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MECHANICAL PROPERTY CHANGES IN ORTHODONTIC WIRES AFTER EXPOSURE TO CHLORHEXIDINE MOUTHWASH: A REVIEW STUDY

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Abstract.

Orthodontic wires, especially nickel-titanium (NiTi) and stainless steel (SS), are widely used in clinical orthodontics due to their favorable mechanical properties. However, these materials are prone to degradation when exposed to chemical agents commonly used in oral hygiene, such as chlorhexidine (CHX). This review aims to assess the effects of chlorhexidine mouthwash exposure on the mechanical properties and corrosion resistance of different orthodontic wire types. A comprehensive review of published studies was conducted, focusing on in vitro investigations evaluating changes in tensile strength, surface morphology, ion release, and corrosion behavior of orthodontic wires following exposure to various concentrations and durations of CHX. Most studies found that CHX, especially in higher amounts or with longer exposure, greatly changes the surface texture and weakens the strength of NiTi and SS wires. Exposure to CHX also showed a likelihood of corrosion and release of ions that could affect how well it works in real-life situations and the safety of patients involved. Extended use of wires with chlorhexidine mouthwash could affect their strength and ability to resist corrosion, so it is important to be careful in recommending CHX based mouth rinses for orthodontic treatment.

Key words. Chlorhexidine, orthodontic wires, Nickel-titanium, Corrosion, Mechanical properties, surface roughness.

Introduction.

Orthodontic care has seen advancements over the years; however, fixed appliance systems continue to be crucial in providing comprehensive orthodontic treatment. Orthodontic support systems rely heavily on wires to carefully exert controlled forces for precise and expected tooth movements during treatment procedures. Various types of wires such as stainless steel (SS) nickel titanium (NiTi) and beta titanium (TMA) are utilized in orthodontic treatments due to their unique mechanical properties such as flexibility and shape memory capabilities as well as resistance to corrosion. Proffit et al., 2019 discussed the characteristics of these wires in detail [1]. The success of procedures largely hinges upon the reliable mechanical performance of these wires, throughout the entire treatment process taking care of your teeth can be challenging with braces as they can trap plaque easily and cause gum problems like gingivitis or periodontitis when bacteria multiply in your mouth uncontrollably; this is why dentists often suggest using mouthwash, such, as chlorhexidine gluconate (CHX). CHX is a choice because it works against various bacteria and has been shown in research by Sanz et al to help decrease plaque buildup and gum inflammation effectively [2]. In the year 2013, although the beneficial antimicrobial properties of CHX are well recognized and supported by research findings; a growing body of evidence suggests that prolonged or repeated interaction with this substance may compromise the chemical properties of arch wires over time. Studies have observed changes in wire structure resistance, to corrosion and mechanical behavior when subjected to CHX [3]. These modifications could potentially affect the effectiveness of force application during treatment procedures. Result in extended treatment durations and potential wire breakdown issues. Considering the use of CHX mouthwash in various situations and the significant impact of archwire effectiveness on treatment outcomes it's important to understand how exposure, to CHX could affect the physical characteristics of different types of orthodontic wires analysis seeks to consolidate existing literature on how CHX influences the mechanical traits of wires, specifically looking at tensile strength, elastic modulus, surface roughness, and resistance to corrosion. Furthermore, the analysis delves into the implications of these findings and offers evidence-based suggestions for healthcare professionals.

Materials and Methods.

Types of Orthodontic Wires:

Various types of metal alloys are used to make arch wires for different stages of treatment based upon their mechanical properties and suitability. Stainless steel wires are known for being very rigid and resistant to corrosion while also being easy to work with in procedures for precise tooth movement control in the advanced stages of treatment [4]. Nickel Titanium (NiTi) wires are renowned, for their flexibility and ability to retain their shape memory features during the early stages of alignment and leveling procedures. They provide consistent light forces over extended durations, enhancing patient comfort and treatment efficiency [5]. Beta-Titanium (TMA), These wires offer an intermediate level of stiffness and flexibility, along with favorable spring back and weldability properties. They are frequently used during intermediate and finishing stages of treatment [6].

Chlorhexidine Mouthwash:

Chlorhexidine gluconate is a bisbiguanide antiseptic commonly utilized in concentrations of 0.12% or 0.2%. It exerts its antimicrobial effects through disruption of bacterial cell membranes and precipitation of intracellular components [7]. In orthodontic settings, CHX is frequently recommended to mitigate plaque accumulation around brackets and archwires, particularly in patients at heightened risk for periodontal complications [8]. Its efficacy in reducing plaque and gingival inflammation has made it a standard adjunct in oral hygiene protocols during fixed appliance therapy.

Experimental Protocols in Published Studies:

Extensive in vitro studies have delved into the impact of CHX exposure on the surface characteristics of orthodontic arch wires. Typically, researchers adhere to established protocols by immers wire sections in CHX solutions, for specified durations before carrying out comprehensive assessments of mechanical and surface properties [9]. It is recommended to acclimate the experiments to their surroundings to initiation for enhanced precision and dependability.

• Description of the Immersion Process: Wire sections are submerged in CHX solutions for purchase at retail outlets and left to simulate oral hygiene routines or prolonged exposure periods in research studies spanning from a few hours to multiple weeks [10].

Mechanical and Surface Characterization:

Evaluating the tensile strength and flexibility of a material requires the use of equipment to test its ability to withstand physical stressors, such as mechanical forces applied to wires under strain tests are conducted to evaluate how force is distributed when an object bends load deflection characteristics are analyzed during these test surface roughness is assessed using profilometry techniques while any changes, in surface topography are examined through scanning electron microscopy (SEM)[11]. Assessing corrosive behavior involves using techniques such as potentiodynamic polarization and impedance spectroscopy [12]. Typically for comparison purposes in research studies or experiments, control samples are stored in solutions, like distilled water or artificial saliva, to establish a baseline for analysis. These investigations provide critical insights into the potential degradative effects of CHX on various orthodontic wire materials and offer guidance for clinical decision-making [13].

Study Selection and PRISMA Flow Summary:

The process of identifying and selecting studies is summarized in the PRISMA diagram (Figure 1). A total of 225 articles were identified through electronic database searches (PubMed, Scopus, Web of Science, and Google Scholar) and manual reference screening. The inclusion criteria encompassed in vitro studies evaluating mechanical or surface property changes in orthodontic wires after exposure to chlorhexidine mouthwash. Exclusion criteria included non-English articles, clinical case reports, and studies without control groups or baseline data.

After removing 45 duplicate records, 190 articles were screened by title and abstract. Of these, 45 full-text articles were evaluated for eligibility, and ultimately, 9 studies met the predefined inclusion criteria and were included in the qualitative synthesis.

PRISMA Flow Diagram (Text Format):

Identification:

• Records identified through database searching and manual methods: n = 225

Screening:

• Records after duplicates removed: n = 190
• Records excluded after title/abstract screening: n = 145

Eligibility:

• Full-text articles assessed for eligibility: n = 45
• Full-text articles excluded (n = 35), with reasons:
o Not in vitro studies: n = 12
o Lacked control group or baseline measurements: n = 9
o Focused on clinical case reports or non-mechanical outcomes: n = 7
o Duplicated data across publications: n = 6

Included:

• Studies included in qualitative synthesis: n = 9

Inclusion Criteria:

• In vitro studies evaluating the effects of chlorhexidine (CHX)

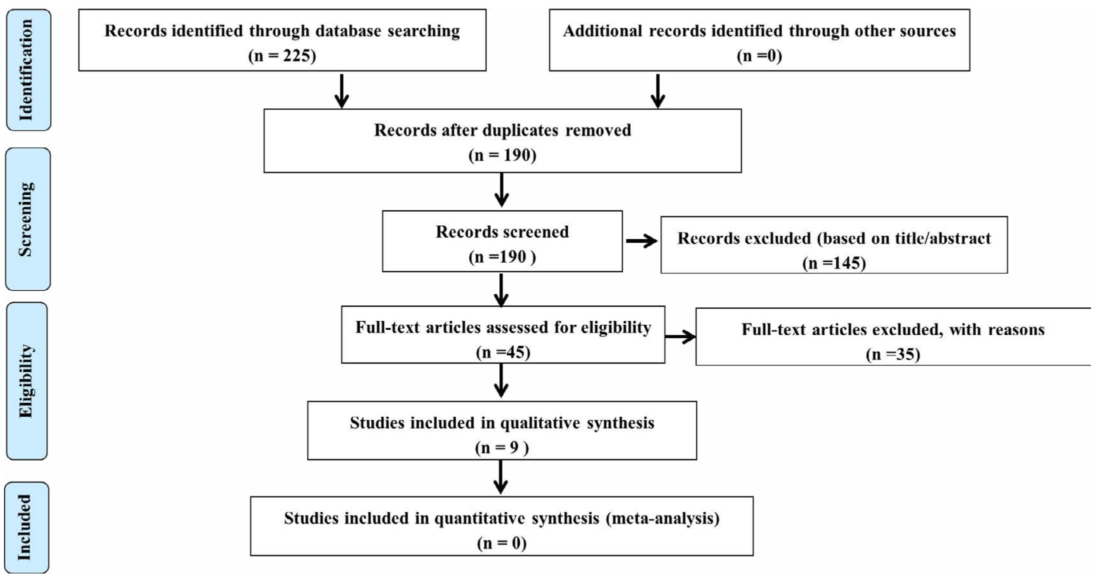

Figure 1. *PRISMA Flow Diagram.*

mouthwash on mechanical or surface properties of orthodontic wires.

- Published in English.
- Included control groups for comparison.
- Provided quantifiable mechanical and/or surface property data.

Exclusion Criteria:

- Clinical studies, case reports, or animal studies.
- Articles not in English.
- Studies without baseline or control data.
- Studies focusing solely on antimicrobial efficacy without material testing.

Effects of Chlorhexidine on Mechanical Properties of Orthodontic Wires:

Multiple in vitro studies have consistently demonstrated that exposure to chlorhexidine gluconate (CHX), particularly at concentrations of 0.2%, results in notable alterations in the mechanical performance of orthodontic wires. The degree of change is influenced by the type of alloy, CHX concentration, and exposure duration. Reductions in tensile strength and elastic modulus were frequently reported, especially for nickel-titanium (NiTi) wires. For example, Amini et al. (2016) observed a statistically significant decrease in tensile strength following 7 and 14 days of immersion in 0.2% CHX solution [14]. NiTi wires treated with CHX showed reduced load deflection in a three-point bending test which affected their ability to apply forces, for tooth movement compared to stainless steel (SS) wires that showed minimal changes and seemed more resistant to CHX induced damage [15].

Surface Morphology and Corrosion Behavior.

Surface Roughness:

Upon examining wires exposed to CHX using scanning electron microscopy (SEM) and atomic force microscopy (AFM) researchers observed increased roughness levels well as signs of microcracks and pitting corrosion. Notably more pronounced in NiTi and titanium molybdenum alloy (TMA) wires [16]. These alterations, in surface characteristics may result in heightened friction and a greater accumulation of biofilms, which could potentially prolong treatment duration.

Ability to withstand corrosion:

Upon subject to exposure CHX the materials displayed an increase in corrosion speed and a reduction in their ability to resist corrosion, with differing levels of corrosion observed in various materials [17]. The corrosion of NiTi wires is primarily affected by the release of nickel ions and the degradation of the protective surface coating [18]. The TMA wires show some corrosion, which seems to have an impact, on them. Stainless steel wires show impact; this could be attributed to the stable chromium oxide protective layer [19].

Time-Dependent Degradation:

Consistently in studies, it was noted that there is a pattern of deterioration over time observed in the materials tested. Short-term immersion for more than 24 hours generally showed minimal effects on the properties of the material, while extended exposure periods ranging from 7 to 30 days led to significant deterioration in both mechanical properties and corrosion resistance [20].

Significantly, conducting repeated cycles of exposure to mimic clinical practice (such as rinsing twice daily) resulted in noticeable changes even after 2 to 4 weeks. This discovery indicates that occasional contact with CHX could potentially harm the durability of orthodontic wires in the long run [21].

Comparative Summary of Evidence:

Table 1 shows a combined overview of discoveries from various studies that reveal a common pattern of wear and tear on orthodontic wires when exposed to CHX solutions. Particularly affecting NiTi wires.

Discussion.

Based on the research conducted in this area of study and its findings show that the use of chlorhexidine mouthwash has an impact on the characteristics of orthodontic wires such, as NiTi and TMA. These outcomes highlight the significance of taking into account orthodontic treatment strategies and upholding oral hygiene habits. Orthodontic wires need to keep a level of force for precise and effective tooth shifting to happen smoothly and controlled in the right way. The decrease in strength and flexibility of NiTi wires after being in contact with CHx is a worrying issue because these wires are known for their ability to

Table 1. *Comparative Summary of the Effects of Chlorhexidine on Orthodontic Wires.*

Study	Wire Type	CHX Concentration & Exposure	Mechanical Changes	Surface/Corrosion Effects	Notes
Amini et al. (2016) [14]	NiTi	0.2%, 7 & 14 days immersion	↓ Tensile strength	Not specified	In vitro
Alavi et al. (2017) [15]	NiTi	0.2%, 14 days immersion	↓ Load-deflection	Not specified	In vitro
Huang et al. (2003) [22]	NiTi, TMA	0.2%, 30 days immersion	Not specified	↑ Surface roughness, pitting, micro-cracks	SEM analysis
Omidkhoda et al. (2017) [23]	NiTi, SS	0.2%, 1.5 hours immersion	↑ Elastic modulus (NiTi), ↓ (SS)	SEM showed surface destruction	In vitro
Farrag et al. (2024) [24]	NiTi	0.2%, 30 days simulated immersion	Not specified	↑ Surface roughness, ↑ Corrosion	Electrochemical analysis
SS = Stainless Steel, NiTi = Nickel-Titanium, TMA = Titanium Molybdenum Alloy, CHX = Chlorhexidine, SEM = Scanning Electron Microscopy, AFM = Atomic Force Microscopy.					

provide constant forces due to their superelastic properties—a feature that gets affected when they interact with CHx for extended periods.

- Medically speaking, weakened wire performance could lead to
- Delayed tooth movement
- Extended treatment duration
- Increased frequency of wire replacement
- Potential for wire fracture

While stainless steel wires showed relative stability, they are not typically used in the early stages of treatment, where NiTi's flexibility is most beneficial. This suggests that early treatment phases are at greater risk of CHX-induced performance decline.

Surface Degradation and Its Implications:

Increased surface roughness and corrosion not only compromise mechanical integrity but may also contribute to greater plaque accumulation on wire surfaces and increased friction between brackets and wires, ultimately reducing the efficiency of tooth movement. These surface alterations, coupled with changes in mechanical properties such as decreased tensile strength and elasticity, can collectively impair orthodontic performance. Additionally, nickel ion release from corroded NiTi wires may trigger allergic reactions in sensitive patients [25]. The long-term presence of such degraded surfaces in the oral cavity might also accelerate deterioration due to mechanical wear from mastication and brushing, further affecting both mechanical performance and biocompatibility.

Material-Specific Vulnerabilities.

Among the three main wire types:

- NiTi is the most vulnerable to CHX exposure, especially over longer periods.
- TMA wires exhibit moderate susceptibility, showing surface degradation and minor mechanical changes.
- Stainless steel remains the most stable and least reactive, making it a safer choice in high-risk patients or in phases where CHX use is expected.

This differential reactivity underscores the importance of wire selection based on a patient's oral hygiene needs and risk profile.

Recommendations for Mouthwash Use in Orthodontics:

While CHX remains a gold standard for managing gingivitis and plaque, its application in patients with fixed orthodontic appliances must be approached with caution. Based on the findings of this review, the following clinical recommendations are proposed:

- Restrict CHX use to short-term periods (e.g., 1–2 weeks) during acute periodontal conditions.
- Encourage alternative antimicrobial rinses for long-term use, such as essential oils, cetylpyridinium chloride, or fluoride-based solutions.
- When CHX use is necessary, opt for stainless steel wires due to their superior resistance to CHX-induce degradation.
- Advise patients to rinse thoroughly with water after CHX use to minimize residual effects on orthodontic appliances.

Based upon repeated observations it has been established that extended contact, with 0.20 percent chlorhexidine can have effects the physical and surface characteristics of NiTi and TMA wires.

Conclusion.

The strength and stability of wires play a crucial role in the effectiveness of fixed appliance treatment methods. A recent assessment has shown that using chlorhexidine (CHX) at a concentration of 0.1% can have adverse effects on the structure and function of orthodontic wires like NiTi and TMA. These effects include weakening tensile strength and flexibility while also causing surface roughness and corrosion. Even though CHX is known for its properties it's important to be cautious with prolonged use, in specific clinical situations. Stainless steel wires are a choice when exposed to CHX because of their chemical stability. Dentists need to think about how oral hygiene products work with wire materials to get the best treatment results. It's important to have real life studies to confirm these effects, in clinics and help create new ways to protect orthodontic materials.

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