Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/mjafi

Original Article

Surface characterization of nickel titanium orthodontic arch wires

Lt Col Manu Krishnan [a,*], Saraswathy Seema [b], Brijesh Tiwari [c], Col Himanshu S. Sharma [d], Maj Gen Sanjay Londhe [e], Lt Gen Vimal Arora, AVSM,VSM**, PHDS[f]

[a] Classified Specialist (Orthodontics), Dept of Dental Research & Implantology, Institute of Nuclear Medicine and Allied Sciences (INMAS), Defence Research and Development Organization (DRDO), Timarpur, Delhi 1100054, India

[b] Research Scholar, School of Medicine and Paramedical Health Sciences, Guru Gobind Singh Indraprastha University, Delhi Cantt, India

[c] Senior Research Fellow (Project), Dept of Dental Research & Implantology, Institute of Nuclear Medicine and Allied Sciences (INMAS), Defence Research and Development Organization (DRDO), Timarpur, Delhi, India

[d] Commanding Officer, Military Dental Centre, Delhi Cantt, India

[e] Addl Director General Dental Services, IHQ of MoD (Army), New Delhi 110001, India

[f] Director General Dental Services & Colonel Commandant, O/o DGDS, Adjutant General's Branch, IHQ of MoD, L Block, New Delhi 110001, India

ARTICLE INFO

Article history:
Received 13 September 2013
Accepted 11 December 2013
Available online 3 April 2014

Keywords:
Nickel titanium arch wire
Root mean square roughness
Scanning electron microscopy
Raman spectroscopy
Atomic force microscopy
3D profilometry

ABSTRACT

Background: Surface roughness of nickel titanium orthodontic arch wires poses several clinical challenges. Surface modification with aesthetic/metallic/non metallic materials is therefore a recent innovation, with clinical efficacy yet to be comprehensively evaluated.

Methods: One conventional and five types of surface modified nickel titanium arch wires were surface characterized with scanning electron microscopy, energy dispersive analysis, Raman spectroscopy, Atomic force microscopy and 3D profilometry. Root mean square roughness values were analyzed by one way analysis of variance and post hoc Duncan's multiple range tests.

Results: Study groups demonstrated considerable reduction in roughness values from conventional in a material specific pattern: Group I; conventional (578.56 nm) > Group V; Teflon (365.33 nm) > Group III; nitride (301.51 nm) > Group VI (i); rhodium (290.64 nm) > Group VI (ii); silver (252.22 nm) > Group IV; titanium (229.51 nm) > Group II; resin (158.60 nm). It also showed the defects with aesthetic (resin/Teflon) and nitride surfaces and smooth topography achieved with metals; titanium/silver/rhodium.

Conclusions: Resin, Teflon, titanium, silver, rhodium and nitrides were effective in decreasing surface roughness of nickel titanium arch wires albeit; certain flaws. Findings have clinical implications, considering their potential in lessening biofilm adhesion, reducing friction, improving corrosion resistance and preventing nickel leach and allergic reactions.

* *Corresponding author*. Tel.: +91 (0) 11 23939588, +91 8860821484.
E-mail addresses: manukrishnanin@yahoo.co.in, manuseema13@gmail.com (M. Krishnan).

http://dx.doi.org/10.1016/j.mjafi.2013.12.006

Introduction

Ever since the report of 'shape memory effect' in nickel titanium (NiTi) alloy in 1962, several applications of the material in medical and dental disciplines have been identified till now.[1] Nickel titanium (NiTi) arch wires with its unique shape memory and super elasticity properties are integral components of contemporary orthodontic practice.[2] However, the high content of nickel (Ni: 47–50%) in NiTi alloys and its extremely rough surface topography are confronting issues in orthodontics.[3] The increased propensity of plaque accumulation, frictional forces at wire-bracket interface, nickel leach and wire fracture ensuing intra oral corrosion are consequent to it.[4] Nickel release, in turn is known to initiate several adverse responses, ranging from allergic hypersensitivity reactions to extremes of carcinogenic changes.[5] As for any other metallic alloy, NiTi also has oxide layers on its surface (TiO_2, TiO, Ti_2O_5 and NiO), which renders it the natural protection.[6] These oxides are formed on the wire surface during its 'wire drawing procedures' from large 'ingot' blocks.[1] Yet, these are removed during clinical use and electrochemical potential differences are generated which initiates pitting and crevice corrosion.[7,8] To a large extent, all these have been attributed to the high surface roughness of NiTi wires.[9–11]

In this context, there are some attempts to modify NiTi arch wire surface with metals, non-metals and aesthetic materials with the objective of reducing surface roughness so as to enhance esthetics and to lessen friction, corrosion and nickel leach.[12] Surface engineering as a distinct discipline has made remarkable strides in the field of material technology during the last two decades and its medical and dental applications are manifold.[12–14] Configuring a surface barrier layer on biomaterials like pacemakers, stents, implants and other devices with an 'environment-friendly material' is an innovative step for improving biocompatibility.[15] Surface modification of dental materials are done either through plasma spraying or physical/chemical vapour deposition; where atoms, ions or molecules activated by plasma, laser or high energy beams are condensed on the substrates.[16,17] The methods specifically used for orthodontic arch wires are electron beam deposition, magnetron sputtering, cathodic arc deposition or pulsed laser deposition.[18]

Surface roughness of materials is measured by profilometric or optical methods and is generally expressed as root mean square (RMS) values.[19] Earlier, invasive profilometric procedures were used to determine surface roughness of NiTi wires.[20] At present, there are many non invasive options for assessing the exteriors of materials used in industry, medicine and dentistry. These include qualitative and quantitative means like scanning electron microscopy (SEM), energy dispersive analysis (EDS), spectroscopic techniques like Raman spectroscopy, atomic force microscopy (AFM) and of late, the advanced three dimensional optical profilometry (3D OP).[21] Still, these have not so far been comprehensively used to evaluate the topography of surface modified NiTi wires. In this study, prototypes of all currently available versions of these wires were included to assess the surface features, which have a close bearing on their clinical performance. Additionally, none of these products are indigenously manufactured and there is an influx of these imported products into Indian dental market at a high cost but with fewer evidences in favour of them.

The aim of the current study was therefore to characterize the topographic features of five newly introduced surface modified NiTi wires along with a conventional type, using advanced optical methods.

Material and methods

The study groups included 5 types of surface modified nickel titanium wires and one group of conventional NiTi in 0.016 inch (0.406 mm) round dimension. Group 1: Conventional NiTi; (Ortho Organizers, San Marcos, CA), Group II: Spectra Epoxy (GAC International, Bohemia, NY), Group III: Neo Sentalloy (GAC International, Bohemia, NY), Group IV: Black Titanium (Class One Orthodontics, St. Lubbock), Group V: Teflon (d-Tech Asia Ltd, Pune) and Group VI: Silver–Rhodium (d-Tech Asia Ltd, Pune). Since group VI had a dual covering of silver and rhodium, they are represented as group VI (i) for silver and group VI (ii) for rhodium. The study design is shown in Table 1.

Preliminary surface analysis of the arch wires were done with SEM (SNE-3000M model, SEC, Korea) at 500× magnification. Elemental mapping was carried out with EDS (SNE-3000M model, SEC, Korea) and Raman Spectroscopy (HR 800, Jobin Yvon, Spectrometer, Horiba Ltd, Minami-Ku, Kyoto) equipped with 1800 grooves/mm holographic grating. Helium–Neon laser of 633 nm was used as the excitation source. The laser spot size of 3 μm diameter was focused on the sample surface using a diffraction limited 10× objective. The laser power at the sample was ≈20 mW and slit width of the monochromator was 400 μm. The back scattered Raman spectra were recorded using super cooled (<-110 °C) 1024 × 256 pixels charge coupled device (CCD) detector with range from 80 cm^{-1} to 2000 cm^{-1} with 5 s exposure time and 20 CCD accumulations. All the spectra were then baseline corrected. Three different areas of the wire were checked for each sample.

Surface roughness was initially evaluated with Solver Pro EC atomic force microscope (NT-MDT, Zelenograd, Moscow). All measurements were carried out in contact mode using a standard conical silicon tip attached to a cantilever having a force constant of 5 nNm^{-1} with a frequency limit from 50 to 150 Hz. The radius of curvature of the tip was 10 nm and the cone angle was $<22°$. The scan area was 50 × 50 μm of each sample, at three different locations. Averages of these from six ($n = 6$/group) wire samples were taken to express the

Table 1 – Study design ($n = 6$ per group) of arch wires in 0.016 inch (0.406 mm) round dimensions.

Group	Product	Manufacturer
I	Conventional NiTi	Ortho Organizers, San Marcos, CA
II	Spectra Epoxy	GAC International, Bohemia, NY
III	Neo Sentalloy	GAC International, Bohemia, NY
IV	Black Titanium	Class One Orthodontics, St. Lubbock
V	Teflon	d-Tech Asia Ltd, Pune
VI	Silver–Rhodium	d-Tech Asia Ltd, Pune