In Vivo Comparison of Ultimate Tensile Strength of Nickel-Titanium Aligning Archwires Exposed to Fluoridated Mouthwash

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ABSTRACT

Introduction: Orthodontists usually prescribe fluoridated mouthwash to their patients to mitigate risk of dental caries. These mouthwashes may alter the mechanical properties of archwires by dissolving the protective oxide-layer. The aim of the study was to examine the effects of fluoridated mouthwash on ultimate tensile strength of NiTi wires after three months of intra-oral use.

Materials & Method: Sixty 0.014" (0.36mm) Nickel-titanium (NiTi) wires (Ormco Corp, Glendora, USA) were divided into three groups: Group A: as-received archwires serving as controls, Group B: intra-oral used wires exposed to placebo mouthwash and Group C: intra-oral used wires exposed to fluoridated mouthwash for a period of 3 months. Each wire was subjected to tensile testing using a table-top tensile testing apparatus. Ultimate tensile strength data was analysed with one-way analysis of variance (ANOVA) and Tukey testing at the 0.05 level of significance.

Result: Results showed that amongst tested wires, those exposed to fluoridated mouthwash had least tensile strength (79.45 ± 1.33 N) as compared to wires exposed to placebo mouthwash (99.95 ± 0.91 N) and those in the control group (117.69 ± 0.66 N). The results were statistically significant at $p < 0.001$.

Conclusion: Ultimate tensile strength was least for wires exposed to fluoridated mouthwashes for a period of 3 months. Non-fluoridated mouthwashes can be used during the initial phase of leveling and aligning with NiTi wires.

Keywords: Fluoridated mouthwash, NiTi, Ultimate tensile strength.

INTRODUCTION

Malocclusion, is a common dental problem in India and has a wide prevalence of 20 to 88 %.[1] Orthodontic mechanotherapy is applied to correct these abnormalities, either by removable or fixed method. Archwires form a cornerstone of such mechanotherapy, by exerting mechanical forces to align maloccluded teeth.

Today's armamentarium of archwires, range from older stainless-steel (SS) wires to newer NiTi (nickel-titanium), CuNiTi (copper nickel-titanium) and TMA (titanium molybdenum alloy) alloy archwires.[2] Among these, NiTi wires have earned a special place due to their inherent properties of superelasticity and shape memory.[3] Corrosion resistance of these wires is supposedly due to formation of a thin, stable titanium oxide layer during intra oral use.[4,5] NiTi wires enable a clinician to apply, light continuous force, over large activation areas with reduced patient discomfort.

Development of dental caries during orthodontic therapy is common, hence orthodontists often recommend prophylactic use of fluoride containing mouthwash to mitigate it.[6,7] There is current evidence to link use of fluoride mouthwashes and increase in the leaching of Ni and Cr ions from NiTi archwires.[8] Fluoridated mouthwashes are commercially available in two strengths, sodium fluoride 0.05 % for daily use and sodium fluoride 0.2% for weekly use, and both are equally effective for prophylactic use.[9]

Systemic consumption of fluorides in some endemic areas, through water and even accidental ingestion (common among small children while brushing with fluoride toothpaste) is detrimental to health (skeletal and dental fluorosis). Ni and Cr ion leaching have been

associated with genotoxic and cytotoxic changes in mucosal cells.[10,11] Further, corrosive damage alters the mechanical properties of NiTi archwires by reducing the ultimate tensile strength and increasing NiTi wire fracture rates.

It is widely known that older stainless steel archwires are more prone to corrosion than newer (NiTi) archwires.[6] Many in vitro studies have been carried out on corrosive resistance properties of NiTi alloys in an artificial physiological solution (fluoridated and non-fluoridated Fusayama–Meyer artificial saliva).[4,12-14] However, scant information exists today to interpret and compare "in vivo" effects of fluoridated mouthwashes on ultimate tensile strength of nickel-titanium archwires. The present study hypothesized that fluoridated mouthwashes alter the mechanical properties of NiTi archwires when used intra-orally for a period of 3 months.

The purpose of this prospective randomised "in vivo" study was to evaluate the effect of fluoride mouthwash when used for a period of three months on the ultimate tensile strength of nickel-titanium archwires.

MATERIALS AND METHOD

Sixty 0.014-inch NiTi archwires (Ormco Corp, Glendora, USA) were divided into three equal sub-groups of twenty each: (A) As-received wires which served as baseline (B) Intra-oral used wires exposed to placebo mouthwash, (C) Intra-oral used wires exposed to fluoridated mouthwash (0.05% sodium fluoride) Colgate Plax (Colgate-Palmolive Ltd, Thailand). All wires were evaluated for their ultimate tensile strength. The study was reviewed and approved by the Institutional ethics committee (ACDS/IEC/11/Jan/2019). All patients participating in this study signed an informed consent form. These 40 patients received MBT (McLaughlin, Bennett, Trevisi) 0.22"x 0.028" prescription brackets (MiniTwin, Ormco, Glendora, USA). Patients were randomly allocated to Groups B or C with the following inclusion criteria: (a) Patients requiring non-extraction orthodontic mechanotherapy (b) Moderate to severe lower crowding with irregularity index > 4 mm (c) No history of any previous orthodontic intervention (d) No visible signs of fluorosis.

Group A consisted of as-received wires. Placebo mouthwash was made by the authors by addition of blue-synthetic food colouring agent (Papilon food flavours and colors, India) to distilled water. Group B subjects were instructed to use 10 ml of this placebo mouthwash twice daily in addition to their routine oral hygiene regimen. Group C subjects were instructed to use 10 ml of "Colgate Plax (0.05% sodium fluoride)" mouthwash twice daily in addition to their routine oral hygiene regimen. All participants used a non-fluoridated toothpaste during the course of the study.

The placebo and fluoridated mouthwash were provided to group "B'' and "C" subjects in clear unlabelled plastic bottles of similar size and shape. 0.014" NiTi archwires of group B and C, were retrieved after three months of intra oral use. All wires after retrieval were rinsed with distilled water to remove loosely bound precipitates and were individually stored in sterilized pouches. Wires from 3 groups were evaluated for ultimate tensile strength using a testing apparatus TA.XTplusC (Stable Microsystems, UK) (Fig1).

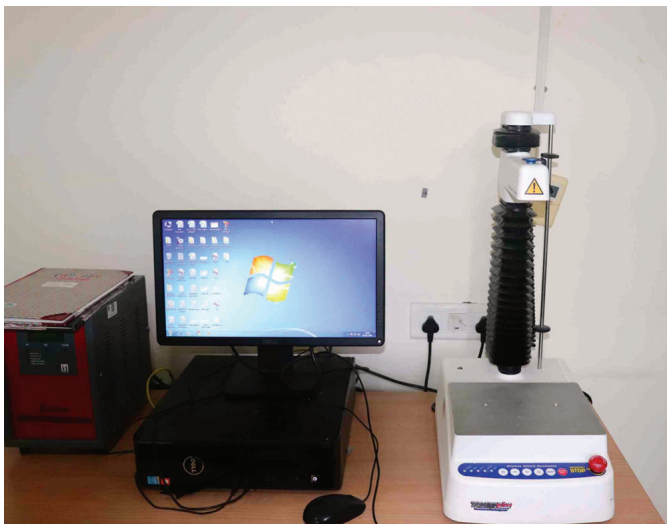

Fig. 1 Tensile testing apparatus TA.XTplusC (Stable Microsystems,UK)

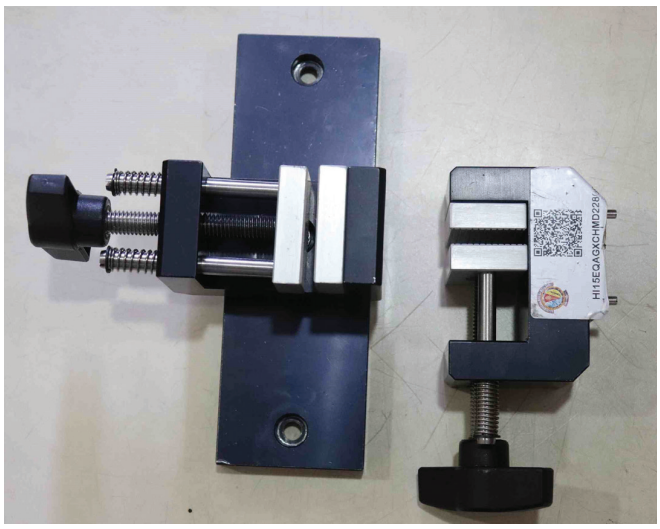

Fig. 2 Tensile grips

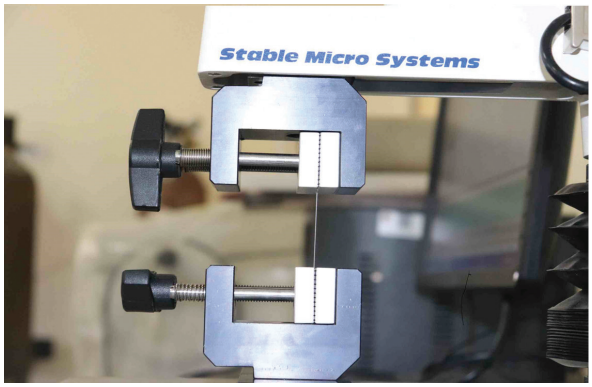

Fig. 3 Wire section tested for ultimate tensile strength

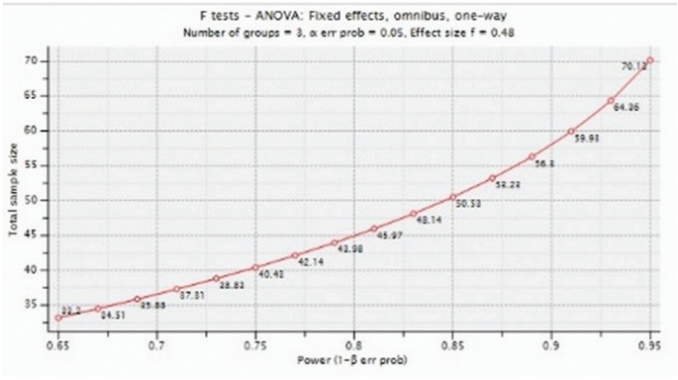

Fig. 4 Power analysis curve

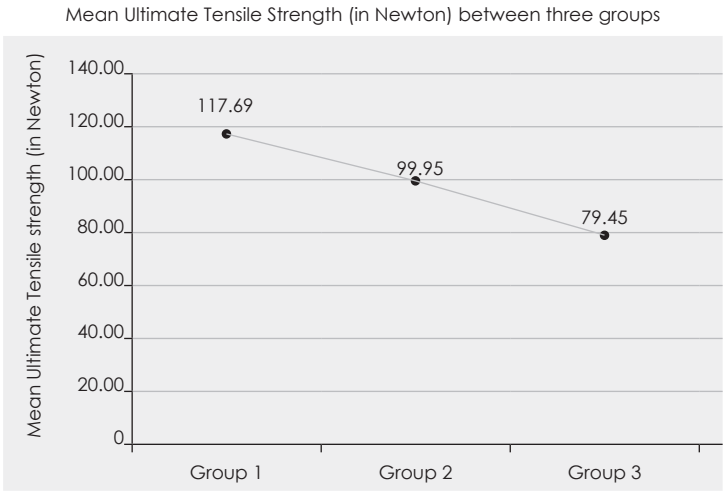

Fig. 5: Mean ultimate tensile strength between three groups (in N)

Methodology as described by Devaprasad and Chandrasekaran15 (2012), was followed in this study. The machine parameters were set to test a scale load of "1000 N", and was operated in a "tensile" mode with a crosshead speed of "5 mm/min" to enable analysis of ultimate tensile strength of each wire. Each wire sample was cut at one end with a standardized span of 20 mm and was placed between the jaws of the machine (Fig 2). The maximum tensile load, which the wire could withstand prior to its failure, was noted (Fig 3).

The required sample size was estimated using G Power software Ver 3.1.9.2 (Fig 4). The measured effect size (f) at 48%, study power at 80%, and error margin at 5%, was considered for which the total sample size required was 45. So, to consider for the attrition bias, sixty subjects were included in this study. Quantitative analysis of tensile strength was evaluated statistically using one-way analysis of variance (ANOVA), with mouthwash serving as a predictor. Group differences were evaluated using Tukey HSD (honestly significant difference) with a p value < 0.05 considered as the level of statistical significance..

RESULT

Table 1 demonstrates the mean ultimate tensile strength measured in Newton (N) for each study group. The mean ultimate tensile strength for control group is 117.69 ± 0.66 N, for placebo mouthwash group, it was 99.95 ± 0.91N and for fluoridated mouthwash group, it was 79.45 ± 1.33N. This difference in the mean ultimate tensile strength between 3 groups was statistically significant at p <0.001. (Fig 5)

Multiple comparisons of mean differences between different groups revealed that the control group showed the highest mean ultimate tensile strength as compared to placebo and fluoridated mouthwash groups, both at p <0.001. This was followed by the placebo mouthwash group showing significantly higher mean ultimate tensile strength as compared to

Table 1: Comparison of mean Ultimate Tensile Strength (in Newton) between three groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	P-Value
Control	20	117.69	0.66	116.2	119.1	<0.001*
Placebo Mouthwash	20	99.95	0.91	98.8	101.5	
Fluoridated Mouthwash	20	79.45	1.33	75.5	80.5	

**statistically significant*

Table 2: Multiple comparison of mean difference in Ultimate Tensile Strength (in Newton) between three groups using Tukey's Post hoc Analysis

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		P-Value
			Lower	Upper	
Control	Placebo Mouthwash	17.74	16.98	18.51	<0.001*
	Fluoridated Mouthwash	38.25	37.48	39.01	<0.001*
Placebo Mouthwash	Fluoridated Mouthwash	20.50	19.74	21.27	<0.001*

**statistically significant*

fluoridated mouthwash group at p <0.001. This infers that the mean ultimate tensile strength is highest in the control group followed by placebo mouthwash group and least in fluoridated mouthwash group. (Table 2)

DISCUSSION

Arch wires play a major role in fixed orthodontic therapy. Ideal arch wire properties include a low load-deflection rate, flexibility with higher resistance to orthodontic forces, low elasticity, low friction coefficient with higher springiness, higher resilience, corrosion resistance and good biocompatibility. NiTi archwires are suitable and yield optimum results for treatment of most orthodontic problems in clinical practice due to their desirable wire properties.[16] Wires with light mechanical force properties and a low load deflection ratio are more efficient and hence preferred for the initial alignment phase.[17]

Keeping the crucial importance of mechanical properties of the wires, efficiency and duration of orthodontic treatment, it was decided to use NiTi archwires in the present study.

In general, mouthwashes are available in either non fluoridated or fluoridated form. Fluoridated mouthwashes are prescribed to reduce the effects of enamel demineralization and white spot formation whereas, non-fluoridated mouthwashes are prescribed as antiplaque agents.[18] Among the plethora of non-fluoridated mouthwashes, Listerine (Johnson and Johnson) caused significant surface corrosion of SS wire when compared to chlorhexidine mouthwash which was attributed to the acidic nature of Listerine.[18] Although not statistically significant, 0.12% chlorhexidine and peroxide showed higher surface degradation of SS and NiTi wires respectively, compared to other mouthwashes.[19]

Hence, fluoridated mouthwashes are usually recommended to patients undergoing orthodontic treatment to maintain oral hygiene.[20] 0.05% fluoride mouthwash concentration was used in this study as it is commonly available[21] and prescribed as the standard recommendation to an orthodontic patient.[20]

All patients were instructed to rinse for 20 seconds with the given mouthwash twice daily for a period of 3 months. Duration of three months represented the time for which the initial NiTi archwires were placed intra-orally before it was to be replaced with a new archwire.

The tensile strength of orthodontic archwire is the ability of the material to withstand pulling (tensile) loads. Tensile strength determines the maximum force that can be distributed by archwires to move teeth orthodontically. It is directly proportional to the mechanical property of the archwire.[22] A table-top tensile testing apparatus was used to measure the ultimate tensile strength. This apparatus is a miniature version of Universal testing machine (UTM), which is previously used in researches.[7]

The reduced corrosion resistance of an archwire in turn, reduces the wire's tensile strength. Factors which affect this corrosion resistance depend on manufacturing process (heat treatment, surface roughness of the alloy, composition) and clinical use (duration and pH of mouthwash used).[23-25]

It is known that titanium (Ti) has a unique property of enhancing corrosion-resistance of orthodontic archwires by forming a protective film of titanium oxide (TiO_2). But on surfaces of nitinol archwires, addition of nickel oxide or metallic Ni to TiO_2 makes it more susceptible to degradation.[26]

The oral cavity is constantly exposed to saliva, ingestion fluids and foods with different pH (right from alkaline food e.g. fruits to acidic e.g. soft drinks) and of variable temperatures. All these factors may alter the mechanical properties of wires. Fluoride and hydrogen ions noted inside the oral cavity after intake of fluoridated mouthwash, can form hydrofluoric acid (HF) which destroys the protective oxide layer.

In an in vitro study, fluoride ions reduced the corrosion-resistance potential of archwires which was attributed to dissolution of TiO_2, in presence of fluoride.[6] The corrosion behaviour of NiTi wire in presence of fluoride can be attributed to either an increase in hydrogen ion concentration intra-orally or the nature of fluoride as an accelerator ion. Further, in an active state and acidic environment, release of Ni ions occurs intra-orally which can cause corrosion and lead to reduction in the tensile strength of orthodontic archwires.[6,7,20,27]

A study by Heravi et al[6] concluded that use of fluoridated mouth rinses destroys the surface of SS wires. Leaching of Ni ions after use of a fluoridated mouthwash can cause allergenicity, toxicity and carcinogenicity,[10,13] an important draw back. This damage in turn may alter mechanical properties of NiTi archwires. Our study showed that ultimate tensile strength of used 0.014" NiTi archwires exposed to fluoridated mouthwash, is lower than that of archwires exposed to placebo mouthwash and as-received archwires. The results were statistically significant ($p<0.05$). Our results were in line with studies done by Ramalingam et al.[28] and Walker et al.,[29] who compared the exposure effects of fluoride rinse and fluoride gels on patients with NiTi wire,[28] and found fluoride agents alter the mechanical properties of the wire[28] and increase the duration of orthodontic treatment.[29]

Perinetti et al,[30] in an in vitro study found no significant effects on the fracture resistance of two commercially available NiTi based archwires exposed to fluoridated agents. NiTi wires when used in-vitro are usually unbreakable,[19] but they do break on intra-oral use. In moderate to severe crowding cases, which require use of an aligning archwire for an extended period of time, fractures of the initial wire were most common problems encountered.[15]

Possibly due to the small sample size, none of our group C patients had wire fractures. Our analysis revealed that, retrieved NiTi archwires are affected on exposure to fluoridated mouthwash, with reduction (30%) in ultimate tensile strength and depicted an increased risk of wire fracture which may prolong orthodontic treatment. Hence, it is recommended to use a non-fluoridated mouthwash when NiTi aligning archwires are being used. Additional research with a larger patient sample and use of non-fluoridated and fluoridated mouthwashes and their effects on NiTi aligning wires could shed more light on this interesting phenomenon. Further, surface evaluation of the exposed archwires can also be done in future studies.

CONCLUSION

- There was a statistically significant reduction in the tensile strength of NiTi archwires after exposure to fluoride mouthwash for a period of 3 months.
- Fluoridated mouthwashes must be used with caution in orthodontic patients who are in the 1st stage of leveling and alignment with NiTi aligning wires.
- Non- fluoridated mouth rinses can be prescribed by orthodontists as an adjunct to oral hygiene regime to orthodontic patients with NiTi aligning archwires.

OJN

REFERENCES

1. Siddegowda R, Satish R. The prevalence of malocclusion and its gender distribution among Indian school children: An epidemiological survey. SRM J Res Dent Sci. 2014;5(4):224.
2. Sandhu S, Shetty V, Mogra S, Varghese J, Sandhu J, Sandhu J. Efficiency, behavior, and clinical properties of superelastic NiTi versus multistranded stainless steel wires. Angle Orthod. 2012;82(5):915-921.
3. Burstone C, Qin B, Morton J. Chinese NiTi wire—A new orthodontic alloy. Am J Orthod.1985;87(6):445-452.
4. Schiff N, Grosgogeat B, Lissac M, Dalard F. Influence of fluoride content and pH on the corrosion resistance of titanium and its alloys. Biomaterials.2002; 23(9):1995– 2002.
5. Rondelli G, Vicentini B. Effect of copper on the localized corrosion resistance of NiTi shape memory alloy. Biomaterials. 2002; 23(3): 639– 644.
6. Heravi F, Moayed M , Mokhber N. Effect of Fluoride on nickel-titanium and stainless steel orthodontic archwires: an in-vitro study. J. Dent. Tehran Univ.Med Sci.2015;12:49-59.
7. Srivastava K, Chandra P K , Kamat N. Effect of Fluoride mouth rinse on various orthodontic archwire alloys tested by modified bending test: an in vitro study. Ind J. Dent. Res.2012; 23: 433-444.
8. Chitra P, Prashantha G S, Rao A. Long-term evaluation of metal ion release in orthodontic patients using fluoridated oral hygiene agents: An in vivo study. JWFO.2019;8(3):107-111.
9. Asl Aminabadi N, Balaei E, Pouralibaba F. The Effect of 0.2% Sodium Fluoride Mouthwash in Prevention of Dental Caries According to the DMFT Index. J Dent Res Dent Clin Dent Prospects. 2007;1(2):71-76.
10. Li X, Wang J, Han EH, Ke W. Influence of fluoride and chloride on corrosion behavior of NiTi orthodontic wires. Acta Biomater. 2007; 3(5): 807– 815.
11. Hildebrand HF, Veron C, Martin P. Nickel, chromium, cobalt dental alloys and allergic reactions: an overview. Biomaterials. 1989; 10(8): 545–548.
12. Huang HH, Chiu YH, Lee TH, Wu SC, Yang HW, Su KH,et al. Ion release from NiTi orthodontic wires in artificial saliva with various acidities. Biomaterials. 2003; 24 (20): 3585– 3592.
13. Schiff N, Grosgogeat B, Lissac M, Dalard F. Influence of fluoridated mouthwashes on corrosion resistance of orthodontics wires. Biomaterials. 2004; 25 (19): 4535– 4542.
14. Boere G. Influence of fluoride on titanium in an acidic environment measured by polarization resistance technique. J Appl Biomater.1995; 6(4): 283– 288.
15. Devaprasad A, Chandrasekaran T. Effects of intraoral ageing on ultimate tensile strength and surface topography of superelastic NiTi wires from two different manufacturers: a comparative in vivo study. J Ind Orthod Soc.2012; 46:119-125.
16. Serafim CM, Gurgel Jde A, Tiago CM, Tavarez RR, Maia Filho EM. Clinical Efficiency of Two Sequences of Orthodontic Wires to Correct Crowding of the Lower Anterior Teeth. Sci. World J. 2015:1-5.
17. Gravina MA, Canavarro C, Elias CN, das Graças Afonso Miranda Chaves M, Brunharo IH, Quintao CC. Clinical evaluation of dental alignment and levelling with three different types of orthodontic wires. Dent Press J Orthod. 2013.18(6):31–37.
18. Al saqer M, Al-Waeli W. The effect of mouthwashes on the corrosion resistance of stainless steel wire. Iraqi Dent J. 2017;39(2):59.
19. Omidkhoda M, Poosti M, Sahebnasagh Z, Zebarjad S. Effects of three different mouthwashes on the surface characteristics of nickel-titanium and stainless steel archwires in orthodontics. J Dent mat and techniques. 2017;6(1):19-26.
20. Fatimah DI, Anggani HS, Ismah N. Effect of fluoride mouthwash on tensile strength of stainless steel orthodontic archwires. J Phys Conf Ser. 2017;884(1). 012102.
21. Borzabadi-Farahani A, Alavi S, Barooti S. An in vitro assessment of the mechanical characteristics of nickel-titanium orthodontic wires in fluoride solutions with different acidities. J Orthodont Sci, 2015;4(2):52.
22. Proffit W R, Fields H W, Sarver D M, Ackerman J L. Contemporary Orthodontics. 5th ed. St.Louis:Mosby; 2013.
23. Denizoglu S, Duymus ZY, Akyalcin S. Evaluation of ion release from two base metal alloys at various pH levels. J. Inter. Med. Res.2004; 32(1): 33-38.
24. Huang HH. Surface characterization of passive film on Ni Cr-based dental casting alloys. Biomaterials.2002; 24(9): 1575-1582.
25. Reclarul L, luthy A, Eschler PY, Blatter J. Corrosion behavior of Co –Cr dental alloy doped with precious metal. Biomaterials. 2005;26(21):4358-65.
26. Kassab EJ, Gomes JP. Assessment of nickel titanium and beta titanium corrosion resistance behavior in fluoride and chloride environments. Angle Orthod. 2013;83(5):864-9.
27. Castro S, Ponces M, Lopes J, Vasconcelos M, Pollmann M. Orthodontic wires and its corrosion--the specific case of stainless steel and beta-titanium. J. Dent. Sci. 2015; 10:1-7.
28. Ramalingam A, Kailasam V, Padmanabhan S, Chitharanjan A. The effect of topical fluoride agents on the physical and mechanical properties of Ni-Ti and copper Ni-Ti archwires. An invivo study. Aust Orthod J. 2008 ;24(1):26-31.
29. Walker MP, White RJ, Kulac KS. Effect of fluoride prophylactic agents on the mechanical properties of nickel titanium- based orthodontic wires. Am J Orthod Dentofacial Orthop. 2005;127(6):662-669.
30. Perinetti G, Contardo L, Ceschi M, Antoniolli F, Franchi L, Baccetti T, et al. Surface corrosion and fracture resistance of two nickel – titanium based archwires induced by fluoride, pH, and thermocycling. An in vitro comparative study. Eur J Orthod. 2012;34(1):1-9.