A method of measuring the volume of human dental pulp cavities

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Summary. A method of measuring the volume of the human dental pulp cavity is described.

The crown of an extracted tooth is divided from its root. After cleaning the pulp cavity, it is filled with an elastomer, and the fractured tooth surfaces repositioned before the elastomer sets.

The tooth is corroded in acid to release the elastomer which is then weighed, and its volume calculated.

The method has been applied to representatives of each human tooth type, and mean values are given.

Introduction

A knowledge of the dimensions of the human dental pulp cavity is of importance to the clinician practising endodontics and other procedures in conservative dentistry, to students of oral anatomy and to research workers measuring temperature changes in dental tissues. The size, shape and anatomical variations of the pulp cavity have been extensively described in the literature; however, the volume has not been previously reported.

In 1925, Hess presented a comprehensive historical background in his book and reviewed the work of previous authors, among which were Carabelli's (1844) description of root canal variations, Preiswerk's (1908) metal corrosion preparations which showed the complicated pattern of the canals for the first time, the celluloid moulds of the pulp cavity prepared by Fischer (1908), the molten metal injection technique of Adloff (1913) and the Indian ink preparation of Moral (1914). Hess (1925) himself investigated the shape of root canals of permanent teeth by reproducing them in vulcanized rubber. Davis et al. (1972) studied the morphology of endodontically prepared root canals, using an injectable silicone impression material. Barker et al. (1973) cut a channel through to the pulp chamber, injected a radio-opaque elastomer into the cavity and took radiographs from various aspects. They also reproduced translucent replicas of teeth in clear resin, in which the pulp cavities were injected with red resin. Fisher et al. (1975) also gained entrance into the pulp chamber via an access cavity, prepared a dyed reproduction of the pulp space in resin and positioned it within a transparent tinted outer tooth structure. Robertson et al. (1980) described a method which made the tooth transparent and then, via an access cavity, injected India ink into the pulp chamber to outline the root canals.

A major criticism of the techniques previously reported is that part of the pulpal wall was destroyed by grinding the teeth, or by cutting an access channel into the pulp chamber. The object of this paper is to describe a method which preserved the integrity of the pulpal walls and at the same time produced an accurate replica, so that not only could the volume of the pulp cavity be measured, but also its anatomical variations could be appreciated.

Materials and methods

Ten teeth of each human tooth type were chosen, making a total of 160 teeth. The criteria for selection were that they should be freshly extracted, non-carious, fully formed permanent teeth without undue attrition.

A ringed groove was sawn around the crown, using a rotating disc, just coronal to the amelo-cemental junction, without expos-
ing the pulp chamber. The root was then held firmly in a vice and the crown broken off with a pair of pliers. A fracture of the tooth produced in this manner ensured that when the two pieces were realigned, an accurate apposition of the jagged crown and root surface took place, without any lateral movement.

The two pieces were then immersed in a solution of 20 volumes hydrogen peroxide for approximately 7–10 days, to facilitate removal of the pulp; when instruments were used in some cases to remove the pulpal residue, care was taken not to scratch the pulpal walls. The crown and root were next thoroughly irrigated with copious quantities of saline to remove all traces of hydrogen peroxide and then dried.

An empty disposable injection syringe barrel with its needle end sawn off, or a transparent plastic cylinder of a diameter slightly larger than an average molar tooth was selected. The apical half of the fractured tooth was partially inserted in one end and sealed with plasticine so that its fractured surface was visible externally; a vacuum pump was connected to the opposite end of the cylinder (Fig. 1).

A mix of Silastic E RTV mould-making rubber was subjected to a vacuum of a pressure of less than 20 mm of mercury to eliminate trapped air. It was then introduced into the pulp chamber of the apical half of the root piece and by means of the vacuum provided from the opposite end of the cylinder, the mix was drawn through the root canal and apical foramen (Fig. 1). The vacuum was maintained until all the air from the pulp cavity was systematically removed and the Silastic extruded from the apical foramen. In some instances when narrow pulp canals were present, this procedure took as long as 20–25 minutes. The shallow roof of the pulp chamber in the crown portion of the divided tooth was next filled with the mix and the crown vibrated to exclude air bubbles.

The fractured surfaces of the crown and root were next repositioned together accurately and maintained in position by means of a spring clip for 72 hours in a warm place, to allow the mix to set in the enclosed pulp space. The tooth was then corroded in a solution of 50 per cent hydrochloric acid for 24 hours and the resultant Silastic replica was carefully washed with water (Fig. 2).

If the crown and root fragments had been accurately aligned, a negligible excess of Silastic was found at the junction. This was flaked off carefully with a knife and the specimen was then examined for air bubbles. A stereo-magnifier \((\times 30)\) was employed for both these procedures. The specimen was next weighed and its mass was divided by the density of the Silastic \((1.12)\), thus giving the volume of the pulp cavity according to the equation: \(v = \frac{m}{d}\).

Each Silastic replica was then cut into slices...
Table I. Mean volume (mm$^3$) and standard deviation (SD) of dental pulp cavities

<table>
<thead>
<tr>
<th>Tooth type</th>
<th>Maxillary</th>
<th>Mandibular</th>
</tr>
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<tbody>
<tr>
<td>Central incisor</td>
<td>12.4</td>
<td>6.1</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>11.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Canine</td>
<td>14.7</td>
<td>14.2</td>
</tr>
<tr>
<td>First premolar</td>
<td>18.2</td>
<td>14.9</td>
</tr>
<tr>
<td>Second premolar</td>
<td>16.5</td>
<td>14.9</td>
</tr>
<tr>
<td>First molar</td>
<td>68.2</td>
<td>52.5</td>
</tr>
<tr>
<td>Second molar</td>
<td>44.3</td>
<td>32.9</td>
</tr>
<tr>
<td>Third molar</td>
<td>22.6</td>
<td>31.1</td>
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at 1 mm intervals and examined under the stereomagnifier for the presence of air bubbles and if any were found, the specimen was discarded; approximately 20 per cent of the replicas were eliminated from the study for this reason.

In order to eliminate any untoward effect of acid on the Silastic, three specimens of the rubber material were weighed before and after immersion in 50 per cent hydrochloric acid for 24 hours.

The minimal size of the pulp cavity was appreciated by comparing it with the volume of a drop of water. A 21G hypodermic needle was attached to a 1 ml syringe filled with distilled water and the plunger depressed with the barrel held vertically, until a drop of water detached itself from the tip of the needle. Ten drops of water thus obtained were weighed individually.

Results
The mean volumes of the pulp cavities of 10 teeth of each tooth type were calculated and the results of the maxillary and mandibular teeth are shown in Table I.

Following immersion of the three specimens of Silastic in 50 per cent hydrochloric acid for the same length of time as in the experiment, it was found that no significant loss of weight was detected.

The mean weight of one drop of water was found to be 12.2 mg with a standard deviation of 0.26 mg. The drop therefore had a volume of 12.2 mm$^3$.

Discussion
The study illustrates a simple and inexpensive means of measuring the volume of dental pulp cavities; by virtue of the selection criteria for the specimens, extremes of age were excluded. The measurement of pulpal volume has hitherto been an unknown quantity and factors such as heredity and secondary dentine complicate its standardization. This variation was reflected by the high standard deviation (Table I) obtained in this sample of ten teeth of each tooth type.

To appreciate the small volume of the pulp cavity, the average volume of a drop of water obtained under the conditions specified was similar to the average volume of the pulp cavity of an upper central incisor in this series. It was interesting to note that the maxillary first molar pulp cavity showed the largest average volume followed by the mandibular molar, while the lower central incisor pulp cavity showed the smallest volume measurement.

The method of fracturing the tooth near the amelo-cemental junction facilitated access into the cavity and at the same time preserved the integrity of the inner pulpal surface.
When the apposition of the crown and root pieces was accurate, a negligible excess of Silastic appeared at its junction. Although this excess was easily trimmed with a knife, it could have been a possible source of error in measurement. Silastic was a very suitable material as far as reproduction of detail, available working time and resistance to tear were concerned. The presence of trapped air in the set material was minimized by following the manufacturer's instructions rigidly and by discarding the mould if bubbles were found in the slices after weighing.

In conclusion, an accurate replica of the pulp cavity provides the clinician and student with an appreciation of the dimensions of a complex root canal system. In addition, the method described furnishes information on pulpal volume, a previously unreported aspect.

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