Pulp Capping – from Conventional to Laser-assisted Therapy (II)

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ABSTRACT: This article presents an overview of the current knowledge in conventional and laser-assisted pulp capping, based on different research records. The pulp capping technique is mainly based on the healing ability of pulp tissue. The most obvious reparatory response of the pulp lesion is the formation of tertiary dentin. Moreover, this paper outlines the use of different laser wavelengths in order to improve the outcomes of pulp capping. Laser therapy has proven its effectiveness in pulp capping and vital pulpotomy by its capacity to stimulate the repair dentin formation by the pulp tissue, its ability to decontaminate irradiated surfaces, as well as its pain reducing effect. Three clinical cases are also presented.

Keywords: pulp capping, laser, conventional treatment, tertiary dentin.

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LASER-ASSISTED PULP CAPPING AND VITAL PULPOTOMY

Human studies

To date, Stabholz and Rocca confirm the existence of many studies indicating an increasing success rate of laser-assisted therapy in pulp capping.[25] The importance of laser technology in preserving pulp vitality is emphasized by the favorable and much more predictable results (there are good results in ~90% of cases, compared to only 60% in traditionally treated cases).[100]

In 2000, Yamaguchi studied the effect of Nd:YAG laser on blood flow in pulp tissue using Doppler laser flowmetry, as well as on pulpal response using electrical tests in mandibular canines from 13 human subjects. A significant increase of blood flow was noticed in all Nd:YAG laser irradiated teeth, and electrical tests revealed increased pulpal response in 6 cases and decreased pulpal response in another 6 cases, and only 1 tooth had unaffected sensibility.[101]

Regarding the efficiency of laser-assisted treatment compared to conventional pulp capping treatment, Santucci reviewed the records of 83 patients who were subject to direct pulp capping, involving 29 treatments using calcium hydroxide and 64 using Nd:YAG laser and Vitrebond. The comparative results revealed a significantly higher survival rate in laser and Vitrebond treated teeth, compared to those treated with calcium hydroxide, during an observation period of 9 to 54 months after treatment. The cumulative survival rate in calcium hydroxide treated teeth showed values of 89.7% one month after surgery, decreasing to 79.4% after 3 months, 76% after 6 months, and to only 43.6% at the end of the 54-month observation period. The laser-treated specimens showed a cumulative survival rate of 98.4% one month after surgery, 93.8% after 3 months, and 90.3% after 6 months, the last value remaining stable until the end of the observation period (54 months). The conclusion was that the pulpal response produced by laser and Vitrebond treatment is much more predictable than the one produced by calcium hydroxide. The survival rate of permanent teeth which were subjected to direct laser-assisted pulp capping is significantly higher than that of permanent teeth treated with calcium hydroxide for the 9- to 54-month period.[102]

In an attempt to compare the results obtained in 1996 for continuous mode CO_2 laser with the results obtained for superpulsed mode CO_2 laser used in direct pulp capping, Moritz et al performed a 2-year

study on a total number of 260 cases. In 1998, they observed a pulp survival rate of 93% in laser treated specimens, compared to a 68% survival rate in specimens that belonged to the conventionally treated control group. Considering the lack of correlation between the average age of the laser-treated group (34.8 years), the average exposure diameter (0.6 mm), the type of treated teeth and the therapeutic prognosis, the authors concluded that the best results were obtained with superpulsed mode CO_2 laser, energy level 1, exposure time 0.1 s, 1 s interval between pulses, applied until the dental pulp was completely sealed. The treatment was completed by covering the area with calcium hydroxide (Kerr Life) and filling the cavities with glass-ionomer cement (Ketacfill). The final filling was performed 6 months after treatment.[103,104]

In 2005, Todea conducted a histological and clinical study to find the most effective laser therapy for pulp tissue vitality preservation in accidental pulp exposure. The study was divided into two parts: a histological examination on recently extracted teeth and a clinical trial. One hundred twenty-nine patients with accidental pulp exposures were included in the clinical study. The pulp capping procedure was performed in group one with CO_2 laser (wavelength 10,600 nm; total dose 9.54 J/cm^2; 0.8 mm ceramic tip), followed by $Ca(OH)_2$, and in group two with Nd:YAG laser (wavelength 1060 nm; optical fiber of 300 μm) followed by $Ca(OH)_2$. The control group was treated with $Ca(OH)_2$ only. After clinical evaluation (one week, 6 weeks, 6 months and one year), 62.5% of the teeth treated with CO_2 laser and $Ca(OH)_2$ were clinically asymptomatic. These results show that under the established conditions of this study, CO_2 laser was the most effective for pulp capping in accidental pulp exposure.[105]

In their review, Pescheck and Moritz present the following procedure for pulp capping in deciduous and permanent human teeth, performed using CO_2 laser applied without direct contact to the pulp tissue, and using a He-Ne laser to point at the target area. The pulp tissue is irradiated (power 1 W, pulse duration 0.1 s, 1 s intervals) immediately after exposure. In order to obtain hemostasis and the exposure's sealing, 2 to 3 cycles of irradiation are required. After laser treatment, the exposure sites are covered with calcium hydroxide, and the cavities are filled with glass-ionomer cement; the final filling will be performed 6 months after treatment in order to check the healing process and the vitality of pulp tissue. The authors also emphasize the need for periodical control, every 30 days, one year after treatment.[78]

In a randomized experimental study, Huth tested the efficacy of Er:YAG laser, calcium hydroxide, and ferric sulphate compared to formocresol, in an attempt to maintain the vitality of 200 permanent molars, belonging to 107 healthy children, after partial pulpotomy. The following laser settings were used according to the initial model of Keller and Hibst from 1991:[106] pulsed mode, 2 Hz, 180 mJ per pulse, with an average of 31.5 ± 5.9 pulses per tooth, no cooling system. Favorable results were obtained for Er:YAG laser, with a success rate of 93% 12 months after treatment, and 78% 24 months after treatment, compared to 86% for formocresol and only 53% for calcium hydroxide.[107]

In a study by Blanken, 9 vital human teeth displaying deep carious lesions were treated with an Er,Cr:YSGG laser (Biolase, USA) with spray cooling, and pulp capping was performed using a modified glass-ionomer cement (Vitrebond, 3M, USA), while permanent restorations were made with Cavex Clearfil APX (Kuraray, Japan). As hemorrhage control could not be achieved in 2 cases, partial pulpotomy was performed until bleeding stopped, with power settings of 0.25 to 0.50 W in defocused mode for coagulation. Clinical and radiographic evaluation followed 3 to 8 months after treatment, with no clinical signs of inflammation and positive vitality tests in 8 cases. The author considers that further research is necessary for determining indication and prognoses of Er,Cr:YSGG laser pulp cappings, preferably by conducting human in vivo studies or experimental animal studies.[80]

Olivi et al conducted an extensive evaluation (from 1 month to 4 years after treatment) of the efficacy of 2780-nm Er,Cr:YSGG laser and 2940-nm Er:YAG laser, combined with the use of a self-setting base with calcium hydroxide, for pulp capping of permanent human teeth affected by caries, in 34 subjects of different ages (average age 27.1 years). The Er,Cr:YSGG laser had a success rate of 80% and the Er:YAG laser had a success rate of 75%. The age of the patients was irrelevant for the success or failure of the treatment.[108]

In another study conducted in 2007, on patients with an average age of 14.5 years, the same author determined the applicability of 2780-nm Er,Cr:YSGG laser combined with a base of calcium hydroxide for direct and indirect pulp capping. Most of the dental specimens treated with Er,Cr:YSGG laser had preserved their vitality one month after treatment, with a success rate of 84.6% for the group without pulpal exposure and of 83.3% for the group with pulpal exposure. The following laser settings were used for indirect pulp capping: focused mode for disinfection, water cooling 55%, air cooling 65% and defocused mode for dentin

melting at 1 W, 20 pps for a period of 30 s, water cooling 15%, air cooling 10%. For direct pulp capping the following laser settings were used: defocused mode at 0.5 W, 20 pps for a period of 10 s, no water cooling and 45% air cooling. Based on these promising results, the authors emphasize that it is necessary to resume the study with more than 25 subjects.[100,108]

Saltzman et al conducted a randomized split-mouth study, in which they compared conventional pulpotomy with formocresol/zinc oxide eugenol and the modern alternative with laser diode/MTA in human deciduous teeth with pulpal involvement. The used laser equipment was Biolitec 980-nm diode laser, continuous mode, power 3 W, optical fiber with a diameter of 0.5 mm. During the treatment, there was direct contact between the tip of the fiber and the pulp tissue. Multiple applications were made, in order to achieve the ablation of the superficial tissue layer and to obtain hemostasis. The radiographic results showed a moderate success of the laser treatment compared to the conventional treatment; but 15 months after treatment, the results were not statistically significant. The authors consider that for a correct evaluation of the applicability of the combined laser diode/ MTA therapy in vital pulpotomy, it is necessary to conduct an extensive study over a longer observation period.[109]

Kurumada performed a series of vital pulpotomies in 1990 using GaAs laser light without calcium hydroxide and concluded that laser irradiation enhanced calcification in the wound surface and stimulated formation of calcified tissue.[110]

Ohbayashi conducted an experimental study on isolated human dental pulp cells irradiated with two different doses of GaAlAs laser and observed increased collagen production and calcified nodule numbers together with enhancement of osetocalcin and alkaline phosphate activity.[111]

During an experimental study, Matsui et al determined the stimulation effect of hydroxyl radicals generated by GaAlAs laser radiation on the mineralization ability of human dental pulp. The results of the study showed the ability of GaAlAs laser (continuous mode, set at 1.0 W or 5.0 W, with a total energy of 7.643 J/cm^2, corresponding to an exposure of 500 s) to trigger the hard tissue neoformation process, by tissue engineering in a human pulp cell culture.[79]

The review by Hode et al, published in 2004, presented a number of studies conducted on humans using LPT (Laser Phototherapy). In 1988, with the purpose of exploring the effect of HeNe laser light in direct pulp capping with three calcium hydroxide-based capping agents, Paschoud observed dentin bridge formation over a shorter period of time in pulps treated with HeNe laser, than in those treated only with calcium hydroxide-based capping agent. The author concluded that HeNe laser further stimulates new formation of dentin.[77] Also, Nagasawa found that using Nd:YAG laser irradiation within LLL (low level laser) strongly stimulates the formation of secondary dentin.[112,113]

In terms of LLL therapy, Gutknecht considers that treating childern is not different from treating adults, because to a child, laser resprents a challenge rather than a threat. In this sense, Tunér and Hode recommend a dose of 0.5 to 2 J as an additional treatment in deciduous-tooth pulp capping for improvement of treatment outcome.[75,76]

DISCUSSION

Pulp capping is more effective in mechanical pulp exposures than in exposures caused by cavities. Hemostasis of the pulp tissue is of crucial importance. There is a dispute among researchers in the field of conventional pulp capping concerning the capping agent and not the procedure itself.[15]

Bergenholtz recommends the development of instruments for correct evaluation of the pulp's status before treatment, in order to achieve a correct technique and to ensure a favorable outcome. Another goal of research is to identify procedures for encouraging pulpal regeneration and not for repairing the affected pulp tissue.[6]

Following a review of worldwide studies, Olsson considers that the histologic and microscopic study of dental pulp status should not be the final goal of the study, instead, it should be considered an intermediate stage. The real purpose of a study dedicated to pulp capping should be to determine the antibacterial barrier capacity of the newly-formed tissue in time (the ability to withstand a subsequent bacterial exposure) or, even better, how long a capped pulp can be maintained healthy and functional in the oral cavity. The author also excluded the applicability of results obtained in animal studies for human dental pulp, due to the impossibility of comparing the tissue regeneration capacity of different species.[73]

According to Mogil, the healing capacity of pulp tissue combined with the absence of pain has a direct link to the individual's genetic makeup. Thus it is necessary to identify the DNA components involved in tissue regeneration and repair mechanisms.[114]

Fig 2a Clinical case 1. Initial clinical situation.

Fig 2e Clinical case 1. Final restoration.

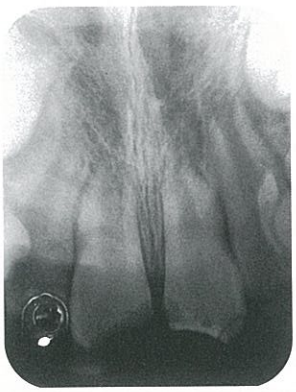

Fig 2b Clinical case 1. Initial Rx.

Fig 2c Clinical case 1. Rx 6 weeks after laser direct pulp capping.

Fig 2d Clinical case 1. Rx 6 months after laser direct pulp capping.

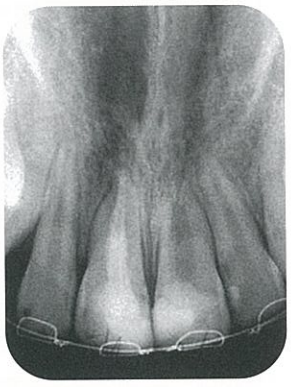

Fig 2f Clinical case 1. Rx one year after treatment.

Pertaining to animal studies, Todea considers that a succesuful animal research project depends on the possibility of using an animal model which will allow extrapolating experimental findings to humans; the validity of extrapolation lies in the similarities between the chosen species and humans, as well as between the organs compared. Regarding clinical and experimental trials, in order to avoid bias, use of the control group randomization and blinding represent the classical techniques. Therefore, human studies should be standardized concerning the protocol of clinical trials, methodology (ethical approval and informed consent, inclusion and exclusion criteria, evaluation, end-point measurements, interval of evaluation and measurement, and statistical considerations related to sample size), and data collection.[75]

CLINICAL CASE PRESENTATIONS

Case 1

A 9-year-old girl visited our dental emergency department due to an accident which occured at the amusement park. A complicated crown fracture with minimal pulp exposure involved tooth 21 and a medium pulp exposure involved tooth 11 (Figs 2a and 2b). After rubber-dam placement, direct pulp capping was performed in tooth 21 and vital pulpotomy in tooth 11. Nd:YAG laser irradiation (wavelength of 1060 nm, pulsed operation mode, optical fiber of 320 µm, total energy dose of 13.38 J/cm^2) was used in both procedures. After 6 weeks, tooth 11 became symptomatic and vital pulpectomy was performed. Tooth 21 re-

Fig 3a Clinical case 2. Initial clinical situation.

Fig 3b Clinical case 2. Initial Rx.

Fig 3c Clinical case 2. Restorative procedure after laser-assisted direct pulp capping.

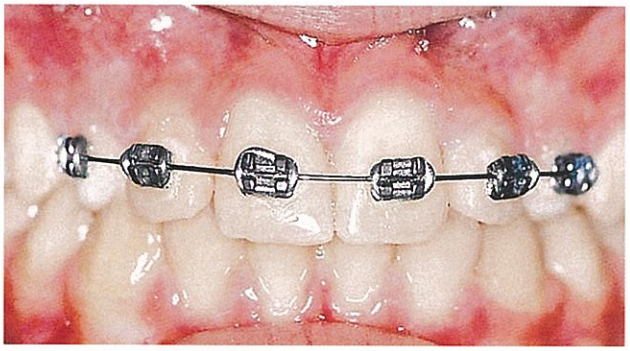

Fig 3d Clinical case 2. Clinical situation during fixed orthodontic treatment.

Fig 3e Clinical case 2. Final restoration.

Fig 3f Clinical case 2. Final Rx.

sponded well to the treatment procedure and vitality was maintained 6 weeks, 6 months and one year after. Final restoration of both teeth was performed after 6 months. After one year, fixed orthodontic treatment was possible (Figs 2c to 2e).

Case 2

A 7-year-old boy with a fighting accident visited our dental emergency department. After a short examination, complicated crown fracture with minimum pulp exposure was noticed in tooth 11. No pulpal involvement occurred in tooth 21 (Figs 3a and 3b). After rub-

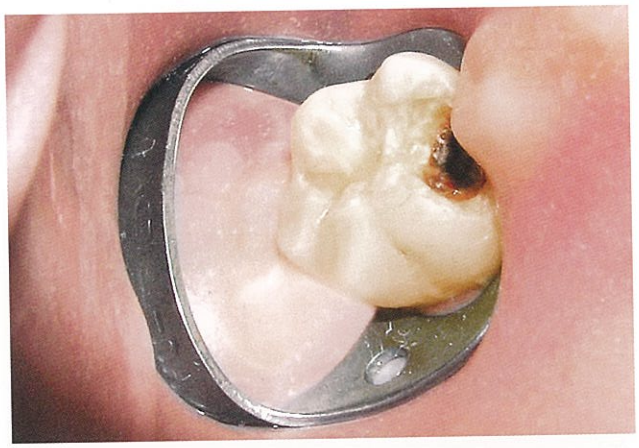

Fig 4a Clinical case 3. Initial clinical situation with minimal pulp exposure.

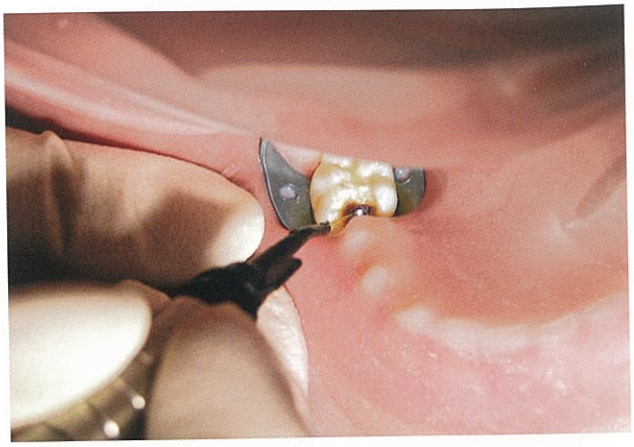

Fig 4b Clinical case 3. Laser-assisted direct pulp capping.

Fig 4c Clinical case 3. Restoration with glass-ionomer cement.

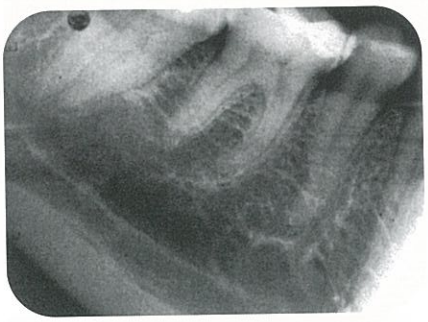

Fig 4d Clinical case 3. Rx after treatment.

ber-dam placement, direct pulp capping was performed in tooth 11 using CO_2 laser irradiation (wavelength of 10,600 nm, pulsed operation mode, optical fiber tip of 0.8 mm, total energy dose of 9.54 J/cm^2). After 6 weeks, final restoration was performed on tooth 11, and the mesiodens was extracted (Fig 3c). Three months later, tooth 11 remained vital and fixed orthodontic treatment was performed (Fig 3d). After 18 months, fixed orthodontic appliances were removed and the tooth maintained its vitality (Figs 3e and 3f).

Case 3

A 38-year-old female came to our oral rehabilitation department with a lost restoration and a fractured cusp. After excavation of the carious lesion in close proximity to the pulp, minimal pulpal exposure occurred, therefore the treatment choice was a direct pulp capping with high-power diode laser (980 nm, pulsed operation mode, optical fiber of 320 µm, energy dose 1.43 J), followed by $Ca(OH)_2$ and glass-ionomer cement (Fig 4). The final restoration will be performed after 6 weeks if the tooth maintains its vitality.

CONCLUSIONS

Regarding laser-assisted pulp capping, it is obvious that this method offers new treatment opportunities and improves working conditions, the biological quality of the irradiated surface, and the conventional therapy methods, by increasing the effectiveness of the interaction between pulp tissue and capping agent.

It is still necessary to improve laser technology, in order to produce multiple parameters for specific actions. Optimal parameters must be identified to insure the success of laser therapy in pulp capping and vital pulpotomy.

Laser therapy has proven its effectiveness in pulp capping and vital pulpotomy by its capacity to stimulate repair dentin formation by the pulp tissue, its ability to decontaminate irradiated surfaces, as well as its pain reducing effect.

Laser biomodulation seems to have significant influence in the pulpal wound healing process. It is well known that laser phototherapy is a painless, noninvasive and nonpharmaceutical procedure, with few side effects, enjoying great acceptance from patients.

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