidant activity (Kadhim *et al*., 2021). Avocado-seed extracts have numerous health-related bioactive properties, such as anti-hyperglycaemic, anticancer, anti-hypercholesterolemia, antioxidant, anti-inflammatory, and anti-neurogenerative impacts are clearly illustrated how these properties can be utilized to define or brace nourishment (Bangar *et al*., 2022). The extract from avocado seeds (*Persea americana*) is recognized as a potential corrosion inhibitor. Inside the extract, ethanol acts as solvent, and it contains tannin compounds at a concentration of 0.2044% (Rivai *et al*., 2019). Rais and Wahyuningtyas (2021) found that avocado seed extract with a concentration of 2.5 g/L was effective in reducing the corrosion rate of steel metal. Tannins can hinder the corrosion rate on metal surfaces by acting as a coating and forming a passive layer. The passive layer may be a condition in which the metal loses its reactivity, in this manner improving resistance to the ion release (Adha *et al*., 2019). The aim of this study was to examine the viability of avocado seed extract as a corrosion inhibitor on the surface characteristic of orthodontic wires with surface roughness measurement.

MATERIAL AND METHOD

This study was laboratory experimental research with a post-test control group design. The characteristic of surface orthodontic wires were evaluated with based on the average of surface roughness (ΔR_a). Samples were used 3 different types of wires consisting of stainless steel, nickel titanium, and TMA wire, from ORMCO Ltd, with size 0.017 × 0.025 inches were prepared with a length of 60 mm. All type of wire were divided into 4 treatment groups including control group, treatment 1 (T-1 : 1.5 g/L), treatment 2 (T-2 : 2 g/L), and treatment 3 (T3 : 2.5 g/L). Each group according to Daniel's formula consisted of 4 samples. The total for each wire was 16 samples and the total for the 4 wire categories was 48 samples.



(a) (b)

Figure 1. (a) Soaking the sample in a petri dish, (b) After treatment all samples were stored in an incubator

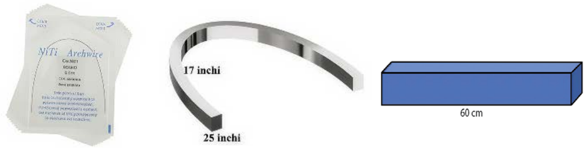
Processing avocado seed extract

Avocado seeds were dried in a broiler at 40 °C and pulverized to powder form can be seen in Figure 1. The maceration process used 95% ethanol solvent. The ratio of avocado seed powder and solvent is 1 : 10. The final product is thick avocado seed extract. The thick extract of avocado seeds was weighed using a digital analytical balance and then dissolved in 1000 mL of artificial saliva as a corrosive medium, with inhibitor concentrations in each treatment group being 1.5 g/L, 2 g/L, and 2.5 g/L (Sanjaya *et al*., 2020).

Treatment of samples

Preparation test can be seen in Figure 2. Each sample was put into a sterile petri dish and labeled concurring to the group, namely group (K) for control, (P-1) for the concentration of 1.5 g/L, (P-2) for the concentration of 2 g/L, and (P-3) for a concentration of 2.5 g/L. All samples had previously been filled with artificial saliva and stored in an incubator at 37 °C for 7 days. As for the treatment group, each sample was immersed in a sterile petri dish containing avocado seed extract for 1 minute and then returned to artificial saliva in the incubator at 37 °C. After 1 minute, samples were washed utilizing refined water returned to the petri dish containing artificial saliva, and after that put back into the incubator at 37 °C. The immersion process was performed twice daily (morning and evening), each time for 1 minute, and repeated every day for 7 days (Setyaningsih *et al*., 2019). This protocol was designed to simulate oral conditions as the peak of corrosion on orthodontic wires in the oral cavity is reported to occur in the 7th day (Angeline *et al*., 2021).

After 7 days, all samples were removed from the incubator. Then the sample was removed from the petri dish using tweezers and cleaned using 100 ml of H_2SO_4 solution which was dissolved with distilled water to 1000 ml at a temperature of 20 – 25 °C for 1-3 minutes. According to ASTM G1-90 "Standard Practice for Preparing, Cleaning and Evaluating Corrosion Test Specimen" (ASTM, 2017). Then to remove air humidity in the control and treatment group samples, all samples were placed in a desiccator for 24 hours. After 24 hours, each sample was removed from the desiccator and placed on a petri dish which had been labeled according to the group. Roughness test TR 220 was used to evaluate the roughness average (ΔR_a) of orthodontic wire.



(a) (b) (c)

Figure 2. Sample preparation: (a) Orthodontic wire from Ormco, (b) Illustration shape and size of wire, (c) Illustration of sample

The measurement of surface roughness (ΔRa)

The surface roughness of the samples was measured using a surface roughness analyzer TR 220. Measurements are taken on one side of the sample on three different lines. Each sample's average surface roughness (ΔRa) was then noted and analyzed can be seen in Figure 3.

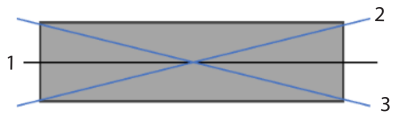


Figure 3. Illustration of average surface roughness measurement line

Statistics analysis

The average surface roughness (ΔRa) data were analyzed using a Statistical Package for the Social Sciences 25.0 (SPSS for Macbook; SPSS, Chicago, IL, USA). One-way ANOVA and post hoc LSD tests at the confidence level of 95% ($\alpha = 0.05$).

RESULT

The average surface roughness value for all samples in this research can be seen in Figure 4. Figure 4 shows the highest average surface roughness is see was observed on NiTi wire in all groups while the lowest was found on stainless stell wire. Parametric statistical analysis using the one-way ANOVA test showed that there were significant differences in all control groups compared to the treatment groups in the 2 wires, nickel titanium (p-value = 0.001) and TMA (p-value = 0.004), except for stainless stell wire which did not show a significant difference with p-value = 0.716. Post hoc LSD test were performed for NiTi and TMA wired to analyze difference between groups).

The Least Significant Differences (LSD) test on Niti wire is shown in Table 1, there are significant differences in the control group with treatment groups T2 and T3 as well as between groups treatment T1 with treatment groups T2 and T3. Table 2 shows the LSD test on TMA wire, significant differences are shown in the control group with all treatment groups.

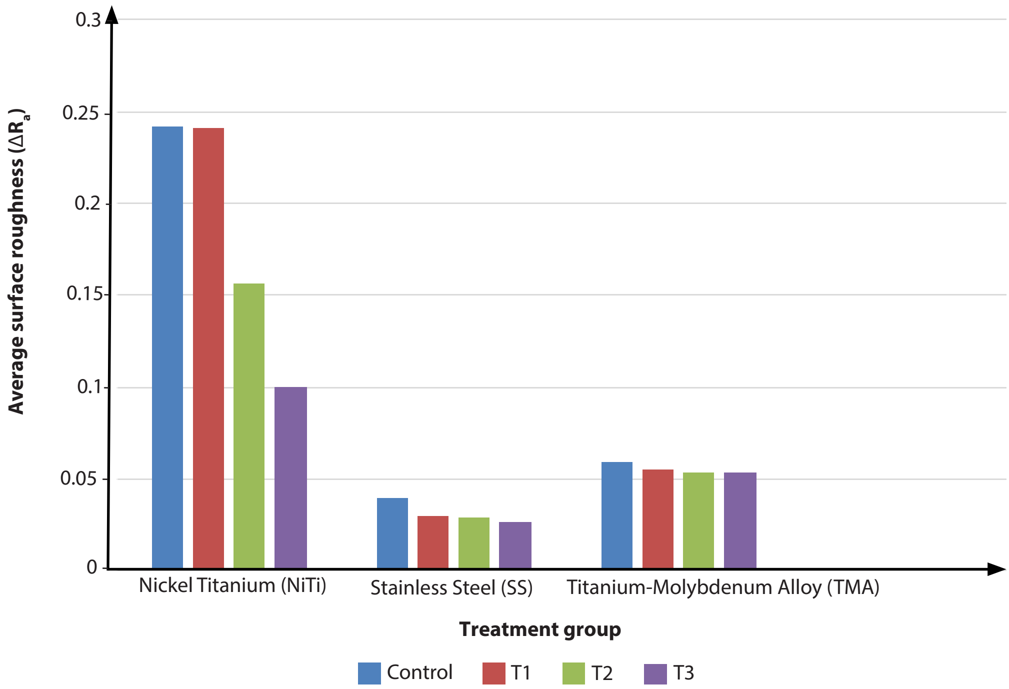


Figure 4. Diagram of surface roughness average (ΔR_a) orthodontic wires. Nickel Titanium (NiTi), Stainless Steel (SS), Titanium Molybdenum Alloy (TMA)

Table 1. Post hoc Least Significant Differences (LSD) test on the average surface roughness (ΔR_a) of NiTi wire

Groups	Control	T 1	T 2	T 3
Control		0.943	0.009*	0.000*
T 1			0.010*	0.000*
T 2				0.065
T 3				

Table 2. Post hoc Least Significant Differences (LSD) test on the average surface roughness (ΔR_a) of TMA wire

Groups	Control	T 1	T 2	T 3
Control		0.026*	0.001*	0.003*
T 1			0.076	0.271
T 2				0.447
T 3				

DISCUSSION

The corrosion process that occurs in orthodontic wires is strongly influenced by the wires components. The austenitic 18 - 8 stainless steel type is most commonly utilized in stainless steel wire, it contains chromium and nickel substance of around 18% and 8%, individually. The foremost important quality of 18 - 8 stainless steel is its high resistance to corrosion by the arrangement of a passivated oxide layer, which pieces assist oxygen dissemination to the fundamental mass (Castro *et al*., 2015).

Nickel is the most unstable ion, these ions are very easily released in a corrosive environment. Stainless steel wires contain a small amount of nickel, but they are designed to be rigid to achieve bodily tooth movement. Although nickel itself is flexible, the overall composition and high chromium content of stainless steel provide great corrosion resistance compared to other wires. Stainless steel differs from ordinary steel by its chrome content (Minami *et al*., 2015). Carbon steel will corrode when exposed to moist air. The iron oxide shaped is dynamic and will accelerate corrosion by the arrangement of more iron oxide (Anusavice *et al*., 2012). Stainless steel has an adequate percentage of chrome that will form a passive layer of chromium oxide that will prevent further corrosion. Stainless steel wire with 70% Fe content is relatively more stable compared to other wires, as shown in Figure 4 the least number of surface roughness average on stainless steel wire, and ANOVA test on stainless steel wire having no significant difference with p-value = 0.716.

NiTi wires exhibit greater elasticity and lower hysteresis, enabling longer constant force during deactivation which is beneficial to effective tooth movement. However, some studies mentioned, Niti wire has lower corrosion resistance (Mousavi *et al*., 2017; Rasyid *et al*., 2014) The ANOVA test for Niti wire showed that there were significant differences between control group and treatment group (T2 and T3), but between control group and treatment (T1) show no significant differences.

The highest content in TMA wire is titanium ion which is a transition metal having the characteristics of being light, strong, shiny, and corrosion-resistant. Titanium is one of the intermittent table's chemical components with the symbol Ti atomic number 22. The important properties of titanium as the premise for the utilize of titanium are corrosion resistance and the most elevated strength-to-density proportion among all metals (Leni *et al*., 2019). This explains the difference in concentration effectiveness in this study. Table 2 shows that a concentration of 1.5 g/L is effective in decreasing surface roughness on the TMA wire to resist corrosion TMA orthodontic wires rely on a protective layer (passive layer) of titanium dioxide (TiO_2) which is very stable and has a passivating effect on the metal. In any case, even though this protective layer (inactive layer) is display on the metal surface, metal ions can still be released. The passive layer of titanium dioxide (TiO_2) is not only susceptible to mechanical and chemical disturbances, but it can also degrade when the metal is exposed to oxygen in corrosive environments (Castro *et al*.., 2015).

Ion release, an early sign of corrosion, can increase surface roughness. The addition of avocado seed extract containing compounds to the treatment group was proven to reduce the corrosion process, including tannins, alkaloids, and flavonoids. These natural compounds consist of polar groups containing molecules (N, S, and O), electronegative groups, and conjugated twofold bonds as the most adsorption center of corrosion inhibitors (Nardeli *et al*., 2019).

Tannin molecules have a few hydroxyl and carbonyl groups on the fragrant ring containing oxygen molecules that can give their solitary sets of electrons to form chelates with metal cations. Hydroxyl and carbonyl groups act as electron givers on the metal surface that ties to inhibitor molecules, causing an increase in electron density. The increase in electron density causes corrosion restraint (Hasyim *et al*., 2016; Proença *et al*., 2022) clarified that the capacity of tannins to inhibit corrosion comes from the response of polyphenol subunits in tannin molecules with metal ions that shape a cross-linked organize, specifically metallic-tannates can be seen in Figure 5. This compound will act as a boundary to water for coordinate contact with metal so that it capacities as a inactive layer. When utilized within the oral cavity, orthodontic wires will come into contact with saliva. Saliva consists of approximately 98% water and 2% organic and inorganic substances (Zhang *et al*., 2022) the passive layer formed by tannin will protect the orthodontic wire from contact with saliva so that the corrosion rate can decrease.

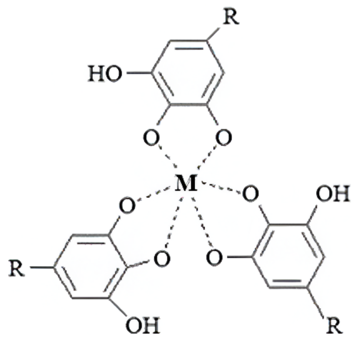


Figure 5. Metallic-tannate complex compound (Source: Proença *et al*., 2022)

Tannins can also inhibit corrosion through an adsorption mechanism. On the metal surface, tannins will bind physically and chemisorption. The surface of the orthodontic wire in the oral environment will always be adsorbed by water molecules. Physical adsorption of inhibitors works by replacing these water molecules so that the wire surface is protected. Meanwhile, the chemisorption interaction between tannins and metal surfaces takes place more slowly and is very dependent on temperature, in which corrosion inhibition will be higher at high temperatures. This interaction can happen due to the nearness of polar utilitarian groups in tannins (Proença *et al*., 2022; Saputri *et al*., 2015). Tannin adsorption is influenced by a number of factors such as concentration, surface area, and contact time (Mardiah *et al*., 2018). The higher the concentration of inhibitor the more inhibitor molecules that will get adsorbed on the metal surface coming about within the arrangement of more layers that block the dynamic surface locales on the metal surface and a more tightly complex bond (Taqwa *et al*., 2021).

Previous research demonstrated that, avocado seed extract at a concentration of 2.5 g/L has the greatest inhibition efficiency in reducing the corrosion rate of steel immersed in HCL acid solution (Rais and Wahyuningtyas, 2021). Meanwhile, data analysis in this study showed that the NiTi and TMA orthodontic wires sample group treated with 2 g/L extract concentration inhibitor (T2) with 2.5 g/L extract concentration (T3) had no significant difference in corrosion rate. Table 1 and 2 concluded that the amount of avocado seed extract concentration of 2 g/L is sufficient to be used as a corrosion rate inhibitor for orthodontic wires. This is because the manufacturing process and chemical composition between steel and orthodontic wire are different. The orthodontic wire is applied to humans so that it goes through an accurate production stage and is good in terms of shape, strength, and biocompatibility (Furlan *et al*., 2018).

CONCLUSION

The characteristics and corrosion resistance of orthodontic wires are greatly influenced by their elemental composition. The research showed that stainless steel wire is the most corrosion-resistant. A concentration of 1.5 g/L avocado seed extract was effective to reduce corrosion in TMA wires whereas a higher concentration of 2 g/L was necessary for NITI wires.

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