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THE EFFICACY OF GREEN TEA (Camellia sinensis) LEAVES EXTRACT AS CORROSION INHIBITOR FOR ORTHODONTICS STAINLESS-STEEL WIRE

(Research report)

Neny Roeswahjuni[1], Delvi Fitriani[2], Annisa Dwi Wardanianti[3]
[1]Department of Orthodontics, Faculty of Dentistry, Brawijaya University
[2]Department of Dental Material,Faculty of Dentistry, Brawijaya University
[3]Faculty of Dentistry, Brawijaya University

ABSTRACT
***Background**: Stainless-steel orthodontic wire is one of appliance component frequently used in orthodontics treatment and persisted in oral cavity for an extended period, thus may generate corrosion via ion release. An attempt to reduce corrosion rate is by using organic inhibitor which contains antioxidant. This substance can be simply found in green tea leaves. **Objective**: To discover the efficacy of green tea leaves as a corrosion inhibitor for stainless-steel orthodontic wire. **Methods**: It is an experimental laboratory research with post-test only control group design. As many as 24 samples were divided into 4 groups which immersed in artificial saliva: one group without any treatment and 3 groups given green tea leaves extract, each in 6.25%, 12.5% and 25% concentration. Corrosion rate was measured using potentiodynamic methods (Tafel). Data was analyzed using one way ANOVA test followed by post-hoc tukey HSD test. **Result**: There was significant difference in corrosion inhibitory efficacy among treatment groups (p<0.05). The highest corrosion rate value was found in no-treatment group (average value 0.195). The highest corrosion rate reduction was found in treatment group number four supplemented with 25% concentration of green tea leaves extract as inhibitory substance (p=0.0325). **Conclusion**: Green tea leaves extract is proven to be effective as corrosion inhibitor for stainless-steel orthodontic wire.*

***Keyword**: Corrosion inhibitor, green tea, potentiodynamic, stainless-steel orthodontic wire,*

Correspondence: Neny Roeswahjuni, Departemen Ortodonsia, Faculty of Dentistry, Universitas Brawijaya, Jl. Veteran, Malang, Jawa Timur, email: nenyroes@yahoo.co.id

INTRODUCTION

Orthodontics treatment to correct malocclusion has been popularly conducted as the awareness of dental and oral health maintenance has been increase. Wire is an important component in orthodontic appliance. One of wire frequently used in orthodontic appliance is stainless steel type. Stainless steel wire is commonly used because of its properties such as good elastic modulus, low average brittleness, corrosion durability and low price.[1] In spite of the fact that stainless steel is believed to be resistant upon corrosion, several study claimed that corrosion may persist. This is caused by stainless steel wire which persistently immersed in saliva. In oral environment, orthodontic wire will gradually experience corrosion or alloy-composed metal element release.[2,3] This can be affected by temperature change, micro flora, enzyme and saliva acidity (pH).[3] Released element can provide biological effect such as allergic reaction, carcinogenic, mutagenic and cytotoxic effect.

Corrosion, or particularly known as rusting, is a destructive process which occurs in almost metal types. Corroding process of a metal was generated by the interaction between metal surfaces with external environment which contains water and oxygen. This will induce the dissolve of lower reduction potential elements than other potential elements composing structure found in metal combination. The longer orthodontic wire contacts with electrolyte liquid, the higher the rate of metal ion release.[6]

The incidence of corrosion cannot be hindered, but corrosion rate can be diminished. Reducing corrosion rate can be conducted by catodic protection, anodic protection, coating and inhibitor addition. Corrosion inhibitor addition using particular substance acts to lessen metal corrosion rate.[7,8]

Corrosion inhibitors are categorized into organic and inorganic inhibitor (green inhibitor). Anorganic inhibitor such as arcenic, chromat, silicate, and phosphate are an exorbitant dangerous chemical substance which is not eco-friendly thus presenting bad effect in its direct interaction with the body. Currently, organic substances are developed to be used as a safe and biocompatible inhibitor material for the body.[9,10]

Previously studied organic inhibitor is proven to contain antioxidant compounds. Antioxidant contents such as polyphenol, tannin, alkaloid, saponin, astringent oil, and amino acid possess abundant N (nitrogen), O (oxygen), P (phosphor) and S (sulphur) element. These elements form a complex compound which hardly dissolved by metal ion, enable them to inhibit orthodontic wire corrosion.[11] One of natural substances which contain antioxidant and likely potential as corrosion green inhibitor substance is green tea (*Camellia sinensis*).[12]

MATERIAL AND METHODS

This is a laboratory experimental study with post test only control group design, comprised of 24 samples of 0.7 mm diameter stainless steel orthodontic wire immersed in artificial saliva. These samples were divided into 4 treatment groups. Group 1: given no corrosion inhibitor, Group 2: given 6.25% concentration of green tea leaves extract as inhibitor, Group 3: given 12.5% concentration of green tea leaves extract as inhibitor, Group 4: given 25% concentration of green tea leaves extract as inhibitor.

Determination of Green Tea Plant

Before the process of green tea leaves extract, determination test was conducted to ensure that the sample is green tea plant leaves. Test was preceded at Technical Conducting Unit, Materia Medica Batu, Dinas Kesehatan Provinsi Jawa Timur.

The Making of Green Tea Leaves Extract

Green tea leaves extract was fabricated at Laboratorium Analisa Instrumental, Chemical Engineering Technic Faculty, Politeknik Negeri Malang. Green tea extract was generated from dry green tea leaves preparate using maceration method which dissolved with 70% ethanol solvent to obtain 100% concentration of green tea leaves extract. Followed by its dilution with sterile aquadest, 6.25%, 12.5% and 25% concentration of green tea leaves extract were susbequently obtained.

Testing Solution

Testing solution using artificial saliva from McDougall in buffer pH (6.75 +- 0.15) in 58,80g $NaHCO_3$; 48g $Na_2HPO_4.7H_2O$; 3,42g KCl; 2,82g NaCl; 0,72g $MgSO_4.7H_2O$; 0,24 g $CaCl_2$ composition.

Sample Preparation

Stainless steel orthodontics wire 0.7 mm diameter was cut into 40 mm length and given an isolator in the form of fuel sleeve of 20 mm length put in the center of wire.

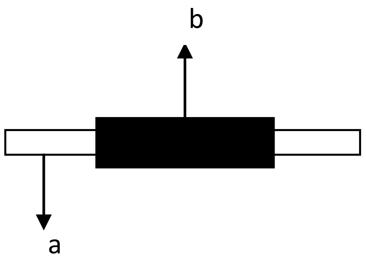

Figure 1. Sample preparation (a. Stainless steel wire, b. Isolator)

Potentiodynamic Test

Potentiodynamic test was conducted at Analytical Science and Instrument Laboratorium, Science and Mathematics Faculty, Institut Teknologi

Sepuluh November Surabaya. Potentiodynamic test was done by measuring stainless steel corrosion rate immersed in artificial saliva using Metrohm Autolab potentiostat PGSTAT302N tool connected with Nova 1.11 software for potentiodynamic (Tafel) method. Potentiostat tool possessed three electrodes comprised of working electrode (stainless steel wire), additional electrode (platina) and comparison electrode (SCE). Measurement was obtained in -500 mV to+500 mV potential range and scanning rate was 0,5 mV/s.

Figure 2. A set of corrosion rate testing tools (a. testing tube, b. monitor, c. potentiostat)

Prior to the measurement, wire was previously prepared by cleaning it with acetone. The end of wire which uncovered by fuel sleeve was connected with working electrode and the other end was immersed in testing solution for 30 minutes. The value of immersed surface area was input into connected software with potentiostat tool. Sample surface area in this study is wire surface area uncovered by fuel sleeve.

The wire then connected into potentiostat tool and immersed for 30 minutes in testing solution with or without inhibitor substance before software was processed. The tool was then generated with NOVA software until Tafel graphic on the monitor was terminated. Testing was conducted one by one for each sample.

Potentiodynamic was acquired in the form of a curve between the potential as x axis and log function from current density as y axis. This curve was extrapolarized by Tafel to produce corrosion rate density data (I_{corr}), the data was later calculated to obtain corrosion rate data (mpy) with following formula:

$$CR = K\, I_{corr} \frac{Ew}{\rho}$$

where CR is for corrosion rate (mpy), K is constant (0.129 for mpy and 0.00327 for mmpy). I_{corr} is corrosion rate, Ew is equivalent weight (gr), ρ as density (gr/cm3).

The Calculation of Inhibitory Effect

Inhibitory efficacy can be obtained by calculating the percentage of metal corrosion rate reduction which compared the corrosion rate when given inhibitory substance and those without any.

Inhibitor efficacy can be calculated in this following equation:

$$(IE\%) = \frac{X_a - X_b}{X_a} \times 100\%$$

where X_a is the average corrosion rate without given any inhibitor and X_b is the average corrosion rate by adding inhibitory substance.[13]

RESULT

The result of corrosion rate value in stainless-steel orthodontic wire in artificial saliva with or without inhibitory substance using potentiodynamic (Tafel) method is demonstrated in Table 1.

Table 1. The result of corrosion rate measurement

Repetition	Corrosion Rate value (mpy)			
	Group 1	Group 2	Group 3	Group 4
1	0,193	0,100	0,061	0,035
2	0,202	0,094	0,048	0,038
3	0,186	0,095	0,052	0,029
4	0,198	0,076	0,042	0,032
5	0,209	0,082	0,064	0,035
6	0,183	0,090	0,056	0,026
Total N	1.17	0,537	0,323	0,195
Mean	0,195	0,0895	0,0538	0,0325

After discovering the result of corrosion rate value, corrosion inhibitory efficacy score was calculated as it can be observed in table 2.

Table 2. Corrosion inhibitory efficacy result

Group	Average Corrosion Rate (mpy)	Inhibitor Activity (%)
1	0,195	Uncountable
2	0,0895	54,10
3	0,0538	72,41
4	0,0325	83,33

Data normality test was examined using Shapiro-Wilk method. It is confirmed that data was normally distributed with significance value α=0.573 ($\alpha > 0.05$) in all groups. Followed by Levene statistic test for data homogeinity test, data was confirmed to be homogeny with significance value $\alpha = 0.300$ ($\alpha > 0.05$). Statistic analysis was preceded using oneway ANOVA. It was discovered that there was significant difference in each treatment group with significant p value = 0.000 ($p < 0.05$). It can be interpreted that there was significant difference in the corrosion rate between sample given no corrosion inhibitory substance and those given corrosion inhibitory material such as 6.25%, 12.5% and 25% green tea leaves extract. The next step was to analyze data using Post Hoc Tukey HSD to obtain which group illustrated the most significant difference in reducing corrosion rate on stainless-steel orthodontic wire.

DISCUSSION

In its application inside oral environment, stainless steel wire can experience corrosion process. This process can induce metal ion release which composing the wire, especially Nickel (N) and Chromium (Cr) metal ion.[14] The release of Ni and Cr metal ion can affect biological aspect of oral mucosa such as contact dermatitis, hypersensitivity and citotoxicity.[15]

This study used artificial saliva as testing solution in the resemblance of orthodontic wire immersion and direct contact with saliva in oral environment. Saliva contains inorganic components such as (N+, K+, Cl- and HCO3-) which act as electrolyte media to induce electrochemical reaction. Electrochemical reaction is an existing reaction in metal ion as anode and hydrogen ion of electrolyte media as catode which eventually induce the release of Cr and Ni in stainless steel orthodontic wire as a sign of corrosion process.

The result of this study depicts the value of average corrosion rate in group 1 which is higher than other group given inhibitory substance from green tea extract (Figure 3).

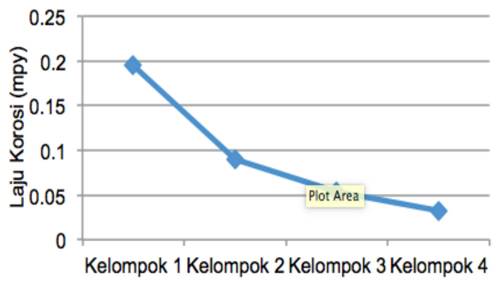

Figure 3. Graphic of average corrosion rate (mpy) based on potentiodynamic method testing in each treatment group.

Corrosion rate reduction in groups given inhibitory substance is caused by active compound presented in green tea leaves extract such as tannin, saponin, alkaloid and flavonoid. The compounds contain C-O, O-H, and C-C group which act as antioxidant, enable them to bind free electrons on metal surface.[9,12] These complex compounds will inhibit corroding ions from the external environment to bind with the metal surface.[10]

Inhibitory efficacy value is inversely proportional to the value of corrosion rate. Therefore, if lower inhibitory efficacy value obtained, the inhibitory effect will tend to be higher. Efficacy of green tea leaves extract in this study is 54.10% by utilizing 6.25% green tea leaves extract as inhibitory compound, 72.41% in 12.5% green tea leaves extract group and 83.33% in 25% green tea leaves extract groups. Higher inhibitory concentration will contribute in the increase of metal part covered by active compounds as inhibitory substance and will be more effective in the formation of passive layer on metal surface. This layer acts as corrosion rate control by separating metal from external environment without reacting or releasing aggressive ion in respective situation. When the wider layer is formed, this will reduce corrosion rate and increase inhibitory efficacy.[7,8]

Inhibitory process of corrosion inhibitor occurs reversibly. Minimal concentration of corrosion inhibitor should always be exist in metal environment in order to constantly maintain protecting layer on metal surface.[8]

Although various alloy combination used in orthodontic treatment are produced with acceptable corrosion durability property, but the possibility to experience several local corrosion caused by oral cavity condition is still exist. Corrosion process induces ion release of metal combination used in its fabrication. In several studies, the process of ion release in oral cavity can generate biological effects such as contact dermatitis, hypersensitivity and citotoxicity.[15]

More endangering effects from metal ion release in oral environment is DNA damage (genotoxicity) in human cell. Genotoxicity effect from metal combination may be developed from DNA oxidation (direct interaction) or DNA replication disturbance (indirect interaction).[16,17] Based on previous study in children using fix orthodontic appliance, it is obtained that released metal ion from orthodontic device with stainless steel material and free nickel alloy combination can enhance DNA damage in oral mucosal cells.[18]

In the past 10 years, there are various literatures discussed about allergic reaction from metal ion release in orthodontics patient which investigated using diverse methods. Most of them concluded that the number of metal ion released from orthodontic appliance in blood and saliva are detected significantly under food intake average and not preserved in toxic concentration. However, previous study mentions that this non-toxicity still may affect cell biological aspect of oral mucosa.[18,19]

All orthodontists should be advised to use stainless-steel metal with optimal corrosion resistance level so that it can minimized the number of metal ion affecting general health. Addition of corrosion inhibitor can also be an alternative in reducing the corrosion rate of orthodontics material. This study demonstrates that the higher green tea leaves extract concentration, the lower corrosion rate occurs in stainless-steel wire. Thus, it is effective as corrosion inhibitory material. It can be concluded that green tea leaves extract is effective as corrosion inhibitor for stainless-steel orthodontic wire.

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