The Effect of Rate of Increase of Electrical Current on the Sensation Thresholds of Teeth
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What is This?
The effect of the rate of increase of electrical current during stimulation of human teeth was examined on clinically sound upper anterior teeth. The teeth were stimulated with a current of 10 msec duration at a frequency of 50 Hz. Eight different rates of current increase were used, viz.: 1, 2, 3, 4, 5, 6, 7, and 8 μA/sec.

The results showed that there was a linear relationship between the sensation threshold and the rate of current increase, and that the threshold increased significantly as the rate of current rise increased.

Slowly increasing current gave more accurate and reproducible results than did rapidly increasing current, and a rate of 2 μA/sec was found to be appropriate for clinical pulp-testing.


Introduction.

The sensation threshold value is important when pulpal responses of traumatized teeth are compared over a period of time and when the effects of factors such as sex or age on the sensation threshold are investigated. Also, it is generally accepted that electrical pulp-testers can distinguish vital from non-vital teeth (Mitchell and Tarplee, 1960; Garfunkle et al., 1973). However, no definite evidence is available to support the view that the sensation threshold is indicative of the pathological condition of the pulp.

Mumford and Lewis (1976) and Mumford (1982) noted that a disadvantage of many electric pulp-testers was the fact that the current was increased manually until the subject felt a sensation. This procedure may not be reproducible when one is testing several teeth or conducting comparison tests. A search of the literature failed to discover any study which examined the effect of rate of current rise on the sensation thresholds of teeth. It was, therefore, decided to investigate whether the pulpal sensation threshold varies with the rate of current increase.

Materials and methods.

The electric pulp-tester used in this study was designed specifically for research purposes and was similar to that described by Mumford and Lewis (1976). It is a mains-operated unipolar constant-current generator (Romotex Ltd., Stockport, Cheshire, England). The tooth electrode is cathodal and made of conducting rubber with a surface area of 10 mm². The hand electrode is anodal and is metal, thus ensuring good conductivity. A spring-loaded microswitch is attached to the hand electrode and is operated by the subject to start and stop the current. A micro-ammeter measures the current flow and is calibrated from 0 to 200 microamps. During stimulation, the current is electronically increased, and nine different rates of current rise are available: 0.5, 1, 2, 3, 4, 5, 6, 7, and 8 microamps per second. The teeth were stimulated with a current of 10 msec duration at a frequency of 50 Hz. These values have been shown to be satisfactory for clinical pulp-testing (Mumford, 1964).

The subjects were 15 dental students, seven males and eight females, and they ranged in age from 19 to 23 years. The tests were performed on clinically sound permanent anterior teeth — that is, caries-free and without restorations. A total of 27 upper central incisors, 28 upper lateral incisors, and 29 upper canines was tested. All the teeth were tested when the current was increased by 1, 2, 3, 4, 5, 6, 7, and 8 μA/sec. All tests were carried out during the morning to avoid the effects of diurnal variations in sensation thresholds (Taylor, 1953), and each test was completed in a single sitting, with a rest interval of five minutes between tests to reduce subject fatigue. Each tooth was tested twice with each rate of current increase, but only the first reading was used for the statistical analyses. The second reading was used to assess the reproducibility of the response, but, because of the possibility of adaptation to the stimulus (Mumford, 1965), it was not used in the analyses.

Sequential use of the eight different rates of current increase was randomized. The subjects were not aware which rate of current increase was being used, and the pulp-tester was placed so that the micro-ammeter could not be seen by the subject, since this may have affected each subject’s perception and thus biased the results.

The teeth being tested were isolated with a rubber dam and dried by a stream of compressed air. A drop of normal saline was applied to the tooth electrode before each test, since this has been shown to act as an effective conducting medium (Taylor, 1953). The electrode was placed on the middle of the labial surface of the tooth to be tested, and the subject started the test with the microswitch on the hand electrode. The test was terminated by the subject releasing the microswitch when the first sensation was felt. The micro-ammeter reading was then noted.

Computerized repeated measures of analyses of variance were used to compare the sensation thresholds of teeth when tested with the eight different rates of current increase.

Results.

All the 84 teeth tested gave positive responses to the tests. The ranges of the sensation thresholds of all the teeth tested with the eight rates of current increase are shown in the Table, together with the mean values. It is evident that the sensation thresholds of all the teeth increased as the rate of current rise increased. The analyses of variance revealed that the sensation threshold differed significantly with the rate of current increase (P < 0.001 in all cases).

The statistical analyses were extended to determine whether there was a direct relationship between the sensation threshold and the rate at which the current was increased. A regression analysis was used, and the fitted regression equations were:

For the upper central incisors,

\[ Y = 5.65 + 0.35X, \]  

where

\( Y \) is the sensation threshold in microamps, and

\( X \) is the rate of increase of the current.
TABLE
SENSATION THRESHOLDS (MEAN, S.D., AND RANGE) OF TEETH TESTED

<table>
<thead>
<tr>
<th>Sensation Threshold (μA) when the Current was Increased by</th>
<th>1 μA/sec</th>
<th>2 μA/sec</th>
<th>3 μA/sec</th>
<th>4 μA/sec</th>
<th>5 μA/sec</th>
<th>6 μA/sec</th>
<th>7 μA/sec</th>
<th>8 μA/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Central Incisor</td>
<td>Mean</td>
<td>6.19</td>
<td>6.56</td>
<td>7.48</td>
<td>7.93</td>
<td>8.43</td>
<td>8.93</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>1.42</td>
<td>1.74</td>
<td>1.93</td>
<td>1.73</td>
<td>1.97</td>
<td>2.2</td>
<td>2.03</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>4 to 9</td>
<td>4 to 9</td>
<td>4 to 11</td>
<td>5 to 11</td>
<td>5 to 12</td>
<td>6 to 13</td>
<td>5 to 13</td>
</tr>
<tr>
<td>Upper Lateral Incisor</td>
<td>Mean</td>
<td>5.68</td>
<td>6.57</td>
<td>7.29</td>
<td>7.89</td>
<td>8.21</td>
<td>8.79</td>
<td>9.29</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>1.59</td>
<td>1.55</td>
<td>1.46</td>
<td>1.75</td>
<td>1.37</td>
<td>1.4</td>
<td>1.56</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>3 to 8</td>
<td>4 to 10</td>
<td>5 to 10</td>
<td>5 to 12</td>
<td>5 to 10</td>
<td>6 to 11</td>
<td>6 to 12</td>
</tr>
<tr>
<td>Upper Canine</td>
<td>Mean</td>
<td>8.62</td>
<td>9.17</td>
<td>9.31</td>
<td>10.0</td>
<td>10.97</td>
<td>11.24</td>
<td>12.03</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>2.51</td>
<td>2.25</td>
<td>2.21</td>
<td>2.8</td>
<td>2.81</td>
<td>2.68</td>
<td>2.51</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>5 to 13</td>
<td>5 to 13</td>
<td>5 to 12</td>
<td>6 to 14</td>
<td>6 to 15</td>
<td>7 to 15</td>
<td>7 to 16</td>
</tr>
</tbody>
</table>

(Standard error of the regression coefficient = 0.03, t = 21.12, with 182 degrees of freedom, P < 0.001.)

For the upper lateral incisors,

\[ Y = 6.08 + 0.54X \]

(Standard error of the regression coefficient = 0.03, t = 21.48, with 189 degrees of freedom, P < 0.001.)

For the upper canines,

\[ Y = 7.96 + 0.56X \]

(Standard error of the regression coefficient = 0.03, t = 16.82, with 196 degrees of freedom, P < 0.001.)

The analyses demonstrated a simple linear relationship between the sensation threshold and the rate of current increase. The sensation threshold increased as the rate of current rise increased, and the slopes of the regression lines were similar for the different categories of teeth tested (analyses of variance showed no significant difference between the slopes of the regression lines for the different categories of teeth). Furthermore, the analyses of variance showed that the simple linear relationship accurately described the relation between the sensation threshold and the rate of current increase, and that there was no significant deviation from this linear relationship.

Discussion.

The problems involved in electrical stimulation of human teeth and the limitations of vitality tests have been reviewed by many authors (Ziskin and Wald, 1938; Mumford and Bjorn, 1962; Mumford, 1964; Matthews and Searle, 1974; Chambers, 1982). The test is further complicated by the choice of the electric pulp-tester, since they are of different types and there are different views concerning the best type to use. Hannam et al. (1974) argued that bipolar pulp-testers were more accurate than unipolar pulp-testers. On the other hand, Kaletsky and Furedi (1935) and Matthews and Searle (1974, 1976) were of the opinion that unipolar pulp-testers were more reliable than bipolar pulp-testers, because, if vital pulp tissue is confined to the root canal(s), it may be difficult to determine pulp vitality with the bipolar pulp-tester. In addition, variable current pulp-testers are widely considered to be more reliable than variable voltage-testers because of the high and very variable electrical resistance of enamel (Matthews and Searle, 1976).

For these reasons, a unipolar pulp-tester with variable current output was used in this study.

It is evident that the findings of this study have implications in clinical electrical pulp-testing. The results clearly showed that it is necessary to maintain the same rate of current increase at all times when one is electrically stimulating teeth. Failure to do so will lead to altered sensation thresholds and thus invalidate comparison of results.

In addition, it is highly probable that the reaction time of the subjects affected the results obtained. The reaction time is defined as the time taken for the subject to terminate the test after the first sensation has been perceived. The effect of the reaction time can be explained as follows:

Assume that the subject’s threshold is N μA. If the reaction time of the subject is X seconds, then the threshold reading on the ammeter would be: N + X (S) μA, where S is the rate of current increase, because the current will be increasing until the subject reacts and terminates the test.

The mean reaction time of normal subjects has been found to be 180 milliseconds (Mumford, 1982). It follows that if the threshold for a subject is 6 μA and the current used was increased by 1μA/sec, then the pulp-tester reading would be 6 + (1 × 0.18) = 6.18 μA.

If the current were increased by 8 μA/sec, the threshold reading would be 6 + (0.18 × 8) = 7.44 μA.

Both of these ammeter readings will be the observed sensation thresholds of the same tooth, which will vary with variations in the rate of current increase. However, in the latter case (when the current was increased by 8 μA/sec), the threshold would probably be surpassed due to the rapid rate of current rise.

This explanation of the effect of the reaction time on the ammeter readings is supported by two observations: first, by the linear relation demonstrated between the sensation thresholds and the rate of current increase. From the examples given above, it is clear that such a relationship exists. Moreover, the fact that there was no significant difference in the slopes of the regression lines for the different categories of teeth tested suggested that all the slopes were dependent upon a common variable which could well be the reaction time of the subject.

Second, it was observed in this and other studies (Kleier et al., 1982) that many subjects experienced somewhat painful sensations with rapid (> 6μA/sec) rates of current increase. On the other hand, slowly increasing currents (< 5 μA/sec) did not produce pain. This observation suggests that the sensation threshold was overshot with the rapid rates of current increase, and hence the subjects experienced pain. Incidentally, it also supports the contention that sensations other than pain can be appreciated by the pulp (Mumford and Stanley, 1981).

It follows therefore that a slowly increasing current is pref-
The results of the present study suggested that a current increase of 2 μA/sec is appropriate for clinical pulp-testing, since a current increasing by 1 μA/sec was found to be somewhat slow and tedious when a large number of teeth is being tested. From these results, it can be concluded that pulpal sensation thresholds differ significantly with the rate of current increase. The variation in the threshold was linearly related to the rate of current increase, so that, as the rate of current rise increased, the sensation threshold also increased. The results further indicated that it is necessary to maintain the same rate of current rise during electrical stimulation of teeth, and a current rate of 2 μA/sec is suggested.

REFERENCES


