

# Properties of crimpable archwire hooks: a laboratory investigation

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**SUMMARY** The aim of the present study was to utilize a strain gauge, which enabled the force applied to produce firmly attached crimpable hooks to rectangular stainless steel archwires, to be measured. *In vitro* testing of two hooks, American Orthodontic (AO) and TP Orthodontic (TP), and two dimensions of stainless steel archwire,  $0.019 \times 0.025$  and  $0.018 \times 0.025$ -inch, was carried out using an Instron Universal Testing machine.

The results demonstrate that there was a significant difference in the behaviour of the two types of crimpable hooks, with almost twice the force needed to dislodge the TP hooks compared with the AO hooks (11.7 and 6.22 N, respectively). When using TP hooks attached to either  $0.019 \times 0.025$  or  $0.018 \times 0.025$ -inch stainless steel wires, the archwire size makes little difference to the force required to produce movement. The clinical significance of these findings is discussed.

## Introduction

The introduction of the pre-adjusted edgewise orthodontic bracket system (Andrews, 1972) has simplified the construction of orthodontic archwires. With individual tooth prescriptions being incorporated into the bracket design, archwire fabrication has been considerably simplified. This permits the placement of archwires, devoid of any loops or customizing bends, that allow free sliding of either individual teeth (e.g. canine retraction) or groups of teeth (e.g. closure of residual extraction spaces) along the archwire. The commonly used force delivery systems involve either elastomeric materials or nickel-titanium closed coil springs (Nattrass *et al.*, 1997), activated between the posterior anchorage units and the labial segment, either directly to attachments on the teeth or, more usually, to hooks on the archwire.

Methods of applying traction to the archwire include fabricated tieback loops, soldered brass hooks, and the use of pre-posted archwires. Tieback loops are difficult to bend in preformed archwires and negate many of their advantages.

Soldering requires chairside or laboratory equipment, is time-consuming, and may lead to annealing of the archwire (Davies *et al.*, 1982; Alger, 1987). The use of pre-posted wires requires a large inventory of stock and has cost implications. Crimpable archwire hooks allow quick and simple placement of the hooks in the desired position with the archwire in or out of the mouth. They have the potential for cost saving both in time and materials, and are associated with minimum discomfort. Excessive force during crimping can cause both gabling of the wire and the introduction of unwanted force into the wire (Evans and Jones, 1991). Griffin and Ferracane (1998) examined the effect of the addition of sandblasting and/or dental adhesives on the stability of the crimpable hook when positioned and crimped onto surgical archwires. The combination of sandblasting and dental adhesive increased the force required to dislodge the hook by a factor of 10 (Griffin and Ferracane, 1998). Little research has been undertaken to evaluate the resistance to sliding of newly introduced crimpable archwire hooks, despite their extensive use in everyday clinical practice.

The aims of this laboratory-based research project were:

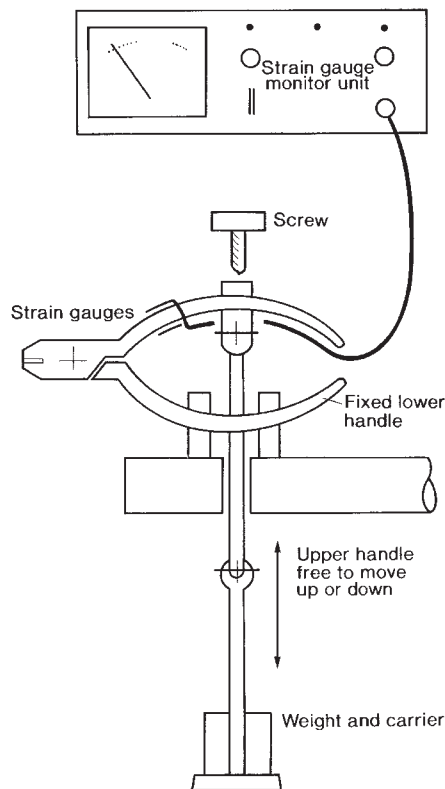
- (1) to produce a pair of crimp hook pliers to measure the 'crimping force';
- (2) to determine the 'typical crimping force';
- (3) to compare the force required to move two different types of crimpable hooks;
- (4) to compare the effect of wire dimensions on the force required to move a single type of hook.

### Materials and methods

Crimpable hooks, from TP Orthodontics (LaPorte, Indiana, USA) and American Orthodontics (Lane End, High Wycombe, UK), were investigated. In order to be able to control and measure the force applied during the crimping process, a pair of strain gauges were bonded in a half-bridge configuration to the crimping pliers as shown in Figure 1. The system was calibrated by applying dead loads to the weight carrier. A predetermined load can be applied by adjusting the screw.

A pilot study was carried out to determine the typical force applied clinically, at the chairside, to produce firmly attached hooks. Two operators each attached 10 TP hooks to a length of  $0.019 \times 0.025$ -inch stainless-steel wire out of the mouth and the applied force was measured using hand-held calibrated TP orthodontic pliers. The average force value was found to be 18 kg. No wire showed any evidence of gabling at this magnitude of force.

In order to compare crimpable hooks from different manufacturers a single operator (AJ), utilizing the recommended pliers, tested 30 hooks of each type. A 4-cm length of  $0.019 \times 0.025$ -inch stainless-steel wire was cleaned with ethanol and allowed to air dry. The hook was then attached to the wire and a force value of 18 kg applied using strain gauge calibrated pliers (Figure 2). The wire was then mounted in an Instron Model 1193 Universal Testing machine (Instron Corporation, Canton, Massachusetts, USA) with a 0.7-mm loop attached from the hook to the load cell (Figure 3). The force required to move the hook was then determined at a rate of 0.5 mm/min.



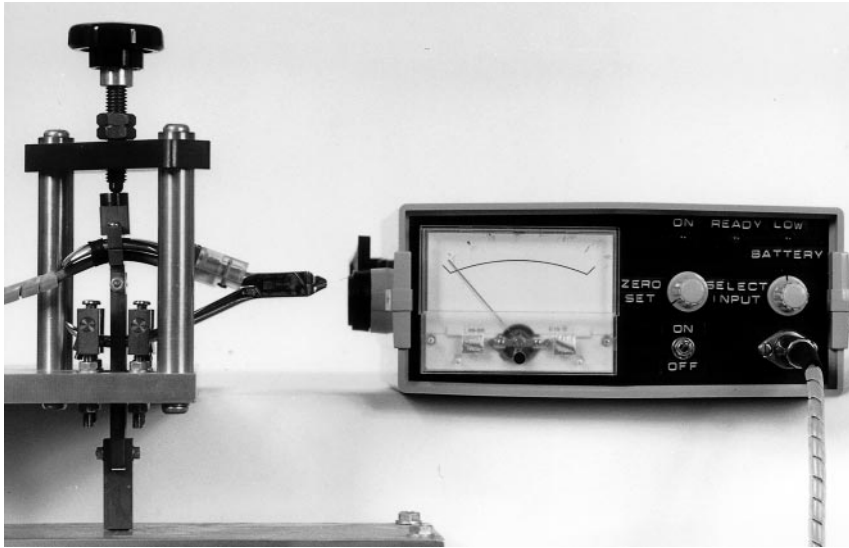
**Figure 1** Schematic diagram illustrating how the force applied during the crimping process was controlled and measured using a pair of strain gauges bonded in a half-bridge configuration to the crimping pliers.

The above procedure was repeated using 30 TP hooks with a 4-cm length of  $0.018 \times 0.025$ -inch stainless-steel wire.

### Results and data analysis

Data was analysed using Stata Version 4.0 (Stata Corp., Texas, USA). Significance was predetermined at  $\alpha = 0.05$ . The Shapiro–Francia test was used to test the data for normality. There was no significant difference in the crimping force applied by the two operators and data was normally distributed.

The mean crimping force and standard error of the mean were 18.2 and 0.44 kgf, respectively. However, a log transformation was necessary to transform the force required to slide the hooks to normality. Univariate summary statistics are

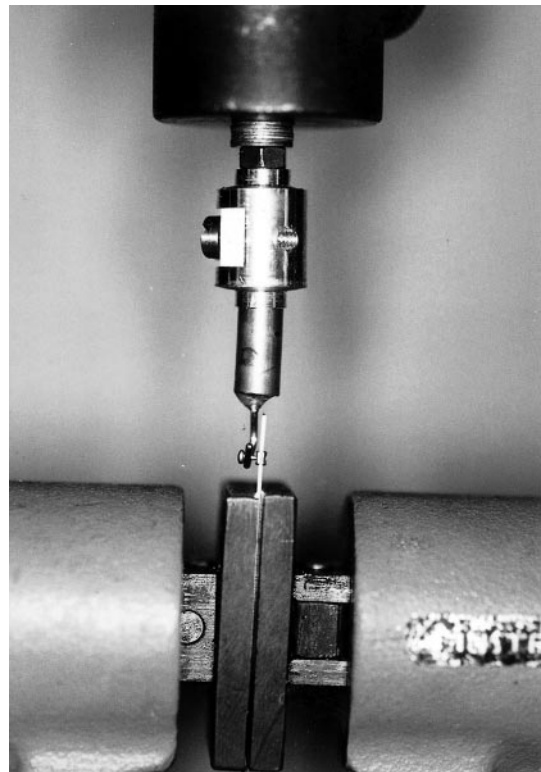


**Figure 2** Custom-made jig and strain gauge for the attachment of crimpable hooks to archwires using a predetermined force.

given in Table 1. A one-way analysis of variance showed there to be a significant difference between the three groups ( $F = 9.22$ ,  $P > F = 0.001$ ). Bonferonni's multiple comparison of means test indicated a significantly higher force was required to slide TP compared with AO hooks on the same dimension wire. There was no significant effect of wire dimension on the force required to slide TP hooks (Table 2). A retrospective calculation showed the power of this test to be 87 per cent.

### Discussion

No study has previously investigated the magnitude of force used by clinicians to apply crimpable archwire hooks. Evans and Jones (1991), in their study designed to evaluate different crimping hook pliers, reported that some operators achieve less consistency in the force applied at the hook/archwire system. The custom-made unit, following initial calibration, permitted the investigation of the force used by clinicians of different gender to produce firmly attached hooks to rectangular stainless steel archwires. The mean value for males was slightly higher than for females (18.7 and 17.7 kg force, respectively). This finding confirms the subjective opinion of previous workers (Evans



**Figure 3** Each test sample was mounted in the crosshead of the Instron Universal Testing machine and a 0.7-mm wire loop was attached from the load cell to the crimpable hook.

**Table 1** Univariate summary statistics. In all experiments the sample size was 30.

Hook	Wire	System	RAW			Log transformation		
			SF	Mean	SD	SF	Mean	SD
AO	19 × 25	1	0.118	6.22	0.76	0.056	1.82	0.13
TP	19 × 25	2	0.002	11.70	6.78	0.746	2.31	0.55
TP	18 × 25	3	0.002	11.71	7.81	0.848	2.26	0.64

19 × 25 = 0.019 × 0.025-inch; 18 × 25 = 0.018 × 0.025-inch.

SF, probability associated with Shapiro–Francia statistic; Mean, mean crimping force in Newtons; SD, standard deviation in Newtons.

**Table 2** Bonferroni's multiple comparison of means test. The upper value in each cell is the difference between the system means, and the lower value the probability associated with the Bonferroni test.

System	1	2
2	0.494 0.001	
3	0.445 0.002	−0.049 1.000

and Jones, 1991), but more importantly, allowed the mean of these values to be used, with reproducibility, for the attachment of crimpable hooks in the main study enhancing validity.

Evans and Jones (1991), in their evaluation of AO hooks reported a mean force of between 2.97 and 3.33 N for the two male operators, and 0.88 N for the female operator. Whilst the differences were attributed to the lesser physical strength associated with the female operator, the median values were in the order of 3 N. The results of this study, comparing AO and TP crimpable hooks attached to 0.019 × 0.025-inch stainless steel wire, showed that a significant difference existed between the two types of hooks. Almost twice the force was needed to dislodge the TP hooks compared with that required to make the AO hooks slide (11.7 and 6.22 N, respectively). However, the standard deviation (6.78 N) for the TP hooks was significantly higher than for the AO hooks (0.76 N). There is no obvious

explanation for this finding as the crimpable hooks were attached using a pair of new pliers specific to each hook manufacturer. The mean value for the AO hooks is significantly higher than those previously reported. However, Evans and Jones (1991) utilized 0.018 × 0.025-inch stainless steel wire and this may account for the difference.

In a more recent study (Griffin and Ferracane, 1998), designed to examine the effect of the addition of sandblasting and/or dental adhesives on the stability of crimpable hooks, a mean force of 2 N was required to dislodge hooks attached to a 4-cm length of 0.019 × 0.025-inch stainless steel wire by crimping alone. The force required to dislodge the hook was increased by a factor of 10 where sandblasting and adhesives were applied. However, the authors failed to report the type of archwire crimpable hooks employed in their study and their only criteria for ensuring the force level applied in attaching the hooks was that no bending of the archwire occurred. Their concern for inadvertent gabling of the archwire could explain why the force required to dislodge the hooks subjected to crimping alone was found to be so low.

The results comparing TP hooks attached to two dimensions of stainless steel archwire, 0.019 × 0.025 and 0.018 × 0.025-inch, demonstrated that no significant difference existed between them, with the mean values recorded being 11.7 and 11.71 N, respectively. Thus, when using TP hooks, the archwire size makes little difference to the force required to produce movement.

### *Clinical relevance*

Nattrash *et al.* (1997), in their comparison of three different force delivery systems, reported that clinicians applied extremely wide ranges of force (0.44–3.54 N) to the dentition during closure of residual extraction spaces. Frost (1990) stated that lower levels of force are needed to achieve bone remodelling and tooth movement. Thus, it would appear that, although the magnitude of force required to produce sliding of AO hooks is approximately half that required for TP hooks, clinically this may not be particularly significant as such force levels are rarely achieved intra-orally. This is further supported by the fact that TP hooks are associated with a substantially higher standard deviation. The finding that it makes little difference to the magnitude of force required to produce sliding of TP hooks attached to either  $0.019 \times 0.025$  or  $0.018 \times 0.025$ -inch stainless steel wires means that clinicians can utilize the advantages a larger dimension archwire offers, such as additional torque control during space closure.

### **Conclusions**

1. TP orthodontic crimpable hooks offer substantially greater resistance to movement compared with American Orthodontic hooks, when tested under laboratory conditions.
2. When using TP hooks attached to either  $0.019 \times 0.025$  or  $0.018 \times 0.025$ -inch stainless steel wires, the archwire size makes little difference to the force required to produce movement.

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### **Acknowledgements**

The authors would like to thank the following at Guy's Hospital: Alan Black (Scientific Workshop) for constructing the custom-made jigs, Lou Boddie (Clinical Instrumentation, Medical Physics Directorate) for building the electronic components and Richard Mallet (Laboratory Scientific Officer). We are also grateful to TP and American Orthodontics for supplying the crimpable hooks and pliers.

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