Evaluation of the carbon dioxide laser on vital human primary pulp tissue

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Abstract

Purpose: The purpose of this study was to evaluate the response of the human primary pulp to the carbon dioxide laser and formocresol for vital pulp therapy.

Methods: Fifteen healthy children with intact, caries- and restoration-free, contralateral primary cusps with at least two-thirds of the roots remaining who were scheduled for orthodontic extractions were randomly assigned to pulpotomy treatment with a carbon dioxide laser or formocresol. The treated teeth were clinically and radiographically evaluated at 28 and 90 days post-treatment prior to extraction. The extracted teeth were evaluated histologically for pulpal response.

Results: All teeth were asymptomatic and clinically normal at both observation periods. Internal root resorption was observed in one formocresol and two laser-treated teeth. There was a significant inverse correlation between the laser energy applied to the pulp and the degree of inflammation at 28 days (P = .01) but not at 90 days (P = .27).

Conclusion: Carbon dioxide laser treatment compared favorably to formocresol for pulpotomy in primary teeth. (Pediatr Dent 21:327-331, 1999)

Carbon dioxide laser and to compare the effects of the carbon dioxide laser to formocresol for direct vital pulp therapy.

Methods and Materials

Children between 6 and 10 years of age and in good health having two or four contralateral caries- and restoration-free primary cusps with two-thirds or more root remaining and required extraction as part of the patient's orthodontic treatment were selected for the study. The research protocol and associated consent/assent forms were reviewed and approved by the University of North Carolina (UNC) School of Dentistry Committee on Investigations Involving Human Subjects.

The intraoral soft tissues and teeth were examined and a periapical radiograph was taken of each primary cuspid to confirm that it met the inclusion criteria. A coin toss was performed to assign the first cuspid in an arch to either the test group (laser-treated) or control group (formocresol). Randomization resulted in eight patients in the 28-day protocol and seven patients in the 90-day protocol. A total of 30 teeth were included in the study. The mean age of the patients in the 28-day group was 8 years, 4 months (range: 7 years 3 months—9 years 11 months) and the mean age of the 90-day group was 9 years 4 months (range: 7 years 5 months—10 years 3 months). All of the teeth in the study were anesthetized, by block injection when possible, using 2% lidocaine with 1:100,000 epinephrine. The teeth were then isolated with a rubber dam, swabbed with povidone iodine 10% solution (Clinidine Solution — The Clinidine Corporation, Guilford, CT) followed by 70% isopropyl alcohol, and dried with a sterile gauze pad. No instruments used previously were reintroduced to the surgical field. The access cavity on the lingual surface of each tooth was partially completed with a high-speed dental handpiece using a new, sterile #245 bur under water spray. The pulp was exposed with a slow-speed round bur without air or water spray. Pulp amputation was completed with a new, sterile #4 slow-speed round bur and spoon excavator followed by copious irrigation with sterile saline. A cotton pellet dampened with sterile saline was placed over the amputated pulp stump for five minutes prior to pulp therapy with either the carbon dioxide laser or formocresol.

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In the control group teeth, a cotton pellet dampened with formocresol was placed in contact with the pulp for five minutes followed by placement of a zinc oxide and eugenol base. Varnish (Copalite, Teledyne Getz, Elk Grove Village, IL) was applied to the cavity margins and a dental amalgam (Sybraloy Capsules – Kerr Manufacturing Company, Orange, CA) restoration placed. All operative procedures for the test group (laser) were the same as described for the control group except for pulp treatment. Following amputation of the pulp and control of bleeding, the amputated pulp stump was laser at the canal orifice using the carbon dioxide laser (LX-20 Dental, ESC Medical Systems, Bothell, WA) set at 6 watts, 0.1 second, single impulse (mode 9). The laser energy was delivered through a 1.0 m (length) hollow wave guide attached to a right angle handpiece with a hollow 0.8 mm diameter ceramic tip. The distance between the end of the ceramic tip and the canal orifice was approximately 1-1.5 mm. Multiple firings were administered until a char layer was present over the amputated pulp tissue and there was no evidence of recurrent bleeding. The mean amount of energy applied to each tooth was 12.6±4.2 (7.2-21.0) joules. An increase in applied energy equates to increased heat exposure to the pulp stumps.

The teeth were extracted at either 28 days or 90 days after treatment. Each tooth and surrounding soft tissue was evaluated and a periapical radiograph was obtained prior to extraction. The extracted tooth was placed in a code-labeled bottle containing 10% formalin solution. The teeth were de-calcified in 5% formic acid, embedded in paraffin, sectioned parallel to the long axis of the teeth at 5-6 µm thickness, and stained with hematoxylin and eosin. An oral pathologist, blinded to the mode and time of treatment, examined each specimen at 40x and 100x. An inflammation score was assigned to each section using a numerical scale. Table 1. The presence and intensity of inflammatory cells were graded for four fields. The score assigned to the tooth was the mean value of the four examined sections.

Two clinicians, blind to the mode and time of treatment examined the pre-extraction radiographs. Evidence of internal resorption, pulpal calcification, dentinal bridging, or pathologic root resorption was recorded as either present or absent. The pre-treatment radiograph served as a baseline for the post-treatment radiographic evaluation. The Mantel Haenszel row mean score test was used for inflammation and

<table>
<thead>
<tr>
<th>Grade 1</th>
<th>Occasional inflammatory cells seen throughout the pulp without a specific pattern. The odontoblastic layer was intact along the radicular pulp walls.</th>
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</thead>
<tbody>
<tr>
<td>Grade 2</td>
<td>One focus of inflammatory cells was present which occupied less than one fourth of the pulp. A small section of odontoblasts was disrupted.</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Inflammatory cell infiltrates were present in over one-half of the pulp and edema was prominent. Extensive areas were missing in the odontoblastic layer.</td>
</tr>
<tr>
<td>Grade 4</td>
<td>Heavy collections of acute inflammatory cells and areas of necrosis occupying the pulp chamber were noted. Odontoblasts could not be identified.</td>
</tr>
<tr>
<td>Grade 5</td>
<td>Ischemic (gangrenous) non-vital pulp</td>
</tr>
</tbody>
</table>

Table 1. Inflammation Intensity Score

Fig 1. Formocresol 28-day protocol group. Section shows a zone of necrosis (N) adjacent to the zinc oxide and eugenol base material (Z), inflammatory cells (I) and intact odontoblasts (O). (Mag. 40X)

Fig 2. Formocresol 90-day protocol. Section exhibits a zone of necrosis (N) adjacent to the zinc oxide and eugenol base material (Z) and inflammatory cells (I) throughout the pulp. (Mag. 40X)
a general association test was used for other outcomes. A Breslow Day test of homogeneity for 2x2 tables was used to compare 28-and 90-day subjects controlling for group (formocresol or laser). McNemar’s test was used to compare responses to laser and formocresol treatment (P=.05).

Results

Clinical and Radiographic Results
No teeth were found to exhibit clinical signs of pathologic mobility, history of pain, presence of fistula/abscess, or abnormal supporting soft tissues. No pathologic external root resorption or abscess formation was observed. One formocresol group cuspid (28-day protocol) and two laser group cuspids (one 28-day protocol and one 90-day protocol) exhibited evidence of internal root resorption. (Tables 2 and 3)

Histological Results

Formocresol (28-day)
The formocresol treated pulps received inflammation scores ranging from 2 to 5 (Table 1); the most common score was a 4. A typical pulp showed inflammatory cell infiltrate in the coronal portion which varied from moderate to severe. A thick zone of necrosis and heavy infiltration with acute inflammatory cells was present adjacent to the zinc oxide and eugenol base. Below this zone, the pulp was edematous and heavily infiltrated with acute and chronic inflammatory cells. Occasional inflammatory cells were present and a small number of multinucleated giant cells were seen within the lacunae of the dentin near the apex. The odontoblasts were somewhat flattened in the middle third of the pulp. (Fig 1)

Formocresol (90-day)
The formocresol treated pulps received inflammation scores ranging from 2 to 4; the most common score was a 3. A typical pulp exhibited a zone of edema and infiltrates of chronic and acute inflammatory cells below a zone of fixation and necrosis. There was a mild chronic inflammatory cell infiltrate throughout the length of the pulp. Flattened but intact odontoblasts were present along much of the length of the pulp. (Figure 3)

Laser (28-day)
Inflammation scores ranging from 1 to 4 were recorded; the most common score was a 3. A typical pulp exhibited a zone of edema and infiltrates of chronic and acute inflammatory cells below a zone of fixation and necrosis. There was a mild chronic inflammatory cell infiltrate throughout the length of the pulp. Flattened but intact odontoblasts were present along much of the length of the pulp. (Figure 3)

Laser (90-day)
Inflammation scores ranging from 1 to 3 were recorded; the most common score was a 2. A typical pulp exhibited moderate but less concentrated acute and chronic inflammatory cell infiltrate beneath the zinc oxide and eugenol base. Columnar odontoblasts were prominent along the dentin wall. (Figure 4)

Statistical Results
There was a statistically significant difference (P=.0001) between 28 and 90 days in the percentage of subjects demonstrating reparative dentin in the pulp. The difference in the presence of reparative dentin between 28 and 90 days was similar for both laser and formocresol. In comparing the laser and formocresol for inflammatory response, all—subjects regardless of protocol time—were included in the analysis. There were no statistically significant differences observed (Table 4). There was no statistically significant difference between formocresol and laser in stimulating an odontoblastic layer or dentin formation (Table 5).

In the laser group, the association between inflammation and amount of energy applied is moderately strong when 28-and 90-day data are combined (r_s=-.49; P=.06). At 28 days (r_s=-.83; P=.01) the relationship was much stronger than at 90 days (r_s=.48; P=.27).

Discussion
In this study, there were no significant differences between the formocresol and laser groups with respect to symptomatic, clinical, or radiographic findings. The observed presence of isolated areas of internal resorption in one of the formocresol treated teeth and two of the laser treated teeth was puzzling. An ex-

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Formocresol 28-day</th>
<th>Formocresol 90-day</th>
<th>Laser 28-day</th>
<th>Laser 90-day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N=8)</td>
<td>(N=7)</td>
<td>(N=8)</td>
<td>(N=7)</td>
</tr>
<tr>
<td>Excess mobility</td>
<td>0</td>
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<td>History of pain</td>
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<tr>
<td>Fistula/Abscess present</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Soft tissues appear normal</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>7</td>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N=8)</td>
<td>(N=7)</td>
<td>(N=8)</td>
<td>(N=7)</td>
</tr>
<tr>
<td>External root resorption</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Abscess formation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Internal root resorption</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
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</table>
The histologic observations in this study revealed three interesting effects which were consistent with previous observations. First, the laser treatment was at least as effective in minimizing post-treatment inflammation as the formocresol treatment. Second, there was no statistically significant recovery from inflammation between the 28- and 90-day observation period in either the laser or formocresol group. Third, there was a strong and statistically significant inverse correlation between the energy used during the respective laser pulpotomies and the degree of inflammation observed at 28 days.

The data imply that there is an energy threshold necessary to create some condition required to minimize an initial inflammatory response. We speculate that the higher energy created a thicker char layer over the remaining pulp which in some way had a favorable effect. This energy threshold appears to be less important over time. Miserendino et al. reported that the pulp can predictably heal itself when the temperature does not rise more than 5.5°C above physiological baseline. In this study, the total energy applied did not exceed 21 joules; thus it would be reasonable to assume that we were well within the safety threshold dose level for carbon dioxide laser pulpotomy.
Conclusions
1. On the basis of symptomatic, clinical, radiographic, and histologic findings, the carbon dioxide laser for pulpotomy appears to compare favorably to formocresol treatment.
2. The application of enough laser energy to create a dense char layer results in less initial inflammatory response in the residual pulp.
3. Additional studies should be conducted to establish the ideal applied laser energy to maximize optimum residual pulp response, and to explore the effects of laser treatment to pulps exposed previously by caries.

References