Research, Society and Development, v. 11, n. 14, e61111436028, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i14.36028

Evaluation of the influence of patients' diet on the system of forces applied by nickel-titanium closed springs: an in vitro study

Avaliação da influência da dieta dos pacientes no sistema de forças aplicadas por molas fechadas de níquel-titânio: um estudo in vitro

Evaluación de la influencia de la dieta de los pacientes en el sistema de fuerzas aplicado por muelles cerrados de níquel-titanio: un estudio in vitro

Received: 10/01/2022 | Revised: 10/12/2022 | Accepted: 10/14/2022 | Published: 10/19/2022

Fabiane Louly
ORCID: https://orcid.org/0000-0003-0837-9521
Universidade Uniderp, Brazil
E-mail: fablouly@hotmail.com
Gabriela Soares Loureiro
ORCID: https://orcid.org/0000-0002-4906-596X
Centro Universitário Unisagrado, Brazil
E-mail: gaabiloureiro@outlook.com
Joel Ferreira Santiago Junior
ORCID: https://orcid.org/0000-0003-1735-2224
Centro Universitário Unisagrado, Brazil
E-mail: fj.santiagojunior@gmail
Renata Rodrigues de Almeida Pedrin
ORCID: https://orcid.org/0000-0002-4283-1051
Universidade Uniderp, Brazil
E-mail: repedrin@gmail.com
Thais Maria Freire Fernandes
ORCID: https://orcid.org/0000-0002-4368-8568
Universidade Uniderp, Brazil
E-mail: thais.poleti@platosedu.com.br
Paula Vanessa Pedron Oltramari
ORCID: https://orcid.org/0000-0002-2285-5179
Universidade Uniderp, Brazil
E-mail: pvoltramari@hotmail.com
Ana Claudia de Castro Ferreira Conti
ORCID: https://orcid.org/0000-0001-9658-1652
Universidade Uniderp, Brazil
E-mail: accfconi@uol.com.br

Abstract
The objective of this work was to evaluate the influence of the patients' diet on the strength degradation of Nickel-titanium closed springs. Forty 9mm nickel titanium springs from the Morelli brand were used, divided into 2 groups of 20 according to the immersed solution. These springs were stretched to 100% of their original length and kept in devices immersed in recipients with the evaluated solutions (artificial saliva and distilled water with coke). The resulting forces were measured with a precision orthodontic dynamometer (grams) performed shortly after initial distension (T0) and after 28 days of distension (T1), then at the end of 20 and 30 months, T2 and T3 respectively. To compare times and groups, analysis of variance for repeated measures and Tukey's test were used. A significance value of 5% was adopted for the analyses. In the intragroup results, the springs showed a significant decrease in force between the evaluated periods. When comparing the values of forces between the groups (artificial saliva vs coke) in each period, it was observed that there was no significant difference, indicating that the type of solution did not influence the degradation of the forces of the springs. It was concluded that, regardless of the ingestion of liquids such as coke, NITI springs show significant strength degradation during the first 3 months. It is necessary to measure the forces of the springs during orthodontic treatment, aiming to establish an adequate force for movement and optimization of treatment time.
Keywords: Orthodontics; Orthodontics corrective; Orthodontic appliance.

Resumo
O objetivo deste trabalho foi avaliar a influência da dieta dos pacientes na degradação de força de molas fechadas de Níquel-titânio. Foram utilizadas 40 molas de níquel titânio de 9mm da marca Morelli divididas em 2 grupos de 20 de

acordo com a solução imersa. Essas molas foram distendidas em 100% do seu comprimento original e mantidas em dispositivos imersos em recipientes com as soluções avaliadas (artificial saliva artificial e água destilada com coke). As forças resultantes foram medidas com dinamômetro ortodôntico de precisão (gramas) realizadas logo após a distensão inicial (T0) e após 28 dias de distensão (T1), depois ao final do 2^0 e 3^0 meses, T2 e T3 respectivamente. Para a comparação entre os tempos e grupos foi utilizado a análise de variância para medidas repetidas e o teste de Tukey. Adotou-se um valor de significância de 5% para as análises. Nos resultados intragrupos, as molas apresentaram diminuição da força significantemente entre os períodos avaliados. Quando se comparou os valores das forças entre os grupos (artificial saliva vs coke) em cada período, observou-se que não houve diferença significante, indicando que o tipo de solução não influenciou a degradação das forças das molas. Concluiu-se que, independentemente da ingestão de líquidos como a coke, as molas de NITI apresentam uma degradação de força significante durante os 3 primeiros meses. É necessário fazer a mensuração das forças das molas durante o tratamento ortodôntico, visando estabelecer uma força adequada para a movimentação e otimização do tempo de tratamento
Palavras-chave: Ortodontia; Ortodontia corretiva; Aparelhos ortodônticos.

Resumen
El objetivo de este trabajo fue evaluar la influencia de la dieta de los pacientes en la degradación de la resistencia de resortes cerrados de níquel-titanio. Se utilizaron 40 resortes de níquel titanio de 9 mm de la marca Morelli, divididos en 2 grupos de 20 según la solución sumergida. Estos manantiales se estiraron al 100% de su longitud original y se mantuvieron en dispositivos sumergidos en recipientes con las soluciones evaluadas (artificial saliva artificial y agua destilada con coke). Las fuerzas resultantes se midieron con un dinamómetro de ortodoncia de precisión (gramos) realizado poco después de la distensión inicial (T0) y después de 28 días de distensión (T1), luego al final de 20 y 30 meses, T2 y T3 respectivamente. Para la comparación de tiempos y grupos se utilizó el análisis de varianza para medidas repetidas y la prueba de Tukey. Se adoptó un valor de significación del 5% para los análisis. En los resultados intragrupo, los resortes presentaron una disminución significativa de fuerza entre los periodos evaluados. Al comparar los valores de fuerzas entre los grupos (artificial saliva vs coke) en cada periodo, se observó que no hubo diferencia significativa, indicando que el tipo de solución no influyó en la degradación de las fuerzas de los resortes. Se concluyó que, independientemente de la ingestión de líquidos como coke, los resortes de NITI presentan una importante degradación de su resistencia durante los primeros 3 meses. Es necesario medir las fuerzas de los resortes durante el tratamiento de ortodoncia, con el objetivo de establecer una fuerza adecuada para el movimiento y la optimización del tiempo de tratamiento.
Palabras clave: Ortodoncia; Ortodoncia correctiva; Aparatos ortodóncicos.

1. Introduction

One of the most common types of orthodontic movement is space closure. The main objective of these mechanics is to eliminate the spaces remaining from extractions or tooth loss.

Orthodontic movements of anterior retraction to close the extraction or distalization space, as well as movements of mesialization of molars into the edentulous space, require that biologically compatible forces be applied and that these forces are maintained during the period between consultations(Nightingale & Jones, 2003; Proffit et al., 1998; Santos et al., 2007; Schwars, 1932).

For this purpose, various devices can be used such as elastomeric chains (chain or chain module), association of metallic ties with individual elastics and also closed section springs. These springs, manufactured in material with great power of distension and deflection, nickel and titanium alloy, aim to solve the problem of permanent deformation of elastomeric materials in the oral environment(Dixon et al., 2014; Miura et al., 1988; Shaw & Kyriakides, 1995).

The greatest advantages of NITI springs can be attributed to the lower percentage of force degradation compared to chain elastics, and more mechanical efficiency(Badran et al., 2022; Barsoum et al., 2021), however, as these devices are kept for a long time in the oral cavity, unlike elastics that are changed at each appointment, there is also a percentage of strength degradation, which may be influenced by the patients' diet. Alcoholic beverages or beverages that alter the pH of artificial saliva could also contribute to corrosion and loss of strength over time(Cox et al., 2014; Magno et al., 2015; Nattrass et al., 1998).

It is important to note that despite receiving adequate strength guidelines from the manufacturer, these parameters may not be reliable. Therefore, it is necessary to measure the force generated when the helical spring is extended, to verify the force delivered, as well as to be done in each session. This is to ensure that the degrading force of the spring does not impair tooth movement and can activate when necessary (Conti et al., 2020; Prado et al., 2020).

In any case, during the application of a force, the greatest tooth movement should always be sought, with the least damage to the supporting tissues and the greatest comfort for the patient. However, in order not to exceed the orthodontic forces, specific tensiometers are usually used to measure the applied forces(Nightingale & Jones, 2003; Parvizi & Rock, 2003; Proffit et al., 2006; Schwars, 1932; Van Leeuwen et al., 2010)

Due to the lack of consensus on the forces released by NITI springs over time, especially considering the individualities of each patient in relation to diet and chewing force, the objective of this work was to evaluate the values of the forces resulting from the distension of closed springs of Nickel-titanium Morelli immersed in artificial artificial saliva and distilled water solution with coke for an evaluation period of 3 months

2. Methodology

The methodology of this research is quantitative, being a laboratory research (Estrela, 2018; Severino, 2017).

2.1 Sample size

Forty 9mm nickel titanium springs from the Morelli (Dental Morelli Ltda., Sorocaba, Brazil) were divided into 2 groups of 20 according to the solution in which they were immersed

2.2 Sample preparation and handling

This in vitro study comprised 40 9mm nickel titanium springs from the Morelli (Dental Morelli Ltda., Sorocaba, Brazil) divided into 2 groups of 20 according to the solution in which they were immersed (Figure 1). These 9mm long springs were stretched to 100% of their original length and kept in devices (Figure 2) immersed in recipients with artificial saliva and a 750ml solution of distilled water with coke (Coke Company, Bauru-SP, Brazil/ Figures 3 and 4). The resulting forces were measured with an orthodontic dynamometer (Figure 5) with precision in grams (Zeusan, Campinas/SP – Brazil).

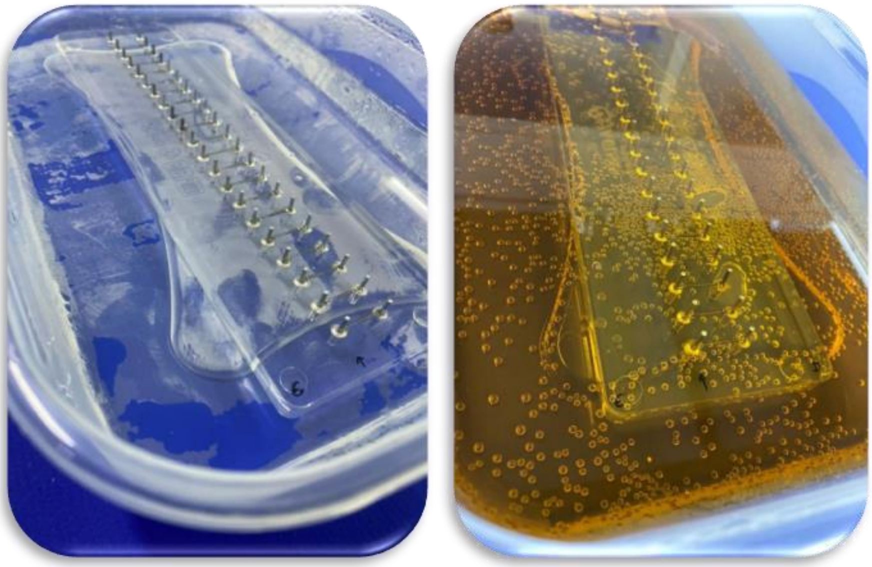
Figure 1: Morelli 9 mm nickel titanium springs.

Source: Authors.

Figure 2: Device for spring distension, containing 20 springs.

Source: Authors.

Figures 3 e 4: Devices with 40 springs submerged in containers with artificial artificial saliva and distilled water with coke.



Source: Authors.

Figure 5: Precision dynamometer, Zeusan (São Paulo, SP).

Source: Authors.

The following assessment times were studied: right after initial distention (T0) and after 28 days of distension (T1), then at the end of 20 (T2), 30 (T3) months. The data were transferred to a spreadsheet and the mean strength values of each group were used for the analyses. The artificial artificial saliva ingredients were as follows: 1.3 g/L of potassium chloride, 0.1 g/L of sodium chloride, 0.05 g/L of magnesium chloride, 0.1 g/L of chloride of calcium, 2.5 105 g / L of sodium fluoride, 0.035 g / L of potassium dihydrogen phosphite (KH_2PO_4) and 0.162 g / L of $ZnSO_4$. The pH value was 7.0 and preserved at 37°C, simulating the oral environment. To maintain this temperature, an oven was used . Data were recorded in a spreadsheet in Excel Software (Microsoft).

2.3 Statistical Analysis

Data from the collection of information were organized in a table in Excel format (Microsoft Office Excel, Redmond, WA, United States) and submitted to SigmaPlot software (SigmaPlot, San Jose, CA, USA) version 12.0. These data were initially analyzed in relation to normal distribution (Shapiro-Wilk test) and, later, an analysis was performed considering the time factors (T0,T1,T2,T3) and medium (coke and artificial saliva) using the analysis of variance test for repeated measures (ANOVA). For post-test analysis, the Tukey test was used. A significance level of 5% was adopted for the analyses

3. Results

After the end of the three-month period of active springs submerged in artificial artificial saliva and in distilled water with coke in an oven simulating the oral environment, the values obtained were compared at each time.

First, it was observed that some springs broke at times T2 and T3, in both solutions. The number of springs that broke did not exceed four in both groups. Despite this, with the rest of the springs distended in the devices, we evaluated and generated an average of values in each period.

Table 1 shows the comparison of spring force averages in each solution over the evaluated periods.

Table 1: Intragroup analysis of the average forces (in grams) of nickel-titanium springs between the evaluated periods.

Solution	T0	SD	T1	SD	T2	SD	T3	SD	P
Artificial saliva	195.31(a)		158.5(b)		143.12(c)		128.75(d)		<0.001*
Coke	193.75(a)		156.43(b)		141.25(c)		126.87(d)		<0.001*

*(p<0,005) statistically significant values / * Different letters statistically significant difference. Source: Authors.

Note, in table 1 that regardless of the solution in which the springs were stored, whether artificial saliva or coke**,** the values of forces decreased significantly between periods evaluated, right after initial distention (T0) and after 28 days of distension (T1), then at the end of 20 (T2), 30 (T3) months.

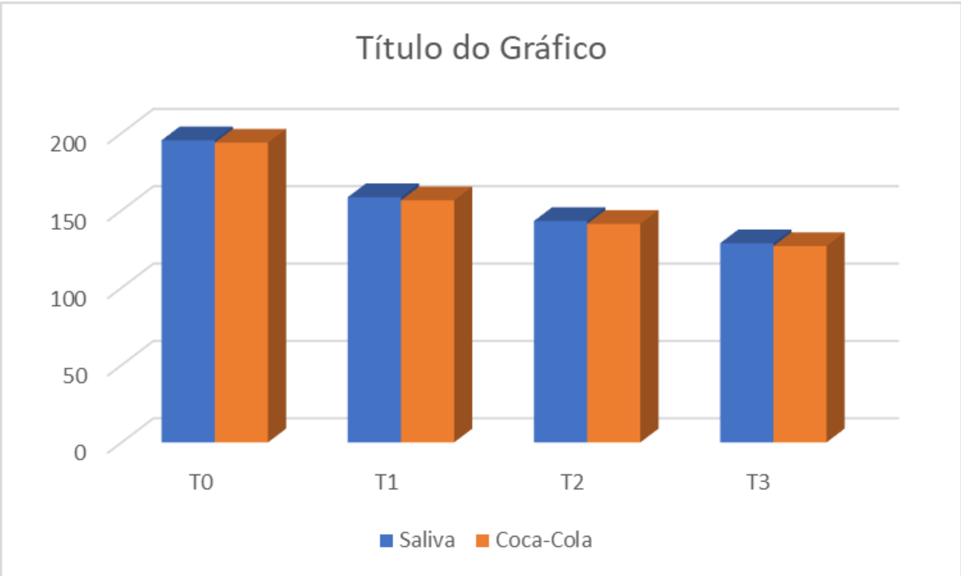
Table 2 shows the intergroup analysis for each period evaluated.

Table 2: Intergroup analysis (artificial saliva vs Coke) of the average forces (in grams) of nickel-titanium springs at each time evaluated.

Tie	Artificial saliva	SD	Coke	SD	P
T0	195.31		193.75		0.73
T1	158.5		156.43		0.66
T2	143.12		141.25		0.68
T3	128.75		126.87		0.68

*(p<0.005) statistically significant values. Source: Authors.

Graph 1: Intergroup comparison (artificial saliva vs Coke) of the means of nickel-titanium spring forces at each time evaluated.



Source: Authors.

In Table 2 and graph 1, it is noticed that the force averages between the solutions were similar for each period, indicating the non-influence of the solution, artificial saliva or coke, in the degradation of the force of the springs.

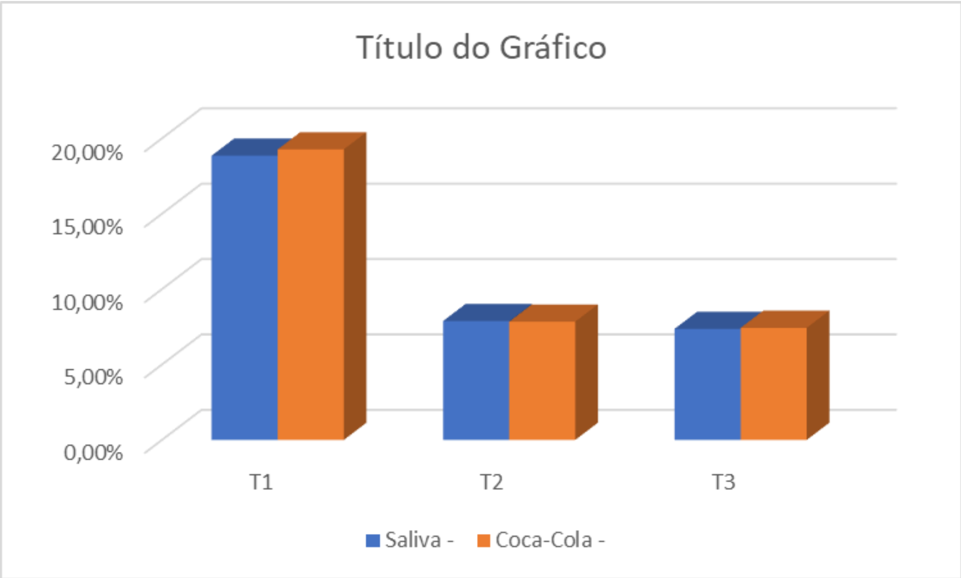
To complete the analysis, we compared the data obtained in percentage to show more significantly the average degradation of forces in each group, artificial saliva or coke, in the evaluated periods of T0 (right after initial distention), T1(after 28 days of distension, T2 (then at the end of 20 months), T3 (endo f 30 months) (Table 3 ans Graph 2).

Table 3: Analysis of force degradation in percentage for each group (artificial saliva and coke) of nickel-titanium springs at each time evaluated.

Time	Artificial saliva	Coke
T0	-	-
T1	18.85	19.27
T2	7.88	7.84

Source: Authors.

Graph 2: Percentage of strength degradation of nickel-titanium springs for each group (artificial saliva and coke) at each time evaluated.



Source: Authors.

Thus, we can see in Table 3 and Graph 2 that the highest percentage of strength degradation occurred between the baseline and the first month (T1), after this period a trend of softer strength degradation was observed.

4. Discussion

This study compared the amount of force dissipated by nickel-titanium springs with time, simulating the oral environment, keeping it in the oven at 37°C, since studies have shown that the oral environment influences a greater degradation(Von Fraunhofer et al., 1992).

Two spring storage solutions were compared to assess the influence of patients' diet on spring strength degradation. Morelli 9mm NITI closed springs were used, submerged in artificial saliva and a solution of distilled water with Coke for a period of three months. At that time the spring forces were measured and computed.

According to the results of table 1, it was noted that there was a significant difference in the dissipation of spring forces during the period evaluated for the 2 solution groups. However, when the 2 groups (artificial saliva vs coke) were compared in each period, it was observed that the means of forces were similar between them in each period, demonstrating the non-influence of the solution on the degree of degradation of the forces of the springs.

Considering the degradation of the forces of the springs over time, in table 3 and graph 2 we can observe the percentage of degradation of the forces when the springs were distended 100% of their length. There was a gradual decrease in the forces released by the springs over the three months of the experiment. However, the greatest degradation occurred after the first month, with the percentage of strength degradation being 18.85% at T1 in the artificial saliva group and 19.27% in the coke group. After this period, the magnitude of strength degradation is smaller and maintains a pattern for both groups, with an average of 7% for both groups at each time.

This information agrees with other studies that reported a reduction of forces between 8 to 20% after 28 days comparing steel, CoCrNi and NiTi springs(Angolkar et al., 1992) as well as with an in vitro and in vivo study in which the springs (GAC Sentalloy) lost approximately 12% of initial forces at 4 weeks, with a further 7% loss between 4 and 8 weeks, when force levels apparently stabilized(Cox et al., 2014). Other authors have also found values of 18 % strength degradation(Schneevoigt et al., 1999).

Even with these values of strength degradation9, the results are still better when compared to the strength degradation of current elastics. Several studies have compared the effectiveness of closed NiTi springs with elastomeric modules. In a systematic review the authors reported that space closure with NiTi closed springs is faster than with elastomeric modules(Mohammed et al., 2018). The space closure rate is 0.21mm/week for chain elastics and 0.26mm/week for NiTi springs(Nightingale & Jones, 2003) other authors stated that the space closure rate with springs NiTi rotates around 1mm per month(Cox et al., 2014).

This difference can be explained by the negative influence that the oral environment causes on the elastomeric modules, thus substances such as water, coke, condiments and the temperature of the mouth affect the strength degradation of the elastics, unlike the springs, which were not affected by the tested substances. All this information validates the use of closed NiTi springs in place of elastic ligatures, as these are superior in orthodontic movement, despite a small degree of force degradation(Nattrass et al., 1998).

It is important to emphasize the limitation of this study because it is an in vitro assay. Probably the effect of the oral environment is more harmful to the spring than the laboratory environment. In addition, this study only evaluated the 9mm springs of the Morelli brand, in future studies it would be interesting to increase the variety of sizes and brands available in the current market.

5. Conclusion

All springs showed strength degradation with time; the solution, artificial saliva or distilled water with coke, did not influence the degree of force degradation of the springs; after three months the forces were still greater than 60% of the initial value.

The suggestions for future research is to evaluate the degradation of forces that occurs comparing other methods of activating the space closing mechanics.

References

Angolkar, P. V., Arnold, J. V., Nanda, R. S., & Duncanson Jr, M. G. (1992). Force degradation of closed coil springs: an in vitro evaluation. *American journal of orthodontics and dentofacial orthopedics*, *102*(2), 127-133.

Badran, S. A., Al-Zaben, J. M., Al-Taie, L. M., Tbeishi, H., & Al-Omiri, M. K. (2022). Comparing patient-centered outcomes and efficiency of space closure between nickel-titanium closed-coil springs and elastomeric power chains during orthodontic treatment. *Angle Orthod*, *92*(4), 471-477. https://doi.org/10.2319/120721-906

Barsoum, H. A., ElSayed, H. S., El Sharaby, F. A., Palomo, J. M., & Mostafa, Y. A. (2021). Comprehensive comparison of canine retraction using NiTi closed coil springs vs elastomeric chains. *Angle Orthod*, *91*(4), 441-448. https://doi.org/10.2319/110620-916.1

Conti, A. C. d. C. F., de Vitto, C., Conceição, L. F., Dourado, G. B., Volpato, G. H., Junior, J. F. S., & de Almeida-Pedrin, R. R. (2020). Force degradation of nickel-titanium closed coil springs: an in vitro. *Research, Society and Development*, *9*(10), e2669108488-e2669108488.

Cox, C., Nguyen, T., Koroluk, L., & Ko, C.-C. (2014). In-vivo force decay of nickel-titanium closed-coil springs. *American Journal of Orthodontics and Dentofacial Orthopedics*, *145*(4), 505-513.

Dixon, V., Read, M., O'brien, K., Worthington, H., & Mandall, N. (2014). A randomized clinical trial to compare three methods of orthodontic space closure. *Journal of Orthodontics*.

Estrela, C. (2018). *Metodologia científica: ciência, ensino, pesquisa*. Artes Médicas.

Magno, A. F., da Costa Monini, A., Capela, M. V., Martins, L. P., & Martins, R. P. (2015). Effect of clinical use of nickel-titanium springs. *American Journal of Orthodontics and Dentofacial Orthopedics*, *148*(1), 76-82.

Miura, F., Mogi, M., Ohura, Y., & Karibe, M. (1988). The super-elastic Japanese NiTi alloy wire for use in orthodontics part III. Studies on the Japanese NiTi alloy coil springs. *American Journal of Orthodontics and Dentofacial Orthopedics*, *94*(2), 89-96.

Mohammed, H., Rizk, M., Wafaie, K., & Almuzian, M. (2018). Effectiveness of nickel-titanium springs vs elastomeric chains in orthodontic space closure: A systematic review and meta-analysis. *Orthodontics & craniofacial research*, *21*(1), 12-19.

Nattrass, C., Ireland, A. J., & Sherriff, M. (1998). The effect of environmental factors on elastomeric chain and nickel titanium coil springs. *The European Journal of Orthodontics*, *20*(2), 169-176.

Nightingale, C., & Jones, S. P. (2003). A clinical investigation of force delivery systems for orthodontic space closure. *J Orthod*, *30*(3), 229-236. https://doi.org/10.1093/ortho/30.3.229

Parvizi, F., & Rock, W. (2003). The load/deflection characteristics of thermally activated orthodontic archwires. *The European Journal of Orthodontics*, *25*(4), 417-421.

Prado, T., Neves, J. G., Correr-Sobrinho, L., Menezes, C. C., Venezian, G. C., Correr, A. B., & Costa, A. R. (2020). Evaluation of the force degradation and deformation of the open-closed and open springs of NiTi: An in vitro study. *International Orthodontics*, *18*(4), 801-808.

Proffit, W. R., Fields Jr, H., & Moray, L. (1998). Prevalence of malocclusion and orthodontic treatment need in the United States: estimates from the NHANES III survey. *The International journal of adult orthodontics and orthognathic surgery*, *13*(2), 97-106.

Proffit, W. R., Fields Jr, H. W., & Sarver, D. M. (2006). *Contemporary orthodontics*. Elsevier Health Sciences.

Santos, A. C. S., Tortamano, A., Naccarato, S. R. F., Dominguez-Rodriguez, G. C., & Vigorito, J. W. (2007). An in vitro comparison of the force decay generated by different commercially available elastomeric chains and NiTi closed coil springs. *Brazilian oral research*, *21*, 51-57.

Schneevoigt, R., Haase, A., Eckardt, V., Harzer, W., & Bourauel, C. (1999). Laboratory analysis of superelastic NiTi compression springs. *Medical engineering & physics*, *21*(2), 119-125.

Schwarz, A. (1932). Tissue changes incident to orthodontic tooth movement. int J Orthod. In: Milwaukee.

Severino, A. J. (2017). *Metodologia do trabalho científico*. Cortez editora.

Shaw, J. A., & Kyriakides, S. (1995). Thermomechanical aspects of NiTi. *Journal of the Mechanics and Physics of Solids*, *43*(8), 1243-1281.

Van Leeuwen, E., Kuijpers-Jagtman, A., Von den Hoff, J., Wagener, F., & Maltha, J. (2010). Rate of orthodontic tooth movement after changing the force magnitude: an experimental study in beagle dogs. *Orthodontics & Craniofacial Research*, *13*(4), 238-245.

Von Fraunhofer, J., Coffelt, M. P., & Orbell, G. (1992). The effects of artificial saliva and topical fluoride treatments on the degradation of the elastic properties of orthodontic chains. *The Angle Orthodontist*, *62*(4), 265-274.