Introduction
Pulp capping is the treatment that marks the boundary between conservative and endodontic therapy: retaining vitality greatly improves tooth prognosis, both from the biomechanical and aesthetic point of view, justifying the quest for new techniques aimed at increasing this procedure’s success rate.

Reviewing the international literature we can see that the high success rates refer to capping procedures performed on front teeth affected by trauma, where the bacterial contamination is lower than that of molars treated for deep caries. Cvek [1978] reported a 93% success rate of pulp cappings and partial pulpotomies performed on fractured front teeth; during the same year, Haskell [1978] reported a success rate of 87% at 11 years, without reporting the kind of tooth involved, and following up less than half of the treated patients.

In the year 2000, Clement reported an average success rate of 73%, with differences between front and back teeth; Auschill [2003] documented an average success rate of 61% with differences in results between the front teeth (83.3%) and the molars (38.9%) also in relation to age; Riccitiello [2005] reported partial pulpotomy as the preferred treatment for exposed pulp of immature permanent teeth, saving endodontic therapy for all exposures on teeth with complete root formation.

On the contrary, more recent literature has shown more predictable results: approximately 90% in laser-assisted pulp cappings performed using different wavelengths (1064 nm, 2780 nm, 2940 nm, 10600 nm) [Santucci, 1999; Olivi, 2006; Jayawardena et al., 2001; Moritz et al., 1998], versus traditional techniques, which presented optimal results of approximately 60%.

Erbium lasers emit electromagnetic radiations in the medium infrared spectrum (2780-2940 nm); interacting preferably with water and hydroxyapatite, these lasers have an efficient ablation effect on both the soft tissues.
(gum and pulp) and the hard dental tissues and, more selectively, with the carious tissue rich in water. The Erbium:YAG laser is absorbed massively by water, with a very superficial interaction of approximately 100 µ; the Erbium Chromium:YSGG laser is slightly less absorbed by the water, permitting a deeper interaction with the tissue (300 µ).

This work’s objective is to verify the effectiveness of laser technology combined with a self-hardening calcium hydroxide base in pulp capping procedures performed on permanent teeth affected by caries. Contrary to traditional recommendations, this treatment was also suggested to older patients, to verify whether the chosen procedure could effectively improve the prognosis compared to traditional treatments.

**Materials and methods**

This study was carried out on 34 patients, aged between 11 and 18 years, with an average age of 14.5 years, who underwent conservative treatment for deep caries of permanent teeth (8 anterior and 26 posterior). Three groups, treated with different techniques, were identified; for each of this group we have chosen other 10 cases, treated with the same method but on adult patients aged from 19 to 40 years, as control group (Table 1).

1. Group 1: 11 elements were treated with traditional rotating instruments and pulp capping with self-hardening calcium hydroxide (Life, Kerr-Hawe).
2. Group 2: 15 elements were treated with Er,Cr:YSGG Laser (2780 nm - Erbium, Chrome: YSGG 600 µ - G6 sapphire tip - Waterlase Millennium, Biolase Technology Inc, San Clemente, Ca, USA) and self-hardening calcium hydroxide (Life, Kerr-Hawe).
3. Group 3: 8 elements were treated with Erbium:YAG laser (2940 nm - Erbium:YAG 600 microns - 80° curves quartz tip - Hoya Conbio DeLigth, Fremont, Ca, USA) and self-hardening calcium hydroxide (Life, Kerr-Hawe).

All patients had checkups (anamnesis, vitality test and intraoral x-ray) after 1, 3, 6 and 12 months and after 2 and 4 years.

For group 1 the cavities were prepared with diamond drills by turbine, multiple-blade drills by handpiece for removing the decayed dentine and, after cleaning and control of bleeding with cotton pellets with saline solution, calcium hydroxide self-hardening paste was placed on the exposed part of the pulp (Fig. 1, 2, 3, 4).

For groups 2 and 3 the cavities were directly prepared with the lasers at the energies and powers normally suited for preparation on enamel and dentine.

---

**Table 1 -**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Study group - teeth</th>
<th>Yrs avg</th>
<th>Control group - teeth</th>
<th>Yrs avg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>anterior</td>
<td>posterior</td>
<td></td>
<td>anterior</td>
</tr>
<tr>
<td>Group 1</td>
<td>2</td>
<td>9</td>
<td>14,1</td>
<td>1</td>
</tr>
<tr>
<td>Group 2</td>
<td>3</td>
<td>12</td>
<td>14,9</td>
<td>2</td>
</tr>
<tr>
<td>Group 3</td>
<td>2</td>
<td>6</td>
<td>14,3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28,3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27,2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25,7</td>
</tr>
</tbody>
</table>

**Fig. 1 -** Pre-operative radiograph.

**Fig. 2 -** Pre-operative view of mandibular first molar.
ADVANTAGES OF LASER-ASSISTED PULP CAPPING

[Fig. 3 - Pulp exposure during drill cavity preparation.]

[Yamada, 2006]. When preparation was complete, the bottom of the cavity was further radiated at 75 -100 mJ (1-1.5 Watt) for 60 sec to ensure complete decontamination (Fig. 5, 6, 7, 8, 9, 10, 11).

Due to the different construction of Erbium laser devices, their use could not be standardised: in our clinical experience we have used lasers with optical fiber transmission preferring user-friendly ones and those with contact handpieces (with focus from 1 to 1.5 mm), in order to reduce encumbrance in the mouth compared to distance handpieces, which working with focalising mirrors are also difficult to control when directing the beam with precision.

The Er, Cr:YSGG 2780 nm Waterlase Millennium laser emits pulsations lasting 140 microseconds at a fixed frequency of 20 pps. Being able to vary the flow of the air/water spray from 0 to 100 gives flexibility, which permits greater interaction with the target tissue according to its water content: then we could switch from ablation of the hard tissue by photoacoustic and photothermal effects (3-5 Watt at 20 Hz, with air-water spray 65%-55% and 92%-85% focalised, for dentine

[Fig. 4 - Pulp capping with calcium hydroxide base.]

[Fig. 5 - Pre-operative radiograph.]

[Fig. 6 - Er, Cr laser cavity preparation.  Fig. 7 - Coagulation with Er, Cr laser.  Fig. 8 - Pulp tissue capping with calcium hydroxide base.]

[Fig. 9 - 4 years post-operative radiograph.]
and enamel) to coagulation by heat effect, which is done without water (25 mJ at 20 Hz with spray 45% air no water - defocalised) (Fig. 12, 13).

In cases where no pulp is exposed but radiological and clinical examination (presence of pulp tissue underneath a thin dentinal layer) show contiguity with the tissue, this defined area can be treated with low-energy laser and little water (75 mJ at 20 Hz with spray 25% air 15% water – defocalised), in order to cause the closure of the dentinal tubules (dentinal melting) through a moderate and controlled heat effect (Fig. 14).

As the Erbium YAG laser used makes it possible to vary the frequencies of the pulsations according to the different clinical situations, it is easy to use in controlling coagulation of the exposed pulp, by aiming the defocalized laser radiation at 3 pps at the target tissue. The precision and quality of the laser tissue interaction was well controlled with a microscopic device, that helped us to avoid undesired effects (carbonisation). The parameters used for the
coagulation of the exposed pulp were 3 Hz 30 mJ defocalised and 75-100 mJ (1.5-2 Watt) for cavity decontamination. In cases of deep caries, with no pulp exposure, in order to obtain the same effect of dentinal melting we desribed for Er,Cr:YSGG, with these machines (Erbium:YAG laser 2940 nm - Hoya Conbio DeLigth), in which we do not have the possibility to modify the intensity of the air water spray, the operative tecinque used was to defocalize the delivery to control the heat effect (75 µ- 100 mJ at 10 Hz - defocused). In every case the tooth must be immediately filled with adhesive systems: a flowable and more highly filled composite, for a direct reconstruction or a build up in case of indirect restoration, is recommended in order to obtain an hermetic barrier that allows the healing.

**Results**

In group 1, which included teeth treated with calcium hydroxide alone, the 2 front teeth had kept their vitality, while 5 of the 9 back teeth showed vitalty after 4 years (total success rate of 63%).

In group 2 (Er,Cr:YSGG + calcium hydroxide), after 4 years all 3 front teeth treated had a positive follow-up while 9 of the 12 back teeth showed vitality (total success rate of 80%).

In group 3 (Er:Y AG + calcium hydroxide), after 4 years, all the 2 front teeth treated and 4 of the 6 back teeth were successful (total success rate of 75%).

The average of success of the adult control groups has been lower for group 1 (total success rate of 50%) and very similar to the study groups for group 2 (total success rate of 80%) and group 3 (total success rate of 70%) (Table 2).

**Discussion**

The indications for pulp capping are: accidental exposure of the pulp, traumatic lesions, caries [Cohen and Burns, 2001; Ingle, 2002].

The intervention strategy depends on the timeframe between trauma and therapy, the patient’s age and the degree of root maturity, the size and location of the exposure, the degree of bleeding, recent dental history and the absence of apical radiolulinescence on intraoral x-ray examination.

In the event of traumatic exposure (Table 3), quick intervention within the first 24 hours reduces bacterial contamination to a minimum and the pulp capping can have a favourable prognosis, especially in younger patients.

After 2 or 3 days, a higher bacterial contamination leads to a less conservative procedure, requiring a partial or cervical pulpotomy [Pagavino et al., 2004].

When there is thickening of the periodontal ligament at the apex on the x-ray examination, or excessive dental mobility, heavy bleeding, a history of nocturnal or spontaneous pain or if there is pus, a procedure of conservative therapy of the pulp is not advisable.

Laser-assisted pulp capping has considerable advantages compared to traditional methods [Santucci, 1999; Jayawardena et al., 2001; Moritz et al., 1998; Iaria et al., 2005; Olivi, 2006].

Basically they can be defined as:

1. decontaminant effect;
2. haemostatic and coagulant effect;
3. reduced rise in pulp temperature;
4. reduction of intracavitary pressure;
5. dentinal melting;
6. biostimulating effect.

1. The sterile field is provided by the bactericidal effect of the laser, an effect common to all lasers, which however takes place differently according to the wavelength [Moritz et al., 1999; Schoop et al., 2004; Gutknecht et al., 2004] and with different depths of penetration of the different laser beams into the target tissue: CO2 and lasers of the Erbium family are more superficial than Diode and Nd:YAG lasers, which penetrate more deeply and have a greater scatter capacity. This effect is especially important in the event of carious exposures where the indications for pulp capping are still present (Table 4).

2. The haemostatic and coagulant capacities of lasers

---

**Table 2**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Study group - Results</th>
<th>Control group - dental elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>anterior</td>
<td>posterior</td>
</tr>
<tr>
<td>Group 1</td>
<td>2/2</td>
<td>5/ 9</td>
</tr>
<tr>
<td>Group 2</td>
<td>3/3</td>
<td>9/12</td>
</tr>
<tr>
<td>Group 3</td>
<td>2/2</td>
<td>4/ 6</td>
</tr>
</tbody>
</table>

---

**ADVANTAGES OF LASER-ASSISTED PULP CAPPING**

**EUROPEAN JOURNAL OF PAEDIATRIC DENTISTRY • 2/2007 93**
guarantee a dry operative area with no bleeding. This fine area of coagulation is created by a superficial necrosis, with an underneath area of reversible damage, this is the seat of migration of the inflammatory cells and the fibroblasts that lead to the constitution of the dentinal bridge.

3. The use of Erbium lasers (2780-2940 nm), compared to lasers with other wavelengths and to the traditional rotary instruments, limits the increase in temperature in the pulp chamber, thanks to the absence of contact and the ablating and cooling action by means of the air-water spray [Rizoiu et al., 1997; Glockner et al., 1998].

4. The use of Erbium lasers for preparing a cavity (2780-2940 nm), compared to the other lasers that have no ablating capacity on the hard tissue (Diodes, Neodymium:YAG, CO2), make it possible to reduce the intracavitary pressure that develops when using rotary and mechanical instruments, thus reducing the risk of dislodging infected dentinal chips in the pulp chamber, a possible cause of accidental and irreversible contamination of the pulp tissue [Cohen and Burns, 2001].

5. The use of Erbium lasers and, in particular, of Erbium Chromium:YSGG, which use a variable air-water spray, makes it possible, by means of a controlled heat effect, to obtain partial closure of the dentinal tubules (melting), creating a physically induced barrier against chemical-physical stimuli harmful to the pulp tissue [Olivi, 2006].

6. What is more, all lasers have a biostimulating effect and, in particular, the use of a diode laser (810-903 nm) is especially favourable in the healing processes of the pulp tissue [Benedicenti, 2005].

TABLE 3 - Indication for pulp capping.

<table>
<thead>
<tr>
<th>Traumatic exposures evaluation parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time elapsed between trauma and therapy (24-48 hours)</td>
</tr>
<tr>
<td>Patient’s age</td>
</tr>
<tr>
<td>Stage of formation of the root and the apex</td>
</tr>
<tr>
<td>Dimensions of the exposure (0.5-1.5 mm)</td>
</tr>
<tr>
<td>Location of the exposure (at the pulp horns, never cervical)</td>
</tr>
<tr>
<td>Amount of bleeding (moderate and sero-hemorrhagic, never truly hemorrhagic or purulent)</td>
</tr>
<tr>
<td>Condition of the pulp tissue (active hyperemia or reversible pulpitis)</td>
</tr>
<tr>
<td>Absence of periapical lesion on the intraoral x-ray examination</td>
</tr>
</tbody>
</table>

TABLE 4 - Indication for pulp capping.

<table>
<thead>
<tr>
<th>Carious pathology exposures evaluation parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absence of painful symptoms or slight sensitivity to heat stimulation</td>
</tr>
<tr>
<td>Dimensions and location of pulp exposure (0.5-1.5 mm with coronal seat at the pulp horns, never cervical)</td>
</tr>
<tr>
<td>Amount of bleeding (moderate and sero-hemorrhagic, never truly hemorrhagic or purulent)</td>
</tr>
<tr>
<td>Absence of periapical lesion on the intraoral x-ray examination</td>
</tr>
<tr>
<td>Type of repair chosen (not advisable for teeth to be prosthetically repaired and/or abutment for a fixed bridge)</td>
</tr>
</tbody>
</table>

The use of Erbium lasers is also important because of their selectivity for the carious tissue, which permits minimally invasive preparations, particularly important for the cavity floor and the possibility of reducing or avoiding the use of a local anaesthetic.

Use of Erbium lasers, compared with other types of laser, proved to be useful in preparing cavities and removing caries, as well as in decontamination and possible coagulation of the exposed pulp. Its use can eliminate rotating instruments which, on the other hand, are required in operative procedures made with CO2, Nd:YAG and Diode lasers, that have the only function of decontamination and coagulation of the exposed pulp. Its use can eliminate rotating instruments which, on the other hand, are required in operative procedures made with CO2, Nd:YAG and Diode lasers, that have the only function of decontamination and coagulation of the exposed pulp, not being effective in ablation of hard tissue. On the other hand, the coagulating capacity of Erbium lasers is decidedly lower than the other wavelengths even though their action is more controllable because of the depth of action [Olivi et al 2006].

The necrotising action chemically induced by the capping materials used in the conventional procedures is replaced by the physical action of the laser, the effectiveness of which is also linked to the knowledge of the laser tissue interaction and the ability of the operator to carry out the most suitable technique.

The average of success of the adult control groups shows that the results are probably more linked to the high bactricidal and biostimulating effect of the laser light used in this technique instead of the stage of development of the tooth or the age of the patient.

**Conclusion**

Laser technology proved effective in improving the
prognosis of pulp capping procedures on teeth affected by deep caries. For accidental exposure and/or superficial contamination of the pulp tissue, responsible for reversible vascular suffering, the success of the prognosis is increased by treatments involving the use of laser beam as a decontaminating, coagulating and biostimulant agent, even in adult patients. Erbium lasers in particular also prove to be suitable for the preparation of complex cavities, even though there is the disadvantage of slightly longer operative times.

References
Aushill TM, Arweiler NB, Hellwig E, Zamani-Alaei A, Sculean A. Success rate of direct pulp capping with calcium hydroxide. Schweiz Monatsschr Z.INCOMPLETA