Original Article

Comprehensive comparison of canine retraction using NiTi closed coil springs vs elastomeric chains: *A split-mouth randomized controlled trial*

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ABSTRACT
Objectives: To compare canine retraction using NiTi closed coil springs vs elastomeric chains comprehensively in a split-mouth randomized controlled trial.
Materials and Methods: The canines in 64 quadrants were randomly retracted into the first premolar extraction spaces using NiTi closed coil springs or elastomeric chains, in the maxilla and mandible. The retraction force was 150 g. Cone beam computed tomography scans and study models were obtained before the start of canine retraction and 6 months later. The rate and total amount of canine retraction, canine rotation, tipping, and root resorption were evaluated. A visual analogue scale was used to evaluate patients' pain experience.
Results: The two methods were statistically similar for dental changes, rate of canine retraction, and root resorption. However, patients reported significantly more days of pain with the elastomeric chain compared to the NiTi closed coil springs.
Conclusions: Within the constraints of the current study, using either NiTi closed coil springs or elastomeric chains as force delivery systems for canine retraction results in no significant difference in the rate of canine retraction, tipping, rotation, or root resorption. Pain experience during retraction using elastomeric chains is more significant yet needs further investigation. (*Angle Orthod.* 2021;91:441–448.)

KEY WORDS: Canine retraction; Coil springs; Elastomeric chains; Root resorption; Pain

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INTRODUCTION

Canine retraction and space closure is considered the most time-consuming phase in orthodontic treatment.[1] Acceleration of this step would reduce overall treatment time, improve patient cooperation, and decrease possible negative side effects.[2,3]

Manipulation of tooth biomechanics[1,4] and tissue reaction[5] have been widely attempted to reduce treatment duration. Additionally, the rate and safety of different canine retraction methods[6] and different force systems[7,8] have been intensely investigated.

The use of sliding mechanics for canine retraction has been frequently reported in the literature.[9] This method reduces the chairside time compared to loop fabrication. Despite the fact that tooth movement along the arch wire is highly predictable, friction between the brackets and arch wires may bring about some limitation to the tooth movement.[10]

The wide use of NiTi coil springs for canine retraction can be attributed to their relatively constant force delivery,[11] hence, reducing the number of appliance

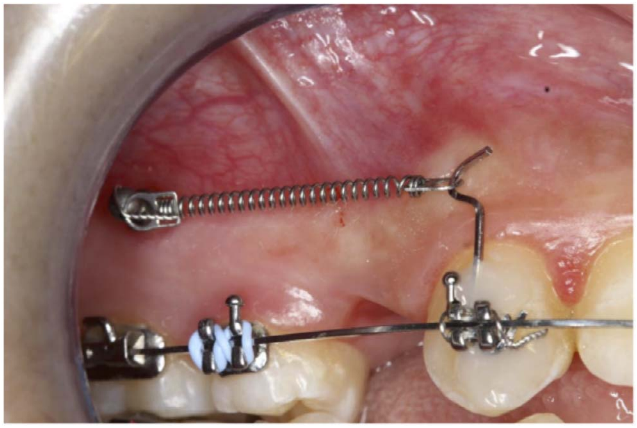

Figure 1. NiTi closed coil spring attached to the vertical power arm and the TAD.

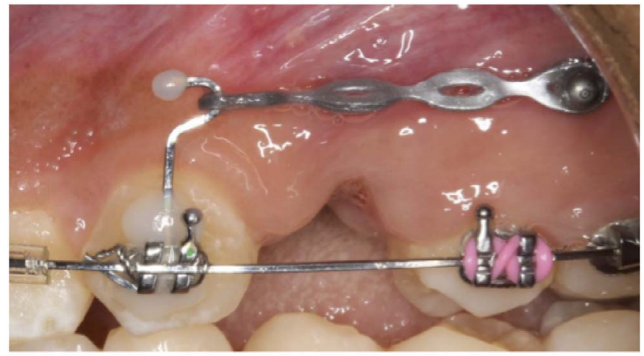

Figure 2. Retraction of a maxillary canine using an elastomeric chain.

reactivations. On the other hand, elastomeric chains deliver an interrupted force that provides periods of rest allowing for regeneration and better tolerance of the supporting tissues.[12,13] Its main weakness is the absorption of oral fluids leading to biodegradation and rapid force decay with a consequent need for frequent reactivation.[14]

Although the efficacy of coil springs and elastomeric chains has been studied frequently, few randomized controlled trials have compared the two methods for canine retraction directly.[15–19] A recent systematic review and meta-analysis[20] compared the efficacy and side effects of power chains and coil springs for space closure. The results showed a similar rate of retraction and insufficient data to compare side effects like pain, root resorption, and patient discomfort.

The aim of the present study was to compare the rate of canine retraction using NiTi closed coil springs and elastomeric chains comprehensively in orthodontic patients requiring first premolar extraction and maximum anchorage. The null hypothesis assumed that there would be no difference in the rate of canine retraction between the two methods. Other side effects were considered, including rotation, tipping, root resorption, anchorage loss, as well as associated pain.

MATERIALS AND METHODS

Trial Design

This split-mouth randomized controlled trial was conducted at the Orthodontic Outpatient Clinic, Future University in Egypt, Egypt, between January 2018 and February 2019. The Institutional Review Board at FUE approved the study in April, 2017. Patients and parents who agreed to join the trial signed consent forms at the start of treatment.

Participants, Eligibility Criteria, and Settings

Thirty-five consecutive patients seeking orthodontic treatment were screened. The inclusion criteria were patients with a full permanent dentition (not necessarily including third molars), patients indicated for bilateral first premolar extractions, and canine retraction in at least the maxillary arch with maximum anchorage required. Patients who reported any systemic disease or medication interfering with bone metabolism or patients with severe skeletal discrepancies indicated for orthognathic treatment were excluded from the study. Other exclusion criteria included pregnancy, patients with craniofacial deformities, or periodontal disease.

Conventional 0.022-inch Roth prescription brackets were used for all teeth except the second molars. The canines were bonded with vertical slot brackets (American Orthodontics, Sheboygan, Wis). The posterior segment was aligned while bypassing the incisors, reaching 0.017- by 0.025-inch stainless steel wires. Vertical power arms, 8 mm in length, were fabricated and inserted into the vertical slots of the canine brackets. Temporary anchorage devices (3M Unitek TAD, St. Paul, Minn., 8 by 1.6 mm) were placed between the roots of the second premolar and first molars in the maxilla and mandible (Figure 1). Patients were then referred for first premolar extractions and canine retraction was initiated within 2 weeks.

Interventions and Outcomes

A NiTi closed coil spring (6 mm; Ormco, Orange, Calif.) was used for canine retraction on one side (Figure 1), while elastomeric chain (American Orthodontics) was used on the contralateral side (Figure 2). Both force delivery systems were extended between the inserted temporary anchorage devices (TADs) and the vertical power arms of the canine brackets. The retraction force was adjusted to 150 g using digital force gauge. A ligature wire was used to attach the coil

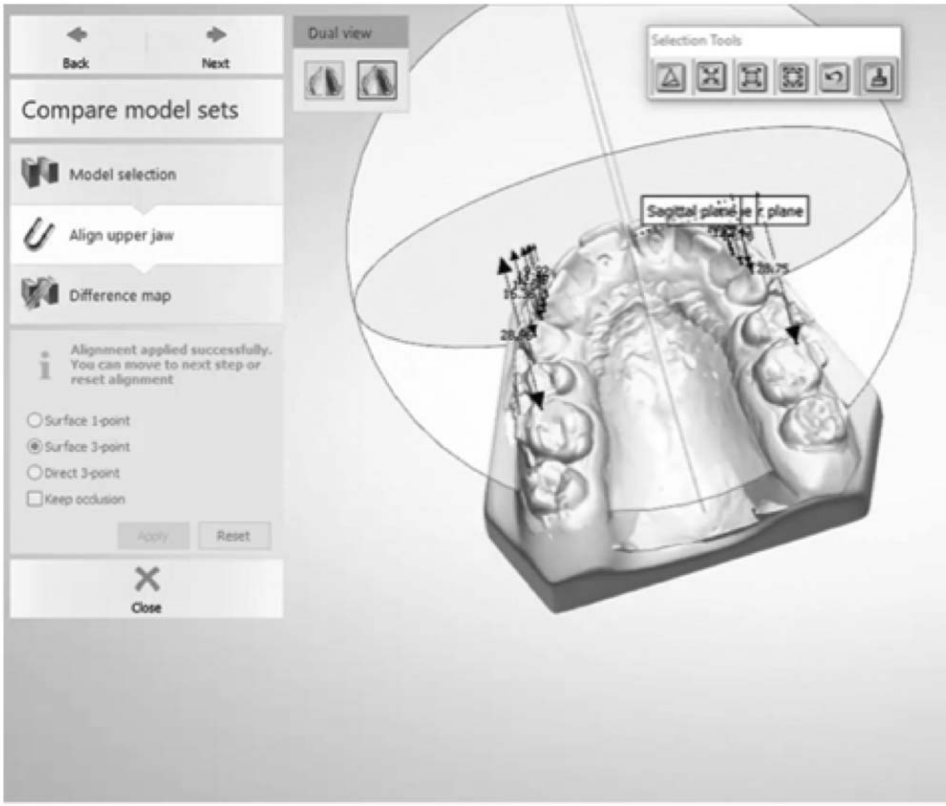

Figure 3. The canine and molar measurements and the orientation of the digital models for superimposition using the reference planes.

spring to the TAD if the force exceeded 150 g. During monthly follow-up visits, the force delivered by the coil spring was measured and adjusted while the power chain was replaced to maintain constant force delivery.

Seven maxillary dental impressions were taken for each patient: immediately before canine retraction and every 4 weeks for 6 months. Digital models were obtained through laser scanning of plaster models using the R500 3Shape scanner (3Shape, Copenhagen, Denmark). Sagittal, horizontal, and frontal reference planes were constructed to orient the pre-retraction digital models and superimpose them on the medial points of the third rugae (Figure 3).

Measurements were taken using 3Shape Analyzer computer software (3Shape). All measurements were calculated as the difference between the pre-retraction model (M0) and the model taken at the end of 6 months of retraction (M6). Total canine retraction was represented by the perpendicular distance from the canine cusp tip to the frontal plane. Likewise, the mesial drift of the maxillary first molar was measured from the mesiobuccal cusp tip to the frontal plane. Canine rotation was measured as the angle between the projected line connecting the mesial and distal contact points of each canine and the frontal plane.

A cone beam computed tomography (CBCT) scan (Acteon X-mind Trium CBCT machine, La Ciotat, France) was obtained before the start of canine retraction and 6 months later. In accordance with the ALARA (as low as responsibly achievable) guidelines,[21] a medium CBCT field of view was used. The digital imaging and communications in medicine (DICOM) images were imported into Invivo Dental 5 software (version 5.3.1, Company, Santa Clara, Calif.) and 3D images were constructed (Figure 4).

The pre- and post-retraction CBCTs were compared. The total amount of canine retraction and canine rotation was measured using the same landmarks used for the analysis of the digital models. Canine tipping was calculated as the change in the angle between the long axis, from cusp tip to root apex, and the frontal plane. Root resorption was measured as the difference in the length of the canines from the cusp tips to the root apices.

The patients reported the presence or absence of dental pain for the first 10 days after each activation. The patients were asked to record the intensity of the pain on a 100 mm visual analogue scale.[22]

Intrarater reliability was evaluated by remeasuring six randomly selected digital models and CBCTs and

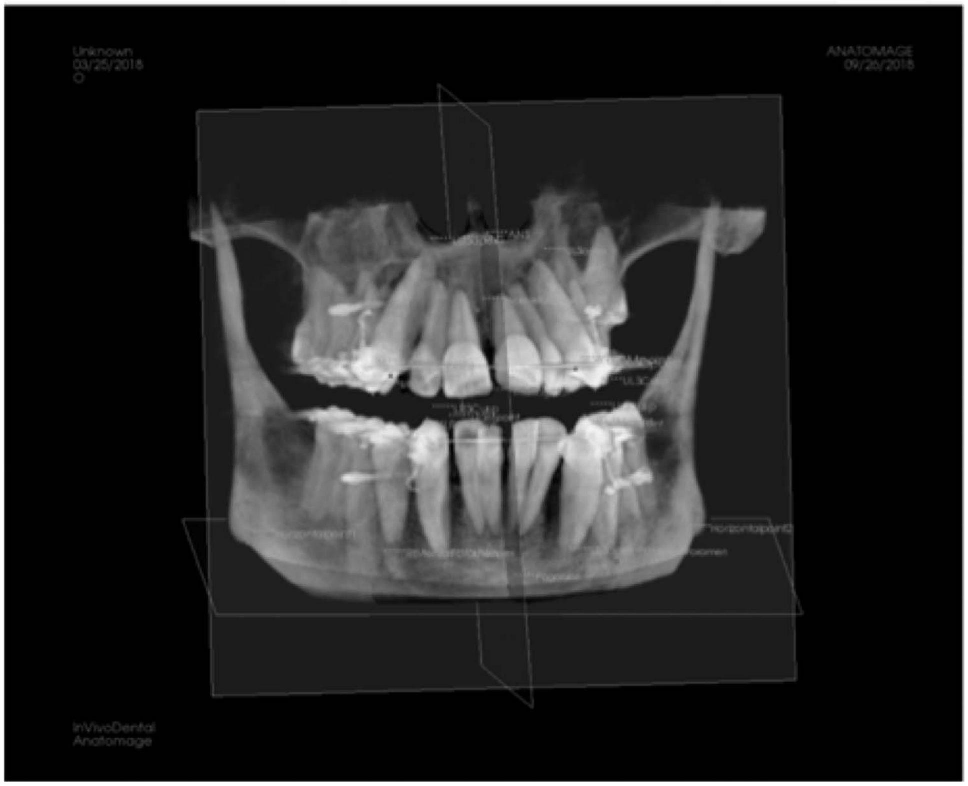

Figure 4. CBCT image orientation on the reference planes.

another investigator measured these records for interrater reliability.

Sample Size Calculation

A priori sample size was determined from the data reported by Dixon et al.[13] using the G*Power software. Twenty-eight observations were required in each group for a study power of 0.8 and an 0.05 alpha error.

Random Sequence Generation and Blinding

In Microsoft Office Excel Mac (version 16.24; Microsoft, Redmond, Wash.), the right quadrants in 32 arches were equally and randomly assigned to one of the two interventions. The contralateral quadrant received the other intervention. The allocation ratio was 1:1.

It was not possible to mask the patients or the orthodontist providing the treatment. However, the outcome assessor was masked to the intervention.

Statistical Analysis and Data Presentation

The data were analyzed using SPSS (version 17, Chicago, Ill.), Descriptive statistics were reported for all outcomes. The Shapiro-Wilk test evaluated data normality. All variables except pain followed a Gaussian distribution. Independent *t*-test was used to compare the mean differences of the two groups for monthly and overall canine retraction rate as well as overall dental change at the end of 6 months. The Mann-Whitney test was applied to compare the pain intensity across the two groups. The number of days with pain for the first 10 days after each activation were described by proportions and percentages and compared using the Z score test. Tests were two tailed and the significance level was set at $P < .05$.

RESULTS

The progress of patient selection and recruitment is shown in Figure 5. The CBCT for one patient was distorted causing some missing data. These measurements were statistically imputed.

Intra- and interobserver agreement for angular and linear measurements on the CBCT and digital models was 0.99 (intraclass correlation coefficient).

There was no statistical difference between the groups for monthly canine retraction rate. The average monthly rate was 0.79 ± 0.138 mm and 0.86 ± 0.14 mm for the NiTi coil spring and the elastomeric chain, respectively (Table 1). The total amount of retraction for pooled maxillary and mandibular canines was 4.44 ± 2.22 mm and 4.33 ± 1.31 mm for the NiTi coil spring and the elastomeric chain groups, respectively (Table

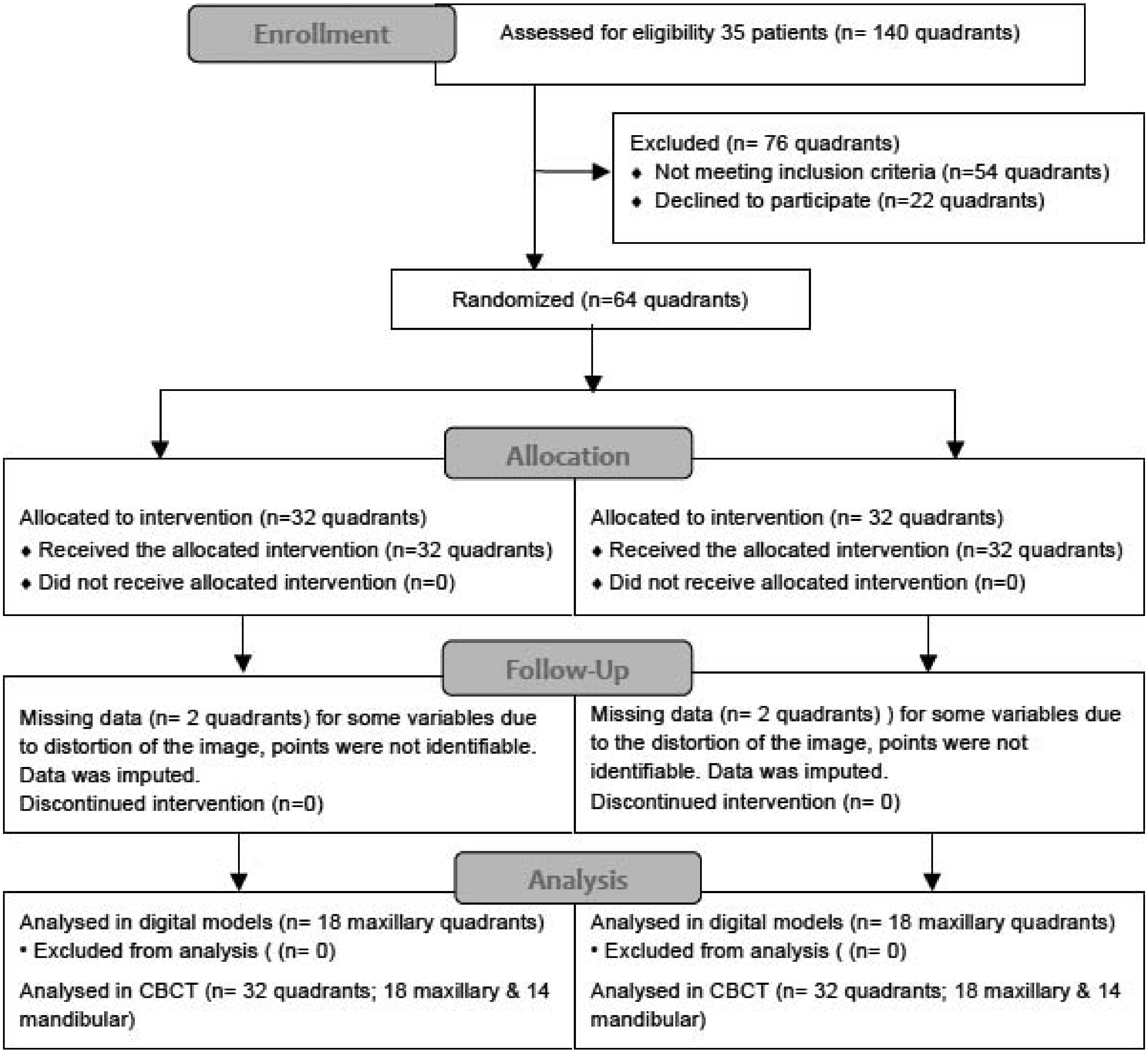

Figure 5. CONSORT flow chart of patients throughout the trial.

Table 1. Comparison of Monthly and Total Canine Retraction Between the NiTi Coil Spring and Elastomeric Chain Groups Over 6 Months (Digital Models)[a]

		Coil Spring		Elastomeric Chain		95% CI			
Time Interval	n	Mean (SD)	n	Mean (SD)	MD (SD)	Lower	Upper	*t*	*P* Value
M0-M1	18	0.80 (0.87)	18	1.09 (0.71)	−0.29 (0.26)	−0.83	0.25	−1.09	.28169
M1-M2	18	0.95 (0.65)	18	0.95 (0.70)	0.00 (0.22)	−0.46	0.45	−0.01	.99411
M2-M3	18	0.81 (0.47)	18	0.81 (0.52)	0.00 (0.17)	−0.34	0.34	0.00	.99736
M3-M4	18	0.68 (0.96)	18	0.83 (0.60)	−0.15 (0.27)	−0.69	0.39	−0.57	.57224
M4-M5	18	0.94 (0.80)	18	0.63 (0.59)	0.31 (0.23)	−0.17	0.78	1.32	.19665
M5-M6	18	0.56 (0.50)	18	0.86 (0.55)	−0.30 (0.18)	−0.66	0.05	−1.72	.09376
M0-M6	18	4.73 (1.64)	18	5.17 (1.71)	−0.44 (0.56)	−1.57	0.70	−0.78	.43893

[a] CI indicates confidence interval; M, month; MD, mean difference; M0, baseline; n, sample size; SD, standard deviation.

Table 2. Change Within the NiTi Coil Spring and Elastomeric Chain Groups at 6 Months of Canine Retraction[a]

Outcome	Time Interval	Coil Spring n	Mean	SD	MD (SD)	*P* Value	Elastomeric Chain n	Mean	SD	MD (SD)	*P* Value
◆ Max. Canine rotation	M0	18	34.72	8.46	−7.18 (13.80)	.04125*	18	33.98	9.43	−9.79 (13.85)	.01010*
	M6	18	27.54	13.99			18	24.19	9.65		
◆ Max. 1st Molar drift	M0	18	30.85	3.62	−0.29 (0.78)	.13635	18	32.32	2.38	−0.13 (0.97)	.59368
	M6	18	30.56	3.25			18	32.19	2.50		
Canine retraction (mm)	M0	32	11.32	2.81	−4.44 (2.22)	<.001*	32	11.34	2.44	−4.33 (1.31)	<.001*
	M6	32	6.89	3.24			32	7.01	2.78		
Canine rotation (°)	M0	32	45.60	11.70	12.66 (11.45)	<.001*	32	45.39	12.64	12.30 (11.67)	<.001*
	M6	32	58.26	12.95			32	57.69	9.49		
Canine tipping (°)	M0	32	20.13	6.34	−6.21 (5.21)	<.001*	32	20.60	6.97	−6.59 (3.79)	<.001*
	M6	32	13.92	7.33			32	14.02	8.10		
Canine root length (mm)	M0	32	26.14	2.44	−0.76 (1.14)	.00109*	32	26.24	2.28	−0.82 (0.72)	<.001*
	M6	32	25.39	2.70			32	25.42	2.50		

[a] Max indicates maxilla; MD, mean difference; n, sample size; SD, standard deviation; ◆Digital models, M0: baseline, M6: at 6 months of canine retraction; *, statistical significance.

2), while it was 4.73 ± 1.64 mm and 5.17 ± 1.71 mm for the maxillary canine retraction (Table 1).

At 6 months, the groups were similar for canine tipping, rotation, and root resorption as well as for maxillary first molar mesial drift (Table 3).

No statistical difference between the groups was reported for pain intensity. However, patients in the coil spring group reported significantly less days with pain (Table 4). About 70% of patients reported pain only for the first 2 months.

DISCUSSION

Many previous studies have evaluated the rate of canine retraction.[15,17 23] The lack of evidence to support a single, fast method with minimal unwanted tooth movement and discomfort has been reported.[6] Hence, there was a recommendation for further studies with more methodological rigor and patient-related outcomes.[20]

Sliding mechanics has been shown to be a controlled and predictable method of space closure. Coil springs and elastomeric chains have been used in a multitude of studies. Yet, only eight primary studies[8,13,15–19,23] compared the efficacy of coil springs and elastomeric chains for canine retraction and space closure. Various outcomes including the total distance of retraction, the percent of closed extraction spaces within a given period of time, as well as weekly, monthly, and overall retraction rate have been measured. The mean differences for the monthly rates reported by Nightingale and Jones,[8] Bokas and Woods,[15] Khanmasjedi et al.,[16] Talwar and Bhat,[17] Davidovic et al.,[23] and Chaudhari and Tarvade[19] were 0.05, 0.17, 0.23, 0.28, 0.21, and 0.25 mm, respectively.

In the current study, the difference between the two groups (0.02 mm) was the smallest compared to previous studies, which ranged between 0.05 mm and 0.28 mm. However, previous results consistently demonstrated that the differences were not clinically significant. This can be explained by the similar biologic response of the periodontium despite the different methods of force application.

The rate of canine retraction in the present study was similar to that reported by Chaudhari and Tarvade[19] and Dixon et al.[13] for the coil spring (0.81 ± 0.51 mm) and the elastomeric chain (0.58 ± 0.3 mm). The highest rates of retraction were reported by Bokas and Woods[15] (1.85 mm) and Khanmasjedi et al.[16] (1.67 ± 0.39 mm) for the coil spring group and 1.68 mm and 1.89 ± 0.36 mm for the elastomeric

Table 3. Descriptive Statistics and Comparisons of Change at 6 Months to Baseline Between the NiTi Coil Spring and Elastomeric Chain Groups[a]

Outcome	Time Interval	n	Coil Spring Mean (SD)	n	Elastomeric Chain Mean (SD)	MD (SD)	95% CI Lower	95% CI Upper	*t*	P Value
◆ Max. Canine rotation (°)	M0-M6	18	−7.18 (13.80)	18	−9.79 (13.85)	2.61 (4.68)	−6.90	12.12	0.56	.58034
◆ Max. 1st Molar drift (mm)	M0-M6	18	−0.29 (0.78)	18	−0.13 (0.97)	−0.16 (0.30)	−0.76	0.44	−0.53	.59680
Canine retraction (mm)	M0-M6	32	−4.44 (2.22)	32	−4.33 (1.31)	−0.11 (0.47)	−1.05	0.83	−0.23	.81898
Canine rotation (°)	M0-M6	32	12.66 (11.45)	32	12.30 (11.67)	0.36 (2.99)	−5.62	6.34	0.12	.90461
Canine tipping (°)	M0-M6	32	−6.21 (5.21)	32	−6.59 (3.79)	0.38 (1.19)	−2.01	2.76	0.32	.75302
Canine root length (mm)	M0-M6	32	−0.76 (1.14)	32	−0.82 (0.72)	0.06 (0.25)	−0.43	0.55	0.24	.80770

[a] CI indicates confidence interval; Max, maxilla; MD, mean difference; n, sample size; SD, standard deviation; ◆Digital models, M0: baseline, M6: at 6 months of canine retraction.

Table 4. Descriptive statistics and comparison of pain intensity and number of days with pain between the NiTi coil spring and elastomeric chain groups[a]

	Pain Intensity					Days with Reported Pain		
	Median	IQ	Mann-Whitney *U*-test	Z Score Test	*P* value	Percent	Z Score Test	*P* value
NiTi coil spring	16.00	22.00	1581.50	1.49	.13587	2.23	2.97	.00295
Elastomeric chain	23.50	41.75				3.70		

[a] IQ indicates inter-quartile.

chain, respectively. Similar rates were produced with different arch wire diameters.[15–17]

Force magnitudes ranging between 50 and 300 g have been used effectively in canine retraction.[1,9,10] Most clinicians activate the spring to produce 100–250 g according to the manufacturers' instructions for most NiTi closed coil springs.

For elastomeric chains, some investigators recommended the use of higher initial forces to compensate for the loss of elasticity and force biodegradation. Nightingale and Jones[8] reported that biodegradation was clinically much lower than the amounts expected. Greater initial forces (300–450 g) were associated with more force biodegradation and were not correlated to the amount of canine retraction.[8]

In the current study, all patients required maximum retraction of the anterior segment and TADs were used for direct anchorage. The average mesial drift of the posterior segment was $<$0.05 mm during 6 months in both groups (Table 2). These results were similar to those reported by Al Suleiman and Shehadah[18] using miniscrews. The use of TADs as direct anchorage during canine retraction is often advocated for patients requiring maximum anchorage.

During tooth movement, force application away from the center of resistance results in unwanted tipping and rotation. The correction of side effects could prolong the overall treatment time. These outcomes should be considered in relation to the rate of canine retraction and space closure.

In this study, canine tipping was similar between the two methods. The amount of tipping was significantly reduced by using the vertical power arm. Tipping was less than that observed by Al Suleiman and Shehadah.[18] Yet the position of the power arm caused cheek lacerations related to the coil springs in two mandibular quadrants. Canine rotations in the present study were almost four times (Table 2) the amount reported by Al Suleiman and Shehadah[18] at $3.43^\circ \pm 1.38$ and $3.32^\circ \pm 1.42$ for the coil spring and elastomeric chain, respectively.

Pain and root resorption have been associated with orthodontic tooth movement. These outcomes have not been investigated in studies comparing NiTi closed coil springs and elastomeric chains for canine retraction. In the current study, the amount of root resorption observed was in agreement with the results of a previous systematic review[24] (0.3–12.83 mm) for tooth movement with conventional brackets. Although the elastomeric chains produced intermittent forces, there was no difference in the amount of root resorption between the two groups. This may be explained by the findings of Nightingale and Jones,[8] in which the difference between force biodegradation in the two groups was not as significant as generally expected.

Pain was investigated using the visual analogue scale,[22] which has been validated and is commonly used for patient reported outcomes. The severity of pain was similar between the two groups. Yet, patients reported significantly fewer days of pain in the quadrants in which NiTi coil springs were used for retraction. Since the retraction force systems were similar for both methods, this may have been due to less activation adjustments required by the coil spring. However, due to the subjective[25] and variable nature of pain, further investigations are needed for conclusive results.

An attempt was made to reduce performance and assessor bias. One clinician treated all the patients with a similar protocol except for the method of retraction. The retraction force was standardized using a gauge. It was not possible to mask patients to the retraction methods. Nevertheless, this had no impact on the results as retraction did not rely on patient cooperation. On the other hand, the outcome assessor was masked to the intervention and assessed de-identified digital models and CBCTs.

The changes in the maxillary arches were measured on digital models scanned from dental casts. Lemos et al.[26] reported the accuracy and reliability of the 3Shape scanners used in this study.

CBCTs were used to assess changes in the mandible due to the difficulty in superimposing subsequent models. Baumgaertel et al.[27] showed that measurements constructed from CBCT scans were accurate and reliable. After the ALARA guideline,[21] the CBCT scans were taken using a medium field of view where images were confined to the borders of the upper and lower arches.

Unlike other studies comparing the NiTi closed coil spring and the elastomeric chain, this study investigated all relevant outcomes to allow a comprehensive comparison regarding efficiency and adverse effects.

CONCLUSIONS

- There was no clinical or statistical difference in canine retraction rate, tipping, rotation, or root resorption between the NiTi closed coil spring and the elastomeric chains to recommend one method over the other.
- Significantly fewer days with pain were reported for the NiTi closed coil spring. Further studies are needed to investigate this finding.

REFERENCES

1. Shpack N, Davidovitch M, Sarne O, Panayi N, Vardimon A. Duration and anchorage management of canine retraction with bodily versus tipping mechanics. *Angle Orthod*. 2008;78:95–100.
2. Weltman B, Vig K, Fields H, Shanker S, Kaizar E. Root resorption associated with orthodontic tooth movement: a systematic review. *Am J Orthod Dentofacial Orthop*. 2010;137:462–476.
3. Julien K, Buschang P, Campbell P. Prevalence of white spot lesion formation during orthodontic treatment. *Angle Orthod*. 2013;83:641–647.
4. Owman-Moll P, Kurol J, Lundgren D. Continuous versus interrupted orthodontic force related to early tooth movement and root resorption. *Angle Orthod*. 1995;65:395–401.
5. El-Angbawi A, McIntyre GT, Fleming PS, Bearn DR. Non-surgical adjunctive interventions for accelerating tooth movement in patients undergoing fixed orthodontic treatment. *Cochrane Database Syst Rev.* 2015;11:CD010887.
6. Kulshrestha RS, Tandon R, Chandra P. Canine retraction: a systematic review of different methods used. *J Orthod Sci*. 2015;4:1–8.
7. Insee K, Pothacharoen P, Kongtawelert P, Ongchai S, Jotikasthira D, Krisanaprakornkit S. Comparisons of the chondroitin sulphate levels in orthodontically moved canines and the clinical outcomes between two different force magnitudes. *Eur J Orthod*. 2014;36:39–46.
8. Nightingale C, Jones SP. A clinical investigation of force delivery systems for orthodontic space closure. *J Orthod*. 2003;30:229–236.
9. Deguchi T, Imai M, Sugawara Y, Ando R, Kushima K, Takano-Yamamoto T. Clinical evaluation of a low-friction attachment device during canine retraction. *Angle Orthod*. 2007;77:968–972.
10. Barlow M, Kula K. Factors influencing efficiency of sliding mechanics to close extraction space: a systematic review. *Orthod Craniofacial Res*. 2008;11:65–73.
11. Cox C, Nguyen T, Koroluk L, Ko CC. In-vivo force decay of nickel-titanium closed-coil springs. *Am J Orthod Dentofacial Orthop*. 2014;145:505–513.
12. Ziegler P, Ingervall B. A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics. *Am J Orthod Dentofacial Orthop*. 1989;95:99–106.
13. Dixon V, Read M, O'Brien K, Worthington H, Mandall N. A randomized clinical trial to compare three methods of orthodontic space closure. *J Orthod*. 2002;29:31–36.
14. Halimi A, Benyahia H, Doukkali A, Azeroual MF, Zaoui F. A systematic review of force decay in orthodontic elastomeric power chains. *Int Orthod*. 2012;10:223–240.
15. Bokas J, Woods M. A clinical comparison between nickel titanium springs and elastomeric chains. *Aust Orthod J*. 2006;22:39–46.
16. Khanemasjedi M, Moradinejad M, Javidi P, Niknam O, Jahromi NH, Rakhshan V. Efficacy of elastic memory chains versus nickel–titanium coil springs in canine retraction: a two-center split-mouth randomized clinical trial. *Int Orthod*. 2017;15:561–574.
17. Talwar A, Bhat S. Comparative evaluation of Nickel-Titanium closed coil spring and Elastomeric chain for canine retraction. A randomized clinical trial. *IOSR-JDMS*. 2018;17:7075.
18. Al Suleiman M, Shehadah M. Comparison of two methods for canine retraction depending on direct skeletal anchorage system (CR-DSAS). *Int J Dent Oral Health*. 2015;1:7–18.
19. Chaudhari C, Tarvade S. Comparison of rate of retraction and anchorage loss using nickel titanium closed coil springs and elastomeric chain during the en-masse retraction: a clinical study. *J Orthod Res*. 2015;3:129.
20. Mohammed H, Rizk MZ, Wafaie K, Almuzian M. Effectiveness of nickel-titanium springs vs elastomeric chains in orthodontic space closure: a systematic review and meta-analysis. *Orthod Craniofac Res*. 2018;21:12–19.
21. Clinical recommendations regarding use of cone beam computed tomography in orthodontics. Position statement by the American Academy of Oral and Maxillofacial Radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2013;116:238–257.
22. Doshi-Mehta G, Bhad-Patil W. Efficacy of low-intensity laser therapy in reducing treatment time and orthodontic pain: a clinical investigation. *Am J Orthod Dentofacial Orthop*. 2012;141:289–297.
23. Davidović M, Savić M, Arbutina A. Examination of postextraction space closure speed using elastic chains and NiTi closed coil springs. *Serbian Dent J*. 2018;65:179–183.
24. Yi J, Li M, Li Y, Li X, Zhao Z. Root resorption during orthodontic treatment with self-ligating or conventional brackets: a systematic review and meta-analysis. *BMC Oral Health*. 2016;16:125.
25. Oliver RG, Knapman YM. Attitudes to orthodontic treatment. *Br J Orthod*. 1985;12:179–188.
26. Lemos LS, Rebello IM, Vogel CJ, Barbosa MC. Reliability of measurements made on scanned cast models using the 3Shape R700 scanner. *Dentomaxillofacial Radiol*. 2015;44:1–7.
27. Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. *Am J Orthod Dentofacial Orthop*. 2009;136:19–25.