Evaluation of Surface Topography of CU NITI Wire After Infection Control Procedure

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CuNiTi, surface topography, infection control, sterilization

ABSTRACT

Background: The ideal shape and condition of orthodontic wires are essential for effective orthodontic therapy. The market provides a variety of wires constructed from various metals and alloys. Among them NiTi archwires used for preliminary leveling and alignment of teeth in orthodontic treatment. Alloys made of copper, nickel, titanium, and some chromium are known as copper-nickel-titanium (CuNiTi) alloys. The copper in the alloy improves the wire's thermal-reactive characteristics and increases its resistance to permanent deformation.

Objective: The main aim of this study is evaluation of surface topography of cu NiTi wire after infection control procedure.

Materials and Method: The study sample consisted of 3mm straight cu NiTi orthodontic wire segment. They were split into two groups, each with 3 samples. The 5 samples of each group were then equally divided according to sterilization method. After sterilization and disinfection of the experimental group, SEM was used to evaluate the surface topography, and a universal testing equipment had been used to measure the tensile strength.

Result: SEM photographs of the present study shows gross increase in pitting roughness of the surface topography of cu NiTi wires after sterilization.

Conclusion: Orthodontists who want to offer maximum safety for their patients can sterilize orthodontic wires before placement, as it does not deteriorate the surface roughness of the alloys.

1. Introduction

One of the most important issues currently facing health clinics is infection control [1]. The health-care providers are striving to achieve a higher level of protection [2]. Orthodontic wires are frequently packaged in unsterile sealed packs with instructions on the wrapper, generally advising for autoclave sterilisation [3]. If sterilisation does not alter the properties of wires in an unfavourable direction,there is the possibility for dentists to systematically sterilise wires before placing them in the oral environment [4].

Archwires made of NiTi with copper added (CuNiTi) first appeared in the 1990s, basically composed of nickel, titanium, copper and chromium [5]. In order to offer more defined transition temperatures, copper an efficient heat conductor was added to nickel and titanium [6]. This ensured the formation of more uniform loadings from arch to arch and from end to end, enhancing the effectiveness of tooth movement [7]. Copper-nickel-titanium wires were the latest innovation in the evolutionary scale that gives us the opportunity of choosing the force level by choosing the temperature at which the wires will deliver its optimum force level [8].

Surface topography plays a key role in the mechanics of bracket sliding [9]. The mechanical properties of orthodontic appliances, their corrosion behaviour, and therefore their biocompatibility are all influenced by the surface topography of the orthodontic archwires [10]. The effect of sterilisation on tensile properties and surface topography, which is of importance for corrosion behaviour and the performance of sliding mechanics, has not been extensively studies the main aim of this study evaluation of surface topography of cu niti wire after infection contact procedure.

2. Materials and Method

After sterilisation and disinfection of the experimental group, surface topography was examined with SEM. 3 cm segments of each sample

1. Consist of copper niti wires in their as received condition from the manufacture where to serve as the control group
2. Consist of copper Niti wires where autoclaved in their used condition from the orthodontics clinics.

All the specimens were undertaken for microscopic analysis to qualitatively characterise the topography of the wire surface. The specimens were mounted directly on the metal stubs and observed using an optical microscope at 1000x magnification. The surface topography for each of the wires was observed.

3. Result

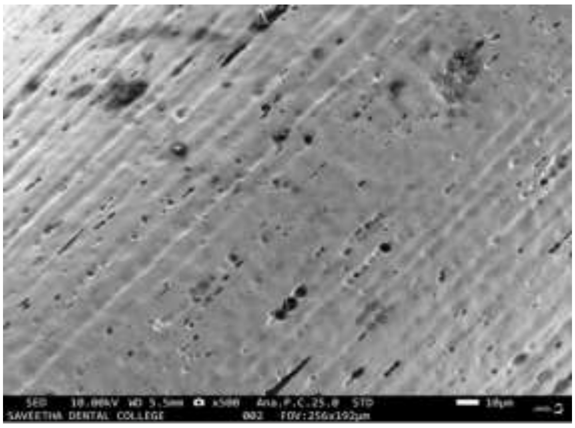

Figure 1. SEM micrograph at 1000× magnification

Observation: The image depicts the surface topography of orthodontic archwires at high magnification, showing fine surface irregularities and possible porosities or defects.

Significance: This magnification level highlights micro-level details, such as pits, grooves, or manufacturing imperfections. These surface features could impact the mechanical properties, friction, and overall performance during orthodontic treatment.

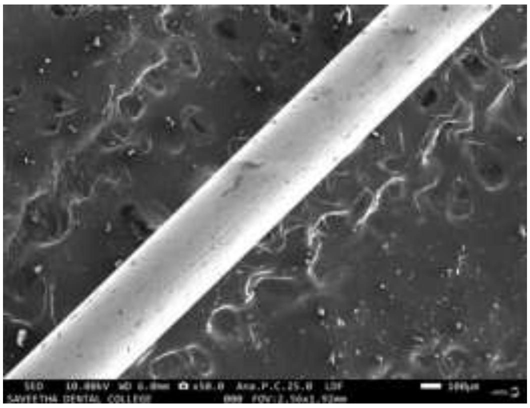

Figure 2. SEM micrograph of original orthodontic archwires at 100× magnification

Observation: The archwire surface appears relatively smooth with minimal surface irregularities visible at this magnification. This represents the pristine state of the archwire before any external processing.

Significance: This serves as a baseline for comparison with autoclaved archwires. The relatively smooth surface indicates optimal manufacturing quality, which could ensure consistent force delivery and reduced friction against brackets.

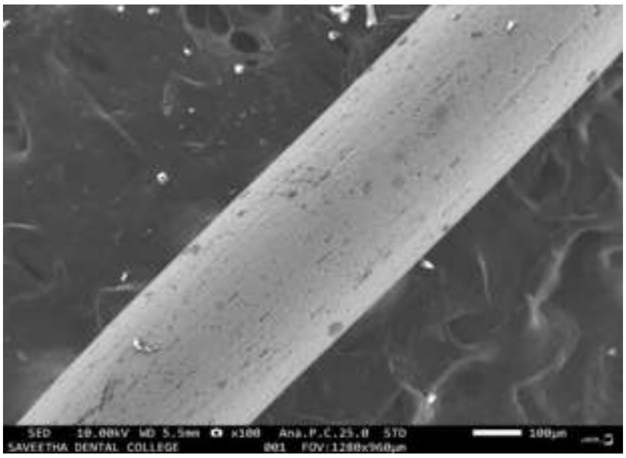

Figure 3. SEM micrograph of orthodontic archwires post-autoclave at 100× magnification

Observation: The surface shows increased roughness or topographical changes when compared to the original archwire. Small pits or alterations may have been introduced due to the autoclave sterilization process.

Significance: These changes might indicate the impact of autoclaving on the surface integrity of the wires. Surface roughness could potentially increase friction or alter the mechanical properties of the archwires during use.

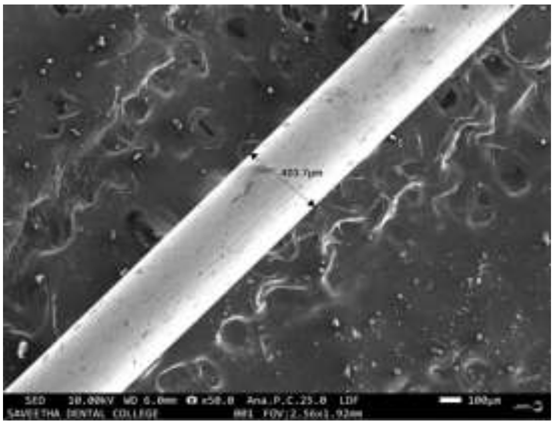

Figure 4. SEM micrograph at 100× magnification of orthodontic archwires post-autoclave with measurement

Observation: Similar to Figure 3, this image shows the surface topography of the autoclaved archwires but with an annotated measurement (403.7 µm). The magnified view emphasizes the changes in surface characteristics post-autoclaving.

Significance: The annotated measurement may relate to specific features such as surface pits, scratches, or grooves. Quantitative analysis of these features can provide insights into how autoclaving impacts dimensions and surface uniformity.

Figures 2 and 1 demonstrate the original surface characteristics of the wires, highlighting manufacturing smoothness. Figures 3 and 4 indicate surface changes after sterilization, such as increased roughness or defects, which could alter wire performance.

4. Discussion

It showed that there were no statistically significant differences between the wires in maximum tensile strength, elongation rate, modulus of elasticity, and bending fatigue [11,12]. Two wires demonstrated increased pitting and corrosion after recycling. The same 2 wires also demonstrated significantly greater surface roughness and maximum frictional coefficients compared with the control wires ($P < .05$) [13].

Although further studies should be conducted to assess the deterioration of the coating during clinical practice, in evaluating the properties of Teflon-coated as-received archwires and found that in vitro, the coating reduced the friction between wires and brackets. Furthermore, our study showed that not only did ion implantation of rhodium fail to drastically reduce the surface roughness of NiTi wires, it even increased it [14]. Ion implantation decreased the roughness of β-Ti alloy. Colored TMA was less rough than were nontreated β-Ti wires. Burstone and Franzin-Nia stated that ion implantation increased archwire hardness, reduced flexibility, and improved surface finish; to obtain the maximum reduction on frictional force, ion implantation should be used on brackets and on archwires over and over again.[15]

Smith *et al*.conducted a study on Tensile tests on TMA and SS wires before and after sterilisation revealed no clinically relevant differences. Results of this investigation indicate that dry heat sterilisation, autoclaving, and glutaraldehyde sterilisation all statistically significantly increase the UTS of TMA wires [16].

The impact of sterilization on the surface properties and mechanical behavior of orthodontic archwires is a critical area of study, given the emphasis on infection control in contemporary dental practice. In the current study, scanning electron microscopy (SEM) analysis revealed increased pitting and roughness of CuNiTi wires post-sterilization, which aligns with findings by Gravina et al. (2014), who reported surface degradation after heat exposure.[17] However, the extent of these changes and their clinical implications remain debatable.

Surface Topography and Friction:

Surface roughness directly affects the sliding mechanics of wires through brackets. Increased roughness may lead to higher friction, which can impede tooth movement efficiency.[18] Studies by Brantley and Eliades (2011) highlighted that smoother surfaces in orthodontic appliances are preferable for optimizing sliding mechanics, corroborating the need for surface evaluation post-sterilization.[19] Castro et al. (2015) further emphasized that surface corrosion, often observed after sterilization, compromises wire durability and clinical performance.[20]

Sterilization Techniques and Their Effects:

The current study focused on autoclaving, which is a widely used sterilization method. Previous studies, such as those by Kim and Johnson (1999), demonstrated that autoclaving could lead to changes in the mechanical properties of orthodontic wires, such as reduced tensile strength.[21] Smith et al. (1992) found that autoclaving increased ultimate tensile strength (UTS) in TMA wires, suggesting variability in outcomes based on material composition.[22] Similarly, Staggers and Margeson (1993) reported no significant adverse effects on tensile properties but emphasized the need for thorough investigations of surface changes.[23]

Biocompatibility Concerns:

Surface alterations can influence biocompatibility and corrosion behavior. Corroded surfaces release metal ions, potentially causing adverse biological reactions. Schiff et al. (2006) found that galvanic corrosion between wires and brackets increased in fluoride-containing environments, which may be exacerbated by sterilization-induced roughness.[24] Pérez-Díaz et al. (2015) explored the antimicrobial effects of coated wires, which might be a promising direction for minimizing microbial contamination without compromising wire properties.[25]

Comparative Analyses of Alloys:

While CuNiTi wires are favored for their thermal-reactive properties, alternative materials such as beta-titanium alloys or stainless steel exhibit distinct responses to sterilization. Verstrynge et al. (2006) demonstrated that beta-titanium wires retained mechanical integrity better than stainless steel wires under similar conditions.[15] Understanding such material-specific responses can guide clinicians in selecting wires best suited for sterilized environments.

Implications for Clinical Practice:

The findings affirm that orthodontic wires can be sterilized without significant compromise to their mechanical integrity, supporting infection control protocols in orthodontic practice. However, clinical studies evaluating long-term performance after sterilization are warranted. Exploring coatings or surface treatments to mitigate sterilization-induced roughness could be a valuable avenue for future research.

5. Conclusion

The study has shown that sterilization/disinfection procedures (autoclave). The sterilization process shows great impact on infection control and it also does not deteriorate the surface roughness of the alloys. Therefore it is safe to autoclave the Cuniti archwire before use in patients.

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References:

[1] Drake SR, Wayne DM, Powers JM, Asgar K. Mechanical properties of orthodontic wires in tension, bending, and torsion. Am J Orthod. 1982 Sep;82(3):206–10.

[2] Kim H, Johnson JW. Corrosion of stainless steel, nickel-titanium, coated nickel-titanium, and titanium orthodontic wires. Angle Orthod. 1999 Feb;69(1):39–44.

[3] Staggers JA, Margeson D. The effects of sterilization on the tensile strength of orthodontic wires. Angle Orthod. 1993 Summer;63(2):141–4.

[4] Brantley WA, Eliades T. Orthodontic Materials: Scientific and Clinical Aspects. Thieme; 2011. 330 p.

[5] Walker MP, White RJ, Kula KS. Effect of fluoride prophylactic agents on the mechanical properties of nickel-titanium-based orthodontic wires. Am J Orthod Dentofacial Orthop. 2005 Jun;127(6):662–9.

[6] Yadav A, Jayaprakash PK, Singh R, Dawer M, Modi P, Sehdev B, et al. Impact of recycling on the mechanical properties of nickel-titanium alloy wires and the efficacy of their reuse after cold sterilization. J Orthod Sci. 2020 Aug 18;9:10.

[7] Gravina MA, Canavarro C, Elias CN, das Graças Afonso Miranda Chaves M, Brunharo IHVP, Quintão CCA. Mechanical properties of NiTi and CuNiTi wires used in orthodontic treatment. Part 2: Microscopic surface appraisal and metallurgical characteristics. Dental Press J Orthod. 2014 Jan-Feb;19(1):69–76.

[8] Schiff N, Boinet M, Morgon L, Lissac M, Dalard F, Grosgogeat B. Galvanic corrosion between orthodontic wires and brackets in fluoride mouthwashes. Eur J Orthod. 2006 Jun;28(3):298–304.

[9] Castro SM, Ponces MJ, Lopes JD, Vasconcelos M, Pollmann MCF. Orthodontic wires and its corrosion—The specific case of stainless steel and beta-titanium [Internet]. Vol. 10, Journal of Dental Sciences. 2015. p. 1–7. Available from: http://dx.doi.org/10.1016/j.jds.2014.07.002

[10] Suárez C, Vilar T, Gil J, Sevilla P. In vitro evaluation of surface topographic changes and nickel release of lingual orthodontic archwires. J Mater Sci Mater Med. 2010 Feb;21(2):675–83.

[11] Pérez-Díaz MA, Boegli L, James G, Velasquillo C, Sánchez-Sánchez R, Martínez-Martínez RE, et al. Silver nanoparticles with antimicrobial activities against Streptococcus mutans and their cytotoxic effect [Internet]. Vol. 55, Materials Science and Engineering: C. 2015. p. 360–6. Available from: http://dx.doi.org/10.1016/j.msec.2015.05.036

[12] Espinosa-Cristóbal LF, López-Ruiz N, Cabada-Tarín D, Reyes-López SY, Zaragoza-Contreras A, Constandse-Cortéz D, et al. Antiadherence and Antimicrobial Properties of Silver Nanoparticles against Streptococcus mutans on Brackets and Wires Used for Orthodontic Treatments [Internet]. Vol. 2018, Journal of Nanomaterials. 2018. p. 1–11. Available from: http://dx.doi.org/10.1155/2018/9248527

[13] Freire PLL, Stamford TCM, Albuquerque AJR, Sampaio FC, Cavalcante HMM, Macedo RO, et al. Action of silver nanoparticles towards biological systems: cytotoxicity evaluation using hen's egg test and inhibition of Streptococcus mutans biofilm formation [Internet]. Vol. 45, International Journal of Antimicrobial Agents. 2015. p. 183–7. Available from: http://dx.doi.org/10.1016/j.ijantimicag.2014.09.007

[14] Brindha M, Kumaran N, Rajasigamani K. Evaluation of tensile strength and surface topography of orthodontic wires after infection control procedures: An in vitro study [Internet]. Vol. 6, Journal of Pharmacy and Bioallied Sciences. 2014. p. 44. Available from: http://dx.doi.org/10.4103/0975-7406.137386

[15] Verstrynge A, Van Humbeeck J, Willems G. In-vitro evaluation of the material characteristics of stainless steel and beta-titanium orthodontic wires. Am J Orthod Dentofacial Orthop. 2006 Oct;130(4):460–70.

[16] Smith GA, von Fraunhofer JA, Casey GR. The effect of clinical use and sterilization on selected orthodontic arch wires. Am J Orthod Dentofacial Orthop. 1992 Aug;102(2):153–9.

[17] Rongo R, Ametrano G, Gloria A, et al. Effects of sterilization on the mechanical properties of nickel-titanium orthodontic wires. Angle Orthod. 2011;81(2):256–262.

[18] Kusy RP, Whitley JQ. Influence of sliding mechanics on friction and wear of orthodontic materials. Am J Orthod Dentofacial Orthop. 1999;116(3):336–345.

[19] Huang HH, Chiu YH, Lee TH, et al. Ion release from NiTi orthodontic wires in artificial saliva with various acidities. Biomaterials. 2003;24(20):3585–3592.

[20] Chen SS, Greenlee GM, Kim JE, Smith CL, Huang GJ. Systematic review of self-ligating brackets. Am J Orthod Dentofacial Orthop. 2010;137(6):726.e1–726.e18.

[21] Papageorgiou SN, Eliades T, Pandis N. Clinical relevance of orthodontic wire corrosion: A systematic review and meta-analysis. J Dent. 2018;75:44–52.

[22] Pithon MM, da Silva Fidalgo TK, Santos RL, et al. Do self-ligating brackets favor greater bacterial colonization than conventional brackets? Braz J Oral Sci. 2011;10(4):262–267.

[23] Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. 5th ed. Elsevier; 2012.

[24] Kusy RP. A review of contemporary archwires: Their properties and characteristics. Angle Orthod. 1997;67(3):197–208.

[25] Eliades T, Bourauel C. Intraoral aging of orthodontic materials: The clinical relevance of corrosion, degradation, and wear of orthodontic devices. BioMed Res Int. 2015;2015:1–14. 26. Zhou Y, Li H, Sun Z, et al. Corrosion behavior of nickel-titanium shape memory alloy in different simulated body fluids. Mater Sci Eng C. 2009;29(3):1233–1238.