Journal of Genetic and Environmental Resources Conservation, 2015, 3(2):126-131.
www.jgerc.com

Assessment of corrosion in esthetic coated nickel titanium orthodontic archwires in dry and wet environment at different intervals (An *In vitro* study)

Shaymaa K. Mohsin* and Iman I. Al-Sheakli

Department of Orthodontics, College of Dentistry, University of Baghdad, Baghdad, Iraq..
*Corresponding author: sarmedanas@yahoo.com

Abstract

This *In vitro* study was designed to evaluate the corrosion pits in nickel titanium archwires coated with teflon and with Epoxy in dry and after immersion in artificial saliva, chlorhexidine (0.2%) (Parodontax) and toothpaste media (Sensodyne) for (1, 7 and 28) days intervals. Moreover, this study intended to compare the corrosion pits for each type of archwires at these different media among all intervals. Two hundred forty pieces of orthodontic wires of Teflon (Hubit) coated Nickel Titanium (120 pieces) and epoxy (Orthotechnology) coated nickel titanium (120 pieces), rectangular in cross section, size (0.019 x 0.025) inch and 15 mm in length divided into four groups, according to immersion media: (dry environment group, artificial saliva group, chlorhexidine group and toothpaste group). The atomic force microscope used to measure the corrosion pits for all samples at dry and wet conditions and after different immersion periods. Statistical analysis showed that there was non-significant coating's type difference in dry environment but highly significant differences at 28 days immersion period in chlorhexidine and toothpaste. The media and the time of immersion influenced highly significant in the corrosion pits.

Keywords: Esthetic coated archwire, Teflon, Epoxy, corrosion, Wet environment, AFM.

Introduction

Nickel-titanium (NiTi) is one of the most commonly used alloys to manufacture archwires (Brantley, 2001; Cioffi *et al*., 2012) because of their interesting elasticity and shape memory capacity, which allow this material to return to its original configurations after being submitted to a stress (Wichelhaus *et al*., 2010; Catauro *et al*., 2014). Nickel Titanium wires are commonly used during the aligning phase of orthodontic treatment, there by better able to provide the light, continuous force desired for orthodontic treatment (Pun and Berzins, 2008; Quintão and Brunharo, 2009; Proffit *et al*., 2013; Senkutvan *et al*., 2014).

Under certain condition, an extensive Ti release may occur *In vivo*. The Ni added to the alloy to increases hardness, strength and corrosion resistance (Vijayaraghavan *et al*., 2012; Brooks *et al*., 2014; Goutam *et al*., 2014). Corrosion of nickel titanium (NiTi) arch wires raises major concern because of their high nickel content (47% to 50% nickel) and associated biocompatibility issues (Locci *et al*., 2000). Because nickel atoms are not strongly held in NiTi alloy as in other intermetallic compounds (Brantley, 2001), its release into the oral cavity during clinical use is reported to cause several types of adverse reactions ranging from mild hypersensitive responses, such as contact dermatitis, to extremes of cytotoxic, mutagenic, and carcinogenic changes. Nickel hypersensitivity reactions to NiTi wires have been observed in orthodontic patients who are nickel-sensitive, although such cases are rare (Chakravarthi *et al*., 2012). NiTi arch wires are constantly exposed to the oral cavity and carry greater risk for toxic effects (Eliades and Athanasiou, 2002).

In acidic pH, hydrogen ions penetrate into the NiTi alloy and form brittle titanium hydrides, which cause arch wire fracture (Yokoyama *et al*., 2001). Similarly, fluoride ions present in various anti caries preparations are also known to increase their susceptibility to corrosion (Walker *et al*., 2005). NiTi archwires are made from an ingot through multiple stages of heat treatment and by different types of wire drawing methods. This causes formation of several oxides of titanium and nickel ($TiO2$, TiO, $Ti2O5$, and NiO), which provide the inherent corrosion resistance (Iijima *et al*., 2001). Even though this mechanism renders good anticorrosive properties for NiTi alloys (Rondelli and Vicentini, 2000). Such oxides are not infallible and can initiate corrosion on disruption (Huang *et al*., 2003).

The high surface roughness of NiTi is cited as one reason for its corrosive characteristics (Oshida *et al*., 1992; Hunt *et al*., 1999; Widu *et al*., 1999). However, certain other studies have related corrosion characteristics of NiTi wires to the residual stresses incorporated into it during manufacturing and not to its surface roughness (Lee *et al*., 2005; Huang, 2005; Kao and Huang, 2010). This means the effects of surface features on corrosive features of NiTi wires are not conclusively known. In this context, surface modification of NiTi arch wires is considered a favorable option for improving its surface roughness and thereby its corrosion resistance and biocompatibility (Tan *et al*., 2003). Additional benefits expected are better esthetics and reduced frictional coefficients (Kim and Johnson, 1999).

In modern society, the esthetic aspect of orthodontic therapy is becoming increasingly important because of the growing number of adult patients (Ziuchkovski *et al*., 2008; Rosvall *et al*., 2009). Utilization of esthetic wires is only a logical extension of demand from a patient base that prefers esthetic brackets. This is especially important considering nickel titanium wires (Washington, 2013). The combination of esthetic archwires and sapphire brackets ranked second in patient preference behind only clear aligners (Feu *et al*., 2012). Different manufacturers, to modify the surface of NiTi arch wires, used esthetic materials such as Teflon and Epoxy. A comprehensive study comparing the efficacy of such coatings on the corrosion behavior of NiTi wires not been reported so far (Krishnan *et al*., 2014). Therefore, it is important to assess and compare the effect of Teflon and Epoxy coating material in the corrosion of Nickel Titanium, to evaluate and compare the effect of dry and wet environment, and to evaluate the effect of immersion time.

Materials and Methods

Total number of (240) pieces of upper-coated Nickel Titanium orthodontic archwires, (120) selected from Ortho Technology Company (Brazil) and (120) selected from Hubit Company (Korea) were tested for corrosion (Figure 1).

The specimens used in the study having a rectangular (0.019 × 0.025 inch) cross section and cut in to pieces of (15mm) length. These pieces of wires divided in to four groups according to the media they immersed in (dry, artificial saliva, chlorhexidine mouthwash and toothpaste). They subdivided into three groups according to the period of immersion (1, 7 and 28 days). Thirty pieces of each wire's type were left in Dry environment for 1, 7 and 28 days intervals. Another thirty pieces of each wire's type were immersed in Artificial saliva (pH = 6.75 ±0.15) (400 mg/l NaCl, 400mg/l KCl, 795 mg/l $CaCl_2.2H_2O$, 690 mg/l $NaH_2PO4.H_2O$, 5 mg/l $Na_2S.9H_2O$, 1000 mg/l Urea, 500ml deionized water, 500ml Distilled water) (Iijima *et al*., 2001; Rondelli and Vicentini, 2000; Huang *et al*., 2003), chlorhexidine mouthwash (GSK, Germany, Exp: 06 /2015) and toothpaste (GSK, UK, Exp: 06 /2015).

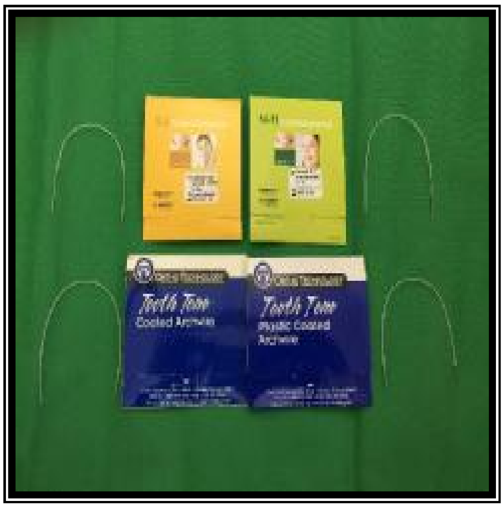

Figure (1): Coated archwires.

These wire's pieces were incubated in covered glass containers at 37^0C for the entire testing period (Sultan, 2008). The corrosion pits measured at the following time intervals: 1, 7 and 28 days. Corrosion pits measurements were obtained by Atomic Force Microscope (AFM; JPK Nanowizard, Nr: H-01-0086, and JPK Image Processing software, version 3.0; JPK Instruments A.G., Berlin, Germany) with a non-contact tip coated with silicon (NCLR-20; NanoWorld, Neuchatel, Switzerland), with a constant force of 48 N/mm and resonance frequency of 190 kHz (Figure 2). After preparation, the samples washed with distilled water, immersed in 70% ethanol for 4-5sec, then immersed in acetone (act as a volatile organic solvent) for 8-10sec, and dried by dry air for one minute. This method of cleaning used to remove all contaminated layer formed on the alloy during storage (Oh and Kim, 2005).

The artificial saliva replaced every 7 days with a fresh solution to avoid its saturation with the corrosion products (Elshahawy *et al*., 2009; Khamees, 2013). The chlorhexidine solution used according to the manufacturer instruction and the samples immersed completely in the solution in the test tubes and covered perfectly by theirs covers, shake by the shaker for 1min, then they were removed and washed with distilled water, dried by dry air and re-put in the artificial saliva, then incubated at 37^{0}C. This procedure would repeated two times daily for (1, 7 and 28 days) intervals (Sultan, 2008).

The samples of Toothpaste groups were immersed completely in the paste on a slap for 2min After the 2min were completed the wires were removed and washed with distilled water, dried by dry air and re-put in the artificial saliva, then incubated at 37^{0}C. This procedure would be repeated 3 times daily for (1day, 7 days, and 28 days) intervals (Sultan, 2008).

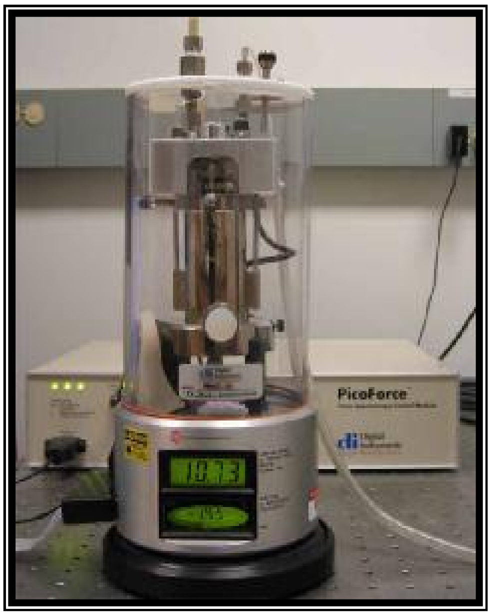

Figure (2): Atomic force microscope (AFM).

Statistical analysis: Data collected analyzed by using relevant software statistical package of social science (SPSS, Chicago, 21). These data of the corrosion pits for all specimens averaged, and the results analyzed with the following statistics:

1. Descriptive statistics:(mean of corrosion pits and its standard deviation).

2. Inferential statistics: {Independent sample t-test, one way analysis of variance (ANOVA) and least significant difference (LSD)}.

Results and Discussion

The effect of coating material: In dependent sample t-test showed non-significant coating type difference in the corrosion pits in dry environment at different intervals. The result also showed there were significant differences at 1 and 7 days in chlorhexidine and highly significant differences at 7 days immersion in artificial saliva and 28 days immersion in chlorhexidine and toothpaste (Table 1).

The effect of the immersion media: Analysis of variance difference (ANOVA) has demonstrated high-significant differences among all the different media for the two wire's type except for Hubit (Teflon) at 1 day immersion period, which showed significant difference (Table 2).

The effect of the time intervals: The time interval has non-significant effect on the corrosion pits at dry environment. Analysis of variance difference (ANOVA) has demonstrated highly significant differences among the different time intervals for each wire in wet environment (Table 3).

Table (1): The effect of coating material difference for each wire immersed in specific media for different intervals

Media	Intervals	Descriptive statistics				Company difference (d.f.=18)		
		Hubit		Orthotechnology				
		Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	Mean Difference	t-test	value
Dry	1 day	0.000484	0.000162	0.000485	0.000199	0.000001	-0.012	0.990
	7 days	0.000541	0.000138	0.000473	0.000186	0.000068	0.927	0.366
	28 days	0.000504	0.00018	0.000499	0.000198	0.000005	0.059	0.954
Artificial saliva	1 day	0.000287	0.000091	0.000233	0.000078	0.000054	1.424	0.172
	7 days	0.000619	0.000023	0.000516	0.000032	0.000103	8.220	*0.000
	28 days	0.000523	0.000143	0.000438	0.000133	0.000085	1.374	0.186
CHX	1 day	0.000381	0.000131	0.000283	0.000064	0.000098	2.128	*0.047
	7 days	0.000429	0.000136	0.000319	0.000056	0.000110	2.356	*0.030
	28 days	0.000208	0.000066	0.000644	0.000095	0.000436	11.970	*0.000
Tooth paste	1 day	0.000349	0.000140	0.000382	0.000136	0.000033	-0.534	0.600
	7 days	0.000283	0.000046	0.000285	0.000086	0.000002	-0.065	0.949
	28 days	0.000683	0.000105	0.000906	0.000026	0.000223	-6.540	*0.000

(*) mean significant (*) mean highly significant.

Table (2): The effect of different media on the corrosion pits of different wires and intervals

Company	Intervals	Descriptive Statistics								Media difference (d.f.=39)	
		Dry		Artificial saliva		Chlorhexidine		Tooth paste			
		Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	Mean Pits/ nm	S.D.	F-test	p-value
Hubit	1 day	0.000484	0.000162	0.000287	0.000091	0.000381	0.000131	0.000349	0.000140	3.806	*0.018
	7 days	0.000541	0.000138	0.000619	0.000023	0.000429	0.000136	0.000283	0.000046	21.042	*0.000
	28 days	0.000504	0.000180	0.000523	0.000143	0.000208	0.000066	0.000683	0.000105	23.009	*0.000
Ortho technolo	1 day	0.000485	0.000199	0.000233	0.000078	0.000283	0.000064	0.000382	0.000136	7.277	*0.001
	7 days	0.000473	0.000186	0.000516	0.000032	0.000319	0.000056	0.000285	0.000086	11.091	*0.000
	28 days	0.000499	0.000198	0.000438	0.000133	0.000644	0.000095	0.000906	0.000026	26.011	*0.000

(*) mean significant (*) mean highly significant.

Table (3): The effect of time of immersion in each media for each wire

Media	Company	Descriptive statistics						Intervals difference (d.f.=29)	
		1 day		7 days		28 days			
		Mean Pits/nm	S.D.	Mean Pits/nm	S.D.	Mean Pits/nm	S.D.	F-test	p-value
Dry	Hubit	0.000484	0.000162	0.000541	0.000138	0.000504	0.00018	0.323	0.727
	Ortho Technology	0.000485	0.000199	0.000473	0.000186	0.000499	0.000198	0.045	0.956
Artificial saliva	Hubit	0.000287	0.000091	0.000619	0.000023	0.000523	0.000143	29.863	*0.000
	Ortho technology	0.000233	0.000078	0.000516	0.000032	0.000438	0.000133	25.730	*0.000
CHX	Hubit	0.000381	0.000131	0.000429	0.000136	0.000208	0.000066	10.108	*0.001
	Ortho technology	0.000283	0.000064	0.000319	0.000056	0.000644	0.000095	73.354	*0.000
Tooth paste	Hubit	0.000349	0.000140	0.000283	0.000046	0.000683	0.000105	42.101	*0.000
	Ortho technology	0.000382	0.000136	0.000285	0.000086	0.000906	0.000026	125.738	*0.000

(*) mean highly significant.

The effect of coating material: The highly significant differences at 7 days immersion in Artificial saliva was similar to the results reported by the previous studies, Which showed a severe deterioration and a greater surface roughness compared to the preclinical used (Elayyan *et al*., 2008; Wichelhaus *et al*., 2010; Zegan *et al*., 2012 da Silvaa *et al*., 2013). The result of this study also agree with Khamees (2013) *In vitro* study, but disagree with Krishnan *et al.* (2014) study in which there was significant improvement in corrosion resistance of teflon as compare to Epoxy.

The significant differences at 1 and 7 days in chlorhexidine and the highly significant differences at 28 days immersion in chlorhexidine and toothpaste may be due to the type and nature of coating material.

The effect of the immersion media: The significant and high-significant differences among all the different media for the two wire's type may be qualified to the element that initiate the corrosion process, to the variances in pH and presence or absence of fluoride ions.

The effect of the time intervals: The time interval has no effect on the corrosion pits at dry environment. This may related to the constant factors of the environment at this study. The highly significant differences among the different time intervals of teflon coated wires (Hubit) in artificial saliva may attributed to the delayed formation of passive protective layer in presence of the coating film. This result disagree with Neumann *et al.* (2002) who stated that Teflon coating prevented the corrosion of the wire completely. The highly significant discrepancies in the effect of time in each wire's type immersed in chlorhexidine mouthwash may be due to increased acidity (decreasing pH). This was in agreement with

Yokoyama *et al.* (2001). The highly significant differences among the three immersion periods for each wire in Toothpaste may attributed to the fluoride-containing environment and a longer immersion time, which might enhance the corrosion of the surface layer. This result was agree with Walker *et al.* (2005) result.

Conclusion

The two types of coated wires take the same manner in different media except that in chlorhexidine and Toothpaste at 28 days in which Epoxy coated nickel titanium wires show more corrosion behavior with increased time. This mean Epoxy coated nickel titanium wires should be change in shorter periods than teflon coated nickel titanium in patients using oral hygiene index regularly.

References

Brantley, W.A. 2001. Orthodontic wires. In: Brantley WA, Eliades T, eds. Orthodontic Materials: Scientific and Clinical Aspects. Stuttgard, Germany: Thieme.

Brooks, E.; Tobias, M.; Krautsak, K. and Ehrensberger, M. 2014. The influence of cathodic polarization and simulated inflammation on titanium electrochemistry. J. Biomed. Mater. Res. B Appl. Biomater., 102(7): 1445-1453.

Catauro, M.; Bollino, F.; Papale, F.; Giovanardi, R. and Veronesi, P. 2014. Corrosion behavior and mechanical properties of bioactive sol-gel coatings on titanium implants. Mater. Sci. Eng. C Mater. Biol. Appl. 43(10): 375-382.

Chakravarthi, S.; Padmanabhan, S. and Chitharanjan, A.B. 2012. Allergy and orthodontics. J. Orthod. Sci., 1(4): 83-87.

Cioffi, I.; Piccolo, A.; Tagliaferri, R.; Paduano, S.; Galeotti, A. and Martina, R. 2012. Pain perception following first orthodontic archwire placement—thermoelastic vs superelastic alloys: a randomized controlled trial. Quintessence Int., 43: 61–69.

da Silvaa, DL.; Mattos, C.T.; Simão, R.A. and de Oliveira Ruellas, A.C. 2013. Coating stability and surface characteristics of esthetic orthodontic coated archwires. Angle Orthod., 83(6): 994-1001

Elayyan, F.; Silikas, N. and Bearn, D. 2008. Ex vivo surface and mechanical properties of coated orthodontic archwires. Eur. J. Orthod., 30(6): 661-667.

Eliades, T. and Athanasiou, A.E. 2002. *In vivo* aging of orthodontic alloys: implications for corrosion potential, nickel release, and biocompatibility. Angle Orthod., 72(3): 222–237.

Elshahawy, W.; Watanabe, I. and Koike, M. 2009. Elemental ion release from four different fixed prosthodontic materials. Dent. Mater. J., 25(8): 976-981.

Feu, D.; Catharino, F.; Duplat, CB. and Capelli, JJ. 2012. Esthetic perception and economic value of orthodontic appliances by lay Brazilian adults. Dental Press J. Orthod., 17(5): 102-114.

Goutam, M.; Giriyapura, C.; Mishra, S.K. and Gupta, S. 2014. Titanium Allergy: A literature review. Indian J. Dermatol., 59(6): 630.

Huang, H.H.; Chiu, Y.H. and Lee, T.H. 2003. Ion release from NiTi orthodontic wires in artificial saliva with various acidities. Biomaterials, 24(20): 3585–3592.

Huang, H.H. 2005. Variation in corrosion resistance of nickel titanium wires from different manufacturers. Angle Orthod., 75(4): 661–665.

Hunt, NP.; Cunningham, SJ.; Golden, CG. and Sheriff, M. 1999. An investigation into the effects of polishing on surface hardness and corrosion of orthodontic archwires. Angle Orthod., 69(5): 433–440.

Iijima, M.; Endo, K.; Ohno, H.; Yonekura, Y. and Mizoguchi, I. 2001. Corrosion behavior and surface structure of orthodontic Ni-Ti alloy wires. Dent. Mater. J., 20(1): 103–113.

Kao, C.T. and Huang, T.H. 2010. Variations in surface characteristics and corrosion behavior of metal brackets and wires in different electrolyte solutions. Eur. J. Orthod., 32(5): 555–560.

Khamees, A. 2013.Comparison of Metal Ions Release and Corrosion Potential from Different Bracket Archwire Combinations (An *In vitro* Study). A Master thesis, Orthodontics Department, College of Dentistry, University of Baghdad.

Kim, H. and Johnson, J.W. 1999. Corrosion of stainless steel, nickel titanium, coated nickel-titanium, and titanium orthodontic wires. Angle Orthod., 69(1): 39–44.

Krishnan, M.; Seema, S.; Kumar, AV.; Varthini, NP.; Sukumaran, K.; Pawar, V.R. and Arora, V. 2014. Corrosion resistance of surface modified nickel titanium arch wires. Angle Orthod., 84(2): 358-367

Lee, TH.; Huang, T.K.; Lin, S.Y.; Chen, L.K.; Chou, M.Y. and Huang, H.H. 2010. Corrosion resistance of different nickel-titanium archwires in acidic fluoride-containing artificial saliva. Angle Orthod., 80(3): 547–553.

Locci, P.; Lilli, C. and Marinucci, L. 2000. In vitro cytotoxic effects of orthodontic appliances. J. Biomed. Mater. Res., 53(5): 560–567.

Neumann, P.; Bourauel, C. and Jäger, A. 2002.

Corrosion and permanent fracture resistance of coated and conventional orthodontic wires. J. Mater. Sci. Mater. Med., 13(2): 141-147.

Oh, K.T. and Kim, K.N. 2005. Ion release and cytotoxicity of stainless steel wires. Eur. J. Orthod., 27(6): 533–540.

Oshida, Y.; Sachdeva, R.C. and Miyazaki, S. 1992. Microanalytical characterization and surface modification of NiTi orthodontic archwires. Biomed. Mater. Eng., 2(2): 51–69.

Proffit, W.R.; Fields, H.W. and Sarver, D.M. 2013. Contemporary orthodontics.5th ed. St Louis: Mosby.

Pun, D.K. and Berzins, D.W. 2008. Corrosion behavior of shape memory, superelastic, and nonsuperelastic nickel-titanium-based orthodontic wires at various temperatures. Dent. Mater. J., 24(2): 221-227.

Quintão, C.A. and Brunharo, V.P. 2009. Orthodontic wires: knowledge ensures clinical optimization. Dental Press J. Orthod., 14(6): 144-157.

Rondelli, G. and Vicentini, B. 2000. Evaluation by electrochemical tests of the passive film stability of equiatomic Ni-Ti alloy also in presence of stress-induced martensite. J. Biomed. Mater. Res., 51(1): 47–54.

Rosvall, M.D.; Fields, H.W.; Ziuchkovski, J.; Rosenstiel, S.F. and Johnston, W.M. 2009. Attractiveness, acceptability, and value of orthodontic appliances. American J. Orthod. Dentofacial Orthop., 135(3): 276. e 1-12.

Senkutvan, R.S.; Jacob, S.; Charles, A.; Vadgaonkar, V.; Jatol-Tekade, S. and Gangurde, P. 2014. Evaluation of nickel ion release from various orthodontic arch wires: An in vitro study. J. Int. Soc. Prev. Community Dent., 4(1): 12-6.

Sultan, Z. 2008. Measurements of Depth and Number of Corrosion Pits in Some Types of Orthodontic Wires (An *In vitro* study). A Master thesis, Orthodontics Department, College of Dentistry, University of Mosul.

Tan, L.; Dodd, R.A. and Crone, W.C. 2003. Corrosion and wear-corrosion behavior of NiTi modified by plasma source ion implantation. Biomaterials, 24(22): 3931–3939.

Vijayaraghavan, V.; Sabane, V.A. and Tejas, K. 2012. Hypersensitivity to Titanium: A Less Explored Area of Research. J. Indian Prosthodont Soc. December; 12(4): 201–207.

Walker, M.P.; White, R.J. and Kula, K.S. 2005. Effect of fluoride prophylactic agents on the mechanical properties of nickel titanium-based orthodontic wires. American J. Orthod. Dentofacial Orthop., 127(6): 662–669.

Washington, B.C. 2013. Mechanical Properties of Coated vs. Non-Coated Nickel Titanium Wires. A Master thesis, Orthodontics Department, University of Illinois at Chicago.

Wichelhaus, A.; Brauchli, L.; Ball, J. and Mertmann, M. 2010. Mechanical behavior and clinical application of nickel-titanium closed-coil springs under different stress levels and mechanical loading cycles. American J. Orthod. Dentofacial Orthop., 137(5): 671-678.

Widu, F.; Drescher, D.; Junker, R. and Bourauel, C. 1999. Corrosion and biocompatibility of orthodontic wires. J. Mater. Sci. Mater. Med., 10(5): 275–281.

Yokoyama, K.; Hamada, K.; Moriyama, K. and Asaoka, K. 2001. Degradation and fracture of Ni-Ti superelastic wire in an oral cavity. Biomaterials., 22(16): 2257–2262

Zegan, G.; Sodor, A. and Munteanu, C. 2012. Surface characteristics of retrieved coated and nickel-titanium orthodontic archwires. Rom. J. Morphol. Embryol., 53(4):935–939.

Ziuchkovski, J.P.; Fields, H.W.; Johnston, W.M. and Lindsey, D.T. 2008. Assessment of perceived orthodontic appliance attractiveness. American J. Orthod. Dentofacial Orthop., 133(4): 68–78.