Orthodontic mechanotherapy encompasses the use of several archwires during specific stages of treatment. Stainless steel, Nickel titanium (NiTi), thermally activated Nickel titanium (CuNiTi), & b titanium (TMA) wires are the ones predominantly in use. The efficiency of sliding mechanics depends upon minimizing friction at the bracket arch wire interface. Friction may be influenced by several factors such as the force with which the archwire contacts the brackets, the contact angle between the archwire and bracket as well as the surface characteristics of the brackets and archwires. Alteration of the surface characteristics of archwires by way of pitting and corrosion of the surface would add to the coefficient of friction in the mechanics, thereby compromising the sliding of brackets along archwires.

This study was carried out to evaluate the effect of routinely used fluoride prophylactic agents on the relevant mechanical properties as well as surface topography of various orthodontic arch wires and dwell on the consequence of the same in routine clinical orthodontic practice.
agents. Mary P. Walker & Richard White in 2005 have shown that titanium based arch wires particularly NiTi and CuNiTi show occurrence of corrosion, pitting and inclusion bodies on the surface upon exposure to neutral and acidulated fluoride prophylactic agents. Also the wires exhibited deterioration of relevant mechanical properties namely modulus of elasticity and yield strength during the unloading or deactivation phases which may influence effective tooth movement brought about by these wires. On the other hand Schwanger and Sarkar in 1982 had evaluated flexural properties of Nitinol wires, namely modulus of stiffness, flexural yield strength and fatigue after periods of immersion in 1% NaCl solution and concluded that corrosion does not affect the physical properties of the arch wires. An S.E.M. examination of the surfaces fractured after repetitive 90° bending also revealed similar i.e. ductile modes of fracture for both corroded and control samples.

The titanium based archwires are known to have high corrosion resistance attributable to the formation of a stable oxide layer as a result of passivation. The stainless steel alloys also have significant corrosion resistance due to the passivating effect of chromium.

It would be interesting to evaluate the effect of routinely used fluoride prophylactic agents on the relevant mechanical properties as well as surface topography of various orthodontic arch wires and dwell on the consequence of the same in routine clinical orthodontic practice. For the purpose of convenience, this article has been divided into 2 parts; part I dealing with effects on mechanical properties and part II dealing with surface topography.

AIMS

1) To evaluate alterations in the mechanical properties i.e. modulus of elasticity and yield strength in loading and unloading phases for five different orthodontic arch wires, namely stainless steel, Nickel titanium, copper nickel titanium, b titanium and Australian 0.016″ stainless steel wires upon exposure to routinely used fluoride prophylactic agents for a predetermined period of time.

2) To determine alteration in surface topography (i.e. evaluation of corrosion, surface pitting and scratches and inclusion bodies) of the above mentioned wire specimens after exposure to fluoride containing prophylactic agents for a predetermined period of time.

OBJECTIVE

The prime objective of this study is to determine whether possible pitting and corrosion on the surface of various orthodontic arch wires following exposure to fluoride prophylactic agents and subsequently increase in the friction at the bracket wire interface is a deterrent for the use of these agents considering the established beneficial effects of these prophylactic agents in preventing decalcification of teeth around orthodontic brackets.

Evaluation of deterioration of relevant mechanical properties in the wires will also indicate whether the ill-effects outweigh the benefits of these prophylactic agents.

METHOD AND MATERIALS

The study was carried out at the metallurgy laboratory of the ‘AUTOMOTIVE RESEARCH ASSOCIATION OF INDIA’, (ARAI), Pune and the Department of Orthodontics and Dentofacial Orthopedics, Bharati Vidyapeeth Deemed University, Dental College & Hospital, Pune.

The material used for the study included five (5) different types of pre-formed arch wires namely NiTi, CuNiTi, TMA (beta titanium), stainless steel, and Australian stainless steel wires; three (3) fluoride containing prophylactic agents and a control solution (artificial saliva). Each of the five groups of wires consisted of 24 wire specimens. The five groups of wires selected were:

Group I : 0.017″ x 0.25″ NiTi arch wires  
(LIBRAL, Okhla Industrial Area, New Delhi, India ; Lot # 545)

Group II : 0.017″ x 0.25″ CuNiTi arch wires  
(LIBRAL, Okhla Industrial Area, New Delhi, India ; Lot # 685)

Group III : 0.017″ x 0.25″ TMA (b Titanium) arch wires  
(LIBRAL, Okhla Industrial Area, New Delhi, India ; Lot # 2105)

Group IV : 0.017″ x 0.25″ Stainless Steel arch wires  
(LIBRAL, Okhla Industrial Area, New Delhi, India ; Lot # 3105)

Group V : 0.016 " A.J. WILCOCK. SPECIAL PLUS Australian Arch Wire Spool (Ref : 505-RCK CO795 AJ WILCOCK Pty.Ltd. Whittlesea 3757 Australia)
The fluoride agents selected were as follows, (Photograph 1)

1) Acidulated phosphate fluoride gel (APF gel) containing 1.23% w/v sodium fluoride with a pH of 3.5 ± 0.5 Pascal company Inc P.O. Box 1478; Bellevue WA, USA

2) Neutral fluoride gel (1.10% w/v sodium fluoride with a pH of 6-8 Pascal company Inc P.O. Box 1478; Bellevue WA, USA)

3) Phosflur mouth rinse (1.23% sodium fluoride acidulated phosphate; 0.04% w/v sodium fluoride pH = 5-6 Colgate oral pharmaceuticals, Canton Mass; USA)

These agents were selected since they are commonly prescribed by the orthodontists to his/her patients during orthodontic treatment. Also, their pH values were significantly different from each other.

The control solution used was artificial saliva containing methyl cellulose 0.5% w/v and glycerin 30% w/v per 5 ml of solution, pH=7 (ICPA health products LTD. 286 GIDC. Ankleshwar 393002) (Photograph 1)

Each wire specimen was 0.42 x 0.62 x 25 mm in dimension, cut from the straight portion of the preformed archwires except the 0.016” Australian s.s. wire, where the specimens were cut from the spool for the desired length.

Method:
The control group & experimental groups were established as follows:

CONTROL GROUP : Thirty (30) wire samples consisting of six (6) samples from each wire group which were immersed in artificial saliva.

EXPERIMENTAL GROUPS :
Group 1 : Thirty (30) wire samples consisting of six (6) samples from each wire group which were immersed in the APF gel.

Group 2 : Thirty (30) wire samples consisting of six (6) samples from each wire group which were immersed in the Neutral fluoride gel.

Group 3 : Thirty (30) wire samples consisting of six (6) samples from each wire group were immersed in the phosflur fluoride rinse.

Six specimens from each wire group were incubated in 10 ml artificial saliva at 37⁰c in an individual plastic container. This constituted the control sample (30 wire specimens). Six (6) specimens from each group were also incubated in each of the three fluoride containing agents (10 ml each agent) in individual plastic containers at 37⁰c for 90 minutes. These wire specimens constituted the three experimental groups (30 wire specimens in each group; Photograph 2). The exposure time of 90 minutes would be equivalent to three months of 1 minute daily topical fluoride application or fluoride rinse as stated by Mary Walker and Richard White in 2005.

Just before mechanical testing, the specimens in the experimental groups were removed from their respective solutions, rinsed with artificial saliva and placed in new, clean containers.

After the mechanical testing, as described in part I of the article one representative specimen was selected from each wire/experimental condition group including one specimen from the control solution for SEM analysis.
to qualitatively characterize the topography of the wire surface. The specimens were mounted directly on the metals stubs and observed using a FEI Quanta 200S.E.M. set at 15.0KV and observed at a depth of 20 micron. The SEM photomicrographs were made at 2500x magnification. The SEM photomicrographs were evaluated for alterations in the surface topography of the various wire specimens in the form of pitting, corrosion and fluoride inclusion bodies.

The NiTi wire surfaces exposed to artificial saliva show some dark areas without evidence of corrosion, which may be by-products of the manufacturing process. After exposure to the APF gel, the surface of the wire specimen exhibited a pitted appearance and chemical segregations of black areas in the matrix. There was an increased appearance of black spots which appeared to be inclusion bodies that may have been revealed by the action of the fluoride agent. Similar effects were also noticed upon exposure of the wire specimen to the phosphor APF rinse along with distortion of the metal surface. Exposure of the NiTi wire specimen to the Neutral fluoride gel also resulted in chemical segregation of black areas in the metal matrix and distortion of the metal surface.

Exposure to artificial saliva had no effect on the surface topography of the Cu NiTi wire specimens. Upon exposure to the APF gel and the phosphor APF rinse, pitting of the wire surface was seen. There appeared to be segregation of black areas in the metal matrix indicating significant corrosion of the metal surface. Numerous black spots were also visible which may represent inclusion bodies. Wire samples exposed to the neutral fluoride gel also exhibited pitting and corrosion of the wire surface with segregation of black areas in the metal matrix, but to a lesser extent than with the acidulated fluoride agents.

The TMA wire samples exposed to artificial saliva did not show any alterations in surface topography with no signs of corrosion of the metal surface. The wire specimen exposed to the phosphor APF rinse, the neutral fluoride gel and the APF gel showed pitting and erosion of the metal surface with increased appearance of black spots which may represent inclusion bodies. The wire specimen exposed to the APF gel showed especially heavy distortion of the metal surface. The wire samples exposed to the neutral fluoride gel showed limited chemical segregations of black areas in the metal matrix indicating erosion of the metal to a lesser extent as compared to the acidulated fluoride agents.

Exposure of SS wire samples to artificial saliva had no corrosive effect on the stainless steel metal surface. Occasional gray and black areas were seen which may be by-products of the manufacturing process. Upon exposure to the phosphor APF rinse, chemical segregation of black areas in the metal matrix was seen along with erosion of the metal surface. Exposure of the stainless steel wire specimen to the APF gel resulted in chemical segregation of black areas along the direction of extrusion of the metal surface in a single direction. The stainless steel wire specimen exposed to the neutral fluoride gel exhibited limited

Result

The results for the mechanical testing of the wires have been addressed in Part I of this article. The following are the results of SEM scans of the corresponding wire specimens.
seggregation of black areas in the matrix with no erosion effect on the metal surface.

Exposure of the Australian SS wire specimens to artificial saliva had no erosive effect on the surface area of the metal matrix. Exposure to the phosflur APF rinse resulted in pitting marks in the extrusion direction due to surface roughness which may be caused by the fluoride agent. The wire specimen exposed to the neutral fluoride gel showed limited chemical segregation of black areas in the metal matrix and pitting marks in the direction of extrusion along with surface roughness. Upon exposure of the Australian stainless steel wire specimen to the APF gel, chemical segregation of black areas within the metal matrix was seen along with heavy pitting of the metal surface. The pitting in this case was also in the direction of extrusion of the metal surface.

The representative S.E.M photomicrographs demonstrating the effect of various fluoride agents on the tested wire sample are displayed below:

Photomicrograph showing chemical segregation of black areas in the matrix of NiTi wires on exposure to APF gel.

Photomicrograph showing chemical segregation of gray and black areas in the matrix along with erosion effect of stainless steel in phosflur rinse.

Photomicrograph showing pitting marks in extrusion direction due to surface roughness in Australian SS wire on exposure to APF gel.
DICUSSION
The Cu-NiTi wire specimens exposed to fluoride agents exhibited pitting and corrosion of the wire surfaces as suggested by the S.E.M. photomicrographs. In a clinical setting, corrosion of the Cu-NiTi wire surfaces may add to the coefficient of kinetic friction at the bracket-wire interface, thereby interfering with effective tooth movement.

Exposure of the TMA wire specimens to fluoride agents resulted in pitting and erosion of the wire surfaces as suggested by the SEM photomicrographs. The APF gel caused particularly heavy distortion of the wire surfaces. It was interesting to note that despite the corrosive effects seen on the TMA wire surfaces, the unloading mechanical properties of the wire specimens were not affected. In clinical situations, although the surface corrosion caused by the fluoride agents may add to the component of kinetic friction, the clinically mechanical properties of the TMA wires, namely, the springback and resiliency may not be affected. Hence the effectiveness of tooth movement particularly during retraction of teeth using TMA loop mechanics or intrusion of anterior teeth using TMA utility arches may not be adversely affected.

The effect of the fluoride agents on stainless steel wire specimens in this study seems to be limited to corrosive effects on the wire surfaces particularly in case of acidulated fluoride agents. These corrosive effects may add to the coefficient of kinetic friction at the bracket-wire interface in clinical situations and thereby interfere with effective tooth movement brought about by stainless steel wires i.e. it may interfere with tooth movement during sliding mechanics, where rectangular stainless steel wires are used to retract the anterior teeth.

Exposure of the Australian stainless steel wire specimens to the fluoride agents also resulted in pitting and corrosion of the wire surfaces as suggested by the SEM photomicrographs. Clinically, this may result in an increased coefficient of kinetic friction at the bracket-wire interface, particularly during canine retraction using sliding mechanics, thereby unduly straining the anchor units as well as delaying the canine retraction.

A qualitative S.E.M. analysis of the wire surface topography was also included in this study to study the possible corrosion of the orthodontic wires following exposure to fluoride agents as well as to determine a possible link between deterioration of mechanical properties and alteration of surface topography of orthodontic wires by the experimental fluoride agents. The effect on titanium based wires included pitting and corrosion of the wire surfaces and appearance of inclusion bodies along the entire length of the wire surfaces. There was variation amongst specimens in the severity of pitting and inclusion bodies which may be attributable to the agents having a lower pH and higher fluoride concentration. In addition to the afore-mentioned observation in titanium based wire specimens, this study also found severe corrosion effects i.e. pitting and corrosion of the surface with inclusion bodies on the surface of stainless steel and Australian stainless steel wires. In all the five wire groups, the acidulated fluoride agents had a greater corrosive and pitting effect than the neutral fluoride agent, with greater distortion of the metal surface.

Although the three fluoride agents produced surface corrosive topographical effects on NiTi, Cu-NiTi, bTi, Titanium, stainless steel & Australian stainless steel wires, the degradation of mechanical properties occurred only in the NiTi, Cu-NiTi and Australian stainless steel wire specimens.

Hence a possible link between surface corrosion and mechanical property deterioration could exist for NiTi, Cu-NiTi and Australian Stainless Steel archwires exposed to fluoride containing agents. There may be a possible correlation between the surface corrosion and hydrogen embrittlement with subsequent alteration of the crystal lattice structure in the above mentioned archwires. These events may eventually result in the deterioration of the mechanical properties in the arch wires.

SUMMARY AND CONCLUSION
All the tested wire specimens exhibited corrosive alterations in their surface topography upon immersion in fluoride agents. The acidulated fluoride agents appeared to cause greater corrosive effects and degradation of unloading mechanical properties of the wire specimens as compared to the neutral fluoride agents. Corrosive effects observed on the wire specimen surfaces may have the clinical implication of increased coefficient of friction of the bracket wire interfaces in clinical settings. This may interfere with effective sliding of teeth across the arch wires. In case of the Australian stainless steel wires, the increased frictional resistance may add extra strain on the anchor units when these wires are used for retraction of canines during sliding mechanics resulting in anchor loss. Additionally, the increased friction may also delay the desired tooth movement.
REFERENCES


