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Advantages of a Pulsed CO_2 Laser in Direct Pulp Capping: A Long-Term In Vivo Study

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Background and Objective: **A previous study [Moritz et al., Z Stomatol 1996; 93:451–454] had shown that favourable results in direct pulp capping could be achieved using a continuous wave CO_2 laser in addition to the conventional calcium hydroxide dressing technique. In this study, these results are compared to those achieved using a CO_2 laser working in superpulsed mode.**
Study Design/Materials and Methods: **A total of 260 direct pulp capping procedures were carried out; 130 were performed with a superpulsed CO_2 laser, followed by a calcium hydroxide dressing, and 130 conventionally by applying only a calcium hydroxide preparation. Recall examinations were performed after 1 week and monthly for 18 months after treatment. A final examination was carried out 2 years after treatment. Thermal tests were used for vitality assessments and laser Doppler flowmetry for direct measurement of pulpal blood flow.**
Results: **In the group of pulps treated with the superpulsed CO_2 laser, the last recall examination at 2 years revealed that 93% of the teeth had remained vital. In the control group, the success rate was considerably lower (66.6%). Exposure site sizes and average patient age were nearly identical in both groups.**
Conclusion: **The CO_2 laser seems to be a valuable aid in direct pulp capping; the efficiency of laser treatment can be increased by using a pulsed CO_2 laser. Lasers Surg. Med. 22:288–293, 1998.** **© 1998 Wiley-Liss, Inc.**

Key words: dentin; endodontics; teeth; vitality

INTRODUCTION

Direct pulp capping is considered a valid treatment method in today's endodontics, because successful capping can preserve tooth vitality in an exposed pulp cavity. Calcium hydroxide preparations are normally used as capping material. Several preparations are commercially available [3]. Due to superficial necrosis resulting from the highly alkaline pH of the capping material and the subsequent formation of fiber-rich scar tissue, normal pulp cells are transformed into secondary odontoblasts and secondary dentin is formed [2].

The success rates reported in the literature vary between 44% and 95% and depend on the size of the exposed pulp area, the location of the site to be capped, and the age of the patients [2,4–6].

Between 1985 and 1987, Melcer et al. [7–9] suggested that the CO_2 laser be used for direct pulp capping and stated that the advantages of laser irradiation would be an improved restoration (scarring) of dentin tissue through formation of secondary dentin and, above all, sterilization because of the thermal effects of laser treatment. In 1986, Melcer [8] even described successful pulp

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restoration after direct capping of inflamed pulps with laser.

Three years ago in our department, we started cw CO_2 laser-assisted direct pulp capping. First results were encouraging [1]. The next step was to introduce a superpulsed CO_2 laser into clinical treatment.

This study deals with CO_2 laser-supported direct capping of clinically asymptomatic pulps. We used a cold test and laser Doppler flowmetry for vitality assessment. This method is perfectly suitable for measurements of pulpal blood flow as shown by Gazelius et al. in 1986 [11] and Wilder-Smith in 1988 [12].

MATERIALS AND METHODS

All test persons were recruited from the patients of our department. They were randomly subdivided into two groups (a laser group and a control group). In all patients, the pulps had been accidentally exposed during (mechanical) cavity preparation because of deep decay. According to thermal vitality tests performed before treatment, all teeth had been vital and without any clinical signs of pulpitis prior to treatment. Treatment by direct pulp capping was therefore indicated. In most cases, a rubber dam was applied before the start of the preparation procedure. In a few cases it was applied later, when the exposure of the pulp was detected.

Our study included a total of 260 patients; all of which had given their written consent to participate in our study. In 130 patients, pulp capping treatment was carried out with the superpulsed CO_2 laser, whereas the remaining 130 patients were treated with a conventional capping technique using Kerr Life® dressing, which contains calcium hydroxide.

The average age in the laser group was 34.8 years, the youngest patient being 15 years old and the oldest patient 65. The exposure sites had a mean diamenter of 0.6 mm, the smallest diameter being 0.1 mm and the largest 1.2 mm. In the control group, the average age was 33.9 years, the youngest patient being 9 years old and the oldest patient 68. The exposures had a mean diameter of 0.6 mm, the smallest diameter being 0.1 mm and the largest diameter 1.5 mm. The diameters of the exposures were assessed with the help of a calibrated magnifying glass. Table 1 gives a brief overview of the locations of the pulp exposure sites in both groups.

TABLE 1. Pulp Exposure Sites

Tooth	Laser group	Control group
Upper molar	39	41
Lower molar	28	26
Upper premolar	18	16
Lower premolar	11	12
Upper canine	2	4
Lower canine	1	2
Upper incisor	25	18
Lower incisor	6	9

A Sharplan 1030 CO_2 laser was used in the laser group. This laser is operated at an output power of 0.5 to 30 W, either in cw, pulsed, or superpulsed mode. The exposed pulps were irradiated at an output power of 1W at several intervals; 0.1 sec pulses were followed by 1 sec pulse intervals. This procedure was repeated until the exposed pulps were completely scabbed.

The treated pulps were then dressed with Kerr Life® and the cavities filled with glass ionomer cement (Ketacfil®). Final filling of the cavities was carried out after 6 months.

In the control group, the pulps were capped with Kerr Life® without prior laser treatment. The cavities were also filled with Ketacfil® and final filling of the cavities was carried out after 6 months.

Recall examinations were carried out after 1 week, then monthly for 18 months after treatment. A final examination was carried out after 2 years. The patients' subjective symptoms and the vitality of the treated teeth were examined. To assess tooth vitality, thermal tests and measurements of pulpal blood flow with laser Doppler flowmetry (using the Periflux 4001 device by Perimed) were carried out. With this method, typical perfusion curves synchronous with heart beat and vasomotion can be obtained, which allow assessment of the vitality of a tooth. To ensure a reproducible positioning of the laser Doppler probe and to avoid any motion artifacts, the laser Doppler probe was attached to the teeth using silicone impressions.

RESULTS

Two years after treatment, 200 patients were still available for recall: 100 patients in the laser group and 100 control subjects. Of the teeth, 93% in the laser group were vital (i.e., they showed a positive reaction to cold and a healthy perfusion index in laser Doppler measurements)

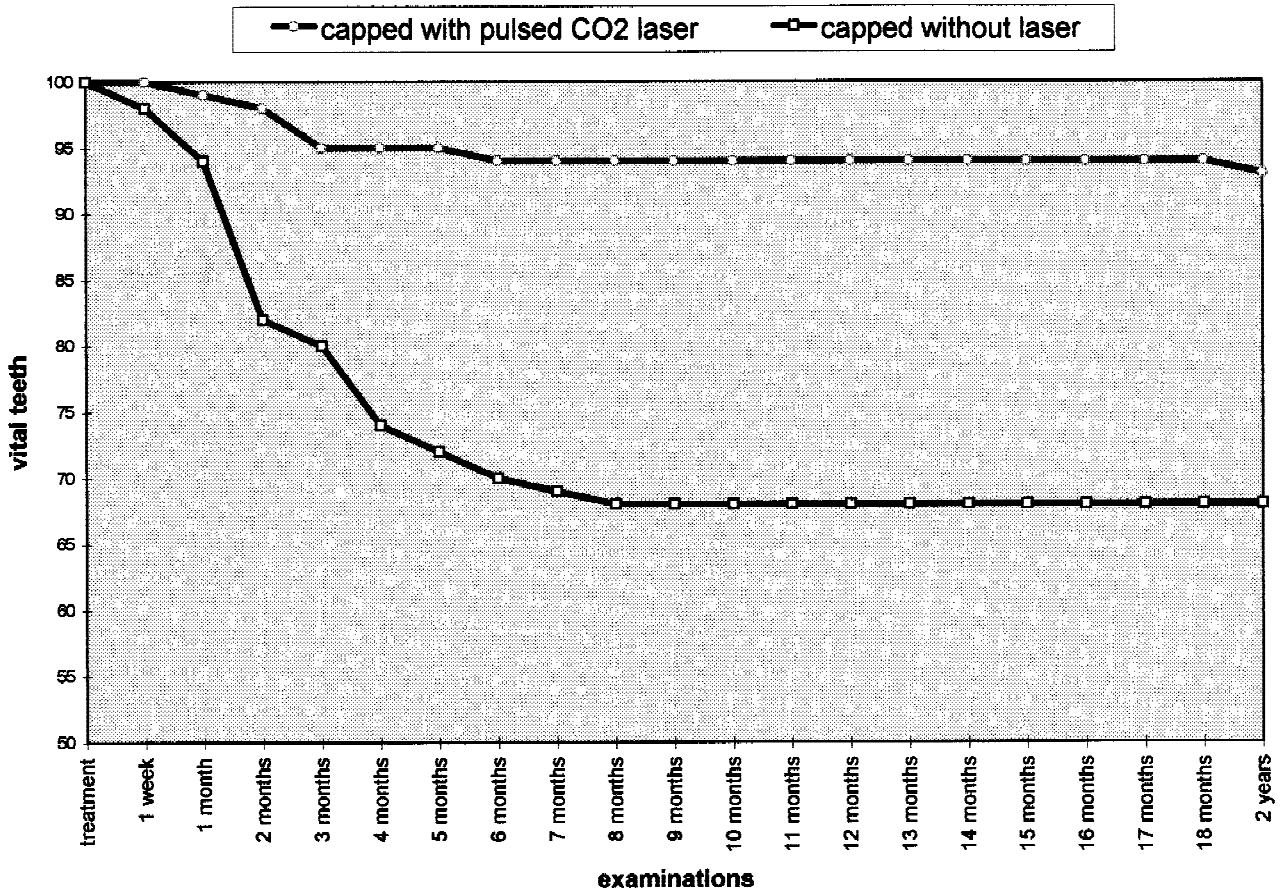

Fig. 1. Course of vitality.

and asymptomatic. Seven teeth were affected by pulpitis and required extirpation. In the control group, 68 teeth remained vital, corresponding to a success rate of 68%.

The upper curve in the Figure 1 shows that the number of vital teeth in the superpulsed laser group dropped only slightly during the recall period, whereas in the control group, only 68 teeth were vital at the last recall examination. The lower curve in Figure 1 shows the vitality development in the control group.

None of the groups showed a significant correlation between the size of the exposed pulp region, the patients' average age, type of the teeth examined (molar, incisor, etc.), and success of treatment. Figures 2 and 3 illustrate the success of treatment in relation to the size of the exposed pulp region and the patients' age, respectively.

All perfusion values obtained in the laser Doppler examination were consistent with the results of the cold test. There were no discrepancies with regard to pulpal blood flow and sensitivity.

DISCUSSION

As stated by Ketter [2] in 1978, the early beginnings of treatment of exposed pulps date back to the year 1765. In 592 cases followed-up out of a total of 1,429 cases, Reuver [4], in 1992, found a success rate of 91% in the group of 10–20-year-old patients, which continuously dropped to 58% in the group of 70–80-year old patients. In a type of opening, which the author described as "punctiform," the success rate ranged ~73%; when an area of 1–9 mm^2 was exposed, it was 61%. A total of 68% of the teeth were vital at the last recall examination. However, the timing of the last recall examination varied between 4 months and 24 years in Reuver's study.

A long-term study carried out by Marti in 1979 [5] revealed that the healing success depends on the age of the patients. Marti [5] found a success rate of 84% in the group of 10–25-year-old patients, which dropped to only 44% in the group of 46–70-year-old patients. This may be due to the

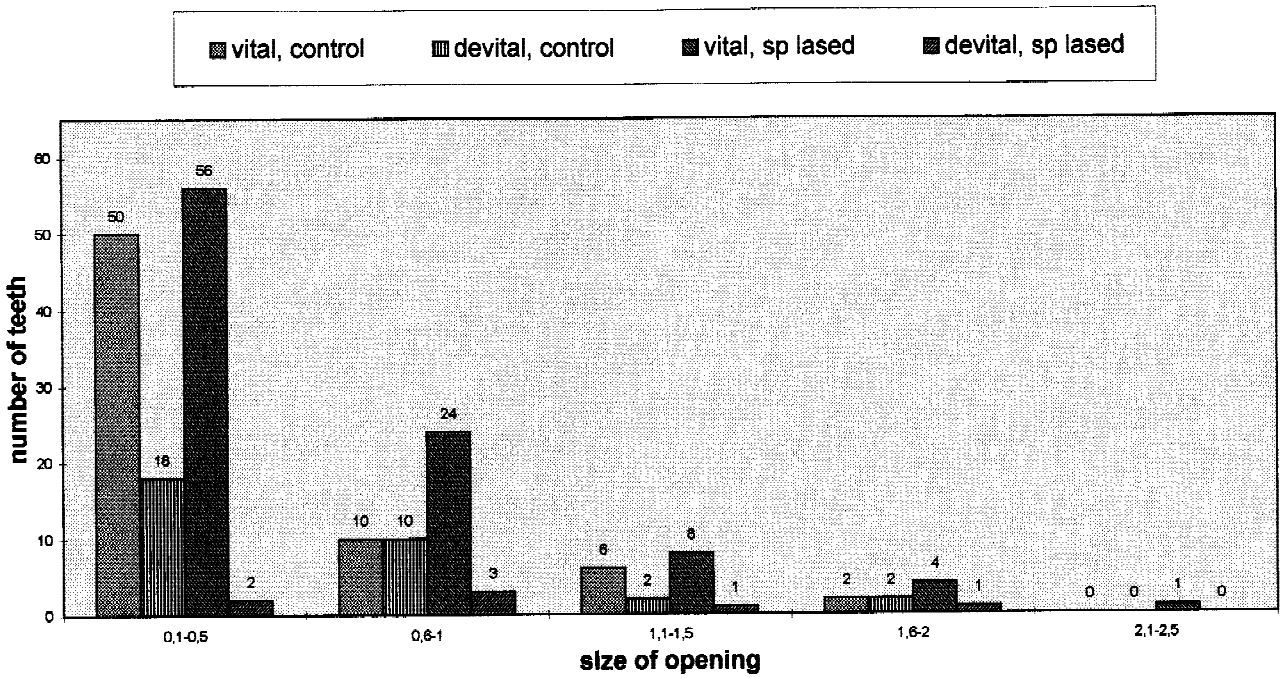

Fig. 2. Tooth vitality in relation to the size of opening.

fact that the pulps of younger subjects are richer in cells and have a higher ability to regenerate.

In 1979, Honegger et al. [6] reported a success rate of 83% in a total of 110 teeth subjected to recall examinations. Like Ketterl in 1987 [2], Schroeder [13] and Kopel [14] stated that direct pulp cappying is indicated only in pulps that have not been affected by inflammation a priori.

An obvious problem in an in vivo study involving such a large number of patients is their continuous availability for recall examinations. In fact, 200 out of 260 patients treated were still available for recall after 24 months.

The success rate of 93% in the superpulsed laser group is markedly higher than that obtained in the control group and the success rates reported for conventional pulp capping techniques in the literature [2,4–6]. It is even higher than the success rate achieved using the cw CO_2 laser [1]. Similar to this study, the quoted authors worked on pulps that have been exposed during the removal of carious decay and were clinically asymptomatic.

None of the groups examined in this study showed a significant correlation between the success rate and the size of the exposed sites, or the patient's mean age.

Another interesting aspect seems to be the chronological course of vitality. The most noticeable loss of tooth vitality takes place within the first 4 months posttreatment. These 4 months seem to be the decisive period.

The most important effects of laser irradiation seem to be sterilization and scar formation [7–9] in the irradiated area due to thermal effects, which may help to preserve the pulp from bacterial invasion. In addition, laser irradiation should minimize the formation of a hematoma between the pulp tissue and the calcium hydroxide dressing, allowing a close contact between the dressing and the exposed pulp. Another effect of laser treatment may be the direct stimulation of dentin formation, as indicated by Paschoud and Holz in 1988 [14]. However, in contrast to this study, these authors examined the effects of soft lasers on dentin formation.

The long intervals (1 sec) between the pulses (0.1 sec), the relatively lower power setting (1 W) and the wavelength (10,6 μm), which is absorbed by ~100 μm, is sufficient to avoid any thermal damage to the pulp.

The reduced thermal strain on the pulp exerted by the superpulsed CO_2 laser seems to be responsible for the greater success rate in com-

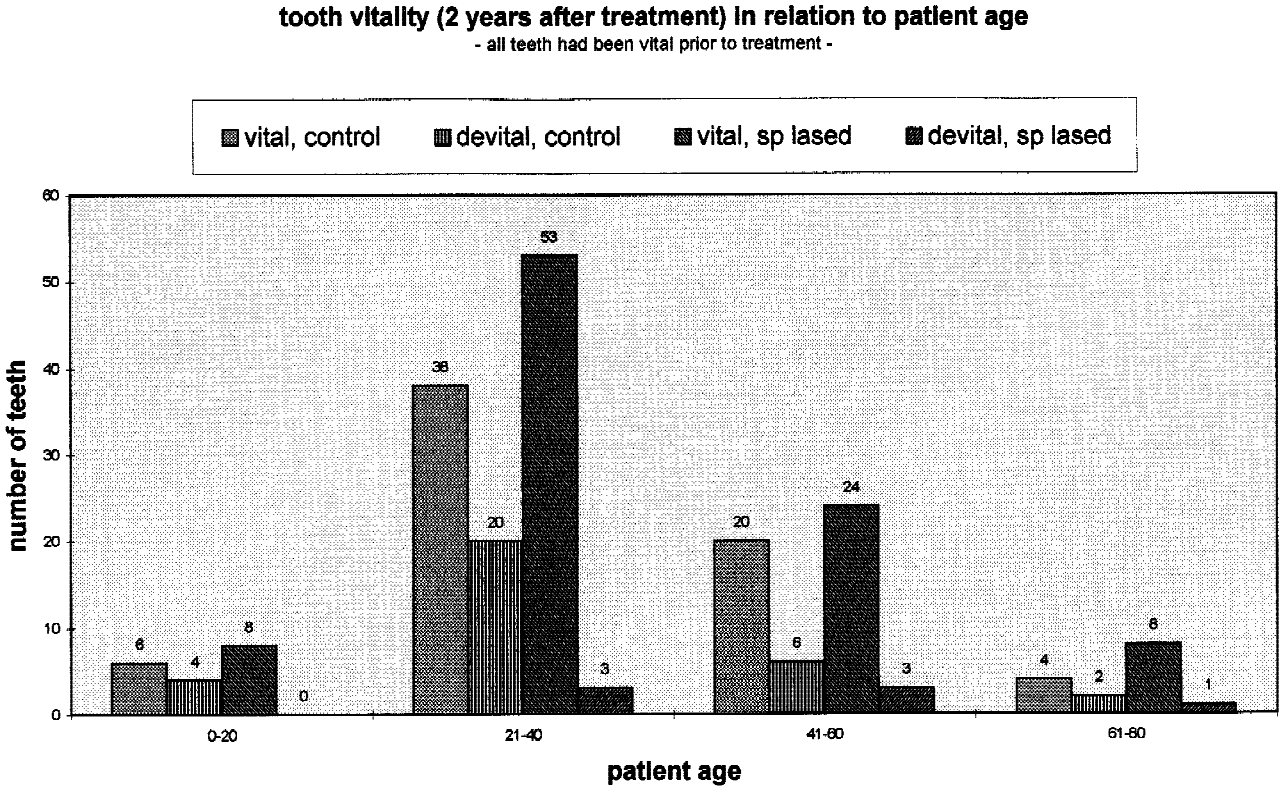

Fig. 3. Tooth vitality in relation to patient age.

parison with the cw CO_2 laser. However, one advantage of the cw CO_2 laser used in the previous study (Lasersat by SATELEC) is its easy application. Since the actual laser is contained in the handpiece, a bulky delivery system is avoided.

In the laser Doppler method, laser light in the infrared range, which is delivered to the tissue to be examined, undergoes a Doppler frequency shift. A sensor records the wavelength of the light backscattered by moving particles (erythrocytes). Conclusions about blood flow in the capillary region can be drawn by comparing the wavelengths of the light transmitted to the tissue under study and the backscattered light. Because the measurements are not affected by the function of the sensitive pulpal nerve-endings, possible false negative results of an indirect test can be avoided, as shown by Gazelius in 1986 [10].

Vitality control with the laser Doppler technique has shown to be very reliable, also in luxated and re-perfused teeth, as demonstrated by Olgart et al. in 1988 [15]. In our examinations, the Doppler vitality results were fully congruent with the results of the thermal tests.

We believe that our results give clear proof of the favorable effects of laser application in direct pulp capping, for which a pulsed laser should be preferred.

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