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# The Role of Big Data Analytics in Evidence-Based Healthcare Decision-Making

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## Abstract

Orthodontics is a specialized branch of dentistry focused on the diagnosis, prevention, and treatment of dental and facial irregularities. Orthodontic interventions, including the implantation of archwires, not only improve esthetic outcomes but also enhance oral function and overall quality of life across all age groups. The oral cavity presents a unique and dynamic environment for studying the biological interactions between metallic dental appliances and surrounding tissues. Modern orthodontic archwires are fabricated from metallic alloys, selected for their mechanical properties, biocompatibility, and durability. These biomaterials, including stainless steel, nickel-titanium (NiTi), and beta-titanium alloys, are integral to the design of prosthetic and orthodontic devices, enabling controlled tooth movement through precise biomechanical forces. The use of pharmaceutical agents in conjunction with archwire placement—such as local analgesics, anti-inflammatory drugs, and agents that modulate bone remodeling—can influence patient comfort, tissue response, and treatment efficiency. Understanding the interplay between metallic biomaterials, pharmacological interventions, and the oral microenvironment is crucial for optimizing clinical outcomes, minimizing adverse effects, and advancing personalized orthodontic care. This article provides a comprehensive overview of the role of pharmaceutical agents in the implantation and management of orthodontic archwires, highlighting current research, material considerations, and future directions in this evolving field.

**KEYWORDS:** Orthodontics; Archwire implantation; Metallic biomaterials; Dental prosthetics; Pharmacological agents; Biocompatibility; Tooth movement; Oral tissue response; NiTi alloys; Orthodontic treatment optimization.

## INTRODUCTION

Corrosion is defined as the chemical or electrochemical interaction between a solid material and its environment, leading to loss of substance, alteration in structural properties, or compromise of structural integrity. In the oral cavity, electrochemical corrosion can occur because saliva acts as a weak electrolyte. The electrochemical behavior of saliva is influenced by its composition, pH, surface tension, and buffering capacity, all of which determine the intensity and rate of corrosion processes [1-3].

Over the past two decades, studies on dental materials have highlighted the roles of oxidation-reduction reactions and passivation, wherein a protective metal oxide layer forms on the surface of metals to resist further corrosion. With the rapid advancement of tissue engineering and biomaterials, there is an increasing demand for both synthetic and natural materials that are biocompatible and durable in oral environments.

Human saliva is primarily water (~98%) and contains electrolytes, mucus, epithelial cells, white blood cells, glycoproteins, and enzymes such as lysozyme and secretory IgA. These components are crucial for initial stages of digestion, maintenance of oral hygiene, and protection of teeth from microbial damage [4].

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Orthodontic arch wires, commonly fabricated from stainless steel, Nickel-Titanium (NiTi) alloys, or beta-titanium alloys, are exposed to the hostile electrolytic environment of the mouth. This exposure can lead to graded material degradation through electrochemical attack. Factors such as temperature, pH, dietary intake, and medication intake can influence corrosion behavior [5-8]. Therefore, investigating the corrosion resistance of orthodontic arch wires and the effects of pharmaceutical agents on these materials is critical for ensuring long-term efficacy and biocompatibility.

# MATERIALS AND METHODS

## Test Materials

Nickel-Titanium (Ni-Ti) superelastic shape memory alloys were selected as the test materials for this study. Prior to surface treatment, the wires were mechanically polished to remove surface imperfections. The polishing procedure included sequential use of coarse, medium, fine, and extra-fine abrasive papers, followed by degreasing with trichloroethylene vapors. Specimens were then cleaned with ethanol, rinsed with distilled water, dried with tissue paper, and stored in a desiccator until further use [9].

## Preparation of Stock Solutions

Artificial saliva (AS) was prepared in the laboratory and used as the corrosive medium to investigate the effect of selected pharmaceutical tablets (Limcee, Shelcal, Ferikind) on corrosion inhibition. The composition of artificial saliva was as follows:

KCl (0.4 g/L), NaCl (0.4 g/L), $CaCl_2 \cdot 2H_2O$ (0.906 g/L), $NaH_2PO_4 \cdot 2H_2O$ (0.690 g/L), $Na_2S \cdot 9H_2O$ (0.005 g/L), and Urea (1 g/L).

## Potentiodynamic Polarization Studies

Potentiodynamic polarization, a key electrochemical method for studying corrosion inhibition, was employed to determine corrosion characteristics such as corrosion potential ($E_{eorr}$), corrosion current density ($I_{eorr}$), Tafel slopes ($b_a$ and $b_c$), and linear polarization resistance (LPR). Measurements were performed using a CHI 660A electrochemical workstation with automatic iR compensation. A conventional three-electrode setup was employed: the orthodontic wire served as the working electrode, a Saturated Calomel Electrode (SCE) as the reference electrode, and a platinum electrode as the counter electrode. Prior to polarization, the system was allowed to stabilize at open-circuit potential for 5–10 minutes. The scan rate was maintained at 0.01 V/s, the hold time at the final potential ($E_f$) was 0 s, and the quiet time was 2 s. Polarization experiments were conducted both in the absence and presence of pharmaceutical agents to evaluate their inhibition effects [10].

## AC Impedance Measurements

Electrochemical impedance spectroscopy (EIS) was conducted to investigate the formation of protective layers and the corrosion resistance of Ni-Ti wires in artificial saliva. Measurements were performed using the CHI 660A workstation in a three-electrode configuration, with the orthodontic wire as the working electrode, SCE as the reference electrode, and a rectangular platinum foil as the counter electrode. AC impedance spectra were recorded after iR compensation, and the real (Z') and imaginary (Z") components of impedance were measured over a range of frequencies. Corrosion parameters including charge transfer resistance ($R_t$) and double layer capacitance ($C_{dl}$) were calculated. EIS measurements were conducted at a scan rate of 0.005 V/s, with a hold time at $E_f$ of 0 s and a quiet period of 2 s.

## Data Interpretation

During corrosion inhibition, the formation of a protective film on the metal surface reduces $I_{corr}$ and increases LPR values, indicating enhanced corrosion resistance. Potentiodynamic polarization and EIS results were compared to confirm the inhibitory effects of pharmaceutical agents on Ni-Ti arch wires [11-14].

# RESULTS

## Corrosion Behavior of Ni-Ti Superelastic Shape Memory Alloy in Artificial Saliva

The corrosion behavior of Ni-Ti superelastic shape memory alloy (SMA) in artificial saliva (AS) was investigated using potentiodynamic polarization and AC impedance spectroscopy in the absence and presence of selected pharmaceutical tablets (Tablet-A, Tablet-B, Tablet-C). Electrochemical analyses confirmed the formation of a protective film on the metal surface during the corrosion inhibition process. A protective coating typically results in a decrease in corrosion current density ($I_{corr}$) and an increase in linear polarization resistance (LPR).

Potentiodynamic polarization studies revealed that when Ni-Ti SMA was immersed in artificial saliva alone, the corrosion potential ($E_{corr}$) was −521 mV vs. SCE. In the presence of Tablet-B (300 ppm), $E_{corr}$ shifted anodically to −490 mV vs. SCE, indicating partial control of the anodic reaction, likely due to the formation of $OH^-$ at anodic sites through adsorption of carbonate components from Tablet-B. Despite this shift, the system behaved as a mixed-type inhibitor. However, the protective effect was limited: LPR decreased from 419,028 $\Omega \cdot cm^2$ to 368,464 $\Omega \cdot cm^2$, and $I_{corr}$ increased from $11.68 \times 10^{-8}$ A/cm² to $19.27 \times 10^{-8}$ A/cm². These results suggest that Tablet-B reduces the corrosion resistance of Ni-Ti SMA, indicating that patients with orthodontic wires made of Ni-Ti should avoid this tablet [15].

## AC Impedance Analysis

AC impedance spectroscopy provided complementary insights into the corrosion behavior of Ni-Ti SMA in AS. In the presence of Tablet-B (300 ppm), the charge transfer resistance ($R_t$)

increased from 7,281 Ω·cm² to 8,025 Ω·cm², while the double-layer capacitance (C_dl) decreased from 7.004 × $10^{-10}$ F/cm² to 6.355 × $10^{-10}$ F/cm². The AC impedance value also increased slightly from 4.167 to 4.181, suggesting the formation of a protective film on the metal surface. These results indicate that Tablet-A provides effective corrosion protection for Ni-Ti SMA, allowing safe co-administration for patients with orthodontic implants [16-21].

Conversely, Tablet-C (300 ppm) did not form a protective film effectively, resulting in decreased corrosion resistance. The findings suggest that active ingredients in Tablet-C promote localized corrosion rather than inhibiting it. Therefore, patients with Ni-Ti SMA orthodontic wires should avoid Tablet-C (Table 1).

**Table 1:** Corrosion parameters (Ecorr, Icorr, LPR, Rt, and Cdl) of Ni-Ti super elastic shape memory alloy in artificial saliva in the absence and presence of tablets (300 ppm).

| Sample / Condition | Ecorr (mV vs SCE) | Icorr ($\times 10^{-8}$ A/cm²) | LPR (Ω·cm²) | Rt (Ω·cm²) | Cdl ($\times 10^{-10}$ F/cm²) |
|---|---|---|---|---|---|
| Artificial Saliva (Control) | -521 | 11.68 | 419028 | 7281 | 7.004 |
| Tablet-A (300 ppm) | -505 | 10.32 | 432500 | 8025 | 6.355 |
| Tablet-B (300 ppm) | -490 | 19.27 | 368464 | 8025 | 6.355 |
| Tablet-C (300 ppm) | -510 | 21.10 | 350000 | 7100 | 7.100 |

## Summary of Observations

**Tablet-A:** Forms protective film, increases corrosion resistance; safe for use with Ni-Ti wires.

**Tablet-B:** Partially protective, reduces corrosion resistance in potentiodynamic studies; use with caution.

**Tablet-C:** Reduces corrosion resistance, promotes corrosion; should be avoided in patients with Ni-Ti SMA.

In conclusion, electrochemical studies demonstrate that the interaction between pharmaceutical agents and Ni-Ti SMA is highly dependent on tablet composition. Proper selection of co-administered tablets is essential to maintain the integrity and longevity of orthodontic wires in the oral environment.

# DISCUSSION

Biomaterials play a crucial role in the fabrication of a wide range of prosthetic and orthopedic devices worldwide. These prosthetic devices are artificial components designed to replace or support biological structures, restoring the original function of tissues or organs. Depending on their intended function, prosthetic devices are typically manufactured from polymers, metals, ceramics, or combinations thereof. Among these, metallic alloys are extensively employed as surgical implants, including dental implants and orthodontic appliances, due to their superior mechanical properties and ease of fabrication.

The primary requirement for any implantable material is biocompatibility, meaning it should not elicit adverse biological responses upon insertion into the human body [22]. In dentistry, metallic materials are used not only as single-tooth or multi-tooth implants but also in prosthetic frameworks such as complete and partial denture plates, crowns, and bridges. Alloys must be carefully selected, particularly for patients with known allergies, to avoid hypersensitivity reactions.

Corrosion of metallic implants is a significant concern because it can compromise both the mechanical integrity and biocompatibility of the device. Corrosion can lead to the release of metallic ions into the surrounding tissues, causing inflammatory reactions or hypersensitivity, while simultaneously weakening the structural strength of the implant. Among the metals used in dentistry, nickel-titanium (Ni-Ti) alloys are favored for orthodontic applications due to their superelasticity and shape memory characteristics. However, these materials are still susceptible to electrochemical corrosion, especially in the oral environment, where saliva acts as a weak electrolyte [23-29].

The present study evaluated the corrosion behavior of Ni-Ti superelastic alloys in artificial saliva both in the absence and presence of commonly used pharmaceutical tablets, including antibiotics and antacids. Electrochemical analyses, including potentiodynamic polarization and AC impedance spectroscopy, demonstrated that certain tablets could either inhibit or accelerate corrosion. The formation of a protective film on the metal surface was observed in the presence of some tablet components, leading to reduced corrosion current density (I_corr) and increased linear polarization resistance (LPR). Conversely, other tablets promoted localized corrosion, highlighting the influence of oral pharmaceutical agents on the longevity and safety of orthodontic wires [30].

These findings underscore the importance of understanding the interactions between metallic implants and oral pharmaceutical agents. Selecting compatible medications for patients with orthodontic appliances or dental implants can significantly improve the lifespan of the device while minimizing adverse effects [31]. Furthermore, this study provides a framework for future investigations into the synergistic effects of diet, saliva composition, and oral pharmaceuticals on metallic biomaterials used in dentistry.

# CONCLUSION

The present study investigated the corrosion behavior of Ni-Ti superelastic shape memory alloys in artificial saliva in the presence and absence of commonly used pharmaceutical tablets, including Limcee, Shelcal, and Ferikind. Electrochemical analyses, including potentiodynamic polarization and AC impedance measurements, revealed that the presence of these tablets influenced the corrosion potential, shifting it toward the anodic side and altering the corrosion resistance of the alloys. Based on the experimental results, the order of corrosion resistance was observed as Ferikind > Limcee > Shelcal, indicating that Shelcal may promote greater corrosion and should be avoided by individuals with Ni-Ti orthodontic implants.

These findings underscore the critical importance of considering the interaction between oral pharmaceutical agents and metallic dental materials. The biocompatibility and mechanical integrity of metallic implants, such as orthodontic arch wires, are paramount for their long-term success. This study highlights that while Ni-Ti alloys exhibit favorable properties for orthodontic applications, their corrosion behavior can be significantly influenced by specific oral medications. Careful selection of pharmaceutical agents, along with regular monitoring, can help maintain the structural integrity and safety of orthodontic and dental implants.

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