

# The effect of the mismatch between the core diameter of self-threading dentine pins and the pinhole diameter

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## Abstract

This laboratory study incorporated the use of three different sized twist drills to prepare pinholes in extracted upper molar teeth. The diameter of each pinhole was measured. A pre-measured self-threading pin was then placed in each pinhole. The amount of strain created during pin placement (placement strain), the temperature rise during pin placement, the amount of strain remaining (residual strain) within the tooth structure after pin placement and the removal force (retention) were recorded for each pin.

The results showed that, during the placement of a self-threading dentine pin, the difference between the pincore diameter and the pinhole diameter was an important parameter. This difference determined the amount of strain created during pin placement, the temperature rise during pin placement, the amount of strain remaining within the tooth structure after pin placement and the retention of the pin.

The placement strain, temperature rise, residual strain and retention were all greater when the pin core diameter exceeded the pin hole diameter.

**Key words:** Dentine pins, pin core diameter, pinhole diameter, strain, retention.

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## Introduction

Self-threading pins are widely used to retain restorations in severely damaged teeth. However, production of stress within the tooth structure occurs during and after pin placement.<sup>1-3</sup> It has been speculated that stress can result from pin/channel mismatch which can be defined as the difference between the pin diameter and the pinhole diameter. Stress is accompanied by strain which is deformation per unit length.<sup>4</sup> Consequently, it would appear that pin/channel mismatch can influence the amount of strain produced during and after self-threading pin

insertion. Dilts *et al.*<sup>3</sup> suggested that, as pin diameter increases, stress increases since they found that TMS (Table 1) stainless steel self-threading Regular pins (diameter 0.787 mm) produced more craze lines in dentine than TMS stainless steel self-threading Minim pins (diameter 0.584 mm). This suggestion is supported by Khera *et al.*<sup>5</sup> and Webb and Straka.<sup>6</sup> Khera *et al.*<sup>5</sup> concluded that the frequency and degree of dentinal damage depended on the difference between drill and pin diameters. Collard and Caputo<sup>7</sup> found, using Reten (Table 1) pins, that pin/channel mismatch appeared to affect the amount of stress produced and this also was observed by Durkowski *et al.*<sup>8</sup> Durkowski measured the drill and pin diameters and calculated the pin oversize. He found using TMS pins that Regular non-shearing pins with a pin oversize of 0.102 mm caused greater enamel crazing than Minim non-shearing pins with an oversize of 0.076 mm. Harris and Lund<sup>9</sup> concluded that the method of insertion of the pin (by hand or mechanical) had no effect on pin seating but that a mismatch between the pin and drill of more than 15 per cent may lead to incomplete seating. They also speculated that incomplete seating may be a measure of too much friction but there was no evidence of fracture or deformation of the thread.

Duncanson and Korostoff,<sup>10</sup> Korostoff *et al.*<sup>11</sup> and Tengrove *et al.*<sup>12</sup> showed that the visco-elasticity of dentine may allow stress to dissipate from pin placement but permanent changes may occur in the dentine due to tubule collapse with strains of 0.6 per cent.<sup>11</sup>

Retention provided by pins can also be affected by the degree of pin/channel mismatch.<sup>13-15</sup> In results tabled by Moffa *et al.*,<sup>15</sup> using Whaledent self-threading pins (Table 1), a pin/channel mismatch of 0.05 mm resulted in a retention value of 135 N and a pin/channel mismatch of 0.1 mm resulted in a retention value of 225 N. Moffa *et al.*<sup>15</sup> considered

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**Table 1. Materials and equipment used and suppliers**

Beuhlar sectioning saw	Isomet, Buehlar, Lake Bluff, IL, USA
Strain gauge CEA-06-032W 120	Micromasurements, Raleigh, NC, USA
M-Bond 200	Micromasurements, Raleigh, NC, USA
P&N Jobber drill	Cutting Tools, Melbourne, Australia
Twist drill Kodex 0.525/2 mm	Whaledent Int, New York, NY, USA
Whaledent pins	Whaledent Int, New York, USA
Reten pins	Star Dental Mfg Co Inc, Conshohocken, PA, USA
TMS Minim pins	Whaledent Int, New York, USA
X-Y table	Daedal Inc, Harrison City, PA, USA
Drill press table	Phoenix Inc, Taichung, Taiwan
Drill press	Yukiva Seiko In, Ojiya, Nigata, Japan
MacLab/4	AD Instruments Pty Ltd, Castle Hill, NSW, Australia
Nikon measurescope	Nippon, Kogaka, Japan
Handpiece	Kavo, Bibernach, Germany
Surveyor	Krupp Dental, Essen, Germany
Universal testing machine	Autograph IS-500, Shimadzu, Kyoto, Japan
Cricket Graph 111 Version 1.5.1	Computer Associates International, Islandia, NY, USA
Student's <i>t</i> test	Excel, Microsoft, Redmond, WA, USA

pin/channel mismatch to be the difference between pin size and twist drill size.

Dilts *et al.*<sup>14</sup> stated that an inverse relationship between retention and pin-twist drill diameter existed. They suggested that a mathematical equation could be developed to allow retention values to be calculated, based on the type and dimensions of the pin system used.

The aims of this investigation were to determine (a) if the strain produced during pin placement was related to pin/channel mismatch; and (b) whether there was a pin/channel mismatch which caused low strain production but resulted in adequate pin retention.

## Materials and methods †

### Specimen preparation

Six extracted upper right third molar teeth were collected immediately after extraction and stored in phosphate buffered saline solution to which was added 0.05 per cent sodium azide to inhibit bacterial and fungal growth. These teeth were visibly free from coronal and radicular damage. Each tooth was coaxially mounted in self-curing acrylic in 20 mm long sections of 15 mm diameter plastic tubing. Retention was ensured by notching both the roots of the teeth and the internal surface of the tubing. The teeth were then sectioned 4 mm coronal to the cemento-enamel junction and perpendicular to the long axis of the tooth. The level of sectioning was chosen in order to accommodate the future



Fig. 1.—Stripping of TMS Link Plus Minim pin when placement attempted in pinhole prepared with 0.48 mm drill bit.

mounting of strain gauges on coronal enamel. A low speed, water cooled, diamond sectioning saw was used. Throughout the experiment the mounted teeth were stored in 100 per cent humidity.

Four pin sites were selected for each tooth: mesiobuccal, distobuccal, mesio palatal, distopalatal. A strain gauge was bonded on enamel at each of the corresponding tooth angles adjacent to the selected pin sites with M-Bond 200. The drill bits used for pinhole preparation were 0.52 mm drill bit (P&N Jobber drill), 0.525 mm drill bit (Kodex 0.525/2 mm) and 0.55 mm drill bit (P&N Jobber). Each drill bit was used to prepare eight pinholes and then discarded.

Three drill bits were chosen as a result of preliminary trials. During these trials drill bits sizes 0.48 mm, 0.50 mm, 0.52 mm, 0.55 mm, 0.58 mm and 0.60 mm (P&N Jobber drill) were used to prepare pinholes. TMS Minim pins were then placed in these prepared pinholes. Pins placed in the pinholes prepared with the 0.48 mm, 0.50 mm, 0.58 mm and 0.60 mm drill bits did not shear. Pins inserted in pinholes prepared with the 0.48 mm drill bit were stripped of their thread (Fig. 1).

### Experimental procedure

The procedure at each selected site was as follows.

†The details of equipment used, suppliers of materials and computer data program used are listed in Table 1.

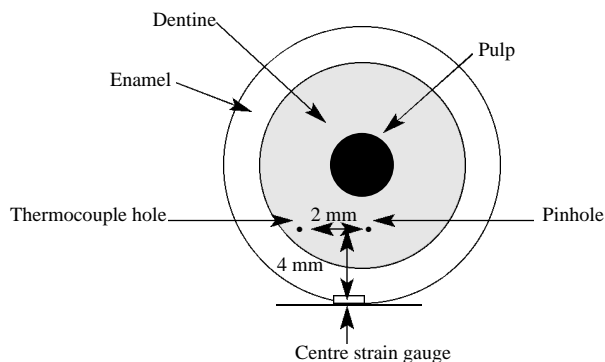


Fig. 2.—Diagrammatic representation of relative positions of pinhole and thermocouple hole in dentine.

### Pinhole preparation

The mounted tooth was secured in a nylon collar which was then mounted on an X-Y table which was in turn mounted on a drill press table. A 1 mm diameter drill bit (P&N Jobber) mounted in the drill press (running at 600 rpm) was used to prepare a thermocouple hole in dentine to a depth of 2 mm. The thermocouple hole was situated 4 mm perpendicular to the centre of the strain gauge and 2 mm lateral to this point (Fig. 2). A thermocouple (J-type) attached to a MacLab/4 input was secured in this hole with M-bond 200. A pinhole was then prepared in dentine to a depth of 2 mm by first drilling to half depth, withdrawing the drill, cleaning the flutes and then drilling to full depth. The position of the pinhole was 4 mm perpendicular to the centre of the adjacent strain gauge and 2 mm from the pre-prepared thermocouple hole (Fig. 2). The tooth was removed from the nylon collar and the diameter of the pinhole at the surface was measured immediately after preparation using a Nikon measurescope. In an exploratory study measurement of the diameter of six different pinholes had shown no significant taper existed. In this exploratory study each pinhole was ground sequentially from the occlusal surface in 0.25 mm increments and the surface pinhole diameter measured at each level.

### Pin placement

The mounted tooth was then fitted into a steel collar, retained by thumb screws, and the collar placed on a magnetic chuck. The same handpiece mounted in a surveyor, and the same motor was used by one operator (HB) for pin placement throughout the experiment. A pin (TMS Link Plus Minim) with pre-measured core and thread diameter (Nikon measurescope) was then placed in the pinhole. Figure 3 shows diagrammatically the relationship of the pin to the pinhole once the pin was in place. The temperature and strain produced during and after pin placement were measured and recorded using the MacLab/4. For all strain recordings a balancing tooth was used in close proximity to the

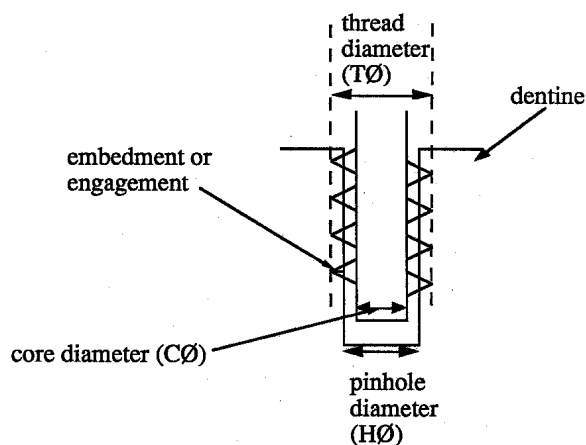


Fig. 3.—Diagrammatic representation of the relationship of the pin to the pinhole. The mismatch is considered to be  $C\varnothing-H\varnothing$ .

test tooth to compensate for external temperature changes.

### Pin removal

Following placement the pin was removed by direct traction in a universal testing machine. The magnetic chuck mounted tooth was fixed on the bottom member of the testing machine. The upper member of the testing machine held a three jaw drill chuck which tightened onto the protruding pin. The crosshead speed was 0.5 mm per min.<sup>6</sup> The force required to remove the pin was measured, and recorded with MacLab/4.

Results were considered in two groups:

Group 1 – Pincore diameter ( $C\varnothing$ ) greater than pinhole diameter ( $H\varnothing$ ).

Group 2 – Pincore diameter ( $C\varnothing$ ) less than pinhole diameter ( $H\varnothing$ ).

### Evaluation of data collected

Data were analysed using the Student's *t* test.

**Table 2. Percentage thread embedment (E%) for each pin calculated from the equation –  $\frac{\text{thread diameter (T}\varnothing\text{)}-\text{hole diameter (H}\varnothing\text{)}}{\text{thread diameter (T}\varnothing\text{)}-\text{core diameter (C}\varnothing\text{)}} \times 100$**

	E% when $C\varnothing < H\varnothing$	E% when $C\varnothing > H\varnothing$
	90	142
	84	123
	90	101
	64	108
	90	124
	29	112
	56	220
	62	155
	99	139
	61	
	70	
	53	
	31	
Mean	68	136
Standard deviation	22	36

**Table 3. Mean peak placement strain (microstrain) and mean peak temperature increase for pin placement, mean residual strain (microstrain) after pin placement, mean removal force**

	Mean peak placement strain	Mean peak placement temperature (°C)	Mean residual strain	Mean removal force (N)
Core diameter > hole diameter	$70 \times 10^{-6}$	1	$29 \times 10^{-6}$	302
Core diameter < hole diameter	$24 \times 10^{-6}$	0.65	$11 \times 10^{-6}$	232

**Results**

**Pin placement**

*Thread engagement*

Table 2 shows that when the core diameter (CØ) of the pin is less (<) than the pinhole diameter (HØ) the mean percentage engagement (%E) of the pin thread into dentine is 68 per cent and when the CØ is greater (>) than the HØ the %E is 136 per cent.

*Peak strain*

Table 3 shows that when CØ>HØ the mean peak strain recorded was  $70 \times 10^{-6}$ . When CØ<HØ the mean peak strain recorded was  $23 \times 10^{-6}$ .

As the core diameter increased the peak strain increased (Fig. 4).

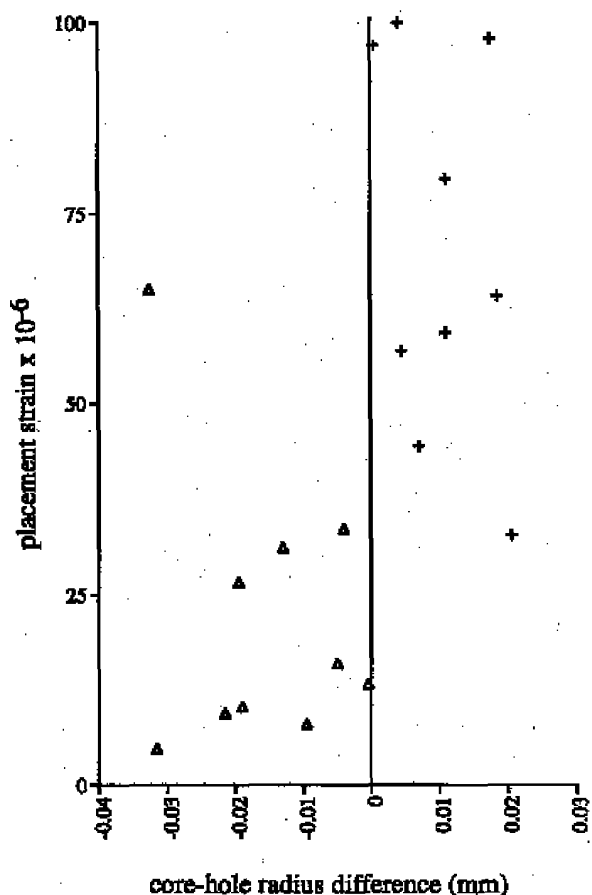


Fig. 4.-Scatter graph of placement strain (microstrain) versus CØ>HØ(+) and CØ<HØ (Δ) where 0 signifies CØ=HØ.

The difference between the two groups was statistically significant (p<0.05).

*Peak temperature*

Table 3 shows that when CØ>HØ the mean peak temperature rise recorded was 1°C and when CØ<HØ the mean peak temperature was 0.65°C, demonstrating that as core diameter increased, the temperature rise increased (Fig. 5).

The difference between the two groups was statistically significant (p<0.05).

*Residual strain*

Table 3 shows that when CØ>HØ the mean residual strain recorded after pin placement was  $29 \times 10^{-6}$  and when CØ<HØ the mean residual strain was  $11 \times 10^{-6}$ .

As core diameter increased the mean residual strain after pin placement increased (Fig. 6), and the difference between the two groups was statistically significant (p<0.05).

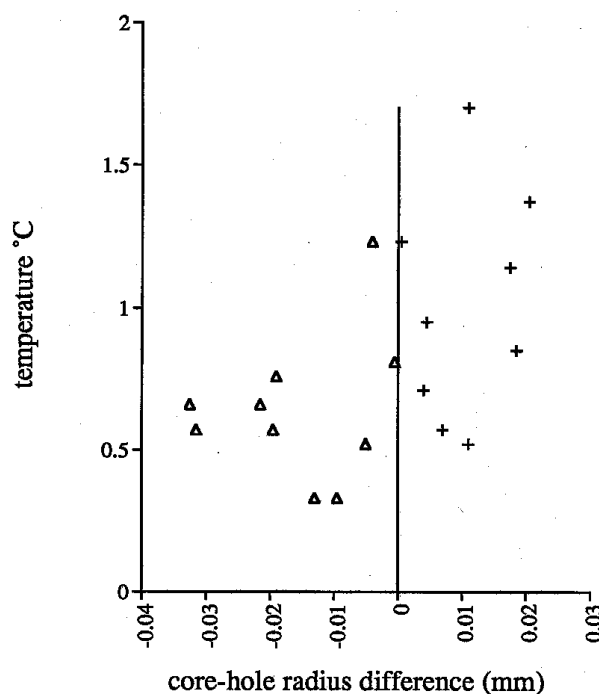


Fig. 5.-Scatter graph of temperature rise during pin placement (°C) versus CØ>HØ(+) and CØ<HØ (Δ) where 0 signifies CØ=HØ.

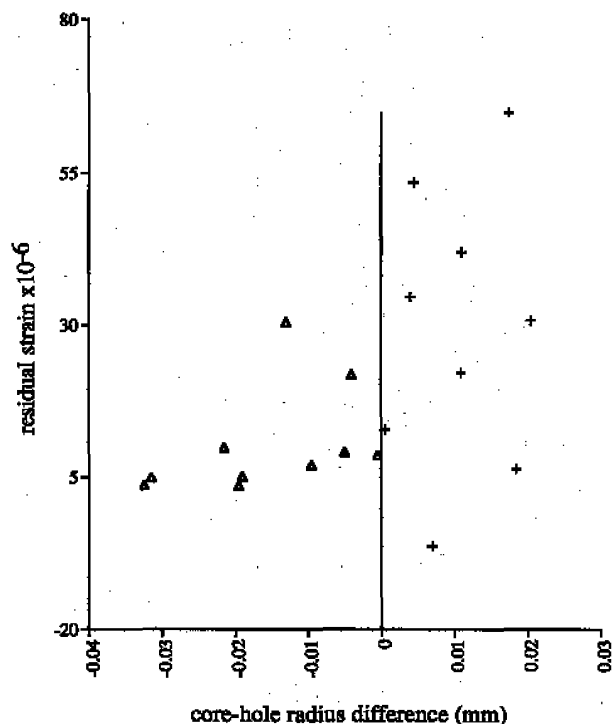


Fig. 6.-Scatter graph of residual strain (microstrain) after pin placement versus  $C\varnothing > H\varnothing (+)$  and  $C\varnothing < H\varnothing (\Delta)$  where 0 signifies  $C\varnothing = H\varnothing$ .

### Pin removal

#### Removal force

Table 3 shows that when  $C\varnothing > H\varnothing$  the mean removal force recorded was 302 N and when  $C\varnothing < H\varnothing$  the mean removal force was 230 N.

As the core diameter increased the force required to remove the pin increased i.e., pin retention increased (Fig. 7), and the difference between the two groups was statistically significant ( $p < 0.05$ ).

### Discussion

#### Pin placement

##### Thread engagement

The self-threading pin is retained in the dentine as a result of the pin thread engagement in the dentinal wall of the pre-prepared pin hole. Engagement of the thread is a result of the deforming action of the pin on the dentinal wall and the elasticity of the dentine. The pins used here were not designed to cut into the dentine.

The percentage engagement of the pin thread (%E) can be determined by the equation –

$$\%E = \frac{T\varnothing (\text{thread diameter}) - H\varnothing (\text{hole diameter})}{T\varnothing - C\varnothing (\text{core diameter})} \times 100$$

The larger the core diameter, the greater the engagement. When the core diameter exceeds the pinhole diameter the percentage engagement is above 100 per cent. It may be possible that deformation of the dentine allows a core of greater

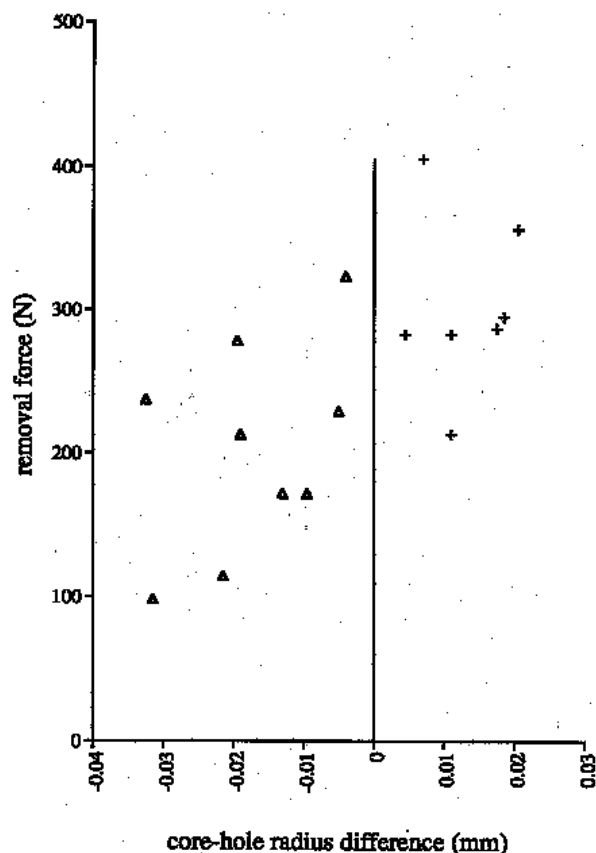


Fig. 7.-Scatter graph of removal force (N) versus  $C\varnothing > H\varnothing (+)$  and  $C\varnothing < H\varnothing (\Delta)$  where 0 signifies  $C\varnothing = H\varnothing$ .

diameter than the pinhole to enter the pinhole. As a result of the core entering the pinhole ahead of the thread, the pinhole is already enlarged before the pin thread progresses along the channel. Hence, the %E calculated is greater than 100 per cent because this figure was calculated on the original pinhole size. However, since the core diameter is greater than the pinhole diameter, full engagement of the pin thread will be achieved.

In preliminary trials, pins would not shear in pinholes prepared with 0.48 mm, 0.50 mm, 0.58 mm and 0.60 mm drill bits. The pin inserted into the 0.48 mm pinhole showed stripping of the thread (Fig. 1). The thread was stripped off the shaft from the pin tip, so the pin did enter the pinhole. This may be due to initial entry being aided by the small tip taper but then the force needed to drive the pin into the hole exceeded the strength of the thread. Friction from the rotating core and thread forcing entry may also have led to the thread damage. A photograph of a pin placed in a 0.50 mm pinhole showed flattening of the threads which may have led to non-embedment. This thread damage was a milder form of that seen with the 0.48 mm pin. The 0.58 mm and 0.60 mm pins, when compared photographically with an unused pin, showed little or no

thread damage suggesting that the pin may have had no contact with the channel wall in this situation, or the dentine was stripped.

#### *Placement strain*

When  $C\varnothing < H\varnothing$  the peak placement strain recorded was one-third of that recorded when  $C\varnothing > H\varnothing$ . When  $C\varnothing < H\varnothing$  the pin threads are the portion of the pin which deforms the dentine. The closer  $C\varnothing$  is to  $H\varnothing$  the greater the embedment which leads to greater stress in the dentine and therefore greater strain.

When  $C\varnothing > H\varnothing$  the core itself relies on the deformation of the dentine to allow penetration of the pinhole which causes a larger strain in the tooth structure. The pin thread also strains the dentine as it becomes embedded into the dentinal wall.

The difference between  $C\varnothing$  and  $H\varnothing$  determines the amount of pin embedment into the dentine. Once the core diameter exceeds the hole diameter the amount of strain produced, although increased, does not have a definite relationship to the amount of mismatch suggesting that it is the initial deformation of the dentine by the core which determines strain production in this situation.

#### *Temperature rise during pin placement*

A temperature rise was recorded during pin placement.

When  $C\varnothing < H\varnothing$  the temperature rise was one half of that when  $C\varnothing > H\varnothing$ . The circumstance where the core must force its way into the pinhole when  $C\varnothing > H\varnothing$  suggests that the physical contact of the rotating pin core and thread with the pin channel wall creates an interference which can lead to heat production. The greater the surface area of contact between the rotating pin and the channel wall the greater would be the expected interference. The situation of maximum surface area contact would arise when full embedment of the pin occurred.

When  $C\varnothing < H\varnothing$  only the pin threads are pushing into the pin channel wall. The pin core may have no contact with the dentine, especially if the difference between core and hole is large.

The size of temperature rise is low during pin placement and is unlikely to be a major problem for the tooth.

#### *Residual strain after pin placement*

The mean peak placement strain was two and a half times the mean residual strain. Viscoelasticity of the dentine allows for some strain release even though the pin is in place, which could account for the residual strain being less than the peak strain during pin placement. However, the engagement of the threads in dentine may result in a plastic defor-

mation of the dentine due to collapse of the adjacent tubules. Korostoff *et al.*<sup>11</sup> suggested that permanent changes may occur in the dentine due to tubule collapse with strains of 0.6 per cent which is considerably greater than the 0.007 per cent recorded in this study. However, the strains recorded by Korostoff *et al.* were constant compressive strains measured at the point of application of the load. The present study demonstrated a tensile strain at the tooth surface which was 2 mm from the point of load application. Strain must be much higher at the point of load application due to the compressive effect of the threads on the inside of the pinhole which then push out on the dentine resulting in a tensile effect on the surface. This strain was largely recoverable with removal of the pin, however, a recordable tensile strain remained which could lead to tooth fracture.

#### *Pin removal*

##### *Removal force (retention)*

The force required to remove the pin when  $C\varnothing > H\varnothing$  is higher than that required to remove the pin when  $C\varnothing < H\varnothing$ . When  $C\varnothing > H\varnothing$  the threads of the pin are fully encased by dentine which may also be more highly stressed. When  $C\varnothing < H\varnothing$  the core is not contacting dentine and the threads are only partially engaged which suggests that retention would be less.

However, it should be noted that the retention results obtained both for  $C\varnothing > H\varnothing$  and  $C\varnothing < H\varnothing$  are consistent with pin removal forces reported in previous literature.<sup>13,16-18</sup> It would appear that although a larger  $C\varnothing$  to  $H\varnothing$  difference gives slightly greater retention it may be still acceptable to have a smaller  $C\varnothing$  to  $H\varnothing$  difference giving adequate retention while at the same time reducing placement strain and residual strain. The retention requirements of a pin have not been clearly defined. Healey and Chandler<sup>8</sup> questioned whether values recorded for retention of self-threading pins were excessive and implied that it may be better for a restoration to be lost than for a tooth to suffer unrestorable fracture.

#### **Conclusions**

The core/hole mismatch determines the amount of strain created during pin placement, the temperature rise during pin placement and the amount of residual strain present after pin placement. The mismatch also determines the level of retention of the pin after placement. The larger the core diameter, the greater are these factors, there being a marked increase in values except retention once the core is larger than the pinhole.

The TMS Link Plus system has been well designed to allow inevitable differences in pin and hole size to not affect retention significantly.

It is argued that a pin with  $C \ll H$  gives appropriate retention and low strain effects.

### Acknowledgements

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