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Influence of different recycling protocols on load deflection of nickel titanium orthodontic wire

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Abstract

The purpose of this study was to investigate the changes in the load deflection of nickel titanium orthodontic wire after different recycling protocols. A spooled 0.014 inch nickel titanium wire was separated into 7 groups: as received condition (T0,control group),treated in artificial saliva for 4 weeks (T1), treated in artificial saliva and autoclaved (T2), treated in artificial saliva and dry heated (T3), treated in artificial saliva and disinfected by glutaraldehyde (T4), treated in artificial saliva and disinfected by iodophor (T5) and treated in artificial saliva and disinfected by chlorhexidine (T6).The changes in the load deflection were observed by special test apparatus based on 3-point bending mechanism, the findings of the current study showed that there was highly significant difference in mean load deflection of nickel titanium wire between all recycling protocols ($P < 0.0001$). The recycling by sterilization of the wire by heat autoclave or disinfection by chlorhexidine both seem to be the best recycling protocols because of lowest detrimental effect on the load deflection, while the disinfection by glutaraldehyde or iodophor shows intermediate detrimental effect on the load deflection, and the sterilization by dry heat seems to be the worst recycling protocol because it shows highest detrimental effect on the load deflection value.

Key word: Influence of recycling, load deflection, orthodontic nickel titanium wire.

Introduction

Nickel titanium orthodontic wires have been attractive because of their unique properties of high spring back and low stiffness while maintaining good strength[1]. These properties make the wires resistant to permanent deformation so that the wires return to their original shape after clinical usage, their high cost has hampered their universal appeal. As a consequence both the cost factor and the retention of elastic properties of being return to their original form have prompted some clinicians to reuse these arch wires [2,3,4,5].

To minimize the potential health hazard to the patient who receives either new or recycled wires since these new wires are frequently packed in individual sealed bags in order to avoid cross-contamination .The instruction on the wrapper generally advise sterilization of the bag and/or disinfection of the wire if additional protection is required, and to minimize the potential health hazard to the patient who receives a recycled wires, therefore accepted techniques of sterilization or disinfection must be

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adopted [6,7] and their effects on the wires must be known.

Since 1980s, studies have been undertaken to investigate the possibility of changes in orthodontic wires resulting from sterilization. But till now no clear literature exists concerning the reuse of the wires following treatment with currently accepted heat sterilization or cold disinfection techniques.

However, both in vivo and in vitro studies suggest that nickel titanium is susceptible to a pitting–type corrosion attack, and most chemicals used for disinfection or sterilization processes are corrosive and attack metals that are immersed or placed in them [5, 8, 9, 10]

In light of the fact that nickel titanium wire is being reused, in the present study the fundamental load deflection of this wire is tested.

The main aims of the present study were:

1. To evaluate the changes in load deflection of nickel titanium orthodontic wire after incubation in artificial saliva and the consequences of sterilization or disinfection protocols for assessment the efficacy of their reuse.
2. To determine which the best sterilization or disinfection protocol is that maintains the load deflection of nickel titanium orthodontic wire intact from deterioration.

Materials and Methods

Orthodontic Wire: The orthodontic arch wire used is 0.014 inch (0.35 mm) spooled round nickel–titanium orthodontic arch wire (supplied by Ortho-Organizers Company);

Media: The immersion media that were used in the present study can be classified into test and control include:

Chemical disinfectants (test): considered as the most popular classes approved by the American Dental Association (ADA) [11].

-2% acid glutaraldehyde (Banicide) ;(Pascal Intentional Corp.;Bellevue ;Wash.;USA).

-Iodophor (Wescodyne); (West Chemical Products Inc.;N.Y; USA).

-2 % Chlorhexidine gluconate; (Al-Mansour pharmaceuticals; Iraq)

<u>Artificial saliva (control)</u>: 1.44 gm/l Na HCO_3 ,0.21gm/l Ca Cl_2 and 0.46 gm/l NaH_2PO_4 were diluted in 1000ml deionized water and continuous stirring with electromagnetic stirrer and pH monitored with pH meter until required pH(7)was reached [12] .

Equipment: The heat sterilization equipment tested, considered as the most accepted heat sterilization procedures by the ADA include[6]:

- Memmert dry heat sterilizer (Schwaback,W.Germany).
- Dako steam autoclave (Dako – Line,Germany).

Methods

A new test apparatus was specially designed [13] (Figure 1) based on the mechanism of three-point bending test [10, 13, 14, 16, 17, 18]. The wire tested was spooled 0.014 inch round nickel titanium arch wire cut into 70cut pieces. The length of each piece was 4cm [19]. Then these 70 cut pieces of the wire were separated into 7 examination groups “10 cut pieces for each examined group” ,one control group(T0,n=10) as received condition “with out any treatment” and six experimental test groups, wires in the 1st experimental test group (T1,n=10) were exposed to artificial saliva(ASA) after being placed in AFMA-Dispo inert plastic container of 10 ml capacity and maintained in an incubator at 37^{o} C for 4 weeks [5]; wires in the 2^{nd} experimental test group (T2,n=10)were subjected to the same artificial saliva and incubation treatment for 4 weeks, cleaned by a piece of clean cotton then sterilized by steam autoclave at 121^{o}C (250^{o}F) and 15-20 psi for 20 minutes [4,5] ; wires in the 3 rd experimental test group (T3,n=10)were subjected to the same artificial saliva and incubation treatment for 4 weeks, cleaned by a piece of clean cotton then sterilized by dry heat at 180^{o}C(355^{o}F) for 60 minutes [4] ; wires in the 4th experimental test group (T4,n=10) were subjected to the same artificial saliva and incubation treatment for 4 weeks , removed and cleaned by a piece of clean cotton then immersed in acid glutaraldehyde “Banicide” (AG)after being placed in the inert plastic container for 10 hours [3] ; wires in the 5th experimental test group (T5,n=10) were subjected to the same artificial saliva and incubation treatment for 4 weeks , removed and cleaned by a piece of clean cotton then immersed in iodophor “Wescodyne” after being placed in the plastic container for 10 hours [3] ;wires in the 6th experimental test group (T6,n=10) were subjected to the same artificial saliva and incubation treatment for 4 weeks , removed and cleaned by a piece of clean cotton then immersed in Chlorhexidine after being placed in the plastic container for 10 hours, then after each group, any cut piece of the wire cleaned by a piece of clean cotton and tested by the following steps [in coincidence with three-point bending test fixture configuration]:

1) The arch wire is ligated centrally to brackets [Ultratrimm edgewise 0.022x0.030 inch Supplied by Dentaurum Company] using ligature elastics [Supplied by Dentaurum Company] (inter-bracket distance was 14mm) [20].
2) A stable compression force is applied through the force gauge “170gm” [Supplied by Anthogyr ,France] .
3) The amount of deflection was measured by mounted sensitive dial gauge [Supplied by HENRI HAUSER-BIENNE- SUISSE].

Then write down the specified reading in the dial gauge (load deflection), after the data was collected from the dial gauge, the data was analyzed statistically to know the effect of recycling on nickel titanium arch wire load deflection, after comparing with the control group.

Results and Discussion

A. The changes in load deflection of Ni -Ti arch wire:

The as received (T0) and the immersed in artificial saliva “ASA” (T1) Ni -Ti arch wires: The mean load deflection of the as received Ni -Ti arch wire(T0) is similar to that after the immersion in ASA(T1) and considered of highest mean deflection values among all examined groups, the range of load deflection is 0.02 ,which is considered to be high, this means that the flexibility of the as received or immersed in ASA Ni-Ti arch wire is still high and not affected, this expressed by the same mean load deflection value of Ni-Ti arch wire, as shown in table 1 and figure 2.

The steam heat autoclave sterilized Ni -Ti arch wire (T2): The mean load deflection of Ni -Ti arch wire after sterilization by the heat autoclave (T2) is one of the high values among all examined groups, the range of load deflection is 0.02 and this value is similar to that of the as received controlled (T0) and immersed in ASA(T1) wires in being high, this means that the flexibility of Ni -Ti arch wire is not highly affected after the heat autoclaving sterilization procedure and this is approved by one of the highest mean load deflection value among the experimental test groups as shown in table 1 and figure 2.

The dry heat sterilized Ni -Ti arch wire (T3): The mean load deflection of Ni -Ti arch wire after sterilization by the dry heat is the lowest mean deflection value among all examined groups, the range of load deflection is 0.01 and this value which is also the lowest value, this means that the flexibility of Ni –Ti arch wire is low and this is approved by lowest mean load deflection value among all experimental groups as shown in table 1 and figure 2. .

The chemical glutaraldehyde disinfected Ni -Ti arch wire (T4): The mean load deflection of Ni -Ti arch wire after disinfection by glutaraldehyde is considered to be intermediate among all examined groups, the range is 0.015 and this value is considered as low value among the experimental test groups, this means that the flexibility of the wire is low also, and this expressed by reduction in mean load deflection value among the experimental test groups as shown in table 1 and figure 2.

The chemical iodophor disinfected Ni -Ti arch wire (T5): The mean load deflection of Ni -Ti arch wire after disinfection by iodophor is also considered to be intermediate among all examined groups; the range is 0.015 and as low as that in case of disinfection with glutaraldehyde if compared with the remaining experimental groups, this means that the flexibility of the wire is low also after disinfection of Ni -Ti arch wire with iodophor , and this expressed by reduction in mean load deflection value as shown in table 1 and figure 2.

The chemical Chlorhexidine disinfected Ni -Ti arch wire (T6): The mean load deflection of Ni -Ti arch wire after disinfection by chlorhexidine is one of the high values among all examined groups, the range of load deflection is 0.02, and so both the mean and range are similar to that in case of sterilization of the wire by steam heat autoclave and closest to the as received controlled wire, this means that the flexibility of the wire in case of T6 is not highly affected ,this is approved by one of the highest mean load deflection value among the experimental test groups as shown in table 1 and figure 2.

B. Mean comparison for the load deflection:

Comparison between all examined groups:

The result of the F test by ANOVA table as demonstrated in table 1 shows that there is a highly significant difference between all examined groups (T0, T1, T2, T3, T4, T5 and T6) for the mean load deflections of Ni-Ti arch wires at $P < 0.0001$, this is due to the lowest mean deflection value in case of T3, intermediate mean deflection values in cases of T4 and T5, high mean deflection values in cases of T2 and T6, and highest mean deflection values in cases of T0 and T1 .We can deduce that some recycling protocols could decrease the load deflection of Ni -Ti arch wire and this could agree with previous reports [20, 21, 22] This probably due to the surface interruption, oxidation and pitting which may lead to subsequent degradation in mechanical performance of Ni -Ti arch wire.

***Comparison between 2 different recycling protocols*:**

Student t-test between two different recycling protocols for the mean load deflections of Ni-Ti arch wires was performed as shown in table 2, the results of this test show that there is no significant difference between T0 and T1, this is due to the fact that titanium and its alloys are easily passivated metals due to the thin stable titanium oxide (TiO_2) layer which was formed within nanoseconds of exposure to air, thus preventing further diffusion and penetration of oxygen, resulting in excellent corrosion resistance and this surface oxide does not breakdown under physiological conditions or tissue simulated fluoids such as the ASA [23 ,24] therefore there was no detrimental effect on load deflection and subsequently no significant difference in mean load deflection of Ni-Ti arch wire between T0 &T1 and this could agree with other studies [5,25].

There is no significant difference between T0 and T2, this is due to the fact that sterilization by the heat autoclave shows no detrimental changes in the load deflection, this is probably due to the sterilization by the heat autoclave not adversely affects the titanium oxide layer which was formed therefore there was no detrimental effect on load deflection and subsequently no significant difference in mean load deflection of Ni-Ti arch wire between T0 &T2 and this is in accordance with other reports [4 ,7]

There is highly significant difference between T0 and T3, this is due to the fact that sterilization by the dry heat could adversely affect the titanium oxide layer which was formed therefore there was a detrimental effect on load deflection, and subsequently a highly significant difference in mean load deflection of Ni-Ti arch wire between T0 &T3 and this could agree with a study [10] and disagree with another [4] .

There is significant difference between T0 and T4 or T5, this is due to the fact that the disinfection by glutaraldehyde or iodophor shows detrimental changes in the load deflection, this is probably due to the disinfection by glutaraldehyde or iodophor adversely affects the titanium oxide layer of Ni-Ti arch wire which was formed therefore there were detrimental effects on load deflections because of corrosion, and subsequently significant differences in mean load deflections of Ni-Ti arch wire between T0 &T4 or T5 and this shows disagreement with other study [26].

There is no significant difference between T0 and T6, this is due to the fact that the disinfection by chlorhexidine shows no detrimental changes in the load deflection probably because it does not adversely affect the titanium oxide layer of Ni-Ti arch wire which was formed.

There is no significant difference between T1 and T2 or T6 , this is due to the fact that sterilization by the heat autoclave or disinfection by chlorhexidine shows high mean load deflection value if compared with the highest mean load deflection value of Ni-Ti arch wire after immersion in ASA.

There is highly significant difference between T1and T3, this is due to the fact that sterilization by the dry heat shows lowest mean deflection value among all examined groups if compared with the highest mean load deflection value after immersion in ASA.

There is significant difference between T1 and T4 or T5, this is due to the fact that the disinfection by glutaraldehyde or iodophor shows intermediate mean load deflection if compared with that of highest value after immersion in ASA.

There is highly significant difference between T2 and T3, this is due to the fact that sterilization by the heat autoclave shows high mean load deflection value if compared with that of lowest value after sterilization by the dry heat.

There is no significant difference between T2 and T4, T5 or T6 , this is due to the fact that sterilization by the heat autoclave or disinfection by chlorhexidine both show high mean load deflection values if compared with the intermediate mean load deflection values of Ni-Ti arch wire after disinfection by glutaraldehyde or iodophor respectively.

There is highly significant difference between T3 and T4, T5 or T6; this is due to the fact that sterilization by the dry heat shows lowest mean deflection value if compared with the intermediate mean load deflection values of glutaraldehyde or iodophor, and high value after disinfection by chlorhexidine respectively.

There is no significant difference between T4 and T5 or T6, this is due to the fact that disinfection by glutaraldehyde or iodophor shows intermediate mean load deflection if compared with the high value after disinfection by chlorhexidine .Also there is no significant difference between T5 and T6 this could be due to the intermediate mean load deflection of Ni-Ti arch wire after disinfection by iodophor and the high value after disinfection by chlorhexidine respectively.

Summery and conclusions

- For orthodontists who want to guarantee maximum safety for the patients, sterilization or disinfection of the Ni-Ti orthodontic wires before placement could alter the properties of the wire alloy, therefore those different recycling protocols could decrease the load deflection value and this could be due to corrosive degenerative changes of the passive TiO_2 film on the wire and subsequently detrimental effect on load deflection.
- The sterilization by the heat autoclave or disinfection by chlorhexidine both seem to be the best recycling protocols because both show least detrimental effect on the load deflection because those protocols show high mean load deflection values which were closer to the control.

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Table 1: Descriptive and comparative statistics for the load deflection of Ni-Ti orthodontic wire after different recycling protocols.

Group	Mean (mm)	SD	Min	Max	Range	ANOVA (F test)	p-value
T0	.048	.00580	.040	.060	.020	13.687	.000 **
T1	.048	.00580	.040	.060	.020		
T2	.044	.00459	.040	.060	.020		
T3	.030	.00550	.020	.030	.010		
T4	.043	.00483	.040	.055	.015		
T5	.042	.00486	.040	.055	.015		
T6	.044	.00459	.040	.060	.020		

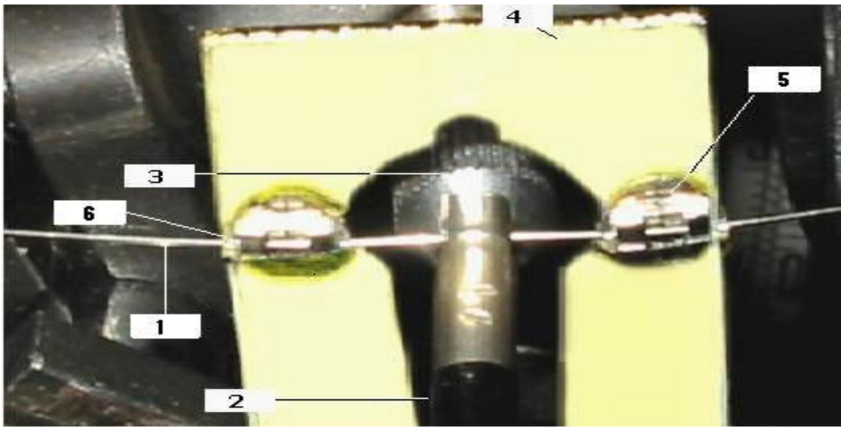
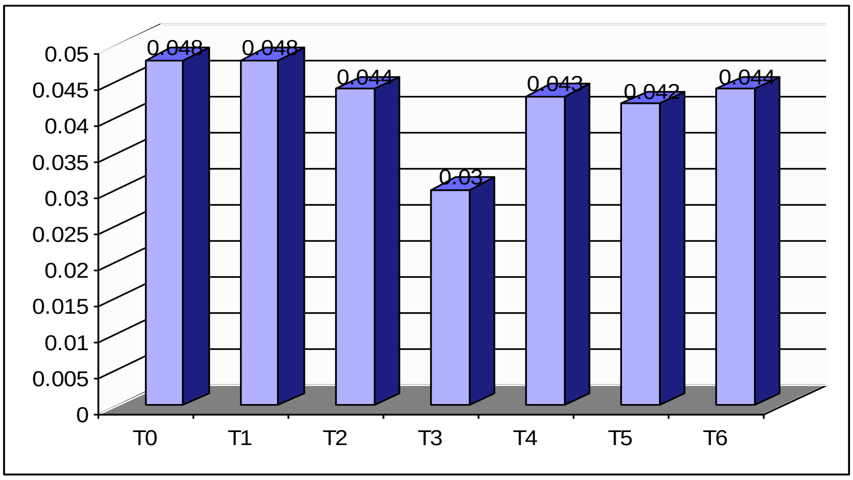


Figure 1: Magnified view of the loading cell of the test apparatus .
1: By pass vertical stud.
2: Dynamometer
3: Dial gauge.
4: Arch wire.
5: Bracket.
6: Ligature elastic.



Different recycling protocols

Figure 2: Bar-chart for the mean load deflection of Ni-Ti arch wire after different recycling protocols

Table 2: Mean comparison for the load deflection of Ni-Ti arch wire *between 2 different recycling protocols by using student t-test.*

Groups	t-test	p-value
T0 vs T1	.000	1.000
T0 vs T2	1.924	.070
T 0 vs T3	7.121	.000 **
T0 vs T4	2.305	.033 *
T0 vs T5	2.508	.022 *
T0 vs T6	1.924	.070
T1 vs T2	1.924	.070
T1 vsT3	7.121	.000 **
T1 vs T4	2.305	.033 *
T1 vs T5	2.508	.022 *
T1 vs T6	1.924	.070
T2 vs T3	5.955	.000 **
T2 vs T4	.474	.641
T2 vs T5	.709	.487
T2 vs T6	.000	1.000
T3 vs T4	-5.399	.000 **
T3 vs T5	-5.169	.000 **
T3 vs T6	-5.955	.000 **
T4 vs T5	.231	.820
T4 vs T6	-.474	.641
T5 vs T6	-.709	.487

N=10 for each group
df=69
** = High significant (P<0.0001)
Vs: Versus.
df=18
**: Significant (P<0.05)*
***: High significant (P<0.0001)*