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The effect of different environmental factors on force degradation of three common systems of orthodontic space closure

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ABSTRACT

Background: Different environmental conditions, such as high temperature or exposure to some chemical agents, may affect the force decay of different methods of space closure during orthodontic treatment. The aim of this *in vitro* study was to evaluate the force decay pattern in the presence of tea as a popular drink in some parts of the world and two mouthwashes that are usually prescribed by the orthodontist once the treatment is in progress.

Materials and Methods: Elastic chain (EC), nickel-titanium (Ni-Ti) closed coil spring and tie-back (TB) method were used as the means of space closure. The specimens were placed in five different media: Hot tea, hot water (65°), chlorhexidine mouthwash, fluoride mouthwash and the control group (water at 37°). The specimens were stretched 25 mm and the elastic force of three systems was measured at the beginning of the study, after 24 h, after 1 week and after 3 weeks. One-way ANOVA was used to compare the results between the groups and Duncan test was carried out to compare the sets of means in different groups ($P \leq 0.05$).

Results: Tea increases the force decay in the EC and TB groups. Oral mouthwashes also resulted in more rapid force decay than the control group. EC and Ni-Ti groups were not much affected in the presence of oral mouthwashes.

Conclusion: Regarding the immersion media, TB method showed the biggest variation in different media and Ni-Ti coil spring was least affected by the type of media.

Key Words: Elastic chain, environmental factors, force degradation, nickel-titanium coil spring, tie back

INTRODUCTION

During the space closure phase of orthodontic treatment, sliding mechanics might be chosen as the treatment of choice. Different force delivery systems such as coil spring (either nickel-titanium [NiTi] or stainless steel), elastomeric chains, or elastic tie back (TB) method[1] (elastomeric modules attached to wire ligatures) have been used.[2] It has been wildly accepted that light continuous forces are the efficient method for achieving optimum tooth movement in fixed orthodontic treatment.[3-5] Therefore, regardless of the distance a tooth is to be moved, light continuous forces are the system of choice.

Synthetic elastomeric chains have been in use in orthodontics for more than 6 decades. It is well-understood today that elastomeric chains lose their force substantially once they are stretched.[6-11] It has been suggested that elastomeric chains lose the majority of their force (about 50-70%) during the first 24 h which is followed by a steady yet slow decline in the next 3-4 weeks.[6,12,13] Elastic TBs are also an efficient and easy method for space closure.[1,14] However, elastic modules are also reported to lose

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much of their force in the first 24 h.[15,16] TB method, on the other hand, is reported to have a more progressive force decay and its initial force is also reported to be lower.[17]

Stainless steel and NiTi coil springs have also been used extensively for space closure. Even though, they are reported to lose some of their force over time,[18] they have relatively lower force loss rate when compared with elastomeric chains and therefore are more effective clinically.[16]

The effect of different environmental conditions on force decay patterns of elastomeric modules, elastomeric chains and coil springs has been investigated.[13,19,20] Different environmental conditions such as temperature, pH changes, salivary enzymes and masticatory forces have been related to the behavioral changes of elastic chains (ECs).[7,8,21] However, it has been reported that unlike elastomeric chains, changes in the environment minimally affects NiTi coil springs and temperature only subtly affects their force delivery.[19] Teixeira *et al*.[20] in their study have reported that the immersion of elastomeric chains in Coke did not affect their force decay pattern, whereas Nattrass *et al*.[19] found Coke and turmeric solution to have a greater effect on force decay than water.

Even though, the effect of some beverages in the daily diet on the properties of elastomeric chains and modules as well as NiTi coil spring has been investigated,[11,19,22,23] there are some other beverages, which are very popular in other parts of the world. Tea is a highly consumed beverage in oriental countries. Not only chemical compound, but also the high temperature of tea in the time of consumption, might affect force decay pattern of different systems used in orthodontic treatment. The main ingredients of tea are polyphenols and caffeine and is highly suggested by doctors due to its anti-carcinogenic and anti-mutagenic activity.[24,25]

On the other hand, due to the need for meticulous oral hygiene maintenance in orthodontic patients, different mouthwashes are usually prescribed by the orthodontists once the treatment is in progress.

Considering the aforementioned factors, the aim of this study is to evaluate the effect of tea and two different mouthwashes - chlorhexidine and sodium fluoride- on the force decay properties of three common systems for space closure namely elastomeric chains, TB and NiTi coil springs.

MATERIALS AND METHODS

Three different means of space closure were tested in this study:

1. Four links of clear medium sized closed elastomeric chains (Maximum™ power chain, Ortho Technology, Tampa, Florida, USA) which is the usual length for retraction of canine in premolar extraction site according to the previous studies,[19,20,22,23,26]
2. 9 mm of superelastic NiTi closed coil spring[19] (TruFlex™ NiTi closed coil spring, Ortho Technology, Tampa, Florida, USA) and
3. TBs made by an elastomeric module stretched twice its size and attached to the ligature wire (Powerstick™ elastomeric ligatures, Ortho Technology, Tampa, Florida, USA).

In order to deliver the intended force, five acrylic bases of 26 cm × 5 cm × 1 cm in size were made. 15 jigs were constructed on each device; each jig was made up of 2 dowel pins that were placed parallel to each other and perpendicular to the base in two rows on either side of the base. The inter-pin distance was 25 mm as suggested by Nattrass *et al*.[19] Each of the force delivery systems was attached onto five jigs.

Each one of the five devices was immersed in one of the following test media according to the following instructions:

1. Tea (Lipton, yellow label), at 65°C for 3 min once a day. In order to determine the time each person takes to drink a cup of tea and the temperature at which it is consumed, 7 people were observed while drinking tea and the average elapsed time and the temperature of tea at the time they first started drinking the tea was recorded. To prepare the test media, 5 tea bags were placed in 1.5 L of boiling water for 5 min for the tea to brew. The temperature was checked with a thermometer and the devices were immersed in this media once it was 65°C.
2. Hot water at 65°C for 3 min once a day, this media was chosen to clarify whether the effect of tea on force decay is due to the chemical substances in it or merely a function of its high temperature.
3. Cordosyl 0.2% chlorhexidine digluconate mouthwash (Corsodyl, Glaxosmithkline co., Middlesex, UK) for 1 min, once a day, according to the manufacturer's directions.
4. Oral-B 0.05% sodium fluoride mouthwash (Oral-B Fluoride mouthwash, Germany) for 1 min,

once a day, according to the instructions of the manufacturer.

5. Control group: One of the devices served as the control group and was kept in distilled water at 37°C and did not receive any further treatment.

Therefore, the device placed in each media consisted of five samples of each of the three space closure systems.

In each case, force was measured at six times: At the beginning of the study and before treatment with different solutions (T0), 1 day (T1), 1 week (T2) and 3 weeks (T3) after placement in the certain media. Measurement at the end of day one was carried out as the specimens were immersed once in one of the four test media and had been returned to distilled water.

To measure the force, one end of the elastomeric chain, coil spring or the ligature wire end of the TB was held in one dowel pin and the other end was held by the lever of the Correx force gauge (Dentaurum, Germany) and was stretched along the line between two pins and the value was recorded. All the measurements were carried out by one operator by a precision down to 5 g. The force decay was defined as the percentage of force decrease during each time interval compared to the initial force.

Statistical analysis

SPSS 17 (SPSS Inc., Chicago, IL, USA) was used for data analysis. Mean and standard deviation of the force and the percentage of force decay were recorded for each group after the four time intervals. One-way ANOVA was used to compare the results between the groups and Duncan test was carried out to compare the sets of means in different groups. $P \leq 0.05$ was considered to be significant.

RESULTS

The mean and standard deviation of the force value in all 15 groups are outlined in Table 1.

Table 2 compares the parentage of force decay in different force delivery systems based on the media in which they were immersed. A sudden decrease in the force decay is observed in the 1st time interval (T0-T1), especially in the EC group.

The percentage of force decay over time in different force delivery systems - regardless of the media - are also reported in Table 3. When the effect of immersion media was not considered, the percentage of force decay was still the highest in the EC group and the lowest in the Ni-Ti closed coil spring group.

Figure 1 represents the pattern of force decay in three different systems of space closure based on the immersion media and the effect of the immersion media on the force decay over time is illustrated in Figure 2.

Table 1: The mean and SD of the force value (g) in different systems (EC, TB method and NiTi closed coil spring) and environments (tea, hot water, chlorhexidine, Oral-B fluoride mouthwash and control group) based on different time intervals

Environment	Space closure system	Time							
		T0		T1		T2		T3	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Tea	EC	488	59.1	200	18.9	194	35.3	162	14
	TB	449	89.2	280	28.2	274	28.4	250	21.5
	NiTi	227	32.5	198	17.7	189	14.1	180	12.8
Hot water	EC	478	40.5	208	30.1	188	31.2	161	21.3
	TB	508	59.0	366	41.1	342	56.1	236	36.6
	NiTi	221.0	16.1	171.5	10.8	168	13.5	159	7.7
Chlorhexidine mouthwash	EC	460	45.2	218	26.6	190	28.7	172	30.1
	TB	512	89.0	396	40.1	392	27.0	279	28.5
	NiTi	212.5	16.7	170	16.3	153	18.6	153	17.7
Sodium fluoride mouthwash	EC	508	51.9	216	32.4	187	21.1	172	18.1
	TB	462	71.5	348	30.1	325	37.5	297	30.6
	NiTi	207.5	17.2	162	14.6	151.5	12.3	149	13.5
Control	EC	500	26.6	242	22.0	216	27.6	197	18.9
	TB	502	55.3	434	32.7	400	26.7	376	32.7
	NiTi	224	13.2	166	18.2	159	9.7	150	11.1

EC: Elastic chain; TB: Tie-back; NiTi: Nickel-titanium; SD: Standard deviation

Table 2: The percentage of force decay in different space closure systems (EC, TB and NiTi) and environments (tea, hot water, chlorhexidine, fluoride mouthwash and control) based on different time intervals

Environment	Space closure system	24 h (T0-T1)		7 days (T1-T2)		21 days(T2-T3)	
		Force decay (%)	*P* value	Force decay (%)	*P* value	Force decay (%)	*P* value
Tea	EC	59	0.00	60.2	0.49*	66.8	0.005
	TB	37.6	0.00	38.9	0.59*	44.3	0.022
	NiTi	12.7	0.44	16.7	0.041	20.7	0.31*
Hot water	EC	56.4	0.00	60.6	0.20*	66.3	0.001
	TB	27.9	0.00	32.6	0.37*	53.5	0.00
	NiTi	22.6	0.00	23.9	0.52*	28	0.008
Chlorhexidine mouthwash	EC	52.6	0.00	58.6	0.018	62.6	0.001
	TB	22.6	0.006	23.4	0.716*	45.5	0.00
	NiTi	19.8	0.001	27.8	0.017	28.7	0.090*
Sodium fluoride mouthwash	EC	57.4	0.00	63.1	0.015	66.1	0.018
	TB	24.6	0.00	29.6	0.037	35.7	0.055*
	NiTi	21.7	0.00	27	0.017	28	0.13*
Control	EC	51.6	0.00	56.8	0.003	60.6	0.018
	TB	13.5	0.001	20.3	0.009	25	0.06*
	NiTi	25.8	0.00	29	0.218*	33	0.056*

*Non-significant. EC: Elastic chain; TB: Tie-back; NiTi: Nickel-titanium

Table 3: The percentage of force decay in different space closure systems (EC, TB and NiTi coil spring) regardless of the media over time

Space closure system	24 h		7 days		21 days	
	Force decay (%)	*P* value	Force decay (%)	*P* value	Force decay (%)	*P* value
EC	55.4	0.00	59.9	0.00	64.4	0.00
TB	25.2	0.00	29	0.008	40.8	0.00
NiTi	20.5	0.00	24.9	0.00	27.7	0.00

EC: Elastic chain; TB: Tie-back; NiTi: Nickel-titanium

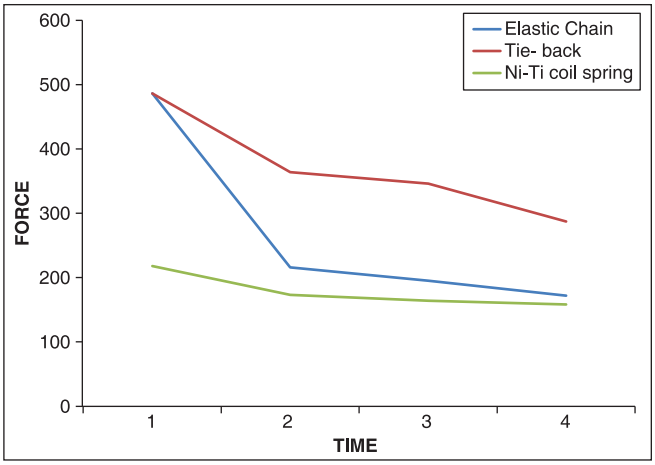

Figure 1: The pattern of force decay in three different systems of space closure regardless of the immersion media

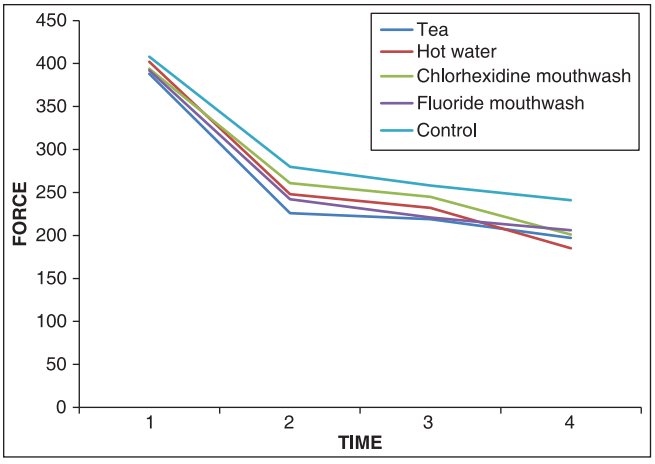

Figure 2: The effect of the immersion media on the force decay over time

DISCUSSION

According to the results, the highest percentage of force decay in the first 24 h was reported in the EC group regardless of the immersion media, whereas the lowest percentage was recorded in the NiTi group. When the overall percentage of force decay over 21 days was recorded regardless of the immersion media, same results were observed. When different immersion media were compared, TB seemed to be most affected by the type of media in which it was immersed while EC and NiTi group did not seem to be affected as much.

In this study, the acrylic bases were placed in water in lieu of artificial saliva, since it has been shown that there is no difference in force decay when water and artificial saliva were compared as the medium environment.[16,17,22]

The immersion time for sodium fluoride mouthwash was selected based on the fact that each orthodontic patient is asked to rinse 10 ml of the mouthwash before bedtime for 1 min and not to take anything for 30 min according to the instructions of the manufacturer.[27] The chlorhexidine mouthwash is used by orthodontic patients according to the manufacturer's directions after tooth brushing according to the following regimen: 0.5 ounces of 0.2% chlorhexidine gluconate is applied for 30 s after breakfast and before bedtime. The patients are instructed not to take any liquid or food into their mouths for at least 30 min after using the prescribed mouthwash.[28] Therefore, the mouthwash will be in contact with teeth as well as orthodontic appliances for a minute per day in high concentration; the same conditions were reproduced in this study.

Three different methods of space closure were used in this study that represents the most common choices for canine retraction by an orthodontist in clinical practice. The range of initial force produced by EC and TB systems was above the optimal range for retraction (which is between 100 and 250 g as suggested by Storey and Smith).[29] The mean initial force of the EC group in different media was above 450 g. The mean initial force in the TB group method was almost within the same range as EC. The higher initial force recorded by EC or TB method in space closure has been reported by other investigators. In this study, like the previous ones, the ECs or TBs were stretched as much as the usual clinical implications and the force was then measured.[11,17,30] Some other *in vitro* studies have reported lower initial forces. However, in those studies, the ECs were stretched to a certain degree to produce 150-250 g of force as the initial force and were stabilized. These systems were then placed in different environmental conditions which explain the difference in results.[20,23] The authors believe that the conditions introduced in this study are more similar to the routine clinical conditions. However, it should be noted that higher forces might cause patient discomfort and a higher chance for root resorption.

In contrast, the mean initial force for Ni-Ti was between 210 and 220 g in all different media. This finding is in agreement with previous literature, which indicated that the initial force produced by Ni-Ti closed coil spring is closer to the ideal range compared with other methods of space closure.[19,30,31]

When the percentage of force decay in different methods of space closure was compared, EC showed a force decay percentage of approximately 55% in different media during the first time interval. The percentage of force decay in the TB group was lower than EC group and was lowest in the Ni-Ti closed coil spring group. As expected, the EC group lost about half of its initial force during the first 24 h. Hershey and Reynolds[32] also reported that only 51% of the initial force of elastomeric chains was retained after the first 24 h in distilled water. Oshagh and Ajami[17] also reported that the highest percentage of force decay in the first 24 h belonged to the EC group. While De Genova *et al*.[11] reported a higher initial force in ECs, yet a lower force decay pattern.

All three different systems were also evaluated after 21 days and the mean force was measured. The TB group showed higher force values in comparison to the other two groups. In the previous studies, the retained force in the TB group over time was higher than the EC group as well.[17] However, the force level was within the same range in EC and Ni-Ti group. The EC group lost much of its force during the first 24 h; however, the interesting fact was that during the third time interval (7-21 days), the Ni-Ti group did not have a significant reduction in the force decay except for the hot water group. The Ni-Ti group showed a more progressive pattern of force decay during the course of study than the EC group.[30] After 21 days, the force was between 150 and 250 g in most of the study groups. This means that the force tended to get closer to the ideal recommended value over time. However, the force values recorded never reached zero even after 3 weeks of the study. This can be attributed to the constant distance of the jig used in this study which is the same as other *in vitro* studies.[16,17] This would be different from the *in vivo* studies, which have an average of 0.5 mm of space closure each week which in turn has a drastic effect on the residual force.[17]

The pattern of force decay based on different systems of space closure and different media is also outlined in Figures 1 and 2. According to Table 2, both EC and the Ni-Ti group, showed the same pattern of force decay in all different media which shows that

a change in environmental conditions exerts the least effect on the pattern of force decay in these two groups. In contrast, the TB group showed the most versatile force value in different environments. This could indicate that a change in the oral conditions affects the TB system more than the other two groups. The reason for such a phenomenon might be that both elements in the TB system are affected by the environmental conditions. In addition to the elastic component of the TB, the changes in temperature and chemical elements of the media affect the ligature wire as well and therefore, these changes could have a double effect on the TB system. However, to prove such theory, further studies are required.

The highest percentage of force decay was observed in tea media in both TB and EC groups. In contrast, the Ni-Ti group had the lowest percentage of force decay in the tea immersion media. The rate of force loss in the Ni-Ti group was opposite to what was observed in the other two groups. It might seem at the first glance that temperature has a significant effect on the pattern of force decay. A study by Nattrass *et al*.[19] concluded that with an increase in temperature, the stress relaxation increases. The rate of force loss in hot water (65°) and tea was higher than the control group in both the EC and the TB groups. However, the percentage of force loss during the first time interval was higher in tea than in hot water. In the TB group, the percentage of force decay between T0 and T1 in tea was 3 times as much as in the control group. It can be concluded that there are chemicals in tea that also exert an influence on the pattern of force loss other than the mere temperature of the environment. As for the Ni-Ti group, rate of force loss in tea was much lower than in the hot water or the control group. Regarding the effect of immersion media, the results have been contradictory. While Nattrass *et al*.[19] concluded that Coke and turmeric solution had a greater effect on the force loss of elastomeric chains when compared to water, other author concluded that Coke did not significantly affect the force decay pattern.[20,21] In our study, the presence of different chemicals in tea affected the force decay pattern as well as the high temperature.

Based on Table 2, the percentage of force decay during the first 24 h in both types of mouthwashes was higher than the control group, but lower than tea or hot water in the TB group. The TB group was most affected by the type of media in which it was immersed as stated earlier. However, the effect of high temperature or tea was higher on its force degradation pattern than usual mouthwashes prescribed by the clinician. On the other hand, when two different mouthwashes were compared, the pattern of force decay was almost similar to the control group for the EC and Ni-Ti systems, which can indicate that consumption of oral mouthwashes does not result in more rapid force decay in these two systems. Ramazanzadeh *et al*.[33] also showed that daily use of sodium fluoride mouthwash does not affect the force degradation pattern of EC. The same results were reported for the mouthwashes containing bleaching agents in the study conducted by Pithon *et al*.[34]

Figure 2 compares the pattern of force decay based on the immersion media when different systems of space closure were not considered. All five media showed the same curve of force decay. Unlike what was expected, the presence of hot water or oral mouthwash did not significantly affect the rate of force decay when the means of space closure was not considered as a factor.

CONCLUSION

1. The most force decay occurred during the first 24 h in the EC group and the least force decay was recorded in the Ni-Ti closed coil spring group.
2. The temperature of the immersion media plays an important role in the pattern of force decay. However, the chemicals present in tea also affected the pattern of force decay.
3. TB method of space closure is most affected by the type of immersion media and Ni-Ti is least affected.
4. Tea increases the force decay in the EC and TB group, but decreased the force decay in the Ni-Ti group.
5. EC and Ni-Ti groups were not much affected in the presence of oral mouthwashes.

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