An *in vitro* comparison of the force decay generated by different commercially available elastomeric chains and NiTi closed coil springs

Comparação *in vitro* da degradação da força gerada por cadeias elastoméricas e por molas fechadas de NiTi de diferentes marcas comerciais

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Abstract: This *in vitro* study was designed to compare the forces generated by commercially available elastomeric chains and NiTi closed coil springs, and to determine their force decay pattern. Forty elastomeric chains and forty NiTi closed coil springs were divided into 4 groups according to the following manufacturers: (1) Morelli®, (2) Abzil®, (3) TP Orthodontics® and (4) American Orthodontics®. The specimens were extended to twice their original length and stored in artificial saliva at 37°C. Initial force was measured by means of an Instron universal testing machine and then at 1, 4, 7, 14, 21, and 28 days. The results revealed that the elastomeric chains delivered a mean initial force of 347 g for Morelli®, 351 g for American Orthodontics®, 402 g for Abzil®, and 404 g for TP Orthodontics®. The NiTi closed coil springs generated a mean initial force of 196 g for American Orthodontics®, 208 g for TP Orthodontics®, 216 g for Abzil®, and 223 g for Morelli®. The mean percentage of force decay observed after 28 days for the elastomeric chains was 37.4% for TP Orthodontics®, 48.1% for American Orthodontics®, 65.4% for Morelli®, and 71.6% for Abzil®. After 28 days, the NiTi closed coil springs presented a mean percentage of force decay of 22.6% for American Orthodontics®, 29.8% for Abzil®, 30.6% for Morelli®, and 45.8% for TP Orthodontics®. At the end of the study, significant differences were observed between the elastomeric chains and the NiTi closed coil springs. The results indicated that the studied NiTi closed coil springs are more adequate for dental movement than the elastomeric chains.
Descriptors: Orthodontics, corrective; Orthodontic appliance design.

Resumo: Este estudo *in vitro* foi delineado para comparar a força gerada por cadeias elastoméricas e por molas fechadas de NiTi comercialmente disponíveis e para determinar seu padrão de degradação de forças. Para tal, 40 segmentos de cadeia elastomérica e 40 molas fechadas de NiTi foram divididas em 4 grupos de acordo com a marca comercial: (1) Morelli®, (2) Abzil®, (3) TP Orthodontics® e (4) American Orthodontics®. As amostras foram distendidas ao dobro de seu comprimento original e imersas em solução de saliva artificial a 37°C. Uma máquina de ensaio (Instron) foi utilizada para aferir a força inicial e em 1, 4, 7, 14, 21 e 28 dias. Os resultados mostraram que as cadeias elastoméricas liberaram uma força média inicial de 404 g para a marca TP Orthodontics®, 402 g para Abzil®, 351 g para American Orthodontics® e 347 g para Morelli®. As molas fechadas de NiTi geraram uma força média inicial de 223 g para a marca Morelli®, 216 g para Abzil®, 208 g para TP Orthodontics® e 196 g para American Orthodontics®. A percentagem média de degradação da força após 28 dias para as cadeias elastoméricas foi de 37,4% para TP Orthodontics®, 48,1% para American Orthodontics®, 65,4% para Morelli® e 71,6% para Abzil®. A percentagem média de degradação da força após 28 dias para as molas fechadas de NiTi foi de 22,6% para American Orthodontics®, 29,8% para Abzil®, 30,6% para Morelli® e 45,8% para TP Orthodontics®. Ao final do experimento, observaram-se diferenças significantes entre as cadeias elastoméricas e as molas fechadas de NiTi. Os resultados permitem recomendar as molas fechadas de NiTi estudadas como dispositivos mais adequados para movimentação dentária do que as cadeias elastoméricas.
Descritores: Ortodontia corretiva; Desenho de aparelho ortodôntico.

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Introduction

Different systems have been proposed to close spaces in orthodontics. Although current knowledge on the various properties of the space closure system is extensive, the search for the ideal device still goes on. The ideal space closure system should have mechanical properties that provide a continuous light force, preserve periodontal integrity, and close the space within a minimum time.[2] Space closing systems in common use include elastomeric products, such as elastomeric chains and modules, and nickel titanium (NiTi) coil springs. Elastomeric products are more frequently used because of simplicity and low cost.[6]

In order to compare elastomeric chains, stainless steel closed coil springs and NiTi closed coil springs, Han, Quick[4] (1993) extended samples to twice their rest length, and held them at that length while immersed in artificial saliva at body temperature for 0, 2, 4 or 6 weeks. Plots of force *vs*. deformation were made as the springs were stretched from rest length to three times that length and then relaxed back to rest. NiTi closed coil springs suffered no degradation of their spring properties. In contrast, stainless steel closed coil springs and elastomeric chains lost a large portion of their force-generating capacity.

According to previous *in vitro*[1,4,5,8,12,13] and clinical[3,10,11] studies, NiTi closed coil springs were preferable over elastomeric chains, because the springs exerted a light, continuous force over a long range of increasing or decreasing activation, and therefore they closed spaces more quickly and more consistently than elastomeric chains. Significant differences were not observed only in one previous clinical study.[9]

The force generated by space closing systems depends not only on the device itself, but also on the force applied by clinicians. Investigating three systems of space closure (elastomeric chain, an elastomeric module on a steel ligature, and a NiTi closed coil spring), it was observed that clinicians were consistent in their force application, as individuals, but there was a wide range of forces applied by different individuals[7]. Therefore, most clinicians applied very different forces when using different force delivery systems. When using the module on a ligature, the greatest force was applied, whilst the nickel titanium coil springs provided the least force.[7]

Gross color change in elastomeric chains is a common clinical finding in patients who consume spiced food. Besides aesthetic damage, elastomeric chains exposed to spiced food, moisture and high temperatures presented higher force decay than those exposed to water alone[8]. In contrast, NiTi closed coil springs were little influenced by temperature, and were not influenced by spiced food.[8]

Since sliding mechanics have been widely employed to close residual extraction spaces, it is important to compare the force exerted by different space closing systems to help orthodontists in choosing between commercially available devices.

This study aimed at comparing the force generated by commercially available elastomeric chains and NiTi closed coil springs, and at determining their force decay during prolonged exposure to a simulated oral environment.

Material and Methods

Forty pieces of elastomeric chains and forty NiTi closed coil springs were divided into 4 groups according to the following manufactures: (1) Morelli® (Sorocaba, SP, Brazil), (2) Abzil® (São José do Rio Preto, SP, Brazil), (3) TP Orthodontics® (La Porte, IN, USA), and (4) American Orthodontics® (Sheboygan, WI, USA). Initial length of each piece of elastomeric chains and of each NiTi closed coil springs was 12 mm, except for the NiTi closed coil springs from TP Orthodontics® that were 3 mm long. The distance between the links of the elastomeric chains was .136”. The catalog code for the elastomeric chains was 60.05.511 for Morelli®, 410-109 for Abzil®, 390-150 for TP Orthodontics® and 854-211 for American Orthodontics®. The studied NiTi closed coil springs had a .010” diameter wire and a .030” lumen size. The catalog code for the NiTi closed coil springs was 35.20.066 for Morelli®, 467-732 for Abzil®, 210-510 for TP Orthodontics®, and 855-181 for American Orthodontics®.

To simulate the use of the springs and elastics in an oral environment, the samples were stretched to twice their original length, and held at constant stretch by means of a brass base with four screws that compounded two independent columns (Fig-

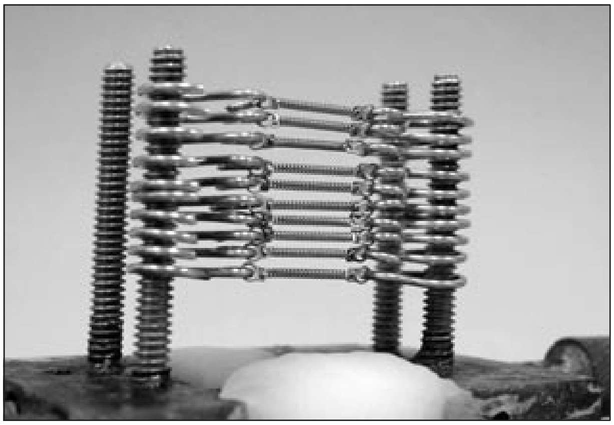


Figure 1 - The test specimens were held stretched by means of a brass base with four screws that compounded two independent columns.

ure 1). Steel hooks, made of 1.2 mm orthodontic wire, were used to hold each side of the specimens on the screws of the base. Care was taken to ensure that each pair of hooks used to support a single test specimen provided the necessary distance to hold samples stretched twice their original length during the whole period of the study. The distance was determined by a digital caliper (Mitutoyo®, Kawasaki, Japan) and was considered as being constant because the mean rate of space closure per week was negligible (0.19 to 0.24 mm).[10] Nattrass *et al.*[8] (1998) demonstrated that 25 mm was the most frequent distance across four links of medium-spaced elastomeric chains applied in clinical practice. This finding was used as a first reference to determine the distance between steel hooks. The second reference was taken from manufacturers who recommended a stretch to twice the original length of the material to achieve its ideal force magnitude. Therefore, four links of elastomeric chains and a 24 mm stretch were chosen for this experiment. Subsequently, NiTi closed coil springs were also stretched to twice their original length to match the elastomeric chains.

In order to simulate clinical conditions, the elastomeric chains and NiTi closed coil springs were immersed in artificial saliva (Saliform®, Fórmula e Ação, São Paulo, Brazil) at 37°C for 28 days.

Initial force was measured by means of an Instron universal testing machine (Instron Corp.®, Canton, MA, USA) and then at 1, 4, 7, 14, 21, and 28 days (Figure 2). The samples were carefully held stretched, especially while transferred from the base to the Instron device, and back to the base. Transference was performed with Mathieu tweezers (Dentaurum®, Ispringen, Germany). The distance between the screws of the base and the screws coupled to the Instron device were the same, and were determined by a digital caliper (Mitutoyo®, Kawasaki, Japan). Each sample was placed in the Instron device, and subsequently the machine was turned on to inform the force generated, and immediately turned off to avoid changes in the distance previously determined.

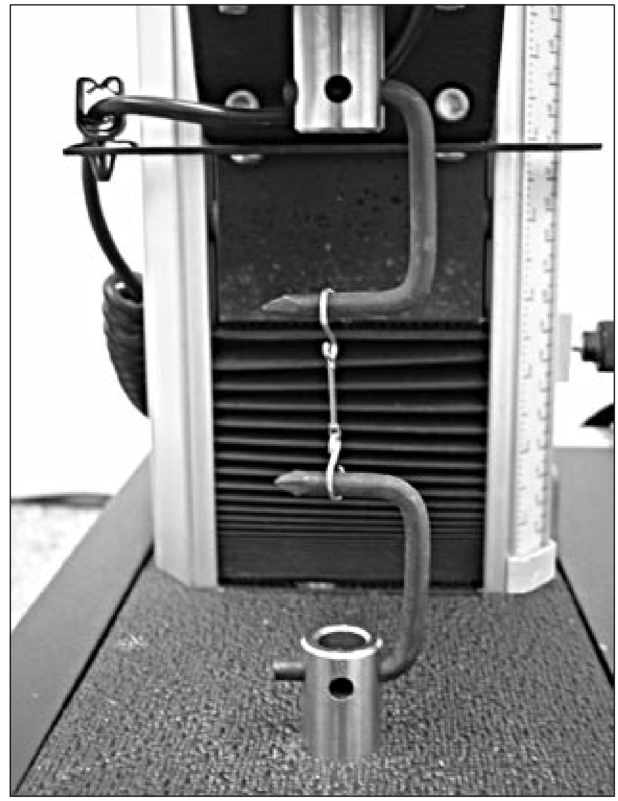


Figure 2 - Specimens being tested by the Instron universal testing machine.

The means and standard deviations of force were calculated for each studied group after each time interval. The percentage of force loss after each time interval was also calculated. Analysis of variance (ANOVA) was performed to determine whether the means were significantly different for each studied device after each time interval.

Results

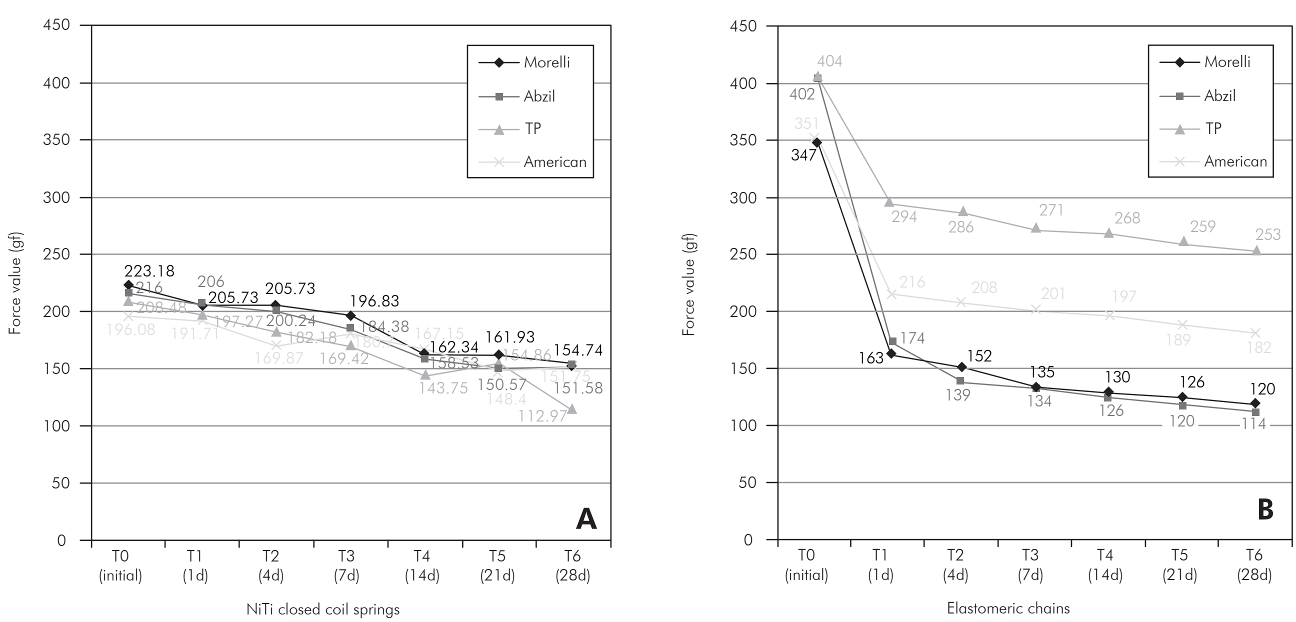
Table 1 and Graph 1 depict the means and standard deviations of the force value in gram force (gf) for the elastomeric chains and for the NiTi closed coil springs of the studied brands. The percentage of force loss for all the elastics and springs is shown in Table 2. A comparison of the mean values of force in gram force (gf) for the elastomeric chains and for the NiTi closed coil springs of the studied brands after the time intervals is presented in Table 3. Significant differences were noted by means of the Tukey test at a significance level of 5% (Table 3).

One NiTi closed coil spring from TP Orthodontics® had one of its elastic eyelets broken after 24 hours and another had it broken after 21 days. Therefore, after the first time interval, this group decreased to 9 specimens; after the fifth interval, it decreased further to 8 specimens. The reduced sam-

Table 1 - Means and standard deviations of force values (gf) for the elastomeric chains and NiTi closed coil springs of the studied brands after the time intervals.

		Initial		1 day		4 days		7 days		14 days		21 days		28 days	
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Morelli®	EC	347	21	163	9	152	10	135	7	130	8	126	8	120	9
	CCS	223	7	206	10	206	10	197	9	162	6	162	7	155	7
Abzil®	EC	402	28	174	12	139	5	134	4	126	6	120	6	114	4
	CCS	216	8	206	7	200	2	184	7	158	14	150	10	151	10
TP®	EC	404	20	294	19	286	23	271	16	268	16	259	16	253	18
	CCS	208	21	197	14	182	14	169	14	144	13	155	11	113	13
American®	EC	351	21	216	14	208	10	201	6	197	6	189	6	182	8
	CCS	196	8	192	7	170	8	180	8	167	3	148	7	152	7

M = Mean; SD = Standard deviation; EC = Elastomeric chains; CCS = NiTi closed coil springs.



Graph 1 - Means of force values (gf) for the NiTi closed coil springs (**A**) and elastomeric chains (**B**) of the studied brands after the time intervals.

Table 2 - Percentage of force loss for the elastomeric chains and NiTi closed coil springs of the studied brands over time.

		1 day	4 days	7 days	14 days	21 days	28 days
Morelli®	EC	53.1%	56.2%	61.1%	62.6%	63.7%	65.4%
	CCS	7.2%	7.8%	11.8%	27.2%	27.4%	30.6%
Abzil®	EC	56.7%	65.4%	66.6%	68.7%	70.2%	71.6%
	CCS	4.6%	7.3%	14.6%	26.6%	30.3%	29.8%
TP®	EC	27.2%	29.2%	32.9%	33.6%	35.9%	37.4%
	CCS	5.4%	12.6%	18.7%	31%	25.7%	45.8%
American®	EC	38.5%	40.7%	42.7%	43.8%	46.1%	48.1%
	CCS	2.2%	13.3%	7.8%	14.7%	24.3%	22.6%

EC = Elastomeric chains; CCS = NiTi closed coil springs.

ple size of this group did not influence the results, since a low variance was observed.

Discussion

Concerned about consistent and healthy dental movement, this study proposed to compare the force delivered by some of the commercially available elastomeric chains and NiTi closed coil springs. The ideal magnitude of force for space closure in orthodontics was found to be between 150 and 200 g.[10] The elastomeric chains presented a high mean initial force of 404 g for TP Orthodontics®, 402 g for Abzil®, 351 g for American Orthodontics®, and 347 g for Morelli®. In contrast, the NiTi closed coil springs showed a mean initial force of 223 g for Morelli®, 216 g for Abzil®, 208 g for TP Orthodontics®, and 196 g for American Orthodontics®. According to literature, the results of this study pointed out that the NiTi closed coil springs delivered an initial force magnitude closer to the ideal, and were more resistant to force degradation than the elastomeric chains.[4,8] The Tukey test, applied to compare the elastomeric chains and NiTi closed coil springs, presented significant values of force after every time interval (Table 3). Comparing the results of this study with data from the study of Moresca, Vigorito[6] (2005), the elastomeric modules delivered an initial force value lower than that delivered by the elastomeric chains, but higher than that delivered by the NiTi closed coil springs.

Force decay was different between the elastomeric chains and NiTi closed coil springs. The elastomeric chains exhibited a high percentage of force loss during the first 24 hours, but after that the force decay continued progressively. The NiTi closed coil springs, however, presented a gentle and progressive force decay over 28 days. After 24 hours, the elastomeric chains from Morelli® and Abzil® presented a lower force value than that presented by the NiTi closed coil springs of these brands. The elastomeric chains from TP® and American®, however, still showed significant higher force values than those found for the NiTi closed coil springs of these brands after 24 hours. Those values were acceptable for dental movement. At the end of the study, the elastomeric chains showed a significantly greater force decay than that presented by the NiTi closed coil springs. Han, Quick[4] (1993) observed a lower force decay for NiTi closed coil springs than that found in the present study. The authors, however, returned the samples to their rest length before measuring the plots of force *vs.* deformation. In contrast, the samples were held constantly stretched in this study, and the same spring was measured after increasing time intervals.

The amount of activation accomplished by this study was steadied to twice the original length of the device. Clinically, however, a wide range of stretch could be achieved depending on the operator, but the NiTi closed coil springs were less influenced by the operator.[7] Plots of force *vs.* deformation had explained this behavior.[4,5,12,13] Superelasticity allowed the NiTi closed coil springs to deliver a constant low force over a wide range of clinical activation. Hence, the NiTi closed coil springs deliver similar force lev-

Table 3 - Comparison of means of force values (gf) for the elastomeric chains and NiTi closed coil springs of the studied brands after the time intervals by means of the Tukey test.

	Initial	1 day	4 days	7 days	14 days	21 days	28 days
Morelli EC *versus* Morelli CCS	124*	–43*	–54*	–62*	–32*	–36*	–35*
Morelli EC *versus* Abzil EC	–55*	–11	13	1	4	6	6
Morelli EC *versus* Abzil CCS	131*	–43*	–48*	–49*	–28*	–24*	–31*
Morelli EC *versus* TP EC	–57*	–131*	–134*	–136*	–138*	–133*	–133*
Morelli EC *versus* TP CCS	139*	–34*	–30*	–34*	–14*	–29*	7*
Morelli EC *versus* American EC	–4	–53*	–56*	–66*	–67*	–63*	–62*
Morelli EC *versus* American CCS	151*	–29*	–18*	–45*	–37*	–22*	–32*
Morelli CCS *versus* Abzil EC	–179*	32*	67*	63*	36*	42*	41*
Morelli CCS *versus* Abzil CCS	7	0	6	13*	4	12*	4
Morelli CCS *versus* TP EC	–181*	–88*	–80*	–74*	–106*	–97*	–98*
Morelli CCS *versus* TP CCS	15	9	24*	28*	18*	7	42*
Morelli CCS *versus* American EC	–128*	–10*	–2*	–4*	–35*	–27*	–27*
Morelli CCS *versus* American CCS	27*	14*	36*	17*	–5	14*	3
Abzil EC *versus* Abzil CCS	186*	–32*	–61*	–50*	–32*	–30*	–37*
Abzil EC *versus* TP EC	–2	–120*	–147*	–137*	–142*	–139*	–139*
Abzil EC *versus* TP CCS	194*	–23*	–43*	–35*	–18*	–35*	1
Abzil EC *versus* American EC	51*	–42*	–69*	–67*	–71*	–69*	–68*
Abzil EC *versus* American CCS	206*	–18*	–31*	–46*	–41*	–28*	–38*
Abzil CCS *versus* TP EC	–188*	–88*	–86*	–87*	–110*	–109*	–102*
Abzil CCS *versus* TP CCS	8	9	18*	15*	14*	–5	38*
Abzil CCS *versus* American EC	–135*	–10*	–8*	–17*	–39*	–39*	–31*
Abzil CCS *versus* American CCS	20*	14*	30*	4	–9	2	–1
TP EC *versus* TP CCS	196*	97*	104*	102*	124*	104*	140*
TP EC *versus* American EC	53*	78*	78*	70*	71*	70*	71*
TP EC *versus* American CCS	208*	102*	116*	91*	101*	111*	101*
TP CCS *versus* American EC	–143*	–19*	–26*	–32*	–53*	–34*	–69*
TP CCS *versus* American CCS	12	5	12*	–11	–23*	7	–39*
American EC *versus* American CCS	155*	24*	38*	21*	30*	41*	30*

EC = Elastomeric chains; CCS = NiTi closed coil springs; *Significance level of 5% ($p < 0.05$).

els even when activated by different operators. Elastomeric chains, in contrast, generate force levels proportional to the activation applied by the clinician.

The NiTi closed coil springs from TP Orthodontics® were 3 mm long, because this manufacturer does not carry 12 mm long springs. Spring length had great influence on the force-deflection rate according to Boshart *et al.*[1] (1990), who analyzed stainless steel and Cr-Co-Ni closed coil springs. However, differences were not observed in this study. When stretched to twice their original length, the NiTi closed coil springs from TP Orthodontics® did not exhibit significant differences in initial force values compared to those of the other manufacturers (Table 3). This can be explained by the fact that the NiTi alloy has a superelasticity property, whereas stainless steel and Cr-Co-Ni do not.

Therefore, the NiTi closed coil springs showed a more appropriate behavior for consistent dental movement compared to the elastomeric chains. Wide employment of NiTi closed coil springs, however, is limited because of their higher cost.

Conclusion

The results support the conclusion that the elastomeric chains generated higher initial force values than those generated by the NiTi closed coil springs, and presented a higher force decay within the first 24 hours. By contrast, the NiTi closed coil springs showed initial force values closer to the ideal, and presented a gentle and progressive force decay over 28 days. At the end of the study, the elastomeric chains exhibited a significantly greater force decay than that presented by the NiTi closed coil springs. Therefore, the results reinforce literature, which points out NiTi closed coil springs as more appropriate devices for space closure in orthodontics than elastomeric chains.

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