Comparative evaluation of Silver Dioxide Coated Stainless Steel wire and non-coated Stainless-Steel Wire for Susceptibility to Corrosion- An In-Vitro Study- A Research Protocol.

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Abstract

Background: Stainless steel wire (SS) is a prevalent material in orthodontics, valued for its corrosion resistance, mechanical properties, and biocompatibility. However, its performance can be compromised by the internal oral cavity environment, leading to different forms of corrosion. These corrosion activities can result in the release of potentially toxic metal ions. Silver dioxide-coated stainless-steel wire has been proposed as a solution to this problem due to its improved corrosion resistance and potential for better biocompatibility.

Objective: This study seeks to address this gap by examining the resistance to corrosion of these two types of orthodontic arch wires, aiming to comprehend their vulnerability to corrosion.

Methods: This in-vitro study will be done on a sample of forty Stainless Steel Orthodontic Arch Wire, divided into two groups of 20 each—one with silver dioxide-coated stainless-steel wire and one with uncoated stainless-steel wire. The samples will be immersed in different solutions simulating the oral environment, including artificial saliva, saliva with sodium fluoride, protein-containing saliva, and a chlorine-containing solution. The corrosion will be assessed by measuring weight loss and analysing released ions using inductively coupled plasma-optical emission spectrometry.

Results: The additional silver dioxide coating on the stainless-steel arch wires may reduce the corrosion susceptibility of the arch wire than the un-coated stainless steel arch wire, thereby reducing the prevalence of leaching of ions and their toxic effect.

Conclusions: This finding may prove their potential use in orthodontic treatments, which may suggest that they could be safer and more durable option, contributing to better patient outcomes.

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Comparative evaluation of Silver Dioxide Coated Stainless Steel wire and non-coated Stainless-Steel Wire for Susceptibility to Corrosion- An In-Vitro Study- A Research Protocol.

Abstract

Introduction

Stainless steel wire (SS) is a prevalent material in orthodontics, valued for its corrosion resistance, mechanical properties, and biocompatibility. However, its performance can be compromised by the internal oral cavity environment, leading to different forms of corrosion. These corrosion activities can result in the release of potentially toxic metal ions. Silver dioxide-coated stainless-steel wire has been proposed as a solution to this problem due to its improved corrosion resistance and potential for better biocompatibility.

Need For the Study - Although stainless steel is commonly utilized in orthodontics, there's a dearth of research on the corrosion resistance of both silver dioxide-coated and non-coated SS wires. This study seeks to address this gap by examining the resistance to corrosion of these two types of orthodontic arch wires, aiming to comprehend their vulnerability to corrosion.

Aim-To evaluate and compare Silver Dioxide Coated Stainless Steel wire and non-coated Stainless-Steel Wire for Susceptibility to Corrosion.

Material and Methods

This in-vitro study will be done on a sample of forty Stainless Steel Orthodontic Arch Wire, divided into two groups of 20 each—one with silver dioxide-coated stainless-steel wire and one with uncoated stainless-steel wire. The samples will be immersed in different solutions simulating the oral environment, including artificial saliva, saliva with sodium fluoride, protein-containing saliva, and a chlorine-containing solution. The corrosion will be assessed by measuring weight loss and analysing released ions using inductively coupled plasma-optical emission spectrometry.

Key words: Stainless Steel Arch Wire (SS), Corrosion Resistance, Silver Dioxide Coating, Spectrometry, Toxicity reduction.

Introduction:

Orthodontic wires are fundamental to the practice of orthodontics, staying in the mouth for 18-24 months. This long exposure to the complex conditions in the oral environment, it's very likely for a arch wire to undergo degradation[2]. Stainless steel (SS) has long been used in orthodontics for a long generation due to its mechanical properties, resistance to corrosion, affordability, and biocompatibility[1].

Clinical procedures lasting for a long time, makes it very crucial, a very biocompatible, durable, and material working to its full potential is chosen for treatment, which will eventually enhance patients' aesthetics. Finding a material which show reduced risk to corrosion which simultaneously affect the biocompatibility of a material is quite challenging to find, cause metals tend to leach out ion when suitable electrochemical conditions are provided and oral cavity being one of it. The oral environment is subject to constant chemical fluctuations from saliva, food, beverages, oral hygiene products, and fluoridated water, all containing various substances like salts, proteins, fluoride, and chlorine, all of this leads to formation of corrosion products which affects the oral cavity and eventually body and also reducing the mechanical potential of a material [1].

The leaching of metallic ions from these materials has been linked to allergic reactions in some individuals. Orthodontic wires containing nickel are frequently used in treatment, but if they corrode and release nickel ions, they can trigger allergic responses in patients with nickel sensitivity. [3] The wet conditions in the mouth promote electrochemical corrosion, with metals generally remaining stable as long as their protective oxide layer remains intact [9] However, stainless steel has shown susceptibility to various types of corrosion such as pitting, stress, and crevice corrosion when exposed to chloride ions, amino acids, and proteins found in the oral environment[7]. When stainless steel wires corrode, they can release metal ions that may be toxic to surrounding tissues[6].

Despite the wide use of stainless steel in orthodontics, there's a lack of studies exploring the corrosion resistance of silver dioxide-coated and non-coated stainless-steel wires. This study aims to fill that gap by comparing the resistance to corrosion of silver dioxide-coated and non-coated stainless steel orthodontic arch wires to understand their susceptibility to corrosion.

Materials and Methods

An in-vitro observational study will be performed at the Orthodontic and Dentofacial Orthopaedic Department of Sharad Pawar Dental College in Wardha, Maharashtra, India, starting in April 2024 and lasting for approximately one year, pending approval from the Institutional Ethical Committee (DMIHER(DU)/IEC/2024/253).

A total of 40 samples will be used in this research, comprising 20 silver dioxide-coated SS wires and 20 non-coated stainless-steel wires. These will be divided into 2 groups: the control group with non-coated wires and the experimental group with coated wires. Each of these groups will be further subdivided into four experimental subgroups, each exposed to a different solution for testing.

To create the silver dioxide coating, a sputtering technique will be used to apply a thin film of photocatalytic silver dioxide on the surface of orthodontic SS wires (measuring 0.19x.025). This process ensures a consistent film thickness (15-20 mm) across the wire surface. The sputtering technique involves bombarding a solid cathode (the target) with a positive ion from an inert gas (Argon), removing surface atoms, and deposited onto a substrate to form a thin coating. In this study, a vacuum chamber with a titanium target will be used to create the plasma, and the silver will be sputtered onto the orthodontic Stainless-Steel Wire, which acts as the substrate[4].
The corrosion resistance of both coated and uncoated SS wires will be assessed by measuring the number of ions leached into the surrounding environment. This will be done using a spectrometer[1].

The study will use four different experimental solutions to simulate oral conditions:
1. Physiological solution containing 0.9% NaCl.
2. Phosphate-buffered saline solution with a lactic acid to adjust pH at 6.75.
3. Phosphate-buffered saline with 0.1 wt% sodium fluoride a fluorinated solution.

4. A protein-containing solution comprising phosphate-buffered saline with 0.1% BSA(Bovine serum albumin).

GROUPS	EXPERIMENTAL GROUP	CONTROL GROUP
GROUP A- Solution with 0.9% NaCl	5 Samples of Silver Dioxide coated Stainless Steel arch wire.	5 Samples of non-coated Stainless Steel arch wire.
GROUP B- Phosphate Buffered Solution with lactic acid.	5 Samples of Silver Dioxide coated Stainless Steel arch wire.	5 Samples of non-coated Stainless Steel arch wire.
GROUP C- Phosphate	5 Samples of Silver Dioxide	5 Samples of non-coated

Buffered Solution with Sodium Fluoride.	coated Stainless Steel arch wire.	Stainless Steel arch wire.
GROUP D- Phosphate Buffered solution with BSA.	5 Samples of Silver Dioxide coated Stainless Steel arch wire.	5 Samples of non-coated Stainless Steel arch wire.

Samples will be immersed in the above-mentioned solutions and incubated at 37°C for a period of up to twenty-eight days. After 14 days, the solution in each container will be replaced with fresh solution, and at the end of the 28 days, the samples will be cleaned with acetone and weighed to determine weight loss due to corrosion. The collected solutions will then be analysed for ions using inductively coupled plasma-optical emission spectrometry[1].

The study is designed to run for six months, with evaluations conducted every 45 days to monitor the progress and gather relevant data.

Sample Size

The Sample size formula used are as follow:

$$n_1 = \frac{(\sigma_1^2 + \sigma_2^2/\kappa)(Z_{1-\alpha/2} + Z_{1-\beta})^2}{\Delta^2}$$

The notation for the formulae are:

n = sample size of Group 1

σ_1 = standard deviation of Group 1

σ_2 = standard deviation of Group 2

Δ= difference in group means

κ = ratio = n2/11

$Z_{1-\alpha/2}$ = two-sided Z value (eg. Z=1.96 for 95% confidence interval).

$Z_{1-\beta}$ = power

Mean Epit(mV/SCE) in chronic solution=102
Mean Epit(mV/SCE) in protein containing AS = 131
σ1= SD of Epit(mV/SCE) in chronic solution = 18
σ2= SD of Epit(mV/SCE) in protein containing AS =11
For detecting mean difference of 29 i.e. Δ = 1131-102 = 29
K =1

$$N = \frac{(18*18 + 11*11)(1.96+0.84)^2}{29*29}$$

= 4.14 =5
= 5 Samples needed in each group.
Reference: Chao Zhang et al
Power of the Test: 80%
Level of significance: 5%, 95% confidence interval

Statistical Analysis:

Statistical analysis will be done by using descriptive and inferential statistics using Chi-square test, Student's paired, unpaired t test, one way ANOVA, Two way ANOVA, Tukey Test and software required in the analysis will be SPSS 27.0 version and GraphPad Prism 7.0 version and $p<0.05$ is considered as level of significance.

Result

The additional silver dioxide coating on the stainless-steel arch wires may reduce the corrosion susceptibility of the arch wire than the un-coated stainless steel arch wire, thereby reducing the prevalence of leaching of ions and their toxic effect.

Discussion

Dental materials operate in a very complex oral environment with a continuous exposure to variety of dietary intake of a person which gives material challenges to perform to their potential and orthodontic materials being one of them. Studies recently being done have been exploring critical factors such as corrosion resistance, biodegradation, and antimicrobial properties to ensure the durability and weather materials are ore biocompatible or not. This discussion encapsulates key results from recent investigations and highlighting their implications for orthodontic treatment[3].

Orthodontic components, like retainers, arch wires and brackets, bands, springs are in persistent contact with food particles, saliva with pH levels continuously fluctuating, which can promote corrosion. In a study by Zhang et al. the corrosion susceptibility of composite arch wires was tested in simulated oral environments. The research exemplified robust resistance to electrochemical corrosion over distinct solutions, with the highest resistance in protein-rich environments and the lowest in chlorine-containing solutions. This variance underscores the importance of selection of material based on the specific conditions expected during orthodontic treatment[1].

The orthodontic materials undergo biodegradation, particularly metal-based ones, has gathered attention due to the potential health risks associated with the leaching of elements like nickel and chromium. Gopalkrishnan et al. investigated various orthodontic wires for their biodegradation and found that certain alloys, such as titanium molybdenum, displayed minimum leaching compared to others. This is crucial as nickel and chromium release could cause a lot of allergic reactions or other unfavourable effects in patients. Thus, this study supports the need for biocompatible materials reduces the risk of biodegradation[2].

Similarly, Theodore et al. conducted a comprehensive review which focused on the in vivo aging of orthodontic alloys. The study brought spotlight to the biological risks of Ni(nickel)release and the techniques used to estimate ion release, stressing the importance of thorough biocompatibility evaluation. These insights can direct clinicians in selection of materials that lessens patient exposure to potentially harmful substances[8].

Orthodontic appliances can act as an adjunct in plaque buildup, increasing the chances of tooth decay and gum disease. Gilani et al. inspected the use of silver dioxide-coated orthodontic brackets to lessen plaque adherence. The research found that these coated brackets remarkable decreased bacterial adherence compared to traditional brackets, leading to the conclusion that antimicrobial coatings could be a valuable tool to sustain oral hygiene during orthodontic treatment[4].

Innovations in material science have introduced new possibilities for orthodontic materials. Nie et al. compared bulk nanocrystalline and microcrystalline biomedical 304 stainless steel and explored that the nanocrystalline variant put forward superior resistance to corrosion and lower toxic ion release, with upgraded cytocompatibility. This proposes that nanocrystalline materials could play a significant role in advancing risk-free and more long-lasting orthodontic appliances[5].

Conclusion

The study may provide evidence that silver dioxide-coated SS arch wires offer more favourable corrosion resistance in simulated oral environments. This finding may prove their potential use in orthodontic treatments, which may suggest that they could be safer and more durable option, contributing to better patient outcomes.

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