Thermographic assessment of root canal obturation using thermomechanical compaction

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Summary

The temperature changes on the root surface of 30 extracted human premolar teeth during thermomechanical root canal obturation with gutta-percha were determined using an infrared thermal imaging camera. Three handpiece rotational speeds of 8, 12 and $16 \times 10^3$ r.p.m. were used, in conjunction with a Gutta Condensor. On completion of the procedure, the quality of tooth canal obturation was examined radiographically. Under the conditions of this experiment, surface root temperature rises of $>97^\circ$C were recorded during all three speed settings. The radiographic quality of obturation between the groups appeared not to be significantly different. The clinical relevance of these findings is uncertain, but the temperatures reported are of a magnitude to be of biological importance.

Keywords: infrared thermography, thermomechanical obturation.

Introduction

The final stage of root canal treatment is to fill the entire root canal system with a nonirritating, hermetic sealing agent (Nguyen 1987). Several techniques have been described to achieve this, including cold lateral condensation, warm vertical condensation (Schilder 1967), injection techniques (Yee et al. 1977) and thermomechanical compaction (McSpadden 1980). The thermomechanical technique as described by McSpadden uses a reverse threaded steel instrument, sometimes described as an inverted Hedström file, which is used in a slow speed handpiece. The principle of its use relies on the frictional heat of the instrument initially plasticizing the gutta-percha at a temperature of between 30°C and 60°C and then the thread pattern of the instrument propels the gutta-percha laterally and towards the apical region.

There has been some concern about the effect of large temperature rises on the periodontium and the subsequent long-term implications (Hardie 1986). Some investigators have attempted to measure the temperature rises produced during obturation by using thermocouples which measure the temperature at individual points on the root surface (Fors et al. 1985, Saunders 1990). This method, whilst providing information about the temperature at certain points over the root surface, does not give dynamic information about the whole root surface nor how the temperature travels across the root surface and other surfaces of the tooth. In contrast, electronic infrared thermography (IRT) involves no contact with the surface under study and can be used to analyse the thermal changes occurring at multiple sites over the whole root surface area.

Infrared thermography has been used sporadically by most academic and scientific disciplines since the 1960s (Williams 1969, Baillie et al. 1990). However, within the field of dentistry its use has been scarce. This was mainly because of equipment costs and lack of sensitivity and image processing of older equipment. Today, through technical developments and image processing applications, modern equipment is sensitive enough to record changes of 0.1°C and, with dedicated image processing software, allows for highly flexible usage in the field of thermology. In addition, suitable software programs for image analysis provide great detail about the temperature pattern and the extent of temperature changes. The thermal image achieved is a visual representation of the temperature distribution on the surface of the object. Infrared thermography depends on the interrelationship between the object and its environment. The control of the environment and an understanding of the thermal processes involved are necessary before inferences can be drawn from thermographic
examination. Measurements must be recorded within a controlled environment which is free from external radiation sources, convective air currents and extremes of humidity.

Infrared thermography scanners employ detectors such as mercury cadmium telluride sensitive to the wavelength range of 8–12.5 μm. The radiation emitted by the object surface is focused onto the detector via a series of oscillating and rotating mirrors and polygons. The detector output is digitized and transmitted to the system controller, hence it can be viewed and examined on a monitor or stored in 12-bit format for subsequent analysis with real time accuracy.

The purpose of this study was to investigate temperature changes on the root surface of teeth using infrared thermography during thermomechanical obturation at three different handpiece speeds (8, 12 and 16 × 10³ r.p.m).

Materials and methods

Thirty freshly extracted mature human permanent premolar teeth were selected for this study. Access to the root canals was achieved using a round diamond bur in a high speed handpiece. The root canals were prepared to an ISO size 50 master apical file using the stepback filing method. Between each filing sequence the canals were irrigated with 0.5% sodium hypochlorite solution. The prepared teeth were all fitted with a cuff of light cured acrylic (Triad; Dentsply, Dentsply International Inc., York, PA, USA) which surrounded the coronal part of the teeth but kept clear of the root. This cuff enabled the teeth to be secured in a table vice for instrumentation of the root canal without movement. The teeth were then stored in normal saline at room temperature until the obturation procedure. Each tooth had a custom gutta-percha cone fitted to the working length which was verified radiographically. The sample teeth were then divided into three groups of ten and each canal was obturated with gutta-percha using the thermomechanical technique (Gutta Condensor, Maillefer, Ballaigues, Switzerland). Handpiece working rotation speeds of 8, 12 and 16 × 10³ r.p.m. were used for the three groups. The Gutta Condensor was used in accordance with the manufacturer’s recommendations, so that a size 50 condensor was inserted into the canal to a point 1.5 mm from the apex. The canal preparations were suitably flared so that accessory gutta-percha cones could be fitted around the Gutta Condensor drill when it was tried in against the master cone. Tubliseal root canal sealer (Kerr Sybron, Romulus, Michigan, USA) was used in the insertion of the gutta-percha points. The handpiece (Kavo Intrasept 905; Kavo, Amersham, Bucks, UK) allowed accurate setting of the rotational speed with a digital readout. This particular drill allows the speed to be set as a constant and is unaffected by minor changes in resistance. A new Gutta Condensor file was used after every four obturations to avoid instrument fatigue and potential file fracture within the canal.

During each obturation, the temperature change occurring on the root surface was measured and recorded by an infrared thermal imaging camera (Thermovision 900; Agema, Danderyd, Sweden), and its dedicated software packages. The camera was mounted on a stand which held it perpendicular to the root surface under examination. Images were recorded every 2 s for a period of 20 s, at which time obturation was complete. The thermal images were examined and the software programme analysed the temperature changes on the root surface during the root filling procedure for each group of teeth.

Postoperative radiographs were taken following obturation to confirm the quality of obturation.

Results

Table 1 shows a typical example of the type of data obtained using the thermographic technique combined with the sophisticated image processing facilities.

The mean maximum temperatures encountered during obturation at the three chosen speeds are seen in Table 2. Mean maximum temperatures of between 75°C and 81°C were measured but several individual specimens demonstrated temperatures in excess of 90°C.

An analysis of variance did not reveal any statistically significant differences between the three groups (F-value 0.227, P-value 0.798).

Figure 1 a–c shows typical thermograms obtained during obturation at 12 × 10³ r.p.m.

Figure 2 shows the mean maximum temperature recorded on the root surfaces over time during the obturating procedure. The data suggest that the temperature increases more quickly for the 12 × 10³ r.p.m. and 16 000 r.p.m. groups compared to the 8 × 10³ r.p.m. group. The data level off after the initial temperature rise, with little further temperature increase occurring after the first 10 s.

Figure 3 shows the mean of the average surface temperatures recorded for the ten samples against time in each of the three groups. This graph shows a more gradual temperature rise than Fig. 2, as the cooler peripheral zones reduced the average values calculated.
for the whole root surface area. All the postoperative radiographs showed well condensed obturation of the root canals.

**Discussion**

This study shows how the thermal imaging camera can be used to measure temperature rises on the root surface of teeth during root canal obturation *in vitro*. The technique is not only able to quantify these changes, but unlike the thermocouple, which is restricted to the point of contact with the root surface, the thermography software enables the accurate measurement of temperature at any point on that surface. The images can also be used to study the dynamic pattern of the temperature rise over the surface during the obturation procedure.

The manufacturers of the Gutta Condensor advocate that speeds of at least $8 \times 10^3$ r.p.m. are used. This study shows that higher rotation speeds produce slightly higher maximum temperatures and also a faster rate of temperature rise. The highest temperatures produced by the three rotation speeds studied were similar and this is to be expected, as the gutta-percha will flow away from the rotating flutes of the drill and so reduce the frictional component. Higher earlier temperatures produced by the higher speeds would cause early plasticization and therefore reduced friction between the drill and the gutta-percha at the plateau portion of the graph in Fig. 2. The final result of the thermoplastic obturation would appear to be radiographically similar, but the high temperatures produced would suggest that the periodontal ligament would need to dissipate this heat to prevent potential damage occurring at this interface. These results are in keeping with previous studies (Fors *et al.* 1985, Hardie 1987) which found temperatures up to $74^\circ$C and $87^\circ$C, respectively, on the root surface. This method of root canal obturation can generate large temperature rises which are of biological concern. Eriksson & Albrektsson (1983) showed that temperature rises above $47^\circ$C produce fatty changes in bone. Although dentine is a poor thermal conductor (Brown *et al.* 1970), the high temperatures in excess of $90^\circ$C which can be produced on the root surface by thermo-mechanical obturation may have a deleterious affect on the surrounding periodontium and adjacent alveolar bone. Despite this, however, there is a lack of evidence to show that such a technique affects the long-term prognosis of root canal treatment. The average temperature rises on the root surfaces did not significantly differ when the handpiece was used at the three different speeds, but the maximum temperatures recorded were greatest with the higher handpiece speed settings and it would seem advisable to use the lowest hand piece speed consistent with a satisfactory obturation.

This study shows how the thermal imaging camera can be successfully used to measure temperature rises on the root surface of teeth during root canal obturation *in vitro*. It is not only able to quantify these changes, but the software packages enable the accurate measurement of temperatures at any point on that surface, unlike the thermocouple, which is restricted to the points of contact. The thermal images can also be used to

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**Table 1** An example of the information collected from a specimen obturated thermomechanically at $12 \times 10^3$ r.p.m. over a 20-s period. Specimen 213, root area = 55.1 mm$^2$, root length = 13.2 mm

<table>
<thead>
<tr>
<th>Time (S)</th>
<th>Min temperature (°C)</th>
<th>Max temperature (°C)</th>
<th>Difference (°C)</th>
<th>Average temperature (°C)</th>
<th>Median temperature (°C)</th>
<th>SD</th>
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<tbody>
<tr>
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<td>21.6</td>
<td>23.6</td>
<td>2.0</td>
<td>22.63</td>
<td>22.64</td>
<td>0.39</td>
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<tr>
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<td>21.9</td>
<td>43.1</td>
<td>21.2</td>
<td>24.76</td>
<td>23.21</td>
<td>3.84</td>
</tr>
<tr>
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<td>22.6</td>
<td>83.6</td>
<td>60.9</td>
<td>34.82</td>
<td>27.41</td>
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</tr>
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<td>6</td>
<td>22.9</td>
<td>74.3</td>
<td>51.5</td>
<td>39.41</td>
<td>33.74</td>
<td>16.04</td>
</tr>
<tr>
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<td>23.3</td>
<td>65.6</td>
<td>42.3</td>
<td>41.65</td>
<td>40.17</td>
<td>14.16</td>
</tr>
<tr>
<td>10</td>
<td>23.4</td>
<td>61.2</td>
<td>37.8</td>
<td>43.19</td>
<td>44.79</td>
<td>12.32</td>
</tr>
<tr>
<td>12</td>
<td>23.6</td>
<td>61.8</td>
<td>38.2</td>
<td>44.12</td>
<td>46.59</td>
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</tr>
<tr>
<td>14</td>
<td>24.0</td>
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<td>34.9</td>
<td>44.47</td>
<td>46.99</td>
<td>9.29</td>
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<tr>
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<td>24.3</td>
<td>55.9</td>
<td>31.5</td>
<td>44.35</td>
<td>46.59</td>
<td>7.92</td>
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<td>24.8</td>
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<td>28.9</td>
<td>43.92</td>
<td>45.94</td>
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<td>25.6</td>
<td>51.9</td>
<td>26.3</td>
<td>43.49</td>
<td>45.35</td>
<td>6.1</td>
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</table>

**Table 2** The mean maximum temperatures measured during obturation at the three different drill speeds

<table>
<thead>
<tr>
<th>r.p.m.</th>
<th>Mean maximum temperature (°C)</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>8000</td>
<td>76.90</td>
<td>15.78</td>
<td>40.2–97.1</td>
</tr>
<tr>
<td>12 000</td>
<td>77.32</td>
<td>15.06</td>
<td>52.4–97.4</td>
</tr>
<tr>
<td>16 000</td>
<td>80.96</td>
<td>13.54</td>
<td>52.6–97.7</td>
</tr>
</tbody>
</table>
Fig. 1 a–c Typical thermograms from a specimen obturated at 12 × 10³ r.p.m.

Fig. 2 The mean maximum surface temperatures recorded for the three drill speeds used.

Fig. 3 The mean of the average temperature recorded on the root surface of the 10 specimens in each of the groups.
study the pattern of temperature change over the surface during the procedure, so dynamic study is possible.

Conclusions

This study has shown the pattern of temperature rise on the root surface associated with thermomechanical obturation using the Gutta Condensor. The results suggest that higher speeds of rotation create higher root surface temperatures and do this more rapidly. The maximum temperatures recorded would place demands on the surrounding tissues and blood supply to dissipate this heat. It is unknown how these elements will accept this insult and also how this may affect the root/periodontium interface in the longer term. Further research in this area should address these issues.

References


