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A Comparative Evaluation of Force Decay Characteristics between Retraction Springs and Elastomeric Chains - An In-Vitro Study

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Abstract

Objective: To compare the forces degradation between elastomeric chain , NiTi closed coil spring and stainless steel closed coil spring in dry and wet condition in a simulated oral environment over 21 days.

Materials and Methods: Materials used for the study were Group A – 30 Short Elastomeric chains in dry & wet conditions; Group B- 30 NiTi retraction springs in dry & wet conditions; Group C -30 Stainless Steel retraction springs in dry & wet conditions were evaluated, resulting

In total 90 specimens. Each was extended to 22 mm of length and force was measured at 1st day in dry condition and at 21st day after dipping the sample in artificial saliva at 37 degree Celsius on Instron machine. The data collected were analyzed by ANOVA.

Results: The mean±SD of force for Elastomeric chain and stainless steel closed springs were found to be statistically significant with P value <0.0001 and of NiTi closed coil springs was found to be statistically non-significant.

Conclusions: Between the three materials tested, NiTi closed coil springs showed the non-significant mean force decay, followed by stainless steel closed coil springs, and maximum force decay was shown by elastomeric chains.

Keywords: Nickel titanium closed coil spring; Stainless Steel Closed coil springs; Elastomeric Chain; Retraction Spring; Canine Retraction; Force comparisons

Introduction

For 100 years, orthodontic theory and practice has been based on the Angle paradigm. By early 1960s, more than half the American patients undergoing orthodontic treatment had extraction of some teeth, usually but not always the first premolars.[1]

In recent years elastomeric chains have become popular with the orthodontist as tooth-moving elements of the fixed appliance. These polyurethane materials have largely replaced latex elastics for intra-arch tooth movement. Force decay in these materials is significant and has been a clinical problem.[2]

Orthodontic coil springs made of stainless steel are relatively inexpensive and can be designed to provide sufficiently high applied forces to move teeth. However, stainless steel coil springs are often unable to maintain an optimal force over a sufficient range of spring action without either some detrimental effect like root resorption or the spring being too large to fit comfortably in the patient's mouth.

Nickel titanium (NiTi) alloys have gained substantial popularity since their introduction into orthodontics in 1971. Two unique properties, the super elasticity and shape memory phenomenon, have attracted considerable attention. The most desired factor is the constant force delivery in relation to time, use and activation. Closed coil springs are used above all for space closure and distalization of impacted canines.[3]

There are many treatment alternatives to close spaces after extractions have been executed for orthodontic treatment in friction mechanics as well as frictionless mechanics. The main motive of friction mechanics is continuous torque control, which is challenging to achieve in frictionless mechanics. So we chose friction mechanics and tried to find out which spring would give us the fastest results.

The purpose of this study was to compare the rates of force degradation between elastomeric chains, NiTi closed coil springs and stainless steel closed coil springs in dry and wet conditions during retraction of teeth individually and amongst each other in a simulated oral environment. There is a scarcity of studies comparing these three retraction materials. Hence this study was done to compare these springs for faster rate of retraction using sliding mechanics.

Materials And Methods

This study was conducted to evaluate the force decay of elastomeric chains, NiTi closed coil springs and stainless steel closed coil springs of G&H Wire Orthodontics (Franklin, IN, USA). Materials Used for the study were group A1– 30 Short Elastomeric chains (6 ringlets) G & H (Dry conditions), Group A2 - 30 Short Elastomeric chains (6 ringlets) G & H (Wet conditions); Group B1- 30 NiTi retraction springs (9 mm Length) G & H (Dry conditions), Group B2 -30 NiTi retraction springs (9 mm Length) G & H (Wet conditions); Group C1-30 Stainless Steel retraction springs (18mm Length) G & H (Dry conditions), Group C2 30 Stainless Steel retraction springs (18mm Length) G & H (Wet conditions).

Before commencing the study, an average distance of canine bracket hook to mesio buccal cusp of the molar teeth was calculated by analyzing 50 patient models. The sample consisted of 20 Angle's Class I malocclusions, 25 Angle's Class II malocclusions and 5 Angle's Class III malocclusions. An average value of 22mm was obtained as the standard inter-hook distance.

Acrylic jigs were prepared with stainless steel pins fixed, maintaining a standard distance of 22mm between the pins. (Figure 1). Two jigs were prepared (Figure 2) to clamp on to a Universal testing machine so as to facilitate the stretching of springs and elastomeric chains.

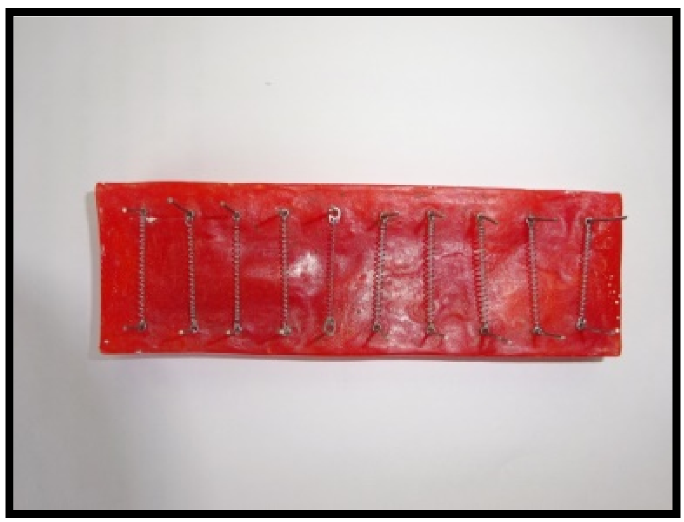


Figure 1: Acrylic jigs with stainless steel pins

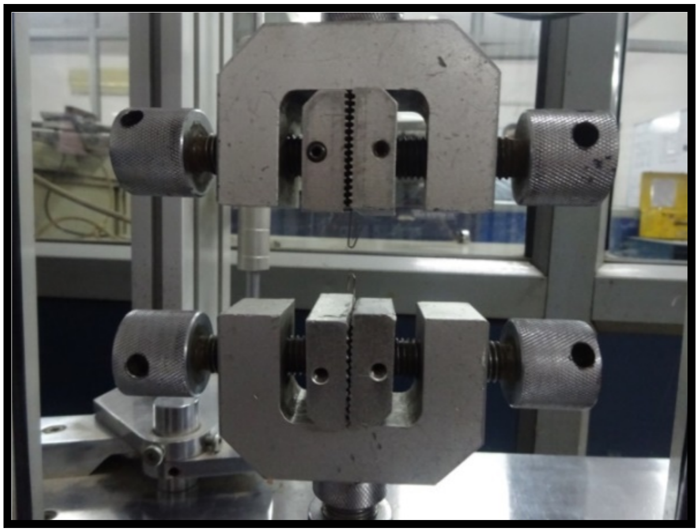


Figure 2: Jigs (for clamping on universal testing machine)

Elastomeric chains were taken and their length was fixed at 18mm with 6 ringlets each so that when stretched to 22mm, they would exert a force in the range of 150-300 grams which is the optimum force range recommended for retraction of canines (Figure 3).[4,5]

Figure 3: Elastomeric Chains stretched on the vertical jig clamped on the Universal testing machine at 22 mm

Similarly, NiTi retraction springs were taken. The springs were 9mm in length and 0.010x0.030 inch in dimension. The length of 9mm was selected so that the springs would exert a force in the range of 150-300 grams.

Also, stainless steel retraction springs each were taken. The springs were 0.0l0x0.030 inch in dimension. An optimum length of the springs had to be selected so that when stretched to 22mm, the springs would exert a force in the range of 150-300 grams. To do this, a pilot study was conducted testing different lengths of stainless steel springs. First, a length of 9mm was selected to match the length of the NiTi springs.

However, the spring underwent permanent deformation when stretched to 17mm and also exerted a force in excess of 450 grams when measured by a Correx gauge. Next a spring of length 16mm was selected and the force measured. The springs did not show any permanent deformation when stretched to 22mm, but the force exerted was in excess of 450 grams. Finally, a spring of length 18mm was selected and force measured by stretching the spring to 22mm. The spring exerted a force in the range of 200-250 grams without showing permanent deformation. This length was chosen as the standard length of all the stainless steel springs to be tested.

The elastomeric chains and springs were then stretched between the aluminum jigs clamped on to the Universal Testing Machine and the jigs were moved apart. The reading was recorded when the distance between the two vertical jigs was 22mm.

All the 90 samples were then transferred to the acrylic jigs and immersed in artificial saliva for 21 days and incubated at 37^{o} C.The trays were filled with artificial saliva so that the acrylic jigs with elastomeric chains and springs are fully immersed in it.

After 3 weeks the elastomeric chains and the springs were again transferred to the Universal testing machine and their force values recorded as before.

The force values on the first and twenty first day of testing were tabulated and were subjected to Paired sample T-test and One way ANOVA.

Results

The mean forces of all the three groups were calculated individually and amongst each other (Table 1). The mean±SD of force for Elastomeric chain A group was 2.63±0.244 at pre-test and 1.20±0.172 at post-test. On comparison of force from pre-test to post test showed a mean difference of -1.43 which was found to be statistically significant with P value <0.0001.Whereas the mean±SD of force for NiTi Closed Coil Spring B group was 1.44±0.197 at pre-test and 1.00±0.138 at post-test. On comparison of force from pre-test to post test showed a mean difference of -0.44 which was found to be statistically non-significant with P value 0.094. Also, the mean±SD of force for Stainless Steel Closed Coil Spring C group was 3.17±0.155 at pre-test and 2.22±0.182 at post-test. On comparison of force from pre-test to post test showed a mean difference of -0.95 which was found to be statistically significant with P value 0.001.

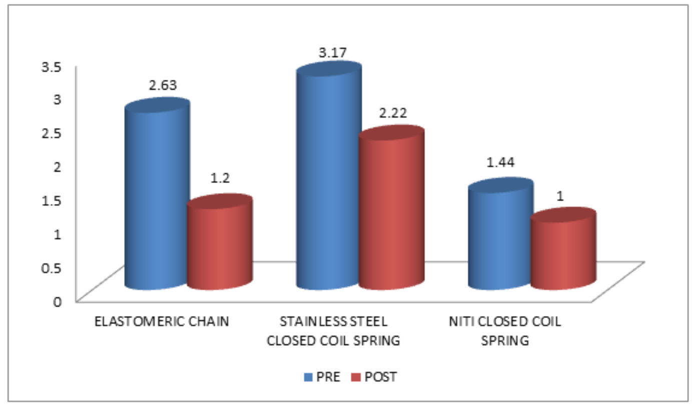
Table 1: Paired Sample T- Test

		Mean	N	Std. Deviation	Std. Error Mean	Mean Difference	%Change	p Value	S/NS
Elastomeric Chains	PRE	2.63	30	0.244	0.045	-1.43	-54.37	<0.0001	S
	POST	1.20	30	0.172	0.032				
Niti Closed Coil Spring	PRE	1.44	30	0.197	0.037	-0.44	-30.56	0.094	NS
	POST	1	30	0.138	0.026				
Stainless Steel Closed Coil Spring	PRE	3.17	30	0.155	0.029	-0.95	-29.97	0.001	S
	POST	2.22	30	0.182	0.034				

Table 2: Post Hoc Tests: Multiple Comparisons Tukey HSD Test

Main Group	Main Group	Mean Difference	Std. Error	p Value	95% Confidence Interval		NS/S
					Lower Bound	Upper Bound	
Elastomeric Chains A	NiTi Closed Coil Springs B	0.20	0.410	<0.0001	0.116	0.284	S
Elastomeric Chains A	SS Closed Coil Spring C	-0.84	0.088	<0.0001	-1.06	-0.62	S
NiTi Closed Coil Springs B	SS Closed Coil Spring C	0.55	0.093	<0.0001	0.32	0.79	S

Graph 1: Comparison of GROUP A, GROUP B and GROUP C.



Inter comparison of force decay between elastomeric chain and NiTi closed coil spring revealed the mean difference of 0.20 which is statistically significant (Graph 1).Inter comparison of force decay between Elastomeric chains and Stainless Steel closed coil spring revealed the mean difference of -0.84 which is statistically significant.Inter comparison of force decay between NiTi Closed Coil spring and Stainless Steel Closed Coil Spring revealed the mean difference of 0.55 which is statistically significant (Table 2).

Discussion

Over the years, a variety of materials have been used to close spaces between teeth as in the case of canine retraction after the extraction of premolars. These include latex elastics, coil springs, synthetic elastic modules, headgear, and magnets.[6] Many investigators have indicated the importance of using proper magnitude of force during orthodontic treatment to attain optimal tissue response and rapid tooth movement.[7,8] The retraction force during retraction of canines into the premolar extraction space should be in the range of 150- 300gms[9].

In 1996, Clemens Manhartsberger and Walter Seidenbusch[10] investigated Sentalloy springs of open and closed type. The closed coil springs were subjected to a tensile and the open coil springs to a compression test. The springs were tested for force decay over a 4 week period. During the course of the study the samples were maintained at 37°C. The samples showed a mean loss in force decay in the range of 10-15%.

C. Nightangale[11] investigated the force retention and rates of space closure achieved by elastomeric chain and nickel titanium coil springs. The elastomeric chains showed a mean force loss of 47% at the end of 4-6 weeks whereas Kyung-Ho Kim et al[12]evaluated the effects of pre-stretching on time-dependant force decay of synthetic elastomeric chains and showed mean force loss of 45-49% at the end of 3 weeks.

In the present study, NiTi retraction springs were found to be better than elastomeric chains and stainless steel retraction springs. However, to gain a more complete understanding of the mechanical properties of these materials under clinical conditions, it would be advisable to include thermal cycling, simulated chewing and tooth movement in the simulated oral environment.Padmaraj V. Angolkar[4] conducted a study and concluded that the NiTi springs showed a mean force loss of 9.9% at the end of 3 weeks, whereas the stainless steel coils springs showed a mean force loss of 21.4% over the same time period. V. Dixon[13] conducted a randomized clinical trial to compare the rates of orthodontic space closure for active ligatures, polyurethane power chain and nickel-titanium springs and concluded that NiTi springs gave the most rapid rate of space closure and may be considered the treatment of choice.

Orthodontic movement of teeth occurs as a result of biological response and as the physiological reaction to biomechanical forces. Orthodontic appliances are required to deliver a light continuous force regardless of the distance the teeth have moved. There are a variety of force systems that produce optimal force levels to move teeth through alveolar bone. The purpose of this study was to compare the rates of force degradation between elastomeric chains, NiTi closed coil springs and stainless steel closed coil springs.

The force decay was assessed by stretching the materials on a Universal testing machine following which they were transferred on to acrylic jigs. The jigs were stored in an artificially simulated oral environment by immersing the materials in artificial saliva at 37°C over a period of 3 weeks. After 3 weeks, the same materials were again tested on a universal testing machine to assess the force decay in the materials.

The retraction springs (NiTi closed coil spring and Stainless Steel Closed coil spring) and elastomeric chains tested in the study showed significant differences amongst themselves. Of the three materials tested, NiTi springs showed insignificant force decay, followed by stainless springs which showed little force decay, and lastly elastomeric chains which showed significant force decay.

The result of this study commends the hypothesis that nickel – titanium alloy is a better material to be used for the retraction mechanics as it gives a continuous force with non-significant force degradation when paralleled to other materials such as stainless steel alloy which although gives moderate amount of force decay, but is not as tenacious as nickel – titanium. Also, elastomeric chains in our study have shown the maximum amount of force degradation within a period of 21 days when kept in a simulated oral environment of 37°held at constant length in artificial saliva.

However, to gain more precise understanding of the mechanical properties of these materials, more clinical tests and more research on newer materials are required to effectively and efficiently get the desired results with least amount of undesired effects.

Conclusion

The purpose of this study was to compare the rates of force degradation between elastomeric chains, NiTi closed coil springs and stainless steel closed coil springs.

The retraction springs (NiTi closed coil spring and Stainless Steel Closed coil spring) and elastomeric chains tested in the study showed significant differences amongst themselves. Of the three materials tested, Group B (NiTi springs) showed insignificant force decay, followed by Group C (stainless springs) which showed little force decay, and lastly Group A (elastomeric chains) which showed significant force decay.

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