Force Deflection Behaviors of NiTi Archwires at Different Bending Conditions: A Mini Review

A. Munir and M. F. Razali

Abstract This study's objective is to describe the force–deflection behaviour of NiTi archwires when bent into different configurations. NiTi archwires revolutionised orthodontics by generating light, constant force across a larger displacement range than conventional stainless steel archwires. This capacity to provide constant mild force during orthodontic treatment improves treatment efficacy, especially during the aligning and levelling phase. In order to comprehend the force–deflection behaviour of NiTi archwires in bracket settings in light of the varied malocclusion statuses of different patients, several settings have been studied. It is observed that the force behaviour of NiTi archwires varies with the extent of bending, distances specified between brackets, bracket material and ligation technique. This knowledge on the magnitude and trend of force variation is essential for orthodontists to identify archwires and brackets according to the irregularity state of the teeth, hence enhancing the patient's treatment experience.

Keywords Force–deflection behavior · Orthodontic bracket · Bending · NiTi archwires

1 Fixed Appliance Therapy

Fixed appliance therapy is utilised in most orthodontic treatment as it improves proper tooth alignment [1]. The archwire and the metal bracket are the primary components of the fixed appliance utilised in this treatment. After attaching the dental brackets to the tooth, an archwire is carefully positioned inside the bracket slot by following the irregularity of the bracket location, causing local bending along the length of the archwire. The archwires are then locked inside the slot using small rubber rings, fine archwires, or a metal door, depending on the chosen bracket's ligation type. Throughout the length of therapy, as the archwires attempt to restore their straight shape, the

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malpositioned tooth is gradually dragged downwards in the bending recovery direction. For the initial and alignment phases of orthodontic treatment using edgewise appliances, it is believed that the shape memory and superelastic properties of NiTi alloy archwires correspond to physical properties that provide light, continuous force for tooth movement [2].

2 Application of NiTi Archwires in Orthodontic Levelling Treatment

Orthodontic therapy is provided in stages. First, the teeth are aligned and levelled, next the bite is corrected (the upper and lower teeth are made to fit together), and last, the spaces between the teeth are closed. The superelastic NiTi archwires have been a popular option for the alignment and levelling stage of orthodontic treatment, as this material offers an extraordinarily broad activation range at a lower and more consistent force magnitude. Most research on the biomechanics of orthodontic therapy have focused on the early stage of treatment. The most often replicated scenario is the levelling treatment of a severely misplaced canine [3, 4].

After being engaged to each bracket, the unloading of the archwires, accompanied with tooth movement, causes a sliding motion of the archwires within the neighboring bracket slot. Figure 1 depicts the friction component formed at the archwires-bracket interface during the recovery of archwire curvature in the bracket system. The NiTi archwires' force is dependent on the strength of both resistance components encountered during sliding mechanics because of the requirement of sliding motion during levelling [5]. Additionally, the NiTi application proved safe and facilitated long-term oral intake in patients with difficult-to-treat hypopharyngeal or cervical esophageal strictures, hence eliminating the need for periodic dilations [6].

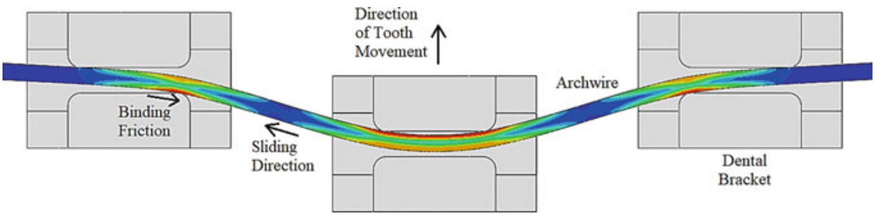

Fig. 1 Schematic representation of sliding friction component in a three-bracket system

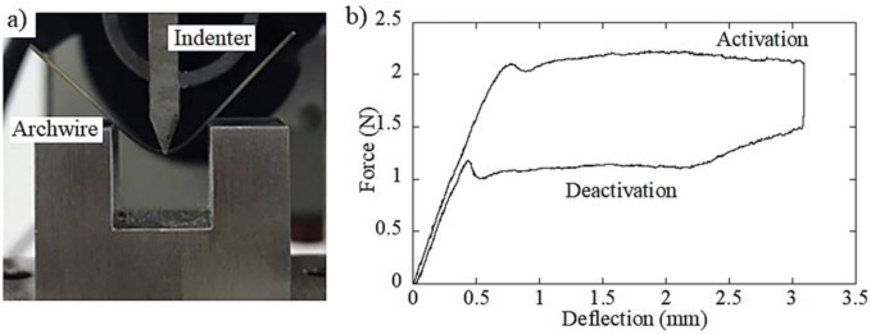

Fig. 2 Simple bending of orthodontic archwires: **a** three-point bending model and **b** force–deflection of NiTi archwire in a three-point bending model

3 Archwires Bending in Three-Point Bending System

Figure 2a illustrates how the force–deflection of orthodontic archwires has been tested for years using a standard three-point bending test. Even though this test does not reflect the actual bending environment in the mouth, it has been utilised extensively for the convenience of comparison between research. Figure 2b shows the force–deflection characteristics of nickel titanium (NiTi), as determined by a standard three-point bending test. Observations indicate that NiTi archwires produce a lighter, more consistent force over a broad deflection range. Despite the existence of two force levels on the force–deflection curve, the section of interest is the unloading course because it indicates the amount of the force transferred by the archwires to the teeth [7, 8].

4 Archwires Bending in Bracket System

After discovering the significance of contact friction during levelling treatment, researchers began including brackets into bending study experimental setups. Figure 3a depicts the typical three-bracket bending arrangement used to examine the force deflection of archwires. Most of the research performed for the wire bending test in bracket arrangement has concentrated on minor archwire deflection, often 2.0 mm or less. Research work considering the small deflection bending reported that the NiTi archwires exhibited a consistent force throughout the deactivation course [9]. Recent expansion of bending testing to accommodate deflections greater than 3.0 mm such reported in [10] is a relatively latest improvement. As seen in Fig. 3b, the force of the archwires varied throughout the activation and deactivation of the bending load. This trend in gradient force was attributed to the sequential production of binding friction in relation to the rise in archwire deflection.

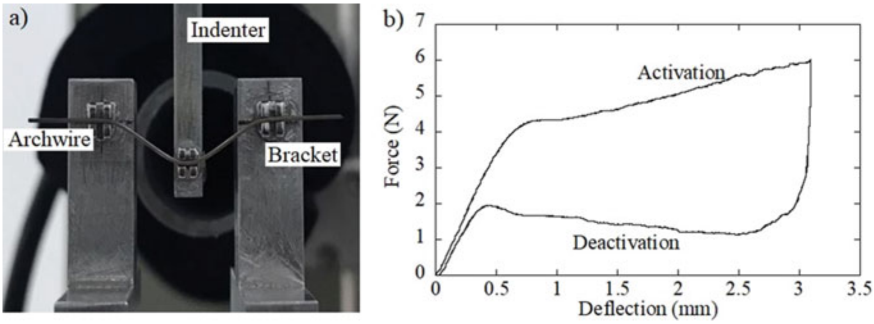

Fig. 3 Modified bending of orthodontic archwires: **a** three bracket bending model and **b** force–deflection of NiTi archwires in a three-bracket bending model

Early archwire force evaluation is essential to measure the amount of force being transferred to the teeth during orthodontic treatment. In order to move the misaligned teeth effectively, force must be used within an appropriate force range. Because the friction of the bracket changes the continuous force behaviour into a slope, this force prediction method is more difficult in bracket systems. Archwires can vary substantially in their ability to exert force during the course of therapy, which is not ideal for tooth movement.

4.1 Archwires Deflection

In-vitro experiments on the vertical displacement of dental brackets have been conducted at numerous deflection magnitudes ranging from 0.5 to 6.0 mm [11]. According to studies, the bracket displacement magnitude modifies the interaction between the archwires and the bracket slot, hence altering the force–deflection trend. Razali et al. [12], who investigated the force–deflection behavior of NiTi archwires at different deflections, found that the archwires exhibited variation in unloading force magnitude as it recovered from 3.0 and 4.0-mm deflections.

4.2 Inter-Bracket Distance

Inter-bracket distance is an additional component that is frequently overlooked while studying the force–deflection behaviour of NiTi archwires [13]. Inter-bracket distance is the distance between the midpoints of the teeth over which the bracket is placed during the installation of a fixed appliance system. Sathler et al. [14], who studied the force deflection of NiTi archwires at various inter-bracket intervals, discovered that the deactivation force varied between 66.34 and 179.28 cN. The author drew the conclusion that force deflection was not highly reliant on inter-bracket distance after seeing a narrow force fluctuation during testing.

4.3 Bracket Material

The rising popularity of aesthetic brackets in orthodontic treatments, especially among young adult patients, is due to their natural appearance. The functionality of beautiful brackets has been the subject of fewer investigations than that of ordinary brackets. Baccetti et al. [15] found that bending 0.36 mm-NiTi archwires in the presence of ceramic brackets required a larger activation force of 1.10–1.20 N than bending the same archwires in the presence of stainless-steel brackets (0.10–1.20 N). Even though the difference in force was not statistically significant, the increased activation force needed when employing ceramic brackets at each tested deflection of 1.50, 3.0, 4.5, and 6.0 mm underlined the significance of binding friction to the archwires forces.

4.4 Ligation Technique

Several researches have considered the influence of ligation on the force released to the teeth by NiTi archwires. Baccetti et al. [16] examined the pressures released by 0.3-mm NiTi archwires prior to bending while utilising self-ligating and traditionally ligated brackets. At a minor deflection magnitude of 1.5 mm, the differences between the two bracket systems' deactivation forces were minimal. At 4.5 mm of archwire deflection, the self-ligating system produced a positive force of 1.2 N whereas the traditional system produced zero force. The author noted that the added friction from the elastic ties increased the total sliding resistance, hence decreasing the springback potential of the archwires.

5 Conclusion

The force magnitude and behaviour of NiTi archwires are contingent on the bending test configuration. In a three-point bending arrangement where the influence of friction on force magnitude is negligible, NiTi archwires can only generate a light and continuous force. In the bracket system, the force released by the archwires is dependent on the characteristics and arrangement of the brackets, with a greater force anticipated in cases requiring greater archwire deflection, smaller distances between brackets, the use of conventional ligation technique, and the application of ceramic-based brackets.

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