Root Resorption and Alveolar Bone Changes in the Maxillary Canine Retraction Using NiTi Closed-Coil Springs Versus Elastomeric Chains: A Split-Mouth Trial

Lam Nguyen Le[1], Hanh Ngoc Ma[2], Thao Thi Do[3], Khanh Vu Phuong Le[2]

[1]Department of Pediatrics Dentistry and Orthodontics, Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam, [2]Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam, [3]Department of Oral Pathology and Periodontology, Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam

Abstract

Aim: To compare apical root resorption and alveolar bone changes induced by the maxillary canine closure procedure performed on patients with Angle Class I malocclusion using NiTi closed-coil springs versus elastomeric chains. **Materials and Methods:** Thirty-one adult patients who had been instructed to undergo bilateral maxillary first premolar extraction completed a randomized clinical trial split-mouth study with a double-blind design. Elastomeric chains will be used on the left side, and NiTi closed-coil springs will be used on the right side for patients with even numbers. Elastomeric chains will be used on the right side of patients with an odd number, whereas NiTi closed-coil springs will be used on the left side of patients. For each patient, cone-beam computed tomography of the maxillary canine and lateral cephalometric radiographs were carried out before and after treatment to evaluate apical root resorption and perform cephalometric measurements. **Result:** The tooth root length decreased by 0.90 ± 0.60 mm in the NiTi closed-coil spring group. The alveolar bone level increased by 0.53 ± 0.66 mm on the buccal side and by 0.79 ± 0.72 mm on the lingual side. These changes were statistically significant ($P < 0.001$). In the elastomeric chain group, the tooth root length was decreased by 0.92 ± 0.69 mm, and the levels of vertical buccal and lingual alveolar bone increased significantly ($P < 0.001$). Compared to NiTi closed-coil springs and elastomeric chain groups, there was a 0.03 ± 0.878 mm difference in the tooth root length; however, this difference was not statistically significant ($P = 0.878$). **Conclusion:** Elastomeric chains and NiTi closed-coil springs both generated tooth root resorption, but the results were comparable and the difference was not statistically significant. There was no statistically significant difference between the elastomeric chain and NiTi closed-coil spring groups regarding the changes in alveolar bone loss around the maxillary canines.

Keywords: *Canine retraction, elastomeric chains, NiTi closed-coil springs, root resorption, split-mouth trial*

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Introduction

The use of digital technology and software for improved treatment planning has contributed to successful results in orthodontic progress, both

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Address for correspondence: Dr. Lam Nguyen Le, Department of Pediatrics Dentistry and Orthodontics, Faculty of Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam.
E-mail: lenguyenlam@ctump.edu.vn

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clinically and technically. The biomechanical systems during treatment become better as a result of ongoing modifications to the archwire and bracket systems.[1-3] The segment of orthodontics treatment that is time-consuming is the process of narrowing the jaw and closing the gap. In routine clinical practice, there is often not enough space to relocate all of the existing teeth into the arch; hence, tooth extraction is frequently advised during orthodontics treatment. Closing the canine gap with sliding mechanics is a common procedure.[2] Accelerating this part of the treatment will shorten the entire course of treatment, increase patient compliance, and lessen unfavorable side effects such as undesired torque, gingival recession, and bone loss, particularly tooth root resorption.[4] Many factors such as the duration of the treatment, the type and amount of force used, the level of tooth movement, and other related aspects influence root resorption. Root resorption resulting from orthodontic treatment is inescapable but is crucial to understand the elements that may be controlled and reduce the extent of root resorption to the greatest extent feasible.[5] Many authors have also agreed that the use of NiTi closed-coil springs to close the canine gap can provide a good force and is considerably more stable than other canine retraction methods and forces in terms of speed and safety.[6-8] Chain elastics, on the other hand, provide an unpredictable force, enabling the periodontal ligament to rest for a while, regenerate, and then exert a stronger force, while supporting the tissues around it. Degeneration in the salivary glands, which causes quick biodegradation and force decay and thus frequent reactivation, is its fundamental drawback. Although the efficiency of NiTi closed-coil springs and elastomeric chains has been studied, not many studies have performed controlled trials for comparing the two methods.[9,10] Therefore, this study aimed to compare apical root resorption and alveolar bone changes in the maxillary canine closure procedure on patients with Angle Class I malocclusion using NiTi closed-coil springs in comparison to elastomeric chains.

Materials and Methods

Study participants

Inclusion criteria

Patients (≥16 years old) with Angle class I malocclusion on one or both sides, those who have not undergone any previous orthodontic treatment, indications for fixed appliances, premolar extraction to create space during treatment, and positions of the two maxillary canines that are similar on the model cast before the beginning of the canine distal movement consented to participate in the study.

Exclusion criteria

Patients with a history of craniofacial traumas, anomalies, congenital defects, or systemic diseases related to osteogenic metabolisms, for example, diabetes mellitus, kidney diseases, and osseous diseases; patients who took anticoagulant drugs that affected bone metabolism (e.g., heparin, warfarin, non-steroidal anti-inflammatory drugs, cyclosporine, glucocorticoids, and medroxyprogesterone acetate); and those with mini screw and hook failure were excluded.

Study methods

A split-mouth investigation using a randomized clinical trial design was carried out by our research team. Elastomeric chains will be used on the left side and NiTi closed-coil springs on the right side for patients with even numbers. Elastomeric chains will be used on the right side for patients with an odd number, whereas NiTi closed-coil springs will be used on the left side. One orthodontic professional collected and analyzed data from all oral exams, radiographs, and model casting techniques.

This was based on the formula for calculating the sample size in clinical trial research to compare the average value between two groups (including a control group) and combine calculations based on previous studies by Barsoum *et al.*[11] which determined that the sample size was about 31 participants. The ethics committee in biological research (approval number: 22.042. HV–ĐHYDCT) approved this study.

$$n = \left[\frac{\left(z_{1-\frac{\alpha}{2}} \sqrt{p_o (1-p_0)} + z_{1-\beta} \sqrt{p_a (1-p_a)} \right)}{(p_a - p_0)} \right]^2$$

where n is the sample size, Z is the normal distribution value, p_o is the value of the proportion to be tested, α is the probability of type 1 error, p_a is the true proportion of the population, and β is the probability of type 2 error.

Ahn (2013) studied the alveolar bone changes in the maxillary anterior teeth after en masse retraction with maximum anchorage.[12]. A cone-beam computed tomography (CBCT) film radiography revealed the alveolar bone area in the cervical area following treatment. Compared to the value before treatment, the alveolar bone area in the cervical region decreased by 80%. If $\alpha = 0.05$, then $z1-\alpha/2 = 1.96$ $z\alpha/2 + z2\beta$, $\beta = 0.1$ then $z1-\beta = 1.28$, $p_o = 0.5$, and $p_a = 0.79$. By applying the formula, we can calculate the value of

Figure 1: Use of an elastomeric chain and NiTi closed-coil springs to retract the canine in two separate maxillary quadrants

n. So with the split-mouth trial design, the number of patients needed for this study was determined to be 31.

Study procedure

Step 1

General information included clinical examination, classification of facial symmetry while facing forward, profile, state of the temporomandibular joint, associations between the first molar teeth, and canine association. Patients with bilateral type I angle malocclusion were selected. The PAR (W) index was calculated using the model cast as a measurement. Following that, the patients' model casts, standardized intraoral and extraoral photographs, panoramic films, and cephalometric films were used for the second selection. A patient's upper first premolar was removed if orthodontic treatment was indicated. Using customized software with copyright WebCeph (AssembleCircle Corp., Korea), all cephalometric film measurements that complied with the study's requirements were performed. Before beginning orthodontic therapy, we evaluated the patients who fulfilled the inclusion criteria and tested the bleeding time, clotting time, and platelet count. To participate in the study, patients must sign a written informed consent and be briefed about the study goals and methods.

Step 2

Apply Transbond™ XT Light Cure Adhesive and the Victory Series Metal Bracket System (MBT 0.022 slot, 3M Unitek®, Monrovia, CA, USA). Before beginning the canine distalization phase, we performed the optimal sliding process for the closing stage after the leveling and alignment stages. Before beginning the canine retraction process, the patient must be equipped with a 0.016 × 0.022 stainless steel (SS) wire (3M Unitek). Using elastomeric chains (AlastiK CHAIN-3M Unitek®) or NiTi closed-coil springs (6 mm; Ormco, Orange, CA, USA) for each quadrant mounted from a vertical support arm, 8 mm long, manufactured and inserted into the vertical slots of the canines and mini-screws inserted in similar positions on both sides of the maxilla. T-Ties Silver (Ortho Organizers, Carlsbad, CA, USA) was used to attach the remaining teeth to the archwire. The roots of the second premolar and the first molar in the maxilla were separated with a temporary anchoring device (8 mm × 1.6 mm, 3M Unitek TAD, St. Paul, MN, USA). After that, the canine retraction was initiated within 2 weeks, and the maxillary premolar was removed concurrently and the process continued. The 200 g of total applied force was activated every 4 weeks and was managed by a tension gauge (Morelli, Sorocaba, Brazil). Except for retractions using elastomeric chains and NiTi closed-coil springs, the tools, materials, and process were the same for both [Figure 1; Chart 1].

Step 3

Using the scan ITero scanner (Align Technology, Inc., San Jose, CA, USA), digital models were created by scanning the sample placed in the patient's mouth. The matching digital models are oriented and superimposed on normalization points using vertical, horizontal, and anterior vertical reference planes. The difference between the prior distalization at the beginning (*T*0)

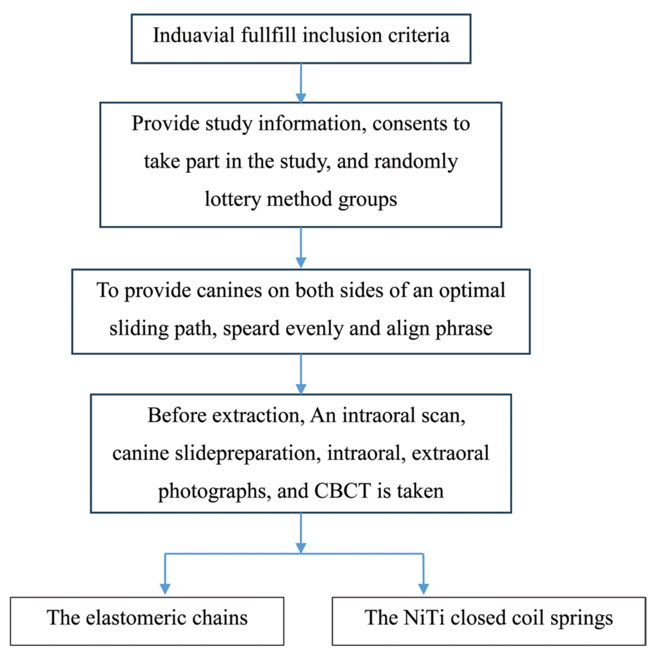

Chart 1 : Design flowchart for research

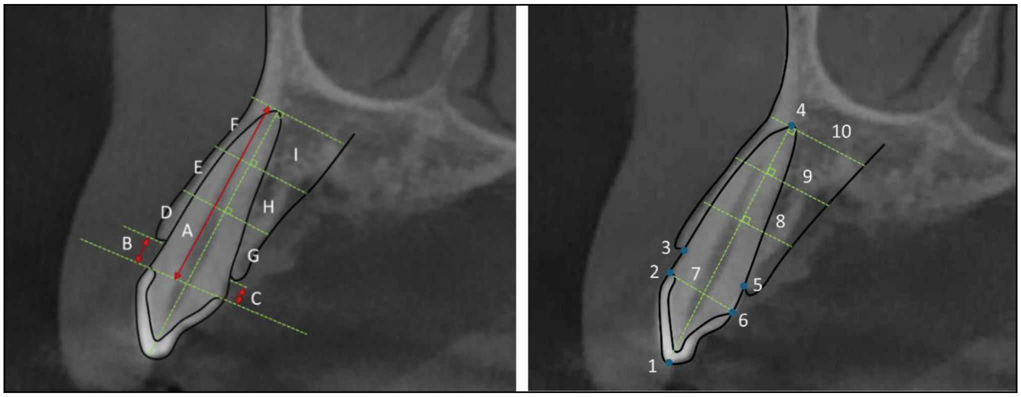

Figure 2: Study variables measured on CBCT (sagittal plane): (A) root length (from CEJ to the root apex point); (B and C) vertical alveolar bone level (from CEJ to the alveolar crest); (D–F) cervix, middle, and apical regions of the buccal alveolar bone; (G–I) cervix, middle, and apical regions of the lingual alveolar bone; (1) canine tip point; (2 and 6) cementoenamel junction (CEJ) points; (4) root apex point; (3 and 5) alveolar crest points; (7) CEJ line; (8) the intersecting line perpendicular to 14 lines at the cervical third of root length; (9) the intersecting line perpendicular to 14 lines at the middle third of root length; and (10) the intersecting line perpendicular to 14 line at the root apex point

and the measurements obtained each month up to the end of 6 months (*T*6) is used to determine all measures. The distance parallel to the canine cusp concerning the frontal plane is used to indicate the entire canine retraction. In the following scans, the space lost by the first maxillary tooth about the anterior plane was calculated from the top of the canine crown. The angle between the projected line connecting the midpoint and point of contact of each canine and the frontal plane is used to estimate the canine rotation. Cone beam computed tomography (CBCT) was performed on the Orthophos SL 3D X-ray machine (Dentsply Sirona, Charlotte, CA, USA) before and 6 months after retraction [Figures 2 and 3] as low as reasonably achievable, according to the As Low As Reasonably Achievable guidelines.[13]

Statistical analysis

Statistical Package for the Social Sciences version 22.0 software (IBM Corp., Chicago, IL, USA) was used to process the study variables and for data analysis. The statistical test is used. Paired-sample *t* test was used to compare two time points within a single group. For comparing the results of canine movement by using elastomeric chains and NiTi closed-coil springs, an independent-sample *t* test with a level of significance of 95% was used to analyze the variables on radiographs.

Results

In the group using elastomeric chains, the tooth root length decreased by 0.92 ± 0.7 mm, with statistical significance ($P < 0.001$). The buccal alveolar bone level increased by 0.54 ± 0.73 mm, the vertical lingual alveolar bone level increased by 0.72 ± 0.79 mm, and the angle of the upper canine (U3) to the palatal plane (PP) decreased by 8.33 ± 5.91 mm, with statistical significance ($P < 0.001$) [Table 1]. In the group that used NiTi closed-coil springs, the tooth root length decreased by 0.9 ± 0.60, the vertical buccal alveolar bone level increased by 0.53 ± 0.66 mm, the vertical lingual alveolar bone level increased by 0.79 ± 0.73 mm, and the angle of the upper canine (U3) to the palatal plane (PP) decreased 7.4 ± 5.17 mm, with a statistical significance ($P < 0.001$) [Table 2]. Compared to NiTi closed-coil springs and elastomeric chains, there was a 0,.03 ± 0.878 mm difference in tooth root length; however, this difference was not statistically significant ($P = 0.878$) [Table 3]. In the group using elastomeric chains, from the buccal side, the cervix area increased by 0.39 mm ($P < 0.001$), the middle area increased by 0.53 mm ($P = 0.017$), and the apical area increased by 0.70 mm ($P = 0.156$); from the lingual side, an increase of 0.97 mm ($P < 0.001$) was observed in the lingual cervix area, 0.39 mm ($P = 0.695$) in the middle area, and 0.79 mm ($P = 0.476$) in the apical area [Table 4]. In the group using NiTi closed-coil springs, the buccal area caused changes in the alveolar bone: the cervical area increased by 0.70 mm ($P < 0.001$), the middle area increased by 1.00 mm ($P < 0.003$), and the apical area increased by 1.31 mm ($P < 0.003$); on the lingual cervix area, a decrease of 1.03 mm was observed ($P < 0.001$), the middle area decreased by 1.37 mm ($P = 0.24$), and the apical area decreased by 4.07 mm ($P = 0.003$) [Table 5]. Canine alveolar bone: the lingual cervix area difference was 0.65 mm ($P = 0.846$), the middle area difference was 0.98 mm ($P = 0.517$), the apical area difference was 3.28 mm ($P = 0.057$), and the buccal cervix area difference was

0.31 mm ($P = 0.128$), the middle area difference was 0.48 mm ($P = 0.206$), and the apical area difference was 0.61 mm ($P = 0.338$), which was not statistically significant [Table 6].

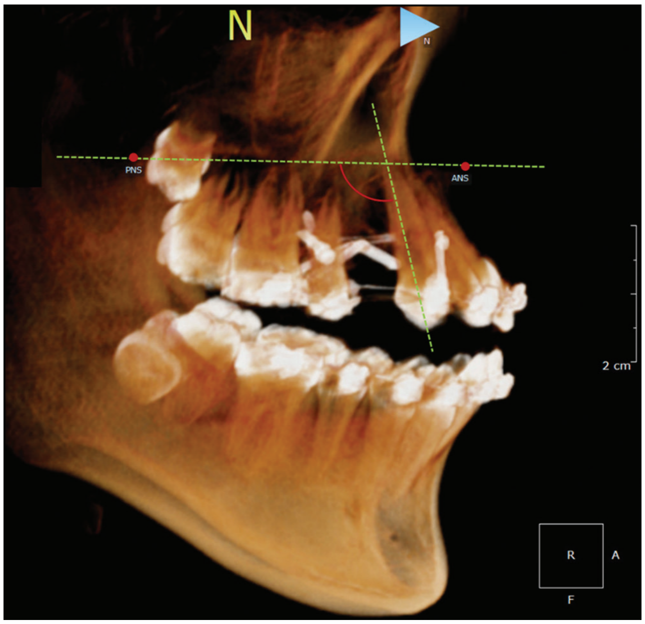

Figure 3: The angle of the upper canine (U3) to the palatal plane (PP) represents the magnetic connection between the PNS (posterior nasal spine) and the ANS (anterior nasal spine)

Discussion

In orthodontic tooth movement, the force causes both tension-side bone formation and pressure-side alveolar bone resorption. In orthodontics, a traditional hypothesis holds that the alveolar bone remains constant in width while following the direction of tooth movement.[14] On the other hand, many studies assessing the periodontal state following orthodontic treatment have shown that very aggressive anterior tooth retraction may result in treatment-related side effects such as reduced alveolar bone, fissures, gummy smiles, and receding gums. To prevent unexpected side effects, it is crucial to confirm that the alveolar bone is indeed undergoing bone regeneration. Few participants were frequently used in previous studies for assessing the correlation between incisor retraction and alveolar bone width/height, which might have influenced the results.[15,16] Consequently, to examine the alterations in alveolar bone, more participants and more comprehensive studies are required.

Large measurement errors introduce uncertainty into clinical and scientific endeavors. If clinical practice utilizes imaging measurements to assess the effectiveness of the treatment and track its side effects, such as root resorptions, large errors could impact the course of therapy. It is advised to delay the therapy for 2–3 months and resume it after 6–9 months if root shortening is

Table 1: The change of canine root position and vertical alveolar bone level (from CEJ to alveolar crest) in the group using elastomeric chains

Characters	*T1*	*T6*	*Δ (T6–T1)*		*Δ (T6–T1)/1 month*
	Mean ± SD	Mean ± SD	Difference	*P*	Mean±SD
Canine root length (from CEJ to the root apex point)	15.44 ± 1.67	14.52 ± 1.54	−0.92 ± 0.7	<0.001*	−0.15 ± 0.12
Buccal alveolar bone in vertical	2.55 ± 0.79	3.09 ± 1.07	0.54 ± 0.73	<0.001*	0.09 ± 0.12
Lingual alveolar bone in vertical	2.59 ± 0.84	3.31 ± 0.83	0.72 ± 0.79	<0.001*	0.12 ± 0.13
The angle of U3 to PP	110.92 ± 6.31	102.59 ± 6.85	−8.33 ± 5.91	<0.001*	−1.39 ± 0.98

U3: upper canine, PP: palatal plane

Paired samples *t* test.

*$P < 0.05$

Table 2: The change of canine root position and vertical alveolar bone level (from CEJ to alveolar crest) in the group using NiTi closed-coil springs

Characters	*T1*	*T6*	*Δ (T6–T1)*		*Δ (T6–T1)/1 month*
	Mean ± SD	Mean ± SD	Difference	*P*	Mean ± SD
Canine root length (from CEJ to root apex point)	15.35 ± 1.64	14.45 ± 1.55	−0.9 ± 0.6	<0.001*	−0.15 ± 0.1
Buccal alveolar bone in vertical	2.27 ± 0.58	2.79 ± 0.47	0.53 ± 0.66	<0.001*	0.08 ± 0.11
Lingual alveolar bone in vertical	2.37 ± 0.77	3.16 ± 0.82	0.79 ± 0.73	<0.001*	0.13 ± 0.12
The angle of U3 to PP	111.23 ± 4.88	103.83 ± 6.83	−7.4 ± 5.17	<0.001*	−1.23 ± 0.86

U3: upper canine, PP: palatal plane.

Paired samples *t* test.

*$P < 0.05$

Table 3: Comparison of canine root position changes between two groups of chain elastics and NiTi closed-coil springs at time *T6*

Characters	Δ (*T6*–*T1*) EC Mean ± SD	Δ (*T6*–*T1*) NiCS Mean ± SD	Δ (*T6* EC–*T6* NiCS) Mean ± SD	*P* value
Canine root length (from CEJ to root apex point)	−0.92 ± 0.7	−0.9 ± 0.6	0.03 ± 0.878	0.878
Buccal alveolar bone in vertical	0.54 ± 0.73	0.53 ± 0.66	0.02 ± 0.917	0.917
Lingual alveolar bone in vertical	0.72 ± 0.79	0.79 ± 0.73	0.07 ± 0.72	0.723
The angle of U3 to PP	−8.33 ± 5.91	−7.4 ± 5.17	0.93 ± 0.514	0.514

EC: elastomeric chain group, NiCS: Niti closed-coil spring group, U3: upper canine, PP: palatal plane

Independent samples t test, * $P < 0.05$

Table 4: The change of alveolar bone using the elastomeric chain group

Alveolar bone	*T1*	*T6*	Δ (*T6*–*T1*)	
	Mean ± SD	Mean ± SD	Difference means	*P* value
Buccal				
Crestal	1.44 ± 0.76	1.84 ± 0.77	0.39 ± 0.61	0.001*
Middle	2.84 ± 0.89	3.37 ± 1.14	0.53 ± 1.16	0.017*
Apical	4.96 ± 1.92	5.66 ± 2.83	0.7 ± 2.68	0.156
Total	9.24 ± 2.26	10.86 ± 3.29	1.62 ± 3.27	0.01*
Lingual				
Crestal	3.4 ± 1.59	2.43 ± 1.55	−0.97 ± 0.21	<0.001*
Middle	17.17 ± 6.69	16.78 ± 7.74	−0.39 ± 0.98	0.695
Apical	29.73 ± 10.9	28.93 ± 10.94	−0.79 ± 1.09	0.476
Total	50.30 ± 17.76	48.15 ± 18.82	2.15 ± 9.86	0.234

Paired samples t test.

$^{*}P < 0.05$

Table 5: The change of alveolar bone using the NiTi closed-coil spring group

Alveolar bone	*T1*	*T6*	Δ (*T6*–*T1*)	
	Mean ± SD	Mean ± SD	Difference means	*P* value
Buccal				
Crestal	1.44 ± 0.75	2.14 ± 1.27	0.7 ± 0.92	<0.001*
Middle	2.82 ± 0.85	3.83 ± 1.64	1.01 ± 1.72	0.003*
Apical	4.99 ± 2.37	6.31 ± 2.77	1.31 ± 2.28	0.003*
Total	9.25 ± 2.55	12.27 ± 3.91	3.02 ± 3.4	<0.001*
Lingual				
Crestal	4.22 ± 1.95	3.19 ± 1.7	−1.03 ± 0.26	<0.001*
Middle	18.51 ± 6.08	17.14 ± 7.17	−1.37 ± 6.38	0.24
Apical	31.83 ± 10.22	27.76 ± 9.43	−4.07 ± 7.13	0.003*
Total	54.57 ± 16.88	48.09 ± 16.69	−6.48 ± 12.98	0.009*

Paired samples t test.

$^{*}P < 0.05$

observed. This will allow the tissues to heal and enable further evaluation of root resorption. Occasionally, it becomes necessary to modify the therapy's course. In theory, large measurement inaccuracies may result in needless treatment discontinuations and delays. If the difference exceeds the measurement error, we may need to halt the therapy in other circumstances due to genuine root resorption.[17]

The suggestion was to prefer intermittent pressures over continuous forces to prevent excessive root resorption.[18] Aras *et al.*[19] determined that intermittent pressures lead to fewer root resorptions compared to continuous forces. It is believed that discontinuous pressures provide periods of rest that favor cell development in the supporting tissues. During these periods of rest, the resorption cavities are repaired by secondary cementum deposition. Dindaroğlu and Doğan[18] and Owman-Moll *et al.*[20] conducted a split-mouth design study and found no significant variance in the quantity and intensity of root resorption when comparing continuous versus interrupted pressures. The reason

Table 6: Comparison of Niti closed-coil springs and elastomeric chains in canine alveolar bone

Alveolar bone	Δ (*T*6–*T*1) The elastomeric chains group	Δ (*T*6–*T*1) The NiTi closed-coil springs group	*P* value
Buccal			
Crestal	0.39 ± 0.61	0.7 ± 0.92	0.128
Middle	0.53 ± 1.16	1.01 ± 1.72	0.206
Apical	0.7 ± 2.68	1.31 ± 2.28	0.338
Lingual			
Crestal	−0.97 ± 0.21	−0.97 ± 0.21	0.846
Middle	−0.39 ± 0.98	−0.39 ± 0.98	0.517
Apical	−0.79 ± 1.09	−0.79 ± 1.09	0.057

Independent samples *t* test.

$P < 0.05$

given was that the exact duration and length of the rest intervals needed in an interrupted force system, which are essential for minimizing root resorption while still ensuring treatment effectiveness, are not yet well understood. Weiland[21] noted a significant increase in the size and volume of the resorption lacunae on roots displaced with superelastic nickel titanium wires, compared to those displaced with stainless steel wires. Superelastic wires provide a consistent force during a wide range of deactivation processes, whereas stainless steel wires initially exert a strong force that decreases quickly.[22,23]

This present study was similar to that of Sun's *et al.*,[15] which had 308 participants and aimed to determine how the alveolar bone height and alveolar bone width of the buccal and lingual upper incisors had changed after treatment. Achieving an optimal occlusion is one of the primary goals of orthodontic treatment. One of the key factors in choosing this kind of treatment is the position of the upper incisors, particularly concerning the upper lip.[24,25] The best course of action for individuals with exposed gums and protruding is retraction of the upper incisors. An increase in labial tension, lowering of protrusion, and mildly crowding teeth are benefits of complete anterior tooth retraction. Many doctors accepted the novel anchoring retention that was offered by the sliding mechanism supported by TADs.[26] The development of three-dimensional imaging methods like CBCT has allowed for the qualitative and quantitative evaluation of the length, thickness, and height of the alveolar bone. Similar to Ahn's *et al.*[12] study, 37 female patients were studied using CBCT, both before and after space closure following measurements of the rate of interdental cracks at the bone crest, middle, and apical levels, as well as the alveolar bone area, vertical bone level, tooth root length, and tooth root area. Depending on the comparison used, the minimal degree of slope variation may account for the similarity in results among studies.

In terms of alveolar bone remodeling, orthodontic tooth movement is based on two theoretical ideas. The tooth stays inside the alveolar cortex if the alveolar bone regenerates in a manner that coordinates resorption and alignment, resulting in a 1:1 ratio between tooth movement and bone regeneration. The term "movement with bone" refers to this kind of tooth movement. Nevertheless, the tooth will travel out of the alveolar cortex, a process known as "bone penetration," if the equilibrium between bone resorption and the location of the alveolar bone is not maintained during tooth movement. On the other hand, very forceful pulling of the front teeth may result in treatment-related side effects, including gum recession, opening gums, tooth root resorption, and alveolar bone loss.[27] To clarify the therapeutic limitation of tooth movement in orthodontics and to distinguish between the notions "with bones" and "through bones," the morphological evaluation of the alveolar bone and anterior tooth root following complete retraction may be a useful method. This is dependent on the force intensity as well as the force and moment application locations. The most efficient and widely used form of movement in terms of biomechanics is the rope. The slight change in alveolar bone position during incisal retraction corresponds with that in previous studies, which indicated that the maximum retraction of the maxillary anterior teeth was determined by the palatal bone position before primary tooth retraction. Atik *et al.*[28] stated that as these variables increase the possibility of alveolar bone loss, changes in tooth inclination toward the lips and subsidence distance should be taken into account throughout the maxillary incisor subsidence process. The present results were in concordance with those of Eksriwong and Thongudomporn[29] for the palatal side, but not for the labial side. The maxillary incisors should not be overworked toward the palate, especially in the study where the cortices of the alveolar bone were thin, as shown by the stability of the palate, which was independent of the degree of retraction of the maxillary anterior teeth.[29] If more teeth need to be retracted than the palatal bone was in its pretreatment position, uncontrolled mechanics may expose the patient to fissures, alveolar bone loss, or tooth root resorption. On the other hand, Son *et al.*[30] found that there was no statistically significant connection between age and the degree of retraction and intrusion of the maxilla anterior teeth and the angle formed between the maxillary central incisors and the alveolar bone surface before and after treatment. The study conducted in the

1960s showed that there occurred 1:1 regeneration of bone surrounding the tooth socket when orthodontic tooth movement took place. The speed of alveolar bone remodeling may not be consistent with maxillary incisor retraction or maxillary anterior tooth inclination, according to recent CBCT investigations.[29] Significant associations were also observed between changes in alveolar bone tilt and changes in the jawbone, the level of intrusion, and the velocity of tooth movement in these CBCT-based investigations. However, the tooth axial served as a reference line, which helped determine if mechanical treatment was safe and how much the surrounding alveolar bone would support the tooth after it had moved. However, because the measured bone point was also altered when the tooth axis did, this method cannot be used to investigate the true reaction of alveolar bone to tooth movement in orthodontics. Furthermore, measurements taken before and after treatment will not be made of the same bone positions if the tooth moved vertically. In the current study, external reference lines made of stable bony structures were employed to measure changes in alveolar bone position and tooth movement to precisely quantify the amount of alveolar bone modifications following orthodontic tooth movement. This type of measurement may be used to calculate the ratio of tooth movement to bone remodeling at various root positions. Therefore, using stable structures as a point of reference, the purpose of this study was to assess alveolar bone changes related to changes in tooth position after maxillary incisor retraction. The parameters associated with changes in alveolar bone were examined. The study's null hypothesis claimed that the ratio of tooth movement to bone remodeling was not equal to 1:1 and that there was no discernible shift in the location of the alveolar bone after maxillary incisor retraction. This research demonstrated that during orthodontics, the labial alveolar bone experienced simultaneous remodeling with root movement by using stable structures as a point of reference. All root levels showed a roughly 1:1 ratio of bone remodeling to tooth movement, which was in line with earlier CBCT studies that used the tooth axis as a point of reference. The results of the study highlighted how crucial it was to measure the space between the palate plane and the root surface for individuals having maxillary incisor retraction. Beyond this point, excessive retraction may allow the tooth root to come into contact with the cortical bone, which may result in a variety of issues such as bone abnormalities and root resorption. In situations where there is a small space between the tooth root and the palate bone, safer treatment alternatives like orthognathic surgery or cortical surgery with bone grafting should be taken into account. Alveolar bone remodeling was not impacted by the distance of retraction, according to Hong *et al.*[31] who believed the thickness of the bone changed very little when it was retracted. Tooth movement in orthodontics did not result in bone loss, according to Zoizner *et al.*[32] The risk of periodontal deterioration during orthodontic treatment was a concern that the orthodontist must constantly be conscious of, though. Therefore, especially for individuals receiving orthodontic treatment, a thorough periodontal evaluation was required.[32] Samandara *et al.*[33] conducted a thorough investigation and found that, in direct comparisons from randomized studies, self-ligating brackets and conventional brackets did not differ in root resorption after treatment; however, there was a significant difference in root apical resorption after superior anterior retraction between the anterior and posterior positions of the screw for anchorage. According to Chaimongkol's *et al.*[34] theory, developing individuals who move the maxillary incisors with mild force and translational motion experience changes in the length of the palate and labial alveolar bone, as well as an increase in alveolar bone thickness, compared to the untreated group. CBCT was used by Khandelwal *et al.*[35] to assess bone changes in 20 individuals' maxillary central incisors. At the level (3 mm) and mid-root (6 mm), the alveolar bone's buccal and palatal thickness as well as its overall quantity were measured.

More trials that were well-designed had more extensive sample sizes and persisted for a lengthier duration of therapy were highly recommended. More definitive data regarding the efficacy of the therapy under investigation may be obtained from these studies. The validity of the findings may be further enhanced by the inclusion of diverse patient populations and control groups. The adoption of a comprehensive study strategy in this discipline is imperative for the advancement of our knowledge and the improvement of patient care. We consider the product's indications and contraindications that have been provided. Histology studies have not yet been conducted on the product.

Conclusion

Using NiTi closed-coil springs and elastomeric chains caused the canine root position to change. As a result, both the root length and the level of the lingual and buccal alveolar bones in the vertical direction increased ($P < 0.001$). Compared to NiTi closed-coil springs and elastomeric chains, there was a 0.03 ± 0.878 mm difference in tooth root length; however, this difference was not statistically significant ($P = 0.878$). There is no big deal with the elastomeric chains and NiTi closed-coil springs, the angle of the vertical tooth axis, or the amount of change in the alveolar bone on either the lingual or buccal side. Furthermore, a longer period following treatment is required to effectively investigate the possibility of tooth resorption, the chance of recurrence, and the long-term stability of the results of fixed orthodontic treatment.

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Conflicts of interest

There are no conflicts of interest.

Author contributions

All authors contributed equally to this work.

Ethical policy and Institutional Review board statement

Ethics committee approval was received for this study from the Ethics Committee in Biological Research of Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam.

Patient declaration of consent

All operations have earned informed consent filled by the patient.

Data availability statement

The data of this study are available on request from the corresponding author, Lam Nguyen Le (lenguyenlam@ctump.edu.vn).

References

1. Richmond S, Shaw W, O'Brien K, Buchanan IB, Jones R, Stephens CD, *et al*. The development of the PAR Index (Peer Assessment Rating): Reliability and validity. Eur J Orthod 1992;14:125-39.
2. Sebastian B, Bhuvaraghan A, Thiruvenkatachari B. Orthodontic space closure in sliding mechanics: A systematic review and meta-analysis. Eur J Orthod 2022;44:210-25.
3. Soheilifar S, Soheilifar S, Ataei H, Mollabashi V, Amini P, Bakhshaei A, *et al*. Extraction versus non-extraction orthodontic treatment: Soft tissue profile changes in borderline class I patients. Dent Med Probl 2020;57:275-83.
4. Rizk MZ, Mohammed H, Ismael O, Bearn DR. Effectiveness of en masse versus two-step retraction: A systematic review and meta-analysis. Prog Orthod 2017;18:1-11.
5. Heboyan A, Avetisyan A, Karobari MI, Marya A, Khurshid Z, Rokaya D, *et al*. Tooth root resorption: A review. Sci Prog 2022;105:368504221109217.
6. Barsoum HA, ElSayed HS, El Sharaby FA, Palomo JM, Mostafa YA. Comprehensive comparison of canine retraction using NiTi closed coil springs vs elastomeric chains. Angle Orthod 2021;91:441-8.
7. Kulshrestha R, Tandon R, Chandra P. Canine retraction: A systematic review of different methods used. J Orthod Sci 2015;4:1-8.
8. Hashemzadeh H, Soleimani M, Golbar M, Dehghani Soltani A, Mirmalek SP. Canine and molar movement, rotation and tipping by NiTi coils versus elastomeric chains in first maxillary premolar extraction orthodontic adolescents: A randomized split-mouth study. Int Orthod 2022;20:100601.
9. Cox C, Nguyen T, Koroluk L, Ko C-C. *In-vivo* force decay of nickel-titanium closed-coil springs. Am J Orthod Dentofacial Orthop 2014;145:505-13.
10. Halimi A, Benyahia H, Doukkali A, Azeroual M-F, Zaoui F. A systematic review of force decay in orthodontic elastomeric power chains. Int Orthod 2012;10:223-40.
11. Barsoum HA, ElSayed HS, El Sharaby FA, Palomo JM, Mostafa YA. Comprehensive comparison of canine retraction using NiTi closed coil springs vs elastomeric chains: A split-mouth randomized controlled trial. Angle Orthod 2021;91:441-48.
12. Ahn HW, Moon SC, Baek SH. Morphometric evaluation of changes in the alveolar bone and roots of the maxillary anterior teeth before and after en masse retraction using cone-beam computed tomography. Angle Orthod 2013;83:212-21.
13. Colceriu-Şimon IM, Băciuţ M, Ştiufiuc RI, Aghiorghiesei A, Ţărmure V, Lenghel M, *et al*. Clinical indications and radiation doses of cone beam computed tomography in orthodontics. Med Pharm Rep 2019;92:346-51.
14. Li Y, Zhan Q, Bao M, Yi J, Li Y. Biomechanical and biological responses of periodontium in orthodontic tooth movement: Up-date in a new decade. Int J Oral Sci 2021;13:20.
15. Sun Q, Lu W, Zhang Y, Peng L, Chen S, Han B. Morphological changes of the anterior alveolar bone due to retraction of anterior teeth: A retrospective study. Head Face Med 2021;17:30.
16. Lu CL, Li BW, Yang M, Wang XQ. Relationship between alveolar-bone morphology at the mandibular incisors and their inclination in adults with low-angle, skeletal class III malocclusion: A retrospective CBCT study. PLoS One 2022;17:e0264788.
17. Van Doornik SP, Pijnenburg MBM, Janssen KI, Ren Y, Kuijpers-Jagtman AM. Evaluation of the use of a clinical practice guideline for external apical root resorption among orthodontists. Prog Orthod 2024;25:15.
18. Dindaroğlu F, Doğan S. Root resorption in orthodontics. Turk J Orthod 2016;29:103-8.
19. Aras B, Cheng LL, Turk T, Elekdag-Turk S, Jones AS, Darendeliler MA. Physical properties of root cementum: Part 23. Effects of 2 or 3 weekly reactivated continuous or intermittent orthodontic forces on root resorption and tooth movement: A microcomputed tomography study. Am J Orthod Dentofacial Orthop 2012;141:e29-37.
20. Owman-Moll P, Kurol J, Lundgren D. Continuous versus interrupted continuous orthodontic force related to early tooth movement and root resorption. Angle Orthod 1995;65:395-401; discussion 401-2.
21. Weiland F. Constant versus dissipating forces in orthodontics: The effect on initial tooth movement and root resorption. Eur J Orthod 2003;25:335-42.
22. Parvizi F, Barker CS, Weiland F, Sandy JR. Orthodontics and root resorption. Dent Update 2024;4:707-9.
23. Rokaya D, Srimaneepong V, Qin J. Modification of titanium alloys for dental applications. In: Rajendran S, Naushad M,

Durgalakshmi D, Lichtfouse E, editors. Metal, Metal Oxides and Metal Sulphides for Biomedical Applications. Cham: Springer; 2021. p. 51-82.
24. Hou J, Meng X. Orthodontic treatment of an adult class II division 1 malocclusion with nonextraction assisted by lip myofunctional training: A case report. Clin Case Rep 2020;8: 1171-9.
25. Sangalli L, Dalessandri D, Bonetti S, Mandelli G, Visconti L, Savoldi F. Proposed parameters of optimal central incisor positioning in orthodontic treatment planning: A systematic review. Korean J Orthod 2022;52:53-65.
26. Umalkar SS, Jadhav VV, Paul P, Reche A. Modern anchorage systems in orthodontics. Cureus 2022;14: e31476.
27. Montiel RRR, Ramos LP, Palmas SO, Oyen OJ, Padrón MIC, Arias CJE, *et al*. Biology and mechanobiology of the tooth movement during the orthodontic treatment: Chapter 6. In: Belma Işik A, editor. Orthodontics: Current Principles and Techniques. Rijeka: IntechOpen; 2024.
28. Atik E, Gorucu-Coskuner H, Akarsu-Guven B, Taner TJK. Evaluation of changes in the maxillary alveolar bone after incisor intrusion. Korean J Orthod 2018;48:367-76.
29. Eksriwong T, Thongudomporn U. Alveolar bone response to maxillary incisor retraction using stable skeletal structures as a reference. Angle Orthod 2021;91:30-5.
30. Son EJ, Kim SJ, Hong C, Chan V, Sim HY, Ji S, *et al*. A study on the morphologic change of palatal alveolar bone shape after intrusion and retraction of maxillary incisors. Sci Rep 2020;10:14454.
31. Hong SY, Shin JW, Hong C, Chan V, Baik U-B, Kim YH, *et al*. Alveolar bone remodeling during maxillary incisor intrusion and retraction 2019;20:1-8.
32. Zoizner R, Arbel Y, Yavnai N, Becker T, Birnboim-Blau G. Effect of orthodontic treatment and comorbidity risk factors on interdental alveolar crest level: A radiographic evaluation. Am J Orthod Dentofacial Orthop 2018;154:375-81.
33. Samandara A, Papageorgiou SN, Ioannidou-Marathiotou I, Kavvadia-Tsatala S, Papadopoulos MA. Evaluation of orthodontically induced external root resorption following orthodontic treatment using cone beam computed tomography (CBCT): A systematic review and meta-analysis. Eur J Orthod 2019;41:67-79.
34. Chaimongkol P, Thongudomporn U, Lindauer SJ. Alveolar bone response to light-force tipping and bodily movement in maxillary incisor advancement: A prospective randomized clinical trial. Angle Orthod 2018;88:58-66.
35. Khandelwal T, Agarwal V, Singh K, Singh LD, Mittal S, Bhapkar K. A comparative evaluation of changes in marginal alveolar bone in anterior maxilla caused by maxillary incisors intrusion using miniscrews and utility arch: A 3-dimensional study. Int J Appl Dent Sci 2022;8:303-8.