# A clinical comparison of three aligning archwires in terms of alignment efficiency:

# A prospective clinical trial

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# ABSTRACT

**Objectives:** To clinically evaluate the effectiveness of three orthodontic aligning archwires in relation to tooth alignment speed during the initial alignment stage of treatment.

**Materials and Methods:** A consecutive sample of 74 patients requiring lower only or upper and lower fixed orthodontic appliances were randomly allocated into three different archwires (0.014-inch superelastic nickel-titanium [NiTi], 0.014-inch thermoelastic NiTi, or 0.014-inch conventional NiTi). Good quality impressions were taken of the lower arch before archwire placement (T0) and at designated serial stages of alignment (every 2 weeks: T2, T4, T6, ..., T16). The change in tooth alignment was measured in millimeters from the resultant casts using Little's irregularity index. Demographic and clinical differences among the three groups were compared with the chi-square or analysis of variance (ANOVA) test. The difference in the change of lower anterior tooth alignment over time among the three groups was explored with a Split Plot ANOVA (SPANOVA, or within- and between-groups ANOVA). The Kruskal-Wallis nonparametric test was used when data were not normally distributed.

**Results:** The SPANOVA and Wilks Lambda Multivariate test confirmed that the wire type had no influence on the rate of change in alignment (P = .98).

**Conclusion:** The three forms of NiTi wires were similar in terms of their alignment efficiency during the initial aligning stage of orthodontic fixed appliance therapy. (*Angle Orthod.* 2015;85:434–439.)

KEY WORDS: Alignment; Archwires

#### INTRODUCTION

Contemporary orthodontic treatment involves the use of both fixed and removable appliances. Fixed orthodontic appliances include a wide variety of archwires used as a means of delivering forces on

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teeth. Ideally, archwires are designed to move the teeth with light continuous forces, which may reduce patient discomfort, tissue hyalinization, and root resorption.<sup>1.2</sup> The aligning archwires are intended to be inserted into the fixed orthodontic appliance at the beginning of the treatment, mainly to correct crowding and dental rotations. The success of the orthodontic treatment may depend on the selection of the aligning archwires, it is important to know which is the most efficient during the initial aligning stage of the treatment. In order for the orthodontist to select the most appropriate archwire, it is important to understand the optimal characteristics for all of the available archwires.

Light and continuous forces are desirable to achieve physiologic tooth movement with minimum pathological effect on the teeth and their surrounding structures.<sup>1,2</sup> Clinically, this means that we need the optimal force with which to produce the fastest tooth movement with the least root resorption and/or pain for the patient. The forces delivered by the archwires depend largely on the physical properties and dimensions of

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the wire material.<sup>3</sup> An ideal aligning archwire should have a good formability, spring-back, stiffness biocompatibility, low friction, Join ability, and cost.<sup>4,5</sup>

Multistranded stainless-steel wires offering a good combination of strength and springiness were originally used as initial archwires,<sup>6</sup> but since the development of the nickel-titanium (NiTi) wires, the popularity of the stainless-steel wires has been reduced.

The use of NiTi archwires in orthodontics was first described by Andreasen and Hilleman<sup>7</sup>; these wires were manufactured as Nitinol wires. Later on came the introduction of the superelastic NiTi archwires, which were first adopted in 1985 by Burstone et al.<sup>8</sup> and Miura et al.<sup>9</sup> in Japan. Since their development, improvements in their manufacturing and composition designed to enhance their properties have been introduced. It has been suggested that because superelastic alloy archwires provide a more continuous light force to the teeth than do other alloy archwires, rapid tooth movement will result. Superelastic wires have a considerable advantage over conventional Nitinol wires in that engagement of the displaced tooth is readily achievable.<sup>10</sup>

NiTi archwires have many theoretical advantages over others in the initial alignment of the teeth. However, most of these advantages are based on in vitro testing methods, and in order for this advantage to be validated, these wires should be assessed clinically. The conclusions of some published clinical trials have not agreed with those of laboratory tests and have found no significant differences in alignment efficiency between NiTi wires and multistranded stainless-steel wires.<sup>6,10–12</sup> On the other hand, another trial<sup>13</sup> has proved that a greater amount of tooth movement occurs with superelastic NiTi wires, although the accompanying root resorption was greater.

Other studies<sup>11,14</sup> found no significant differences in the alignment speed between different NiTi wires. Bearing these studies in mind, there are no definite conclusions as to which archwire is the best in terms of alignment efficiency.<sup>15</sup> Therefore, the aim of this study is to compare clinically three types of NiTi archwires in terms of the efficiency of alignment each affords.

#### MATERIALS AND METHODS

This study was approved and supported by the Institutional Research Board at Jordan University of Science and Technology. A prospective double-blind clinical trial was conducted between January 2012 and June 2013 in private orthodontic practice clinics and graduate dental clinics at the Jordan University of Science and Technology to clinically evaluate the alignment efficiency of three orthodontic aligning archwires—conventional NiTi, superelastic NiTi, and thermoelastic NiTi—during the initial alignment stage of treatment. All archwires were from 3M Unitek<sup>™</sup> (Monrovia, Calif).

The overall study sample size consisted of 87 patients requiring lower arch only or upper and lower fixed orthodontic appliance therapy. Sample size calculation on the basis of previous studies<sup>6,16</sup> revealed that using at least 75 subjects would provide adequate statistical power (80%) to detect a significant difference between the three types of archwires (P < .05). To compensate for nonresponsive and incomplete data, 12 additional patients were recruited. Informed consent forms were obtained from the patients or the parents if the patients could not give consent. Eightyseven randomly allocated types of archwires (three types) were fitted in 87 consecutive patients, as follows: 0.014-inch superelastic NiTi aligning archwire (3M Unitek), 0.014-inch thermoelastic NiTi aligning archwire (3M Unitek), and 0.014-inch conventional Nitinol aligning archwire (3M Unitek).

#### **Criteria for Patient Selection**

Exclusion criteria for participants' selection included the following:

- 1. Patients who had undergone previous active orthodontic treatment.
- 2. Patients with spacing in the lower anterior region.
- 3. Patients whose treatment plans included extraction of a lower incisor.
- 4. Patients with a blocked-out tooth that did not allow for placement of the bracket at the initial bonding appointment.
- 5. Patients with a relevant medical history.
- 6. Patients with poor oral hygiene or periodontally compromised teeth.

Patients were matched according to age, sex, degree of initial crowding, malocclusion (incisor classification), type of treatment (extraction vs nonextraction), as well as the most displaced tooth.

Participants and outcome assessor were blinded to the allocated groups. No changes to methods were made after commencement of the trial.

# **Data Collection**

The pretreatment lower anterior crowding was assessed to determine pretreatment equivalence among the three groups. This was calculated as the difference between the available and the required arch lengths. The required arch length was calculated by summing the mesiodistal widths of the incisors and canines. The space available was calculated by summing the distance from the distal contact point of Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-14 via free access

the canine to the mesial contact point of the central incisor on both sides of the arch.

The archwire was tied at each visit with figure-ofeight elastomeric modules to achieve complete engagement, where clinically possible, and was fully retied at the follow-up appointments. If debonding occurred during treatment, rebonding was done within 24 hours; otherwise, it was considered a dropout.

#### Measurements

Good-quality mandibular alginate impressions were taken for the lower dental arch at the designated serial stages of alignment (every 2 weeks: T0, T2, T6, ...) until initial alignment was completed (0.014-inch archwire shows no deflection at any site anteriorly regardless of remaining buccal irregularities). Patients were called to remind them of upcoming appointments 1 to 2 days ahead of time. Impressions were sent to the laboratory, where they were poured with dental stone.

The principal researcher assigned an identification number to each model prior to measurement in order to mask the patient name, archwire group, and the time point during study model analysis. The models were rematched to the patient and archwire group after data collection was completed.

The change in the tooth alignment of the six anterior teeth is measured in millimeters from the resultant casts using Little's irregularity index<sup>17</sup> at each stage (T0, T2,  $\rightarrow$  T16) using a Vernier caliper accurate to 0.05 mm. There were no changes to trial outcome after trial commencement.

#### **Measurement Error**

Observer bias was reduced by ensuring that measurements were performed by a single examiner who was blinded to the patients' allocated group. All models were collected and measured in random order. To reduce the random error, duplicate readings were made for the cast series at a suitable interval. The mean value of the duplicate measurements was used in the analysis of the data. The error associated with the alginate impression and model preparation has been shown to have a 97% coefficient of reliability.<sup>11</sup> Intraexaminer reliability was determined by remeasuring 40 models 4 weeks after the original measurements were taken.

#### Statistics

Data analysis included descriptive and analytic statistics obtained with Statistical Package for the Social Sciences (SPSS) software, version 21.0 (Chicago, III). Descriptive statistics were calculated and the three archwire groups were compared for pretreatment characteristics including gender, age, treatment modality (extraction vs nonextraction), lower anterior crowding, malocclusion, Little's irregularity index, and the maximum displacement point. Data were checked for normality. Comparisons among the three archwire groups were conducted using the analysis of variance (ANOVA) or chi-square test, depending on the examined variable (numerical or categorical). The difference in the change of lower anterior tooth alignment over time among the three groups was explored with a Split Plot ANOVA (SPANOVA). SPANOVA is an extension to the repeated-measures design with a mixed between-within subjects' ANOVA. The Kruskal-Wallis nonparametric test was used when data were not normally distributed. A significance level of P < .05 was used for all tests.

# RESULTS

A total of 87 patients were recruited. Eleven patients were excluded from the trial because of failure to attend the clinic at the correct time. Two more patients were excluded because of bracket debond where rebonding was not performed within 24 hours. Two archwires (thermoelastic) were permanently deformed posteriorly during the observation period, which necessitated their replacement.

The baseline demographic and clinical characteristics for the three groups are shown in Table 1. In total, the sample consisted of 28 males and 46 females, with a mean age of 18.6 years (standard deviation [SD], 4.6 years). No variable was identified to discriminate the three groups. ANOVA and chi-square tests confirmed no significant differences between the groups in relation to age (P = .26), gender (P = .86), treatment modality (P = .96), pretreatment degree of crowding (P = .96), class of malocclusion (P = .883), or maximum point of displacement (P = .11).

Within each group, the mean irregularity score has reduced significantly over time (Figure 1). When comparing the mean irregularity scores at all time points, no statistically significant differences among the three groups at any time point were found (Kruskal-Wallis test). A SPANOVA Multivariate test using Wilks Lambda confirmed that the wire type had no influence on the rate of change in alignment (P = .98) (Table 2).

The mean time (weeks) until complete alignment of lower incisors was achieved for the three groups is shown in Table 3. There was no significant difference among the three groups, with a mean time of 9.84 weeks (one-way between-group ANOVA; P = .79).

# DISCUSSION

This study demonstrates that there is no significant difference among the three types of NiTi wires

	Table 1.	Basic	Characteristics	of the	Three	Groups <sup>a</sup>
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	Superelastic N = 25	Thermal $N = 25$	Nitinol N = 24	P Value*
Gender: male/female_No	10/15	10/15	8/16	86
Age in v. mean (SD)	19.36 (4.5)	17.44 (5.4)	19.29 (3.9)	.26
Class of malocclusion, n (%)	()		()	
Class I	6 (24)	8 (32)	10 (41.7)	.883
Class II, division 1	9 (36)	7 (28)	6 (25)	
Class II, division 2	1 (4)	2 (8)	1 (4.2)	
Class III	9 (36)	8 (32)	7 (29.2)	
Extraction, n (%)	12 (48)	11 (44)	11 (45.8)	.96
Crowding, n (%)				
Mild (1–4 mm)	12 (48)	13 (52)	13 (54.2)	.96
Moderate (5-8 mm)	11 (44)	11 (44)	10 (41.7)	
Severe (>8 mm)	2 (8)	1 (4)	1 (4.2)	
Maximum displacement, mean (SD)	2.3 (1)	1.9 (1)	1.7 (0.78)	.11

<sup>a</sup> The three groups are comparable with regard to basic characteristics. SD indicates standard deviation.

\* P value for comparison of group means by chi-square test or analysis of variance (ANOVA) test.

(conventional, superelastic, thermoelastic) in terms of alignment efficiency.

All patients received  $0.022 \times 0.028$ -inch slot Gemini 3M (Unitek) Roth Rx brackets, and a supply of relief wax was provided. As the first stage of the fixed appliance therapy is concerned with tooth alignment, the effectiveness of this stage depends on several variables. In addition to the biological factors (periodontal health, cellular and connective tissue response), which are outside the orthodontist's control, the choice of the bracket system and archwires has a direct influence on the success of orthodontic tooth movement. As our study aims to compare different archwires, it is important to standardize all other possible factors that determine the rate of tooth alignment, including the bracket span.



Figure 1. Change of the mean irregularity scores over time.

The introduction of NiTi archwires has revolutionized the field of orthodontics as a result of these archwires' ability to deliver light continuous forces, thus increasing the interval between appointments. Superelastic NiTi archwires (Active NiTi) have been widely accepted for initial alignment of malocclusions, mainly because of their unique properties of superelasticity and shape memory. These are particularly useful where large deflections are necessary to align severely malpositioned teeth. Although superelastic NiTi wires show different behavior than do conventional NiTi wires under laboratory test conditions, 1,9,18,19 the clinical advantage of these wires could not be verified in this clinical trial. It has been speculated by Drescher. through a personal communication with Evans and Durning,<sup>10</sup> that in order to reach the superelastic plateau of the wire, large deflections (50-70° bending angle) would be necessary. Such deflections are rarely encountered clinically. One should not also forget the individual variations in the metabolic response within the periodontal ligament and bone, which might have masked any possible difference.

This is the first clinical trial to compare the alignment efficiency among the three types of NiTi wires. Previous studies<sup>10,12</sup> compared the aligning capabilities of superelastic NiTi wires and multistranded stainlesssteel wires and failed to demonstrate any significant difference. In contrast, West et al.<sup>6</sup> found that superelastic NiTi wires produced improved alignment in the lower labial segment only, when compared to multiflex stainless-steel wires, suggesting that the improved physical properties of the superelastic alloy are most potent where the interbracket span is reduced, as in the lower incisor segment.

On the other hand, O'Brien et al.<sup>11</sup> compared the speed of initial tooth alignment between 0.016-inch

Table 2.	Irregularity	Score	Comparison	Between	Three	Archwire	Groups <sup>a</sup>
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	Superelastic N = 25	Thermal $N = 25$	Nitinol $N = 24$	Р
Alignment, mean (SD)				
Time 0	5.996 (2.81)	5.968 (2.78)	5.996 (2.81)	Time <i>P</i> < .0005
8 wk	1.232 (1.20)	1.108 (1.32)	1.246 (1.07)	Time $ imes$ Type .98
16 wk	0.276 (0.28)	0.296 (0.27)	0.354 (0.299)	
Alignment, med (P25–P75)*				
Time 0	5.2 (3.65-7.45)	4.9 (4.05-7.3)	5.3 (3.725–7.95)	.99
2 wk	4 (2.15–6)	3.9 (3.3–6.3)	3.75 (2.5–6.3)	.81
4 wk	2.6 (1.65-4.75)	2.8 (2-4.3)	2.45 (1.2-4.825)	.72
6 wk	1.2 (0.75-3.95)	1.6 (1-2.6)	1.45 (0.6–3.6)	.95
8 wk	0.6 (0.4–1.9)	0.7 (0.2-1.6)	0.95 (0.5-1.725)	.68
10 wk	0.4 (0–0.8)	0.5 (0-0.65)	0.5 (0-0.875)	.91
12 wk	0.4 (0–0.55)	0.4 (0-0.5)	0.4 (0-0.755)	.78
14 wk	0.4 (0-0.55)	0.3 (0-0.5)	0.4 (0-0.675)	.66
16 wk	0.2 (0-0.5)	0.3 (0–0.5)	0.4 (0–0.575)	.68

<sup>a</sup> The assumptions for normality are not met. There is no nonparametric alternative to Split Plot analysis of variance (SPANOVA). SD indicates standard deviation.

\* SPANOVA also called within- and between-groups ANOVA.

superelastic NiTi and Nitinol archwires and found no significant difference between the two. However, the clinical impression was that the superelastic archwire proved superior to the Nitinol because it was more readily engaged with grossly displaced teeth. Moreover, there was no significant difference in crowding alleviation between 0.016-inch CuNiTi (thermoactive wire) and 0.016-inch NiTi wires.<sup>14</sup>

As was the case with earlier studies,<sup>11,12,14</sup> we assessed the tooth alignment using Little's irregularity index, which addresses the sum of the five contact-point displacements for the lower anterior teeth. Other studies<sup>6,10</sup> used the index of tooth alignment, which assesses the contact-point displacements for the whole dental arch and could be a more useful measure, especially when irregularities are in the posterior dental arch region. Since the posterior tooth alignment with the initial aligning wire would be minimal, our study was limited to the anterior segment.

There are two main methods for measuring the amount of irregularities: direct/indirect measurement with a vernier caliper<sup>12,14</sup> and indirect measurement in three dimensions using specialized instruments such as the Reflex Metrograph<sup>11</sup> or the Reflect Microscope.<sup>6</sup> Although the use of such instruments would give a full picture (three-dimensional) with regard to contact point

**Table 3.** Time Until Complete Alignment (wk) and *P* Value (One-Way Between-Groups Analysis of Variance [ANOVA])

	Superelastic $N = 25$	Thermal N = 25	Nitinol $N = 24$	Ρ
Wk until complete				
(standard deviation)	10.1 (2.3)	9.6 (2.3)	9.8 (2.8)	.79

movements, it would also add to the cost of a clinical study. In our study, measurements using a vernier caliper were done indirectly on dental casts in a random order by one researcher who was blinded to allocation to reduce bias.

#### CONCLUSION

 This study demonstrates that there is no significant difference among the three types of NiTi wires (conventional, superelastic, thermoelastic) in terms of alignment efficiency or the time required to achieve complete alignment during the initial aligning stage.

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