European Journal of Orthodontics 19 (1997) 623–628

Risk of pulp damage due to temperature increase during thermodebonding of ceramic brackets

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SUMMARY The purpose of this study was to perform *in vitro* measurements of the temperature increase at the enamel–dentine interface during electrothermal removal of ceramic brackets, and to analyse, *in vivo*, whether signs of pulp damage can be observed 4 weeks after the procedure.

In vitro study: a total of 29 caries-free human teeth were cut into buccal and lingual halves. The buccal halves were bonded with ceramic brackets, and miniature thermocouples were placed from the pulpal side into holes drilled to the enamel–dentine interface under the centre of the bracket slot. From the onset of thermodebonding, the temperature increase relative to room temperature was recorded for a period of 43 seconds. The maximum temperature increase at the enamel–dentine interface was 6.9°C.

In vivo study: a total of 12 human premolars scheduled for extraction for orthodontic reasons were bonded with ceramic brackets. Electrothermal debonding was performed the following day. After 4 weeks, the teeth were extracted and prepared for histological examination. Following demineralization, sections were prepared for light microscopic examination. No signs of pulpal inflammation were observed.

Introduction

In vitro tests (Winberg *et al.*, 1990; Eliades *et al.*, 1993), as well as case reports (Jeiroudi, 1991), surveys (Lindquist, 1989) and results of clinical studies (Årtun, 1997), suggest that mechanical removal of ceramic brackets is associated with an occasional risk of iatrogenic enamel tear-out and a high risk of enamel crack formation. The most likely explanation is that the lack of ductility of the ceramic material (Scott, 1988; Birnie, 1990) prevents the formation of a peel force in the bracket–adhesive interface on removal, and the applied forces may generate stress build-up in the adhesive–enamel interface (Årtun, 1997).

To reduce the force level required for debonding, and thereby the potential for enamel damage, electrothermal bracket removal has been recommended (Sheridan *et al.*, 1986a,b; Gerkhardt *et al.*, 1988; Baumann and Ruppenthal, 1992; Ruppenthal and Baumann, 1992; Brouns *et al.*, 1993). In short, the technique involves the application of several hundred degrees Celsius to the bracket surface. The heat penetrates the bracket bulk and melts the resin component of the adhesive at the bracket–adhesive interface, reducing the amount of force needed to remove the bracket. The temperature at which the composite resin softens increases with increased amounts of filler particles (Jost-Brinkmann *et al.*, 1989). The time needed for weakening of the bracket–adhesive interface using ceramic brackets decreases with increased contact area between heater and bracket and the increased temperature of the heating device (Jost-Brinkmann *et al.*, 1989).

One disadvantage of electrothermal bracket removal is the potential for iatrogenic pulp damage due to spread of heat through enamel and dentine during the procedure. Several studies have concluded that the temperature increase

within the pulp or at the pulpal wall concomitant with electrothermal removal of ceramic brackets stays below established threshold temperatures (Jost-Brinkmann *et al.*, 1989; Sander and Weinreich, 1989; Bäzner *et al.*, 1991; Baumann and Ruppenthal, 1992; Ruppenthal and Baumann, 1992; Brouns *et al.*, 1993). However, the odontoblast processes extend through the dentine towards the enamel border, where the temperature increase is likely to be considerably higher. Accordingly, inflammatory changes due to damage of the odontoblast processes cannot be ruled out, despite minimal temperature increase within the pulp itself.

Histological examinations have documented pulpal changes such as disappearance of odontoblast nuclei, increase in inflammatory cells and appearance of extravascular erythrocytes within 24 hours after thermodebonding of ceramic brackets (Jost-Brinkmann *et al.*, 1992; Dovgan *et al.*, 1995). However, such changes may be transient and not represent permanent damage to the pulp.

The aim of this study was to perform *in vitro* measurements of the temperature increases at the enamel–dentine interface during electrothermal removal of ceramic brackets, and to analyse *in vivo* whether signs of pulp damage can be observed 4 weeks after the procedure.

Materials and methods

Temperature increase in vitro

A total of 29 caries-free human teeth (7 maxillary incisors, 2 mandibular incisors, 10 canines/premolars and 10 molars) that had been stored in 3 per cent formalin were cut into buccal and lingual halves. The buccal halves were bonded onto 2 mm thick Plexiglas sheets with a light-cured acrylic resin (Acrifix 92; Röhm Kunststoffe, Darmstadt, Germany). In each specimen, a 0.5 mm diameter hole was drilled through the Plexiglas, pulp and dentine to the enamel–dentine interface. Following pumicing and etching for 60 seconds with 37 per cent phosphoric acid, Fascination® Ceramic Brackets (Dentaurum, Pforzheim, Germany) were bonded to the enamel surfaces using Heliosit® (Vivadent, Schaan, Liechtenstein) on 23 teeth, and Transbond® (3M/Unitek, Puchheim, Germany) on 6 teeth and curing for 40 seconds with visible light (Heliomat; Vivadent, Ellwangen/Jagst, Germany). The brackets were placed so that the slots were located directly over the holes. Ni–NiCr thermocouples were placed into the holes and their location in relation to the bracket base was confirmed radiographically. The remaining parts of the holes were filled with 5 per cent agar gel to enhance thermal conductivity. The specimens were stored in agar gel at room temperature. Following drying with compressed air, the heating element of the Ceramic Debonding Unit® (Dentaurum, Pforzheim, Germany) was inserted into the bracket slots, the heat was started, and a moment of approximately 0.1 Nm was applied according to the manufacturers' instructions. The brackets were removed immediately upon loosening. The heat was automatically shut off after 3 seconds and could not be restarted until 6 seconds later. At that time, a second heating cycle was applied if necessary. The thermocouple located at the enamel–dentine interface of each specimen, as well as one placed on the desk top for recording of room temperature, were connected to an amplifier, an A/D converter, and a computer for data collection. Upon starting the heat of the Ceramic Debonding Unit®, the output of the thermocouple was registered every 0.06 seconds for a period of 43 seconds. The temperature increase during thermodebonding was calculated by subtracting the output of the element on the desk top from that at the enamel–dentine interface. For each specimen, the mean temperature increase during the 43 second measuring interval and the maximum temperature increase within the interval were determined. Kruskal–Wallis and Mann–Whitney *U*-tests were performed to determine any differences in temperature increase between molars, incisors and canines/premolars. Lower incisors were excluded from statistical evaluation due to too few specimens ($n = 2$).

Histological investigation

Ceramic brackets (Fascination®) were bonded to 12 premolars of four patients scheduled for extraction for orthodontic reasons, using Transbond® as the adhesive. The following day,

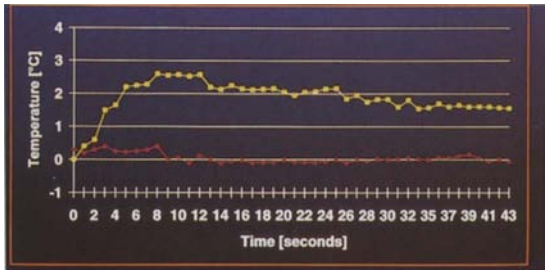

Figure 1 Typical example (maxillary lateral incisor) of temperature course recorded for a period of 43 seconds following onset of thermodebonding from a thermocouple (TC) located at the enamel–dentine border and from a reference thermocouple located on the desk top to record room temperature. Red: Reference TC; yellow: Enamel–dentine TC.

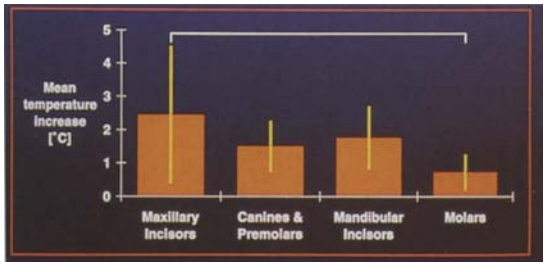

Figure 2 Mean temperature increase during a period of 43 seconds associated with electrothermal debonding of the different groups of teeth. ⌐¬ : $P < 0.05$.

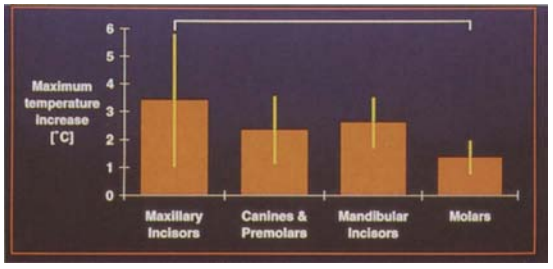

Figure 3 Maximum temperature increase during a period of 43 seconds associated with electrothermal debonding of the different groups of teeth. ⌐¬ : $P < 0.05$.

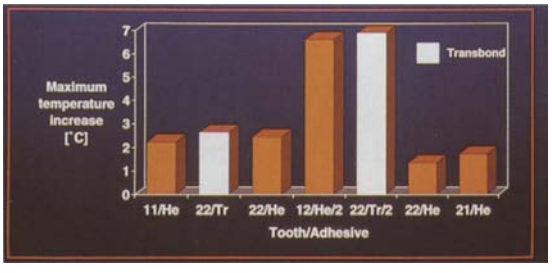

Figure 4 Maximum temperature increase during a period of 43 seconds associated with electrothermal debonding of 7 maxillary central and lateral incisors. He: Bracket bonded with Heliosit; Tr: Bracket bonded with Transbond. 12/He/2 and 22/Tr/2 needed two heating cycles for debracketing.

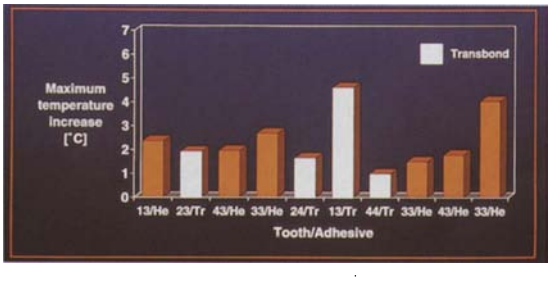

Figure 5 Maximum temperature increase during a period of 43 seconds associated with electrothermal debonding of 10 premolars/canines. He: Bracket bonded with Heliosit; Tr: Bracket bonded with Transbond.

electrothermal bracket removal was performed using the Ceramic Debonding Unit®. After 4 weeks, the teeth were extracted and prepared for light microscopy through fixation in cacodylate buffer, decalcification in EDTA for 5 weeks, dehydration, embedding in paraffin, sectioning (7 μm thick), and staining with Giemsa (Merck, Darmstadt, Germany: No. 9204) and haematoxylin–eosin. Light microscopic examination was performed according to criteria described earlier (Jost-Brinkmann *et al.*, 1992).

Results

Temperature increase in vitro

In all teeth, the temperature at the enamel–dentine interface reached a maximum value several seconds after bracket removal and did not return to the initial level within the 43 second recording interval (Figure 1). Comparisons of mean and maximum temperature increases for the four groups of teeth revealed significantly

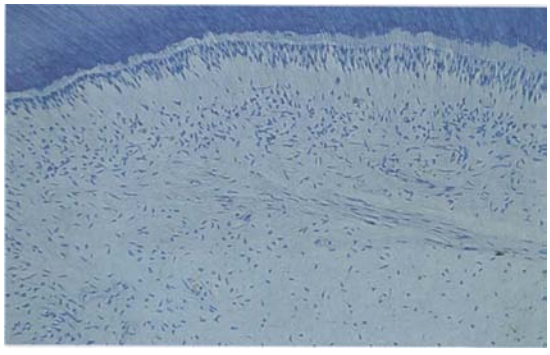

Figure 6 Histological section stained with Giemsa (×125) of pulp tissue underneath the bracket base area 4 weeks after electrothermal debonding, showing no signs of inflammation.

higher values for maxillary incisors than for molars ($P < 0.05$) (Figures 2 and 3). The type of adhesive had no apparent effect on the temperature increase (Figures 4 and 5); however, the numbers were too small for statistical comparison. Only two brackets needed a second heating cycle to be removed. In the corresponding teeth, the temperature increase was approximately twice that seen in the remaining teeth (Figure 4).

Histological findings

All the 12 brackets could be removed electrothermally. Wing fracture occurred in two brackets, and six needed a second heating cycle. The patients felt warmth during debracketing of three teeth, while no discomfort was reported in the remaining nine teeth. Several histological sections revealed artefacts such as ruptures within the pulp tissue. No section demonstrated pathological findings that could be attributed to the thermodebonding procedure (Figure 6). In other words, neither pulpal inflammation, loss of or damage to the odontoblast layer under the respective dentinal tubules, nor formation or irritation of the dentine were observed.

Discussion

The results indicate that electrothermal debonding is associated with a significant temperature increase in the enamel cap and the outer layer of the dentine. The most pronounced increase was measured in the maxillary lateral incisors, as opposed to the lower incisors as documented earlier (Reichrath, 1983). This finding may also be considered in contrast to an earlier study by Ruppenthal and Baumann (1992), who found lower incisors to be most susceptible to intrapulpal temperature increase. Explanations may be intersample variations in bracket volume and size of bracket base area, which actually determines the temperature profile at the bracket–adhesive interface, and thereby the energy flow in the tooth, as well as variations in enamel thickness.

The fact that the temperature in the oral cavity is approximately 16°C higher than room temperature suggests that the adhesive may soften more quickly *in vivo* than in the present *in vitro* experiment. Accordingly, the temperature increase associated with electrothermal debonding is likely to be smaller in the clinic. However, in the clinical part of the study, half of the brackets needed two heating cycles before bracket removal could be performed. This may be a reason for concern since the *in vitro* experiment suggests a temperature increase of approximately a 100 per cent at the enamel–dentine interface in such cases. The large discrepancy between the proportion of brackets needing two heating cycles to be removed in the *in vivo* and *in vitro* experiments may reflect the difficulty in applying a relatively constant force moment to the bracket in the clinic. The manufacturers recommend that a moment of approximately 0.1 Nm be applied to facilitate debonding.

The *in vivo* experiment in this study suggests no signs of inflammation 4 weeks after electrothermal debonding, not even in the teeth where two heating cycles were required. Accordingly, the temperature increase at the extension of the odontoblast processes of almost 7°C, that may be experienced in such cases, is unlikely to produce detectable pulp damage over time. This may not be unexpected since the pulpal tissue may tolerate an intrapulpal temperature increase of 5.5°C (Zach and Cohen, 1965).

Previous studies have found local inflammatory reactions in the pulp 24 hours after

thermodebonding (Jost-Brinkmann *et al.*, 1992; Dovgan *et al.*, 1995). Accordingly, it cannot be ruled out that similar changes were also present in this sample shortly after bracket removal. This speculation may be supported by the finding that patients felt discomfort during the thermodebonding procedure in 25 per cent of the teeth. However, this study suggests that any such initial inflammatory lesions may heal within 4 weeks.

The temperature increase at the enamel surface during electrothermal debonding is likely to be considerably higher than at the enamel–dentine interface. Previous studies indicate that rapid thermal changes at the enamel surface may be an aetiological factor for enamel cracks (Brown *et al.*, 1972). Although not examined in this study, it cannot be ruled out that electrothermal debonding is associated with crack formation. However, the risk may be considerably higher with mechanical removal of ceramic brackets (Årtun, 1997).

This and a previous study (Jost-Brinkmann *et al.*, 1992) suggest that the potential for damage increases when more than one heating cycle is necessary for bracket removal. To minimize the risk, the manufacturers recommend an interval of 5 minutes before a second thermodebonding attempt is made.

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Acknowledgements

This study was supported by a grant from the Humboldt University of Berlin: No. 9246720. We would like to express our thanks to Mrs M. Memering for carrying out the histological preparation.

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