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Review Article on Effect of Mouthwashes on Corrosion Behavior and Surface Topography of Stainless Steel Orthodontic Archwires

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ABSTRACT

Clinical progress and outcome may be impacted by changes in the mechanical characteristics of the materials used in orthodontic appliances, which could also have an impact on the appliances' operational characteristics. This paper aims to investigate the effect of sodium fluoride and chlorhexidine mouthwashes on corrosion and surface topography of stainless steel (SS) archwires. In this paper, three groups were created from the orthodontic archwires collected from patients who were chosen for inclusion: the control group, which consisted of patients who maintained good oral hygiene; the fluoride group, which consisted of patients who used fluoride for intensive prophylaxis; and the chlorhexidine group, which consisted of patients who used chlorhexidine. Scanning Electron Microscope (SEM) was used to evaluate representative samples, and after that, high-resolution SEM pictures were analyzed with Image J software to ascertain surface roughness and gather data for additional statistical analysis. A significant difference was found between the control and the two other groups and a non-significant difference between the sodium fluoride (NaF) and chlorhexidine (CHX) groups. As a result, mouthwashes containing sodium fluoride demonstrated more significant surface alterations than the control and CHX groups.

KEYWORDS: Mouthwash, NaF, CHX, Corrosion, SS, Scanning electron microscope.

1. INTRODUCTION

The hardest orthodontic preventive measure to avoid the often-associated gingival irritation and tooth structure damage is controlling dental biofilm. The simplest tip to prevent those negative effects is to maintain adequate oral hygiene [1]. Plaque buildup can arise from degradation of the tooth surface and the soft tissues surrounding it; this can be accelerated by orthodontic treatment. Thus, throughout orthodontic therapy, a number of preventive measures included the regular use of fluorides and antiseptics [2]. Mouthwashes that are antiseptic also have an antimicrobial effect because they reduce bacteria, gingivitis, plaque accumulation, and promote healing. On the other hand, mouthwashes with fluoride have a cariostatic effect. As is typically permitted in vitro, the application of fluorides and antiseptics caused some corrosion in dental metals [3].

The clinical impact of chlorhexidine and sodium fluoride on the corrosion behavior and surface topography of stainless steel orthodontic archwires has been widely investigated. According to research, chlorhexidine-containing mouthwashes can cause higher corrosion rates and surface roughness on orthodontic appliances than fluoride-containing mouthwashes. Studies have indicated that chlorhexidine mouthwash has a higher incidence of corrosion than fluoride-containing solutions, possibly because of its acidity [4, 5]. On the other hand, fluoride ions have been shown to corrode metal orthodontic appliances, with acidulated phosphate fluoride being more corrosive than fluoridated toothpaste. The concentration of fluoride ions and the acidity of the medium are directly related to the degree of corrosion. Fluoride can cause corrosion in stainless steel and titanium brackets, although cobalt-chromium brackets are resistant. More research is required to confirm these findings and determine the long-term clinical consequences of these impacts on orthodontic therapy [4,5].

Choosing the right biomechanics is crucial for successful orthodontic treatment. Changing the mechanical qualities of orthodontic materials may have an impact on the functioning properties of appliances, hence affecting treatment outcomes. Many studies revealed a relation between alloy corrosion and increased surface roughness, which directly affects the performance of orthodontic archwires [6]. For clinical applications, it was critical to more accurately predict the corrosion resistance of stainless steel (SS) orthodontic archwires and determine the relationship between surface characterization and corrosion resistance. So far, the majority of the research has been done in vitro and in vivo studies are expected to support those findings. It is critical to investigate the impact of employing antiseptics (various mouthwashes) and fluorides on the corrosion behavior and surface topography variations of stainless-steel orthodontic archwires [7]. The following are the main conclusions about how sodium fluoride and chlorhexidine affect orthodontic archwire corrosion, according to the search results provided:

A. Chlorhexidine Mouthwashes:

Compared to other mouthwashes, chlorhexidine mouthwashes have the potential to cause more corrosion and ion release (nickel & chromium) from stainless steel orthodontic brackets and archwires. Chlorhexidine's acidity and capacity to dissolve the protective oxide layer on metal surfaces are probably the causes of its corrosive action. However, other studies discovered that the frictional resistance and surface roughness of stainless steel brackets and archwires were not considerably impacted by a brief (1.5 hour) soaking in 0.2% chlorhexidine [4, 5, 8].

B. Sodium fluoride mouthwashes:

Orthodontic archwires made of nickel-titanium and stainless steel may become more prone to surface roughness and corrosion when mouthwashed with sodium fluoride. The concentration of fluoride ions and the medium's acidity are directly correlated with the degree of corrosion. The protective oxide layer on titanium-based archwires can be harmed by fluoride ions, which can result in increased corrosion and surface roughness. Archwire corrosion and surface properties are generally more negatively impacted by higher fluoride concentrations (>2,500 ppm) [5, 8, 9].

In conclusion, orthodontic archwires are susceptible to increased surface alterations and corrosion from mouthwashes containing high concentrations of sodium fluoride and chlorhexidine. This may have a detrimental effect on the materials' mechanical qualities and therapeutic efficacy.

2. METHODS

To conduct this narrative review on methods to enhance bond durability, a search strategy was conducted in May 2024 across many electronic databases, including PubMed, Science Direct, Scopus and Google Scholar. Papers and articles were searched from 2000 to 2024 using MeSH term/keywords such as 'Mouthwash', 'NaF', 'CHX', 'SS' and 'Corrosion'. Only articles published in English were selected. Initially, 135 articles were selected based on their titles and abstracts. Only full-text articles were selected to conduct this review. After full text evaluation, removing duplicates, conducting a quality assessment of selected articles based on PRISMA checklist and application of the eligibility criteria, 30 articles were selected to conduct the review (Fig. 1).

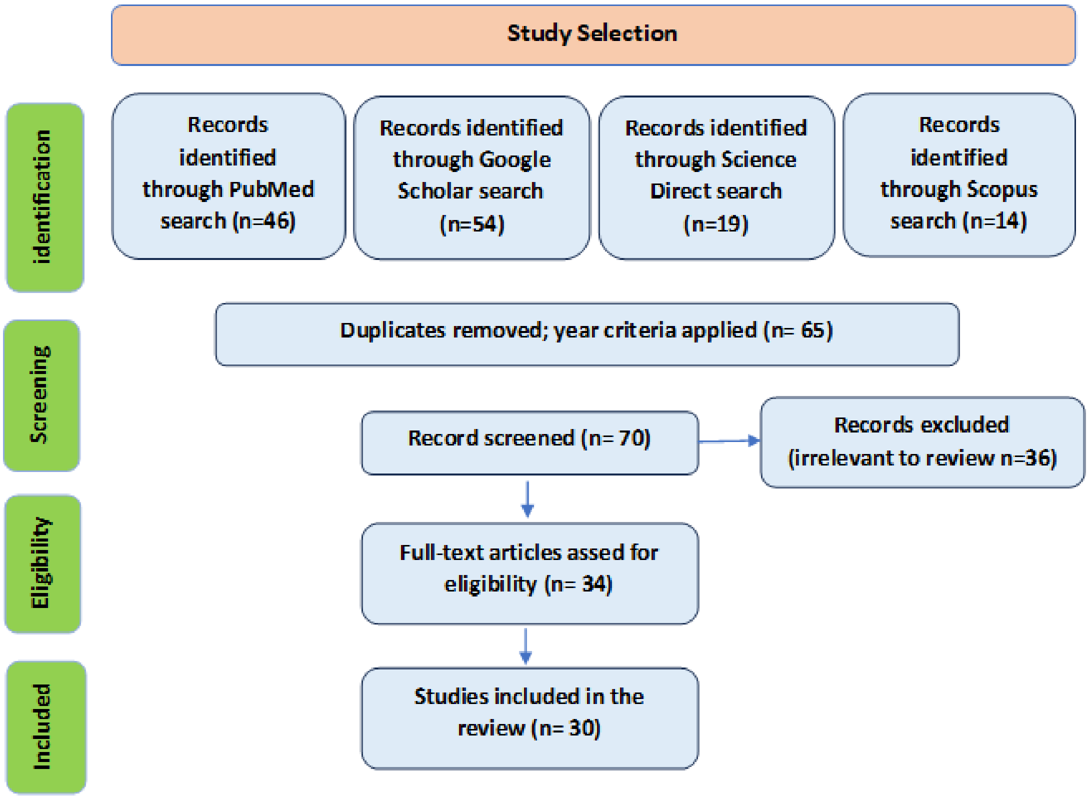

Fig. 1: Flowchart showing the articles selection process to conduct this review.

To organize and synthesize articles related to the narrative review topic of effect of mouthwashes on orthodontic Archwires, a search was conducted on orthodontic archwires that collected from patients who were receiving orthodontic treatment. The selected archwires were randomly allocated into three groups using http://www.randomization.com (10). The distributions of these groups will be as follows: Group 1: (control group) (saliva group) subjects who received regular oral hygiene. Group 2: (fluoride group) subjects who used fluoride for intensive prophylaxis. Group 3: (chlorhexidine group) subjects who used chlorhexidine.

2.1. Materials and Methodology

- Mouthwashes were manufactured with pure concentration, in a trial to eliminate the effect of other ingredients on corrosion behavior and make sure the results are accurate.
  - Chlorhexidine mouthwash, 0.12%,
  - Fluoride mouthwash, 0.2%
- Rectangular stainless-steel orthodontic archwires were used in the upper arch after 6 months of leveling and aligning.
- All patients were directed to brush their teeth with a toothbrush and toothpaste with a low concentration of fluoride. This protocol was commonly applied to patients in orthodontic therapy throughout the study period of one month. (Charter’s technique, three times daily for 2 minutes) [11].

3. OVERVIEW ABOUT RELATION OF MOUTHWASHES AND CORROSION ON ORTHODONTIC ARCHWIRES.

3.1. Factors Affecting Corrosion of Orthodontic Archwires

There were many factors affecting corrosion of orthodontic archwires, such as acidity, manufactural defects, temperature, electrolyte concentration and mouthwashes. It was approved as the following: Using linear sweep voltammetry and electrochemical impedance spectroscopy, the authors examined the electrochemical corrosion behavior of nickel titanium (NiTi) and stainless steel (SS) orthodontic archwires in Ringer's solution at temperatures ranging from 15 to 55 °C. Polarization curves showed that the corrosion current density of SS was greater than that of NiTi alloy. A high corrosion current density was indicative of a lower corrosion resistance since corrosion current density was proportionate to corrosion rate. NiTi alloys therefore corroded less quickly than SS alloys [12].

For orthodontic treatments, stainless steel and nickel titanium alloys were most frequently utilized. Despite the fact that both were known to be resistant to corrosion, certain conditions, such as specific kinds of corrosion attack, wear from the archwire sliding between brackets, and iatrogenic breakdowns, might lead to undesirable results. The effects of the environment on the tribocorrosion and corrosion properties of dental alloys made of stainless steel and NiTi were examined. The effects of pH and fluorides on electrochemical properties were examined using the cyclic potentiodynamic method. The migration of ions from the alloy into saliva was investigated using Inductively Coupled Plasma-Mass spectrometry (ICP-MS) studies both with and without wear. Auger spectroscopy was used to investigate the formation of a passive oxide layer on a number of dental metals [13].

The impact of immersion duration, pH, and wire type on the average corrosion rates of four orthodontic wires was examined. Four distinct kinds of orthodontic wires were utilized by them. a. ceramic (SS), b. regular stainless steel, and c. nickel titanium (NiTi) Artificial saliva was used to raise the pH of titanium-molybdenum alloy (TMA) to 2.5 and Australian stainless steel (Aus) to 6. Either the exam as received or following a ninety-day immersion period was used. To investigate corrosion, linear sweep voltammetry was utilized [14].

The impact on orthodontic nickel titanium archwire (NiTi) corrosion of enamel remineralization treatments with different fluoride concentrations was examined. They used nitrified surface NiTi (NNiTi) with diameters of 0.5080.508 mm, rhodium coated (RhNiTi), and uncoated NiTi (NiTi). Ten wire samples of each type were immersed for an hour at 37° in distilled deionized water without fluorides, Elmex, Mirafluor-k-gel, and MI Paste Plus fluoride-free fluoride agents. (dH2O). Measurements of the acidity of the tested solutions and the concentrations of hydrofluoric acid were made. Flexibility and resilience under load and unload were assessed using the three-point bend test [15].

The main factor contributing to the failure of many metallic orthodontic archwires has been determined to be corrosion. Corrosion can be caused by the direct loss of metal ions into the solution or by the gradual deterioration of the oxide layer that protects the surface. The term "redox reaction" refers to the simultaneous oxidation and reduction process that occurs. Orthodontic archwires with varying physical and chemical properties have become common because of advancements in metallurgy. Orthodontic archwires are susceptible to both chemical and physical degradation in the mouth cavity, which together deteriorates their physical characteristics and raises the risk of failure. These chemical reactions are corrosive. The review article's objectives are to comprehend temperature fluctuations, the deterioration of orthodontic wires under normal oral conditions, and, finally, the use of mouthwash or dentifrices as remedies [16].

3.2. Role of Mouthwashes in Corrosion of Orthodontics Wires.

When three mouthwash solutions were added to various orthodontic wires, the authors analyzed and evaluated the changes in surface morphology and mechanical properties. For this in vitro analysis, five specimens of titanium (NiTi) (0.016 inches), coated NiTi (0.016 inches), and stainless steel orthodontic wires were selected. Zataria multiflora extract, 0.2% chlorhexidine, distilled water (control), and 0.05 percent sodium fluoride (NaF) were all applied to the specimens for 1.5 hours at 37 degrees Celsius. A three-point bending test conducted at intervals of 0.5 mm was used to evaluate the wires' elastic modulus (E) and loading and unloading forces beyond immersion. Surface alterations were seen using a scanning electron microscope (SEM). Both Bonferroni testing and two-way analysis of variance were used to compare the wires' properties. A significance level of 0.05 was established. Orthodontic wires were submerged in different mouthwash solutions, and they found statistically significant variations in E ($P < 0.05$) and loading and unloading forces. In a paired comparison, the impact of various mouthwashes on the E of various wire kinds was discovered to be non-significant ($P > 0.05$). Surface changes were detected by SEM scans in many types of orthodontic wires. Conclusion: The mouthwashes used in this study seemed to affect the mechanical characteristics and surface quality of the orthodontic wires [17].

As orthodontic treatment gained popularity, it became more crucial than ever for orthodontists to advise patients to use fluoride-containing mouthwashes and gels in order to avoid cavities and maintain good oral health. During orthodontic therapy, the researchers measured and assessed the effects of fluoride preventative agents on the mechanical properties of nickel titanium (NiTi) wires using a scanning electron microscope (SEM). They used the mouthwash solutions Prevident 5000 (1.1% sodium fluoride neutral agent, 0.5% w/v fluoride, pH = 7; Colgate Oral Pharmaceuticals) and Phos-Flur gel (1.1% sodium acidulated phosphate fluoride, APF, 0.5% w/v fluoride, pH = 5.1; Colgate Oral Pharmaceuticals). A three-point bending test was performed on every item using universal testing equipment. To see how the surface morphology changes, one wire was randomly selected from each group and analyzed under a scanning electron microscope [18]. A white area could appear beneath the bracket upon debonding, serving as a preliminary clinical sign of a carious lesion. Because caries was more likely to occur under and around orthodontic bands and brackets, caries prevention strategies, including the whole range of fluoride treatment techniques, had to be used. The purpose of the study was to determine the effects of exposure to fluoride prophylactic agents for a predetermined amount of time on the mechanical properties (modulus of elasticity and yield strength) of two different orthodontic archwires: nickel titanium [NiTi] and copper nickel titanium [CuNiTi]. Preformed rectangular NiTi and CuNiTi wires were used, and they were immersed in fluoride solution and artificial saliva (control) for 90 minutes at 37 °C. Specimens were assessed using a 3-point bend test on a universal testing apparatus following immersion. They observed a considerable reduction in the unloading yield strength when NiTi and CuNiTi wires were exposed to APF gel [19].

The impact of mouthrinses with Persica and chlorhexidine on the surface properties of orthodontic appliances and the amount of friction between brackets and stainless-steel orthodontic wires. In this randomized controlled trial, 75 orthodontic patients (aged 13–30) were split into two experimental groups (prescribed with Persica or mouthrinses containing chlorhexidine) and one control group (no prescription). The ovoid stainless steel archwires were implanted after the maxillary first premolar stainless steel edgewise brackets were ligated to wires by elastomeric rings. The patients were called back after a two-week period, at which point the archwires were changed. Archwire and bracket surfaces were examined using atomic force microscopy and scanning electron microscopy. The frictional forces between the brackets and the archwires were measured using universal testing apparatus. To evaluate the surface roughness data, nonparametric Kruskal-Wallis and Mann-Whitney tests were employed. The frictional forces data were analyzed using Tukey's post hoc test and a two-way analysis of variance using SPSS software. A significance threshold of $P<0.05$ was applied [4].

the paper determines how nickel-titanium-based orthodontic wires (NiTi) responded to varying sodium fluoride (NaF) concentrations and how certain medicinal plant extracts (essential oils, hydrosols, and extracts) inhibited corrosion. Content and Procedures: We employed NiTi (3M) and CuNiTi (ORMCO, 35°C, California) orthodontic wires in this investigation. The electrolytes listed below were made ready: A 0.1%, 0.5%, or 1% solution of sodium fluoride was added to lactate ringer solution along with extracts from Artemisia, Syzygium aromaticum (clove), and Celtis australis. Measurements of electrochemical impedance spectroscopy and anodic potentiodynamic polarization were used to investigate corrosion resistance. Microscopic pictures of wires were taken at the conclusion of the experiment. To clarify comparisons across all groups, an ANOVA test was run along with a comparison of the Bonferroni and Tukey tests. Reduced toothpaste prescriptions with sodium fluoride are especially recommended for patients with fixed orthodontic appliances. Eugenol's anti-microbial and anti-corrosive properties make it a viable substitute for sodium fluoride in orthodontic patients' treatment plans [20]. The corrosion resistance of artificial saliva differs between nickel-titanium (NiTi) archwire and NiTi archwire with added cooper (NiTi-Cu). In these laboratory studies, the NiTi and NiTi-Cu archwires were submerged in artificial saliva at a pH of 7, and they were then incubated at 37°C. The ratio of the archwire to the saliva was 0.02 grams per milliliter for one day, 33 days, and 66 days. According to studies, NiTi archwire has a larger concentration of released Ni ions in NiTi-Cu than in NiTi, and it is more corrosion-resistant than NiTi-Cu [21].

The efficiency of tooth movement in orthodontics is impacted by the surface roughness and corrosion behavior of orthodontic brackets and archwires caused by metal ion releases. Orthodontic bracket surface alterations can be quantitatively analyzed using three-dimensional information measurements that can be obtained by atomic force microscopy (AFM). When exposed to different kinds of mouthwash, stainless steel orthodontic brackets and wires can emit metal ions that cause corrosion. This study's primary goal is to assess and compare how the surfaces of self-ligating and traditional metal brackets alter after being submerged in three distinct mouthwashes. Nondestructive AFM was used to assess the surface alterations of sixteen conventional metal brackets and sixteen metal self-ligating brackets that had been evenly grouped and submerged in deionized water, mouthwash solutions containing chlorhexidine, herbal, and betadine, for a period of seven days. The choice of mouthwash should be taken into consideration when prescribing to patients, since the AFM results showed that the surface alterations were more noticeable in the groups that were submerged in herbal and betadine mouthwash than in the other groups [22].

Research has been done on the effects of mouthwash concentrations of sodium fluoride (NaF) on the characteristics of superelastic NiTi orthodontic wires. In this study, wires weighing 55.8% Ni and 44.2% Ti were added to commercial mouthwashes with varying NaF levels (0, 130, 200, and 380 ppm). At1, 4, 7, and 14 days, Ni2+ and Ti4+ ions were released using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The austenitic phase of superelastic orthodontic wires is present at oral temperature; cooling causes it to change into the martensite plastic phase. The chemical composition affects the temperatures at which this happens. Variations in the temperatures and stresses of the stress-induced martensitic transition will result from the wire's ion release. By using a differential scanning calorimeter, Ms, Mf, As, and Af were ascertained (DSC). Using a servo-hydraulic testing apparatus at 37 °C, the transformation stresses (austenite to stress-induced martensite) were ascertained [22].

The surfaces of the mouthwash and the various times were examined using a scanning electron microscope (SEM). In mouthwashes with 380 ppm NaF concentrations, the release of Ni2+ reaches 230,000 ppb and the release of Ti4+ reaches 175,000 ppb in 14 days. After 14 days, the release of Ni and Ti ions occurs at concentrations of less than 200 ppm of NaF. In the case of a greater NaF content, this difference in compositions causes fluctuations in Ms from 27 °C to 43.5 °C. Ni in the wires decreases with increasing immersion times and NaF concentrations, leading to an increase in Ms that surpasses 37 °C and loses superelasticity. Similarly, the martensitic phase causes the stresses (tooth position correction) to drop from 270 MPa to 0 MPa. Ti-rich precipitates may grow as a result of the deterioration (Ti2Ni). In order to prevent the long-term immersion of superelastic NiTi in fluoride mouthwashes from destroying its therapeutic characteristics, these results are very interesting to orthodontic clinics [23].

Fluoride-containing mouthwashes are frequently in contact with the Nickel-Titanium (NiTi) archwires that are frequently used in orthodontic therapy. This in-vitro investigation set out to assess and contrast the corrosion resistance of three commercially available NiTi archwires when they were subjected to mouthwashes containing 0.05 and 0.2 weight percent fluoride. The corrosion resistance of three different types of 0.016″ diameter NiTi archwires from Dentaurum, Global, and GAC, as well as a stainless steel archwire from Dentaurum, were evaluated in Fusayama-Meyer artificial saliva and two other artificial salivas containing 0.05 wt% and 0.2 wt% sodium fluoride (NaF). Potentiostatic and potentiodynamic polarization tests, as well as corrosion potential/time assessments, were performed on the wires following their initial configuration. An electronic microscope that scans surfaces was used to analyze their surfaces (SEM). Fluoride had an effect on the NiTi wires' corrosion resistance, although not as much as it did on the stainless steel archwires [24].

Fluoride-based mouthwashes and gels are useful oral hygiene preventive tools in fixed orthodontics because they can slow down the formation of dental cavities and demineralizations, but they can also lessen the resistance of orthodontic alloys to wet corrosion by changing the acidity of the surrounding environment. A series of in vitro studies were conducted on thirty-two premade rectangular orthodontic wires (eight in nickel-titanium and twenty-four in stainless steel), cut into pieces to yield ninety-six samples, in order to assess the effective chemical stability of these products. To assess weight fluctuations and metal ions eluted by acid corrosion processes, they were weighed three times: once before and once after immersion in five mouthwashes and two fluorinated dental gel. Inductively coupled plasma mass spectrometry was used to analyze elution samples, including a control group consisting of normal saline, in order to identify any remaining concentration of metal ions. Metal ions dissolve from orthodontic wires when exposed to acidic pH materials such as fluorinated agents and regular saline. Fluor concentration in mouthwashes and gels, alloy composition, and elemental chemical makeup all affected dissolution. The time and techniques for using fluorinated chemicals to ensure the prophylactic action without destroying the surface structure of orthodontic alloys are suggested by this study [25].

Research has been done on the effects of mouthwash concentrations of sodium fluoride (NaF) on the characteristics of superelastic NiTi orthodontic wires. In this study, wires weighing 55.8% Ni and 44.2% Ti were added to commercial mouthwashes with varying NaF levels (0, 130, 200, and 380 ppm). At1, 4, 7, and 14 days, Ni2+ and Ti4+ ions were released using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The austenitic phase of superelastic orthodontic wires is present at oral temperature; cooling causes it to change into the martensite plastic phase. The chemical composition affects the temperatures at which this happens. Variations in the temperatures and stresses of the stress-induced martensitic transition will result from the wire's ion release. By using a differential scanning calorimeter, Ms, Mf, As, and Af were ascertained (DSC). Using a servo-hydraulic testing apparatus at 37 °C, the transformation stresses (austenite to stress-induced martensite) were ascertained[26].

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Because of its antibacterial qualities, chitosan aids in maintaining healthy oral hygiene. Orthodontists sometimes prescribe mouthwash to teenage teens. Copper-nickel-titanium (CuNiTi) orthodontic archwire is widely used in orthodontic therapy. The impact of chitosan on the CuNiTi properties of orthodontic archwire is mostly unknown. The aim of this study was to measure the CuNiTi orthodontic archwire's surface roughness, deflection, acidity, and copper ion release after it was immersed in 2% chitosan and artificial saliva. Experimental laboratory research was employed. 42 CuNiTi orthodontic archwires were divided into three groups. Group A contained eighteen archwires immersed in simulated saliva, Group B contained eighteen archwires submerged in 2% chitosan, and Group C contained six archwires for the baseline sample. The two intervention groups (A and B) had varying immersion times (two, four, and six weeks) after being split into three subgroups of six samples. A scanning electron microscope (SEM), atomic absorption spectrophotometry (AAS), a universal testing machine (UTM), pH meters, and deflection were used to quantify the acidity, copper ion release, and surface roughness. In addition to having reduced copper ion release, minimal variations in unloading forces, and a comparatively smoother surface, chitosan buffers the pH [27].

What a robust TMA and stainless steel archwires are in relation to one another after being immersed in both apple cider and artificial saliva, as well as just apple cider. The samples were divided into two treatment groups, one of which received apple cider immersion for TMA and stainless steel archwires, and the other two groups received artificial saliva submersion. Each group consisted of seven samples, each measuring 0.016 by 0.022 inches in diameter and 11.6 cm in length. After each sample was incubated, resilience was assessed using a Tensilon RTF-1350 universal testing instrument. Significant differences were seen in the durability of TMA and stainless steel archwires following their immersion in apple cider [28].

The first corrosion processes that may impact the mechanical properties of the archwire are copper (Cu), nickel (Ni), chromium (Cr) ion release, and surface topographical change from the orthodontic wire. Our goal is to assess how CHX, NaF, and chitosan affect surface roughness, archwire deflection, and the release of nickel and copper ions during the corrosion of CuNiTi wire. Using their immersion solution, ninety samples of CuNiTi TanzoTM archwires were split into five groups: Artificial Saliva, CHX, NaF, CHX-NaF, and chitosan group. Three subgroups (n=6) representing the equivalent immersion times—two, four, and six weeks—were created from each group. Using a scanning electron microscope (SEM), universal testing machine (UTM), and atomic absorption spectrophotometer (AAS), the samples' corrosion was examined. Mouthwashes containing CHX, NaF, and chitosan may also change the passive layer by increasing the porosity of the CuNiTi archwire surface structure and releasing more nickel and copper ions. However, mouthwashes do not differ in their ability to release the unloading force over the course of two to four weeks [29].

4. DISCUSSION

Our investigation of the corrosion of stainless steel archwires over a 30-day period found significant variances with the used mouthwashes, even though using archwires for more than one month is normal during more advanced periods of orthodontic therapy.

4.1. Effects of Saliva on Orthodontic Wires

Results of the control group showed that the corrosion in SS archwires anteriorly was more than posteriorly. This is in agreement with Yu, Jian-Hong, et al. [30] and Omidkhoda et al. [31]. However, this is in disagreement with Konda et al. [32] and Hosseinzadeh *et al*. [33]. Part of the reason for the varying results may be that these works were conducted in artificial saliva with a consistent pH level as this, which could be a result of the fact that these works were conducted in artificial saliva with a consistent pH level, which may have caused some debate. Controversy in this study: SS archwires were in patient mouths with changeable pH so the destruction of the protective layer of archwire occurred during low pH conditions (Fig. 2).

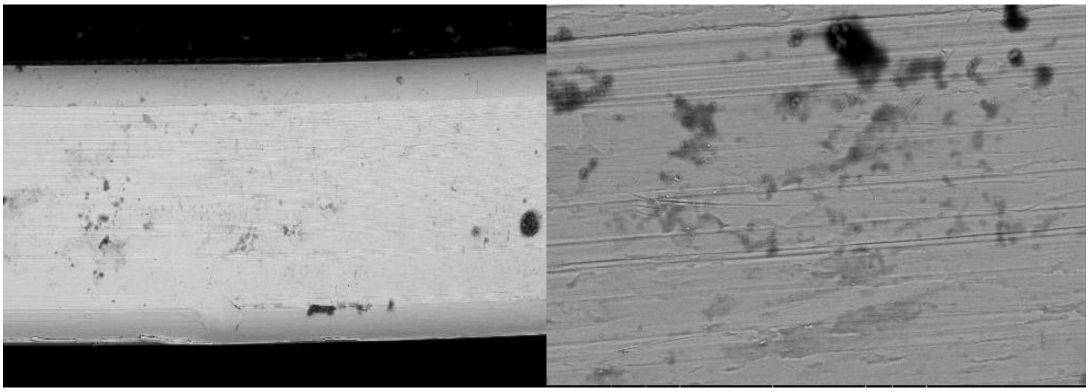

Fig. 2: Illustrative SEM microphotograph showing saliva effect on SS archwires under magnification 500x A. control and magnification 3000x B. control.

4.2. Effects of Mouthwashes on Orthodontic Wires

In the sodium fluoride and chlorhexidine group, the results showed that the corrosion occurred anteriorly more than posteriorly. The differences between anterior and posterior parts for SS archwires were statistically highly significant at the 1% level of probability. This may be due to the anterior part of the archwire being more affected by the mouthwash. While posteriorly, mouthwash is more diluted by the saliva. This is in agreement with Mocnik et al., [34], Geramy et al., [35], Aghili et al., [36], Abdelgader Alwafe et al., [37], Ogawa et al. [38] and Ehrami et al., [39]. Moreover, the patterns of corrosion were different SS archwires present pitting corrosion. After the passive layer breaks down, stable pits are initiated and propagated. Crevice corrosion may occur when the potential at the pit bottom is lower than that at the outer surface. These defects are the preferential corrosion areas. Abalos et al., [40]. These defects were more prominent in NAF than CHX mouthwash (Fig. 3).

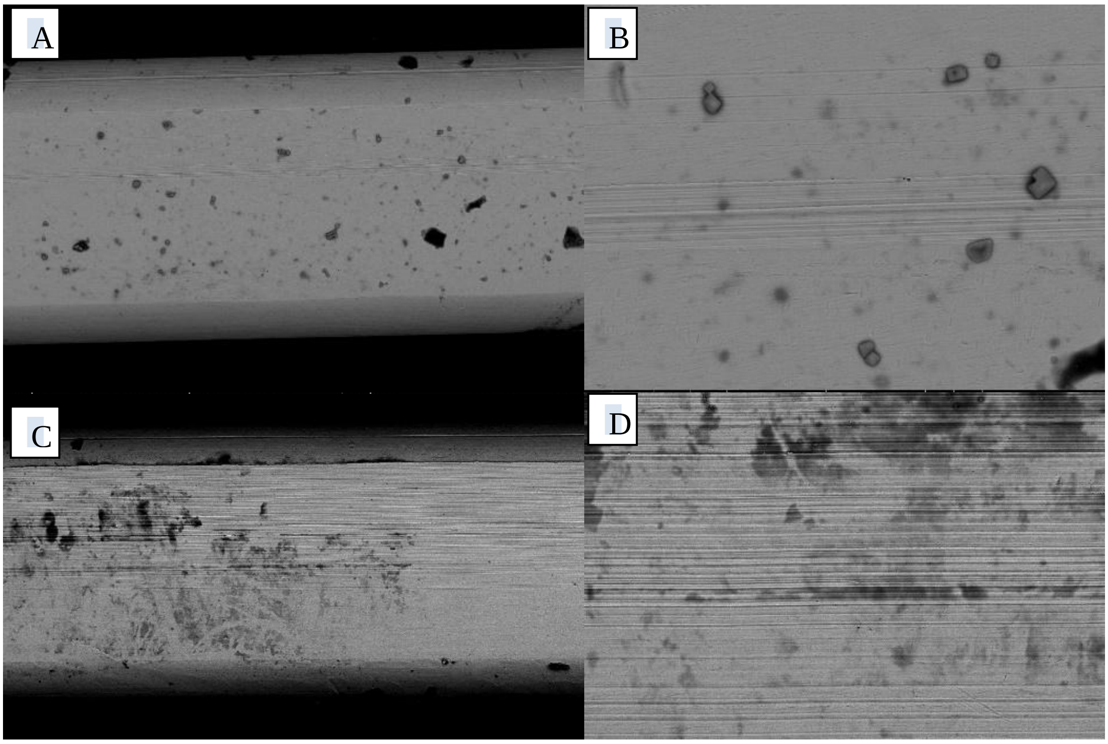

Fig. 3: Illustrative SEM microphotograph showing mouthwashes effect on SS archwires under magnification 500x A. control and magnification 3000x B. control.

A statistically significant difference was found between the control and the two other groups, as both showed a higher corrosion rate than the control group in the anterior and posterior parts. This may be due to the lower pH of the used mouthwashes, which is advantageous for their antibacterial effect. On the other hand, lower pH promotes corrosion.

In general, the obtained results of this study shows that sodium fluoride and chlorhexidine mouthwashes increase the corrosion of stainless steel archwire. Sodium fluoride mouthwash produced more corrosion than chlorhexidine mouthwash. The control group showed the least corrosion rate.

5. CONCLUSION

The following could be deduced within the constraints of the present study:

- Alterations in surface of SS archwires by NaF mouthwashes were higher than control and CHX groups.
- Chlorhexidine-containing mouthwash might be the mouthwash of choice during all phases of orthodontic treatment.

6. RECOMMENDATIONS

1- Prophylactic agents should be used with caution, and new mouthwashes must have less detrimental effects on corrosion and, as a result, the mechanical characteristics of the archwires used for orthodontic therapy.

2- It is advised to utilize light, long-term, and steady force-valued archwires during the first stage of orthodontic biomechanics. These wires should also be resistant to corrosion caused by using prophylactic agents.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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APPENDIX A: LIST OF ABBREVIATIONS

CHx	Chlorhexidine
Cr	Chromium
Cu	Copper
NaF	Sodium Fluoride
NiTi	Nickle Titanium
Ra	Arithmetic mean roughness
SEM	Scanning electron microscopy
SS	Stainless Steel