Effects of nickel-titanium and stainless steel leveling wires on the position of mandibular incisors

Ricardo Moresca*, Alexandre Moro**, Gladys Cristina Dominguez***, Julio Wilson Vigorito****

Abstract

Objective: Investigate the effects of heat-activated NiTi and stainless steel wires to evaluate potential changes in the position of mandibular incisors in extraction cases as correlated with treatment length. **Method:** The sample consisted of 36 individuals of both genders, Brazilian Caucasians with mean initial age of 15 years and 5 months with Class I and Class II malocclusions, divided into two groups. In Group 1 (n=17) leveling was performed with Sequence 1, comprised of three different wire cross-sections: 0.016-in and 0.019 x 0.025-in heat-activated NiTi wires and 0.019 x 0.025-in stainless steel wires. In Group 2 (n=19) Sequence 2 was tested using only stainless steel wires (0.014-in, 0.016-in, 0.018-in, 0.020-in and 0.019 x 0,025-in) with passive torque in the mandibular incisors. Data were collected using computerized cephalometry and compared using Student's t-test with 5% significance level. **Results:** In Group 1, mandibular incisors were inclined lingually although only the crowns showed significant movement (1.6 mm). In Group 2, mandibular incisors remained stable. No vertical changes were noted in either group. **Conclusions:** Sequence 2 yielded better mandibular incisor control with no changes in their initial positions, while Sequence 1 allowed torques in the bracket prescription to be expressed, leading to the lingual inclination of these teeth. Treatment length was shorter when Sequence 1 was used. The evaluated biomechanic variations presented advantages and disadvantages that should be known and considered by the orthodontist during treatment planning.

Keywords: Leveling. Orthodontic wires. Biomechanics.

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* PhD in Orthodontics, School of Dentistry, University of São Paulo (FO-USP). Head Professor, Undergraduate and Graduate courses in Orthodontics, Federal University of Paraná State (UFPR). Head Professor, Master Degree Course in Clinical Dentistry, Positivo University.

** PhD in Orthodontics, School of Dentistry, University of São Paulo (FOB-USP). Head Professor, Undergraduate and Graduate courses in Orthodontics, UFPR. Head Professor, Master Degree Course in Dentistry, Positivo University.

*** PhD in Orthodontics (FO-USP). Associate Professor, Discipline of Orthodontics, Department of Orthodontics and Pediatric Dentistry (FO-USP).

**** PhD in Orthodontics (FO-USP). Head Professor, Discipline of Orthodontics, Department of Orthodontics and Pediatric Dentistry (FO-USP).

INTRODUCTION

Leveling can be defined as the first active phase of orthodontic treatment and involves correction of individually malpositioned teeth, bracket slot leveling, correction of tooth arch discrepancy, initial correction of the curve of Spee, and torque adjustment.[9,16,20] Uncontrolled tooth movements during leveling – which lead to anchorage loss and destabilize mandibular teeth – can decisively affect the achievement of the best goals set in orthodontic plan. Therefore, tooth movement planning becomes essential and plays an important role from the beginning of malocclusion correction.

Defining the wire sequence to be used in leveling can vary depending on technique, type of brackets, practitioner preference and treatment goals. In theory, this selection should allow a progression of less rigid wires in the early stages to enable dental alignment, and then more rigid rectangular wires in the final stages to three-dimensionally control dental movements[1,5] The ideal orthodontic archwire should be able to produce light forces delivered at constant levels, thereby providing optimal conditions for tooth movement with minimal discomfort to the patient, with no tissue hyalinization or root resorption.[6,16]

Within the current context, four types of alloys are most commonly used by orthodontists: Stainless steel, nickel-titanium, cobalt chromium, and beta-titanium. The former two types are more commonly used in leveling. Stainless steel first became available in the 40's and since then has been successfully used in orthodontics. It still remains popular due to its low cost, excellent formability, weldability and good mechanical properties. It features relatively greater hardness than most of today's materials.[6]

The first nickel-titanium (NiTi) alloy was developed by the U.S. Naval Ordnance Laboratory space program and was named Nitinol.[15] The emergence of this alloy significantly contributed to the advancement of treatment mechanics, primarily associated with prea-djusted appliances.[2,13] NiTi alloys have been widely used during the early phases of orthodontic treatment and are especially well indicated for clinical situations that require great flexibility and elastic memory. They also feature low hardness, high work potential while producing low levels of force. However, they have limited formability, produce high frictional forces and cannot be so effectively welded.[6,15]

Currently, NiTi alloys fall into three subdivisions: A conventional alloy (NiTi classic) and two superelastic alloys (pseudoelastic and thermoelastic), each with its unique properties.[6,15] The superelastic feature means that the wire deliver the same force regardless of the degree of activation.[2] Due to its versatility, provided by a combination of shape memory, excellent mechanical properties, biocompatibility and delivery of constant forces, the use of superelastic NiTi is widespread in orthodontics.[6,17] For some authors, superelastic NiTi archwires have potential advantages compared to conventional stainless steel archwires as they enable the application of a constant level of force during tooth movement.[6,7,15,17] Conversely, several clinical studies that evaluated the properties of routinely used orthodontic archwires demonstrated no significant advantage in the ability of superelastic NiTi wires to align teeth, even in comparison with NiTi classic wires or multistrand steel wires.[3]

Therefore, the reason to use more expensive NiTi wires seems to lie in the fact that they deliver lighter forces,[13,17] although there is some controversy in the literature regarding their ability to provide continuous forces. According to some authors, in clinical practice NiTi wires are rarely deformed enough as to allow their superelastic properties to be fully utilized.[3,15,17] Another application of superelastic alloys is the use of rectangular wires in the early stages of leveling.

The purpose would be to provide three-dimensional tooth movement control from the start of treatment, thereby developing controlled force levels.[17]

In general, in reviewing the literature one finds that despite considerable interest in laboratory experiments there is a lack of *in vivo* studies to support the choice of a wire sequence. This scarcity is due to difficulties in assessing (a) the behavior of different alloys and (b) the force they deliver within the oral environment.[10]

This study was conducted in order to shed light on the effects produced by activated NiTi wires compared to the effects produced by stainless steel wires in evaluating potential changes in the position of mandibular incisors during leveling. Thus, two different sequences of orthodontic wires were used and correlated with treatment time.

MATERIAL AND METHODS

Material

Sample

The sample consisted of 36 Brazilian Caucasian research subjects (20 women and 16 men) with Class I and Class II malocclusions, complete natural dentition, with the exception of third molars. The mean age of the sample at the start of treatment was 15 years and 5 months and ranged from 13 years and 8 months to 17 years and 5 months. Mandibular first premolar extraction was indicated for all patients. The sample was divided into two groups: Group 1 consisted of 17 individuals whose leveling was performed using a sequence of three orthodontic wires, named Sequence 1: 0.016-in and 0.019 x 0.025-in of heat-activated NiTi wires and 0.019 x 0.025-in stainless steel wires; and Group 2 consisted of 19 individuals whose leveling was performed with Sequence 2, comprising only stainless steel wires: 0.014-in, 0.016-in, 0.018-in, 0.020-in and 0.019 x 0.025-in with passive torque in the mandibular incisors. This research project was approved by the Ethics Committee of the School of Dentistry, University of São Paulo.

Methods

Orthodontic treatment

Orthodontic treatment of the sample subjects under study was performed by students enrolled on the orthodontics graduate courses, at Master's and PhD levels. Before starting treatment, the protocol for the clinical procedures adopted in this research was thoroughly debated in seminars by the faculty responsible for clinical research and operators.

Orthodontic treatment was performed with the extraction of first premolars using as anchorage a lingual arch made of 0.9 mm wire and welded to the mandibular first molar bands. Pre-adjusted orthodontic appliances were used (0.022 x 0,028-in Victory series brackets, 3M Unitek, Monrovia, CA, USA) in the MBT prescription, with 6° of lingual torque in the mandibular incisor crowns. Given the negative tooth arch discrepancy found at the beginning of orthodontic treatment, lacebacks were placed during leveling to trigger canines retraction and create space for incisors alignment. The lacebacks were reactivated every 21 days on average.

In Group 1, leveling was started with 0.016-in and 0.019 x 0.025-in OrthoForm II heat-activated NiTi wires (3M Unitek, Monrovia, CA, USA). Thereafter, 0.019 x 0.025-in stainless steel archwires were engaged. Each archwire was used for approximately 90 days and average leveling time was 11 months. In Group 2, the first wire used (0.014-in) was passively inserted in the bracket slots by means of 1st and 2nd order bends, copying the improper tooth positioning. From then on the bends were progressively decreased at each visit until passive wire engagement became possible without the need for any bends. No bends were placed in any of the other archwires, which were replaced whenever their tooth-moving potential was exhausted. The 0.019 x 0.025-in archwire was inserted passively in the mandibular incisor bracket slots. To this end, some lingual torque was added to this region to neutralize the -6° torque present in the mandibular incisors, as prescribed by the MBT technique.[11] In this group, the mean leveling time was 21 months.

In both groups the round archwires were bent on the distal side of the second molar tubes. Passive lacebacks were placed over the rectangular stainless steel archwires, extending from the hooks welded between canines and lateral incisors to the hooks on the second molar tubes. Steel archwires were individually diagrammed according to the method proposed by McLaughlin, Bennett and Trevisi.[11] Leveling was considered complete when the 0.019 x 0.025-in stainless steel archwires exhibited a passive engagement in the tubes and brackets.

Computerized cephalometry

Two lateral cephalograms were made for each subject in the sample, one at the beginning (T_0) and one at the end (T_1) of the leveling phase. The radiographs were obtained by orienting each patient's head in a head holder to ensure parallelism between the Frankfort plane and the ground. The ear rods were placed in the external auditory meati with light pressure and the anterior vertical rod was set to touch the region between the nasal and frontal bones. The radiographs were taken with the mouth open for better visualization of dental structures. The distance from the X-ray source to the midsagittal plane of the head was 1.52 m and the distance between the film cartridge holder and the face was set as short as possible. Image magnification was set at 10%. The X-ray films were processed in an automatic processor.

The study of possible dental changes occurring during leveling was conducted using computerized radiographic cephalometry. Initially, the radiographs were scanned with 300 dpi resolution, grayscale mode, 8 bits, JPEG format at 1:1 ratio, as recommended by Ongkosuwito et al.[14] Cephalometric measurements were then obtained using Radiocef software, Version 4.0 (Radio Memory, Belo Horizonte, MG, Brazil). The use of computerized cephalometry allowed the landmarks, lines and cephalometric measurements to be identified directly on the digitized radiographic image, thereby rendering unnecessary the drawing of anatomical tracings.

Study of changes in the position of mandibular incisors

For this study two cephalometric landmarks were identified:

» C1 – Superior-most point on the crown of the mandibular right central incisor.

» R1 – Inferior-most point on the root of the mandibular right central incisor.

The mandibular plane (Go-Me) was used as horizontal reference and the symphysis line was used as vertical reference, perpendicular to the mandibular plane passing through the posterior-most point of the mandibular symphysis (S). To evaluate the position of the mandibular incisors four linear measurements were employed, starting at points C1 and R1 and extending perpendicularly to the horizontal and vertical reference lines (C1-S, C1-PM, R1-S and R1-PM). The angle formed by the long axis of the mandibular central incisor and the mandibular plane (C1-R1.PM) was also observed (Fig 1).

Error analysis method

To assess potential operational errors, the study was repeated in all sample subjects starting at the stage of cephalometric landmark identification by the same operator, with a minimum 15-day interval. Dahlberg's formula was adopted to determine random error. Systematic error was evaluated by Student's t-test for paired samples[8] with a 5% significance level. Random errors

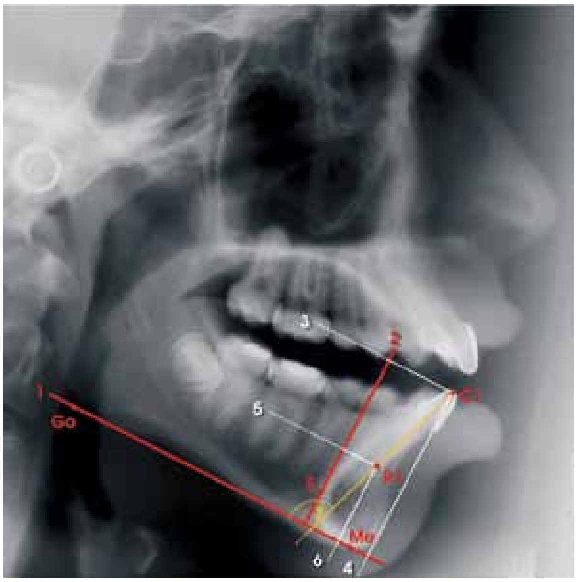

FIGURE 1 - 1) Mandibular plane; 2) symphysis line; 3) C1-S; 4) C1-PM; 5) R1-S; 6) R1-PM and 7) C1-R1.PM.

showed no variations greater than 0.74 mm for linear measurements (R1-S) and 1.6° for angular measurements (C1-R1.PM). Regarding systematic errors, a significant difference was found only for measure R1-S. In this case, however, the difference was minor and related to the root apex of the mandibular central incisor, which is a complex structure and hard to identify in lateral radiographs[18].

Statistical method

Central tendency and dispersion measurements were obtained (arithmetic mean and standard deviation) of the measures under study for phases T_0 and T_1. Within each group, means were compared using Student's t-test for paired samples. Central tendency and dispersion measurements (average and standard deviation) were calculated for the differences between the means at phases T_0 and T_1 in Groups 1 and 2, which were compared using Student's t-test for independent samples. A 5% significance level was adopted.

RESULTS

The outcome data are presented in Tables 1, 2 and 3.

TABLE 1 - Mean, standard deviation (SD), difference between means and comparison between means (P) of variables in Group 1.

Group 1	T_0		T_1		Difference between means	P
	Mean	SD	Mean	SD		
C1-S	7.91	2.22	6.24	2.31	-1.67	0.028*
C1-PM	42.14	3.22	42.67	3.74	-0.53	0.422
R1-S	4.91	1.38	4.97	1.43	0.06	0.623
R1-PM	21.44	3.66	21.30	3.79	0.14	0.402
C1-R1.PM	97.71	4.80	93.41	4.37	-4.30	0.014*

* Statistically significant difference.

TABLE 2 - Mean, standard deviation (SD), difference between means and comparison between means (P) of variables in Group 2.

Group 2	T_0		T_1		Difference between means	P
	Mean	SD	Mean	SD		
C1-S	7.10	4.32	6.51	3.99	0.59	0.118
C1-PM	45.34	4.27	45.56	4.69	-0.22	0.397
R1-S	4.99	2.03	4.81	2.35	0.18	0.533
R1-PM	22.54	3.79	22.70	4.28	-0.16	0.588
C1-R1.PM	95.28	7.69	94.45	6.81	0.83	0.554

TABLE 3 - Difference between means, standard deviation (SD) and comparison of differences between means (P) for Groups 1 and 2.

T_0-T_1	Group 1		Group 2		P
	Mean	SD	Mean	SD	
C1-S	-1.67	1.39	0.59	1.57	0.031*
C1-PM	-0.53	0.70	-0.22	1.09	0.978
R1-S	0.06	1.10	0.18	1.24	0.273
R1-PM	0.14	1.09	-0.16	1.24	0.810
C1-R1.PM	-4.30	5.02	0.83	6.02	0.037*

* Statistically significant difference.

DISCUSSION

Leveling is a phase of orthodontic treatment in which tooth movements can be complex and require careful planning.[12] In using this planning, orthodontists must select a bracket prescription, choose a wire sequence and determine the need for anchorage. A proper combination of these factors may allow goals to be achieved faster and with fewer complications.

Regarding wire sequence, no single alloy can boast all features necessary at all stages of orthodontic treatment.[10,15,16,17] Orthodontists should be knowledgeable of all properties and clinical effects produced by the wires they use and select the best possible option for each treatment stage.

In this study, important clinical observations could be made about the wire sequences under study. In using Sequence 1, a statistically significant lingual movement occurred in the crown of the mandibular incisor (1.6 mm), although root position remained unchanged. The combination of these outcomes produced a lingual inclination of 4.3° in this tooth (Table 1). Sequence 2 caused the initial position of the mandibular incisor, both crown and root, to remain unchanged. Statistical comparisons revealed no significant difference between means at T_0 and T_1 (Table 2). The lingual inclination in the mandibular incisor after using Sequence 1 presented different characteristics in the two groups when these groups were compared (Table 3). In none of the sequences any vertical changes were noted in the position of mandibular incisors.

An interesting contribution that could be drawn from this study is the efficient control of tooth movement afforded by the sequences of stainless steel wires. The addition of passive torque to the mandibular incisor region allowed an adequate control of the buccolingual movement of these teeth, regardless of their initial inclination and bracket prescription. These results confirm the findings of Garcia[4] and emphasize that tooth movement achieved with stainless steel wires can be better controlled, allowing trained professionals to apply forces with a more balanced distribution in the anterior and posterior sectors and consequently achieve better anchorage control. Thus, one can selectively control tooth movement during orthodontic treatment.

Moreover, it was shown that reciprocal moments arising from the mutual interaction of heat-activated wires, especially rectangular wires (zero torque), interacting with the torques in the pre-adjusted brackets (-6°) did not allow full control over incisor movements since the information built into the orthodontic appliances prevailed. This action was complemented by rectangular stainless steel wires, also used with zero torque. Badran et al[1] also noted some uncontrolled tooth movement when using NiTi wires. In their experiment, the intercanine width tended to increase even when the transverse distance of the dental arches at the start of treatment was the same as the width of the orthodontic archwires. The deflection present in the anterior portion of the leveling archwires engaged in incisor brackets may have produced this expansion trend in intercanine width.

Considering the initial features of the cases in both groups, given the presence of a negative tooth arch discrepancy, one would expect mandibular incisors proclination, which failed to occur. This finding may be explained by the extraction of premolars and the use of lacebacks, which have proven effective in preventing the proclination of mandibular incisors during leveling.[19]

The time required for leveling was smaller using Sequence 1 (11 months) compared to Sequence 2 (21 months). However, one must consider that this investigation was conducted in a clinical research setting in postgraduate courses, and treatment time was accounted for by considering the dates of the radiographs. In Group 2, there was a greater delay in patient registration, extending treatment time. It is likely that, depending on the private practice, treatment length can be reduced, especially in Group 2. But in general, the use of heat-activated wires yielded outstanding time savings.

FINAL CONSIDERATIONS

Today, the use of archwires with shape memory without criteria and proper assessment of the benefits and issues arising from its use has become commonplace. The results of this study do not allow one to determine which wire sequence performed better. In fact, the major question is: What tooth movements are desired? If the bracket prescription, especially in terms of torque succeeds in producing desirable movements, then rectangular archwires with shape memory can be a very efficient tool. But if the idea is to avoid these movements, the goal cannot be achieved with these wires. The solutions to this stalemate would be to vary the prescription of the orthodontic appliance or individualize the torques using stainless steel wires. In contrast, the use of heat-activated archwires can be simpler and more convenient, reducing chair time and total treatment length. In this study, the time needed to complete leveling was shorter using Sequence 1.

Therefore, it is reasonable to assume that no single, optimal treatment method exists. All biomechanical variations under study showed advantages and disadvantages, which orthodontists should be aware of and consider in planning cases. Orthodontists should not generalize the wire sequence but rather select the best possible option to meet the needs of each patient. Biological diversity is so extraordinary that it is bound to always require orthodontists' willingness to individualize orthodontic treatment in all its details.

The merit of well trained orthodontists lies not just in ensuring with their approach that a standardized, reliable method is implemented, but mainly in exploring the benefits and controlling the side effects of the various biomechanics employed, in their quest for the best treatment option to fulfill the unique needs of each patient.

CONCLUSIONS

Based on the methods applied and the results achieved in the present study, Sequence 2, which used stainless steel wires, yielded better mandibular incisor control with no changes in their initial positions, while Sequence 1, which used heat-activated wires, allowed the torques built into the bracket prescription to be expressed, leading to the lingual inclination of these teeth. Treatment time, however, was shorter using Sequence 1.

The biomechanical variations under study showed advantages and disadvantages, which orthodontists should be aware of and take into account in planning cases.

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Contact address
Ricardo Moresca
Av. Cândido de Abreu, 526, sala 1310-A
CEP: 80.530-905 - Centro Cívico – Curitiba/PR, Brazil
E-mail: ricardo@moresca.com.br