

How to Cite:

Mahmood, A. B., Alhuwaizi, A. F., & Hussein, M. R. (2022). A review of nickel titanium alloy for orthodontic arch wires. *International Journal of Health Sciences*, 6(S9), 92–99.
<https://doi.org/10.53730/ijhs.v6nS9.12172>

A review of nickel titanium alloy for orthodontic arch wires

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Abstract---NiTi alloys are in demand in commercial and biomedical industries. This article discusses Ni-Ti alloy characteristics and applications. Ni-Ti is a smart material that can demonstrate thermal-induced shape memory at lower operational temperatures. Its biomedical applications are described. Biomedical industry end products must pass many biocompatibility testing. Biomedical implants must pass haemocompatibility, lysis and thrombogenicity. All the precise approaches and procedures aid with selection.

Keywords---biomedical, nickel titanium, biocompatibility.

Introduction

Orthodontic therapy repositions teeth. Optimal tooth movement force doesn't damage teeth or gums. When applying force, the kind of movement and tooth size are important considerations. Although the appropriate force is difficult to quantify [1], orthodontic/orthodontic forces usually range from 0.15-0.5 N [2, 3]. Excessive force below vascular blood pressure impairs periodontal cellular activity and delays tooth progress [4]. Lower pressures improve treatment quality and mobility between sessions. Permanent orthodontic wires apply forces on teeth. They release energy by applying pressure and tension to teeth [5]. To create a treatment plan, an orthodontist must understand orthodontic wire biomechanics and clinical usage. Gold orthodontic wire once existed. Pricey gold wires are come cheaper, better-performing stainless steel wires. Modern technology gives cobalt-

chromium, nickel-titanium, and beta titanium multi-stranded wires several features. Orthodontic wires are evaluated using tension, bending, and torsional testing [6-8]. Doctors should consider wire specs. No wire suits all therapeutic periods.

Orthodontic wire

Orthodontic therapy improves and maintains oral health and creates an appealing smile that boosts self-esteem. Orthodontic therapy is founded on the notion that tooth movement can transform stored elastic energy into mechanical effort, and that perfect tooth movement management requires a system of unique forces supported by orthodontic wires. Orthodontic wires are devices that use a wire adapting to the alveolar or dental arch to address tooth position anomalies [9]. Wires are as old as fixed orthodontic therapy and have different properties. Orthodontic wire alloys vary [10].

Nickel-titanium (Ni-Ti) wires

1972 saw the introduction of Nitinol, a worked Ni-Ti alloy. It's high-resilient, limited-formable, form memory, heat memory, and super elasticity. Two major, one intermediate stage Ni-Ti alloys have various phases; higher austenitic cubic body temperature (BCC), lower-temperature, martensitic phase close-packed hexagonal structure (HCP). The Intermediate phase delayed austenite till cooler temperatures to martensite achieved [11].

Reducing the temperature from an excessive temperature or applying stress can cause a phase transformation (from BCC austenitic to HCP martensitic) and a volumetric change. This transition creates shape memory and pseudoelasticity [12]. Wire with shape memory is created at temperatures near 482° C, chilled, and then heated through a lower transition temperature range (TTR) to return to its original shape. Cobalt controls the transition temperature range, which can be oral temperature. Stress-induced austenitic-to-martensitic transition produces Ni-Ti wire superelasticity. This definition was based on wire structural changes (phase transition) during temperature or loading [13].

Applications of NiTi in the biomedical industries

Ti-rich Nitinol offers a wide range of medical applications, including orthodontics, drug delivery systems, self-expanding stents; implant devices, atrial occlusion devices, and ophthalmology [13]. The nosepiece and earpiece are manufactured of superelastic SMA for comfort and damage resistance [14]. The superelasticity of NiTi-base alloys gives implants a bone-like behavior, which has many biomedical uses [15]. NiTi alloys (Nitinol) have greater mechanical characteristics, biocompatibility, and hysteresis than 316L stainless steel [16]. Its elastic modulus is identical to the bone, making it perfect for bone staples [17,18]. NiTi-based Shape Memory Alloys (SMAs) have several biomedical uses due to their ability to restore their original shape when heated and their hysteresis during loading and testing. A foreign implant causes blood coagulation and platelet activation [19]. In vitro investigations like haemocompatibility, and tests assist to find and remove unwanted foreign bodies and elements that produce clotting during biomaterial

development. Sodium citrate and heparin are routinely employed as anticoagulants for evaluating NiTi biomaterial haemocompatibility [20].

NiTi alloy in orthodontics

NiTi arch wires revolutionized early orthodontic treatment. Fewer orthodontists use steel arch wires [21]. First used in 1971 by Andreasen and Hilleman [22]. Malposed dental brackets can be a third farther apart without deforming a NiTi arch wire. Crystalline, two-phase NiTi alloys are appealing. High temps and low stresses favor austenite, while low temps and high stresses favor martensite [23]. Unique phases. Softer than austenite is martensite [24]. R-phase martensite-austenite exchange [24]. This explains NiTi arch wires' shape memory and super elasticity [23]. When the alloy's phase changes due to temperature, shape memory develops. Super elasticity occurs when stress is applied and released [25]. Due to absence of temperature changes in the oral environment, using the alloy's shape memory properties clinically has proved difficult [23]. Super elastic NiTi wires improve patient care. When a super elastic NiTi arch wire is deflected into a bracket slot, the structure changes, R-phase austenitifies unloaded wire [26]. The wire features superelasticity (sometimes called plateau behavior) because many phases can coexist [21]. Super elastic arch wires change patient treatment. Prof-fit said super elasticity is "desirable" and unloading and loading curves differ. This means the wire exerts a different strain on the teeth than before. Hysteresis is energy-draining [23]. Super elastic wires can deflect for a malposed tooth under severe stress and return to their normal shape while applying modest, continuous forces to the teeth [27].

Super elasticity limits arch wire modifications as long as the steady low force level is above the minimum requirement for tooth movement. In leveling and aligning, one arch wire has a wider activation range [28]. Low formability; expensive; not weldable [29]. Nitinol wires might break after days of normal wear. Larger, rectangular wires wear more [29]. Ni-element toxicity and Ni-Ti alloy surface treatment to prevent toxicity are poorly understood. Nanoparticles could reduce Ni toxicity and boost Ni-Ti alloy corrosion resistance [29]. Nickel-titanium orthodontic wires are preferred because to their low force delivery and large elastic operating range. These items are clinically configurable.

Orthodontic nickel-titanium wire alloys use NiTi (50 at. percent Ni and Ti). These alloys contain 55% nickel (55-Nitinol) due to atomic weight differences [30]. Unitek (now 3M Unitek, Monrovia, CA) produced nickel-titanium orthodontic wire in 1978. Andreasen and Ray Morrow at Unitek investigated circular and rectangular nitinol and stainless steel wires. Moments and elastic ranges were varied for therapeutically relevant round and rectangular wire sizes [31]. Nickel-titanium wires store more energy than beta-titanium or steel [32]. Improved elasticity and corrosion resistance allow these wires to deflect and activate with little loads [33]. Low formability; expensive; not weldable [33]. Nitinol wires might break after days of normal wear. Larger, rectangular wires wear more [33]. Ni-element toxicity and Ni-Ti alloy surface treatment to prevent toxicity are poorly understood. Nanoparticles can reduce Ni's toxicity and boost Ni-Ti corrosion resistance.

Nanoparticles technology

Nanotechnology manipulates molecules and atoms. Researchers looked at numerous application domains to find and use nanoscale components. Taniguchi coined the name at TSU in 1974 [34]. One nanomaterial dimension is less than 100 nm. It can be grains, threads, clusters, or nanoholes. 1D sheets, 2D nanowires, and 3D quantum dots. This review focuses on nanoparticles' unique mechanical properties, which increase the surface area per unit mass.

Medicine and dentistry employ nanotechnology (nano-dentistry). [35] Nanomedicine uses nanoparticles to prevent, diagnose, and treat disease. Discoveries and research improve life and health. Nanomaterials and nanoparticles' toxicity is a hotly debated topic: some studies we've reviewed don't address it, while others believe there's little data, particularly in dentistry. Nanotech can make clinics easier, but safety is a worry [35]. Nanomaterials Nanoparticles of the same composition have a much greater surface area/volume ratio (volume-specific surface area). After repeated use, they can accumulate in the lungs and gut. DNA mutations, cell damage, and inflammation occur, possibly dental [36, 37]. Dental products use nanoparticles. Few materials emit these molecules, such as intraoral scan sprays or CAD/CAM designs. Dental materials contain nanoparticles [35]. These factors suggest that nanotechnology is new and underexplored. Many ideas are hard to implement because of technological, biological, and ethical constraints. More dental research is needed [35]. Researchers and physicians create new materials for nano-dentistry. Using nanostructured materials and technology, nano-dentistry detects, cures, and prevents oral and dental disease [35]. Enhancing patient dental health, lowering treatment invasiveness, and boosting doctor compliance [36]. Mainly conservative, endodontic, anesthesiology, aesthetics, and orthodontics.

Coated Orthodontic Archwires

Orthodontic treatment involves sliding brackets along an archwire, which stops tooth movement. Orthodontic appliances must overcome tooth resistance. 60% of the orthodontic force is lost to friction [38]. Torque, slot section, ligation, archwire section, inter-bracket distance, and oral functions affect friction [39]. Reducing friction reduces treatment times and root resorption, providing more mobility and anchoring control [38].

Reducing friction took years. First, researchers studied brackets. Archwire alloys and surfaces were studied second. Nanotechnology reduces friction, simplifying the mechanism. Nanoparticle-coated orthodontic archwires are recommended. Friction-reducing MoS₂ and W₂ [40]. Under appropriate reducing and sulfiding conditions, tungsten oxide (WO₃) nanoparticles can produce nested WS₂ fullerene-like nanostructures. Platelet-shaped WS₂ and MoS₂ particles are lubricants [41]. Inorganic fullerene-like nanoparticles have been designed to apply fullerene's chemical and physical capabilities to novel materials, including dentistry. Transition metal chalcogenides (binary salts of S, Se, or Te), especially MoS₂ and W₂, have overlapping molecular planes similar to graphite. 1992: Tenne explains nanoparticles. Due to weak van der Waals forces, nanoparticles roll between metal and solid lubricant [40]. Nanoparticles may maintain intimate

contact with metal surfaces, expend less energy under a load due to elastic deformations, and cool with increasing friction. Weak nano-bonds inhibit oxidation [41]. Some studies reveal no harm following cutaneous application in rats [42]. Further research is necessary to demonstrate there are no toxic effects in humans for the entire length of an orthodontic treatment (Figure 1).

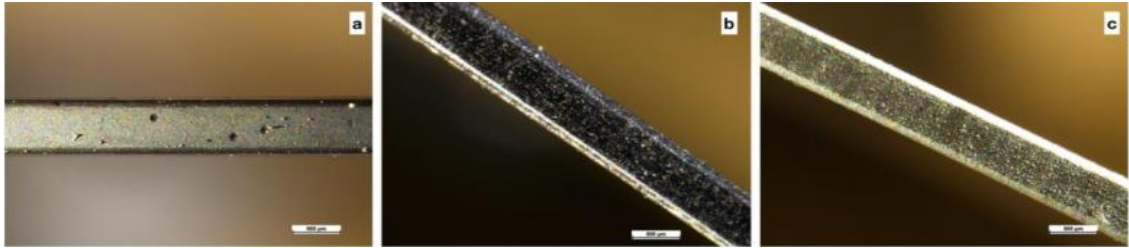


Figure 1: Stainless steel archwires, 0.19×0.25 , coated with MoS₂ (molybdenum disulfide) and W₂ (tungsten disulfide)

Conclusion

Nanotechnology can make poorly soluble, poorly absorbed, and labile physiologically active substances deliverable. Metals, alloys, polymers, and composites make orthodontic wires. Each substance has advantages. Ni-Ti alloy offers clinical potential for numerous applications. Coating substances may speed up orthodontics. Antimicrobial activity and environmental resistance can be compared using TiO₂, ZnO, Ag, and silver nanoparticles and uncoated arches. Archwire antibacterial action depends on coating thickness. Further advances in coating processes and compositions that allow their usage in the oral cavity could reduce orthodontic friction and release nickel ions, reducing treatment time and bacterial adhesion risk.

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