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Original Article

Effect of hydrochloric acid, sodium hypochlorite, and autoclave sterilization on the force characteristics of orthodontic NiTi-closed coils

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ABSTRACT

Background: This study presented a cleaning method for orthodontic NiTi-closed coils and evaluated its effect on the force characteristics of these coils.
Materials and Methods: In this *in vitro* study, 160 orthodontic NiTi-closed coils, 160 orthodontic NiTi-closed coils (9 mm) from two brands G and H and DB, randomly assigned into four groups. Group 1: Three times of immersion in the 10% hydrochloric acid (HCl) solution for 1 min followed by the immersion in 5.25% sodium hypochlorite solution for 5 min. Group 2: Three times autoclave sterilization. Group 3: Three times of immersion in 10% HCl solution for 1 min, followed by the immersion in 5.25% sodium hypochlorite solution for 5 min and autoclave sterilization. Group 4: No immersion and no sterilization. The forces of coils were measured at 25, 23, 21, 19, and 17 mm extension. To measure the force characteristics of coils, an electromechanical universal testing machine was used. For the statistical analysis, Kolmogorov–Smirnov, Kruskal–Wallis, and Mann–Whitney U-tests were used at 0.05 significance level.
Results: In G and H coils, no significant differences between the mean forces of different groups were found in any extensions. In DB coils, only in 25 mm extension, there were no significant differences between the groups ($P = 0.144$). In 17-, 19-, and 21-mm extensions, significant differences ($P < 0.001$) were found like in 23 mm extension ($P = 0.05$). In both brands, more extension makes significant more forces statistically ($P < 0.01$). In all extensions, G and H coils have significant less forces ($P < 0.001$).
Conclusion: Immersion in HCl, 10% for 1 min followed by the immersion in NaOCl, 5.25% for 5 min followed by autoclave sterilization, even three times repeating of this process, did not result in significant changes in the force characteristics of A-NiTi-closed coils.

Key Words: Autoclave sterilization, cleaning, equipment reuse, hydrochloric acid, sodium hypochlorite

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INTRODUCTION

NiTi-closed coils are the routine force sources in sliding mechanics for space closing. The low and consistent forces of them are their principal advantage.[1] Their high cost is the noticeable disadvantage. Therefore, their reuse has been

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considered.[2] Reuse of medical instruments, such as the delicate angiography catheters, has a long history.[3] This can be accomplished only in cases in which the first use and preparation of them for their reuse do not result in significant clinical properties changes. Furthermore, reuse should be possible from an economic point of view and easily implemented in the clinic.[4] The most important reason for reuse is economic considerations.[5,6] Other reasons are bioenvironmental considerations.[6,7]

Many dental instruments are reused, for example, steel crowns,[8] bone drills,[9] polishing cups,[10] polishing disks,[11] endodontic files,[12] and some dental implant components such as healing abutments.[5] In orthodontics, reuse of some instruments has been suggested for many years,[13] for example, metallic[14] and ceramic[15] brackets, bands,[16,17] NiTi wires,[2,18] and orthodontic mini-implants.[4,19]

It is necessary to clean the medical instruments before the sterilization process.[20] The aim of the cleaning is to eliminate or decrease the visible particles, including blood proteins and debris from the surface.[20] The elimination of mineral and organic debris has a pivotal role in infection control, particularly in preparing them for reuse.[21] During the cleaning process, it is necessary to gain access to all the internal and external surfaces of the instrument.[20] The type of the instrument and its design might make the cleaning process difficult. Surface irregularities and porosities, sharp angles, closed ends, dead spaces, rough borders, lumens, long and thin axes, and fissured surfaces make it difficult to eliminate the debris and biofilms.[20] Residual bacterial debris, biofilms, and their drying on the surfaces make it difficult to clean and sterilize them.[20] The clinical process might be mechanical, chemical, or a combination of both techniques.[22] Chemical techniques consist of the use of solutions that have specifically been labeled for cleaning medical instruments. In general, the manufacture of each dental instrument, which can be reused, should explain the correct technique for disinfecting or sterilizing the instrument.[23]

Hydrochloric acid (HCI) is a clear liquid with a corrosive behavior, which is used in home as a cleaning agent in addition to its applications in different industries.[24] The concentration of this agent for household applications is 10%–12% and is used for different cleaning and disinfecting purposes.[25,26] In dentistry, this solution is used to remove the enamel stains,[27] microabrasion to improve decalcification.[28] This powerful acid can be used to eliminate the mineral debris. Sodium hypochlorite is an inexpensive-oxidizing agent and the most commonly used disinfecting agent. One of the main characteristics of sodium hypochlorite is its antibacterial properties due to its proteolytic potential and buffering capacity.[29] This solution is capable of eliminating the organic tissues.

Limited studies have evaluated the reuse of NiTi-closed coils in orthodontics.[30,31] This study presented a novel-cleaning method and evaluated its effect and autoclave sterilization on the force characteristics of these coils.

MATERIALS AND METHODS

This study is a blind-experimental study. 160 NiTi closed coils, with 9 mm length from two brands G and H (G and H Wire Company, 2165 Earlywood Drive, Franklin, IN, USA) and DB, (DBOrthodontics, Ryefeild Way, Silsden, West Yorkshire, UK) were used. Each brand is randomly assigned into four groups (*n* = 20). The inclusion criteria consisted of the absence of any visible and definitive macroscopic defects in the coils. The exclusion criteria were any visible and definitive macroscopic defects in the coils. The coils were mounted on the jigs fabricated with 0.9-mm steel wires, so that the internal distance of the coil eyelets was 25 mm [Figure 1]. In each brand, the test groups underwent different processes as follows:

- Group 1: Three times immersion in the household cleaning solution for 1 min followed by the immersion in home bleach solution for 5 min
- Group 2: Three times autoclave sterilization. (at 134°C and 32 psi)

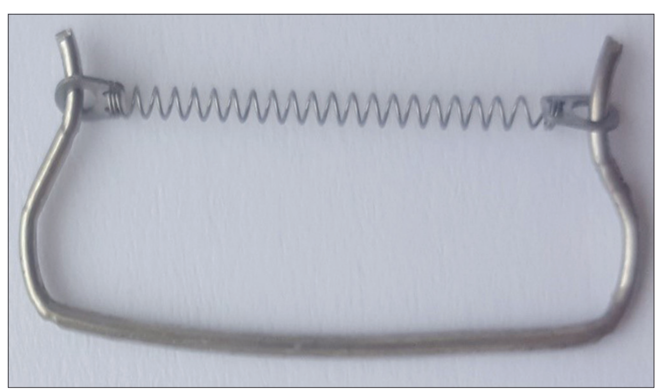

Figure 1: Jigs for mounting the coils; were fabricated with 0.9-mm steel wires so that the internal distance of the coil eyelets was 25 mm.

- Group 3: Three times of immersion in household disinfecting solution for 1 min, followed by the immersion in home bleach solution for 5 min and autoclave sterilization
- Group 4: No immersion and no sterilization (new coils as control).

The household cleaning solution brand was Golrang (Golrang, Tehran, Iran) and consisted of 10% HCI. The home bleach solution consisted of 5.25% sodium hypochlorite solution from Golrang (Golrang, Tehran, Iran). The solutions were prepared fresh with a volume of 20 ml for each sample. After each immersion, the samples were rinsed under running water for 10 s, and then, the next immersion procedure was carried out.

To evaluate the effects of autoclave sterilization, the samples were placed in an open container and transferred to an autoclave (MOCOM; PRIMA, Australia). The coils were placed far from each to provide enough ventilation for a better sterilization. The process was done at 134°C and 32 psi.

For the blinding of measurements, after these steps, the samples were coded by the first researcher, and all the measurements were carried out by the second researcher.

To measure the force characteristics of coils, an electromechanical universal testing machine (K-21046, water + bai, Switzerland) was used. Two hooks were fabricated with 0.9-mm steel wire and placed on each side of the machine so that the distance between them was 25 mm. The first point for measuring the force (25 mm) was approximately equal to the distance between the hook of the canine tooth and that of the first molar tooth. Each coil was placed separately on this setup, and its force was measured. Then, the moving arm moved toward the other at speed of 5 mm/min[1] and the unloading force of each spring was recorded at each 2 mm steps. Hence, the forces of coils were measured at 25, 23, 21, 19, and 17 mm extensions. The effective part of the coil, i. e., the part with an elastic capacity, was around 4 mm less than that reported for the coil.[37] The effective length of coil were measured under a stereomicroscope with 8X zoom (Trinocular zoom Stereo Microscope, SMP-200, Supplied with Moticam 480 DigitalCamera, SP10.0224, Motic Instruments Inc., CA, USA) [Figure 2]. All the tests were carried out under the same condition at the room temperature. One

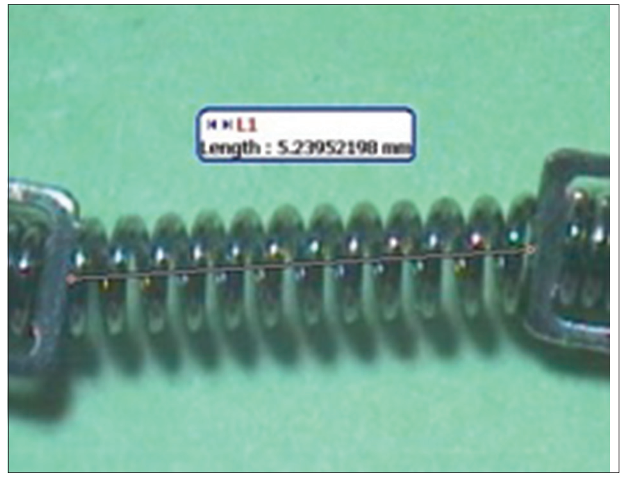

Figure 2: Measuring the effective lengths of closed coils with stereomicroscope.

sample from each group underwent evaluations under the scanning electron microscope (SEM) with 50, 150, and ×1500 zoom for qualitative evaluation of surface changes [Figure 3]. After decoding of the samples, data were analyzed with Kolmogorov–Smirnov, Kruskal–Wallis, and Mann–Whitney U tests with the SPSS software version 22 (SPSS Inc., Chicago, IL, USA). Significance level was set at 0.05.

RESULTS

The mean of force values in different extensions and effective coil lengths is presented in Tables 1 and 2, respectively. One-sample Kolmogorov–Smirnov test showed that only 16 from 48 groups had normal distribution. Hence, nonparametric tests were used. Kruskal–Wallis test was done to compare four different groups in 17, 19, 21, 23, and 25 mm coil extensions, separately.

In G and H coils, no significant difference between the mean forces of different groups was found in any extensions. In DB coils, only in 25 mm extension, there was no significant differences ($P = 0.144$) between the groups. In 17, 19, and 21 mm extensions significant differences ($P < 0.001$) were found like in 23 mm extension ($P = 0.05$). In both brands, more extension makes significant more forces statistically ($P < 0.01$). In all extensions, G and H coils have significant fewer forces ($P < 0.001$). The mean of coil lengths in both G and H ($P = 0027$) and DB ($P < 0.001$) brands had a significant difference between their groups.

In electron microscopic views, no significant changes were seen between different groups of both brands. The surface of v coils seems smoother.

Table 1: Mean (standard deviation) of force values (cN) in different groups and different extensions

	Groups							
	G and H				DB			
	1	2	3	4	1	2	3	4
Extensions (mm)								
17	140.4 (12.8)	153.5 (39.3)	149.0 (8.2)	141.5 (18.2)	339.4 (35.1)	294.3 (35.9)	234.0 (37.0)	244.1 (43.7)
19	158.1 (13.9)	173.7 (51.5)	165.4 (10.9)	163.7 (16.6)	414.7 (50.2)	361.3 (57.6)	310.6 (55.9)	316.5 (53.5)
21	179.7 (11.9)	196.4 (65.9)	183.0 (9.7)	182.0 (15.3)	504.6 (63.8)	448.1 (76.8)	406.7 (70.2)	406.3 (68.1)
23	196.6 (13.9)	216.8 (77.7)	201.8 (9.6)	202.0 (17.7)	586.3 (66.6)	550.7 (94.0)	518.1 (81.2)	508.8 (74.6)
25	220.7 (17.8)	238.3 (90.30	218.1 (10.5)	228.6 (38.9)	662.9 (69.5)	652.3 (85.5)	636.9 (72.3)	611.4 (70.6)

Gray area: Statistically significant difference ($P<0.05$), Group 1: Three times immersion; Group 2: Three times autoclave sterilization; Group 3: Three times immersion and three times of autoclave sterilization; Group 4: Control

Table 2: Mean (standard deviation) of coil spring lengths (mm) in different groups

	Groups			
	1	2	3	4
G and H	3.7 (0.2)	3.8 (0.9)	3.7 (0.1)	3.7 (0.1)
DB	3.7 (0.3)	5.2 (0.4)	5.2 (0.8)	2.9 (0.2)

Group 1: Three times immersion; Group 2: Three times autoclave sterilization; Group 3: Three times immersion and three times autoclave sterilization; Group 4: Control

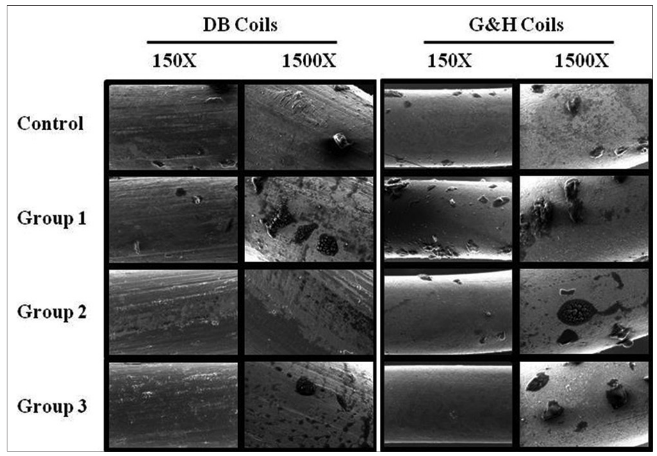

Figure 3: SEM views.

DISCUSSION

Reuse of instruments that are not damaged or do not undergo major changes in their mechanical properties results in a decrease in treatment costs. This can be great to manage of limited resources of healthcare, and finally, leading to increase in the number of patients benefiting from therapeutic services.[32,33]

Some studies have evaluated the effect of the clinical use and oral cavity conditions, including thermal and mechanical cycles, on NiTi-closed coils.[1,30,34-37] Most of them concluded that these factors do not have a significant clinical effect on the force levels of coils.

Before sterilization, cleaning is necessary.[38] In the present study, immersion in 10% HCI, followed by 5.25% sodium hypochlorite, was proposed as the cleaning method for NiTi-closed coils. These solutions are available as inexpensive household cleaning and bleaching agents. HCI, as a strong acid, has a high capacity to eliminate calcium-based minerals. Sodium hypochlorite, apart from its capacity to eliminate organic debris, exhibits high-disinfecting properties. However, it does not damage titanium and its alloys. It is necessary to gain access to all the surfaces of instruments that are prepared for reuse to carry out an effective cleaning procedure. This is more difficult for small objects with specific shape such as coil springs. The separation of coil helices due to mounting on jig and liquidness of cleaning agents make better access to all the surfaces of coil. Good solubility of them in water makes removing them easy with washing with water.

Two different brands of NiTi-closed coils were used: G and H as an A-NiTi coil, and DB as an M-NiTi coil. Sterilization in an autoclave and repetition of the process for three times did not result in a significant change in force characteristics of G and H coils.

However, significant changes were observed in the force properties of DB coils. Momeni *et al.*, too, reported a minor effect of sterilization in an autoclave on the force properties of these coils.[31] Ramazanzadeh *et al.*[39] reported that sterilization with autoclave resulted in a minor increase in the force levels of NiTi wires, which was not significant statistically. Smith *et al.*[40] evaluated the effect of clinical use and different disinfection/sterilization protocols on three types of NiTi wires and concluded that there were no significant clinical differences between the wires. Alavi *et al.*[2] reported that dry heat and autoclave sterilization resulted in a significant decrease in the forces of NiTi wires. Bavikati *et al*.[18] reported significant decreases in tensile strength and surface roughness of NiTi wires due to clinical use and sterilization. It should be noted that the manufacturing conditions and force distributions due to the changes in their form are different between NiTi wires and coils. Therefore, caution should be exercised in extending the results of wires to coils.

Immersion in 10% HCI, followed by immersion in 5.25% sodium hypochlorite and repetition of the procedure for three times did not result in significant changes in the force characteristics of G and H and BD coils. Immersion in 10% HCI, followed by immersion in 5.25% sodium hypochlorite, and then, sterilization in an autoclave and repetition of this process for three times did not result in significant changes in the force characteristics of G and H coils. Therefore, cleaning and sterilization of A-NiTi-closed coils to reuse is possible. In relation to the effect of immersion in the disinfecting solution in the present study or the effect of cleaning alone or in association with sterilization in an autoclave, no similar study was found on orthodontic coils for the comparison. However, it has been reported that the immersion in 5.25% NaOCl for 24 h did not affect the surface characteristics and fracture resistance of NiTi files.[41]

In both coil types, an increase in extension resulted in an increase in force levels, with higher rate in the DB coils, which might be explained by its different types of NiTi alloy (M-NiTi). The less steep force diagram of G and H coils is related to its super-elastic properties. No similar study was found on the effect of use or cleaning/sterilization procedure on the coil length for the comparisons. Comparison of the coils showed that at similar extension the mean force in the DB coil was significantly higher. This can be explained by M-NiTi alloy of DB coils and A-NiTi alloy of G and H ones.

The first point for measuring the force (25 mm) was approximately equal to the distance between the hook of the canine tooth and that of the first molar tooth. This distance has also been used in similar studies.[42-44] The point of termination for force measurement was 17 mm, approximately the distance after the canine tooth reaches the second premolar tooth. In addition, the measurements were carried out at points 19, 21, and 23 mm to make the results more valid and make the force changes gradient clearer at different extensions. Force measurement in the unloading condition is more similar to the clinic.[1,34]

The means of the forces measured in new coils in the control groups were different from those reported by the manufacturers, consistent with the results of previous studies,[1,45] which might be attributed to the differences in the conditions and techniques of measurements.

After the measurement of forces, the changes of effective length of coils were assessed under a stereomicroscope with 8X zoom (Trinocular zoom Stereo Microscope, SMP 200, USA). The effective part of the coil, i.e., the part with an elastic capacity was around 4 mm less than that reported for the coil.[37] In relation to G and H coil, there were no significant differences in coil lengths between the control and experimental groups, which might be attributed to the supper-elastic nature of its alloy. However, in relation to DB coils, there were significant differences in coil lengths between the control and experimental groups. Greater permanent deformity of M-NiTi alloy compared to A-NiTi alloy was predictable and has been reported in other studies, too.[46]

Repetition of the immersion and sterilization process in the present study aimed to evaluate the possibility of several times reuse. Repetition of intervention has been carried out in other studies.[11,47] This provides more confidence to generalize the results to fewer times of reuse. SEM images did not reveal significant surface changes due to immersion and autoclave sterilization procedures [Figure 4]. A study reported insignificant

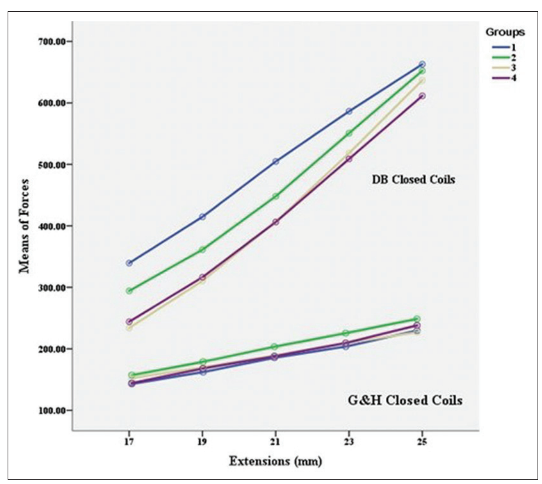

Figure 4: Comparison of force values (cN) in different extensions of the two coil brands. Group 1: Three times immersion; Group 2: Three times autoclave sterilization; Group 3: Three times immersion and three times autoclave sterilization; Group 4: Control.

increase in surface roughness after autoclave[48] and other reported an increase in the surface roughness of NiTi wires[18] and NiTi endodontic files[49] after repeated autoclave sterilization. A study reported 24 h immersion in 5.25% NaOCl has some effects on surface characteristics of NiTi endodontic files.[50]

CONCLUSION

- Three times immersion in household-cleaning liquid (HCl, 10%) for 1 min and immersion in household bleaching liquid (NaOCl, 5.25%) for 5 min did not result in significant changes in the force characteristics of A-NiTi closed coils
- Three times autoclave sterilization did not result in significant changes in the force characteristics of A-NiTi-closed coils
- Three times immersion in household-cleaning liquid (HCl, 10%) for 1 min followed by the immersion in household-bleaching liquid (NaOCl, 5.25%) for 5 min followed by autoclave sterilization, did not result in significant changes in the force characteristics of A-NiTi closed coils.

Hence, A-NiTi closed coils can be reused and this immersion protocol can be suggested as cleaning method before autoclave sterilization.

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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 nonfinancial in this article.

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