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Original Article

Comparing two methods of orthodontics space closure: a randomized clinical trial

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Abstract: The objective of this study was to compare the differences inbilateral asymmetry and therate of space closure in the upper arch between NiTi coil springs and the elastomeric module in adolescent patients. Forty-two adolescent patients with bilateral first premolar extractions in the maxillary arch were enrolled and randomly distributed into the NiTi coil spring group and the elastomeric module group. After aligning and leveling with 0.019×0.025-inch stainless steel archwire,the same initial force was applied in the two groups. Dental casts were made at the beginning of space closure (T1) and the end of retraction (T2). The amount of space closure was measured with adigital caliper. Different ratesof space closure and bilateral asymmetric space closure of the two methods were calculated. The mean rate of space closure in the NiTi spring was significantly higher than the elastomeric module. However, bilateral asymmetric space closure with the elastomeric modulewas more significant than the NiTi spring. To conclude, our research suggested that the NiTi coil spring might be a more efficientforce delivery appliancein orthodontic space closure.

Keywords: Space closure, asymmetry, NiTi coil spring, elastomeric module

Introduction

Sliding mechanics is recommended as highly efficient for space closure in the pre-adjusted straight wire orthodontic system [1]. Various force delivery systems, such as the NiTi coil spring, elastomeric chain, elastomeric module and closing loop, have been applied in orthodontic space closure [2-5].

Among the force delivery systems, the NiTi coil spring and elastomeric module are most widely used. In previous studies, the assessment of the efficiency of these two methods in space closure has been controversial. Dixon V et al. [4] and Barlow et al. [6] compared the NiTi coil spring and elastic module in space closure, and the results showed that the NiTi coil spring was more efficient than the elastomeric module. In contrast, Nightingale et al. [7] and Samuels et al. [8] found that there was no difference in the space closure rate between these two force delivery systems. In previous studies, confounding factors related to tooth movement were not strictly controlled. For example, the magnitudes of the forces applied were variable. The second limitation of previous studies was that adult and adolescent subjects were usually mixed together into the same group, whereas age should be one of the main factors that affects the rate of space closure. Third, previous studies hardly consider the difference between space closure in the upper arch and the lower arch. Finally, the occlusal interferences were not examined either. These confounding factors could possibly affect the results.

In addition, it is common that the rate of space closure between the left and right sides of the dentition is asymmetric in orthodontic practice. In most previous studies, the study models of space closure had a spilt-mouth design, without considering the bilateral asymmetry of the subjects. Nevertheless, pathologic asymmetry in the normal facial features and craniofacial morphology is relatively common [9-11]. Therefore, the results of previous studies on bilateral space closure might be affected by the

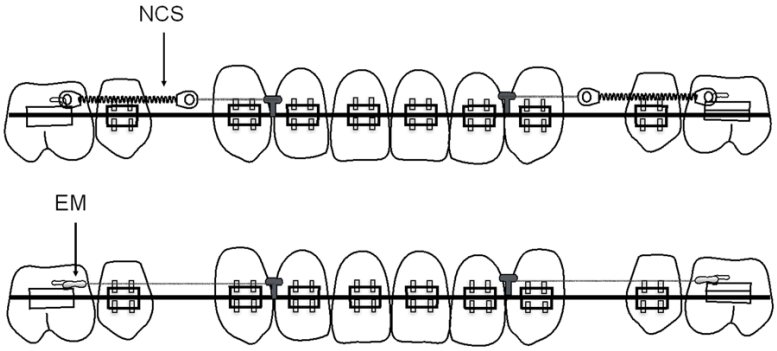

Figure 1. Schematic of space closure with NCS and EM (NCS, NiTi coil spring; EM, elastomeric module).

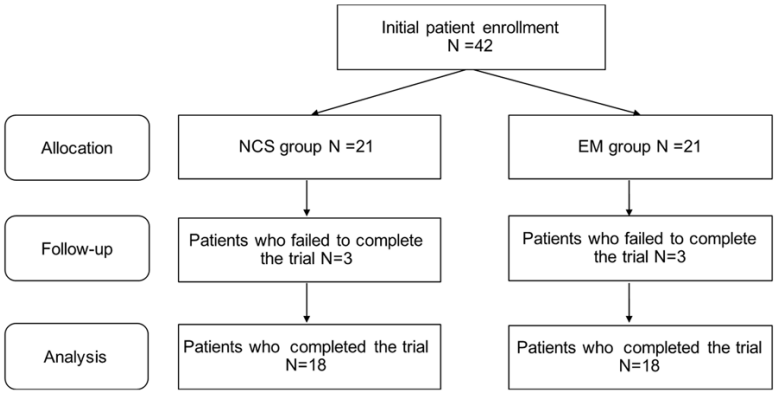

Figure 2. Flow diagram of subjects through the study.

asymmetry of the subjects. However, the investigation on bilateral asymmetry in space closure is rare.

Therefore, the aim of this randomized clinical trial is to compare the differences of bilateral asymmetry andthe rate of space closure in the upper arch between the NiTi coil spring and elastomeric module in adolescent patients.

Materials and methods

Sample size calculation

According to the power analysis of the previous studies, a total of 36 subjects (18 subjects per group) were recruited to detect a clinically meaningful difference of 0.5 mm/month and a standard deviation of 0.5 mm/month in space closure between thetwo force delivery systems with a power of 80% [3]. In total, 42 adolescent patients were recruited to compensate for potential dropouts.

$$n = \frac{(q_1^{-1} + q_2^{-1})(t_{\alpha/2}) + t_{\beta})^2 S^2}{\delta^2}$$

(α = significance level; q = ratio; β = type II error; δ = a clinical deviation of both comparison groups; S^2 = polled standard deviation of both comparison groups).

Subjects

Forty-two subjects treated in the Department of Orthodontics, West China Hospital of Stomatology, Sichuan University from 2014 to 2015 were enrolled according to the following criteria: (1) Adolescent patients with permanent dentition (agedfrom 12 years oldto 16 years old); (2) Angle's Class II division 1 malocclusion; (3) Mild crowding (crowding <4 mm); (4) Treatment plan included bilateral maxillary first premolar extraction. Patients were excluded if they had complex systemic disease, had hypodontia ora midline shift in the maxillary arch, failed to attend appointments on time, used extraoral anchorage or class II elastic retraction to correct the molar relationship, orexperienced failure of the brackets or force delivery appliances. This study was approved by the ethical committee of the West China Hospital of Stomatology. Informed consent was obtained from each patient enrolled in the study. An unstratified subject allocation sequence was carried out using a computer program; random numbers were generated, and the assignment was concealed from the clinician until the appointment when the force delivery appliance was placed. Although the clinician was not blindedto the space closure, the researchers who measured the dental casts were kept blind.

Clinical protocols

All patients were treated with a 0.022-inch slot Pre-Adjusted Straight Wire Appliance (MBT, 3M Unitek, California, USA). After aligning and level-

Table 1. Demographic Characteristics of Treatment Groups

Variables	NCS (n = 18)	EM (n = 18)	P
Gender			NS
Male	8 (44.4%)	8 (44.4%)	
Female	10 (55.6%)	10 (55.6%)	
Mean Age (y)	12.8 (0.9)	12.7 (0.9)	NS

NS, Not Significant.

ling, plain 0.019×0.025-inch stainless steel archwires were engaged in the slots and ligatured with 0.010-inch stainless steel wire. The 0.019×0.025-inch stainless steel archwires were placed in the upper and lower arches for at least one month before space closure to ensure the friction between the brackets and the archwires was at a minimum. The sliding method used in this study followed the protocol suggested by Nightingale et al. [7] with a force magnitude of 170 g. The schematic diagram of space closure with two appliances is shown in **Figure 1**. To maintain the same force magnitude, we measured the forcewith a dynamometer (Aojie, Hangzhou, China) at each visit.

It was important to prevent any anterior occlusal interference during space closure. Dental casts were collected at the start of the space closure (T1) and the end of retraction (T2). The T2 model was collected before there would be any occlusal contact on the anterior teeth because this might have affected the results. During the period from T1 to T2, Inter-arch class II elastics were not used to ensure that the force for space closure was solely generated by the NiTi coil spring or the elastomeric module. Appointments were scheduled every 4 weeks for all the patients to monitor the force level, during which the elastomeric module was replaced while the NiTi spring coil was reactivated.

A digital caliper was used to measure the distance from the cusp tip of the canine to the central groove of the second premolar in each quadrant of the upper arch casts. The rate of space closure was calculated according to the following formula:

$$\text{Rate} = \frac{\text{The distance of T1 - the distance of T2}}{\text{the number of visit during T1 to T2}}$$

The examiner was blind to the treatment groups, the measurements were taken three times, and the average was calculated to minimize the random error. The measurement and calculation were repeatedone week later and showed no statistically significant difference.

The asymmetry rate of the tooth movement of each subject was converted into the asymmetry index according to the following formula:

$$\text{Asymmetry index} = \frac{\text{rate of the rapid side - rate of the slow side}}{\text{rate of rapid side}} * 100\%$$

Statistical analysis

Date wereanalyzed with SPSS software (version 17.0, SPSS, Chicago, USA), and independent Student's t testswere used to analyze the differences in the rate of space closure and the bilateral symmetry of tooth movement between the two force delivery systems. $P<0.05$ was considered statistically significant.

Results

Rate of space closure

Figure 2 shows the flow of the patients through this clinical trial. Six patientsdid not finish this trialdue to the failure of brackets or force delivery appliances. The final samplesize was 18 in each group. Baseline demographic information of the two groups is shown in **Table 1**. Participants who completed the clinical study had similar age distributions (NiTi coil springmean age, 12.8±0.9 years; elastomeric module-mean age, 12.7±0.9 years) and genderdistribution in both groups. The comparison ofthe rate of space closure and the bilateral asymmetry index of both groups is shown in **Table 2**. The results suggested that the rate of space closure of the NiTi springwas significantly higher than the rate of the elastomeric module. Significant differenceswere found in the duration of the space closure with these two methods.The NiTi spring generated an average rate of 1.06±0.16 mm/month, while the elastomeric module displayed an average rate of 0.52±0.14 mm/month.

The bilateral asymmetry of space closure

The asymmetric index of the NiTi springgroup and the elastomeric module groupis illustrated in **Table 2**. The bilateral asymmetry of the

Table 2. Rate of tooth movement and Asymmetry index in the NiTi coil spring and Elastomeric module groups

	NiTi coil spring group		Elastomeric module group		
Variables	Mean	SD	Mean	SD	P
Rate of tooth movement (mm/mo)	1.06	0.16	0.52	0.14	0.000*
Asymmetry index	7.53	2.69	14.75	8.6	0.004*

*Significant at P<0.05.

amount of space closure was observed in both groups. Furthermore, there was significant difference of the asymmetry index between the two groups (P<0.05). The index of theNiTi spring (Mean = 7.53±2.69) was significantly smaller than that of the elastomeric module (Mean = 14.75±8.60), which means that the NiTi spring group displayed a more symmetric tooth movement pattern.

Discussion

This randomized controlled trial suggested thatthe NiTi spring is not only more rapid than the elastomeric module but also more asymmetric in orthodontics space closure.

It is known that the efficiency of space closure is affected by various factors, such as thetype of bracket, size of the wire, and force degradation of the delivery systems [12-16]. In previous studies, the initial force magnitudes of the appliances were usually different. Additionally, the magnitude of the elastomeric module was not well defined. Orthodontists often lack the ability to applythe exact force with the elastomeric module [17]. Additionally, the different structures of the periodontal ligament and bone activity of adult patients and young patients might be related to the rate of orthodontic tooth movement [18]. The variation of alveolar bone resistance influences bone turnover, which would lead to different rates of space closure [19]. Ultimately, the occlusal interference was not consideredin previous investigations [2-8], which might affect the final results. Therefore, in our study, these confounding factors were controlled.

In our investigation, the results showed that the NiTi springclosed spaces more rapidly than the elastomeric module in adolescent subjects with maxillary first premolar extractions. This finding agreed with the previous literature [4, 6]. The magnitude of the initial forces was the same (170 g) in our study, while the force degradation was different between these two methods. In some previous studies, the elastomeric module was usually stretched at the discretion of the clinicians. Although the elastomeric module had a higher initial force, it was suggested that the force degeneration of the elastomeric module was rapid, whilethe NiTi springcould maintain a continuous force with a low magnitude for a longer period of time [14, 15]. Owman Moll et al. [20] demonstrated that constant force made teeth move statistically more rapidly than intermittent force. Moreover, the force loss might be more sensitive with the elastomeric module due to the decreased stretching length in our study, which likely contributed to the results.

In the present investigation, the rate of space closure inthe NiTi spring group was 1.06±0.16 mm/month, greater than the results showed by Dixon V et al. [4], which was 0.81 mm/month. In this study, a different brand of NiTi springwas used, and the study was under strict control. The elastomeric module group showed a rate of 0.52±0.14 mm/month, which was smallerthan that in the study by Nightingale [7] (0.84 mm/month). The initial force of the elastomeric module in the current study was 170 g, which was smaller than the force reported by Nightingale et al. In their study, the mean initial force was 209 g. In addition, the elastomeric module demonstrated acceptable force decay in Nightingale's study. In fact, because the force was maintainedat almost 50 percent during the period between the visits, the teeth kept moving with the elastic module.

The split-mouth design is widely used in clinical studies to eliminate individual differences [21]. However, internal bilateral differences exist and asymmetric space closure is common in orthodontic clinics. In the current investigation, the bilateral asymmetry of space closure was present in both groups, and the elastomeric module group showed more asymmetric space closure. One possible explanation for the bilateral asymmetric space closure was the pathologic asymmetry in the facial features and craniofacial morphology. The asymmetry was usually in three dimensions, leading to disequi-

librium in the oral environment; therefore, the efficiency might be different on both sides. Masticatory muscles function as a local environmental factor and play an important role in regulating craniofacial growth. A unilateral chewing habit contributed to the different masticatory functions, which might lead to changesin width, height, and thickness of the alveolar bone. The different healing processes of the extraction socket might also contribute to bilateral asymmetric space closure [22].

The NiTi springshowed much better bilateral symmetry of space closure than the elastomeric module (**Table 2**). It seemed that during space closure using the split-mouth design, usingthe NiTi spring was more reliable than using the elastomeric module. This may be due to the different force degradation of the materials. The force provided by the elastomeric module is easily affected bythe oral environment.

Clinicians should either increase the initial force level or shorten the period between appointments with the elastomeric module in space closure. In addition, in the split-mouth design space closure study, the factors related to bilateral asymmetry should beconsidered to decrease the influence on the treatment outcome.

Larger sample sizes would be necessary to validate the factors related to tooth movement, such as different growth patterns and different ages; the 3D laser scanning technique could be utilized to analyze the three-dimensional changes in space closure.

Conclusions

The aim of this study was to evaluate the rate and asymmetry of space closure of sliding mechanics with two different force delivery systems in the upper arch of adolescent subjects. The findings were as follows.

1. The NiTi coil spring leads to a significantly greater rate of space closure than the elastomeric module at the same initial force level;

2. Asymmetry of space closure was found in both study groups;

3. Space closure with the NiTi coil spring showed better bilateral symmetry than that with the elastomeric module.

Disclosure of conflict of interest

None.

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References

[1] McLaughlin RP and Bennett JC. Evolution of treatment mechanics and contemporary appliance design in orthodontics: a 40-year perspective. Am J Orthod Dentofacial Orthop 2015; 147: 654-662.

[2] Norman NH, Worthington H and Chadwick SM. Nickel titanium springs versus stainless steel springs: a randomized clinical trial of two methods of space closure. J Orthod 2016; 43: 176-185.

[3] Javanmardi Z and Salehi P. Effects of Orthokin, Sensikin and Persica mouth rinses on the force degradation of elastic chains and NiTi coil springs. J Dent Res Dent Clin Dent Prospects 2016; 10: 99-105.

[4] Dixon V, Read MJ, O'Brien KD, Worthington HV, Mandall NA. A randomized clinical trial to compare three methods of orthodontic space closure. J Orthod 2002; 29: 31-36.

[5] Ribeiro GL, Jacob HB. Understanding the basis of space closure in orthodontics for a more efficient orthodontic treatment. Dent Press J Orthod 2016; 21: 115-125.

[6] Barlow M and Kula K. Factors influencing efficiency of sliding mechanics to close extraction space: a systematic review. Orthod Craniofac Res 2008; 11: 65-73.

[7] Nightingale C and Jones SP. A clinical investigation of force delivery systems for orthodontic space closure. J Orthod 2003; 30: 229-236.

[8] Samuels RH, Orth M, Rudge SJ and Mair LH. A comparison of the rate of space closure using a nickel-titanium spring and an elastic module: a clinical study. Am J Orthod Dentofacial Orthop 1993; 103: 464-467.

[9] Haraguchi S, Iguchi Y and Takada K. Asymmetry of the face in orthodontic patients. Angle Orthod 2008; 78: 421-426.

[10] Tr S and Wr P. The prevalence of facial asymmetry in the dentofacial deformities population at the university of North Carolina. Int J Adult Orthodon Orthognath Surg 1997; 12: 171-176.

[11] Thiesen G, Gribel BF, Freitas MP. Facial asymmetry: a current review. Dental Press J Orthod 2015; 20: 110-125.

[12] Eberting JJ, Straja SR and Tuncay OC. Treatment time, outcome, and patient satisfaction comparisons of Damon and conventional brackets. Clin Orthod Res 2001; 4: 228-234.
[13] Tominaga J, Ozaki H, Chiang PC, Sumi M, Tanaka M and Koga Y. Effect of bracket slot and archwire dimensions on anterior tooth movement during space closure in sliding mechanics: a 3-dimensional finite element study. Am J Orthod Dentofacial Orthop 2014; 146: 166-174.
[14] Cox C, Nguyen T, Koroluk L and Ko CC. In-vivo force decay of nickel-titanium closed-coil springs. Am J Orthod Dentofacial Orthop 2014; 145: 505-513.
[15] Taloumis LJ, Smith TM, Hondrum SO and Lorton L. Force decay and deformation of orthodontic elastomeric ligatures. Am J Orthod Dentofacial Orthop 1997; 111: 1-11.
[16] Santos AC, Tortamano A, Naccarato SR, Dominguez-Rodriguez GC and Vigorito JW. An in vitro comparison of the force decay generated by different commercially available elastomeric chains and NiTi closed coil springs. Braz Oral Res 2007; 21: 51-57.
[17] Nattrass C, Ireland AJ and Sherriff M. An investigation into the placement of force delivery systems and the initial forces applied by clinicians during space closure. Br J Orthod 1997; 24: 127-131.
[18] Becker A and Chaushu S. Success rate and duration of orthodontic treatment for adult patients with palatally impacted maxillary canines. Am J Orthod Dentofacial Orthop 2003; 124: 509-514.
[19] Lv T, Kang N, Wang C, Han X, Chen Y and Bai D. Biologic response of rapid tooth movement with periodontal ligament distraction. Am J Orthod Dentofacial Orthop 2009; 136: 401-411.
[20] Owman-Moll P, Kurol J and Lundgren D. Continuous versus interrupted continuous orthodontic force related to early tooth movement and root resorption. Angle Orthod 1995; 65: 395-401.
[21] Pandis N, Walsh T, Polychronopoulou A, Katsaros C and Eliades T. Split-mouth designs in orthodontics: an overview with applications to orthodontic clinical trials. Eur J Orthod 2013; 35: 783-789.
[22] Häsler R, Schmid G, Ingervall B and Gebauer U. A clinical comparison of the rate of maxillary canine retraction into healed and recent extraction sites—a pilot study. Eur J Orthod 1997; 19: 711-719.