Effect of fluoride mouthwash on tensile strength of stainless steel orthodontic archwires

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Abstract. Patients with orthodontic treatment are commonly recommended to use a fluoride mouthwash for maintaining their oral hygiene and preventing dental caries. However, fluoride may affect the characteristics of stainless steel orthodontic archwires used during treatment. The effect of fluoride mouthwash on the tensile strength of stainless steel orthodontic archwires is still unknown. The purpose of this study is to know the effect of fluoride mouthwash on the tensile strength of stainless steel orthodontic archwires. Examine the tensile strength of 0.016 inch stainless steel orthodontic archwires after immersion in 0.05%, 100 ml fluoride mouthwash for 30, 60, and 90 min. There is no statistically significant difference in the tensile strength of stainless steel orthodontic archwires after immersed in fluoride mouthwash. The p-values on immersion fluoride mouthwash for 30, 60, and 90 min consecutively are 0.790; 0.742; and 0.085 (p > 0.05). The use of fluoride mouthwash did not have an effect on the tensile strength of stainless steel orthodontic archwires.

1. Introduction
Malocclusion is one of the most common oral health problems in Indonesia, following dental caries and periodontal disease. The prevalence of malocclusion reached 83.3% among 12–14 year old junior high school students in Jakarta [1]. Malocclusion can be corrected with orthodontics treatment by using removable or fixed appliances. One component of the appliances is orthodontic archwires [2]. Stainless steel has been widely used as orthodontic wires [3,4]. Other orthodontics wire materials are nickel titanium and beta titanium [5]. The advantages of stainless steel orthodontic archwires are its high strength and elasticity modulus, good biocompatibility, and good resistance to corrosion within the oral environment [3,5,6]. These characteristics are needed to ensure the efficiency of orthodontics treatment and to reduce the amount of wire replacement during treatment [7,8]. The disadvantages are that the wire could be fractured within the oral cavity during treatment. The low pH of the oral environment can cause wire corrosion that leads to the decrease in the mechanical force transmitted from the wire to the tooth, as well as wire fracture [8,9]. Orthodontic wire corrosion is believed to be related to fluoride ions in the oral environment [6,8]. Orthodontic patients are recommended using mouthwash containing 0.05% concentration of fluoride daily or 0.2% weekly for maintaining oral health and preventing dental caries during orthodontic treatment [8,10].

Heravi F. et al., stated that fluoride can reduce stainless steel orthodontics wire resistance to corrosion. If fluoride concentration increases, the resistance to corrosion of stainless steel orthodontic archwires will reduce. This is related to the destructive effect of fluoride on the wire’s oxide protective layer. Heravi carried out an investigation by immersing stainless steel orthodontic wire within fluoride solution for 24 h [8]. Srivastava et al. carried out the same experiment for 1.5 h. The results showed
that fluoride did not have significant effect on the mechanical properties of the orthodontics archwires [10]. It encouraged an investigation on the effect of using fluoride mouthwash for different durations of time on other mechanical properties of stainless steel orthodontic archwires, such as the tensile strength. The tensile strength of stainless steel orthodontic archwires after being immersed in fluoride mouthwash for 30, 60, and 90 min is still unknown. The general aim of this study was to evaluate the effect of fluoride mouthwash for different durations of time on the tensile strength of stainless steel orthodontic archwires and to analyze the difference in the tensile strengths. The specific aim of this study was to analyze the difference in the stainless steel orthodontic tensile strength after being immersed in fluoride mouthwash and artificial saliva.

2. Materials and Methods

This study carried out a laboratory-scale experimental (in vitro) simple analysis. The aim of this study is to test the tensile strength of stainless steel orthodontic archwires after being immersed in a fluoride mouthwash and artificial saliva. The material used is Oral-B® Pro-Health mouthwash with 0.05% sodium fluoride, artificial saliva with pH 7, and ortho organizer stainless steel orthodontic archwires with 0.016 inch diameter and 20 cm length. Stainless steel orthodontic archwires were divided into six groups of treatment. Group A was immersed in 100 ml fluoride mouthwash and stored in an incubator at 37 °C for 30 min. Group B was immersed in 100 ml fluoride mouthwash and stored in an incubator at 37 °C for 60 min. Group C was immersed in 100 ml fluoride mouthwash and stored in an incubator at 37 °C for 90 min. Group D was immersed in 100 ml artificial saliva and stored in an incubator at 37 °C for 30 min. Group E was immersed in 100 ml artificial saliva and stored in an incubator at 37 °C for 60 min. Group F was immersed in 100 ml artificial saliva and stored in an incubator at 37 °C for 90 min. There were five archwires in each treatment group. There were 6 treatment groups, so the total number of samples was 60 archwires.

After being immersed and dried, each treatment group was tested to evaluate the tensile strength using a universal testing machine (UTM) Shimadzu AGS-X operated with a 0.5 mm/s crosshead speed. The tensile strength of the stainless steel orthodontic archwires from the test was then used in the univariate analysis to obtain mean value and standard of deviation in each treatment group. The independent t-test bivariate analysis was carried out to evaluate the tensile strength differences of stainless steel orthodontic archwires after being immersed in fluoride mouthwash and artificial saliva for 30, 60, and 90 min. One-way ANOVA multivariate analysis was used to evaluate the tensile strength mean value differences on the stainless steel orthodontic archwires after being immersed in fluoride mouthwash for 30, 60, and 90 min.

3. Results and Discussion

3.1 Results

The tensile strength test of stainless steel orthodontic archwires in each group showed values ranging between 1808.69 and 1893.38 MPa with 14.66–23.04 standard deviation. The lowest tensile strength

| Group                   | Tensile Strength |
|-------------------------|------------------|
| A=Group immersed in fluoride mouthwash for 30 min | 1882.58 | 31.68 |
| B=Group immersed in fluoride mouthwash for 60 min | 1871.45 | 39.90 |
| C=Group immersed in fluoride mouthwash for 90 min | **1808.69** | **14.66** |
| D=Group immersed in artificial saliva for 30 min | **1893.38** | **23.04** |
| E=Group immersed in artificial saliva for 60 min | 1889.32 | 33.97 |
| F=Group immersed in artificial saliva for 90 min | 1841.83 | 8.273 |
mean value was found in Group C, which was immersed in fluoride mouthwash for 90 min. Meanwhile, the highest tensile strength mean value was found in Group D, which was immersed in artificial saliva for 30 min (Table 1).

The difference in the tensile strength mean values for stainless steel orthodontic archwires immersed in fluoride mouthwash for 30 min (1882.58 MPa) and artificial saliva for 30 min (1893.38 MPa) was 10.8 MPa. A significance test between those groups showed p-value of 0.790, which means that the difference in the tensile strength was not statistically significant (p > 0.05) (Table 2).

| Table 2. Tensile strength difference in stainless steel orthodontic archwires after immersion in fluoride mouthwash and artificial saliva for 30 min |
|--------------------------------------------------|
| Tensile Strength (MPa) Mean (SD) | p-value |
|-----------------------------|---------|
| Group A                    | 1882.58 (70.85) | 0.790 |
| Group D                    | 1893.38 (51.53) |

The difference in the tensile strength mean values of stainless steel orthodontic archwires after immersion in fluoride mouthwash for 60 min (1871.45 MPa) and artificial saliva for 60 min (1889.32 MPa) was 17.87 MPa. The significance test between those groups showed a p-value of 0.742, which means that the difference in the tensile strength was not statistically significant (p-value > 0.05) (Table 3).

| Table 3. Tensile strength difference in the stainless Steel orthodontic archwires after immersion in fluoride mouthwash and artificial saliva for 60 min |
|--------------------------------------------------|
| Tensile Strength (MPa) Mean (SD) | p-value |
|-----------------------------|---------|
| Group B                    | 1871.45 (89.24) | 0.742 |
| Group E                    | 1889.32 (75.97) |

The difference in tensile strength mean value of stainless steel orthodontic archwires after immersion in fluoride mouthwash for 90 min (1808.69 MPa) and artificial saliva for 90 min (1841.83 MPa) was 33.14 MPa. The significance test between those groups showed p-value of 0.082, which means that the difference in the tensile strength was not statistically significant (p-value > 0.05). (Table 4)

| Table 4. Tensile strength difference of stainless steel orthodontic archwires after immersion in fluoride mouthwash and artificial saliva for 90 min |
|--------------------------------------------------|
| Tensile Strength (MPa) Mean (SD) | p-value |
|-----------------------------|---------|
| Group C                    | 1808.69 (32.79) | 0.082 |
| Group F                    | 1841.83 (18.49) |

The difference in the tensile strength value of stainless steel orthodontic archwires after immersion in fluoride mouthwash for 30 min (1882.58 MPa) and 60 min (1871.45 MPa) was 11.33 MPa. The difference in the tensile strength value of stainless steel orthodontic archwires after immersion in fluoride mouthwash for 30 min (1882.58 MPa) and 90 min (1808.69 MPa) was 73.89 MPa. The difference in the tensile strength value of stainless steel orthodontic archwires after immersion in fluoride mouthwash for 60 min (1871.45 MPa) and 90 min (1808.69 MPa) was 62.76 MPa. The significance test between those three groups showed p-value of 0.225, which means that the difference in the tensile strength was not statistically significant (p-value > 0.05) (Table 5).
Table 5. Tensile strength difference in the stainless steel orthodontic archwires after immersion in fluoride mouthwash for 30, 60, and 90 min

|       | Tensile Strength (MPa) Mean (SD) | p-value |
|-------|----------------------------------|---------|
| Group A | 1882.58 (70.85)                  | 0.225   |
| Group B | 1871.45 (89.24)                  |         |
| Group C | 1808.69 (32.79)                  |         |

3.2 Discussion
Patients with orthodontic treatment are commonly recommended to use fluoride mouthwash for maintaining oral hygiene and preventing dental caries during treatment. The aim of this study was to evaluate the effect of fluoride on the mechanical characteristics of stainless steel orthodontic archwires, especially the tensile strength. This study used 30 ortho organizers stainless steel orthodontic archwires with 0.016 inch diameter and 20 cm length. A previous study performed by Silvia–Izabella (2013) stated that most clinicians used stainless steel orthodontics archwires with 0.016 inch diameter. Those archwires were divided into 6 groups depending on the immersion duration, which were 30, 60, and 90 min. Ninety minutes of immersion was selected according to Srivastava et al (2012), who selected this duration to accumulate mouthwash rinsing for one minute each day (30 s twice a day) for 3 months. The immersion time was varied for 30 and 60 min in this study, which represented accumulation of mouthwash after rinsing for 10 and 20 s each day for 3 months. Three months represented the duration for which the stainless steel orthodontic archwires were placed in oral cavity before it was to be replaced with the new archwires. The fluoride mouthwash used in this study is based on recommendation to orthodontic patient to use Fluoride containing mouthwash with 0.05% concentration everyday [6,10]. The tensile strength of stainless steel orthodontic archwires in each group was tested using a universal testing machine (UTM) Shimadzu AGS-X with 5kN load cell and operated using 0.5 mm/second crosshead-speed. This is a computerized and high-accuracy testing tool and easy to run. From the test, the stress–strain curve diagram and tensile strength value of stainless steel orthodontic archwires were obtained. The result data were analyzed afterwards using independent t-test and one-way ANOVA parametric tests.

The tensile strength of the metal material is the ability of the metal material, which in this study is stainless steel orthodontic archwires, to withstand pulling (tensile) loads. Tensile strength of stainless steel orthodontic archwires determines the maximum force that can be distributed by archwires when used as spring to move the teeth. The greater the tensile strength of the archwires, the better is the mechanical properties of the archwires [5]. The test showed tensile strength of archwires immersed in fluoride mouthwash for 30, 60, and 90 min is lower than that of the archwires immersed in artificial saliva. Corrosion of stainless steel orthodontic archwires was suspected to be caused by fluoride mouthwash exposure, so that the nickel and chromium ions embedded on the archwires were lost. This was explained by Minaga MA (2016) and Heravi et al. (2015) on previous studies. It was stated that fluoride contained in mouthwash caused the loss of nickel and chromium ions on orthodontic appliance made by stainless steel and also reduced the resistance of the stainless steel orthodontic archwires to corrosion. It has been known that chromium is a metal element that gives the property of resistance to corrosion by creating a chromium-oxide protective layer (Cr2O3). The presence of fluoride ions and hydrogen inside the oral cavity can form hydrofluoric acid (HF) that can break the protective layer according to the equation: Cr2O3 + 6 HF → 2CrF3 + 3 H2O. In an active state and acid environment, nickel can reduce the corrosion rate and increase the strength of the stainless steel orthodontic archwires. The release of those ions can cause corrosion and lead to reduction in the tensile strength of stainless steel orthodontic archwires [6,8,10].

The change in the tensile strength of stainless steel orthodontic archwires after immersion in fluoride mouthwash for 30, 60, and 90 min showed a pattern. The longer the exposure duration of stainless steel orthodontic archwires to fluoride mouthwash, the lower the tensile strength is [11,12].
However, the difference in the tensile strength is not statistically significant. Fluoride mouthwash rinsing in this study did not affect the mechanical properties of the stainless steel orthodontic archwires, especially the tensile strength. The need for publication on the effect of fluoride mouthwash on the tensile strength of stainless steel orthodontic archwires for dental practitioners and the dental society is suggested. Further research can also be carried out using other variables that affect the tensile strength of stainless steel orthodontic archwires.

4. Conclusion
This study showed that there was a difference in the tensile strength of stainless steel orthodontic archwires after exposure to fluoride mouthwash for 30, 60, and 90 min. There was also a decrease in the tensile strength of the stainless steel orthodontic archwires along with an increase in the immersion duration. However, the difference in the tensile strength is not statistically significant, so it can be concluded that fluoride mouthwash rinsing does not affect the tensile strength of stainless steel orthodontic archwires.

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