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A prospective clinical trial to compare the performance of four initial orthodontic archwires

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The aim of this study was to compare the clinical performance of 4 types of orthodontic wires, indicated for initial tooth alignment: stainless steel, multistranded steel, superelastic and thermoactivated nickel-titanium. A prospective randomized clinical trial was conducted on a sample of 45 patients, at the Dental School of the State University of Rio de Janeiro, Brazil. Fixed appliances were fitted and study casts were obtained from each patient. Randomly, the wires were allocated as follows: 26 dental arches for superelastic NiTi wires, 22 for stainless steel, 22 for multistranded and 20 for thermoactivated archwires. After 8 weeks, the archwires were removed and impressions for study casts were taken again. Using a 3D digitization technique of defined anatomical points on the study cast crowns, a Dental Irregularity Index (DII) was created for each study cast. The difference between DII before and after the archwire insertion expressed the aligning effect of the wires. ANOVA tests were employed to evaluate the anatomical point approximation (positive DII) and separation (negative DII), for each area of the dental arches: upper and lower whole arch and anterior arch. Results showed no significant difference between the different archwires.

(**Key words**: *Orthodontic wires, Randomized clinical trial, Aligning and levelling, Superelasticity*)

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INTRODUCTION

Dental aligning and levelling compose the initial stages of fixed appliance orthodontic treatment.[1,2] According to the more recent literature, the initial archwire most favoured by clinicians is of the superelastic or thermoactivated nickel-titanium type.[3-10] However, there are still many authors who prefer a more traditional multistranded steel archwire to commence treatment,[2] citing amongst their reasons that they are cheaper with no evidence of reduced clinical effectiveness.[11,12]

Previously, traditional laboratory tests have assumed that archwires for the initial stages of treatment should have amongst other properties: high resilience, low rigidity, and high accumulated energy.[1] However, such evaluations give no indication as to the likely clinical performance of such wires or any indication of their value for money.[11]

A large number of archwires are commercially available for selection by the clinician. However, there are very few studies that show their relative clinical efficiency at the beginning of orthodontic treatment. In addition, currently, the clinical performance of many types of alloy archwires is not properly understood. Therefore, properly conducted randomized clinical trials are required to compare the performance of new archwires using as a benchmark, the performance of more traditional steel/multistranded wires. The purpose of the current study was to compare the clinical performance of four archwire types commonly employed by clinicians at the initial stage of fixed appliance treatment (superelastic nickel-titanium, thermoactivated nickel-titanium, multistranded stainless steel, and conventional stainless steel).

MATERIALS AND METHODS

Subjects

Forty five patients (90 dental arches) were consecutively included in the clinical trial at the post-graduate orthodontic clinic of the Dental School of the State University of Rio de Janeiro. Of those, 28 were female (mean age 12.8 ± 1.2) and 17 were male patients (mean age 13.2 ± 1.2). Patients were included in the study according to the following criteria: 1. Presence of all permanent teeth in the oral cavity, except second and third molars; 2. Absence of previous orthodontic treatment and absence of previous palatal expansion device; 3. Absence of previous relevant medical history; 4. Overjet and overbite that would allow for fixing lower anterior teeth, without creating occlusal interference; 5. Crowding degree and dental position that would allow for full insertion of archwire into the bracket; 6. Good oral hygiene and periodontal status.

Protocol

For each patient, the same type of fixed appliance was fitted with bands on molars and bonded brackets from second bicuspid to second bicuspid. A preadjusted edgewise system, with brackets and slot ring tubes 0.022″ × 0.028″ was used in every case (GAC International, NY, USA). Once the orthodontic appliance was in place, impressions were taken of the patient's dental arches, using irreversible hydrocolloid (Jeltrate Plus, Dentsply, PA, USA). Type IV (Mossoro, Rio de Janeiro, Brazil) stone plaster models were then cast. One of 4 dental archwires was randomly allocated to each patient, using a randomised numbering system. The wires available were: superelastic nickel-titanium, round, 0.016″ diameter (Sentalloy 0.016″, Accu Form, reference 511-02, GAC International, NY, USA); thermoactivated nickel-titanium, round, 0.016″ diameter (thermal nickel titanium 0.016″, G & H Wire Company, IN, USA); multistranded steel, round, 0.0155″ diameter (SS Pentacat Accu Form, reference 03-016-23, GAC International, NY, USA) , and stainless steel wires, round, 0.014″ diameter (SS GLD Accu Form, reference 03-014-63 GAC International, NY, USA). The result of randomized allocation was as follows: 26 dental arches were assigned superelastic NiTi wires; 22 multistranded, 22 conventional stainless steel; and 20 thermoactivated NiTi.

Archwires were tied into the brackets to get as full engagement as possible in the slots. The archwires were left in place for 8 weeks. However, during this period, the patient had appointments to check the device's integrity. All wires were placed according to the same regime by one operator. Eight weeks after the insertion of the levelling and aligning wire the archwire was removed and the patient again had impressions taken and plaster models were generated, following the same regime as before. Thus, plaster models of the dental arches were available both before and after the first insertion of the orthodontic wire in each case.

Measurements

Subsequently, the 'before' and 'after' study models were measured to record tooth alignment and levelling

Table 1. ANOVA test for dental anatomical point behaviour for the upper and lower arch

	Upper whole arch			Lower whole arch			Upper anterior area			Lower anterior area		
	N*	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
Points approximation												
Superelastic	10	48.60	40.60	11	34.75	21.81	10	30.29	32.13	9	16.71	16.50
Multistranded	10	21.37	19.46	8	46.38	16.12	9	14.61	15.33	9	22.11	16.33
Stainless steel	10	29.98	18.90	6	36.42	26.23	10	31.73	43.57	8	23.68	17.19
Thermoactivated	6	23.99	15.68	7	38.87	29.13	7	31.97	20.71	5	23.27	21.49
		p = 0.13			p = 0.74			p = 0.58			p = 0.82	
Points separation												
Superelastic	3	-18.28	14.68	2	-11.57	6.11	3	-2.69	1.97	4	-9.63	9.47
Multistranded	1	-31.78	-	3	-16.41	19.44	2	-8.56	1.16	2	-27.54	0.85
Stainless steel	1	-6.62	-	5	-19.80	18.31	1	-2.33	-	3	-18.45	14.51
Thermoactivated	4	-21.97	23.90	3	-15.24	10.08	3	-18.06	20.74	5	-9.81	8.13
		p = 0.84			p = 0.93			p = 0.55			p = 0.17	

* *N* indicates number of cases in which points approximation or separation occurred.

changes, from first molar to first molar, following a similar process to that described previously.[14] Measurements were obtained using a Reflex Microscope (Reflex Measurements, Butleigh, England), from the observation and 3D digitalization of 60 anatomical points, from the mesial surface of the first permanent molar, around the dental arch to the contra-lateral molar, upper and lower. The 3-dimensional co-ordinates for each observed point were automatically recorded and stored using a COMP C3D software, specially created for the Reflex Microscope, at the Department of Dental Health and Development, Dental School, UWCM, U.K. From the recording of point co-ordinates, inter-anatomical point distances were calculated, to allow the generation of a Dental Irregularity Index (DII) for each dental arch. The differences between the DII before and after archwire insertion reflected the changes related to levelling and alignment (DAI, Dental Alignment Index). This method of evaluation was based on Little's irregularity index.[13] The major difference from Little's methodology is that in this current study, anatomical contact points were digitized in three dimensions and the process was extended to the whole dental arch. Anatomical contact points should approximate to show evidence of aligning. However, in this study, the anatomical points showed in some cases an increase in distance, what is referred to as "points separation". Statistical analysis was performed on the data collected, based on application of ANOVA and unpaired t-tests, following statistical advice.

RESULTS

Table 1 shows ANOVA analysis of data for the whole upper and lower arch. Fig 1 shows a histogram expressing the clinical performance of each type of archwire, for the whole upper arch. It can be seen that nickel-titanium wires generally demonstrated improved performance in tooth alignment, followed in order of performance by conventional steel wires, multistranded wires, and finally thermoactivated wires. However, none of the observed differences in the data were found to be at a level of statistical significance. Fig 2

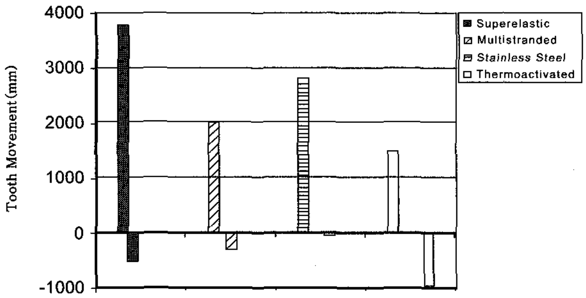

Fig 1. Clinical performance regarding tooth moving ability for the whole upper arch.

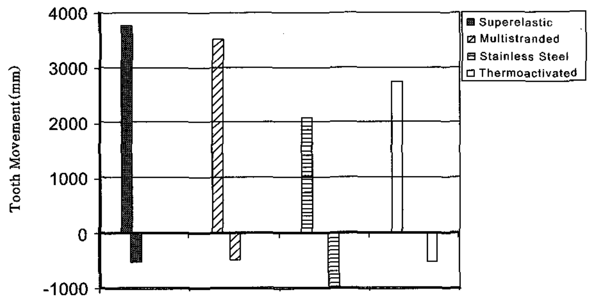

Fig 2. Clinical performance regarding tooth moving ability for the whole lower arch.

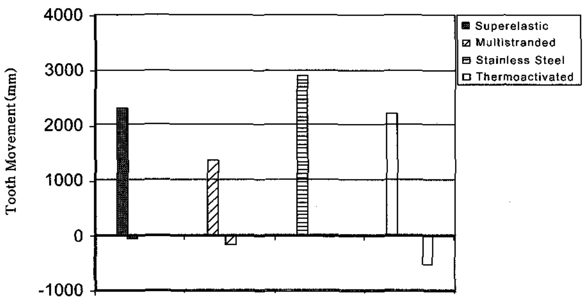

Fig 3. Clinical performance regarding tooth moving ability for the upper anterior region.

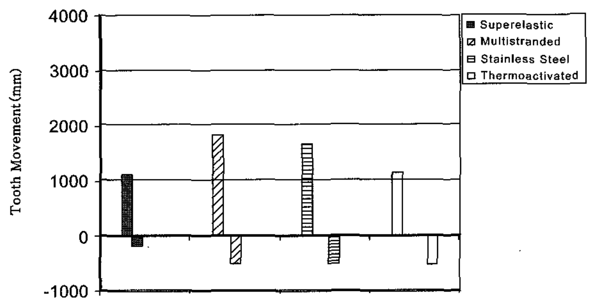

Fig 4. Clinical performance regarding tooth moving ability for the lower anterior region.

shows a histogram expressing the clinical performance of each type of archwire, for the whole lower arch. Conventional stainless steel wires showed the poorest performance in the lower arch. Fig 3 shows a histogram expressing the clinical performance of each type of archwire, for the anterior upper arch. When evaluating the whole upper arch, it is the NiTi wire that shows better performance. Fig 4 shows a histogram expressing the clinical performance of each type of archwire, for the anterior lower arch.

DISCUSSION

A way of reducing methodological bias has previously been suggested by Evans et al[14] in this type of study. Rather than anatomical structures, they used brackets as a reference in evaluating tooth movement. However, the disadvantage of that method is that tooth movement subsequent to the initial crowding cannot be evaluated. For that reason, in this study, anatomical structures were used to obtain a comparison between pre- and post-wire insertion phases.

Archwire performance in the maxillary dental arch

Clinically, it was observed that for NiTi wires, in cases where DII values were higher in the beginning of treatment, there was a higher degree of point approximation, thus a higher reduction of DII. Such clinical observation reinforces similar observations of Evans et al[14] that the superelastic properties of NiTi wires would become more evident when they were deflected at higher angles. This work would suggest that a 50 to 70 degree deflection might be necessary to make best use of the superelastic properties of such alloys. However, such angles of wire deflection to engage brackets would hardly be the norm in the oral cavity. In the normal crowding case, such archwires have limited opportunity to demonstrate their superior properties.[14] In support of this, Tonner and Waters[15] have highlighted that superelastic NiTi wires would need to be deflected at least 2 mm in a 13 mm arm lever to reach the ideal discharge plateau.

Despite the lack of any statistically significant difference between the 4 archwires aligning ability in the whole upper arch, the data distribution might suggest that thermoactivated NiTi wires could present higher levelling and aligning potential than conventional steel wire. Certainly, this view would be supported by the evidence of the physical properties.

In the upper arch, the longer inter-bracket distance would have helped the performance of the conventional steel wire by prolonging the lever arm between brackets, reducing the wire rigidity and facilitating its positioning within the slots. Evans et al[14] agreed that tooth aligning and levelling is more effective in regions of the arch with longer inter-bracket distances. Also, the longer inter-bracket distance in the upper arch may have compensated for the low elastic limit of the multistranded wires. Certainly in this trial, it was observed that multistranded wires showed a greater tendency for permanent deformation, as consequences of mastication forces or of large deflections. Such deformation is more evident in an area of longer inter-bracket distance and this can reduce the archwire's clinical alignment potential.

Archwire performance in the mandibular dental arch

Observing Fig 2 and Table 1, it can be concluded that for the lower arch, the data distribution would suggest that the wire with the higher aligning ability was the multistranded one, followed by superelastic NiTi, thermoactivated and, finally, 0.014″ conventional stainless steel. Having said this no observed difference approached statistical significance.

The shorter inter-bracket distance in the lower arch, probably reduced the permanent deformation susceptibility. For that reason, in the lower arch, the performance of the multistranded wires was better than in the upper arch, although again it should be stressed that the observed differences in the means was not of statistical significance.

Archwire performance in the maxillary incisor region

It is believed that the inter-bracket distance could have a major influence on that result, since being longer in the anterior region, it would allow for rigidity reduction and resilience increase of the wire segments between the brackets, allowing greater effectiveness for the wire. Multistranded wires, once removed from the oral cavity, showed a considerable amount of plastic deformation, highlighting its susceptibility to reduced levelling of areas with longer inter-bracket distances, where residual and permanent deformation would be more common.

Archwire performance in the mandibular incisor region

When considering the lower anterior region alone (Fig 4 and Table 1), the data distribution shows the action of the conventional stainless steel wire to be very similar to the multistranded wire and better than the NiTi wire. That was not expected, for the more evident the irregularity, the more efficient the action of the NiTi wires in tooth movement. Evans et al[14] suggested that NiTi wires are more powerful in regions of shorter inter-bracket distances, such as the region of the lower incisors. However, in the lower anterior region movement can be limited given the nearness of the cortical bone and the lower bone volume.

Overall clinical assessment of archwires

The suggested performance advantage of some archwires over others is most usually based on in vitro physical 'bench' tests. Despite the great merit of those tests in giving comparable values, they may not always represent clinical reality. Unfortunately, there is only a limited literature reporting the clinical performance of superelastic and thermodynamic wires.

If the ideal alignment archwire is the one able to produce a low and enduring load, then the multistranded steel and active NiTi wires would be the best to fulfil such requirements.[16] However, to allow a clinician to be able to choose the most appropriate material, it becomes important to clinically verify if it is more effective in terms of tooth movement, tooth and periodontal tissue preservation, comfort for the patient and cost. In reality, the practice of contemporary orthodontics is largely taking place without good robust evidence of the performances of archwires, when they are sold to the clinician. Until the speciality is convinced of the relevance of having available appropriate data on whether a new technique or material represents a true advance, orthodontic treatment will continue to be largely market driven. Ideally, all treatment should evolve from a sound hypothesis supported by robust theoretical knowledge. Clinical experience is an important parameter, which must be taken into account. However, it should be remembered that a casual observation, even when documented, does not constitute proof. All new orthodontic materials presented to the speciality for purchase, should be accompanied by good evidence to confirm that they are an advance over current materials and that they demonstrate an improvement in clinical performance.

CONCLUSIONS

A number of differences were observed in the alignment and levelling abilities of the 4 archwires included in this randomised clinical trial. Whilst one may speculate on why these differences have occurred it is important to appreciate that no statistically significant differences were found in the clinical performance of the 4 wires under these trial conditions. One may speculate that since no proven differences were found between archwire types, one should choose on the basis of value for money. However this is not the whole story and more research needs to be done particularly focussing on the clinical performance of superelastic type wires. Their true worth may not become apparent until they are used in very crowded dental arches where very displaced and rotated tooth are engaged. It is beholden to manufactures of new orthodontic materials to give clinicians more useful and clinically robust data on their products. This will allow choice to be based on likely clinical performance and relative value for money.

- 국문초록 -

교정치료 초기에 사용되는 4가지 호선의 초기 치료효과를 비교하기 위한 전향적 임상 실험 연구

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본 연구의 목적은 교정치료 초기에 사용되는 스테인레스스틸, 다가닥철선, 초탄성 NiTi, 열활동성 NiTi 재료로 이루어진 총 4가지 호선의 초기 치료효과를 비교하기 위하여 시행되었으며, 실험의 설계는 전향적 임상 실험(prospective randomized clinical trial)으로서 브라질 리오데자네이로 주립 치과대학에 내원한 45명의 고정식 교정장치 환자를 대상으로 시행되었다. 각 호선의 재료는 환자의 치열에 무작위로 배당되었는데 스테인레스스틸은 26 명, 다가닥철선은 22명, 초탄성 NiTi 는 22명, 열활동성 NiTi 는 20 명에게 할당되었고, 8주 후에 모형을 다시 제작한 후 3차원 디지털영상 장비를 이용하여 모형의 치관에 설정된 해부학적 지표의 변화를 측정하였는데 치료전 및 치료후 치열불규칙지수(Dental Irregularity Index)의 차이로 초기 교정치료 효과를 비교하였다. 분산분석을 시행하여 불규칙지수의 변화를 살펴본 결과 호선의 재료에 따른 초기 치료 효과는 유의한 차이가 나타나지 않았다.

(**주요 단어**: 교정용 호선, 전향적 임상 실험, 초기 배열, 초탄성)

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