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"Orthodontics' space closure with Elastomeric chains and Nickel Titanium coils: A systematic review"

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• List of Symbols and Acronyms

AAO: American Association of Orthodontist

EC: Elastomeric Chains

EM: Elastic Module

LM: Lower Molar

MB: Mesiobuccal

NiTi: Nickel Titanium

RCT: Randomized Clinical Trial

SS: Stainless Steal

TB: Tie-Back

TMJ: Temporo-Mandibular Joint

UCI: Upper Central Incisor

UM: Upper Molar

• Abstract

Introduction: In sliding mechanics, the space closure is carried out by either Elastomeric chain (E.C), Nickel-Titanium coils (NiTi coils), or stretched modules with ligatures. E.C is more economical and should produce an optimum level of force without damage to the supportive periodontium when used cautiously for space closure. E.C products lose force over time. Ni-Ti springs lose some of their force over time. The objective of this systematic review is to furnish information for when it is time to choose between an E.C or a Ni-Ti coils during an interdental space closing treatment. **Material & Method**: A search of articles was carried out in Medline Complete, Cochrane Library and Scopus databases, using the following keywords: “Space”; “Closure”; “Elastic”; “Elastomeric”; “Chains”; “Nickel”; “Titanium”; combined with the Boolean operator “AND” and “OR”. A total of 10 relevant articles that fulfilled the inclusion criteria were selected.

Results: Regarding the space closure, Ni-Ti closes faster spaces than E.C, but by changing every 4 weeks these E.C, the difference of rates of space closure between both materials became minim. Regarding the force retentive properties, E. C. loses within 24h half of its force. Ni-Ti coil springs lose force during the first 6 weeks of use. Regarding the factors that can influence the lifetime of the material chosen, the effects of commonly used beverage, soft drink, and mouthwashes on the force delivered by E. C occurred until 7 days, and tea caused highest force decay, followed by mouthwashes and Coca-Cola©. These factors didn’t have that significant importance on the Ni-Ti closed coil springs.

Conclusion: • Nickel Titanium closed coil springs are the first option in terms of the speed of space closure. • Elastomeric Chain loses almost half of its force within the first 24h. • Heavy forces result in high force decay. • E. C. is the material most affected by the environment, and Ni-Ti, the least.

• Keywords:

Orthodontics, Elastomeric chains, Nickel-Titanium, Space closure, Systematic review.

I. INTRODUCTION

1. Orthodontics History

Orthodontics is the branch of dentistry that studies, prevents, and corrects alterations in the development of the maxillary bones and teeth**.** Its goal is to achieve functional balance between every part and organ that organize the oral cavity. The term "Orthodontics" comes from Greek: « Ορθό » / "Ortho" meaning Straight/Correct and « 'Oδovτo » / "Odonto" meaning Tooth.
Even though the orthodontic field is dedicated as much for children as for adults, this specialty can also be found under the name "Dentofacial Orthopedics", with « Παιδί » / "Pedics" in Greek meaning Child.

In the beginning of the 18th century, France was the leading country in the field of the dentistry, thanks to Pierre Fauchard, which has been called the "Father of Orthodontia". In his book "Le Chirurgien Dentiste", he described the use of ligature wires to straighten teeth, as well as the first expansion appliance, known as a Bandeau. Still in the 18th century, John Hunter, an English surgeon presented the first clear statement of Orthopedic principles. He was the first to describe normal occlusion, and the growth of the jaws as a scientific investigation. The 19th century has been marked by two noticeable doctors: One of them; Joachim Lefoulon, was the first to state the term Orthodontics. He used the word "Orthodontosie" in 1841, and by translation, it became "Orthodontia". The second one, Edward H. Angle became the most influent figure in orthodontics, by becoming the "Father of Modern Orthodontics". In 1899, he published his classification of malocclusions, which nowadays remains the most widely used classification, and he founded the American Association of Orthodontist (AAO) in 1901. (1) The AAO defined that *"Orthodontics is that specific area of dental practice that has as its responsibility, the study and supervision of the growth and development of the dentition and its related anatomical structures from birth to dental maturity, including all preventive and corrective procedures of dental irregularities, requiring the repositioning of teeth by functional or mechanical means to establish normal occlusion and pleasing facial contours"*.

1.1 Goals of the Orthodontics

Since always, a proper alignment of teeth has long been recognized to be a crucial factor for aesthetics, function, and overall preservation of dental health. The teeth along with their surroundings structures are required to perform certain significant functions such as Mastication and Phonation. Poorly aligned teeth may predispose to several unfavourable sequelae such as caries, periodontal diseases, anterior teeth trauma, dental impactions, problems regarding the masticatory function, speech, as well as facial muscle tension, TMJ's problems, ear, and neck pain. (2)
Although orthodontic treatment improves facial appearance and is occasionally performed for cosmetic reasons, it should be aimed at the restoration of overall oral health. Orthodontic treatment should increase the efficiency of the oral functions performed and enhance the overall esthetic appeal of the individual.

Orthodontic treatment can be applied both during the growth and development of the teeth and as a corrective treatment in case of malocclusion. For each problem there is a different type of solution, which is individually adapted to the patient's needs. Nowadays, the aesthetic function of orthodontics is becoming increasingly important for young people and adults who want to straighten their smile. This has led to an increase in the demand of orthodontic treatments thanks to the intensification of dental awareness and the better acceptability of appliances.
Orthodontic treatment has the ability to modify the dentofacial skeleton and affect facial esthetics, and many adult patients request orthodontic treatment for their malocclusions. It has been demonstrated that these following groups have a greater awareness of tooth alignment and malocclusion, as well as a better willingness to undergo orthodontic treatment:

- Females,
- Higher socio-economic families/groups,
- Areas which have smaller population to orthodontist ratio. (2)

1.2 Malocclusion in Orthodontics

In orthodontics, a malocclusion is a misalignment or an incorrect relationship between the teeth of the upper and the lower dental arches. Most of the time, a malocclusion results in a cosmetic problem.

If it is important, it can have a serious impact of the person self-esteem, as well as creating functional problems while eating or speaking.

The aetiology of malocclusion is still under studies, but so far, we know that it can occur as a result of genetically determined factors, which can be inherited, environmental, or combination of both. The genetic influences are the factors we can't control, as the jaws or teeth's size for example. The environmental influences are the factors we can change. They are for example, digit-sucking habits, loss of teeth due to a trauma or even due to caries. (1)

As mentioned before, the dental malocclusion can be classified thanks to Angle's work. He based himself upon the belief that the first permanent molars erupted into a constant position within the facial skeleton and this could be used to assess the anteroposterior relationship of the dental arches.

In certain cases, as for example the loss of the first permanent molars, this classification needed to be seen under other approaches.

Nowadays, we continue using the Angle's classification in order to describe the Molar relationship; and the terms used to describe incisor relationship have been adapted into an Incisor classification.

For this, the most widely used classification is from the British Standards Institute. It divides one of Angle's group classification but uses similar terms for the rest. (2)

According to both classifications, we find:

Angle's Molars Classification	British Standards Incisors Classification
• Class I: The mesiobuccal (MB) cusp of the upper 1st molar (1st UM) occludes with the MB groove of the lower first molar (1st LM). • Class II: The MB cusp of the 1st LM occludes Distal to the 1st UM. • Class III: The MB cusp of the 1st LM occludes Mesial to the 1st UM.	• Class I: The lower incisor edges occlude with or lie immediately below the cingulum plateau of the upper central incisors (UCI). • Class II: The lower incisor edges lie posterior to the cingulum plateau of the UCI. • *Division 1*: The UCI are pro-inclined or of average inclination. There is an increase in overjet. • *Division 2*: The UCI are retro-inclined. The overjet is usually minimal or may be increased. • Class III: The lower incisor edges lie anterior to the cingulum plateau of the UCI. The overjet is reduced or reversed.

Table I. Angle's Classification

Even though the group "Class I" in both classifications can be considered as Neutrocclusion, it doesn't exclude the possibilities of having a malocclusion. For example, a patient with a Molar Class I can present dental crowding of the anterior teeth, or on the contrary, present interdental spaces.

Throughout time, thanks to the progresses and improvements in the orthodontics field, almost all malocclusions can be treated. By means of all the different orthodontic devices available nowadays, an orthodontist can for example: close gaps between teeth; align crowded teeth; prevent dental trauma; improve the speech or chewing ability; treat an improper bite. These devices can be Fixed or Removable. As examples, in Fixed appliances, which are the more commonly used, we find Braces, Fixed-Space maintainers; and for the Removable ones, we have Aligners, Headgear. Some of these are more regularly used than others.

The election between one or another will depend on the treatment required, as well as the patient's collaboration. Orthodontists can come up with the best treatment plans for their patients according to their needs, based on physical knowledge regarding dental movement, even though every treatment is unique, as it will depend on each patient physiological response.

One common procedure in daily orthodontic practice is the Interdental space closure. The ideal space closure mechanism should have mechanical features that provide a light and continuous force that closes the orthodontic space in the shortest amount of time. (3)

Although there is no definitive evidence for the optimal force required during space closure, a force delivery system that generates 150-200 grams of orthodontic force is usually prescribed. (4)
Appliance biocompatibility, orthodontic treatment efficiency, and patient convenience are the major issues confronting today's orthodontists.

In this context, different interdental space closing systems have been proposed. The first one involves using "closing loops" in a continuous or segmented arch wire. Once the wire is engaged in the brackets, the spring is activated with a distalizing force. The springback properties of the wires cause the springs to 'close' producing the forces necessary to initiate and continue tooth movement.

The second technique, termed "sliding mechanics", involves pushing or pulling a tooth along a continuous arch wire with a force delivery system adequate to produce and sustain movement. Generally, either a coil spring or a form of elastomeric material is used to accomplish the latter. (5)

2. Orthodontics Material used in Interdental space closing

The continuous evolution of dental materials has led to a constant pursuit of technological innovations in orthodontics.
In sliding mechanics, the space closure is carried out nowadays by either Elastomeric chain, Nickel-Titanium coils (NiTi coils), or stretched modules with ligatures.
Comparatively, both Elastomeric chain and module with ligature wire are more economical and should produce an optimum level of force without damage to the supportive periodontium when used cautiously for space closure. (6)

2.1 Elastomeric chains – What it is

Elastomeric chains are one of several devices used to provide force for orthodontic tooth movement, but the force they exert diminishes over time and can be difficult to control.
Synthetic elastomeric chain was introduced in the 1960s and has been in widespread use since. These chains and single ligatures are manufactured by many companies and are available in a variety of different colors to meet the growing global demand for esthetic orthodontic appliances.

Orthodontic elastomeric chains are made from polyurethane using a die-stamping or injection-molding process. (7)
When a polymer is stretched and the stress within it increases proportionally to the applied strain, the polymer is described as behaving elastically.
However, when elastomeric chain is stretched, it does not behave as a perfectly elastic material.
Elastomeric systems lose force during the duration of their use.
This is thought to be due to a combination of water causing the weakening of intermolecular forces and chemical degradation, and tooth movement resulting in decreasing stretch placed upon the elastomeric chain. (8)

2.2 Nickel Titanium coils – What It is

The Nickel Titanium (NiTi) alloys were a revolutionary innovation and have found wide application in orthodontics, mostly as archwires in the straight-wire technique, due to their unique mechanical properties.

Nickel-Titanium based alloys are part of the family of “Shape-memory alloys”.

The latter are a group of metallic materials that possess the ability to return to their original shape when subjected to appropriate heat treatment.

The properties of NiTi based alloys derive from the fact that they exhibit at least two crystallographic phases: one at high temperature called Austenite, the other at low temperature called Martensite.

• Austenitic or Austenite phase: It is the centered cubic stable phase at high temperature.

• Martensitic or martensite phase: It is the stable phase below the martensitic transformation temperature zone.

At a macroscopic scale, the martensitic transformation involves a homogeneous deformation of the crystallographic lattice, taking place mainly according to a shearing mechanism. In the absence of external stresses, the material retains its initial shape, and the formation of martensite only leads to elastic and therefore reversible deformations.

Nowadays, superelastic and thermal NiTi archwires are commonly used.

We can find the Austenitic-active, superelastic NiTi archwires; the Martensitic-stabilized NiTi archwires, which are not superelastic, but demonstrate reduced stiffness, outstanding range, and high springback in comparison with stainless steel; and the Martensitic-active heat-activated NiTi archwires. (9)

A superelastic NiTi wire has clinical advantages over a flexible work-hardened (martensite-stabilized) NiTi wire only if the working point is on the superelastic plateau. Additionally, superelasticity allows the orthodontist to use greater cross-section dimensions for the NiTi archwires in the early stages of treatment to accomplish various tasks simultaneously, such as correction of rotation, tipping, leveling, and torquing. (9)

The austenite-to-martensite transformation can also occur as a result of temperature decrease, which is termed the thermoelastic martensitic transformation.

There is thus a strong interrelationship between temperature and stress, regarding the induction of martensite: a decrease in temperature is equivalent to an increase in stress. Thermal NiTi wires are martensitic-active alloys and exhibit a thermally induced shape-memory effect. In these wires, the temperatures for transformation from martensite to austenite occur in the region of the ambient oral temperature. (9)

3. Advantages and Disadvantages of Elastomeric chains and Ni-Ti coils in Orthodontics

Elastomers have been used more frequently, as they are more practical and more economic. Also, the use of clear elastomeric chains to move the teeth along the archwires has improved the esthetic aspect of clear orthodontic fixed appliances.

However, force degradation studies have shown that elastomers lose a significant portion of their force-generating capacity over time.

The environment and temperature in which the elastic acts also interfere considerably in maintaining the properties of this type of material.

It is known that elastics conserved in a humid environment and exposed to higher temperatures suffer greater reduction on their force generating capacity. (3)

In general, the initial force level is reduced by 50–70% within the first day after chain extension. After 28 days, the force has decreased by an average of 30 – 40% of its initial level. (3)

Moreover, the oral cavity's moist environment exerts an influence on the chains' force levels. The elastomeric chains in the mouth are subjected to pH variations during the ingestion of liquid and solid foods.

Because of the various factors influencing the complex material properties of the elastomeric chains, it is often difficult for orthodontists to estimate the force levels applied at the beginning and during the application period.

On the other hand, NiTi coils with shape memory may generate lower and continuous forces and be less affected by the humidity and pH of the environment.

NiTi archwires show low loaded deflection ratios and may exert light continuous orthodontic forces, which provide good control of force magnitude and may lead to optimal tooth movement. These characteristics may decrease patient monitoring and lengthen the intervals between visits. (9)

Synthetic orthodontic elastics with memory chain have been launched to the dental market. These elastics are used for intra-arch space closure and are low cost in comparison with the NiTi coils used for the same purpose.

It is well known that elastomeric products lose force over time, even under dry conditions, and that properties are modified by both moisture and temperature. In the case of nickel titanium alloy, the effects of environmental factors, other than temperature, are less well known.

Much of the initial force is lost over the first 24 hours and then continues to decrease at a much slower, steadier rate. High initial loading forces experience greater force decay than initially lower forces, whilst moisture (saliva and water) also increases the rate of force decay. Nickel titanium springs have also been found to lose some of their force over time, although to a lesser extent than elastomers. (9)

II. JUSTIFICATION, HYPOTHESE AND OBJETIVES

This systematic review is done for its importance in the orthodontic field, in order to help both the practician and the patient.

Knowing the physical properties of the different materials we use in our daily practice, with their advantages and inconvenients, will lead the orthodontist to prepare the best treatment plan for the patient; as he will take into account his own experience and ability, as well as his patient's preferences.

This work is done to furnish further information to the orthodontist when it is time to choose between either an Elastomeric chain (E.C) or a Nickel Titanium (Ni-Ti) coils for an interdental space closing treatment.

It will compare their resistance throughout time, through the amount of initial force we chose to use, as well as their effectiveness under everyday factors like the use of mouthwashes, of common beverages, or even under the effect of our own saliva.

Before doing any research, we can suppose that we will find results saying that the use of Nickel-Titanium coil in dental space closing will be more efficient than the use of an elastomeric chain; because a metallic material gives the feeling of being more resistant than an elastic one, especially when it deals with teeth movement. It seems that metal lasts longer than elastic. For example, we've all already found home some old elastics without any elasticity left, especially if they were stored in warm places. Thanks to these properties, a Ni-Ti material seems to last longer, and also to attain faster the expected results. Nevertheless, every material has advantages and disadvantages. We can presume that Ni-Ti coils will have a bigger cost than Elastomeric chains.

This systematic review has three different objectives:

1- Compare the rates of space closure attained with Elastomeric chain and NiTi coil in orthodontics.

2- Investigate the force retentive properties of Elastomeric chain and NiTi coil in the clinical situation.

3- Evaluate which factors can influence the lifetime of the material chosen.

III. MATERIAL AND METHODS

The planning and preparation of this study has followed the guidelines established by the PRISMA declaration for the preparation of systematic reviews, disponible in the Annexes.

1. Eligibility Criteria

This systematic review is made to give an answer to the following question: How does the Elastomeric chains and NiTi coils can impact the dental space closing in orthodontic patients throughout time?

The resources we used to carry out this work had to fulfill the following criteria:

- **P**opulation: Orthodontic patients
- **I**ntervention: Dental space closing
- **C**omparison: E.C & NiTi coils
- **O**utcome: Effects throughout time

Also, we used:

- Inclusion Criteria:

- Randomized controlled clinical trials
- Clinical investigations
- Cohort studies
- In-vivo studies
- In-vitro studies
- Human studies

- Exclusion Criteria:

- Studies not about Dental retraction
- Non-English articles
- Studies not dealing with Space closing

2. Search Strategy

A search of articles was carried out in Medline Complete, Cochrane Library and Scopus databases between the 27th of November 2021 and 27th of December 2021; using the following keywords: "**Space**"; "**Closure**"; "**Elastic**"; "**Elastomeric**"; "**Chains**"; "**Nickel**"; "**Titanium**"; combined with the Boolean operator "**AND**" and "**OR**".

DATA BASE	KEY WORDS	FILTRES	RESULTS	DATE
Medline Complete	Space AND Closure AND (Elastic OR Elastomeric) AND Chain OR Space AND Closure AND Nickel AND Titanium	- Article in English - Article < 10 years	**60**	27/11/2021
Cochrane	Space AND Closure AND (Elastic OR Elastomeric) AND Chain	- Article in English - Article < 10 years	**7**	10/12/2021
Cochrane	Space AND Closure AND Nickel AND Titanium	- Article in English - Article < 10 years	**17**	10/12/2021
Scopus	Space AND Closure AND (Elastic OR Elastomeric) AND Chain OR Space AND Closure AND Nickel AND Titanium	- Article < 10 years - Subject Area: Dentistry - Document Type: Article - Article in English	**45**	27/12/2021

Table II. Search Strategy

3. Study Selection

Once the articles were selected, the data were independently reviewed by this systematic review's tutor.

All the duplicates have been eliminated, and the study titles and abstracts of the remaining articles were screened to make sure they were relevant studies for our review. Consequently, studies that satisfied the eligibility criteria were included through full-text assessment.

For the syntheses, the studies will be gathered in three different groups.

The first group will assemble the studies comparing dental space closing using E.C or Ni-Ti coils. The second one will put together the ones dealing with force decay of both material during its function. The last one will collect the articles that discuss about the stability of the material throughout time under some environmental factors.

4. Data's Election

The data of the eligible studies were further summarized in a tabular form with the information regarding author detail, year, study design, sample size, age, and follow-up period in **Table III**.

5. Quality Evaluation

In order to evaluate the information's quality given by the articles selected, we used the CASPE guide; evaluating which were the different studies results; if they were valid; and if these results could help our review.

IV. RESULTS

1. Studies Selection – Flow Chart

The search process started on the 27th of November 2021 until the 27th of December 2021, and it involved a total of 129 potentially relevant articles.

We found: 60 articles on Medline Complete / 24 articles on Cochrane / 45 on Scopus. After removing duplicates (23 articles), 106 articles were considered for screening. After evaluating if they were meeting the inclusion's criteria, and reading their abstracts, 9 articles were successively excluded.

The full texts of the 97 articles remaining were evaluated independently.

In total, we excluded 86 articles. 47 of them where not dealing with the subject of this systematic review; 19 were excluded for not dealing with Space Closure; 13 were not dealing with the material chosen for this study, and the results of 8 were not pertinent for this study. A total of 10 relevant articles that fulfilled the inclusion criteria were selected, and these were included in this systematic review. All these steps are summarized in the **Figure I**.

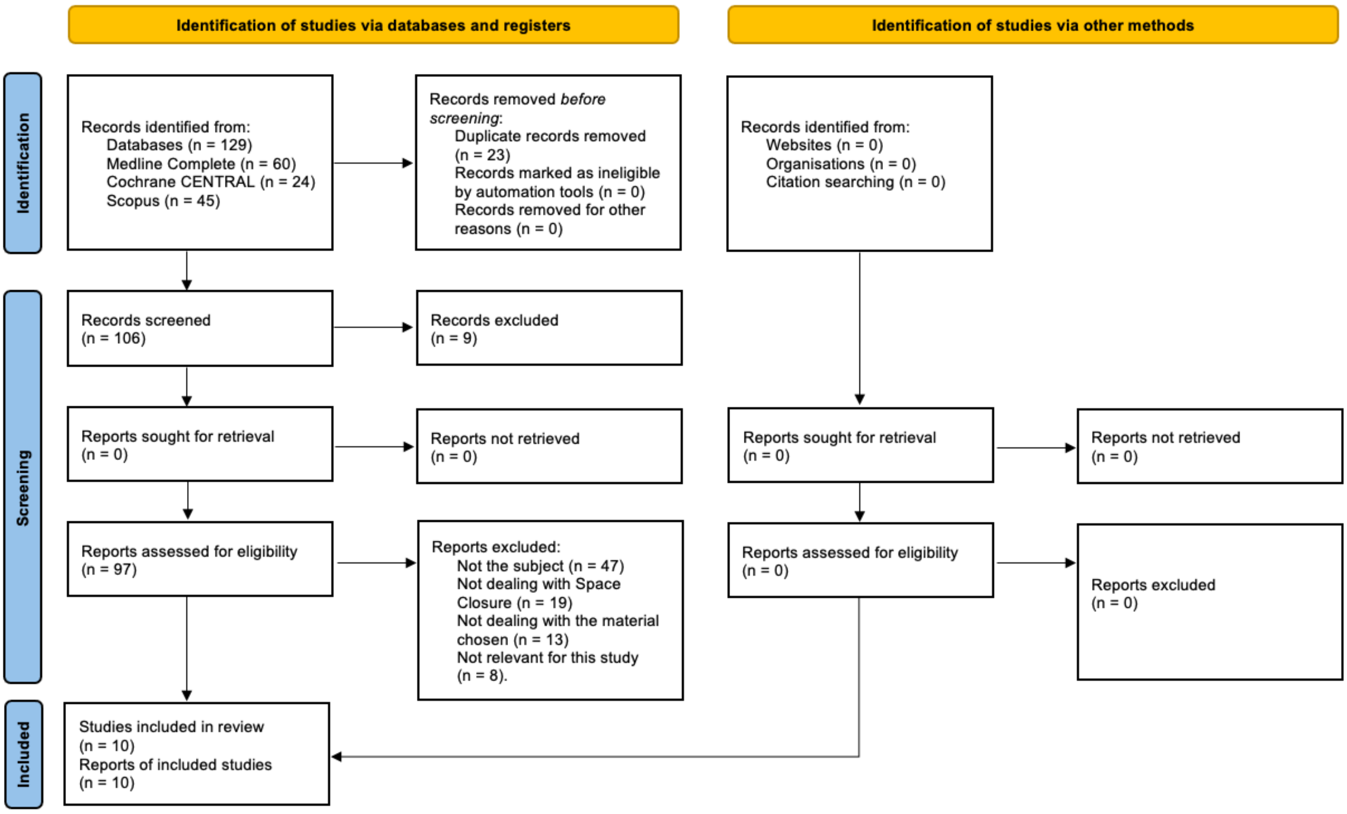

Fig. I. PRISMA Flow Diagram

2. Characteristics Analysis of the included studies

From the included studies, we gathered in the **Table III** all the general characteristics, including the Author details, the Year of publication, the Study design, the Sample size, the Age of the participants, and the Follow-Up period.

Barsoum H. et al (10) published a split-mouth randomized controlled trial, in 2021. The objective of this study was to compare canine retraction using Ni-Ti closed coil springs vs E.C. To carry out this research, the author selected 35 patients needing orthodontics treatments indicated for canine retraction. Conventional 0,022-inch Roth prescription brackets were used, and the canines were bonded with vertical slot brackets. A Ni-Ti Closed Coil Spring was used for canine retraction on one side, and Elastomeric chain on the contralateral side.
The retraction force was adjusted to 150g, using a digital gauge. During the follow-up visits, the author measured and adjusted the force delivered by the coil spring, and the E.C was replaced to maintain constant force delivery.
For the 10 first days after each activation, the patients had to report if they experimented presence or absence of dental pain.

Khalid Z. et al. (11) published a Comparative study, in 2018. The objective of this study was to compare the mean change of tooth movement in canine retraction, between Elastic Module and Ni-Ti coil spring. To carry out this research, the authors selected 32 patients, 14 males and 18 females, aged between 18 - 45 years old, needing orthodontics treatments indicated for canine retraction. On one side, the canine retraction was done by 9-mm Ni-Ti closed coil spring with hooks on both sides and stretched to 21mm to exert 150g of force. On the other side, Active tie back on 16x22 SS wire was used, and stretched to twice of its length and tied to the canine. During the follow-up visits, after four weeks, and they measured the distances between the lateral incisors and the canines on both sides.

Khanemasjedi M. et al. (12) published a R.C.T in 2017. The objective of this study was to compare the efficacy of newly-introduced Elastic Memory Chains (EMCs) and NiTi coil springs in canine retraction. To carry out this research, the authors selected 42 quadrants of 21 patients needing orthodontics treatments indicated for canine retraction. The sliding mechanics used was 0,016-inch SS archwires attached to 0,018-inch standard edgewise brackets. On one side was placed NiTi spring, and with a tension-and-compression gauge with 25g of accuracy, they determined the use of Medium or Heavy NiTi coil, based on the force needed for canine retraction. On the other side was found the E.C, chosen between Short, Long, Closed, and between different numbers of chains links, in order to exert a force close to the NiTi one. During the follow-up visits, every month, for 3 months, the Elastomeric Chains were changed by new ones, but they kept the same NiTi springs.

Cox C. et al. (13) published an In-Vivo study, in 2014. The objective of this study was to evaluate the properties of NiTi closed coil springs and its changes after clinical use. To carry out this research, the authors selected 30 NiTi coil springs used intraorally by 11 patients, aged between 13 - 43 years, and 15 matched laboratory control springs. The springs used were Sentalloy NiTi coil springs of medium grade with delivering force of 150g.
The ones used as laboratory control springs were in simulated intraoral conditions; they were kept in artificial saliva, at 37°C. The springs were evaluated every 4 weeks for a total of 12 weeks during the follow-up visits and were not changed until significant distortion was observed.

Evans K. et al. (14) published an In-Vivo and In-Vitro study, in 2016. The objective of this study was to evaluate if the unaltered E.C can continue to move teeth for 16 weeks and to relate it to the amount of force remaining.
To carry out this research, for the in-vitro part, the authors selected 2 wood jigs made with 10 pairs of steel, and 100 each of 2-unit and 3-unit E.C segments were stretched twice their resting length on the 2 jigs, respectively. Distilled water at 37°C was used to simulate the oral environment.

For the in-vivo part, one extraction side was considered the Control side, with altered E.C, and the other side served as Experimental side, using unaltered E.C. During the follow-up visits, every 28 days, for 16 weeks, the E.C of the Control side (which were the altered ones), were replaced, but the ones from the Experimental side (with the unaltered E.C) weren't.

Alavi S. et al. (15) published an In-Vitro study, in 2015. The objective of this study was to evaluate the effects of the aging process on Ni-Ti closed coils and assess the effects of preactivation on forces generated by these coils. To carry out this research, the authors selected 60 Ni-Ti closed coils and they formed four groups. All the samples of each group were extended to 30% of their original length (stretched to 12mm), and then were returned to their original length. The 1st and 3rd groups were stored at room temperature, and the 2nd and 4th groups, incubated in 37°C in normal saline solution, for 45 days. The force was recorded at every 0,5mm. This process was repeated twice, with the measurements at the 22nd day, and at the 45th day. Before these measurements, the samples of the 2nd and 4th groups, the incubated ones, received 1000 thermocycles, from 5°C to 55°C.

Nightingale C. et al. (8) published a R.C.T, in 2003. The objective of this study was to investigate the force retention and rates of space closure reached by Ni-Ti coil springs and E.C. To carry out this research, the authors selected 22 patients aged between 12 - 18 years old needing bilateral space closure after premolar extraction, using sliding mechanisms. 15 patients had both Ni-Ti coil springs and E.C, and 7 only had E.C. The force delivery systems were 9mm Ni-Ti closed coil springs, and Medium-spaced E.C. During the follow-up visits, every 4-6 weeks until complete space closure or 2 years, the E.C were renewed at each visit, and the Ni-Ti coil springs weren't.

Mirhashemi A. et al. (16) published an In-Vitro study, in 2021. The objective of this study was to compare the force decay pattern of E.C and Ni-Ti coil springs which were exposed to 5 different mouthwashes.

To carry out this research, the authors used 60 pieces of E.C and 60 of Ni-Ti closed coil springs and they divided in 6 groups. The samples were stretched to exert as initial force 250g. The 1st group was immersed in Chlorhexidine 0,2% containing 0,2g Chlorhexidine gluconate in 100mL solution. The 2nd group was Sodium Fluoride 0,2% containing 0,2g Sodium Fluoride in 100mL solution. The 3rd one, Persica mouthwash containing effective materials as tooth plant, mint, and yarrow. The 4th one, Total care Zero Listerine mouthwash. The 5th group, Orthokin alcohol free mouthwash. The 6th group was considered the control group, exposed in an artificial saliva. They soaked the specimens twice a day, for 60 seconds each time, with 12-hour interval. During the follow-up visits, at day 0 – day 1 – day 7 – day 14 – day 28, the force exerted by each group was measured.

Oshagh M. et al. (17) published an In-Vitro study, in 2015. The objective of this study was to evaluate the force decay pattern in the presence of tea and two mouthwashes. To carry out this research, the authors selected 4 links of clear medium sized E.C and 9mm of Superelastic Ni-Ti closed coil spring. Each force delivery systems were attached onto five jigs, and each of the five devices was immersed in one of five different environments. The 1st one was Tea, and the 2nd one, Hot water, both at 65°C, for 3min once a day. The 3rd and 4th one, Cordosyl 0,2% Chlorhexidine digluconato, and Oral-B 0,05% Sodium Fluoride mouthwashes respectively, for 1min, once a day. The 5th one was the control group, distilled water at 37°C. During the follow-up visits, at day 0 – day 1 – week 1 – week 3, the force exerted by each group was measured.

Kumar K. et al. (18) published an In-Vitro study, in 2014. The objective of this study was to evaluate and compare the effect of Coca-Cola©, Tea, Listerine© mouthwash on the force delivered by E.C. To carry out this research, the authors selected 480 four link grey close E.C and they divided them in four specimen groups. The 1st group was placed into Distilled water, the 2nd group into Coca-Cola©, the 3rd one into tea, and the 4th one into Listerine© mouthwash. They soaked the specimens twice a day, for 60 seconds, with 9-hour interval.

Table III. General Characteristics of the included studies

Author Details	Year	Study Design	Sample size	Age	Follow-up period
Barsoum H. et al.[10]	2021	RCT	**64** quadrants	≥ 13 years	6 months
Khalid Z. et al.[11]	2018	Comparative study	**32 patients**	18 - 45 years	8 months
Khanemasjedi M. et al.[12]	2017	RCT	**42 quadrants** of 21 fixed orthodontic patients.	≥ 13 years	3 months
Cox C. et al.[13]	2014	In-Vivo study	**30 Ni-Ti** closed coils springs worn by 11 patients and **15** laboratory **control springs**	13 - 43 years	12 weeks
Evans KS. et al.[14]	2016	In-Vivo + In-Vitro study	*In-Vitro:* **100 2-unit** and **3-unit E.C** segments *In-Vivo*: **30 paired extraction space** sites (**22 subjects**)	< 16 years	16 weeks
Alavi S., Haerian A.[15]	2015	In-Vitro study	**60 Ni-Ti** closed coils divided in **4 groups**. - 2 groups kept in room temperature - 2 incubated in 37°C in normal saline	-	45 days
Nightingale C., Jones SP.[8]	2003	RCT	**15 patients** both **Ni-Ti coil springs and E.C** and **7 patients** only **E.C**	12 - 18 years	2 years
Mirhashemi A. et al.[16]	2021	In-Vitro study	**60** pieces of **EC** and **60 Ni-Ti** closed coil spring divided into **6 groups**.	-	28 days
Oshagh M. et al.[17]	2015	In-Vitro study	**4** clear medium closed **EC**, **9 mm** of **superelastic NiTi** coils spring	-	3 weeks
Kumar K. et al.[18]	2014	In-Vitro study	4 specimen groups with a total sample size of **480 specimens**.	-	28 days

RCT: Randomized Clinical Trial / Ni-Ti: Nickel-Titanium / EC: Elastomeric Chains

3. Assessment of Methodological Quality and Risk of Bias

As explained anteriorly, the quality evaluation of the articles' information has been done using the CASPE scale for each study included, taking into account the study design of all the studies individually. The results obtained are gathered in the **Table IV** for the Randomized Controlled Trials, and in the **Table V** for the Qualitative Studies.

Table IV. CASPE Guide of the included studies – Randomized Clinical Trials	Barsoum H. et al.[10]	Khanemasjedi M. et al.[12]	Nightingale C., Jones SP.[8]
Section A: Is the basic study design valid for a randomized controlled trial?			
Did the study address a clearly focused research question?	**YES**	**YES**	**YES**
Was the assignment of participants to interventions randomized?	**YES**	**YES**	**YES**
Were all participants who entered the study accounted for at its conclusion?	**YES**	**YES**	**YES**
Section B: Was the study methodologically sound?			
• *Were the participants / investigators / people analyzing outcome 'blind' to intervention they were given?*	**• YES / • YES / • YES**	**YES**	**YES**
Were the study groups similar at the start of the randomized controlled trial?	**• YES / • YES / • YES**	**YES**	**YES**
Apart from the experimental intervention, did each study group receive the same level of care (that is, were they treated equally)?	**• YES / • YES / • YES**	**YES**	**YES**
Section C: What are the results?			
Were the effects of intervention reported comprehensively?	**YES**	**YES**	**YES**
Was the precision of the estimate of the intervention or treatment effect reported?	**YES**	**YES**	**YES**
Do the benefits of the experimental intervention outweigh the harms and costs?	**YES**	**YES**	**YES**
Section D: Will the results help locally?			
Can the results be applied to your local population/in your context?	**YES**	**YES**	**YES**
Would the experimental intervention provide greater value to the people in your care than any of the existing interventions?	**YES**	**YES**	**YES**

Table V. CASPE Guide – Qualitative Studies	Khalid Z. et al.[11]	Cox C. et al.[13]	Evans KS. et al.[14]	Alavi S., Haerian A.[15]	Mirhashemi A. et al.[16]	Oshagh M. et al.[17]	Kumar K. et al.[18]
Section A: Are the results valid?							
Was there a clear statement of the aims of the research?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Is a qualitative methodology appropriate?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Was the research design appropriate to address the aims of the research?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Was the recruitment strategy appropriate to the aims of the research?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Was the data collected in a way that addressed the research issue?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Has the relationship between researcher and participants been adequately considered?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Section B: What are the results?							
Have ethical issues been taken into consideration?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Was the data analysis sufficiently rigorous?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Is there a clear statement of findings?	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Section C: Will the results help locally?							
How valuable is the research?	**Very util**	**Util**	**Very util**	**Util**	**Util**	**Util**	**Util**

4. Synthesis of Results

Regarding the rates of space closure attained with Elastomeric chain and Ni-Ti coil in orthodontics, Barsoum H. et al. (10) observed that, in terms of monthly canine retraction rate, there was no statistical difference between the groups.
The groups were sharing comparable results after 6 months. By not having significant differences, no method could be recommended more than the other.
The authors considered the pain intensity during the treatment in order to differentiate the groups anyway. The patients treated with coil springs stated considerably less days with pain. Only about 70% of patients reported pain in the first two months.

Khalid Z. et al. (11) compared the rate of tooth movement between E. C. and Ni-Ti coil spring. This investigation leads to conclude that Ni-Ti coil springs closes spaces faster than E. C.
Khanemasjedi M. et al. study (12) studied and compared the mean rate movement during space closure over three months and compared the results month by month. Their findings revealed that the average speed of space closure during the three months was significantly different between the two groups.

Comparing the amount of space closure each month, the results were not different between the two groups during the 1st and 2nd month. During the 3rd month that the difference of speed of canine retraction became significant.
The authors found that employing E. C. and renewing it every four weeks is just as effective as using Ni-Ti springs for three months. The different results obtained from these articles are gathered in the **Table VI**.

Regarding the force retentive properties of Elastomeric Chains, Evans K. et al. (14), found that the mean space closure at both the altered and unaltered elastomeric chain extraction sites demonstrated continuing clinically and statistically significant tooth movements for the 16 weeks of observation. As shown in **Table VII**, by 4 weeks, the E. C. force had degraded rapidly, but by 16 weeks, it had continued to decline gradually.

Nightingale C. et al. (8) observed that the range of initial forces applied was 70 – 450g, with a mean force of 209g, whilst the range of final forces was 50 – 230g, with a mean force of 109g. 59% of the sample maintained at least 50% of their initial force over a time period of 1 – 15 weeks. The higher the initial force, the greater the force loss experienced.

Regarding the force retentive properties of Ni-Ti coil springs, after 4 weeks of clinical use, Cox C. et al. (13) found that the springs studied showed a statistically significant decrease in force (approximately 12%), with a further significant decrease (approximately 7%) from 4 to 8 weeks, and force levels appearing to remain steady subsequently. Over each time period evaluated, all three spring groups demonstrated statistically significant decreases in average force levels from initial to final testing. The amounts of force loss experienced by the clinical and laboratory springs were significantly greater than those experienced by the control springs, indicating that the force loss was greater than what could be attributed to differences in mechanical testing machines. We can appreciate the values in the **Table VIII**. Regarding preactivation, Alavi S. et al. (15) got as results that the mean forces of preactivated coils (dry and incubated) had no significant difference with the mean forces produced by non-preactivated coils (dry and incubated).

Nightingale C. et al. (8) observed that the range of initial forces applied was 150 – 460g, with a mean force of 300g, and the range of final forces was 95 – 255g, with a mean force of 149g. Ni-Ti coil springs lost force rapidly during the first 6 weeks of use, then reached a plateau for the rest of time. 46% maintained at least 50% of their initial force over a period of 1 – 22 weeks. Again, the greater the initial force, the greater the force decay.

Regarding the factors that can influence the lifetime of the material chosen, Mirhashemi A. et al. (16) observed that, in Ni-Ti coil springs, the force decay was more gradual and lesser than E.C. after 4 weeks of study. E.C had the greatest force reduction in one week, followed by a more regular force reduction in the following weeks. Also, on the first day, there was a statistically significant difference between some groups of mouthwashes in the E.C samples.

At the end of the study period, Listerine was the group exerting the least amount of force of any group, and Persica was the one exerting the most amount of force after the Control group. However, there was no statistically significant difference observed between the groups of Ni-Ti coils. Oshagh M. et al. (17) also found that E.C had greater force reduction, especially within the first week, rather than in Ni-Ti groups. Also, tea and almost all the mouthwashes had detrimental effects on the E.C. We can observe these results in the **Figure II**. Kumar K. et al. (18) focused on the effects of commonly used beverage, soft drink, and mouthwashes on the force delivery by E.C, and found that for all groups, force decay occurred until 7 days, and that tea caused highest force decay, followed by mouthwashes and Coca-Cola©. We can observe these results in the **Figure III**. Moreover, the **Table IX** collects all the numeric results of these three studies.

Barsoum H. et al. (10)

	Minimum movement (mm)	Maximum movement (mm)	Mean movement (mm)
Ni-Ti Group	-	-	0,79
E. C. Group	-	-	0,86

Khalid Z. et al. (11)

	Minimum movement (mm)	Maximum movement (mm)	Mean movement (mm)
Ni-Ti Group	0,66	2 ,01	1,1369
E. C. Group	0,33	1,50	0,7719

Khanemasjedi M. et al. (12)

	1st Month	2nd Month	3rd Month	Total (3m)
Ni-Ti Group	1,93mm	1,71mm	1,36mm	1,67mm
E. C. Group	2,20mm	1,96mm	1,52mm	1,89mm

Table VI. Results for rates of space closure attained with Elastomeric Chain and Ni-Ti coil

Evans K. et al. (14)

Time	Site	Min. movement (mm)	Max. movement (mm)	Mean movement (mm)
Week 4	Unaltered E.C.	0,5	4,3	1,57
	Altered E.C.	0,3	3,7	1,62
Week 8	Unaltered E.C.	0,0	2,1	0,91
	Altered E.C.	0,3	2,2	1,05
Week 12	Unaltered E.C.	0,0	2,6	0,98
	Altered E.C.	0,1	3,1	1,03
Week 16	Unaltered E.C.	0,1	2,1	0,85
	Altered E.C.	0,2	2,2	0,97

Table VII. Force remaining in Elastomeric Chains for space closure, for 16 weeks.

Cox C. et al. (13)

Time	Site	Mean Force Loss (g)	Force Loss (%)
Week 0	Control	5,12	1,71
Week 4	Clinical	34,69	11,57
	Laboratory	36,32	12,12
Week 8	Clinical	56,59	18,88
	Laboratory	52,02	17,36
Week 12	Clinical	53,33	17,36
	Laboratory	58,27	19,44

Table VIII. Average and Percentage of force loss for clinical, laboratory, and control springs over each time period

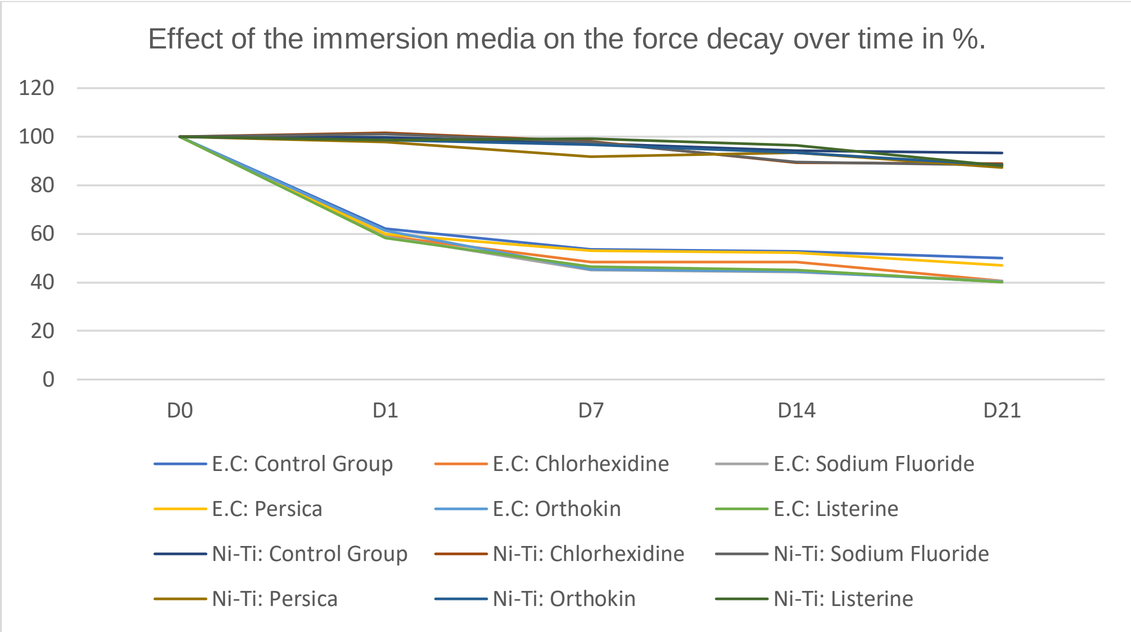

Fig. II. Comparison of the effect of the immersion media on the E.C. and Ni-Ti

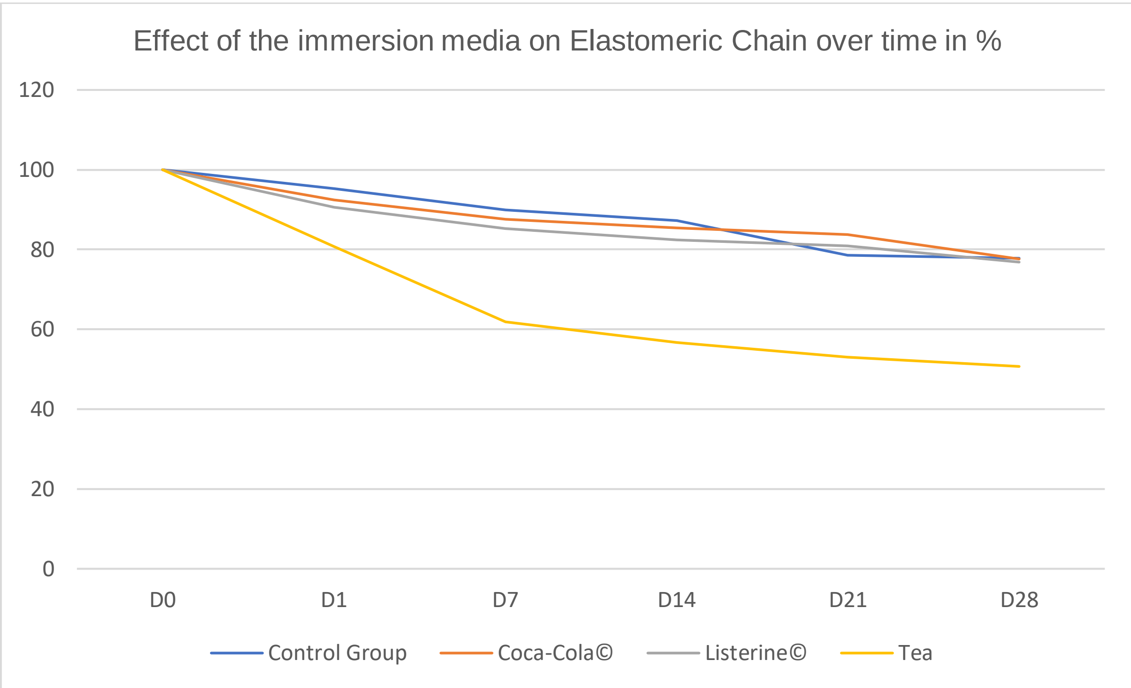

Fig. III. Effect of the immersion media on the Elastomeric Chain

Mirhashemi A. (16)

Mouthwash	Space Closure System	Time				
		T0	D1	D7	D14	D28
Artificial Saliva	E. C.	249,4	**155,0**	133,2	131,2	124,4
	Ni-Ti coils	150	149,5	146,1	141,3	140,0
Chlorhexidine	E. C.	249,8	**147,6**	121,2	**120,8**	**102,8**
	Ni-Ti coils	150	152,4	147,0	134,1	133,4
Sodium Fluoride	E. C.	250,8	**146,8**	**112,6**	**110,6**	**101,6**
	Ni-Ti coils	150	151,6	146,7	134,4	132,5
Persica	E. C.	249,4	**150,0**	132,4	130,4	117,6
	Ni-Ti coils	150	146,8	137,9	139,5	130,9
Total Care Zero Listerine	E. C.	249,6	**145,8**	**116,0**	**112,4**	**100,2**
	Ni-Ti coils	150	147,8	148,6	144,6	132,4
Orthokin Alcohol Free	E. C.	250,6	**153,6**	**113,6**	**111,6**	**100,6**
	Ni-Ti coils	150	148,9	145,2	140,0	131,5

Oshagh M. (17)

Environment	Space Closure System	Time			
		T0	D1	D7	D21
Control group – Artificial Saliva	E. C.	500	**242**	216	197
	Ni-Ti coils	224	166	159	150
Tea	E. C.	488	**200**	194	**162**
	Ni-Ti coils	227	198	189	180
Hot Water	E. C.	478	**208**	**188**	**161**
	Ni-Ti coils	221	171,5	168	180
Chlorhexidine Mouthwash	E. C.	460	218	190	172
	Ni-Ti coils	212,5	170	153	153
Sodium Fluoride Mouthwash	E. C.	508	216	187	172
	Ni-Ti coils	207,5	162	151,5	149

Kumar K. (18)

Environment	Space Closure System	Time					
		D0	D1	D7	D14	D21	D28
Control group	E. C.	100%	95,29	89,95	87,33	78,52	77,82
Coca-Cola©	E. C.	100%	92,5	87,64	85,44	83,72	77,63
Listerine©	E. C.	100%	90,59	85,21	82,47	80,86	76,85
Tea	E. C.	100%	**80,73**	**61,94**	**56,8**	**53,08**	**50,7**

Table IX. Results for the factors that can influence the lifetime of E. C. and Ni-Ti coil

V. Discussion

The effectiveness of orthodontic space closure using two common force delivery systems, Nickel Titanium coil springs and Elastomeric Chain, was investigated in this systematic review. To realize this study, three randomized clinical trials were included, one comparative study, and six in-vivo and/or in-vitro studies. These studies were gathered in three different group, following the objectives of this review.

The first objective of this study was to compare the rates of space closure attained with Elastomeric Chain and Nickel Titanium coil.
These two types of sliding mechanics have been shown to be predictable and controlled method of space closure. (10)
The quantitative synthesis of all included Randomized Clinical Trials revealed a statistically significant difference favoring the Nickel Titanium group in the rate of orthodontic space closure. (11,12)
Measurements of the amount of space closure were taken almost every month in three included trials, and the results translate to a nearly two-month faster closure of the extraction gap/visits with a NiTi coil spring. (11,12)

Ni Ti coil springs have several advantages, including the fact that they are quick and easy to apply, reducing chairside time in each appointment; the magnitude of force can be controlled by the amount of stretching of the spring; and the spring has a longer range and duration of action, requiring fewer adjustments every four to six weeks. Because the NiTi coil spring requires minor adjustments and thus fewer appointments, it may have a clinically significant effect. Nickel Titanium coil unique property of providing a light continuous force over a wide range of action has been well documented. This discovery could be attributed to the Nickel Titanium coil springs low force degradation characteristic and optimal bio sustainability. (11,12)

On another trial, *Nightingale C. et al.* (8) concluded that the rate of space closure of Nickel titanium coil springs and elastomeric chain close space is very similar, even though complete space closure in four quadrants was considered a potential problem because it was not known when space closure occurred, but in any ways, it had occurred within one visit (4 – 6 weeks).

Evans K. et al. (14) study lends credence to the idea that lighter forces can effectively influence tooth movement. Another factor that could be involved in tooth movement and space closure could also be argued. Extraction spaces can close spontaneously over time without the use of mechanical forces, and dentition occlusal contacts may influence space closure. Differences in sex, age, hormones, and other unknown factors may influence tooth movement.

Considering the mean space closure of the Elastomeric chain, *Evans K. et al.* (14) study demonstrated clinically and statistically significant tooth movements for the 16 weeks of observation in both altered and unaltered Elastomeric chain groups. The greatest space closure occurred at 4 weeks after initial placement of the elastomeric chains. For each measurement time point, the altered sites with new elastomeric chains have slightly more mean space closure than the unaltered sites. The altered site with the chain replaced every four weeks did close more than the unaltered chain site, but the difference was minor. (14)
Changing every four to six weeks the elastomeric chains became the conventional and common practice by orthodontists. (12,14)

About the force retentive properties of Elastomeric chain and NiTi coil in the clinical situation, Elastomeric chains initially exert a force which tapers down to 50% of the initial force over the first 24 hours and further reduces over a period of four weeks. (8,10,11,13,14,17)

Although memory elastics can slow the rate at which force decays, they still lose force gradually, just like all other produced elastics. This is determined by the initial force and pre-stretching, as well as the manufacturer's formulas. (12)

The inherent properties of polyurethane materials, which are not perfectly elastic and will show plasticity sooner or later, are one cause of force decay in memory elastics. (8,12,14,17,18) The other reason is that the memory elastics' base materials are not inert and are easily affected by moisture, heat, salivary and microbial enzymes, masticatory forces, and so on. (12,15,17,18)

In the case of Nickel Titanium coil springs, *Cox C. et al.* (13) study finds a statistically significant difference in force loss between the control group springs and the clinical and laboratory springs after 4 weeks of stretching. This implies that the force decay experienced by the springs over a 4-week period is due to their inherent properties rather than a measurement discrepancy between the machines. The initial activation length of nickel-titanium coil springs has been shown to have a significant influence on their force properties.
Over the 4 – 8-week timescale, we observed considerable decreases in force of around 7% (clinical group) and 5% (laboratory group), with force levels appearing to be maintained thereafter. These findings are consistent with those of *Nightingale C. et al.* (8), who demonstrated in a randomized clinical experiment that nickel-titanium coil springs exhibited rapid force loss over a 6-week period, after which the force values bottomed out.

For *Cox C. et al.* (13), the most significant difference between the in-vivo and in-vitro environments that appears to concern researchers when it comes to nickel-titanium springs is the transient temperature changes experienced intraorally, because nickel-titanium force properties have been shown to be highly dependent on temperature. The force properties of the springs, on the other hand, appear to be affected only while the spring is at intraoral temperature, rather than succumbing to some type of permanent deformation as a result of transitory temperature fluctuations. As a result, temperature fluctuations only have a transient effect on the spring force values.

The results of *Alavi S. et al.* (15) study demonstrate that the forces produced by coils held at room temperature did not differ significantly from the forces produced by coils kept in the incubator, implying that prolonged moisture and heat had no effect on the forces produced by Ni-Ti closed coils. It appears that phase change does not occur in Ni-Ti alloys in the oral cavity under normal conditions. In terms of the change in forces produced by Ni-Ti closed coils, it is found that incubated coil forces (either preactivated or non-preactivated) decrease over time, whereas coils kept at room temperature (preactivated or non-preactivated) increase over time. The effects of preactivation on the forces generated by Ni-Ti closed coils are not statistically significant in both dry and incubated settings.

Nightingale C. et al. (8) discovered the elastomeric chain's clinical performance to be better than expected. The rate of space closure achieved was similar to that of nickel titanium coil springs, as already said, and the degree of force retention was extremely satisfactory for a long length of time. High beginning forces, however, did not result in greater space closure, but did result in greater percentage force degradation. With these results, Elastomeric chains maintains adequate amounts of force over long periods of time, refuting the notion that they quickly lost all of their force. The nickel titanium coil springs also worked admirably during a 22-week period. This is promising since it suggests that using the same nickel titanium coil springs over multiple visits is a good clinical practice.

Also, in this systematic review, we considered the stability of the material chosen within time while summited to different environment.

Mirhashemi A. et al. (16) study found that elastomeric chains lost a significant amount of force over time, while coil springs lost less force. It also demonstrates that mouthwashes aggravate elastomeric chain force loss. Mouthwashes had a less noticeable effect on coil springs.

Orthokin and Listerine were linked to the highest force reduction in elastomers, whereas Persica was linked to the largest force reduction in coil springs. In the first week of use, the greatest force decrease in elastomeric chains is also found, while in NiTi coil springs the difference with the initial force is noticeable after four weeks.

Both the Elastomeric Chain and the Ni-Ti groups display a pattern of force degradation in all media in Oshagh M. et al. study (17). The E. C. group experienced the maximum force decay within the first 24 hours, while the Ni-Ti closed coil spring group experienced the least. The Ni-Ti closed coil spring group had the lowest percentage of force decay. During the first 24 hours, the E. C. group lost around half of its initial force, as predicted.
The temperature of the immersion media has a significant impact on the force decay pattern. Tea's compounds, on the other hand, had an impact on the pattern of force decay. Tea accelerates force degradation in the E. C. group but slows it down in the Ni-Ti group.

Orthodontic tooth movement has been linked to pain and root resorption. In studies comparing NiTi closed coil springs and elastomeric chains for canine retraction, these outcomes were not investigated. (10)
Despite the fact that the elastomeric chains produced intermittent forces, there was no difference in root resorption between the two groups. This could be explained by *Nightingale C. et al.* (8) findings, which showed that the difference in force biodegradation between the two groups was not as significant as expected.

In *Barsoum H. et al.* (10) study, the two groups experienced comparable levels of pain. Nonetheless, patients reported significantly fewer days of pain in the quadrants that used NiTi coil springs for retraction. Because the retraction force systems were similar for both methods, this could be due to the coil spring requiring fewer activation adjustments.

However, due to the subjective and variable nature of pain, additional research is required for conclusive results.
Furthermore, no trials investigating adverse periodontal effects and/or patient-centered outcomes were identified in Khanemasjedi M. et al. (12) review. Such critical outcomes are frequently overlooked within the scope of research, despite the fact that they could easily influence the clinical decision to choose one method over another.

Moreover, it is not known exactly how much force is required to move teeth. Indeed, clinicians apply a wide range of forces for space closure and there is no evidence of an optimal force level in the orthodontic literature.
Clinicians must be aware of product variability because they are using a system that they believe provides more biologically favorable forces than some less expensive space-closure materials, such as elastomeric chain, which has been shown to close space at a comparable rate to nickel-titanium coil springs. It also emphasizes the importance of clinicians using an intraoral force gauge when activating these springs to ensure that the desired force levels are delivered.
Also, the method of measuring the space in almost all the studies included in this review was similar to that of all previous reports, but future studies might consider more accurate methods such as 3D intraoral scanning. (8,12,13)

VI. Conclusion

• Based on the current level of evidence, Nickel Titanium closed coil springs are recommended as the first option in terms of the speed of space closure. Clinicians should bear in mind that elastic memory chain offers a cheaper alternative and renewing it every month can provide space closure with speeds comparable to speeds obtained by using a NiTi coil spring.

• Elastomeric Chain loses almost half of its force within the first 24h. On the other hand, aging process does not affect the forces produced by Ni-Ti closed coil spring.

• Preactivation has no statistically significant effect on the forces generated by Ni-Ti closed coils.

• Heavy forces result in high force decay. Hence, it is not appropriate to apply heavy forces in an attempt to counter the effects of force decay.

• E. C. is the material most affected by the environment. Its properties change under higher temperatures, chemicals present in common beverage, like tea, Coca-Cola©, as well as with the use of different oral mouthwashes that can be found in grocery stores, or even in pharmacy.

• Ni-Ti is the method of space closure the least affected by different immersion medias.

• Conflict of Interest

There were no competing interests during all this study.

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VIII. Annexes

• PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1st p.
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p. 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p. 12
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 12
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p. 13
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p. 14
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	p. 14
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p. 15
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p. 15
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	p. 15
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	p. 15
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	p. 15
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p. 15
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	p. 15
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	p. 15
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	p. 16
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	p. 16
Study characteristics	17	Cite each included study and present its characteristics.	p. 17 - 21
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	p. 21 - 22
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	p. 25 - 28
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	p. 23 - 25
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	p. 23 - 25
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	p. 23 - 25
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p. 29 - 32
	23b	Discuss any limitations of the evidence included in the review.	p. 32
	23c	Discuss any limitations of the review processes used.	p. 32
	23d	Discuss implications of the results for practice, policy, and future research.	p. 32
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	p. 35
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

• Article

ABSTRACT:

Introduction: In sliding mechanics, the space closure is carried out by either Elastomeric chain (E.C), Nickel-Titanium coils (NiTi coils), or stretched modules with ligatures. E.C is more economical and should produce an optimum level of force without damage to the supportive periodontium when used cautiously for space closure. E.C products lose force over time. Ni-Ti springs lose some of their force over time. The objective of this systematic review is to furnish information for when it is time to choose between an E.C or a Ni-Ti coils during an interdental space closing treatment. **Material & Method**: A search of articles was carried out in Medline Complete, Cochrane Library and Scopus databases, using the following keywords: “Space”; “Closure”; “Elastic”; “Elastomeric”; “Chains”; “Nickel”; “Titanium”; combined with the Boolean operator “AND” and “OR”. A total of 10 relevant articles that fulfilled the inclusion criteria were selected. **Results**: Regarding the space closure, Ni-Ti closes faster spaces than E.C, but by changing every 4 weeks these E.C, the difference of rates of space closure between both materials became minim. Regarding the force retentive properties, E. C. loses within 24h half of its force. Ni-Ti coil springs lose force during the first 6 weeks of use. Regarding the factors that can influence the lifetime of the material chosen, the effects of commonly used beverage, soft drink, and mouthwashes on the force delivered by E. C occurred until 7 days, and tea caused highest force decay, followed by mouthwashes and Coca-Cola©. These factors didn’t have that significant importance on the Ni-Ti closed coil springs. **Conclusion**: • Nickel Titanium closed coil springs are the first option in terms of the speed of space closure. • Elastomeric Chain loses almost half of its force within the first 24h. • Heavy forces result in high force decay. • E. C. is the material most affected by the environment, and Ni-Ti, the least.

Keywords: *Orthodontics, Elastomeric chains, Nickel-Titanium, Space closure, Systematic review.*

INTRODUCTION:

Orthodontics is the branch of dentistry that studies, prevents, and corrects alterations in the development of the maxillary bones and teeth. Its goal is to achieve functional balance between every part and organ that organize the oral cavity. The term "Orthodontics" comes from Greek: « Ορθό » / "Ortho" meaning Straight/Correct and « 'Οδοντο » / "Odonto" meaning Tooth. Even though the orthodontic field is dedicated as much for children as for adults, this specialty can also be found under the name "Dentofacial Orthopedics", with « Παιδί » / "Pedics" in Greek meaning Child.

Since always, a proper alignment of teeth has long been recognized to be a crucial factor for aesthetics, function, and overall preservation of dental health. The teeth along with their surroundings structures are required to perform certain significant functions such as Mastication and Phonation. Poorly aligned teeth may predispose to several unfavourable sequelae such as caries, periodontal diseases, anterior teeth trauma, dental impactions, problems regarding the masticatory function, speech, as well as facial muscle tension, TMJ's problems, ear, and neck pain.

One common procedure in daily orthodontic practice is the Interdental space closure. The ideal space closure mechanism should have mechanical features that provide a light and continuous force that closes the orthodontic space in the shortest amount of time. Although there is no definitive evidence for the optimal force required during space closure, a force delivery system that generates 150-200 grams of orthodontic force is usually prescribed. (1) Elastomers have been used more frequently, as they are more practical and more economic. Also, the use of clear elastomeric chains to move the teeth along the archwires has improved the esthetic aspect of clear orthodontic fixed appliances. Because of the various factors influencing the complex material properties of the elastomeric chains, it is often difficult for orthodontists to estimate the force levels applied at the beginning and during the application period.

On the other hand, NiTi coils with shape memory may generate lower and continuous forces and be less affected by the humidity and pH of the environment.

This work is done to furnish further information to the orthodontist when it is time to choose between either an Elastomeric chain (E.C) or a Nickel Titanium (Ni-Ti) coils for an interdental space closing treatment.

This systematic review has three different objectives:

1- Compare the rates of space closure attained with Elastomeric chain and NiTi coil in orthodontics.

2- Investigate the force retentive properties of Elastomeric chain and NiTi coil in the clinical situation.

3- Evaluate which factors can influence the lifetime of the material chosen.

MATERIAL AND METHODS:

The planning and preparation of this study has followed the guidelines established by the PRISMA declaration.

Eligibility Criteria: This systemic review is made to give an answer to the following question: How does the Elastomeric chains and NiTi coils can impact the dental space closing in orthodontic patients throughout time?

The resources we used to carry out this work had to fulfill the following criteria:

• Population: Orthodontic patients / • Intervention: Dental space closing / • Comparison: E.C & Ni-Ti coils / • Outcome: Effects throughout time

Also, we used as Inclusion Criteria: Randomized controlled clinical trials; Clinical investigations; Cohort studies; In-vivo studies; In-vitro studies; Human studies. As exclusion criteria's, we fixed: Studies not about Dental retraction; non-English articles; Studies not dealing with Space closing.

Search Strategy: A search of articles was carried out in Medline Complete, Cochrane Library and Scopus databases between the 27th of November 2021 and 27th of December 2021; using the following keywords: “Space”; “Closure”; “Elastic”; “Elastomeric”; “Chains”; “Nickel”; “Titanium”; combined with the Boolean operator “AND” and “OR”.

Risk of bias: In order to evaluate the information’s quality given by the articles selected, we used the CASPE guide; evaluating which were the different studies results; if they were valid; and if these results could help our review.

RESULTS:

Studies Selection: The search process started on the 27th of November until the 27th of December 2021 and it involved a total of 129 potentially relevant articles. We used Medline Complete, Cochrane, and Scopus databases. The steps followed for the studies selection are summarized in **Figure I**.

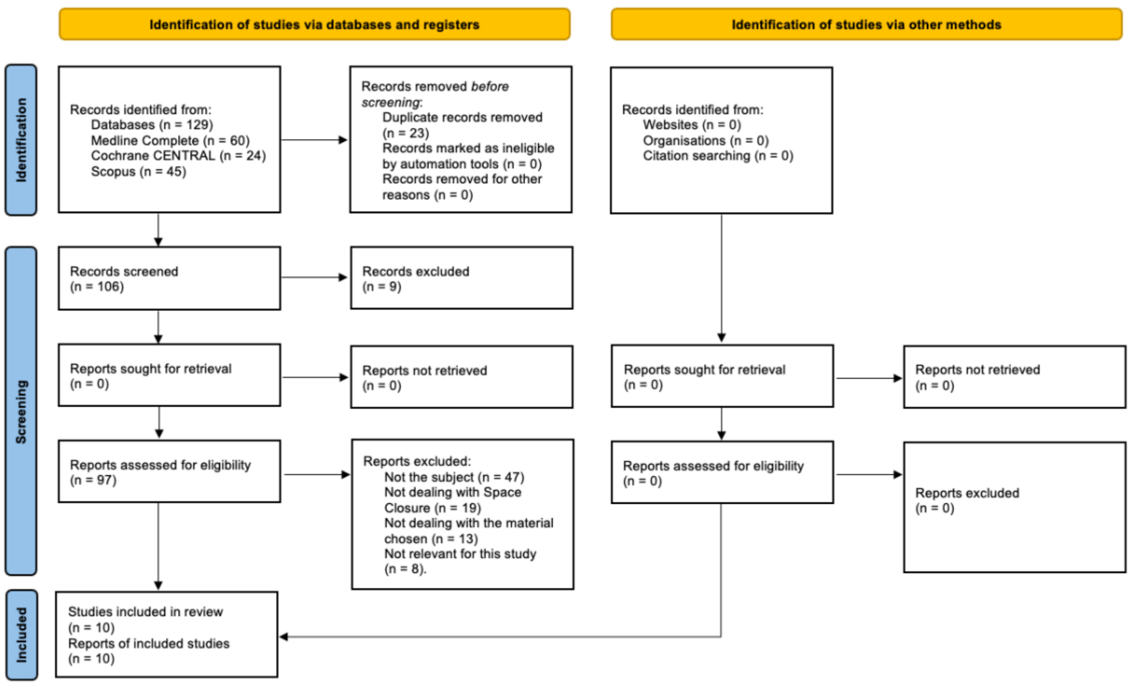

Fig. I. PRISMA Flow Diagram

Characteristics Analysis of the included studies: From the included studies, we gathered in the **Table I** all the general characteristics, including the Author details, the Year of publication, the Study design, the Sample size, the Age of the participants, and the Follow-Up period.

Author Details	Year	Study Design	Sample size	Age	Follow-up period
Barsoum H. et al.[2]	2021	RCT	**64** quadrants	≥ 13 years	6 months
Khanemasjedi M. et al.[3]	2017	RCT	**42 quadrants** of 21 fixed orthodontic patients.	≥ 13 years	3 months
Evans KS. et al.[4]	2016	In-Vivo + In-Vitro study	*In-Vitro:* **100 2-unit** and **3-unit E.C** segments *In-Vivo*: **30 paired extraction space** sites (**22 subjects**)	< 16 years	16 weeks
Nightingale C., Jones SP.[5]	2003	RCT	**15 patients** both **Ni-Ti coil springs and E.C** and **7 patients** only **E.C**	12 - 18 years	2 years
Cox C. et al.[6]	2014	In-Vivo study	**30 Ni-Ti** closed coils springs worn by 11 patients and **15** laboratory **control springs**	13 - 43 years	12 weeks
Alavi S., Haerian A.[7]	2015	In-Vitro study	**60 Ni-Ti** closed coils divided in **4 groups**. - 2 groups kept in room temperature - 2 incubated in 37°C in normal saline	-	45 days
Mirhashemi A. et al.[8]	2021	In-Vitro study	**60** pieces of **EC** and **60 Ni-Ti** closed coil spring divided into **6 groups**.		28 days
Oshagh M. et al.[9]	2015	In-Vitro study	**4** clear medium closed **EC**, **9 mm** of **superelastic NiTi** coils spring		3 weeks
Kumar K. et al.[10]	2014	In-Vitro study	4 specimen groups with a total sample size of **480 specimens**.		28 days
Khalid Z. et al.[11]	2018	Comparative study	**32 patients**	18 - 45 years	8 months

Table I. General Characteristics of the included studies

Assessment of Methodological Quality and Risk of Bias: As explained anteriorly, the quality evaluation of the articles' information has been done using the CASPE scale for each study included, taking into account the study design of all the studies individually.

Synthesis of Results: Regarding the rates of space closure attained with Elastomeric chain and Ni-Ti coil in orthodontics, Barsoum H. et al. (2) observed that, in terms of monthly canine retraction rate, there was no statistical difference between the groups.

Khanemasjedi M. et al. study (3) studied and compared the mean rate movement during space closure over 3 months and compared the results month by month.

Their results shown that as overall, the average speed of space closure during the 3 months was significantly different between two groups. The authors concluded that using Elastomeric chain and renewing it every 4 weeks is as effective than Ni-Ti springs for 3 months. The different results obtained from these articles are gathered in the **Table II**.

Regarding the force retentive properties of Elastomeric Chains, Evans K. et al. (4), found that the mean space closure at both the altered and unaltered elastomeric chain extraction sites demonstrated continuing clinically and statistically significant tooth movements for the 16 weeks of observation. As shown in **Table III**, the elastomeric chain force degraded rapidly by 4 weeks but continued a gradual diminution at 16 weeks.
Nightingale C. et al. (5) observed that the range of initial forces applied was 70 – 450g, with a mean force of 209g, whilst the range of final forces was 50 – 230g, with a mean force of 109g. 59% of the sample maintained at least 50% of their initial force over a time period of 1 – 15 weeks. The higher the initial force, the greater the force loss experienced.

Regarding the force retentive properties of Ni-Ti coil springs, after 4 weeks of clinical use, Cox C. et al. (6) found that the springs studied showed a statistically significant decrease in force (approximately 12%), with a further significant decrease (approximately 7%) from 4 to 8 weeks, and force levels appearing to remain steady subsequently. Regarding preactivation, Alavi S. et al. (7) got as results that the mean forces of preactivated coils (dry and incubated) had no significant difference with the mean forces produced by non-preactivated coils (dry and incubated).
Nightingale C. et al. (5) observed that the range of initial forces applied was 150 – 460g, with a mean force of 300g, and the range of final forces was 95 – 255g, with a mean force of 149g. Ni-Ti coil springs lost force rapidly during the first 6 weeks of use, then reached a plateau for the rest of time. 46% maintained at least 50% of their initial force over a period of 1 – 22 weeks. Again, the greater the initial force, the greater the force decay.

Barsoum H. et al. (2)

	Minimum movement (mm)	Maximum movement (mm)	Mean movement (mm)
Ni-Ti Group	-	-	0,79
E. C. Group	-	-	0,86

Khalid Z. et al. (11)

	Minimum movement (mm)	Maximum movement (mm)	Mean movement (mm)
Ni-Ti Group	0,66	2 ,01	1,1369
E. C. Group	0,33	1,50	0,7719

Khanemasjedi M. et al. (3)

	1st Month	2nd Month	3rd Month	Total (3m)
Ni-Ti Group	1,93mm	1,71mm	1,36mm	1,67mm
E. C. Group	2,20mm	1,96mm	1,52mm	1,89mm

Table II. Results for rates of space closure attained with E. C and Ni-Ti

Evans K. et al. (4)

Time	State of E. C.	Min. movement (mm)	Max. movement (mm)	Mean mvmt (mm)
Week 4	Unaltered	0,5	4,3	1,57
	Altered	0,3	3,7	1,62
Week 8	Unaltered	0,0	2,1	0,91
	Altered	0,3	2,2	1,05
Week 12	Unaltered	0,0	2,6	0,98
	Altered	0,1	3,1	1,03
Week 16	Unaltered	0,1	2,1	0,85
	Altered	0,2	2,2	0,97

Table III. Force remaining in Elastomeric Chains for space closure, for 16 weeks.

Regarding the factors that can influence the lifetime of the material chosen, Mirhashemi A. et al. (8) observed that, in Ni-Ti coil springs, the force decay was more gradual and lesser than E.C. after 4 weeks of study. E.C had the greatest force reduction in one week, followed by a more regular force reduction in the following weeks.

Also, on the first day, there was a statistically significant difference between some groups of mouthwashes in the E.C samples. At the end of the study period, Listerine was the group exerting the least amount of force of any group, and Persica was the one exerting the most amount of force after the Control group. Oshagh M. et al. (9) also found that tea and almost all the mouthwashes had detrimental effects on the E.C. We can observe these results in **Fig. II**. Kumar K. et al. (10) focused on the effects of commonly used beverage, and mouthwashes on the force delivery by E.C, and found that for all groups, force decay occurred until 7 days, and that tea caused highest force decay, followed by mouthwashes and Coca-Cola©.

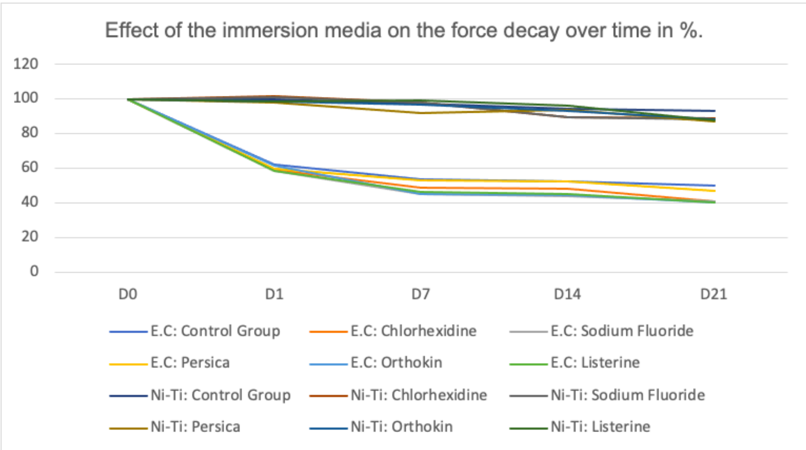

Fig. II. Comparison of the effect of the immersion media on the E.C. and Ni-Ti coil

DISCUSSION:

The effectiveness of orthodontic space closure using two common force delivery systems, Nickel Titanium coil springs and Elastomeric Chain, was investigated in this systematic review. To realize this study, three randomized clinical trials were included, one comparative study, and six in-vivo and/or in-vitro studies. These studies were gathered in three different group, following the objectives of this review.

The first objective of this study was to compare the rates of space closure attained with Elastomeric Chain and Nickel Titanium coil.

These two types of sliding mechanics have been shown to be predictable and controlled method of space closure. (2) The quantitative synthesis of all included Randomized Clinical Trials revealed a statistically significant difference favoring the Nickel Titanium group in the rate of orthodontic space closure. (3,11) Ni Ti coil springs have several advantages, including the fact that they are quick and easy to apply, reducing chairside time in each appointment; the magnitude of force can be controlled by the amount of stretching of the spring; and the spring has a longer range and duration of action, requiring fewer adjustments every four to six weeks. Because the NiTi coil spring requires minor adjustments and thus fewer appointments, it may have a clinically significant effect. Nickel Titanium coil unique property of providing a light continuous force over a wide range of action has been well documented. (3,11)

On another trial, *Nightingale C. et al.* (5) concluded that the rate of space closure of Nickel titanium coil springs and elastomeric chain close space is very similar, even though complete space closure in four quadrants was considered a potential problem because it was not known when space closure occurred, but in any ways, it had occurred within one visit (4 – 6 weeks).

Evans K. et al. (4) study lends credence to the idea that lighter forces can effectively influence tooth movement. Another factor that could be involved in tooth movement and space closure could also be argued. Extraction spaces can close spontaneously over time without the use of mechanical forces, and dentition occlusal contacts may influence space closure. Differences in sex, age, hormones, and other unknown factors may influence tooth movement.

About the force retentive properties of E.C and NiTi coil in the clinical situation, Elastomeric chains initially exert a force which tapers down to 50% of the initial force over the first 24 hours and further reduces over a period of four weeks. (2,4,6,9,11)

The inherent properties of polyurethane materials, which are not perfectly elastic and will show plasticity sooner or later, are one cause of force decay in memory elastics. (3,5,9,10) The other reason is that the memory elastics' base materials are not inert and are easily affected by moisture, heat, salivary and microbial enzymes, masticatory forces, and so on. (3,7,9,10)
In the case of Nickel Titanium coil springs, *Cox C. et al.* (6) study finds a statistically significant difference in force loss between the control group springs and the clinical and laboratory springs after 4 weeks of stretching. This implies that the force decay experienced by the springs over a 4-week period is due to their inherent properties rather than a measurement discrepancy between the machines.

Nightingale C. et al. (5) discovered the elastomeric chain's clinical performance to be better than expected. The rate of space closure achieved was similar to that of nickel titanium coil springs, and the degree of force retention was extremely satisfactory for a long length of time. High beginning forces, however, did not result in greater space closure, but did result in greater percentage force degradation. With these results, Elastomeric chains maintains adequate amounts of force over long periods of time, refuting the notion that they quickly lost all of their force. The nickel titanium coil springs also worked admirably during a 22-week period. This is promising since it suggests that using the same nickel titanium coil springs over multiple visits is a good clinical practice.

Also, in this systemic review, we considered the stability of the material chosen within time while summited to different environment.
Mirhashemi A. et al. (8) study found that elastomeric chains lost a significant amount of force over time, while coil springs lost less force. It also demonstrates that mouthwashes aggravate elastomeric chain force loss. Mouthwashes had a less noticeable effect on coil springs.
Orthodontic tooth movement has been linked to pain and root resorption. In studies comparing NiTi closed coil springs and elastomeric chains for canine retraction, these outcomes were not investigated. (2)

Despite the fact that the elastomeric chains produced intermittent forces, there was no difference in root resorption between the two groups. This could be explained by *Nightingale C. et al.* (5) findings, which showed that the difference in force biodegradation between the two groups was not as significant as expected.

Furthermore, no trials investigating adverse periodontal effects and/or patient-centered outcomes were identified in Khanemasjedi M. et al. (3) review. Such critical outcomes are frequently overlooked within the scope of research, despite the fact that they could easily influence the clinical decision to choose one method over another. Moreover, it is not known exactly how much force is required to move teeth. Indeed, clinicians apply a wide range of forces for space closure and there is no evidence of an optimal force level in the orthodontic literature. Clinicians must be aware of product variability because they are using a system that they believe provides more biologically favorable forces than some less expensive space-closure materials, such as elastomeric chain, which has been shown to close space at a comparable rate to nickel-titanium coil springs. It also emphasizes the importance of clinicians using an intraoral force gauge when activating these springs to ensure that the desired force levels are delivered.

CONCLUSION:

- Ni-Ti closed coil springs are recommended as the first option in terms of the speed of space closure.
- Preactivation has no statistically significant effect on the forces generated by Ni-Ti closed coils.
- Heavy forces result in high force decay.
- E. C. loses almost half of its force within the first 24h and it is the material most affected by the environment. Its properties change under higher temperatures, chemicals present in common beverage, like tea, Coca-Cola©, as well as with the use of different oral mouthwashes.

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