Clinical evaluation of dental alignment and leveling with three different types of orthodontic wires

Marco Abdo Gravina[1], Ione Helena Vieira Portella Brunharo[2], Marcelo Reis Fraga[3], Flavia Artese[4],
Marcio José da Silva Campos[3], Robert Willer Farinazzo Vitral[5], Cátia Cardoso Abdo Quintão[4]

Introduction: A wide variety of orthodontic wires made of different alloys is available to be used in orthodontic practice and may produce different clinical responses during tooth movement. **Objective:** This research evaluated the alignment and leveling of lower dental arches after the use of three types of orthodontic wires. **Methods:** A sample of 36 patients was randomly divided into 3 groups: stainless steel, multistranded steel and superelastic nickel-titanium, according to the first leveling arches used. In order to observe differences in tooth position and axial inclination of the lower incisors, all patients had lateral cephalometric radiographs taken before the insertion of the first arches and 2 months later. The irregularity index and the curve of Spee were measured, compared between groups and considered influential on the proclination of incisors during the initial phase of alignment and leveling. The Reflex microscope was used to measure the irregularity index, whereas the ANOVA analysis of variance was used to verify differences between groups with regard to the degree of dental alignment and leveling. **Results:** There were significant differences between groups only at T_2 for the irregularity index. **Conclusion:** The NiTi and multistranded steel wires showed greater aligning capacity when compared with stainless steel wires.

Keywords: Orthodontic wires. Physical properties. Tooth movement. Orthodontics.

Introdução: uma grande variedade de fios ortodônticos, compostos por diferentes ligas, está disponível para utilização ortodôntica, podendo gerar respostas clínicas diversas, durante a movimentação dentária. **Objetivo:** este trabalho visa a avaliar o alinhamento e nivelamento das arcadas dentárias inferiores, após a utilização de três tipos de fios ortodônticos. **Métodos:** uma amostra de 36 pacientes foi aleatoriamente dividida em três grupos, de acordo com os primeiros arcos utilizados para o alinhamento e nivelamento: aço inoxidável convencional, aço multifilamentado e de níquel-titânio superelástico. Para se avaliar as diferenças relacionadas ao posicionamento dentário e inclinação axial dos incisivos inferiores, foram obtidas radiografias cefalométricas de perfil, de todos os pacientes, em duas fases do tratamento: antes da inserção dos primeiros arcos e dois meses após a inserção dos mesmos. O índice de irregularidade dentária (IID) e a profundidade inicial de curva de Spee, fatores influentes sobre a projeção de incisivos durante a fase inicial de alinhamento e nivelamento, foram avaliados e comparados intra- e intergrupos. Para a medição do IID, foi utilizado o Reflex Microscope, possibilitando a mensuração do grau de alinhamento e nivelamento dentário em terceira dimensão. A análise de variância (ANOVA) foi utilizada para se avaliar as diferenças intergrupos em relação ao grau de alinhamento e nivelamento dentário. **Resultados:** diferenças estatisticamente significativas intergrupos somente foram encontradas em T_2, em relação ao índice de irregularidade dentária, já que os fios de NiTi e aço multifilamentado apresentaram maior capacidade de alinhamento do que os fios de aço inoxidável convencionais.

Palavras-chave: Fios ortodônticos. Propriedades mecânicas. Movimento dentário. Ortodontia.

[1] Associate professor, Department of Orthodontics, College of Dentistry, Federal University of Juiz de Fora (UFJF).

[2] Assistant professor, Department of Orthodontics, College of Dentistry, State University of Rio de Janeiro (UERJ).

[3] Professor, Department of Orthodontics, UFJF.

[4] Associate professor, Department of Orthodontics, College of Dentistry, UERJ.

[5] Associate professor, Department of Orthodontics, UFJF.

Contact address: Marcio José da Silva Campos
Rua Paracatu, 568 – Santa Terezinha – Juiz de Fora/MG — Brazil
CEP: 36.046-040 – E-mail: drmarciocampos@hotmail.com

INTRODUCTION

Alignment and leveling of teeth generally constitute the most important preliminary clinical phase of any orthodontic treatment with fixed appliances. Leveling is the process in which the incisal edges of the anterior teeth and the buccal cusps of the posterior teeth are placed on the same horizontal level; and alignment is the lining up of teeth of an arch in order to achieve normal contact point relationships.[1,2] The process of leveling can be orthodontically performed by means of different techniques, and, in more severe cases, with the aid of surgical procedures.[2-5] The leveling of the curve of Spee by intrusion of anterior teeth and/or extrusion of posterior teeth is important to achieve functional occlusion.[1,3,6,7,8]

The length of the arch can be increased during leveling of the curve of Spee, mostly by incisor proclination, but how much it is increased has not been very well defined yet.[1] The general concept that additional arch space is necessary to level the occlusal plane could be associated with the continuous archwire mechanics adverse effects produced during leveling. Generally, the response to the use of such arches includes the extrusion of lower premolars, some degree of uprighting of lower molars and proclination of lower incisors.[9] The amount of increase in arch length and incisor proclination during leveling should be carefully planned,[1] and space analysis before leveling should not only be calculated in relation to the sagittal, but also in relation to the vertical and transversal planes.[10]

According to orthodontic theories, light and continuous forces are desirable to obtain physiologic and controlled movement of teeth and adjacent structures. Orthodontic wires used for initial leveling and aligning must be capable of generating such forces and to do so they need to be flexible and to transmit light forces in a wide range of activation. For this reason, a variety of multistranded steel wires or superelastic nickel-titanium wires (NiTi) were developed to provide a force-deflection curve with a definite platform and a wider range of activation.[11]

At first, the elastic behavior of orthodontic wires was evaluated by *in vitro* tests.[12] In an attempt to provide clinical significance to recent laboratory tests, several characteristics have been described as necessary for a fine clinical performance of a wire during leveling and alignment, namely: high resistance to orthodontic forces, low elasticity module, high springback and resilience, easy engagement to the brackets, flexibility, biocompatibility, low friction coefficient, resistance to corrosion and hypoallergenicity, absence of fracture under orthodontic forces.[13,14,15]

Only a few studies have evaluated the new alloys that comprise the archwires used in the initial phase of treatment, and none of them were capable to prove the superiority of nickel-titanium wires over other wires used for aligning and leveling the teeth.[13,16,17,18] The clinical relationship between dental arch expansion, incisor proclination and effectiveness of orthodontic wires is still not clear.

In a recent clinical study,[19] which compared the efficiency of three sequences of NiTi orthodontic archwires produced by different manufacturers (3M Unitek, GAC and Ormco), the differences between alignment efficiency, overall discomfort experience and the time required to reach the working archwire were not significant. Pandis et al[20] clinically evaluated mandibular anterior crowding alleviation performed with CuNiTi and NiTi wires. Their results did not find significant differences between wires with regard to alignment efficiency and treatment duration. Moreover, a recent systematic review was unable to show which is the most effective archwire sequence for leveling and aligning the teeth, due to the lack of *in vivo* studies.

Thus, it becomes necessary to compare the clinical performance of conventional alloys, such as stainless steel and multistranded archwires, with the newer ones, such as superelastic nickel-titanium wires and the heat activated alloys, with regard to incisor proclination and leveling of the curve of Spee. For this reason, the aim of this study was to clinically evaluate the effectiveness of three different types of wires regarding lower incisors proclination, irregularity index and the level of the curve of Spee.

MATERIAL AND METHODS

Thirty-six young adolescents with a mean age of 14 ± 2 years, 18 boys and 18 girls, were selected to begin orthodontic treatment. They were selected according to the following criteria: presence of all erupted permanent teeth except for second and third molars; no previous orthodontic treatment; no indications for tooth extraction; overbite and overjet that allowed brackets to be placed on the lower teeth without occlusal interferences; level of crowding and teeth position that allowed a maximum deflection of 2 mm in the archwire when inserted in the bracket slots,[19,20] and good conditions of oral hygiene and health.

Diagnosis, suitable treatment planning and prognosis for each case were determined before treatment onset, based on patient's initial records. The project was submitted and approved by the Institutional Review Board. For legal purposes, parents received and signed Institutional Review Board-approved consent forms.

Lower dental casts and lateral cephalometric radiographs were obtained before treatment (T_1), and standard edgewise brackets (0.022-inch slot - Dentsply-GAC International) were directly bonded to all mandibular teeth except molars. The first and second mandibular molars received prefabricated bands on which 0.022-inch slot - Dental Morelli brackets were welded.

The patients were randomly divided into 3 groups according to the type of precontoured archwire used: Group I (n = 11): stainless steel 0.014-inch lower (SS Gold Accuform, Dentsply-GAC International); Group II (n = 12): multistranded stainless steel 0.015-inch lower (SS Pentacat Accuform, Dentsply-GAC International) and Group III (n = 13): superelastic nickel-titanium 0.014-inch lower (Sentalloy, Light Accuform, Dentsply-GAC International).

The wires were inserted as deep as possible into the bracket slots and tied with 0.008-inch metallic ligature by the same operator. Eight weeks later, the archwires were removed and new dental casts and lateral cephalometric radiographs (T_2) were obtained.

On lateral cephalometric radiographs, the structures directly related to the position of the lower incisors were traced (Fig 1) and linear and angular measurements (Fig 2) were obtained for T_1 and T_2 in order to verify changes in the anteroposterior position and axial inclination of the lower incisors.

The irregularity index (II) and the depth of the curve of Spee (CS) were measured in the lower dental casts for T_1 and T_2. The II was calculated by means of the Reflex microscope (Reflex Measurements, Butleigh, UK), by digitizing 22 dental landmarks of the lower dental arch, from the mesial of the first molars to the mesial of the lower central incisors (Fig 3). Three-dimensional coordinates of each landmark were registered and stored by the COMP C3D Server (Motion Lab Systems, Louisiana, USA) and the distances between them were calculated to determinate the irregularity index.[22] In order to measure the depth of the CS, an acrylic plate was placed on the incisal edges of the lower incisors and mesial buccal cusp of the first or second molars, when the latter were present[23] (Fig 4). The distance from the acrylic plate to the buccal cusp of the deepest tooth of each side was measured by a periodontal probe through an opening on the acrylic plate. The mean of the sum of the right and left distances defined the severity of the curve of Spee.[1,21,24]
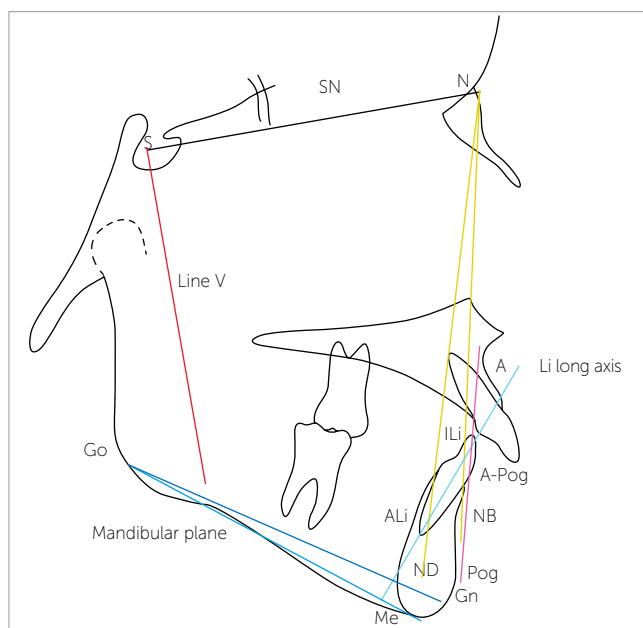

Figure 1 - Tracings, landmarks, lines and cephalometric planes used. The cephalometric landmarks used were as follows: Sela (S), Nasion (N), Point A, Point B, Point D, Gonion (Go), Pogonion (Pog), Gnation (Gn), Menton (Me), ILi (point found on the lower incisor incisal edge) and ALi (point found on top of the lower incisor).
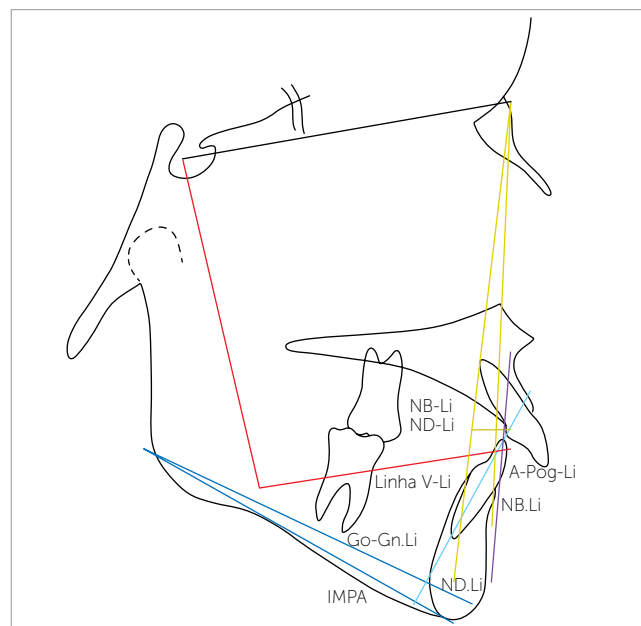

Figure 2 - Cephalometric tracing with the linear and angular measurements used. The linear measurements used were as follows: NB-Li (linear measurement between the NB line and the lower incisor edge, perpendicular to NB), ND-Li, Line V-Li, A-Pog-Li. The angular measurements were as follows: angles NB.Li, ND.Li, IMPA, Go-Gn.Li.
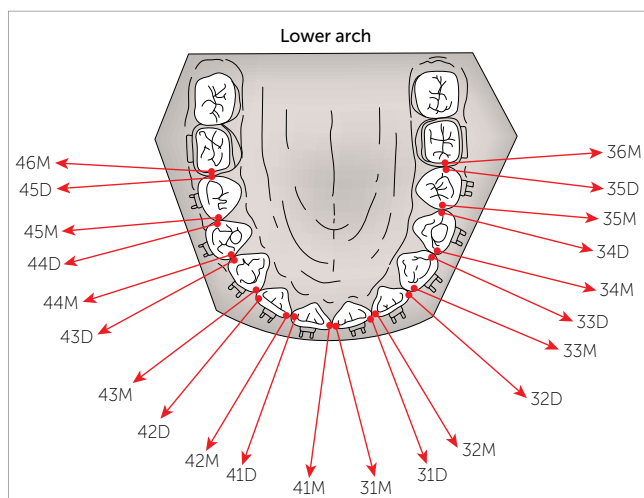
Figure 3 - Diagram of the 22 landmarks digitized on the Reflex microscope.

Figure 4 - Method used to measure the depth of the curve of Spee.

Statistical treatment

To determinate the error of the method (reproducibility), four cephalometric radiographs and 36 dental casts (18 for T_1 and 18 for T_2) were randomly selected. The radiographs were traced ten times and the dental casts were measured twice with a minimum interval of a week. No significant differences were found for the cephalometric measurements (ANOVA) and for the irregularity index and the curve of Spee (Student's t-test).

Means and standard deviations were calculated for all variables. The irregularity index, depth of CS and cephalometric measurements values were compared by one-way ANOVA test to evaluate differences between groups at T_1, T_2 and T_2-T_1. The intragroup differences between T_2 and T_1 for the irregularity index, depth of CS and cephalometric measurements were assessed by the Student's t-test. Statistical significance was set at $P \leq 0.05$.

RESULTS

Means and standard deviations are presented for all cephalometric variables, irregularity index and curve of Spee at T_1 (Table 1) and T_2 (Table 2). No statistically significant difference was found between groups, in T_1, which characterizes the homogeneity of the sample.

The differences between T_2 and T_1 for the cephalometric variables showed positive values for all groups, demonstrating a tendency towards labial tipping of lower incisors during initial alignment and leveling, regardless of the type of archwire used. No statistically significant difference was found between groups (Table 3).

Statistically significant differences were found for the irregularity index between T_2 and T_1 in the NiTi (P = 0.003) and multistranded groups (p = 0.016), only. However, the T_2-T_1 values exhibited no significant differences among three groups (Table 3).

Neither intragroup nor intergroup differences were found for CS between T_2 and T_1 for all three groups, and for T_2-T_1 values, respectively, even though the conventional stainless steel wires demonstrated a higher capacity of occlusal leveling, if compared with the other groups (Table 3).

With respect to the irregularity index at T_2-T_1, conventional stainless steel wires presented the lowest capacity for alignment when compared with the other two groups, however, no significant difference was found between groups.

DISCUSSION

The irregularity index and the depth of the curve of Spee are directly related to the space that is necessary for occlusal leveling, and are considered as influential factors over the amount of incisor proclination during alignment and leveling.[1,9,10,21]

It is well known that a continuous wire, when tied to unaligned and unleveled teeth, assumes the position of the arch and, therefore, requires more wire length than what would be necessary for a leveled and aligned arch. When attempting to return to its original form during alignment and leveling, the wire increases its length in the straight plane, which can explain the tendency towards lower incisor proclination observed in the three types of wires used.[25]

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Table 1 - Mean, standard deviation values and comparison between groups at T_1 for cephalometric measurements, irregularity index and curve of Spee.

	Group I stainless steel	Group II multistranded	Group III Superelastic NiTi	P-value (ANOVA)
NB-Li	7.4 $\pm$ 3.8	5.9 $\pm$ 1.6	6.4 $\pm$ 1.9	0.44
ND-Li	11.5 $\pm$ 4.2	10.0 $\pm$ 2.3	10.7 $\pm$ 2.7	0.47
Line V-Li	60.1 $\pm$ 5.6	60.2 $\pm$ 7.0	58.6 $\pm$ 5.4	0.75
A-Pog-Li	4.4 $\pm$ 3.7	3.2 $\pm$ 1.5	2.8 $\pm$ 2.4	0.33
IMPA	97.1 $\pm$ 5.4	94.4 $\pm$ 5.7	95.0 $\pm$ 6.1	0.51
GoGn-Li	99.7 $\pm$ 5.7	97.0 $\pm$ 5.8	97.7 $\pm$ 6.1	0.54
NB.Li	31.8 $\pm$ 6.0	28.9 $\pm$ 4.9	29.3 $\pm$ 5.2	0.38
ND.Li	28.8 $\pm$ 5.7	26.1 $\pm$ 4.5	26.3 $\pm$ 4.6	0.34
Irregularity Index	232.1 $\pm$ 48.5	210.2 $\pm$ 37.2	205.7 $\pm$ 34.8	0.26
Curve of Spee	4.1$\pm$2.6	4.8$\pm$1.8	5.0$\pm$2.0	0.56

Table 2 - Mean and standard deviation values at T_2 for cephalometric measurements, irregularity index and curve of Spee for the groups.

	Group I	Group II	Group III
NB-Li	8.0 $\pm$ 3.4	6.4 $\pm$ 2.1	7.4 $\pm$ 1.6
ND-Li	12.2 $\pm$ 3.9	10.4 $\pm$ 2.7	11.6 $\pm$ 2.1
Line V-Li	60.7 $\pm$ 6.0	60.9 $\pm$ 7.4	59.9 $\pm$ 5.5
A-Pog-Li	5.0 $\pm$ 3.1	3.7 $\pm$ 1.6	3.7 $\pm$ 1.7
IMPA	99.3 $\pm$ 5.7	95.5 $\pm$ 6.9	97.4 $\pm$ 5.7
GoGn-Li	102.0 $\pm$ 5.9	98.2 $\pm$ 7.4	100.1 $\pm$ 5.6
NB.Li	34.1 $\pm$ 5.4	30.0 $\pm$ 5.5	31.9 $\pm$ 4.1
ND.Li	31.2 $\pm$ 4.9	27.4 $\pm$ 5.1	28.8 $\pm$ 3.8
Irregularity Index	221.2 $\pm$ 52.5	180.9 $\pm$ 54.1	178.1 $\pm$ 33.0
Curve of Spee	3.4$\pm$2.2	4.6$\pm$1.3	4.9$\pm$1.6

Table 3 - Mean values for T_2-T_1 and comparison between T_2 and T_1 for cephalometric measurements, irregularity index and curve of Spee for the groups.

	Group I		Group II		Group III		P-value* (ANOVA) T_2-T_1
	T_2-T_1	P-value* (T_2/T_1)	T_2-T_1	P-value* (T_2/T_1)	T_2-T_1	P-value* (T_2/T_1)	
NB-Li	0.7 $\pm$ 0.8	0.27	0.5 $\pm$ 0.8	0.19	1.1 $\pm$ 1.2	0.36	0.36
ND-Li	0.7 $\pm$ 0.5	0.15	0.4 $\pm$ 1.0	0.38	1.0 $\pm$ 1.2	0.11	0.36
Line V-Li	0.6 $\pm$ 1.1	0.23	0.8 $\pm$ 1.3	0.13	1.3 $\pm$ 1.2	0.23	0.35
A-Pog-Li	0.6 $\pm$ 0.9	0.33	0.5 $\pm$ 0.9	0.38	0.8 $\pm$ 1.2	0.07	0.76
IMPA	2.2 $\pm$ 2.0	0.38	1.1 $\pm$ 2.8	0.21	2.4 $\pm$ 3.2	0.92	0.47
Go-Gn-Li	2.4 $\pm$ 1.9	0.41	1.1 $\pm$ 3.1	0.61	2.4 $\pm$ 3.5	0.55	0.47
NB.Li	2.3 $\pm$ 1.9	0.41	1.1 $\pm$ 2.6	0.82	2.6 $\pm$ 2.9	0.49	0.33
ND.Li	2.4 $\pm$ 2.1	0.32	1.3 $\pm$ 2.8	0.13	2.5 $\pm$ 2.9	0.55	0.46
Irregularity Index	-10.8$\pm$36.6	0.35	-29.2$\pm$33.4	0.016	-27.6$\pm$26.5	0.003	0.33
Curve of Spee	-0.6	0.07	-0.2	0.64	-0.1	0.73	0.50

* Statistical significance was established at P $\leq$ 0.05 (Student´s t-test).

In the lower arch, less potential for tooth movement could be expected with the stainless steel wires when compared with nickel-titanium wires, due to the shorter inter-bracket distance between the lower incisors.[12] Reduction in inter-bracket distance decreases wire flexibility, reducing its resilience and making it difficult to bend and fit into the brackets, which ends up reducing the capacity of tooth movement. On the other hand, the NiTi wires were expected to have an increased potential for tooth movement, since they are more resilient, flexible and easier to fit into the brackets, demonstrating better mechanical properties, specially in the lower incisor region.[26] This could explain the greater aligning capacity of the NiTi wires in comparison to the stainless steel wires, found in this study. The NiTi wire was the only one which significantly improved the irregularity index. When comparing different types of NiTi wires (non-superelastic, superelastic and heat-activated), however, no evidence was found with regard to the efficiency in aligning the mandibular arch. It was concluded that clinical factors, such as the loading pattern of the archwires, may effectively eliminate the advantages of superelastic NiTi observed in the laboratory.[19,20]

Even though no statistically significant differences were found, the NiTi wire presented greater clinical tendency towards incisor proclination, followed by stainless steel wires and by the multistranded steel wires. This finding is in agreement with Wass,[19] who reported that when a 2 mm deformation is placed on a NiTi wire, a maximum load of 365 gf could be reached, and clinically significant incisor proclination would be expected.

The same reasoning could be applied to the multistranded steel wires which demonstrated a significant greater aligning capacity in comparison to the stainless steel wires, despite demonstrating a non-significant, inferior incisor proclination tendency. Such finding could be explained by the low springback and deformation resistance of the multistranded steel wires, which reduce their energy storage capacity when tied.

In the two most recent clinical studies[19,20] comparing the aligning efficiency of different NiTi and CuNiTi orthodontic archwires, the incisor proclination tendency and the leveling of the curve of Spee were not measured. Moreover, Little's[27] irregularity index, which is bidimensional, was used in both studies to quantify the degree of tooth alignment of the six anterior mandibular teeth. In the present study, the II was calculated by means of the Reflex microscope,[12,16] with three-dimensional coordinates for each landmark digitized in the study models. It gave more accuracy to this measure, since the space discrepancy could be calculated not only in relation to the sagittal, but also in relation to the vertical and transversal planes. Incisor proclination and leveling of the curve of Spee were also calculated because they represent important factors for the stability of the treatment.

In clinical studies, however, it is important to describe the tendencies observed even when significant differences are not found[12], since the statistical mean does not always reflect the clinical result.[11] In such case, based on the linear and angular means, it is suggested that the NiTi wires presented a greater clinical tendency towards incisor proclination, even though statistically significant differences were not found. These findings agree with Jones et al[16] who did not observe clinically significant differences between dental alignment in 43 patients that used NiTi superelastic 0.014-inch or multistranded steel 0.015-inch arches, even though the NiTi wire demonstrated greater clinical action in the lower incisor region. Pandis et al[20] in agreement with the present study and with the findings of Jones et al[16] did not find differences in the amount of aligning in 60 patients who randomly received 0.016-inch CuNiTi 35°C (Ormco, Glendora, Calif) or 0.016-inch NiTi (Modern-Arch, Wyomissing, Pa) wires. In the most recent clinical study, it was determined that a minimum number of 120 patients was required to detect a clinically significant difference between the aligning arches with a power of 0.99 to a significance level of P < 0.05[19]. This could explain the absence of statistically significant differences in the three studies above.

A tendency for lower incisor proclination has been observed for the three types of wires. This fact is in agreement with Braun et al[24] who describe that even if the wires are fastened by tie backs or have their ends cinched back after the molar tubes, incisor labial inclination would occur simultaneously to its intrusion during leveling of an accentuated curve of Spee when a continuous archwire or a reverse curve of Spee is used. Such movement would occur because of the system of forces that is created and great part would be minimized if the teeth were leveled with segmented arch mechanics.[24]

The influence of the type of orthodontic wire alloy over lower incisor proclination could be questioned. This study did not use any type of mechanics that could prevent proclination, so that the potential of each alloy, regarding lower incisor proclination could be assessed without the influence of other factors.

For malocclusions similar to the studied ones, the type of wire used did not determine relevant differences regarding initial incisor proclination and initial leveling of the curve of Spee. With regard to malocclusion, patients who used the different alloy wires would not present significant differences in relation to the initial incisor proclination and the level of the curve of Spee. However, when comparing the irregularity index at T_2, the NiTi and multistranded steel wires showed greater aligning capacity in comparison to stainless steel wires. Therefore, it could be inferred from this study that a correct mechanical treatment planning for each case is much more important than the action of a certain wire.

CONCLUSION

No statistically significant differences were found between the changes in cephalometric positions and lower incisor axial inclinations with the three orthodontic wires used. No intergroup differences regarding the leveling of the curve of Spee with the insertion of only one archwire for an 8-week period were found. Statistically significant differences were found between groups with regard to the irregularity index values in T_2, as the NiTi and multistranded steel wires showed greater aligning capacity when compared with stainless steel wires.

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