Lasers in dental traumatology and low level laser therapy (LLLT)

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Abstract

BACKGROUND: Dental trauma in children is a frequent and often complex clinical event in which laser-assisted therapy, particularly using erbium lasers, can offer new treatment possibilities, improving the outcomes and reducing the associated complications. **REVIEW:** In particular, it is worth considering that the use of laser-assisted therapies is associated with a marked reduction in the use of analgesics and anti-inflammatory medications compared with conventional procedures. Laser anaesthesia is another interesting and challenging area. **CONCLUSION:** Given the paucity of data on laser-assisted dental trauma therapy in the international literature and the absence of well-structured guidelines, this is an area ripe for scientific research.

Introduction

Dental trauma in children is a frequent and often complex clinical event leading to injuries whose treatment can necessitate the involvement of specialists from different branches of dental science (endodontics, restorative dentistry, periodontics, oral surgery, and orthodontics), making it a truly multidisciplinary discipline. As shown by the World Health Organisation's revised and extended classification of traumatic dental injuries, these injuries can involve teeth, supporting structures, or gingival and oral mucosa [Andreasen et al., 2007].

Trauma to the teeth of children and adolescents can range from simple crown fractures, to re-plantation, root fractures and luxation injuries. In this setting, laser technology, either complementing or replacing traditional methods with a simpler approach, offers a series of advantages, throughout the therapeutic course. Laser-assisted therapy is minimally invasive, highly selective and, compared with conventional procedures it drastically reduces the need for post-operative medications. For all these reasons, patient compliance is significantly improved. Laser treatment reduces post-operative sensitivity and, being an option for non-vital bleaching, can also be used in the correction of post-traumatic aesthetic defects. Another important attribute is the capacity of laser equipment to induce analgesia, thereby eliminating the need for local analgesia (LA).

Given the paucity of data on laser-assisted dental trauma therapy in the international literature and the absence of well-structured guidelines, this is an area for scientific research. At present, however, even though this challenging technology is emerging as highly suitable for trauma-related problems, the existing dental trauma guidelines and protocols remain the gold standard [Flores et al., 2001; Andreasen et al., 2007].

Epidemiology and prevention. Traumatic dental injuries in children and adolescents occur in a variety of situations. The majority are sustained during play (56%) while others are the result of sporting accidents (21%), road accidents (11%) or acts of violence (12%) [Andreason et al., 2007]. Unfortunately, the latter percentage concerning violence, is probably underestimated. The teeth most frequently affected, both in primary and in permanent dentition, are the maxillary central (50%) and lateral incisors (30%), although the type of varies according to age.

Large-scale studies in the USA have confirmed the high incidence of dental trauma in child populations. Its prevalence in adolescent boys is twice that recorded in girls of the same age, while no gender difference have been observed in younger age groups [Glendor, 2008]. Given that about 20% of children suffer a traumatic injury to their primary teeth and over 15% to their permanent teeth [Andreasen et al., 2007], the importance of prevention in this field cannot be overstated. In this regard, there is a clear need for specific training programs, more continuing education conventions dealing with the prevention and management of traumatic dental injuries, as well as updated guidelines and, in general, a greater dissemination of knowledge on the topic.

Types of lasers suitable for dental traumatology. The therapeutic use of lasers has become standard practice in many medical fields, but dental traumatology is not yet one of them. Different types of laser [Martens et al., 2011] can be used in the treatment of dental injuries, and their specific properties make them suitable for different tissues and different procedures. In particular, each wavelength has a particular use, determined by its specific tissue-interaction and affinities.

Currently, for the treatment of dental traumatic injuries paediatric dentists favour two types of laser: the Er:YAG and the Er, Cr:YSGG. These are highly versatile lasers that can be used to treat both hard and soft tissues [Gutknecht et al., 2008; Olivi et al., 2007]. However, there is also a role for the KTP laser, the Nd:YAG laser, the diode laser and the CO_2 laser [Olivi and Genovese, 2011]. In addition, laser Doppler flowmetry is emerging as a promising method, as yet in the experimental stages, for ascertaining the state of pulp revascularisation (even though pulp testing in dental trauma is still a controversial issue).

Use of lasers in dental traumatology. To date, no randomised clinical studies of laser-assisted treatment of traumatic dental injuries have been conducted, even though the potential of this technology in the dental field is clearly considerable given its compliance with two key aims in dental treatment: tooth preservation (microdentistry). How do lasers prevent injuries? In this article, the authors describe their own clinical experience with the aim of stimulating more extensive scientific research in this field.

Efficacy of laser usage. The PubMed database lists a few studies that investigate the efficacy of lasers in maintaining pulp tissue vitality. Different devices, using different laser wavelengths and parameters, were used in these studies, but in all cases low laser energy (from 0.5 to 1.0 W) was applied, delivered in defocused mode, preferably using a low repetition rate or super-pulsed mode (the latter showing a markedly higher success rate than the continuous wave mode).

Traumatic injuries to hard dental tissue and pulp

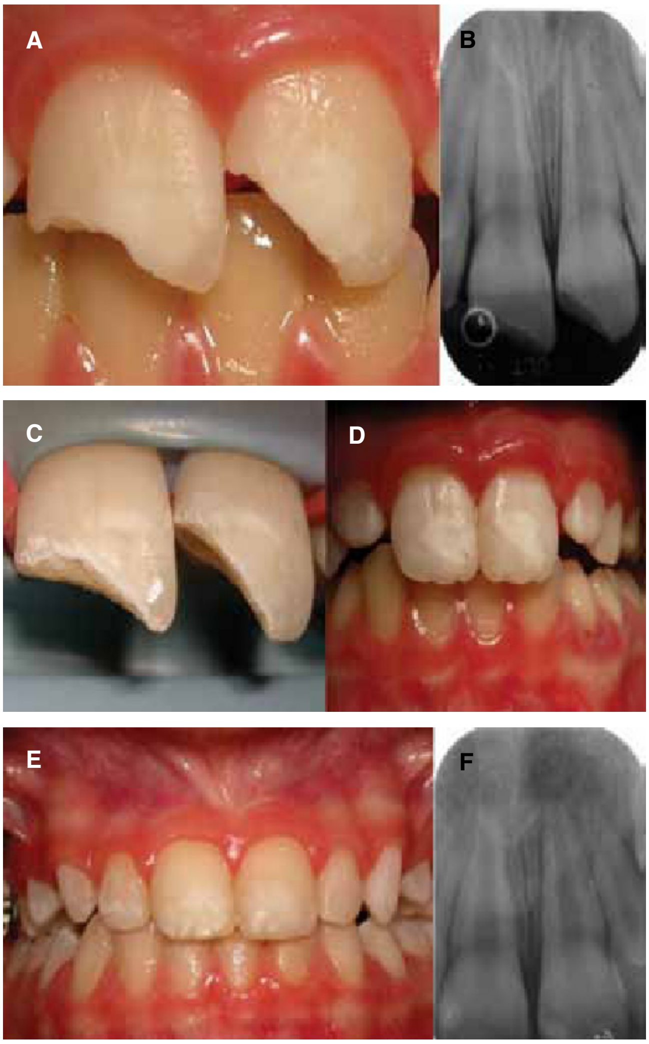
An accurate diagnosis is the prerequisite to successful treatment. Therefore, the approach to the patient must begin with careful dental history-taking and clinical examination. For this purpose, in order to save time while nevertheless ensuring that all aspects are covered, it is useful to develop and use special, standardised charts. Every phase in the clinical course, both pre- and post-treatment, must be fully documented through radiographic and photographic examinations and pulp vitality tests. The availability of this data will make it easier to monitor the patient's clinical course at follow-up visits, and also to compile a full medico-legal report should this be required.

Uncomplicated and complicated crown fractures. Crown fractures involve the enamel and dentine and, if complicated, also expose the pulp. Indeed, in the presence of a crown fracture, the first step, as with all dental trauma, after cleansing the damaged area, is to ascertain whether or not there is pulp exposure and a full medical history and oral examination coupled with appropriate radiographs. Various studies and clinical reports have shown that lasers, used as an alternative to rotary instruments in paediatric restorative dentistry, allow safe and minimally invasive interventions [Kornblit et al., 2008; Olivi and Genovese 2011] that, moreover, patients more readily accept [Keller et al., 1998]. Erbium lasers are indicated for the treatment of crown fractures, both complicated and uncomplicated, and whether or not the tooth-fragment is available. They are very precise, low-invasive instruments that achieve good results, also reducing post-operative discomfort and sensitivity [Genovese et al., 2008], a particularly important consideration in the presence of a traumatic dental injury, particularly when it is accompanied by soft tissue lesions.

In the first decade of research in this area, various authors studied erbium laser parameters and variables (energy density, pulse repetition rate, and use of the air-water jet), evaluating its morphological effects on dental hard tissue and pulp tissue. The results obtained with the laser were comparable to those achieved with orthophosphoric acid [Moritz et al., 2006; Jayawardena et al., 2001; Olivi et al., 2007].

Laser tooth preparation must be carried out bearing in mind the possible effects of a series of variables: fluence, power density, pulse length, laser beam angle, focused mode, and air-water jet intensity are all factors that can cause substructural damage to the dentine. Acid etching of lased dentine and enamel eliminates the thin layer of substructural damage created, exposing the collagen fibres and creating a substrate for the formation of the hybrid layer. The use of lasers for treatment of an uncomplicated crown fracture is illustrated in Figure 1 a-f.

__Figure 1.__ Treatment of a case of uncomplicated enamel-dentine crown fractures of 11 and 21 with oral mucosa laceration: __a.__ initial condition; __b.__ radiographic condition; __c.__ margins of dental fracture after treatment with laser; __d.__ appearance after attachment of fragments; __e.__ clinical appearance after one year; __f.__ radiographic condition after one year.



Erbium lasers. These lasers exert a very precise action on hard tissues and pulp. Furthermore, the procedure cleanses and sterilises the treated surfaces. Cooling with a water spray can decrease any temperature increase during treatment, which is minimal. Because of this, the thermal effect is extremely superficial, keeping the necrotic zone very small.

Crown fractures expose a large number of dentinal tubules: damage to $1mm^2$ of dentine exposes 20,000 to 45,000 dentinal tubules. These open tubules become a pathway for the entry of bacteria into the tooth, and also increase its sensitivity to thermal and chemical irritants. The result is pulp inflammation. In this regard, whereas erbium lasers efficiently remove organic material and smear layer and have a bactericidal effect, the Nd:YAG and diode lasers also exert an effective decontamination action.

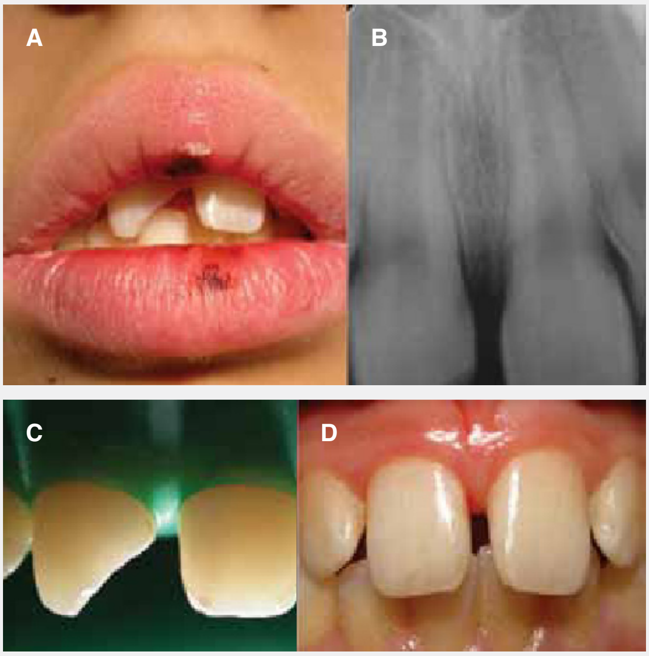
The erbium laser, being able to fuse and seal the dentinal tubules (to depths of up to 4μm), can reduce dentinal hypersensitivity, associated with trauma, by reducing the fluid permeability of the tissue. Another structural change it can induce is vitrification, a useful phenomenon because it increases hard tissue resistance to acid and dental abrasion and promotes remineralisation of the dental tissue, increasing its hardness.

The erbium laser has a number of useful attributes: bactericidal capacities, the ability to remove the smear layer and open the dentinal tubules, allowing hybrid layer formation, and then to seal and fuse them. The laser may be used at any stage of the procedure, i.e., for excavation, coagulation of the exposed pulp (if necessary), pulpotomy or pulpectomy. The use of the erbium laser in a case of deep, but uncomplicated crown fracture is illustrated in Figure 2 a-d.

The Nd:YAG and the diode laser. These lasers also have useful applications in the treatment of direct dental traumas, exploiting their photothermal effect to treat dentinal hypersensitivity, perform indirect or direct pulp capping, remove endodontic material and treat infected root canals. Because most (90-95%) of the energy the CO_2 laser delivers to the tissue is absorbed by a fine tissue layer and transformed into heat, this laser therefore has a purely thermal effect [Moritz et al., 1998]. It can be used for pulp capping (following a dentine fracture), pulpotomy (following a crown or a root-crown fracture), and surgical cutting (e.g. to remove a tooth fragment) [Caprioglio et al., 2008, 2009, 2010].

Laser use for crown-root fractures. Unlike root fractures, in which the fracture is located entirely within the alveolous, crown fractures cannot be expected to heal completely. After removal of the coronal fragment, the treatment must exploit the possibility of using the remaining fragment. If the fracture is superficial and there is no pulp exposure, the loose fragments are first removed, after which the rough subgingival fracture surface is smoothed and the exposed dentine is covered.

Figure 2. *.Deep but un-complicated crown fracture of tooth II:* ***a.*** *initial condition;* ***b.*** *radiographic examination;* ***c.*** *minimally invasive treatment with an erbium laser;* ***d.*** *clinical appearance after composite resin restoration.*



When the coronal fragment comprises 1/3 or more of the clinical root, a pulpectomy and root canal filling are recommended (after removal of the fragment). The fracture surface is then exposed by means of gingivectomy or osteotomy and a prosthetic restoration is carried out. As well as being useful in crown restoration, lasers can be used in the required tissue surgery and endodontic therapy (gingivoplasty, gingivectomy, crown lengthening) [Sarver and Yanosky, 2005; Schoop et al., 2007] as they are able to incise, cut, ablate, and reshape the soft tissue with no or minimal bleeding and less pain than is induced by traditional methods. In addition they have a marked antimicrobial effect.

In these clinical situations, deep-penetrating lasers (Nd-YAG and diode), working as electrosurgical tools, produce a thicker coagulation layer than superficially absorbed ones (CO_2, Erbium). Various other factors promote healing in these clinical situations. They include optimal repositioning, flexible splinting, immature root formation, younger age, and less displacement of the coronal fragment. As splints must remain in situ for several weeks, aesthetic ceramic brackets can be used. Thereafter, a laser (Nd:YAG) can be used to obtain atraumatic debonding: intra-pulp temperature rises less using a laser than using conventional rotary instruments for orthodontic bracket removal. This makes the laser-assisted procedure safer, quicker and more comfortable.

Injuries to developing teeth. Defects of permanent teeth (Fig. 3a-d) caused by traumatic injuries to the primary dentition can be divided into two groups according to the type of dental trauma sustained: direct impact or an indirect lesion.

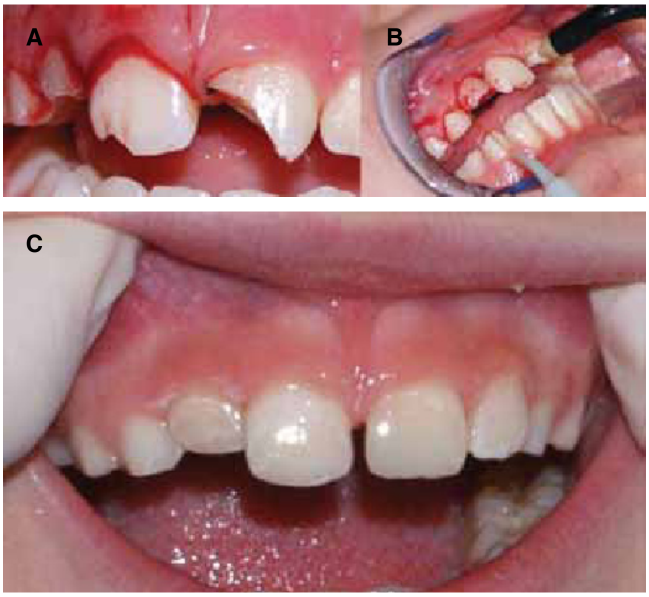
In the literature the reported prevalence of these defects ranges from 12 to 69%. Avulsion and intrusive luxation, in particular, are injuries very frequently associated with developmental complications. In this field, laser-assisted therapy can be useful in a range of clinical situations: enamel discolouration and circular enamel hypoplasia, both of which can be treated using an erbium laser, and ectopic eruption, for which surgical exposure or soft-tissue laser surgery is indicated (all the wavelengths of the near-medium and far-infrared spectrum). The use of lasers to deal with such discolourations is illustrated in Figure 3 a-d.

Figure 3. *Dentine-enamel hypoplasia treated with erbium laser:* ***a.*** *initial condition of affected teeth;* ***b.*** *minimally invasive laser preparation of enamel surfaces;* ***c.*** *final appearance after polishing and finishing;* ***d.*** *follow-up 3 years later.*

Traumatic injuries to periodontal tissues

Traumatic injuries to the supporting structures of the mouth (alveolar bone, periodontum, gingiva, ligaments, fraenum and lips), defined as indirect traumas, can be effectively treated using lasers, in particular the Nd:YAG and the diode lasers. These lasers are useful for: decontamination of the alveolous following a traumatic avulsion, treatment of a periodontal defect following a dental luxation or sub-luxation, microgingival surgery to treat a traumatic dental injury, gingivectomy and gingivoplasty procedures and surgical cutting (e.g. to remove a tooth fragment) [Martens, 2003]. In addition to their decontaminating action and appreciable analgesic effect both on hard and soft tissues, these lasers also exert a biostimulating and a reparative effect. For the patient, this means no sutures, good and rapid healing by second any intention and less discomfort. The use of a laser for a case of intrusive luxation is shown in Figure 4 a-c.

Figure 4. *A case of intrusive luxation injury of 12 with subluxation of 21, together with crown fractures of 11 and 21:* ***a.*** *initial condition of slightly extruded permanent right central incisor;* ***b.*** *the periodontal tissues treated with a diode laser;* ***c.*** *final clinical appearance after tissue healing and composite resin restorations.*



In oral surgery, the diode laser is used in continuous or pulsed mode, whereas the Nd:YAG laser is always used in pulsed mode but with different pulse amplitudes. In luxation injuries the antimicrobial and decontamination effects of a wider range of lasers (Er:YAG, Nd:YAG, diode and argon) create favourable conditions for the attachment of periodontal tissue [Maruyama et al., 2008].

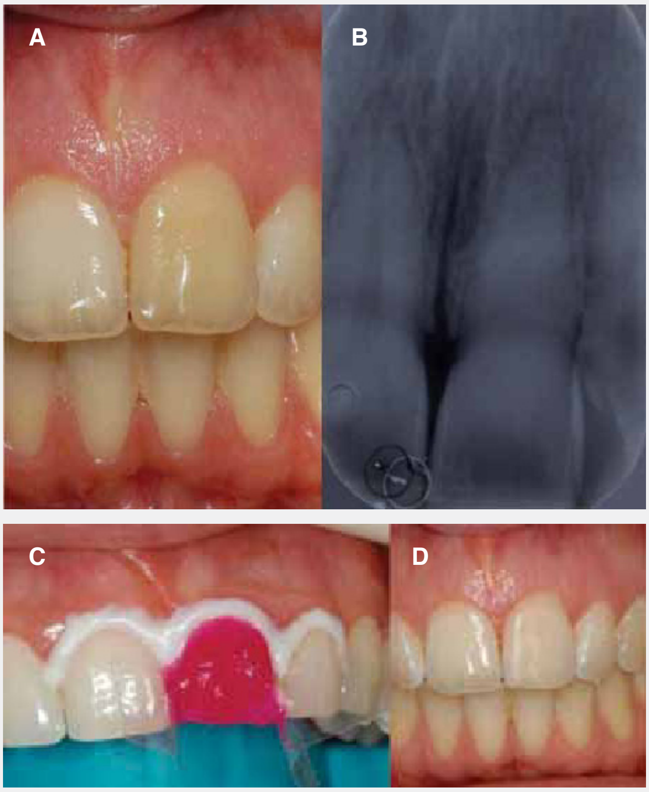
Lasers are thought to be increasingly replacing electrosurgical instruments in post-trauma gingival surgery. A study [Pescheck et al., 2002] evaluating the temperature rise in hard and soft tissue using CO_2 and diode lasers and electrosurgery units for soft-tissue dental surgery came to the conclusion that both procedures respect the tissue, in terms of the temperature increase generated, providing the relevant guidelines are followed. The increase in temperature that lasers produce also has an excellent thermostatic effect. The CO_2 laser is specifically indicated for surgical cutting, for example in order to remove a tooth fragment from lip or oral mucosa.

Non-vital dental bleaching post dental trauma

Dental trauma can produce or induce pulp necrosis and discolouration and therefore bleaching may be required [Dostalova et al., 2003]. For a successful aesthetic result dental bleaching with laser can be performed. In photo assisted bleaching there is interaction of a light source with the bleaching gel:KTP, Nd:YAG or diode laser can be used. The KTP laser energy induces a photochemical reaction on the bleaching gel; this photochemical activation provides a higher intrinsic overall radical yield than thermal activation:

heating of the teeth is highly reduced. The KTP laser for vital and non-vital bleaching can be used with high energy densities, decreasing the time needed for bleaching teeth, this leading to a method with improved efficiency [De Moor et al., 2009]. A typical case of post-trauma discolouration treated by bleaching is shown in Figure 5 a-d.

Figure 5. *Discolouration of 21 due to a luxation injury:* ***a.*** *initial condition;* ***b.*** *radiographic appearance showing root canal obliteration;* ***c.*** *red bleaching gel (KTP laser);* ***d.*** *final result after bleaching.*



Low-level laser therapy or soft laser therapy (LLLT)

Low-level laser therapy (LLLT), otherwise known as soft laser therapy, is indicated for use in dental traumatology [Tuner and Hode, 2004; Caprioglio and Caprioglio, 2010]. It is widely argued that LLLT is a technique that can help prevent patients from experiencing further 'trauma' in the dentist's chair. Although there is a large body of literature on LLLT, there is still considerable difference of opinion over methods and doses. The lasers initially used in this field were the helium-neon type (632.8nm = λ), but these have now been replaced by semi-conductor diode lasers (830nm or 635nm = λ). The water absorption coefficient of the wavelengths used in LLLT is low and the beams are able to penetrate both soft and hard tissue from a distance of 3 to 15 mm.

It is important to note that these effects, which are specific to some wavelengths, cannot be obtained with non-polarised and non-coherent light sources, such as LEDs. Knowing that the analgesic effect of light at 800-900nm is obtained at 30 joules x cm^2 and the biostimulating effect at 50 joules x cm^2, it becomes possible to develop operating protocols that can be compared, standardised and repeated [Benedicenti, 2005]. It is to be hoped that further pursuit of these new horizons might lead to the definition of protocols containing more specific indications as regards times, doses and sites of application.

Conclusions

Lasers are very effective not only in paediatric dentistry but also in traumatic dental injuries. They allow optimal preventive and interceptive interventions on both hard and soft tissue, always using minimally-invasive procedures. It is crucial for operators to have an in-depth understanding of the physical characteristics of the different laser wavelengths and the nature of their interaction with the biological tissues to ensure that they are used in a safe way, and yield all the benefits that this technology offers. Therefore a period of education and training is warranted before using this technology, especially in paediatric patients.

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