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Does the transition temperature of Cu–NiTi archwires affect the amount of tooth movement during alignment?

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Structured Abstract

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Objectives – To examine whether the transition temperature of Cu–NiTi archwires has an effect on the tooth movement during the alignment phase of orthodontic treatment.

Design – 'Split mouth' design in randomly selected patients.

Setting and Sample Population – The Department of Orthodontics, School of Dentistry, University of Aarhus. Fifteen randomly selected patients with identical level of irregularity in the alignment phase of their treatment.

Experiment Variable – Specially manufactured Cu–NiTi archwires for the upper arch were inserted. These consisted of two separate halves, each with its own transition temperature, respectively 27° and 40°C, and clamped together in the middle.

Outcome Measure – The tooth movement, expressed as two translations and a rotation, in the occlusal plane was measured from the patients' intraoral photographs taken upon insertion of the archwires and again after 1 month.

Results – Tooth movements tended to be larger on the 40°C-side, however only in case of the total translation of the premolars was this difference significant. In general, patients had not noticed any difference between the two sides of the archwire, although one patient stated the 27°C-side to be more comfortable as the 40°C-side had bothered her when drinking hot beverages.

Conclusion – The transition temperature of Cu–NiTi archwires has indeed an effect on the amount of tooth movement during alignment. However, the differences are so small though that it is the question whether they can be noticed clinically. The study corroborates the trend towards the use of lower forces within orthodontics.

Key words: alignment; archwires; Cu–NiTi; thermo-elasticity

Introduction

Heat-activated superelastic NiTi wires have been gaining popularity in the orthodontic practice during the last decade. These so-called third generation wires have been marketed with clinically useful shape-memory in addition to the low stiffness, high springback, and superelasticity of the first and second generation NiTi wires. Although these earlier generation wires also displayed shape-memory behavior, the required temperature range for the transition of the martensitic to the austenitic phase, which forms the basis of the shape memory phenomenon (1), was too low to be practical for orthodontic treatment (2,3). Specifically, the addition of copper to the alloy increases the transition temperature range to around the level of the intraoral temperature. An additional effect of the added copper is that the temperature hysteresis between the formation of austenite upon heating and the formation of martensite upon cooling is narrower than for normal NiTi alloys (4) thus, enabling a more well-defined control of the shape memory behavior. In practice, the patient can regulate him/herself the activation and de-activation of the archwire by rinsing with and drinking of warm and cold beverages.

The scientific basis for the use of thermo-responsive wires is that bone remodels more effectively when subjected to a dynamic load in comparison to a static one (5). In case of alignment during orthodontic treatment this principle would then also apply to the alveolar bone around the moving teeth, and an archwire exerting a dynamic load might result in a more desirable tissue reaction than a conventional archwire exerting a static load. A dynamic load can be achieved by heat-activation and the shape memory behavior of a NiTi wire. Although the effect of temperature on the mechanical properties of heat-activated archwires has been evaluated extensively (6–8), still no clear picture exists of how the different transition temperatures of commercial heat-activated archwires, typically 27°, 35° and 40°C, influence the orthodontic treatment. It was, therefore, the aim of this study to compare in a so-called split mouth design the amount of tooth movement measured during the alignment phase of orthodontic treatment in patients fitted with specially manufactured archwires with different transition temperatures on their two sides.

Materials and methods

In 15 randomly selected patients with identical level of irregularity the alignment was performed with specially manufactured Cu–NiTi archwires for the upper arch (Ormco, Glendora, CA, USA). These consisted of two separate halves, each with its own transition temperature, color-coded red (27°C) and black (40°C) and clamped together in the middle.

Tooth movement in the occlusal plane was measured on intra-oral photographs of the upper arch taken prior to and after alignment (Fig. 1). For calibration and reference purposes of these intra-oral photographs, Optosil (silicone material Larbosil, Dreve-Dentamid GmbH, Unna, Germany) impressions were made of the patients' palates on which a plexiglass plate was fixed, parallel to the occlusal plane. On this plate a grid of perpendicular lines was drawn at 5 mm intervals. The intra-oral photographs were then taken with the

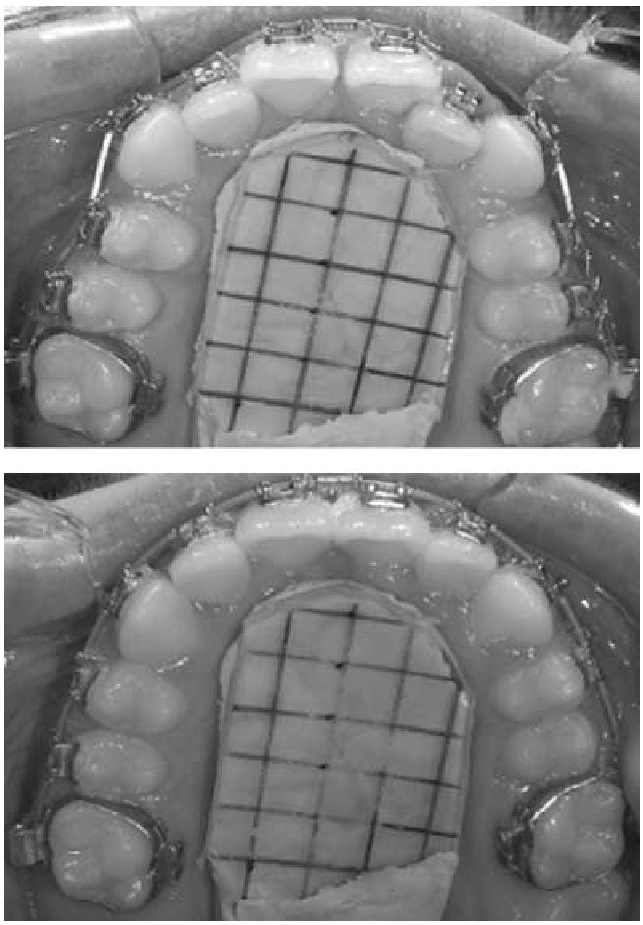

Fig. 1. Intra-oral photographs of a patient's upper arch at the start of the alignment phase (top) and 3 weeks later (bottom).

patients wearing the palate cast and plate. The duration of aligning varied between 3 and 5 weeks.

On the photographs the grid provided a reference system which is stable with regards to the pre- and post-treatment photographs. The photographs were taken with a digital camera and the digital images were subsequently analyzed with image analysis software (SigmaScan Pro 4.0, SPSS Inc., Chicago, IL, USA), running on a Pentium II PC. After verifying the scaling factor and aspect-ratio of the images, lines were drawn from the most posterior central point on the grid (the origin of an XY-coordinate system) to the wings of all brackets (Fig. 2).

By digitizing the origin and the points on the wings of the brackets, the length and the accompanying angle α of the lines connecting the origin with the wings of the brackets were then automatically measured. With this length and angle, the x- and y-coordinates of the points on the wings of the brackets were calculated, whereby the x-axis is directed laterally and the y-axis anteriorly. Furthermore, the two points on the wings of the same bracket determined the angle of the bracket in the plane of the upper arch.

Finally, by comparing the coordinates of the points on the wings of the brackets and the brackets' angulations from the pre- and post-treatment photographs the translation, both in x- and y-direction and the total, as well as the rotation of the individual teeth in the plane of the upper arch could be calculated. For both translations and rotations only the absolute values were used as the difference in the amount of movement was the subject of study, rather than the direction.

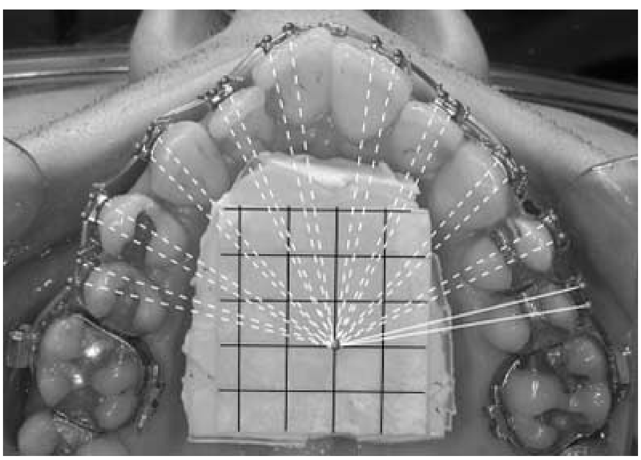

Fig. 2. Intra-oral photograph of a patient's upper arch with the palatal cast and grid. The lines from the origin of the coordinate system to the wings of the brackets are superimposed.

For the comparison between the two sides of the archwire, the translations and rotations of the two incisors and the two premolars on the left and right side were averaged and a non-parametric (Wilcoxon signed ranks) test was performed and statistical significance was assumed for $p < 0.05$.

Results

The statistics for the translations and rotations of the considered teeth are shown in Fig. 3, split into the three groups of teeth (incisors, canines and premolars). For all teeth the translations in the y-direction (anterior/posterior) were generally seen to be larger than the translations in the x-direction (lateral/medial). Within the three groups of teeth, translations were largest for the incisors and varied between 0.7 and 4.8 mm. The largest rotations, up to 15°, were observed for the canines.

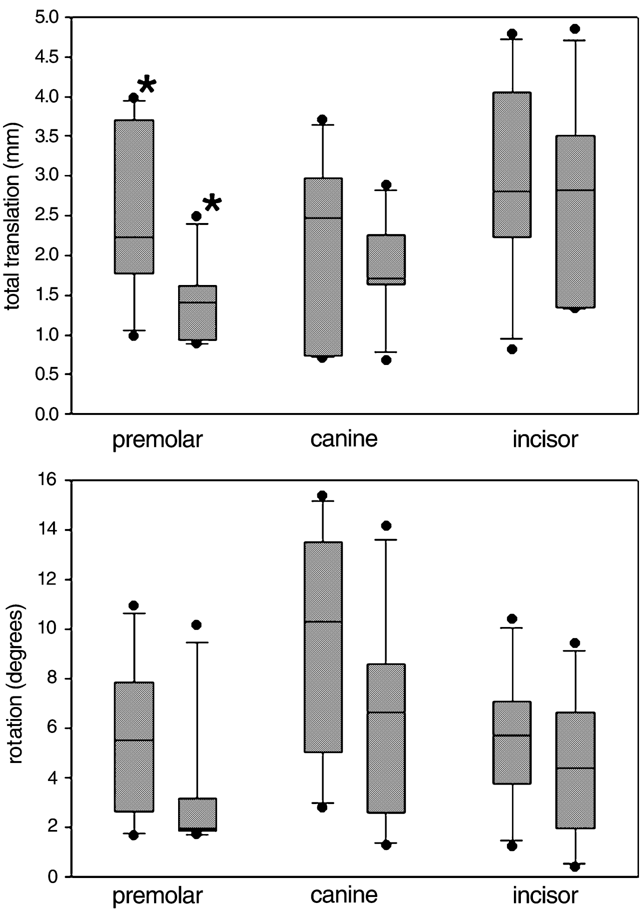

Fig. 3. Statistical overview of the total translations (top) and rotations (bottom) of the considered teeth. The left and right columns refer to the sides with the 40° and 27°C wires, respectively. *Statistically significant difference between the two sides ($p < 0.05$).

Comparing the translations and rotations between the red and black sides of the archwire, a statistically significant difference was found only for the total translations of the premolars. When pooling the data of incisors, canines and premolars, there was a statistically significant difference in both the translation in the *y*-direction and the total translation. In both cases, the average total translation was 2.5 mm on the 40°C side vs. 1.4 mm for the premolars alone and 1.9 mm for all teeth on the 27°C side. Although on average the rotations were in general larger for all teeth on the 40°C side, no statistically significant difference was found here.

When the patients were asked specifically whether they had experienced a difference in both sides of the archwire: in general, they had not, yet one patient stated that she had experienced the 27°C side to be more comfortable as the 40°C side bothered her when drinking hot beverages.

Discussion

In a split-mouth design study the effect of two different transition temperatures of Cu–NiTi archwires has been evaluated by measuring the amount of tooth movement on both sides of the upper arch during the alignment phase of orthodontic treatment. One side of the archwire had a transition temperature just below mouth temperature, while the other side had a transition temperature above it (27°C vs. 40°C). At room temperature both wires would be in a partly martensitic and partly austenitic phase, while at mouth temperature, the low-temperature wire would be entirely transformed into its austenitic phase, while the high-temperature wire would still be partially martensitic and partly austenitic. As NiTi in its martensitic phase is less stiff than in its austenitic phase, force levels in the low temperature wire would be higher for the same amount of deformation.

The displacement of teeth was measured by comparing the different positions of the wings of the brackets in the before and after upper arch intra-oral photographs. This enabled the *in vivo* measurement of the translation and rotation of the teeth in the occlusal plane of the upper arch. Although this method obviously lacks the third dimension, which could have been included by performing the measurement on pre- and post-treatment dental casts, it was quick and less bothering for the patient. Furthermore, in the alignment phase the largest components of movement would be expected to occur in the occlusal plane.

For calibration and reference purposes of the intraoral pictures, a silicon impression was made of the medial palatal rugae. To this impression a grid with 5×5 mm parallel lines was fixed, which served to calculate the scale factor of the pictures as well as to correct for the tilting angle of the occlusal plane in relation to the plane of the picture. The medial aspect of the rugae have generally been reported as stable structures during orthodontic treatment (9–12). In this study, the time between the before and after photographs was only 3–5 weeks and it may, therefore, be safely assumed that the palatal cast and grid can be seen as a stable reference.

Small differences were found for the amount of tooth movement on either side of the archwire. Both larger translations and rotations were observed on the side with the high-temperature wire. For the premolars the larger translations were even statistically significant. However, in an absolute sense the differences were only in the order of a fraction of a millimeter for the translations and 2–3° for the rotations, so the question is whether they would be noticed in clinical practice. Not only the force delivery, but also the force level differs between the two sides. Since it has recently been shown that the tooth movement 'with bone' requires considerably lower force level than previously anticipated (13), the present result underlines the usefulness of the 40°C wire specially for adult patients with a reduced periodontium.

Conclusion

The transition temperature of archwires does have an influence on the amount of tooth movement during alignment. There is a trend for larger translations and mesial rotations for the high-temperature side of the archwire (40°C), yet only for the total translation of the premolars is this difference statistically significant. The differences are so small though that it is the question whether they can be noticed clinically. The study corroborates the trend towards the use of lower forces within orthodontics.

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