

Original Article

Effect of immersion in hydrochloric acid and sodium hypochlorite and autoclave sterilization on the force characteristics of orthodontic nickel-titanium open coils

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ABSTRACT

Background: Nickel-titanium (NiTi) open coils are common tools in fixed orthodontic treatments to apply light and continuous forces. Their favorable mechanical properties and their relatively high cost have prompted many clinicians to decide to reuse them.

Aim: The present study aimed to evaluate the effect of 10% hydrochloric acid (HCl) and 5.25% sodium hypochlorite (NaClO) solution and sterilization, on the unloading force of NiTi open-coils.

Materials and Methods: This experimental *in vitro* study consisted of 160 NiTi open coils from two brands of Highland Metals and Masel were provided. Each group was randomly divided into four subgroups: control, three rounds of immersion, three rounds of autoclave sterilization, and three rounds of immersion and autoclaving. Each round of immersion process included 1 min in 10% HCl, followed by 5 min in 5.25% NaClO. Spring was compressed for 4 mm. Then, the unloading forces of each spring were recorded at 4, 3, 2, and 1 mm of compression, respectively. The data were analyzed with SPSS ($P < 0.05$), using one-way ANOVA and independent *t*-test.

Results: One-way ANOVA showed a significant difference in the 2-mm compression of Group 1 and 3-mm compressions of Groups 1 and 2 compared to the control group in the Highland metals brand ($P < 0.04$, $P < 0.014$, and $P < 0.007$, respectively). There was no significant difference between the different compressed lengths and groups in the Masel brand.

Conclusion: One-minute immersion in 10% HCl and 5-min immersion in 5.25% NaOCl, followed by autoclave sterilization, even after repeating the process three times, did not significantly change the force properties of NiTi open springs. Therefore, the re-use of these springs with the above-mentioned method as preparation can be recommended.

Key words: Hydrochloric acid, orthodontics, recycling, sodium hypochlorite

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INTRODUCTION

Nickel-titanium (NiTi) alloy has been used in orthodontics since the early 1970s.^[1] Due to the proper mechanical properties of this alloy, its use has gradually increased, and it has won great popularity

in recent decades.^[2] The positive characteristic of this alloy is related to its low load deflection rate and, consequently, high flexibility and elasticity.^[3]

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NiTi springs are a common tool in fixed orthodontic treatments to apply light and continuous forces. These springs have been manufactured in both open and closed forms.^[4,5] Open coils are used to provide the space for impacted teeth, severely mal-aligned teeth, distalization of molars, and retraction of incisors.^[6,7] NiTi springs apply the more appropriate force in a longer activation range compared to steel springs. Thus, the force applied is more physiologic.^[5,8]

NiTi alloys are expensive.^[9] Their favorable mechanical properties and their relatively high cost have prompted many clinicians to decide to re-use them.^[10] Economic considerations are the most important cause of their reuse.^[11,12] Their manufacturing process needs to use limited natural resources; therefore, their reuse could help correct this imbalance in the environment.^[13,14] By reusing, costs are reduced by 30%–40% and nature is protected against the depletion of resources.^[13]

Reuse of orthodontic appliances is possible when, in addition to preventing the transmission of infections, the physical characteristics of the appliance do not significantly change after the initial application, cleaning, disinfection, and sterilization processes.^[15]

It is possible to reuse tools and appliances that retain their function after clinical use by observing some principles. This is also implemented in medicine and other dental fields. The reuse of some appliances has also been suggested in orthodontics. These include brackets,^[16-19] bands,^[20] wires,^[21-24] orthodontic mini-implants.^[25,26]

A literature search did not bring up a study on the reuse of NiTi open coils. However, some studies have evaluated the reuse of closed coils. Momeni *et al.* showed that autoclaving could increase their strength; however, the increase was not clinically significant. They claimed that Niti close coils could be reused without a significant change in their strength.^[27] Geng *et al.* reported that thermocycling resulting from the daily use of foods and drinks might result in the loss of the force of NiTi close coils.^[28] Magno *et al.* showed that 6-month clinical use of NiTi close coils could result in a significant increase in stress-strain curve, a decrease in strength, and permanent deformation.^[29]

The results on close coils are contradictory and needed more researches. It should be noted that the manufacturing conditions and distribution of force due

to deformation in open and closed coils are different. There are limited studies available on the reuse of NiTi open coils. Due to their favorable characteristics and high cost, reusing of these springs can be suggested. The present study is aimed to evaluate the effect of the use of 10% hydrochloric acid (HCL) and 5.25% sodium hypochlorite (NaClO) solution to eliminate mineral and organic deposits on NiTi open coils, respectively, followed by sterilization, on unloading force of these springs.

MATERIALS AND METHODS

Ethical approval was granted by the Torabinejad Dental Research Center, Isfahan University of Medical Sciences, Isfahan, Iran, with identification number 398835. This experimental *in vitro* study consists of 160 orthodontic NiTi open coils, 14 mm in length, including 80 from Highland Metals (Encinitas, California, USA) and 80 from Masel) San Jose, California, USA) brand. Each group was randomly divided into four subgroups. By setting a confidence level at 0.95, power at 0.80, and the standard deviation at 6, the sample size should be 20 samples for each group. Groups 0 were control, and Groups 1–3 underwent three rounds of immersion, three rounds of autoclave sterilization, and three rounds of immersion and autoclaving, respectively. Each round of immersion process included 1 min in 10% HCl (Household cleaner solution, Golrang Industrial Group, Tehran, Iran), followed by 10 s irrigation with running water and followed by 5 min in 5.25% NaClO (Bleaching solution, Golrang Industrial Group, Tehran, Iran). Each sample was immersed in a 20 mL fresh solution separately. The autoclaving process included 10 min in 121°C temperature and +1 bar pressure (Gemini BV, Apeldoorn, Netherland).

After this step, the first researcher coded the samples and the second researcher measured the spring unloading forces using an electromechanical universal testing machine (K-21046, Water + Bai, Switzerland) at room temperature [Figure 1]. Spring was compressed up to 4 mm. Then, the unloading forces of each spring were recorded at 4, 3, 2, and 1 mm of compression, respectively. The data after decoding were analyzed with SPSS (version 22) SPSS (version 22) (SPSSInc., Chicago, IL,USA) ($P < 0.05$), using one-way ANOVA and independent *t*-test. The level of significance was set at 0.05. The normality was analyzed using Kolmogorov–Smirnov test.

RESULTS

Kolmogorov–Smirnov test showed the normal distribution of data. One-way ANOVA analysis was carried out to compare the Groups at 1, 2, 3, and 4 mm of activation separately. The mean levels of force at different compressions are shown in Table 1.

In the Highland metals brand, there were no significant differences between groups except in the 2-mm compression of Group 1 and 3-mm compressions of Groups 1 and 2 compared to the control group. ($P < 0.04$, $P < 0.014$, and $P < 0.007$, respectively) There was no significant difference between the different groups in the Masel brand. The control groups of the two brands compared with independent *t*-test. Masel springs had higher

unloading forces than Highlands springs at 1 and 2 mm compression ($P < 0.001$, $P = 0.017$) but at 3 and 4 mm compression there were no significant differences ($P < 0.066$, $P = 0.972$).

DISCUSSION

The most important rationale of medical and dental instruments reuse is economic issues.^[11,12] The removal of organic and mineral debris as cleaning is necessary before sterilization. In this study, immersion in 10% HCL, followed by immersion in 5.25% NaOCl, was proposed as a method for cleaning NiTi open coils before autoclave sterilization. They are known as household cleaner and bleaching solution, and they are inexpensive and available. HCL can remove mineral debris.^[16] NaOCl can resolve organic debris and is a common and powerful disinfectant^[25,26] Autoclave sterilization is carried out as a routine process of sterilization. Cleaning and sterilization processes must not have an adverse effect on the physical properties of equipment if they are reused.^[30,31]

In this study, two different brands of NiTi open coils were used to help better the generalization of the results. Measuring unloading forces at 1–4-mm compression is done to simulate routine clinical use of these coils.

Three times immersion did not show significant changes in force characteristics of the Masel coils; however, the immersion procedure with Highland Metals coils at 2 and 3 mm compression resulted



Figure 1: Measuring unloading force of each coil.

Table 1: Mean (standard deviation) of unloading forces (cN) of nickel-titanium open coil springs in different groups and compression lengths

Activation (mm)	Test groups	Brands					
		Highland metals			Masel		
		Test, mean (SD)	Control, mean (SD)	<i>P</i>	Test, mean (SD)	Control, mean (SD)	<i>P</i>
1	Group 1	47.41 (13.3)	37.88 (10.3)	0.108	52.08 (17.8)	56.94 (13.4)	0.720
	Group 2	47.28 (12.3)		0.115	52.82 (10.0)		0.809
	Group 3	42.45 (15.9)		0.691	48.28 (16.0)		0.248
2	Group 1	112.41 (13.8)	99.65 (18.4)	*0.040	102.50 (18.4)	112.93 (15.2)	0.281
	Group 2	110.55 (12.5)		0.103	115.56 (19.6)		0.969
	Group 3	105.75 (14.1)		0.568	107.53 (17.0)		0.924
3	Group 1	171.61 (15.8)	151.61 (27.1)	*0.014	152.87 (27.6)	167.00 (24.2)	0.314
	Group 2	173.15 (15.4)		*0.007	164.55 (22.9)		0.990
	Group 3	168.07 (21.0)		0.060	164.57 (28.0)		0.991
4	Group 1	339.82 (14.6)	352.06 (39.7)	0.481	347.52 (23.1)	352.43 (25.7)	0.937
	Group 2	336.01 (18.7)		0.244	350.22 (26.6)		0.994
	Group 3	347.08 (27.7)		0.937	355.65 (30.6)		0.981

Group 1: Control, Group 2: Three-times “immersion,” Group 3: Three-times “autoclave sterilization,” Group 4: Three-times “immersion followed by Autoclave sterilization.” *Statistical significant difference. ($P < 0.05$). SD: Standard deviation

in significant changes, statistically, in force characteristics up to 12.6 and 20 cN, respectively, which is not significant clinically.

Three rounds of autoclave sterilization in the Masel group did not result in significant changes in force levels. However, concerning the Highland Metals coils, a decrease of 21.54 cN was recorded in force only at 3 mm compression, with no significant differences at other points. This amount of decrease in force is not significant clinically. Momeni *et al.*^[27] found that even though autoclave sterilization can increase the force levels of Ni-Ti close coils but this is not clinically significant, and it is possible to recycle NiTi closed-coil springs without a considerable reduction in their force levels.

No studies were found about the effect of reuse on NiTi open coils. However, several studies have investigated the effects of clinical use and sterilization on NiTi close coils and NiTi wires. Several studies have supported the reuse of NiTi close coils.^[2,27,32,33]

Crotty examined the effect of autoclave on tensile properties of NiTi wires and reported no significant changes in the tensile properties of NiTi wires sterilized in an autoclave,^[34] which were consistent with Lee's findings.^[35] On the other hand, Bavikati *et al.* showed that autoclave sterilization of NiTi wires and clinical reuse of the wires could reduce the elasticity of the NiTi wires and affect their surface topography.^[36] Alavi also reported the changes in the mechanical properties of NiTi wires after autoclaving.^[9] There was no significant decrease in the force of any of the brands by concomitant autoclaving and immersion for three rounds. No similar study was found for comparison concerning the effect of the cleaning/sterilization process on the spring force.

Three times repeating the process of immersion and sterilization in this study were used to investigate the possibility of reuse for several times. By accepting the lack of the effect of the above process three times on the spring properties, the results could be generalized with greater confidence to less repetitions of the reuse.

CONCLUSION

One-minute immersion in 10% HCL and 5-min immersion in 5.25% NaOCl, followed by autoclave sterilization, even after repeating the process three times, did not significantly change the force properties of NiTi open springs. Therefore, the reuse of these

coils with the above-mentioned method can be recommended.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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