The effects of sterilization on the tensile strength of orthodontic wires

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As overhead costs rise, orthodontists are continually searching for ways to reduce costs. One example of this is the reuse of nickel titanium and beta-titanium wires. Beta-titanium (TMA) wires (Ormco Corporation, Glendora, Calif.) are approximately three times more expensive than stainless steel arch wires, while nickel titanium wires are usually twice as expensive. These two types of titanium wires are extremely popular, and it is unlikely that orthodontists will discontinue their use due to their relatively high price. Therefore, the challenge is to make more cost effective use of these wires. Sterilization and reuse of the more expensive orthodontic wires is one option.

In the past many orthodontic offices have used cold sterilization solutions for pliers, wires and other orthodontic items. However, since items frequently were only placed in the solutions only long enough to achieve disinfection (a few hours) rather than sterilization (10.5 hours)[1] this standard has changed. Dry heat and/or autoclaving are now accepted as the best methods of sterilization for metal items.[1] Cold solutions and gas sterilization are still accepted for non-metal items.[2]

When considering the reuse of orthodontic arch-

Abstract

The purpose of this study was to evaluate the effect of sterilization on the tensile strength of 0.016" beta-titanium, nickel titanium and stainless steel wires. Three common methods of sterilization — autoclaving, dry heat and ethylene oxide—were evaluated in three test trials involving zero, one and five sterilization cycles. For each of the test trials, five pieces each of 0.016" TMA, 0.016" Sentalloy and 0.016" Tru-chrome stainless steel wires were sterilized using a standard autoclave. Five other pieces of each of the same wires were sterilized in a dryclave, while an additional five pieces of each of the three wire types were sterilized using ethylene oxide. The ultimate tensile strengths of the wires were then determined using an Instron Universal Testing Machine. The data were compared for statistical differences using analysis of variance. The results showed that dry heat sterilization significantly increased the tensile strength of TMA wires after one cycle, but not after five cycles. Autoclaving and ethylene oxide sterilization did not significantly alter the tensile strength of TMA wires.

Dry heat and autoclave sterilization also significantly increased the tensile strength of Sentalloy wires , but the mean strength after five sterilization cycles was not significantly different than after one cycle. Ethylene oxide sterilization of Sentalloy wires did not significantly alter the tensile strengths of that wire.

There were no significant differences in the tensile strengths of the stainless steel wires following zero, one or five cycles for any of the sterilization methods.

Key Words

Sterilization • Tensile strength • Wire • Recycling

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Figure 1
The test wire attached to the shackle with RM locks in order to prevent slippage during the tensile strength test.

Figure 2
The test wire attached to the Instron Universal Testing Machine using two shackles and RM Locks.

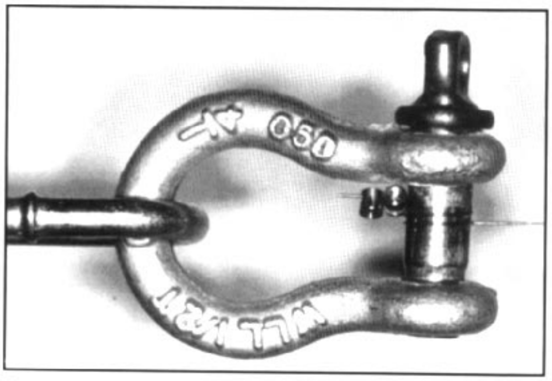

Figure 1

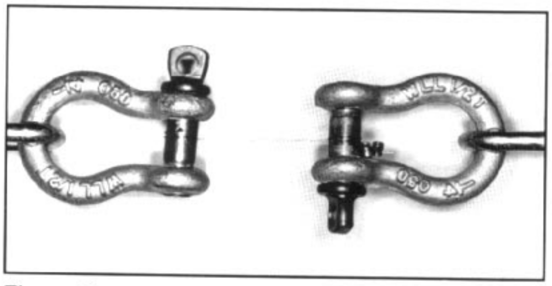

Figure 2

wires, one must evaluate the effect that sterilization has on the physical properties of wire. Changes in the tensile strength will have a direct impact on the clinical use of a wire. If a wire's ultimate tensile strength is decreased, it is more prone to breakage, which presents a problem for the patient and the orthodontist alike. In a 1986 survey, Buckthal et al.[3] reported that 52% of the orthodontists using nickel titanium wires were recycling these wires, and 55% of these orthodontists were concerned about the changes in the physical properties of the nickel titanium wires resulting from sterilization.

Investigation of the effects of sterilization on orthodontic wire properties has been limited. Mayhew and Kusy[4] determined the tensile strengths of nickel titanium wires after sterilization by three methods: dry heat, autoclaving and chemical vapor. After three cycles, none of the sterilization methods appeared to have altered the tensile strengths of the nickel titanium wires. Buckthal and Kusy[5] investigated the effect of cold sterilization solutions on nickel titanium wires. Again, they found no change in the physical properties of the wires following three cycles of sterilization.

Previous studies have concentrated on rectangular nickel titanium wires and have not investigated TMA, stainless steel or round nickel titanium wires. For this reason, the purpose of this investigation was to examine the effect of repeated sterilization on the tensile strengths of round TMA, nickel titanium and stainless steel wires.

Materials and methods

The sterilization methods investigated were dry heat using the Dentronix DDS 5000 dry heat sterilizer (Dentronix, Ivyland, Penn.), (375° F for 20 minutes), autoclaving (250° F for 20 minutes) and ethylene oxide gas (4 hours). The tested wires were 7-inch segments of 0.016" TMA, 0.016" Sentalloy (GAC, Central Islip, NY) and 0.016" Tru-chrome (Rocky Mountain Orthodontics, Denver, Colo.) stainless steel. Three test trials were made using zero, one and five sterilization cycles. For the first test trial, five segments of each type of the above mentioned wires were sterilized one time using one of the three sterilization methods: an autoclave, a dryclave or ethylene oxide. The ultimate tensile strength of each wire segment was then tested. Each of the 7-inch wire segments was prepared for testing by attaching two RM Locks (Rocky Mountain Orthodontics, Denver, Colo.) 4 mm from each end of the wire and attaching each end of the wire to a shackle (Figure 1). The RM Locks and the shackles aided in attaching the wires to the Instron Universal Testing Machine (Instron Corporation, Canton, Mass.) for the tensile strength test (Figure 2). A 10,000 lbs. load cell and a 0.5 mm/minute cross-head speed were used on all test wires. The tensile strength recorded was the maximum stress value in pounds per square inch just prior to fracture of the test wire.[6] For the next test trial, this process was repeated for five segments of 0.016" TMA, five segments of 0.016" Sentalloy and five segments of 0.016" stainless steel wire which were sterilized five times using one of the three sterilization techniques. As before, the wires' tensile strengths were tested using the Instron machine. A final group of five pieces of each type of wire served as the control group, and the tensile strengths were determined without any sterilization.

A separate ANOVA test was run for each sterilization procedure of each type of wire using the data from zero, one and five cycles. Then using the Bonferroni method of setting the experimentwise level of significance at p=0.05, the mean wire tensile strengths for zero, one and five cycles were compared to determine whether one of the groups differed significantly from the others.

Results

The results of the ANOVA tests evaluating TMA wires sterilized by dry heat revealed that dry heat significantly increased the tensile strengths of the TMA wires after one cycle. However, there were no significant differences in the tensile strengths of unsterilized wires and wires sterilized five times.

Autoclave sterilization of TMA wires showed no statistical differences in the tensile strengths following zero, one and five cycles sterilization cycles. Ethylene oxide sterilization of TMA wires also showed no statistical differences in the tensile strengths after zero, one and five cycles.

ANOVA evaluation of Sentalloy wires and dry heat sterilization demonstrated a significant increase in tensile strengths when 0, 1 and 5 cycles were compared. Yet paired comparison of individual cycles means using the Bonferroni correction did not demonstrate a significant difference.

Autoclaving Sentalloy wires produced a significant increase in the tensile strengths of the wires after one and five sterilization cycles. However, the mean tensile strength after five cycles was not significantly different than after one cycle.

Ethylene oxide sterilization of Sentalloy wires demonstrated no significant differences in the tensile strengths following zero, one and five sterilization cycles.

There were also no significant differences in the tensile strengths of stainless steel wires after sterilization using any of the sterilization methods.

Means and standard deviations of the tensile strengths of the three types of wires following sterilization are summarized in Tables 1 and 2.

Table 1
The average tensile strength of 0.016" wire in pounds per square inch.

Wire	Sterilization Method	0 Cycles	1 Cycle	5 Cycles
TMA	autoclave	18,004.4	18,601.2	19,098.6
Sentalloy	autoclave	17,706.0	18,501.8	18,700.7
Stainless Steel	autoclave	26,757.9	26,658.4	26,757.9
TMA	dry heat	18,004.4	19,794.9	18,402.3
Sentalloy	dry heat	17,706.0	18,601.2	17,904.9
Stainless Steel	dry heat	26,757.9	26,061.6	26,658.4
TMA	ethylene ox.	18,004.4	18,501.8	19,198.1
Sentalloy	ethylene ox.	17,706.0	18,004.4	18,501.8
Stainless Steel	ethylene ox.	26,757.9	25,962.2	25,862.7

Table 2
Standard deviations of the mean tensile strength of 0.016" wire in pounds per square inch.

Wire	Sterilization Method	0 Cycles	1 Cycle	5 Cycles
TMA	autoclave	1078.2	754.3	1145.0
Sentalloy	autoclave	272.4	416.1	444.8
Stainless Steel	autoclave	222.1	444.8	222.4
TMA	dry heat	1078.2	648.4	497.3
Sentalloy	dry heat	272.4	444.9	703.3
Stainless Steel	dry heat	222.4	1089.6	272.4
TMA	ethylene ox.	1078.2	1287.4	444.9
Sentalloy	ethylene ox.	272.4	737.7	416.1
Stainless Steel	ethylene ox.	222.4	817.2	994.7

Discussion

The results of this study suggest that sterilization and reuse of orthodontic wires does not alter the ultimate tensile strength as expected. A common reason given for not recycling wire is fear of reducing the wire's strength. The data of this study showed that the tensile strength of both TMA and Sentalloy increased after sterilization, and for autoclave and ethylene oxide sterilization, five cycles, on average, resulted in a greater increase in strength than one cycle. However, when TMA and Sentalloy wires were sterilized by dry heat, on average, one cycle increased the tensile strength more than five cycles. Yet these differences were not significant. Therefore, one can conclude there is no difference between sterilizing TMA and Sentalloy wires one or five times. One can also conclude that sterilization of TMA and Sentalloy wires with dry heat, autoclave and ethylene oxide produces an increase, not a decrease, in tensile strength.

Sterilization of stainless steel wire by any method can be expected to decrease the wire's tensile strength. This may not present a clinical problem since few orthodontists reuse stainless steel wires.

Thus, wire recycling may be one method of reducing orthodontic practice overhead. However, not every wire may be recycled. TMA and stainless steel wires with bends are not candidates for recycling since the same bends will rarely fit more than one patient. Nickel titanium wires are usually placed without orthodontic bends, and most brands of nickel titanium wire are incapable of retaining a bend, which makes this type of wire ideal for sterilization and reuse. Still, breakage and patient abuse of these wires may prevent some wires from being recycled.

Archwires are not the only orthodontic items that may be recycled; brackets may also be reused. However, recycling orthodontic wires and brackets does raise some ethical questions. Scientific research can evaluate the quality of recycled orthodontic materials, yet monitoring the effectiveness of sterilization in private orthodontic offices is not as easily accomplished. Certainly the use of disposable items minimizes the chance of cross contamination between patients, and most orthodontic materials, o-rings, elastics, chain, saliva ejectors, etc., are disposable. Yet one must consider whether reduction of overhead achieved through recycling outweighs the risk of contamination between patients. Currently, orthodontic wires range in price from approximately $0.75 (round stainless steel) to $5.00 (rectangular TMA). If the orthodontic wires are changed at each monthly appointment for the total two-year treatment, approximately $36.00 to $240.00 would be spent on wire, depending on the composition, size and shape of the wires used. When comparing this to the average treatment fee of approximately $3000.00[7], wire costs seem minimal.

One must also consider the patient's opinion about recycling. Even though reducing overhead keeps overall treatment fees from increasing, some patients may not be receptive to recycled appliances or wires in their mouth. A loss of only one patient (and the $3000.00 fee) for this reason, will consume the money saved from the recycling of many wires and brackets.

Conclusion

Whether or not recycling is a practical method of reducing orthodontic overhead must be left for each practitioner to decide. However, the results of this study suggest that orthodontists who choose to recycle nickel titanium or beta-titanium arch wires do not need to be concerned about reducing the wires' ultimate tensile strengths by sterilization procedures.

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