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EXAMINATION OF ORTHODONTIC ELASTOMERIC CHAINS AND NiTi CLOSED COIL SPRING FORCE DURING POSTEXTRACTION SPACE CLOSURE

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Abstract: This paper examines the forces produced by elastomeric chains and NiTi closed coil springs during postextraction space closure. 58 postextraction spaces were analyzed, divided into two groups according to the applied mechanism. Postextraction spaces were monitored for 3 months when force strength and postextraction space width measurements were made. The measurements were carried out every 4 weeks, initially during activation of the mechanism and at the end of the active phase. The results show that elastomeric chains have more force decay over time, with the smaller amount of space closure width than NiTi closed coil springs.
Keywords: elastomeric chain, NiTi closed coil spring, postextraction space.

1. INTRODUCTION

The lack of space for placing all the present teeth in dental arch is a phenomenon that we encounter in everyday clinical practice. An additional space in dental arch that would allow the conditions for achieving the right occlusion can be accomplish in different ways (by their expansion, distalisation of molars, interproximal reduction, protrusion of the teeth) [1]. However, in some cases, additional space is provided by extraction of teeth by reducing the number of teeth in dental arch. The teeth that are most often extracted for orthodontic purposes are the first premolars. The closure of the postextraction space is done by bringing the adjacent teeth to the place of the extracted first premolar, and due to the proper morphology, a satisfactory contact between the canines and the second premolar is achieved [2−4].

There are various techniques for implementing this clinical procedure and one of them is the use of a sliding mechanism. This method is a mechanism that performs proper application and transmission of force within the dental arch. In the case of the extraction of the first premolars, the canines can be moved back into the postextraction space by sliding along a stiff archwire [5−7]. In the sliding mechanism, applied force must overcome the sliding resistance of the archwire through the system of brackets and move the teeth along the archwire, with occurring of friction. It is recommended that this force is between 100 and 200 g/cm^2, which is considered a biologically acceptable framework. To move canine using a sliding mechanism, a force of 100 g /cm^2 is required to move the teeth and an additional 100 g/cm^2 to overcome resistance or friction [8,9].

In terms of duration, fixed orthodontic devices can produce two types of force: continuous and discontinuous. Continuous one shows the same level for 24 hours, and a trend of insignificant fall between follow-up checks. Discontinuous forces fall rapidly, so they are at zero value at the next follow-up [2].

Depending on the size of the force applied, different types of resorption may appear in the displacement areas of the teeth. If severe forces are applied, there may be necrosis of the surrounding tissue and diminishing resorption with the hyalinization zones and will lead to retention in the movement of the teeth. Using mild continuous forces, smooth movement of the teeth leads to the appearance of a preferred resorption form, the frontal resorption [10]. The results of numerous studies show that mild continuous forces provide an optimal system of tooth movement in a biologically

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acceptable way without side effects. Orthodontic movement of teeth requires the application of continuous force over a certain period of time, whereby the efficiency increases if the strength of the force is maintained for as long as possible [11]. It is therefore very important that the orthodontist finds a method that produces a force that has the least decrease over time. In order to apply this system of force, a good knowledge and understanding of materials and methods is needed in order to treat patients in an efficient and biologically acceptable way [12−14]. The bracket debonding forces of the tooth as well as the system for measurements of 3D scanned orthodontic study models were processed in the paper [15,16].

In clinical practice, elastomeric chains and NiTi closed coil springs are among the most commonly used sliding mechanisms.

2. MATERIAL AND METHODS

The research was carried out at the Medical Faculty, Department of Orthodontics in Banja Luka. The total sample in the study consisted of 58 postextraction spaces in patients who were indicated tooth extraction of the first premolars for the purpose of conducting orthodontic treatment. Examiners had to meet the following inclusion criteria: age 12−18 at the beginning of treatment, no contraindications for orthodontic therapy, no other extractions (except premolars), and written consent of the examinee or parents. Exclusion criteria for this study were: lack of one or more teeth (except third molars), cleft palate or some of the craniofacial syndromes, poor oral hygiene, developmental abnormalities of the teeth, patients who come to follow-up irregularly, and patients who have previously been treated with fixed orthodontic devices.

After tooth extraction of the first premolars, the fixed orthodontic appliance was applied (Roth prescription, 0.022 in slot), followed by an initial leveling with the NiTi archwire of round and square forms, before placing stainless steel square archwires. The square stainless steel archwire (0,019x0,025in) was placed in bracket system for at least 4 weeks, so it becomes passive, and appropriate mechanisms for closing the postextraction spaces were applied.

The examinees were randomly selected in two groups according to the mechanism used to close the postextraction space:

· Group 1: Elastomeric chains-30 postextraction spaces

Elastomeric chain was placed into bracket system from the first molar tube hook to the hook on canine bracket, stretching it approximately twice of its initial length. At the next follow-up, it was replaced by a new one (Figure 1).

· Group 2: NiTi closed coil springs - 28 postextraction spaces

NiTi closed coil spring was placed from the first molar tube hook to the hook on canine bracket, with the springs not stretched to more than 9mm. During the treatment, springs were activated on the follow-up appointments (Figure 2).


Figure 1. Activated elastomeric chain

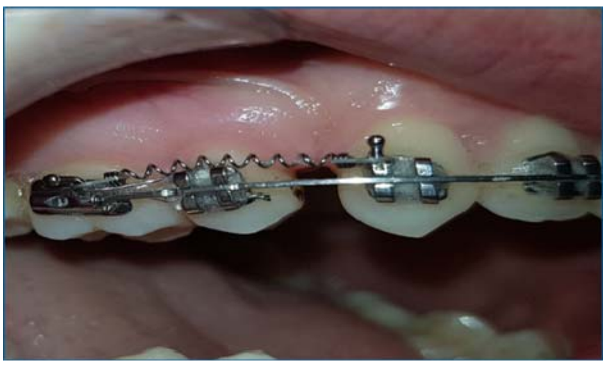
Figure 2. Activated NiTi closed coil spring

Measurements

Postextraction spaces were monitored for 3 months from the beginning of their closure. Follow-up appointments were carried out every 4 weeks and were checked for damage to the applied mechanisms and then their activation. The dynamometer (Force Gauge Dynamometer, White Oak, USA) was used to measure force at the beginning and at the end of the active phase, and digital gauge (precision of 0,01mm) was used to measure maximum distance from the distal surface of the canines to the mesial surface of the second premolar (Figure 3).

Figure 3. Measuring the force level with dynamometer

3. RESULTS

The results of statistical analysis of the initial and residual force ratio for the elastomeric chain method show that there is a statistically significant difference ($p < .01$) in the average values of the measured force at the beginning and at the end of the active phase. In other words, significant residual force reduction on follow-up measurements was found during all three months (Table 1).

Table 1. Measures of descriptive statistics and significance of differences in initial and residual force for elastomeric chain method

	Initial force		Residual force					
	M	*SD*	*M*	*SD*	*N*	*t*	*df*	*p*
1. Month	208.67	27.07	83.67	10.74	30	23.51	58	.000
2. Month	202.76	22.67	84.31	7.29	29	26.80	56	.000
3. Month	196.47	20.14	84.41	8.64	17	21.09	32	.000

The results of the analysis of ratio of the initial and residual force for the NiTi closed coil spring method, similar to the previous findings, show a statistically significant reduction in the residual force relative to the baseline values over all three months ($p < .01$), respectively a significant reduction in the residual force on the follow-up checks during three months (Table 2).

Comparing the average differences in the values of the initial and residual forces between the methods, significant differences were found between the initial and residual force for the elastomeric chain method compared to the NiTi closed coil spring method ($t(4) = 5.29$, $p < .01$). In elastomeric chain method, a significantly greater decrease in residual force than the initial one was found (Table 3).

Table 2. Measures of descriptive statistics and significance of difference in initial and residual force for NiTi closed coil spring method

	Initial force		Residual force					
	M	*SD*	*M*	*SD*	*N*	*t*	*Df*	*p*
1. Month	205.18	23.43	114.11	18.16	28	16.26	54	.000
2. Month	202.32	17.02	113.04	14.80	28	20.94	54	.000
3. Month	199.74	17.44	124.73	9.78	19	16.35	36	.000

Table 3. Average difference in initial and residual force in relation to the elastomeric chain method and NiTi closed coil spring

	M	*SD*	*t*	*df*	*P*
Elastomeric chain	118.50	6.47	5.29	4	.006
NiTi closed coil spring	85.12	8.80			

Analyzing the correlation of force strength and the change in the postextraction space, a statistically significant relationship between the mentioned variables ($p > .05$) was not established, which means that the size of the changes in the postextraction space did not depend on strength of the initial force in elastomeric chain method (Table 4).

In the NiTi closed coil spring method, a statistically significant and positive correlation of the mean strength ($r = .44$, $p < 0.05$) between the strength of the force and changes in the postextraction space was determined in the measurements performed in the second month. Given the character of their relationship, it can be concluded that higher values of the initial force were followed by major changes in the postextraction space (Table 5).

Table 4. Measures of descriptive statistics and correlation ratio of the initial force and changes in postextraction space for the elastomeric chain method

	Space (mm)		Force (g)				
	M	*SD*	*M*	*SD*	*N*	*r*	*p*
1. Month	1.12	.32	208.67	27.07	30	-.10	.56
2. Month	1.23	.51	202.76	22.67	29	.10	.60
3. Month	1.00	.46	196.47	20.14	17	-.24	.36

Table 5. Measures of descriptive statistics and correlation of the initial force and changes in postextraction space for the NiTi closed coil spring method

	Space (mm)		Force (g)				
	M	*SD*	*M*	*SD*	*N*	*r*	*p*
1. Month	1.31	.71	205.18	23.43	28	-.16	.40
2. Month	1.34	.48	202.32	17.02	28	.44*	.02
3. Month	1.81	.34	199.74	17.43	19	-.32	.18

4. DISCUSSION

The first study on the optimal retraction force of the canines was carried out by Storey and Smith and they came to the conclusion that the force of 150-200g led to the most effective movement. They claimed that light forces do not have such efficacy, and that heavy forces lead to tissue hyalinization, which has an obstruction effect in the process of moving the teeth [17]. After a long period of time, these results were confirmed by Lee and associates [18]. In this study, forces with an average value of about 200g were used, which we activated once a month over the observed period of 3 months. It was found that there is a statistically significant force degradation in the elastomeric chain from the beginning to the end of the active phase for an average of 118.5g, as well as in NiTi closed coil springs, but this value was 85.12g.

Weissheimer and associates conducted an in vitro study that examined the force degradation of elastomeric chains between follow-up examinations. They also came to the conclusion that the force decreses most in the first 24 hours, or 50−55%, especially in the first hour of elastomeric chain activation, by 31−41% [19]. Thus, the force produced by the elastomeric chains decreases rapidly in the first 24 hours and then continues to decline until the next follow-up examination, which is why this force can be called intermittent rather than continuous [9].

When elastomeric chains are in the oral cavity, they begin absorbing saliva, lose colour and permanently deform due to the breaking of internal connections. Exposure to salivary and oral temperatures can reduce the possibility of maintaining the same level of force over a longer period of time [20]. Numerous studies have shown that the mode of production and the composition can influence the transfer of force, thus it turns out that the transparent elastomeric chains retain a certain level of force in relation to the colored ones for a longer period [21,22].

Nickel titanium alloys are unique because they have the ability to cross between two different stages: martensitic and austenitic. The martensite phase is more stable at lower temperatures and a higher degree of stress, while the austenite is more stable at higher temperatures and lower stress levels. This capability of transition from one phase to the next allows for the storage of shape and superelasticity, properties that do not have other dental materials [23]. Shape memory is the ability of the material to remember its original shape after plastic deformation in the martensitic phase and allows the material to return to original shape after the force transfer. Superelasticity allows the material to undergo a reversible change in the internal structure, after a defined amount of deformation, finally producing a fairly constant force when it travels over a greater or lesser distance. This allows nickel to titanium alloy to transfer medium continuous forces over a longer period of time [24].

Wichelhaus and associates conducted a study that observed the decrease in the force of NiTi springs over time, taking into account the influence of temperature cycles in the oral cavity and mechanical micro cycles that simulate use of various foods and chewing. They found that these factors have very little effect on the mechanical properties of the NiTi closed coil springs and they do not contribute to the decrease of force over time [25].

In this study, the correlation between the strength of the force and the reduction of the width of the post-extrusion space were tested. It was established that there is no statistically significant relationship between the mentioned variables ($p > .05$), which means that the size of the changes in the postextraction space did not depend on the strength of the initial force in the elastomeric chain method, but also in NiTi closed coil springs, except in the second month where the heavy forces have led to a greater closure of postextraction spaces.

Three separate clinical studies observed the rate of closure of postextraction spaces relative to the applied force, and the results show that although NiTi closed spiral springs lead to a greater closure of the postextraction space relative to elastomeric chains, there is no statistical and clinical significance between these two methods [8,25,26]. Bokas and associates have established a small, but statistically significant difference between these two methods in favor of NiTi closed coil springs at activation of 200g [26]. Nightingale and Jones also came up with similar results, with no statistical significance [25].

In clinical practice, it is common protocol for the screening to be scheduled for every 4 to 6 weeks. If the device produces mild continuous forces and only leads to frontal resorption, no additional activation is required. Frequent activation of the appliances does not allow the proper reparative process to occur, which can lead to damage of teeth [27].

5. CONCLUSION

During the active closure phase of postextracion spaces by sliding mechanics, there is a significant loss of the initial force, whereby the residual force is significantly smaller in the elastomeric chains than the NiTi closed coil springs. Although there is a difference in the rate of movement of tooth and the decrease of force over time between these two methods, these values have no clinical significance. If optimal dental displacement forces are applied, there is no correlation between the speed of closing the postextraction space relative to the strength of force. Using optimal, mild and continuous force with follow-ups at 4 to 6 weeks, the most effective results are achieved.

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ИСПИТИВАЊЕ СИЛЕ ОРТОДОНТСКИХ ЕЛАСТОМЕРНИХ ЛАНАЦА И NiTi ЗАТВОРЕНИХ ОПРУГА ПРИЛИКОМ ЗАТВАРАЊА ПОСТЕКСТРАКЦИОНИХ ПРОСТОРА

Сажетак: У овом раду су испитиване силе коју производе еластомерни ланци и *NiTi* затворене опруге приликом затварања постекстракционих простора. Анализирано је 58 постекстракционих простора, који су били подијељени у двије гурпе према примијењеном механизму. Постекстракциони простори су праћени три мјесеца, при чему су извршена мјерења јачине силе и ширине постекстракционог простора. Мјерења су се проводила на почетку приликом активације механизма и на крају активне фазе, односно сваке четири седмице. Резултати показују да еластомерним ланцима више опада сила кроз вријеме, при чему је износ затварања простора мањи у односу на NiTi затворене опруге.

Кључне ријечи: еластомерни ланас, NiTi затворена опруга, постекстракциони простор.