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Canine retraction with nickel-titanium coil springs versus elastomeric chains: A systematic review

Mariam Chatuan[1], Boutaina Elguennouni[1], Abdelali Halimi[2], Fatima Zaoui[2]

Abstract

Objective: Canine retraction after first premolar extraction is a prevalent orthodontic procedure. This systematic review aimed to evaluate the efficiency of NiTi coil springs and elastomeric chains for canine retraction and assess the side effects of each technique.

Methods: Two reviewers conducted an electronic search of online databases (Medline, Science Direct, Scopus, and Web of Science) and a manual search up to May 8th, 2024, without language restrictions. Only randomized clinical trials (RCTs) were included. The same reviewers assessed the quality of the studies using the Cochrane risk of bias tool for randomized trials. Due to the heterogeneity of data, conducting a meta-analysis was not feasible.

Results: Initially, 2400 records were identified. After evaluating the titles and abstracts, the full texts of 40 studies were reviewed. Eleven RCTs complied with the study selection criteria and were included in the review. The results indicated a faster space closure rate exhibited by NiTi coil springs compared to elastomeric chains. The rate of anchorage loss varied depending on the anchorage devices used. More tipping and rotation were observed with NiTi coil springs. There was no statistical difference between the two groups regarding root resorption, pain intensity, and plaque control.

Conclusions: The results indicated a slightly faster space closure rate with NiTi coil springs compared to elastomeric chains but at the cost of greater tipping and rotation. No significant differences were observed between the NiTi closed coil spring and elastomeric chain force delivery systems in the other evaluated parameters.

Keywords: Canine retraction, Coil springs, Elastomeric chains, Nickel-titanium, Orthodontic space closure, Orthodontic treatment

Introduction

Canine retraction after the first premolar extraction is a widespread orthodontic procedure. Clinicians always try accelerating tooth movements while preserving periodontal integrity (1). The optimum force for retracting the canine is 150 to 250 grams (2). Furthermore, when using fixed appliances, the time required to achieve complete retraction of the maxillary canine is approximately five months (3). Canine retraction can be achieved through sliding or non-sliding (frictionless) mechanics (4).

Closing loops are frequently used to close the extraction space and can be fabricated in a sectional or full archwire. The primary advantage of loop mechanics is the lack of friction between the bracket and archwire during space closure, whereas the main disadvantages are the undesired tooth rotations in the transverse and sagittal planes and the time-consuming fabrication of the loops.

Sliding mechanics are popular among clinicians for the space closure phase of orthodontic therapy. Sliding mechanics involve moving the brackets along an archwire and sliding the archwire through brackets and tubes. This technique creates friction, leading to adverse rotational movements, decreased tooth movement, and increased anchorage loss (5). Various force transmission mechanisms have been proposed for space closure via sliding mechanics, such as elastomeric chains and coil springs. Elastomeric materials are more widely used because they are more convenient and cost-effective. However, most elastomeric chains typically undergo force decay ranging from 50% to 70% within the initial 24 hours (6, 7). On the other hand, NiTi coil springs have the advantage of providing a light, continuous force, albeit at a higher cost than elastomeric chains (8, 9).

Although previous systematic reviews (10, 11) have compared the efficacy of closed NiTi coils springs and elastomeric chains on canine retraction, they did not address the adverse effects of this treatment procedure, such as undesirable periodontal effects or root

[1]Department of Orthodontics, Faculty of Dental Medicine of Rabat, Mouhammed V University, Rabat, Morocco
[2]Faculty of Dental Medicine of Rabat, Mouhammed V University, Rabat, Morocco

*Corresponding Author: Mariam Chatuan
Email: mariamchatuan@gmail.com

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resorption. In addition, patient-related outcomes, such as pain, were not explored.

The primary objective of this systematic review was to evaluate the efficacy of canine retraction using NiTi coil springs and elastomeric chains. Secondary objectives included comparing the association between these methods and orthodontic anchorage, tooth tipping and rotation, root resorption, plaque control, and pain intensity perceived by patients.

Materials and methods

This study was registered in the PROSPERO database under the number CRD42023450713 and followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (12).

Eligibility criteria

The PICOS (population, intervention, comparison, outcome, and study design) for this study was defined as follows:

P: Patients of all ages undergoing fixed orthodontic therapy and requiring canine retraction after premolar extraction

I: Canine retraction with NiTi coil springs

C: Canine retraction with elastomeric chains

O: The clinical efficiency of canine retraction methods regarding space closure rate.

S: Randomized clinical trials (RCTs)

We excluded non-randomized prospective studies, retrospective studies, in vitro investigations, case series, case reports, review articles, animal studies, and studies involving participants suffering from diseases that could influence dental movements.

Search strategy

Electronic searches were carried out in the following databases: PubMed, Science Direct, Scopus, and Web of Science, by two reviewers (MC and AH). A manual search of the references for the articles included was also conducted. Studies published until May 8th, 2024, were included without language restrictions. The search strategy used several MeSH terms joined by boolean operators: ((Canine retraction) OR (Canine distalization) OR (Orthodontic space closure)) AND ((Nickel-titanium spring) OR (Nickel titanium coil)) AND ((Elastomeric chain) OR (Power chain)).

Study screening and data extraction

Two independent authors initially reviewed the title and abstract of the related studies (MC and BE), and studies were selected according to the inclusion and exclusion criteria. The same authors retrieved and reviewed the full texts of qualifying studies. If an article did not comply with the selection criteria, it was excluded from the review. The study selection procedure is presented in the PRISMA flowchart in Figure 1.

One of the authors (MC) extracted data from the eligible studies and checked them with another researcher (FZ). The desired information included the

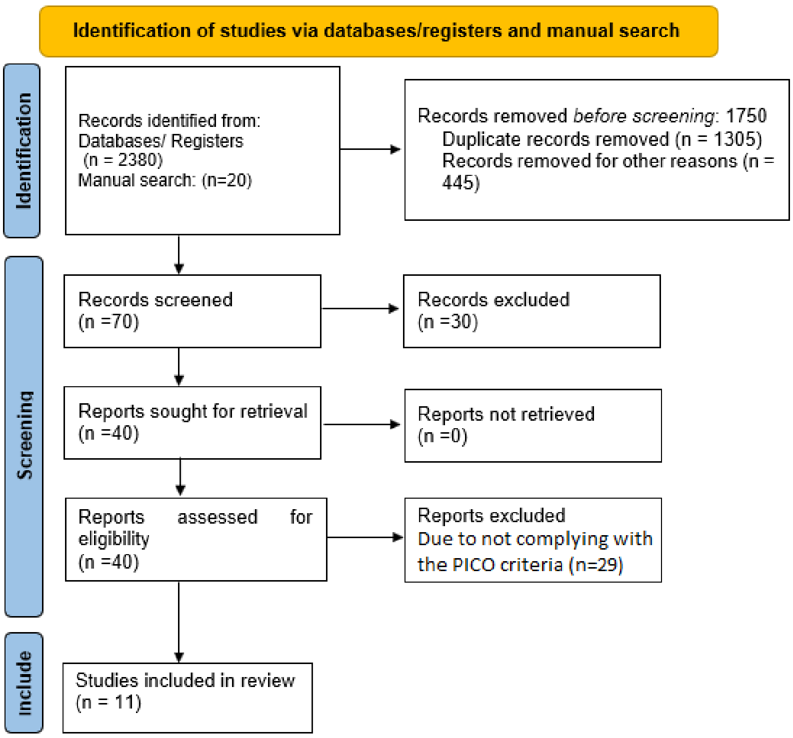

Figure1. Flow diagram of the study process according to the PRISMA statement

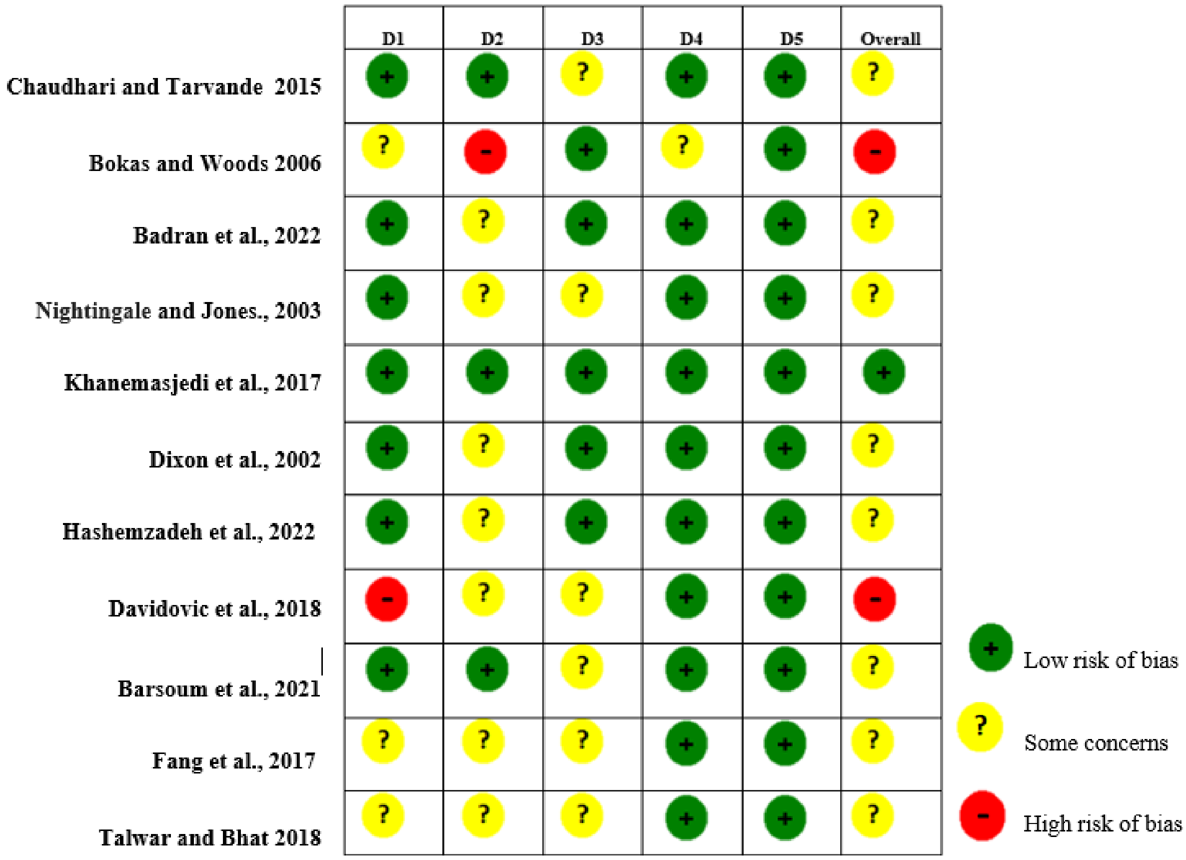

Figure 2. Risk of bias assessment of RCTs using the ROB-2 tool. The different domains have been defined by D1 to D5 (D 1: Randomization process; D 2: Deviations from the intended intervention; D 3: Missing outcome data; D 4: Measurement of the outcome; D5: Selection of the reported result)

names of the study authors, the year of publication, the study design, sample size, the age and gender distribution, the magnitude of force applied with NiTi coil springs and elastomeric chains, the type of archwire utilized, and the protocol of applying force.

Quality assessment

Two authors (MC and BE) assessed the quality of the selected studies using Cochrane's risk of bias tool for randomized clinical trials (RoB 2.0). The RoB 2.0 assessment tool is organized into five different domains: randomization process, deviation from intended intervention, missing outcome data, measurement of outcome, and selection of reported result. Each domain was assessed using one of the following options: low risk, some concern, or high risk. Any disagreements between the two authors were resolved through discussion.

Results

Study selection

A total of 2400 studies were initially identified through electronic (2380) and hand searching (20). After eliminating the duplicates, the titles and abstracts were checked for eligibility, and all papers that did not meet the selection criteria were discarded. The full texts of 40 studies were retrieved and reviewed. Finally, 11 studies were included in this systematic review (4, 13-22).

Risk of bias

Figure 2 summarizes the risk of bias in the evaluated studies. One study exhibited a low risk of bias (4), two studies were judged to have a high risk of bias (14, 21), and the remaining studies were considered to have some concerns about the risk of bias.

Study characteristics

A total of 11 RCTs were included in this analysis. Six RCTs presented with a split-mouth design (4, 14, 15, 17-19), and five presented with a parallel-group design (13, 16, 20-22). The included studies primarily evaluated the space closure and anchorage loss rate after using different canine retraction methods. Some studies assessed the intensity of associated pain and the level of plaque control. Other side effects, such as tooth rotation, tipping, and root resorption, were also evaluated in some studies. The characteristics of the included studies are presented in Table 1.

Table 1. Characteristics of the included studies

Author Year of publication	Study Design	Sample	Intervention	Comparison	Protocol
Chaudhari 2015	Parallel group RCT	40 patients in total Male: 9 Female: 31 Mean age:19.45 20 patients with NiTi-CS Mean age:19.8 years 20 patients with EC	A 9 mm NiTi-CS, with 200 grams of force Archwires: 0.019×0.025 (SS)	EC with 200 grams of force Archwires: 0.019×0.025 (SS)	NiTi-CS were not replaced during treatment, but were activated per month to deliver the force of 200 g. The EC was pre-stretched and changed per month to deliver the force of 200g.
Bokas 2006	Split-mouth RCT	12 patients in total Male: 6 Female: 6 Age:13 -14.5 years 12 quadrants for each space closure intervention	A 9 mm precalibrated NiTi- with 200 grams of force Archwires: 0.016 x 0.016	Premeasured 2-loop length of EC with 200 grams of force Archwires: 0.016 x 0.016	Every 28 days, NiTi-CS was reactivated and EC was replaced to deliver the same amount of force.
Badran 2022	Split-mouth RCT	45 patients in total Male: 12 Female: 33 Mean age:17.5 ±4.1 years 45 quadrants with NiTi-CS 45 quadrants with EC	A 9 mm precalibrated NiTi- with 200 grams of force Archwires: 0.019 ×0.025 SS	EC with 200 grams of force Archwires: 0.019 ×0.025 SS	At six weeks (T1) and 12 weeks (T2) Both the CS and PC were removed
Nightingale 2003	Split-mouth RCT	22 patients Gender: Not reported Age: 12–18 years 16 quadrants with EMC 26 quadrants with NiTi-CS	A 9 mm NiTi-CS Archwires: 0.019 ×0.025 SS	A medium-spaced EPC with a similar force delivery to the NiTi-CS Archwires: 0.019 ×0.025 SS	NiTi-CS were only replaced if distorted; EC was renewed at each subsequent visit
Khanemasjedi 2017	Split-mouth RCT	21 patients in total Male: 5 Female: 11 Mean age: 15.2 years 21 quadrants with NiTi-CS 21 quadrants with EC	A 9 mm NiTi-CS Archwires: 0.016SS	EMC Archwires: 0.016 ss	At the beginning of the retraction, 9 mm NiTi springs were used, which were replaced by 6 mm NiTi springs when the space became too small, and ECMs were replaced with new ones at each visit.
Dixon 2002	Parallel group RCT	10 patients in total Mean age:15.6 Male: 10 Female: 23 40 quadrants with EC 44quadrants with NiTi-CS	NiTi-CS with 200 grams of force Archwires: 0.019 ×0.025 SS	EPC stretched to nearly twice its length Archwires: 0.019 ×0.025 SS	NiTi-CS were not replaced but activated as required; EC was changed at subsequent visits
Hashemzadeh 2022	Split-mouth RCT	20 patients in total Mean age:15.19±2 years Male: 6 Female: 14 20 quadrants with EC 20 quadrants with NiTi-CS	12 mm NiTi with 200 grams of force Archwires: 0.019 ×0.025 SS	EC were pre-stretched to twice their length with 200 grams of force Archwires: 0.019 ×0.025 SS	ECs were pre-stretched to twice their length. A new EC was used in each visit, while the NiTi coil was replaced only if it was damaged or could not return to its initial length.
Barsoum 2021	Split-mouth RCT	32 patients in total Gender/age: Not reported 64 quadrants for each intervention in space closure	A NiTi closed coil spring (6 mm) with 150 grams of force Archwires: 0.017×0.025	EC with 150 grams of force Archwires: 0.017×0.025	Both force delivery systems were extended between the inserted temporary anchorage devices (TADs) and the vertical power arms of the canine brackets. 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.
Fang 2017	Parallel-group RCT	36 patients in total Male: 8 Female: 10 18 patients with NiTi-CS Mean age: 12.8 years 18 patients with EC Mean age: 12.7 years	NiTi-CS with 170 grams of force Archwires: 0.019 ×0.025 SS	Elastomeric module Archwires: 0.019 ×0.025 SS	NiTi-CS were only replaced if distorted; EC was renewed at each subsequent visit
Talwar 2018	Parallel-group RCT	30 patients in total 15 for each group Mean age: 20.4 ± 3.52 Male: 10 Female: 20	NiTi closed coil spring with 200 grams of force Archwires: 0.019 ×0.025 SS	Elastomeric module with 200 grams of force Archwires: 0.019 ×0.025 SS	Every four weeks, the forces were checked and correspondingly adjusted to maintain a load of 200gm by monitoring sufficient activation of the NiTi coil spring and replacement of the EC.
Davidović 2018	Parallel-group RCT	23 patients age: 12–18 (Group 1–12; Group 2–11) Group 1: Elastic Chain Group 2: NiTi closed coil spring Gender: Not reported	NiTi closed coil spring with 200 grams of force Archwires: 0.019 ×0.025 SS	EC with 200 grams of force Archwires: 0.019 ×0.025 SS	The EC stretched it to approximately double the initial length. On each subsequent visit, it was replaced by a new one. NiTi closed coil spring not stretched more than 9 mm. It was activated during each appointment.

*NiTi-CS: Nickle Titanium coil springs *EC: Elastomeric Chain *EPC: Elastomeric power chain *EMC: Elastomeric memory chain *RCT: Randomized clinical trial *SS: Stainless steel

Table 2. Rate of space closure in different studies

Authors (Year of publication)	Rate of space closure	
	NiTi coil springs	Elastomeric chains
Chaudhari and Tarvande (2015)	0.87mm / month	0.62 mm/ month
Bokas and Woods (2006)	1.85 mm/month	1.68 mm/month
Badran et al., (2022)	3.23 mm/4 month	2.33 mm/4 month
Nightingale and Jones (2003)	1.04 mm/ month	0.84 mm/ month
Khanemasjedi et al., (2017)	1.67 mm/ 3 months	1.89 mm/ 3 months
Dixon et al., (2002)	0.81 mm/month	0.58 mm/month
Hashemzadeh et al., (2022)	1.36 mm/ month	0.99 mm/ month
Barsoum et al., (2021)	0.79 mm/ month	0.86mm/ month
Fang et al., (2017)	1.06 ± 0.16mm/month	0.52 ± 0.14mm/month
Talwar and Bhat (2018)	1.62 ± 0.14mm/month	1.33 ± 0.13mm/month
Davidović et al., (2018)	3.94 ± 1.06mm/4 month	3.10 ± 1mm/4 months

Results of individual studies

Table 2 presents the mean rate of tooth displacement reported in each study. The results showed that the space closure with NiTi coil springs was faster than elastomeric chains, showing a rate of 0.79-1.85 mm/month versus 0.58-1.68 mm/month, respectively. However, in the study by Khanemasjedi et al. (4), the canine retraction rate was significantly faster in the group that received elastomeric memory chains.

As presented in Table 3, four studies measured and compared the amount of anchorage loss after using NiTi coil springs and elastomeric chains for canine retraction (13, 14, 17, 18). The differences in the obtained values are mainly explained by the different anchorage devices used.

The amount of canine and molar rotation and tipping was reported in two RCTs (17, 18). The results showed greater tipping and rotation with NiTi coil springs. Barsoum et al. (18) compared the amount of root resorption secondary to canine retraction with NiTi coil springs and elastomeric chains and reported 0.76 mm and 0.82 mm of resorption for each method, respectively. According to studies by Badran et al. (15) and Barsoum et al. (18), there were no statistically significant differences in pain intensity during space closure between NiTi coil springs and elastomeric chains. The study by Bardan et al. (15) was the only one to compare the plaque control level between the two canine retraction methods. The authors did not reveal any statistically significant differences between the two methods regarding plaque scores at 6 and 12 weeks after force application (P=0.078 and P=0.582, respectively). Table 4 compares the evaluated studies regarding the amount of molar and canine tipping, level of associated pain, root resorption, and plaque control.

Table 3. Rate of anchorage loss in different studies

Study (Year)	Anchorage loss	
	NiTi coil springs	Elastomeric chains
Chaudhari and Tarvande (2015)	1.1 mm /4 months	0.82mm /4mo
Bokas and Woods (2006)	0.46 mm/month	0.45mm/month
Hashemzadeh et al., (2022)	1.17mm/month	1.20mm/4months
Barsoum et al., (2021)	0.29mm/6months	0.13mm/6months

Table 4. Comparison of rate of additional variables in different studies

	associated pain	canine and molar tipping and rotation		root resorption		plaque control
	NiTi coil spring/ Elastomeric chain	NiTi coil spring	Elastomeric chain	NiTi coil spring	Elastomeric chain	NiTi coil spring/ Elastomeric chain
Hashemzadeh et al., (2022)		- 7.43° CR/4mo 7.55° CT 1.90° MR -4.80°MT	-4.50°CR/4mo 4.52°CT 0.23°MR -1.45°MT			
Badran et al., (2022)	No significant differences between groups					No significant differences between groups
Barsoum et al., (2021)	No significant differences between groups	12.66°CR / 6mo -6.21°CT	12.30°CR/6mo -6.59°CT	0.76m	0.82mm	

Discussion

This systematic review summarizes evidence from RCTs on canine retraction rate following first premolar extraction using NiTi coil springs and elastomeric chains, the two most commonly used force delivery methods. The evaluated studies either had a split-mouth or parallel-group design. In the split-mouth designs, each patient acts as their control, so inter-subject variability is eliminated, making it possible to increase the study power or reduce the number of participants required. However, apart from the similarity of the sites in split-mouth design, cross-effects between the intervention and control sides are possible due to the lack of a natural barrier, potentially distorting the results. Consequently, the split-mouth study design is not ideal for comparing different space closure systems, as space closure in one quadrant will affect the position of teeth in the other quadrant (10, 23, 24).

The results of the included RCTs showed that NiTi closed coil springs exhibited a greater rate of space closure than conventional elastomeric chains. Systematic reviews by Mohammed et al. (11) and Sebastian et al. (10) also support this finding. However, the memory chain force delivery system showed more effective space closure than the NiTi coil spring (1.89 mm versus 1.67 mm of tooth displacement over 3 months) (4).

Force decay in orthodontic closing appliances refers to the gradual reduction in force generated by devices like elastomeric chains or coil springs (25). The effectiveness of these appliances depends on maintaining a continuous force, but the force they apply tends to diminish over time due to various factors. Multiple interactions can contribute to this force degradation phenomenon, such as the oral environment, masticatory forces, oral hygiene patterns, salivary enzyme activity, and changes in the oral temperature. Several studies (26-28) reported that maximum force decay occurs within the initial days after elastomeric chain placement. A systematic review by Halimi et al. (29) revealed that the force provided by elastomeric chains diminishes over time. Moreover, a recent systematic review and meta-analysis by Andhare et al. (30) showed that the force decay of elastomeric chains reported in clinical studies was greater than that reported in in vitro settings. However, this difference was not statistically significant.

The problem of rapid force decay in elastomer chains has led some clinicians to opt for NiTi coil springs. The latter can provide light and continuous forces, potentially allowing teeth to move more efficiently (31). Previous studies have also shown that NiTi coil springs were minimally affected by oral temperature and other intraoral environmental factors (29, 32). However, it should be considered that the forces exerted by NiTi closed coil springs also degrade over time. Cox et al. (33) reported a reduction of approximately 12% after 4 weeks of clinical use and an additional 7% force decay occurring within 4 to 8 weeks of using NiTi closed coil springs.

Elastomeric memory chains have been engineered to provide gentle, consistent forces with minimal decay over time (34). Khanemasjedi et al. (4) evaluated and compared the clinical efficiency of a modern elastic memory chain versus a NiTi coil spring space closure system. They concluded that the canine can be retracted at a speed comparable to that obtained using NiTi coil springs by employing an elastic memory chain and replacing it monthly. This performance is attributed to the unique properties of polyurethane materials, which, while not perfectly elastic, exhibit a degree of plasticity over time (35). An in vitro study by Dadgar et al. (36) compared the amount of force decay between elastomeric memory chains and conventional chains after using three different types of mouthwashes and two types of toothpaste. The results showed that memory chains delivered greater forces than conventional chains and were more resistant to the effects of various chemical treatments when evaluated on the first and 28th day after placement.

The present study did not reveal any statistically significant differences between NiTi coil springs and elastomeric chains regarding the amount of anchorage loss. According to the pooled results, NiTi coil springs showed 1.1 mm of anchorage loss after 4 months and 0.29 mm after 6 months (13, 18). An average anchorage loss of 0.82 mm and 0.13 mm were observed after using elastomeric chains for 4 and 6 months, respectively (13, 18). Since different anchorage devices were used in each study, we could not compare the anchorage loss values. Bokas and Woods (14) used a transpalatal arch, and Barsoum et al.(18) used temporary anchorage devices (TADS) to support anchorage. This is while no anchorage control device was used in studies conducted by Chaudhari and Tarvade (13) and Hashemzadeh et al. (17). The amount of anchorage loss significantly improved using skeletal anchorage.

When the force is applied at a distance to the center of resistance of a tooth, it results in undesired movement. Two studies compared the tipping and rotation of canines and molars between the NiTi coil springs and the elastomeric chains. Barsoum et al.(18)

found no clinical or statistical difference in canine tipping and rotation between the two groups.

Orthodontic movements may be accompanied by pain and root resorption. According to the findings reported by Barasoum et al. (18) and Badran et al. (15), the pain intensity reported by patients was comparable between the NiTi coil springs and elastomeric chain force delivery systems. However, Badran et al. (15) stated that NiTi coil springs were significantly less comfortable than elastomeric chains. After the initial activation, 71% of patients reported more discomfort on the side with coil springs compared to the side with power chains. After the second activation, 75% of patients reported more severe pain on the side with NiTi coil springs (15). The cited authors also noted that patients found it more challenging to maintain appropriate oral hygiene when NiTi coil springs were in place. Plaque scores were greater on the coil spring than on the power chain side, although this difference was not statistically significant. These findings indicate that patient cooperation is more important than the type of force delivery system for maintaining good oral hygiene. Barsoum et al. (18) compared the amount of root resorption between the NiTi coil spring and elastomeric chain force delivery systems. The results showed no statistically significant differences between the two methods (18).

The main limitation of this systematic review was that it was impossible to conduct a meta-analysis. The main reason was the differences in the designs of studies used in this systematic review. Split-mouth and parallel-group studies require different analytical approaches. If both types of trials are included in a meta-analysis without considering their methodological differences, the results may be unreliable. Separate analyses for split-mouth and parallel-group studies also reduce the number of studies included in each meta-analysis. In addition, there was significant variability in the data extracted from different studies, such as the types of elastomeric chains, difference force magnitude, archwire size, patients' age, and inconsistent follow-up periods. All of these factors complicate the performance of a meta-analysis. More qualified clinical trials are required to clarify the superiority of different force delivery systems in sliding mechanics.

Conclusions

NiTi coil springs and elastomeric chains are effective force delivery systems for orthodontic space closure after the first premolar extraction. A faster rate of canine retraction was observed in the NiTi coil spring than in the elastomeric chain force delivery system. Space closure with elastic memory chains was more rapid than NiTi-closed coil springs. When using NiTi coil springs, canine, and molar tipping and rotation were higher. There was no clinical or statistical difference regarding the amount of anchorage loss, associated pain, plaque control, and root resorption between NiTi coil springs and elastomeric chains.

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Conflicts Of Interest

The authors declared that they have no conflict of interest.

Authors' Contribution Statement

ZF and AH contributed to the management, supervision. BE and MC were responsible for data collection, analysis, and interpretation. , and writing of the manuscript. All authors contributed to the project design, research initiation, and data analysis. All authors have read and approved the final manuscript.

Ethical approval

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