Check for updates

Laser-Assisted Pediatric Dentistry

Konstantinos Arapostathis, Dimitrios Velonis, and Marianna Chala

Contents

D. J. Coluzzi, S. P. A. Parker (eds.), *Lasers in Dentistry—Current Concepts*, Textbooks in Contemporary Dentistry,
https://doi.org/10.1007/978-3-031-43338-2_11

Core Message

The progress of laser application in dentistry is continuous. There are many debates between researchers, clinicians, and scientists who try to carry on research within and with respect to clinical everyday dental practice. The American Academy of Pediatric Dentistry acknowledges using lasers as scientifically documented, alternative, and/or adjunctive treatment provision methods of soft and hard tissue management for infants, children, adolescents, and persons with disabilities. The aim of this chapter is to describe the indications for their use in various therapeutic procedures in pediatric dentistry and to analyze the advantages and disadvantages compared to traditional techniques. Together with the appropriate child's psychological management, proper presentation and approach with the laser are crucial. The technological evolution of dental lasers offers the possibility of completing several therapeutic procedures, such as removing carious dental tissue in permanent and deciduous teeth, usually with less or no anesthesia, and performing laser-assisted pulpotomy and pulpectomy, soft tissue interventions, dental trauma treatment procedures, etc. Depending on the treatment procedure and the targeted chromophores, all laser wavelengths could be used (e.g., KTP, diodes, Nd:YAG, erbium family lasers, CO_2).

11.1 Laser-Assisted Pediatric Dentistry

Pediatric dentistry is a demanding part of dentistry because of its nature to deal with children from birth through adolescence as well as with their parents' compliance. It requires from the clinician a high level of knowledge regarding the stomatognathic system conformation, the special anatomical figures, the prevention and cure, and the prognosis of dental pathologies found in children, but, above all, it requires expertise in treating the child itself. Pediatric dentistry practitioners are responsible not only for providing and promoting good oral and dental health for their patients but also to educate parents that oral health is an integral part of general health with continuous informative sources.

In general, the occurrence of oral diseases in children and adolescents includes dental caries, periodontal diseases (mainly in the form of gingival inflammation), developmental disturbances (morphological or numerical variations in both permanent and deciduous dentition), erosions, malocclusions, cranio-mandibular disorders, oral mucosal lesions (mainly aphthous ulcers, herpes simplex, and other virus infections or oral candidiasis), and, of course, dental trauma [1]. Over the past few years, traditional dentistry has been innovated with the embracement of more microinvasive techniques, moving from the era of "extension for prevention" to "prevention for extension" model of modern dentistry. In this technological-dental evolution with microabrasion, the application of topical fluoride and the use of sealants and the general adhesive techniques, laser technology has started to become more popular to the pediatric dental world. The widespread use of lasers in dentistry can be employed for both diagnosis and treatment, and as stated by the American Academy of Pediatric Dentistry (AAPD), "the use of lasers is an alternative and complementary method of providing soft and hard tissue dental procedures for infants, children, adolescents, and persons with special health care needs" [2].

11.2 Behavior Management and Laser Application

Dental specialists are trained to diagnose and treat dental diseases according to evidence-based dentistry with the behavior guidance to be the priority of the dental treatment. The dental practitioner interacts with the patient and their parents and through that procedure identifies appropriate or not appropriate behaviors, understands the emotional state of each person, and promotes empathy and compassion. The goal is to achieve communication and eliminate dental fear and anxiety in order to build a circle of trust between the child, the parent, the dentist, and the dental staff.

Earning child/parent's trust before managing to achieve high patient cooperation is the ultimate issue in pediatric dentistry. This is a difficult and demanding task, because many children perceive a visit to the dentist as stressful. This is an expected reaction, since an appointment includes several stresses—evoking components, such as strange sounds and tastes, having to lie down, meeting unfamiliar adult people and authority figures, discomfort, and even pain. Even though laser therapy sounds promising and well-accepted by the parents due to the possibility of better therapeutic results for their children and the assumption of no pain treatment (anesthesia may be necessary), the use by the dentist of the new technology still requires a degree of compliance by the child patient. Although a dental practice may have several modern and friendly devices, it remains an unknown and peculiar environment for the young child and may provoke negative emotions and stress during child's first visit. Therefore, the practitioner should choose and offer dental treatment with the appropriate methods and instruments that are suitable for each patient. Sometimes, laser treatment is preferable, especially for young children who refused the transitional dental treatment (Fig. 11.1a–e). Laser treatment can be used to introduce dentistry, gain the

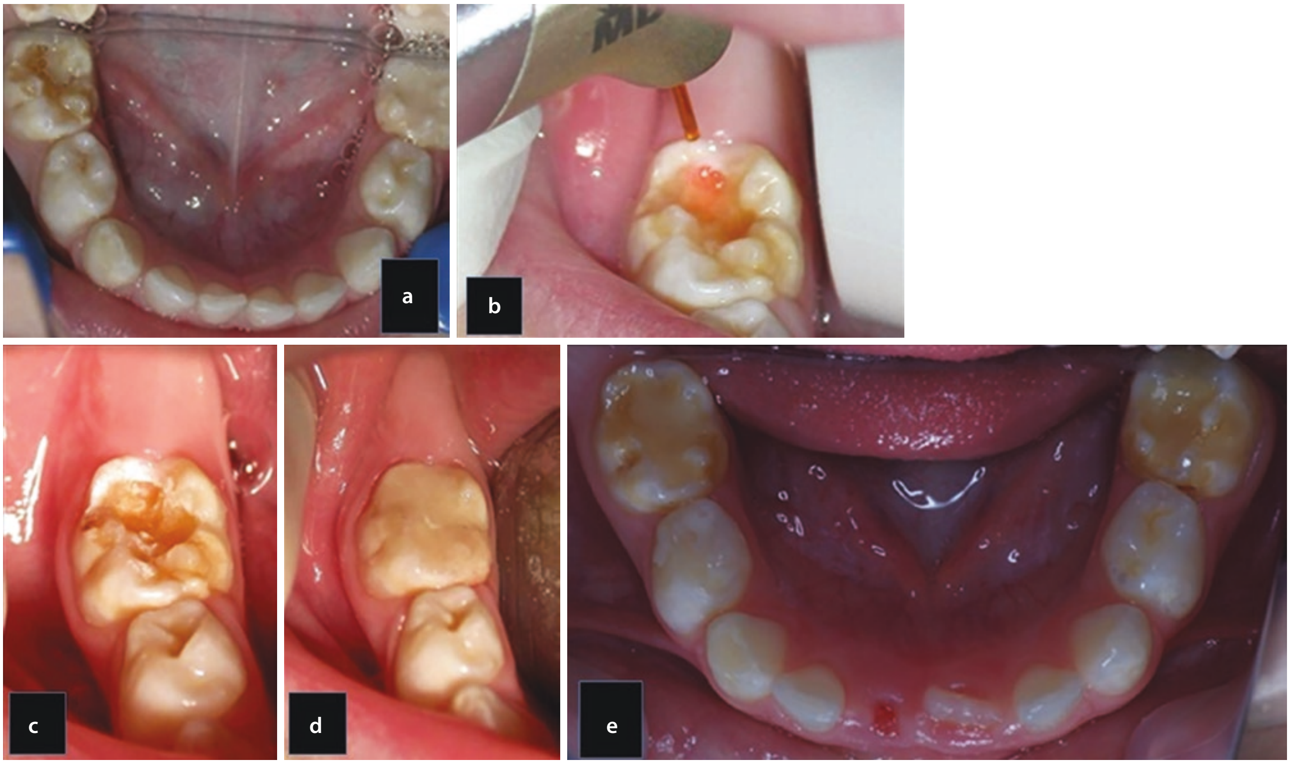


Fig. 11.1 Resin-modified glass ionomer (RMGI) restorations on the primary second molars, without the use of local anesthesia, of a 3-year-old uncooperative girl with primary molar hypomineralization (PMH). **a** Preoperative intraoral view. According to the transitional treatment recommendations, stainless steel crowns (SSC) should be placed on teeth #75 and #85 under local anesthesia. **b** Laser analgesia (starting with 50 mJ, 10 Hz, 82% water (16 mL/min), 70% air, distance 6–10 mm from the tooth, for 40–60 s and continuing with 80–100 mJ for 60 more seconds before tooth preparation) and cavity preparation (see Table 11.2 for energy parameters) by Er,Cr:YSGG (2780-nm gold handpiece, 0.6-mm MZ tip, H tissue mode). **c** After laser preparation. The cavity was well extended into dentin. The child revealed no pain and no complain and cooperation was relatively good. **d** Final RMGI restoration. **e** Intraoral view 24 months after treatment. Restorations are still in place and there are no caries lesions. The patient is now 5 years old and cooperative, and it is the practitioner's decision if and when will provide a more permanent rehabilitation

trust of the child, and perform needle-free and also no painful procedures. Through this, oral laser applications may also offer an alternative strategy in behavior management. A positive experience during dental treatment is of paramount significance for a lifelong confiding relationship between the child and the dentist, which may also lead to better oral health in the adulthood.

Either way, for its successfulness and the child's acceptance, a well-prepared presentation, training, and education on that have to be proceeded before use. The pediatric dentist may use some of the basic behavior techniques to introduce laser to the child. One of the most powerful techniques is "tell, show, do" in which the practitioner explains verbally the consecutive stages of the dental treatment (tell), demonstrates the equipment and shows the different tools/instruments on the hand/finger (show), and executes the procedure (do) [3]. Laser technology can be presented using friendly, familiar, easy-for-the-child-to-understand words like "special flashlight," "magic light," "colored light," etc. The sound of the laser could be like "making popcorn," "playing metal music," etc. The special glasses are going to make you look like "a ninja," "a princess," etc. In conjunction with the technique "tell, show, do," positive reinforcement (e.g., use of phrases like "great job" or a reward at the end of the session) and distraction techniques (e.g., television, movies, music) should be adopted. Children who do not cooperate or the mental status does not allow them to comply cannot be candidates for laser therapy.

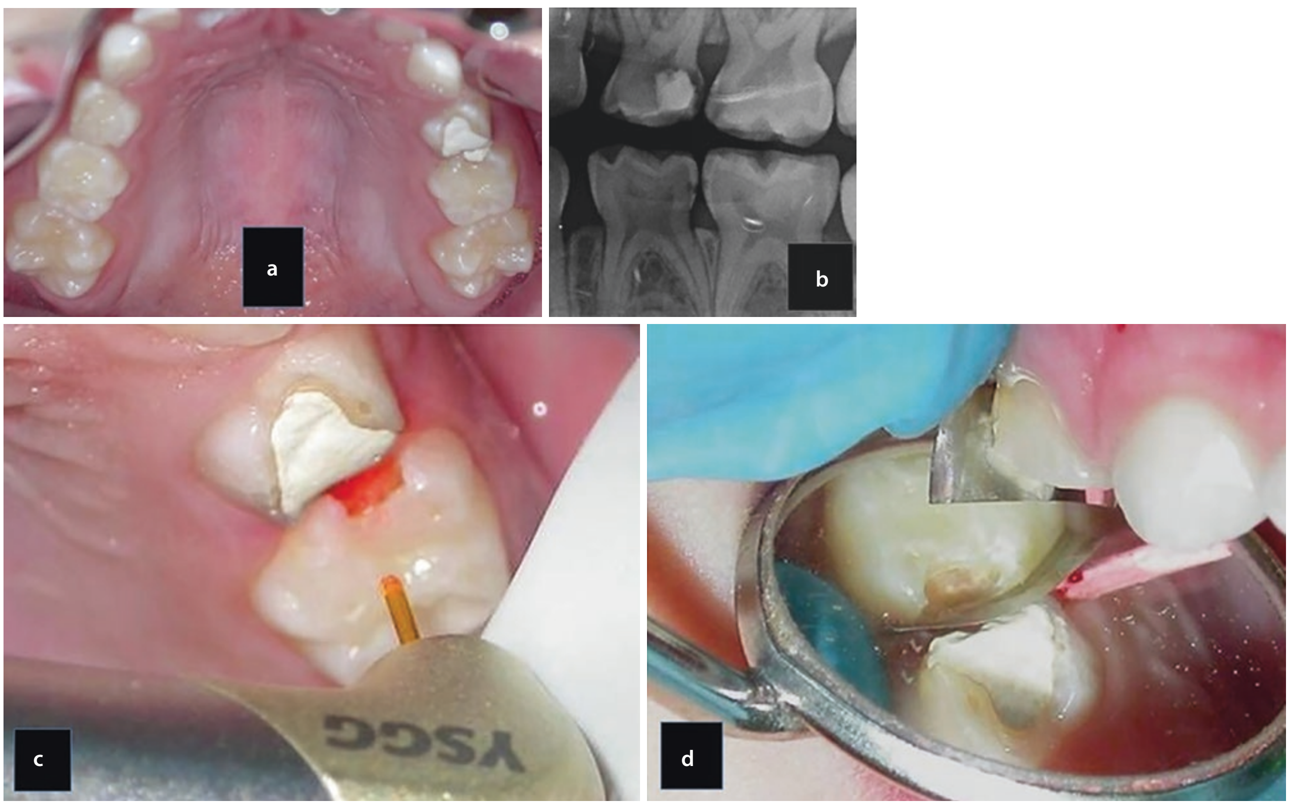
11.3 Local Anesthesia and Laser Application

Local anesthesia is the basis in controlling pain during dental treatment but, at the same time, one of the most common and major fears for the patient. Traditionally, most of the dental treatment procedures need to be performed under local anesthesia. Laser analgesia provides an extra tool for the dentist to avoid or reduce the use of local anesthesia in some cases. It should be stated that analgesia is not really anesthesia but a way to reduce sensitivity, needing a more intensive stimulus for the patient to feel pain. Studies using infrared wavelengths (diode, Nd:YAG) conclude that low-level laser therapy (LLLT) can suppress the excitation of unmediated C-fiber afferents of the pulp. Also, there are studies regarding the potential analgesic effect of erbium family laser irradiation and the mechanism resulting in this effect. Many clinicians report that they have been successful in performing a variety of dental procedures, in pediatric dentistry too [4, 5].

In all clinical cases presented in this section, laser analgesia was applied using the Er,Cr:YSGG (2780 nm) laser with the following parameters: starting with 50 mJ, 10 Hz, (0.5 W), 82% water (16 mL/min), 70% air, and distance 6–10 mm from the tooth for 40–60 s and continuing with 80–100 mJ for 60 more seconds before tooth preparation (gold handpiece, 0.6-mm MZ tip, H tissue mode) (◘ Figs. 11.1a–e, 11.2a–g, and 11.3a–d). There are no studies reporting any analgesic effect of CO_2 wavelength. Theoretically, the ideal laser wavelength choice would be the one that has an analgesic effect and that can be used in all of those treatment procedures at the same time.

The performance of laser analgesia using erbium family lasers could be a useful tool to overcome behavioral problems, especially for needle-phobic children seeking dental treatment (◘ Fig. 11.2a–g). Also, only the application of topical anesthetic gel on dry gingival or mucosa for 3–5 min (e.g., EMLA cream (lido-

11



◘ **Fig. 11.2** Behavior shaping using laser for the completion of dental treatment of a referred 7.5-year-old needle-phobic girl with low cooperation at the dental office. Laser treatment used to introduce dentistry, gain the trust of the child, perform needle-free and also no painful procedures, and "desensitize" the patient through gradual exposure to dental treatment: perform first sealants, needle-free restorations (laser analgesia and preparation), and finally extraction. **a** Initial intraoral view of the upper arch. **b** Left bitewing radiograph. Tooth #64 had to be extracted due to abscess and root resorption. Note that caries was well extended into dentin on #65. **c** Cavity preparation on #65 (see ◘ Table 11.2 for energy parameters). No local anesthesia but laser analgesia (see text and ◘ Fig. 11.1b for laser parameters) and preparation by Er,Cr:YSGG (2780 nm, gold handpiece, 0.6-mm MZ tip, H tissue mode). **d** After laser preparation of #65. The child revealed no pain and no complaint and cooperation was good. **e** After RMGI placement on #65. **f** Intraoral view of the upper arch after 2 months. The patient presented for extraction of tooth #64 with the administration of local anesthesia (4% articaine, 1:200,000 epinephrine). Cooperation was excellent. **g** After 20 months. The permanent successor is erupting and space maintenance has to be removed. Restoration on #65 remains intact

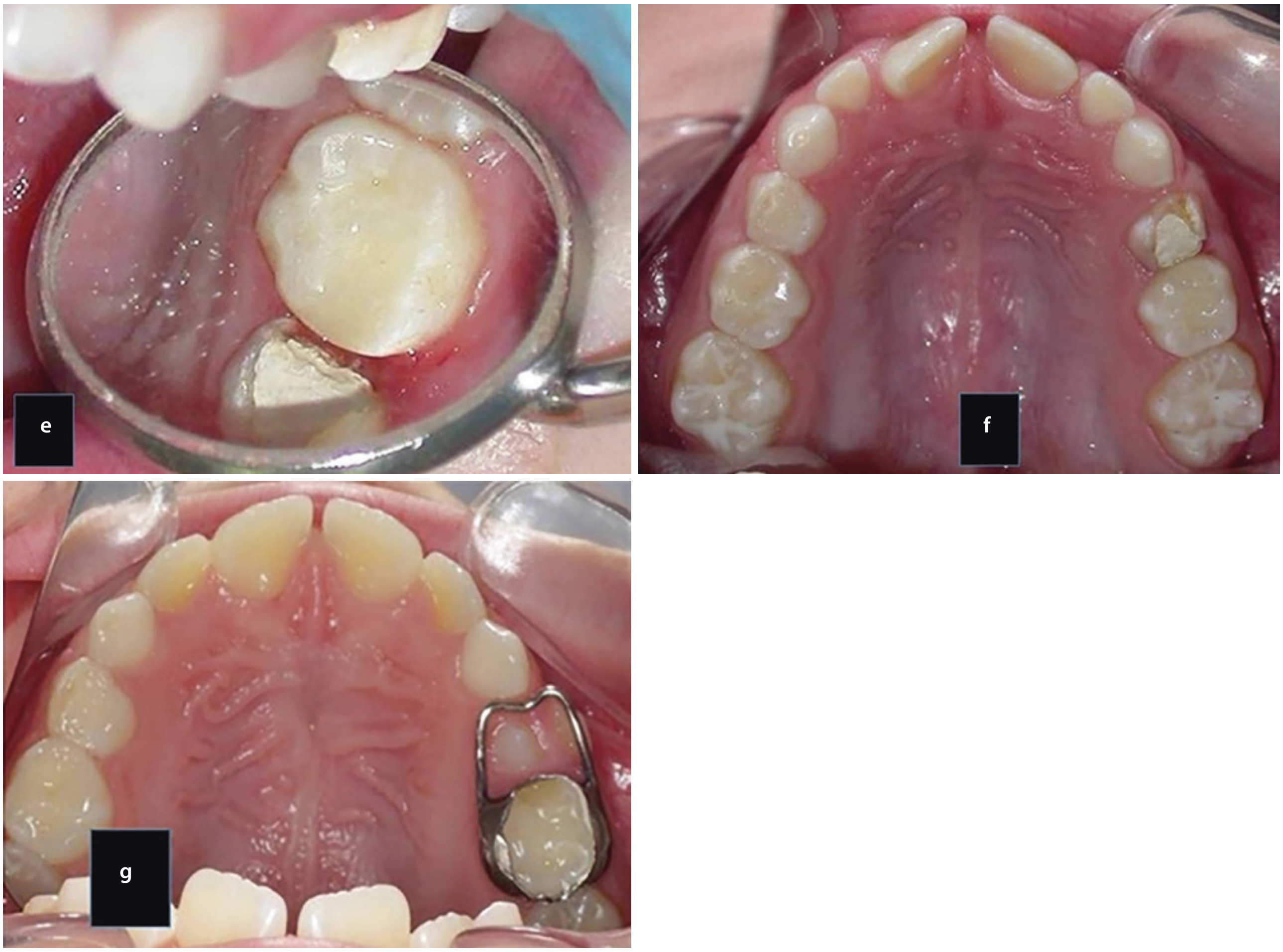
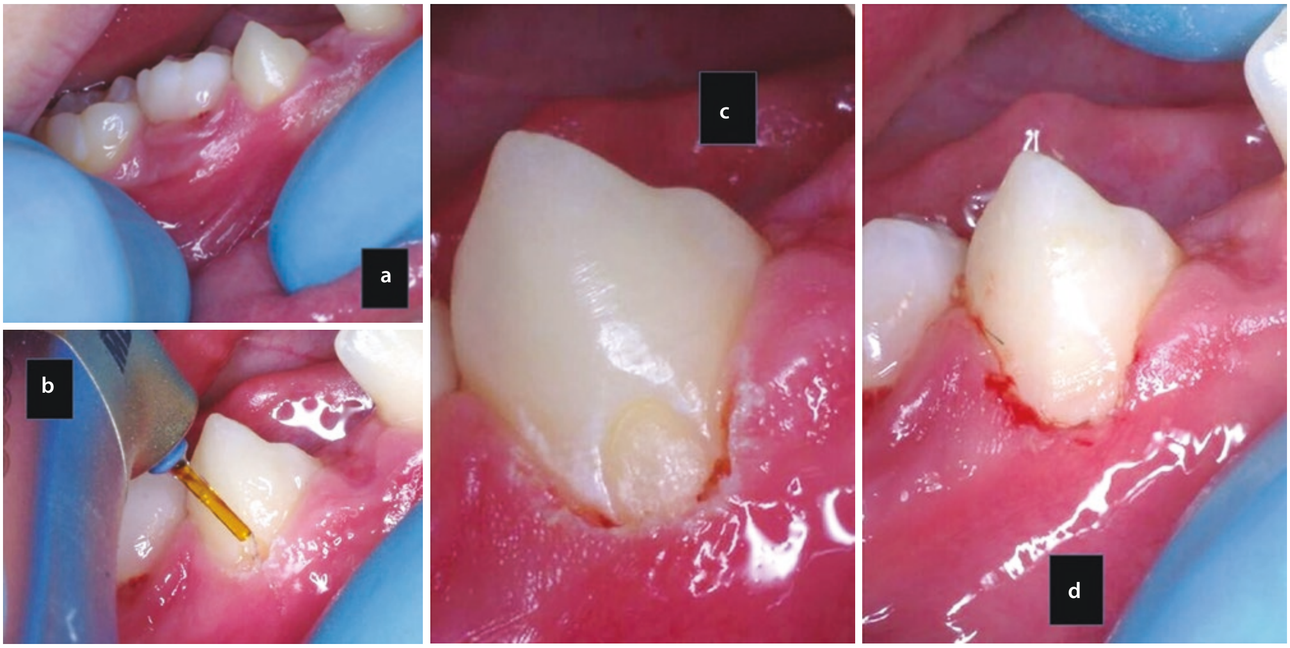


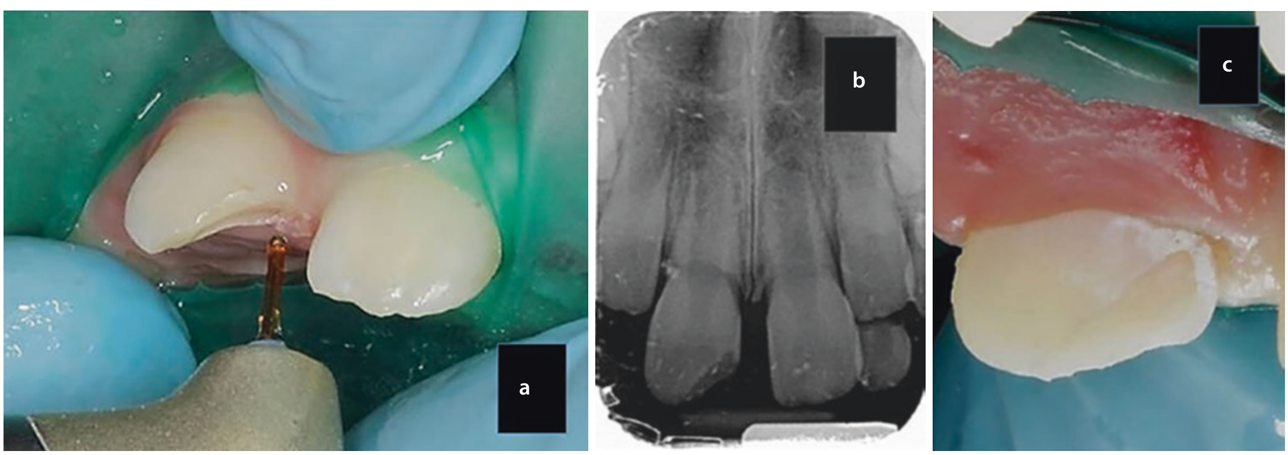
Fig. 11.2 (continued)

caine 2.5% and prilocaine 2.5%); each gram of EMLA cream contains 25-mg lidocaine and 25-mg prilocaine), without the administration of injected local anesthesia, is efficient in performing minimal gingival interventions in several clinical cases by erbium family lasers (Figs. 11.3a–d and 11.4a–f).

It should be noticed that a prerequisite for achieving cooperation with the child and complete dental treatment is the minimization of disturbance and the absence of pain. Completion of dental treatment with children is directly related to the absence of pain. There is always a possibility of pain during dental treatment after laser analgesia, and in this case, laser energy parameters should be altered, or local anesthesia should be delivered. Adult patients can communicate their feelings with the dentist and may tolerate the pain to some extent and to remain cooperative, but children are frightened, lose trust to the dentist when their teeth ache, and then do not cooperate. It is the dentist's responsibility, after evaluating the child's maturity and providing adequate psychological preparation to reach a high degree of cooperation, to decide if local anesthesia should be administered before laser-assisted dental treatment. In general, if there is a possibility of pain, it is preferable to deliver local anesthesia before the start rather than during the dental treatment in children with low cooperation. Examples of such cases are shown at Figs. 11.5a–e and 11.7a–g. These patients were not cooperative (one had extremely high gagging reflex which is very often associated with "hidden" dental anxiety) [6, 7]. Laser analgesia could be used, but it was decided that block anesthesia was more appropriate for these patients.



■ **Fig. 11.3** Minimal gingivoplasty and subgingival composite resin restoration, in a single visit and without administration of local anesthesia, on tooth #83 of a 7-year-old boy. **a** Initial clinical view. Placement for 3 min only EMLA cream (lidocaine 2.5% and prilocaine 2.5%) on dry gingiva. **b** Minimal gingivoplasty using Er,Cr:YSGG (2780 nm) at 50 mJ, 20 Hz, (1.0 W), 30% water (6 mL/min), 70% air, tip distance 1 mm (close contact), tip parallel to the long axis of the tooth (gold handpiece, 0.6-mm MZ tip, H tissue mode). **c** After gingivoplasty and cavity preparation by Er,Cr:YSGG (2780 nm) (see ■ Table 11.2 for energy parameters). **d** Final composite resin restoration



■ **Fig. 11.4** Minimal gingivoplasty using Er,Cr:YSGG and reattachment of tooth fragment, in a single visit and without local anesthesia, following enamel-dentine subgingival (no pulp involvement) crown fracture on a permanent incisor of a 7.5-year-old boy. **a** Rubber dam placement, EMLA cream (lidocaine 2.5% and prilocaine 2.5%) for 3 min. Minimal gingivoplasty using Er,Cr:YSGG (2780 nm) (see laser energy parameters on ■ Fig. 11.3b). **b** Initial radiographic image (no complete root formation). **c** After minimal gingivoplasty and before tooth fragment reattachment using composite resin. There is no gingival bleeding and tooth structures have been exposed. **d** Final restoration. **e**, **f** Clinical and radiographic views 30 months after treatment showing root formation

Fig. 11.4 (continued)

Fig. 11.5 Minimal gingivoplasty and treatment of subgingival caries, in a single visit, on teeth #83, #84, and #85 after preparation by Er,Cr:YSGG (2780 nm) of a 7.5-year-old girl. Also treatment of occlusal caries on #46. **a** Intraoral initial clinical view. **b** Block anesthesia (4% articaine, 1:200,000 epinephrine) and placement of rubber dam. Using Er,Cr:YSGG (2780 nm): (1) remove caries from #46 (enamel: 4 W, 20 Hz, 200 mJ, 82% (16 mL/min) H_2O, 70% air), (RC restoration and sealant) and (2) minimal gingivoplasty on teeth #83, #84, and #85 (see laser energy parameters on Fig. 11.3b). **c** Caries removal from teeth #83, #84, and #85 (see Table 11.2 for energy parameters for primary teeth). **d** Clinical view after 26 months. The girl is almost 10 years old, #83 is movable, and #84 has been normally exfoliated. Restoration on #83 is intact. **e** Placement of SSC on #84 and #85 and buccal RMGI restoration on #83

11.4 Types of Lasers Used in Pediatric Dentistry

Caries management includes prevention (fluoride application, dietary instructions, everyday oral hygiene), detection, and treatment management. Treatment includes the removal of the infected dental tissue, the cavity preparation, and, depending on the case severity, the indirect or direct pulp capping, pulpotomy, and pulpectomy, followed by tooth restoration. At this time, erbium family lasers are the ones that can be commonly used on both hard tissues, for caries removal and cavity preparation, and soft tissues. The targeted chromophore for this wavelength is primarily water and secondarily hydroxyapatite. This in combination with the mid-infrared wavelength (less penetrative compared to shorter wavelengths) results in its superficial effect on tissues, minimizing the risk for collateral thermal damage. The remaining laser wavelengths can be used successfully on the rest of the procedures, especially regarding hemostasis achievement in pulp or gingiva before restoration (Figs. 11.6a–d and 11.7a–g) and decontamination, since the targeted chromophore in soft tissues is hemoglobin and melanin (for KTP, diodes, and Nd:YAG), with respect to their more penetrative wavelength (except for the CO_2 which, due to its longer

11

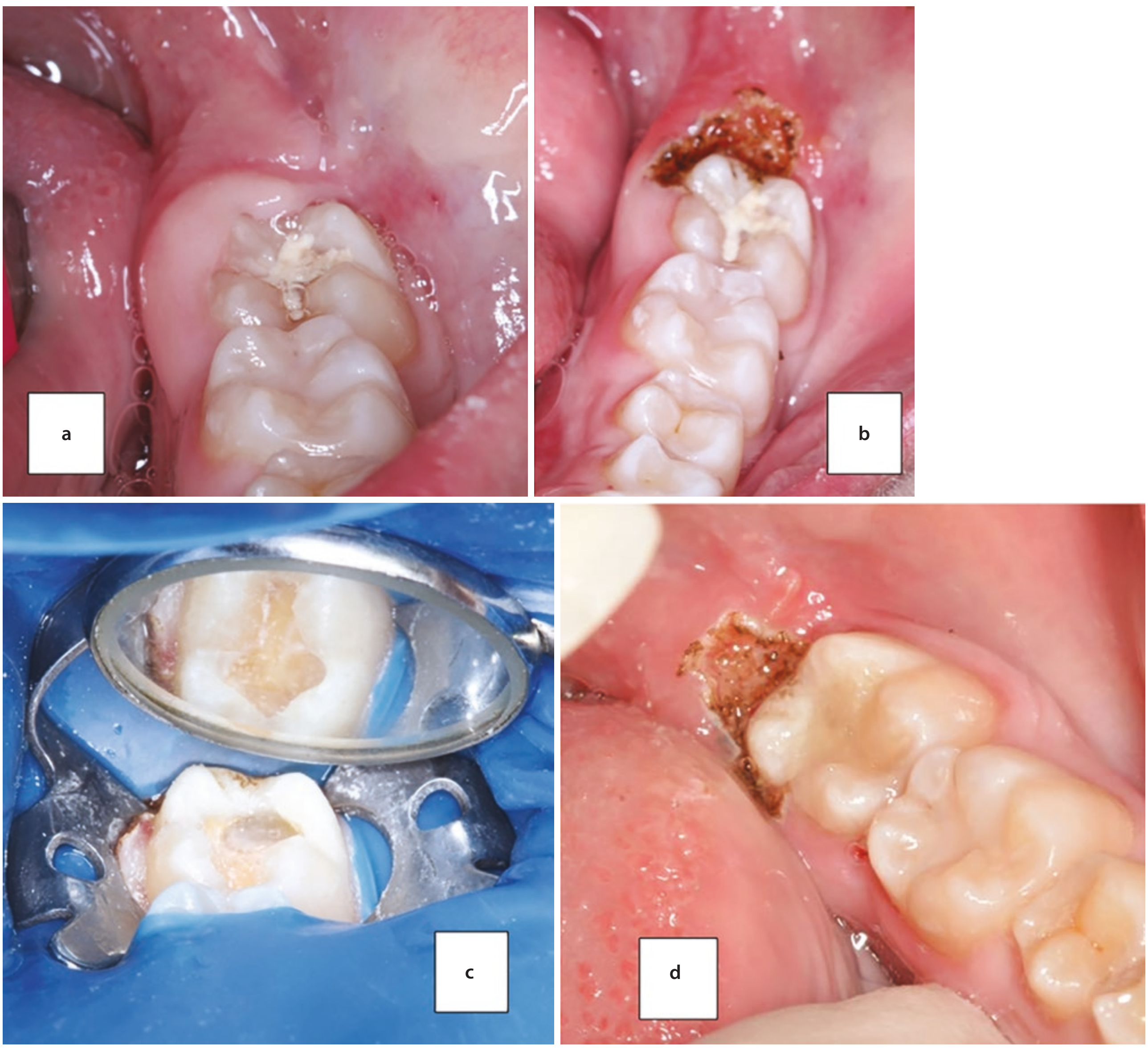


Fig. 11.6 Mimi, 12-year-old girl, clear medical history, caries on #37, under eruption, composite restoration, block anesthesia, gingivectomy with diode laser, Biolase, Epic X, 940-nm wavelength. **a** Intraoral initial clinical view. **b** After gingivectomy 1 W, continuous mode, 300-μm initiated fiber. **c** After cavity preparation. **d** Final intraoral view

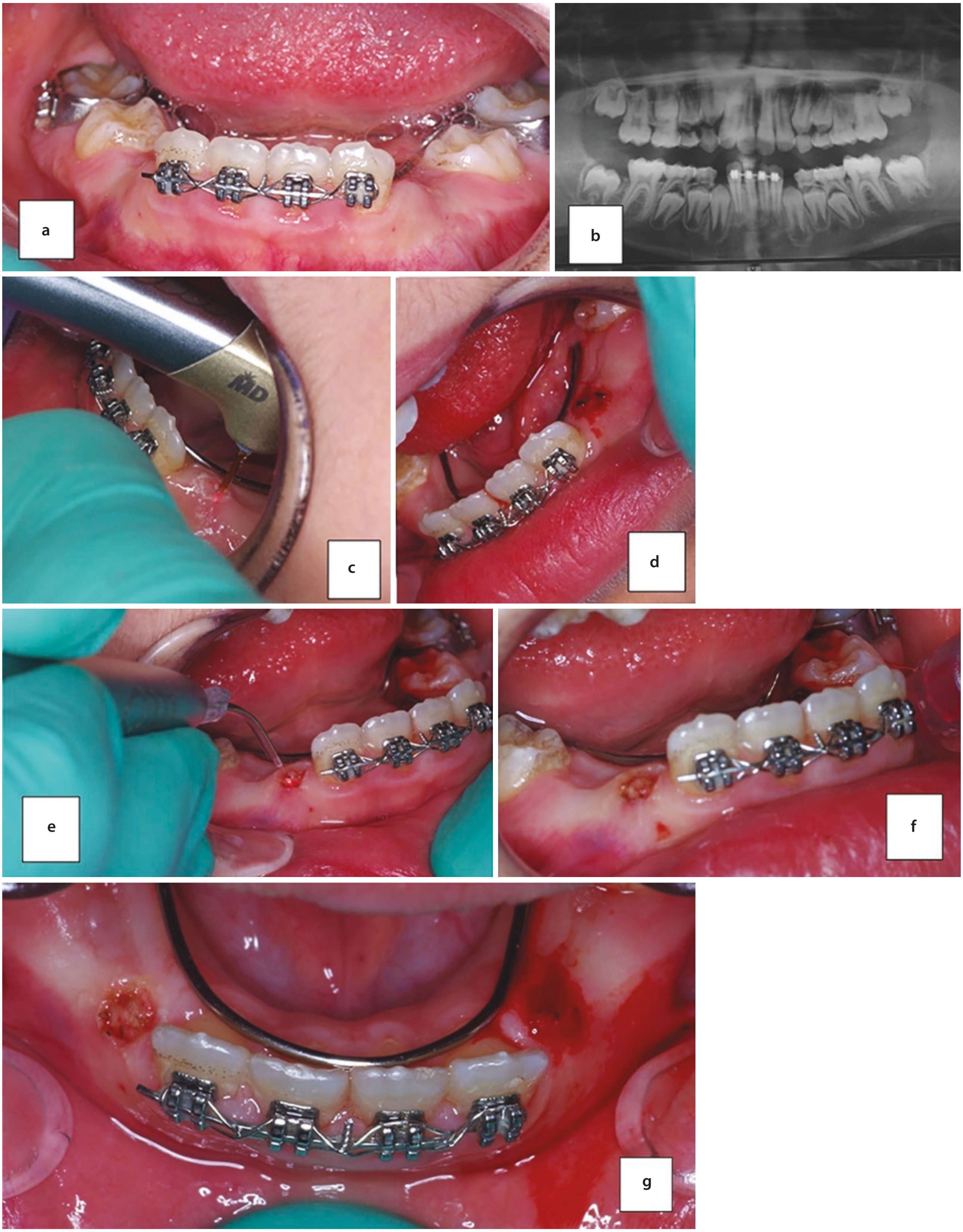


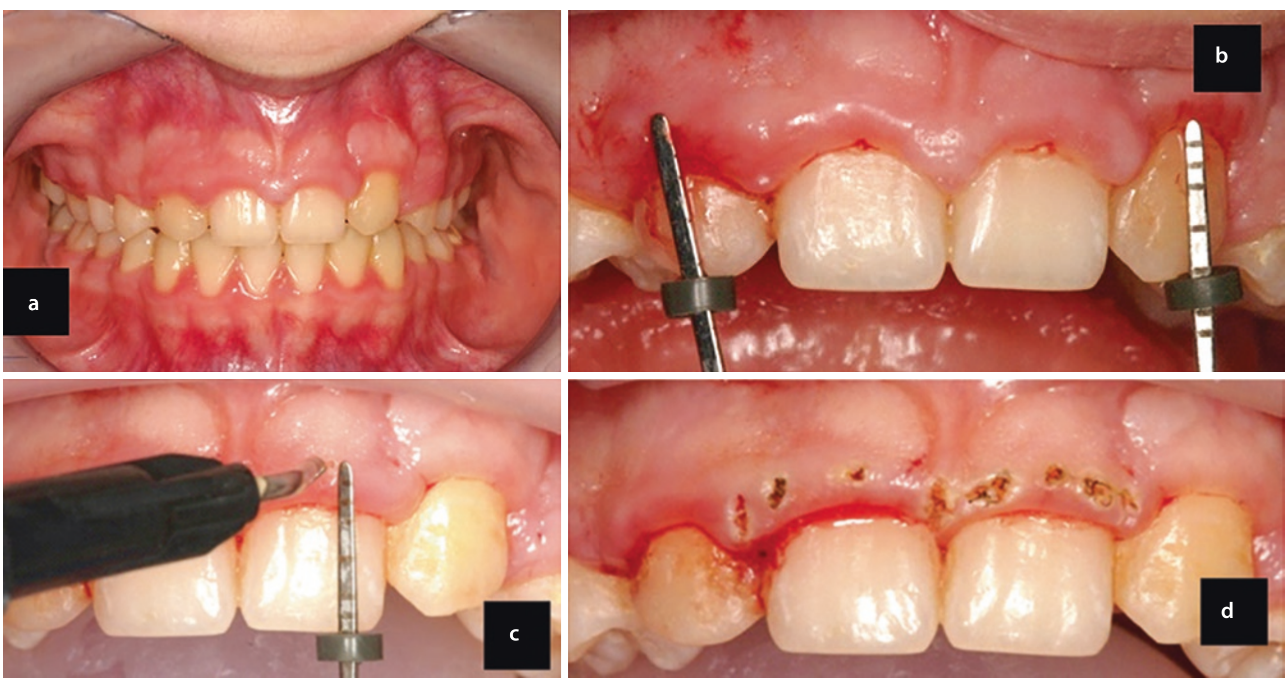
Fig. 11.7 Konstantinos, 11-year-old male, clear medical history, under orthodontic treatment, delay eruption of canines (#43, 33). **a**, **b** Intraoral initial clinical view and X-ray. **c**, **d** Crown exposure with Er,Cr:YSGG, 2.780-nm, Biolase (tooth #33). **e**, **f** Crown exposure with diode laser, Biolase, Epic X, 940-nm wavelength 1 W, continuous mode, 300-μm initiated fiber (tooth #43). **g** Postoperative intraoral view. Hemostasis was better and easier with diode laser

wavelength and high absorption in water, is the less penetrative of all) [8, 9]. Regarding caries prevention CO_2, erbium family lasers and Nd:YAG (due to their high power values emitted and ability to photo-thermally melt enamel) have been tested alone or in combination with fluoride, especially through in vitro studies. Infrared irradiation (diode lasers), due to its high penetration (and low absorption on hard tissue), is used widely in detecting caries.

Periodontal diseases in children usually include minimal severity gingivitis infections, usually due to poor everyday oral hygiene and hyperplastic gingivitis with the formation of pseudo-pockets (not completely erupted teeth). In addition, gingival and periodontal changes may be seen during or following orthodontic treatment, due to difficulties in maintaining good oral hygiene and/or the periodontal tissues following the teeth movement during the orthodontic treatment (◘ Fig. 11.8a–h). All laser wavelengths can be used in these instances for laser decontamination and if needed removal of hyperplastic gingival tissue. They simplify the surgical procedures by minimizing the use of flaps, provide excellent bleeding control without suturing, and result in a fast and less eventful healing (◘ Fig. 11.9a–e)

Apart from tooth decay, tooth injuries represent the most frequent pathology encountered in pediatric dentistry. Around 20% of children suffer a traumatic injury to their primary teeth and over 15% to their permanent teeth [10]. Dental trauma is a stressful and challenging emergency situation for the child, the parents, and the dentist. Accurate diagnosis in combination with immediate intervention is required, so that any risk of sequel problems or healing complications is minimized. Mid-infrared wavelength lasers could be used to reduce acute pain, to improve and speed up tissue healing (photobiostimulation effect), to provide decontamination and inflammation control, and to help control bleeding.

Among other advantages, the use of lasers can often make it easier for the dentist to perform several procedures in the same appointment (◘ Figs. 11.3a–d, 11.4a–f, and 11.5a–e).



◘ **Fig. 11.8** Gingivectomy due to hyperplastic gingiva after orthodontic treatment and aesthetic reasons [canines replacing the missing second incisors] of a 16-year-old girl. **a** Initial situation, **b**–**d** measuring and comparing the size between the same teeth of the opposite sides, using a 1064-nm diode laser [1 W, continuous mode, 300-μm initiated fiber speed of movement 1 mm/s] to create dots and guide the soft tissue removal. **e** Measuring and comparing the size between the same teeth of the opposite sides, using a 1064-nm diode laser [1 W, continuous mode, 300-μm initiated fiber speed of movement 1 mm/s] to create dots and guide the soft tissue removal. **f** Immediate postoperative, **g**–**h** healing at 1 and 3 months postoperative

Fig. 11.8 (continued)

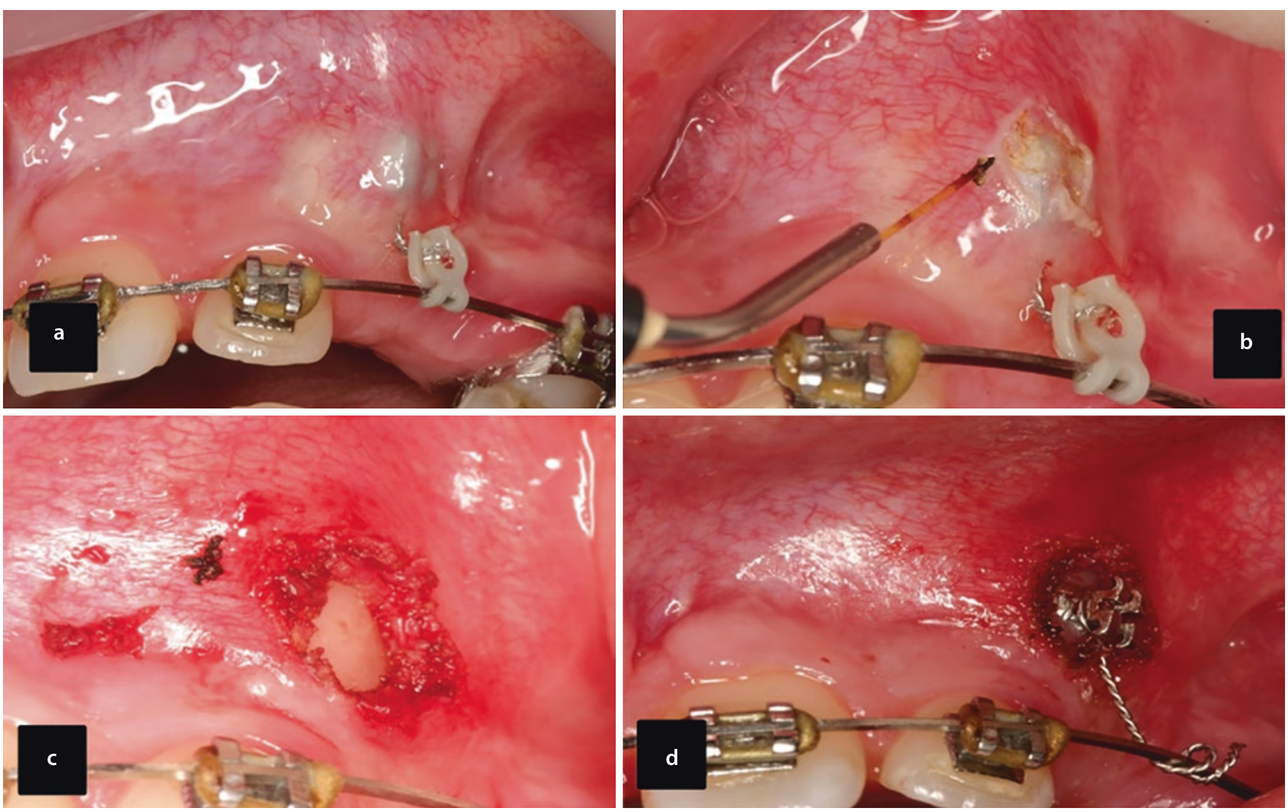


Fig. 11.9 Bracket recovery and re-bonding, 12-year-old boy. **a** Initial situation: the bracket is located under the alveolar mucosa and is no longer bonded on the canine. **b** Surgical procedure and bracket recovery using a 1064-nm diode [0.8 W, continuous mode, 300-μm initiated fiber, speed of movement 2 mm/s]. Extra caution and care to avoid extended thermal trauma [water cooling every 10 s, for 10 s] since the tissue is very thin and the metallic surface of the bracket accumulates heat rapidly. **c**, **d** Excellent hemostasis and bracket bonding. **e** Intraoral view after the end of the orthodontic treatment

Fig. 11.9 (continued)

11.5 Restorations on Primary Teeth

Dental caries is one of the most common diseases in childhood, and several well-established restorative methods and materials have been used for replacing the carious dental tissues of primary teeth. Lasers can be used as alternative instruments to completely or partly substitute traditional instruments and techniques or to help and contribute to traditional dental treatment. The erbium family lasers are used for caries removal and cavity preparation on primary teeth. Enamel and dentine in primary teeth have compositional and structural differences from those of permanent teeth. Primary tooth enamel is less mineralized and more porous, and prisms do not have an orderly spatial organization. Primary tooth dentine has more water, less in number, and narrower dentinal tubules. Therefore, lower laser energy parameters than those for permanent teeth should be used for caries removal and cavity preparation on primary teeth (Tables 11.1 and 11.2). Water flow is given in both percentage and mL/min. The percentage of water given means the percentage of the maximum possible amount of water the specific laser unit could provide. For example, 70% (7 out of 10) for Fotona LightWalker (Er:YAG, 2940 nm) is water flow of 32 mL/min, while 82% for Er,Cr:YSGG (Waterlase MD, 2.780 nm) is 16 mL/min.

All dental restorative materials (composite resin (CR), compomers (C), resin-modified class ionomer (RMGI), glass ionomer (GI)) could be placed after laser cavity preparation on primary teeth (Figs. 11.1a–e, 11.3a–d, and 11.5a–e). There are no long-term randomized clinical trials about restoration of primary teeth using lasers. However, there are several studies concluding that laser abrasion is a safe, useful alternative method for caries removal and cavity preparation on primary teeth [11–14]. Studies on bond strength

Table 11.1 Parameters for cavity preparation with Er:YAG laser (2940 nm) on primary teeth

Energy per pulse (mJ)	Average power (W)
(1) 160–200 mJ, 10 pps	(1) 1.6–2
(2) 80–100 mJ, 10 pps	(2) 0.8–1
(3) 40–60 mJ, 10 pps	(3) 0.4–0.6
(4) 35–50 mJ, 20 pps	(4) 0.70–1
(5) 50 mJ, 20 pps, defocus, for 15 s	(5) 1

Tip diameter 600 μm, 70% water (32 mL/min for Fotona LightWalker), 1-mm tip to tissue distance (1) enamel preparation, (2) dentine preparation, (3) dentine finishing-conditioning and removal of dental caries, (4) enamel finishing-conditioning, and (5) decontamination (based on Professor Selting laser parameter calculation sheet)

Table 11.2 Parameters for cavity preparation with Er,Cr:YSGG (Waterlase MD, 2.780 nm) on primary teeth

Average power (W)	Energy per pulse (mJ)
(1) 2.0 W, 10 pps	(1) 200
(2) 1.5 W, 10 pps	(2) 150
(3) 1 W, 10 pps	(3) 100
(4) 0.5 W, 10 pps	(4) 50
(5) 0.75 W, 20 pps	(5) 37.5
(6) 1 W, 20 pps, defocus, for 15 s	(6) 50

Tip diameter 600 μm, 82% water (16 mL/min), 1-mm tip to tissue distance (1) enamel preparation, (2) dentine preparation, (3) removal of dental caries, (4) dentine finishing-conditioning, (5) enamel finishing-conditioning, and (6) decontamination (based on Professor Selting laser parameter calculation sheet) restorative materials after preparation of primary teeth by laser or traditional method showed lower or equal results [15–20]. The results on marginal microleakage are controversial, but most of the studies report good results (similar or better than the diamond bur) for both laser wavelengths of the erbium family. The restorative materials studied include several types of CR, C, RMGI, and GI. In the case of CR and C, several etching (total etch, self-etch) and adhesive systems (one-step adhesive, two-step adhesive, self-etching adhesive) are studied [21–29]. Also, a study showed no statistically significant difference on marginal microleakage between Er:YAG and Er,Cr:YSGG lasers for any of CR, RMGI, and GI restorations [30]. The main advantages of laser use in restorative pediatric dentistry are patient and parent's acceptance, the administration of no or less local anesthesia, the absence of vibration, the cavity decontamination effect, and the selectivity of dental caries.

Table 11.3 Advantages of laser use with minor surgical applications

Minor surgical applications using proper technique with a dental laser have several advantages
• Little local anesthesia
• No intraoperative or postoperative bleeding
• No suturing
• No postoperative pain and discomfort
• Normal function since day 1
• No antibiotic or analgesic medication use
• Accelerated healing
• No scarring
• Patient acceptance

11.6 Soft Tissue Applications

In any case a laser is used, it is imperative that the dentist/operator is fully familiar with the particular laser's settings and capabilities. It is recommended that a calculation spreadsheet is readily available, allowing the operator to instantly calculate values such as energy density (fluence), power density, and peak power, which are not available from the laser device monitor/dashboard.

11.6.1 Minor Surgical Applications (Table 11.3)

Labial Frenectomy

The frenum of the upper lip (maxillary labial frenum (MLF)) is a dense connective tissue structure with a high content of elastic fibers that tethers the upper lip to the maxilla. Based on the attachment of the fibers, the MLF has been classified by Mirko et al. [31] into four categories: (a) mucosal attachment (at the mucogingival junction), (b) gingival attachment (within the attached gingivae), (c) papillary attachment (extends into the interdental papilla), and (d) papilla penetrating attachment (crosses the alveolar ridge extending into the palatine papilla). Based on other characteristics, an MLF can also be described as simple frenum with a nodule, simple frenum with an appendix, bifid frenum, double frenum, or wider frenum.

The most common indication for frenectomy or frenum modification is when it causes or it is expected to cause an undesired diastema between the central incisors or when it causes periodontal problems, such as dehiscence, gum recession, or inflammation, or is easily traumatized during eating or oral hygiene. The optimal time or age to perform an upper labial frenectomy is under continuous debate. Most evidence points to the time when the upper canines have erupted or are erupting or as part of an orthodontic treatment plan in the mixed dentition. One of the arguments for closing a diastema before resecting the frenum has been that if performed before tooth movement the scar tissue may hinder orthodontic tooth movement and closing of the diastema. While the latter may be true for frenectomies performed traditionally with a scalpel and suturing, in the following section, it will become obvious that this is not true when the frenectomy or frenum modification is performed with a laser and with good technique. Several lasers can be and have been used to perform a maxillary labial frenectomy, and clinical examples are shown (Figs. 11.10a–h, 11.11a–e, 11.12a–k, 11.13a–e, 11.14a–e, 11.15a–d, and 11.16a–d).

Fig. 11.10 Nine-year-and-5-month-old female (dental age ~ 11) with a short labial frenum and midline diastema prior to orthodontic treatment. Frenectomy performed under local anesthesia. *Laser parameters*: pulsed Nd:YAG initiated fiber 320 um, average power 3.2 W, pulse 40 mJ, repetition rate 80 Hz, pulse duration 100 μs. Treatment duration: total < 20 min, 30 s ON/30 s OFF. Mode: contact, parallel to teeth, stretched fibers, by manually pulling the upper lip. Progressive steps are shown. **a** Preop. **b** Step 1. **c** Step 2. Note the direction of the fiber parallel to the roots to minimize absorption of energy in the dental pulp and bone. **d** Step 3. **e** Final postop result. **f** One week F/U. **g** One month F/U. **h** Nine months F/U. Note no excellent coagulation, no carbonization, and no need for suturing. Instructions include rinsing with mild antiseptic solution during the first week of healing with chamomile or active oxygen solutions or drops (Unisept). Also, note excellent healing without scarring

Fig. 11.11 Nd:YAG spontaneous diastema closing after laser frenectomy performed at the stage of upper lateral incisors' eruption in the mid-mixed dentition. No orthodontic movements were made. **a** Six months preop, **b** 2 weeks preop, **c** immediate postop, **d** 1-year F/U, **e** 3-year F/U. *Laser parameters*: pulsed Nd:YAG, average power 3.2 W, pulse 40 mJ, repetition rate 80 Hz, pulse duration 100 µs. Peak power 400 W, fiber diameter. Treatment duration: total < 20 min, 30 s ON/30 s OFF. Mode: contact, parallel to teeth, stretched fibers, by manually pulling the upper lip

Fig. 11.12 Nd:YAG extreme case of upper labial frenum. Nine-year-old male with excessively thick and short frenum, combined with partial orthodontic treatment. **a** Ten months prior to laser frenectomy. **b**, **c** Preop. **d** Immediate postop. **e** One week F/U. **f** Four months F/U diastema closing spontaneously. **g** Sixteen months with partial orthodontic treatment of the lower anteriors and tongue thrust. **h** 22 months F/U with orthodontic treatment. **i** Four years F/U. Note good healing despite extensive modification. **j** Residual mucosal tag. **k** Laser aesthetic removal of the mucosal tag. This is best prevented at the time of the frenectomy by smoothening the end of the attachment of the frenum in the lip mucosa with the laser. *Laser parameters for frenectomy*: pulsed Nd:Yag, average power 4.0 W, pulse 40 mJ, repetition rate 100 Hz, pulse duration 100 µs. Fiber diameter 320 um. Treatment duration: total < 20 min, 30 s ON/30 s OFF. Mode: contact, parallel to teeth, stretched fibers, by manually pulling the upper lip. Laser parameters for the residual mucosal tag: repetition rate reduced to 80 Hz

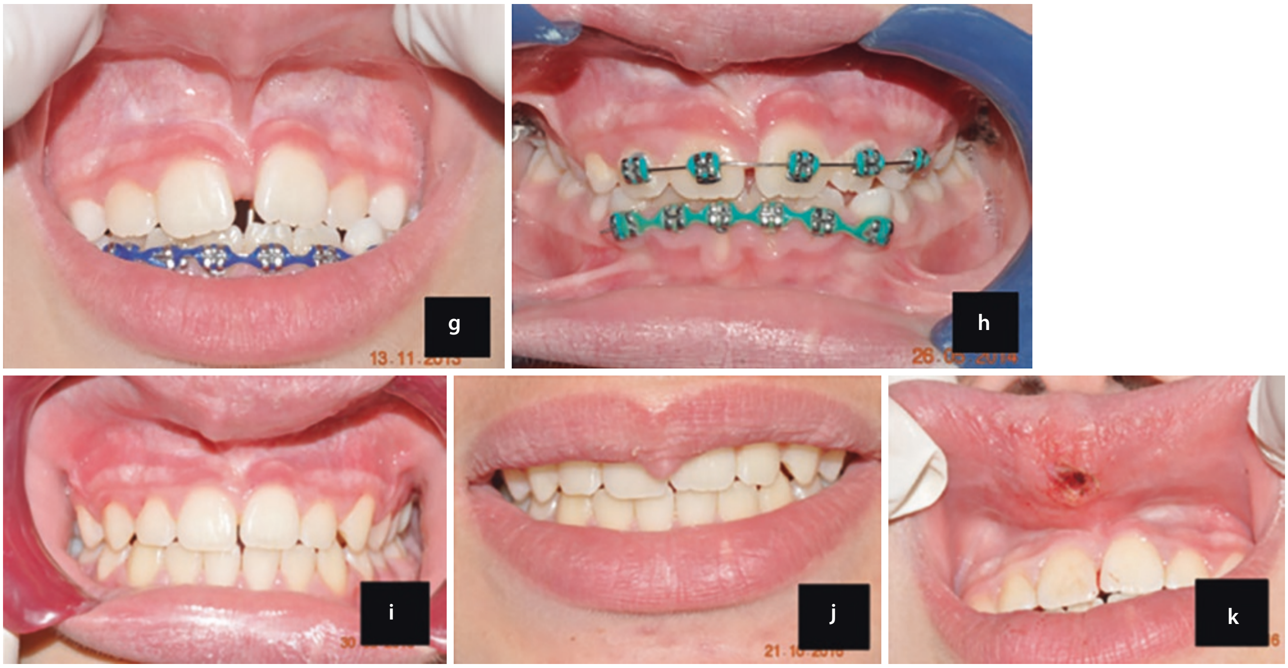


Fig. 11.12 (continued)

Fig. 11.13 Panagiotis, 12 years old, clear medical history, does not like bleeding (taste) and sutures. Er,Cr:YSGG (2780 nm), gold handpiece, 0.6-mm MZ tip. Distance: 1 mm, close contact, hard tissue mode. **a**, **b** Local anesthesia (4% articaine, 1:200,000 epinephrine). **c** Er,Cr:YSGG (2780 nm) was applied at 1.00–1.50 W, 20 Hz, 30% H_2O, 70% air, 6 mL/min H_2O. **d** Complete coagulation after laser application. **e** After 3 days

Fig. 11.14 Aggelos, 7.5 years old. **a**, **b** Clear medical history, space between #11 and #21 and no space for #22, not cooperative, does not like bleeding and sutures Er,Cr:YSGG (2780 nm), gold handpiece, 0.6-mm-MZ tip. Distance: 1 mm, close contact, hard tissue mode. **a**, **b** Local anesthesia (4% articaine, 1:200,000 epinephrine). **c** Er,Cr:YSGG (2780 nm) was applied at 1.00–1.50 W, 20 Hz, 30% H_2O, 70% air, 6 mL/min H_2O. **d** Complete coagulation after laser application. **e** After 2 days. **f** After 1 year. Tooth #22 is in place without any orthodontic treatment

Fig. 11.15 Frenectomy and pseudo-pocket removal, 12-year-old girl. **a** Initial intraoral view. Hyperplastic tissue entirely covering the interdental spaces and in contact with the brackets and the orthodontic wire, compromising dental hygiene. Frenum attached too close to the attached gingiva [less than 2 mm], buccal position of the incisor roots and thin biotype, indicating frenectomy to prevent future gingival recession. **b** Using a 1064-nm diode [0.8 W, continuous mode, 300-μm initiated fiber, speed of movement 1-mm/s water cooling every 10 s for 5 s for thermal relaxation] for both surgical procedures. **c** Immediately postop. No carbonization can be observed. **d** Follow-up after 6 months. The distance between the frenum and the attached gingiva in more than 3 mm, stable result, no scar formation

11

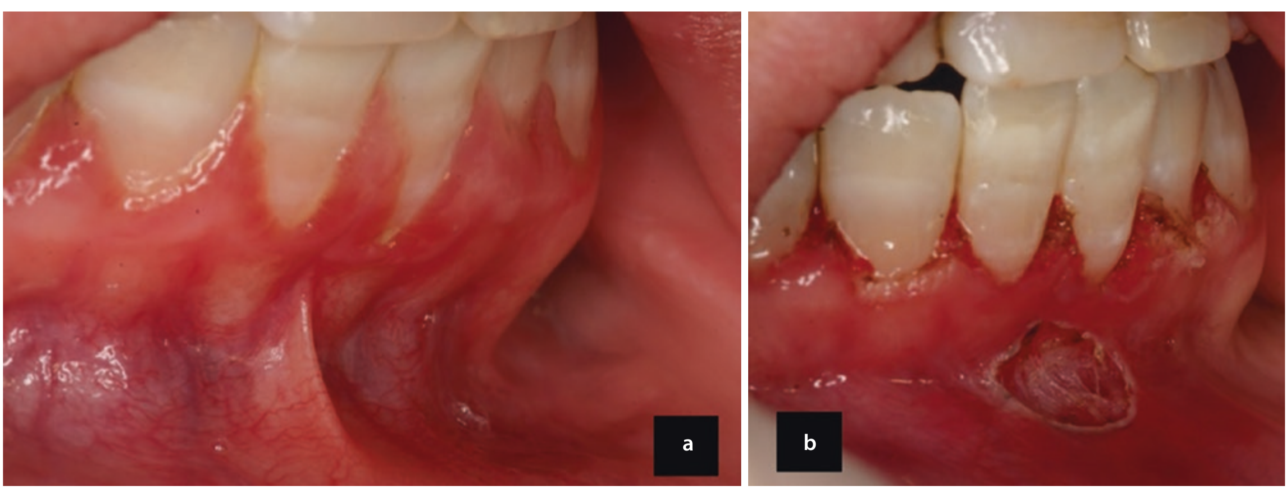


Fig. 11.16 Frenectomy and laser decontamination for gingivitis, 12-year-old girl. **a** Initial intraoral view: gingivitis due to pure hygiene and frenum attached too close to the attached gingiva [less than 2 mm], buccal position of the incisor roots, and thin biotype, indicating frenectomy to prevent future gingival recession. **b**, **c** Using a 1064-nm diode [0.5 W, continuous mode, 300-μm fiber, no initiation, speed of movement 1-mm/s water cooling every 10 s for 5 s for thermal relaxation] for decontamination and a CO_2 laser [2 W, continuous mode, 200-μm spot area at focus, cooling with water every 5 s for 2 s and charring removal with gauze] for the frenectomy. No carbonization and no bleeding can be observed. **d** Follow-up after 1 year. The distance between the frenum and the attached gingiva is more than 3 mm, stable result, no scar formation

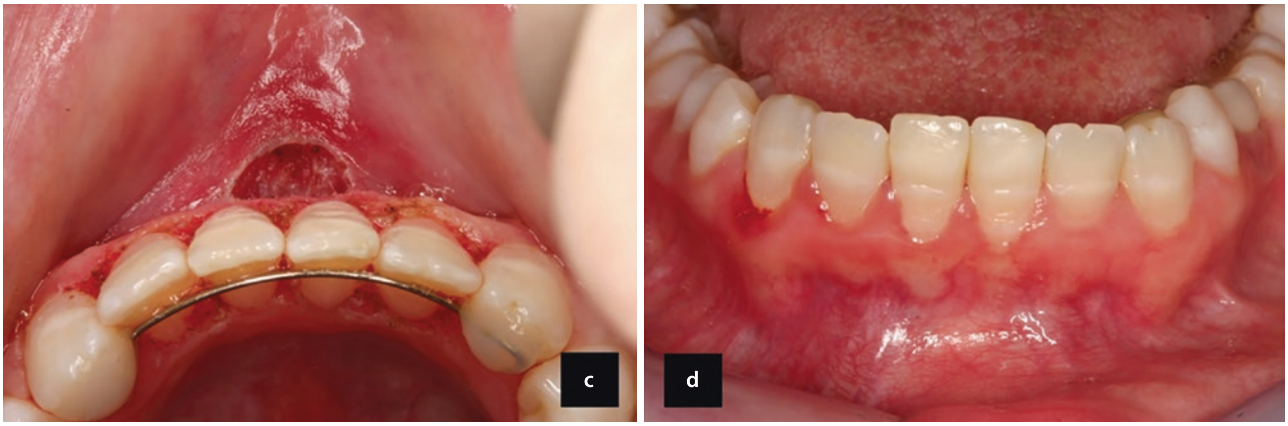


Fig. 11.16 (continued)

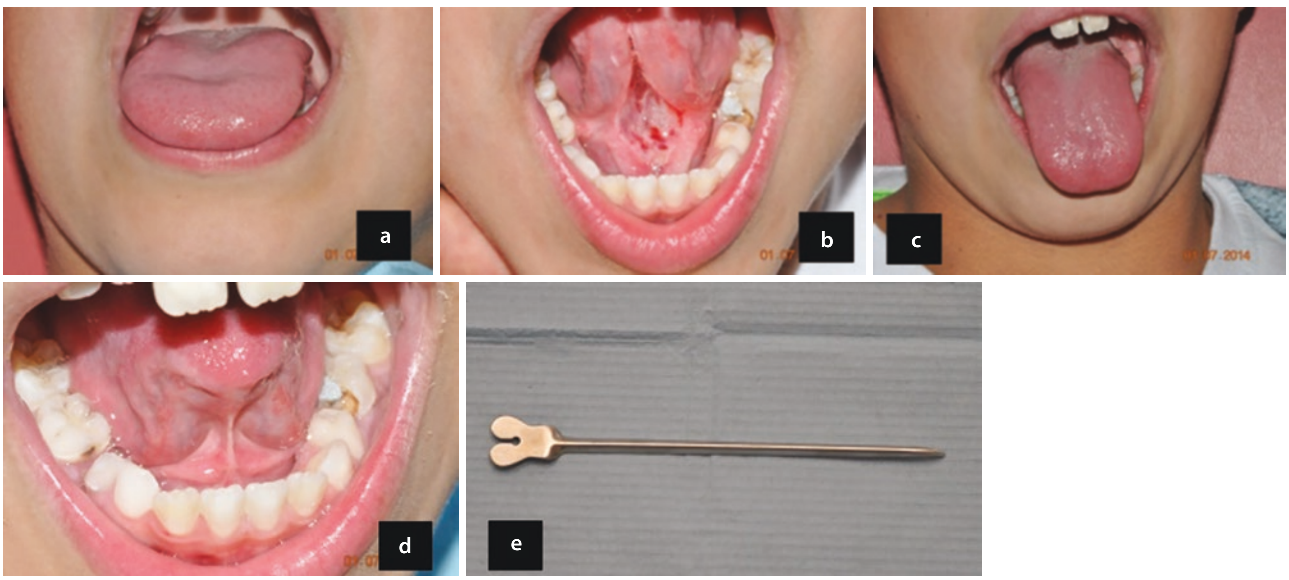


Fig. 11.17 Lingual frenectomy on a 9-year-old male. **a** Tongue mobility restrained to vermillion border. **b** Intraoral view of the lingual frenum. **c** Immediately postop. No suturing needed, no bleeding. Care must be taken to avoid and preserve the sublingual fold and caruncula. **d** Increase in outward tongue mobility immediately postop. **e** “Tongue-tie” instrument, or Sklar Director, or Groove director 5.5″ probe, to hold and stretch the lingual frenum while protecting adjacent structures. *Laser parameters*: pulsed Nd:YAG, average power 3.2 W, pulse 40 mJ, repetition rate 80 Hz, pulse duration 100 µs. Peak power 400 W, fiber diameter 300 µm

Lingual Frenectomy (Fig. 11.17a–e)

Ankyloglossia, or high lingual frenum attachment, or “tongue-tie” is a congenital variation or anomaly in which the tongue has restricted mobility secondary to a short lingual frenum, and cannot be protruded beyond the lower incisors, or the vermillion border of the lips. The restricted mobility of the tongue may also lead to difficulty in swallowing and pronouncing certain consonants that require the tip of the tongue to reach the hard palate [32].

There is no general consensus both on its diagnostic criteria and in the treatment protocols among practitioners of various specialties that examine or treat such patients, including pediatric dentists, oral and maxillofacial surgeons, ENT specialists, plastic surgeons, pediatric surgeons, pediatricians, speech therapists, and so on.

The most widely accepted and used clinical assessment tools are the Hazelbaker Assessment Tool for Lingual Frenulum Function (HATLFF) [33] and the Bristol Tongue Assessment Tool (BTAT) [34].

Ankyloglossia or tongue-tie is also classified into four classes by Kotlow [35] based on the length of the tongue from an insertion of lingual frenum at the base of the tongue to the tip of the tongue: (Normal length is 16 mm.)

- Class I: Mild Ankyloglossia—12–16 mm
- Class II: Moderate Ankyloglossia—8–11 mm
- Class III: Severe Ankyloglossia—3–7 mm
- Class IV: Complete Ankyloglossia—less than 3 mm

Crown Exposure

Crown exposure using proper technique with a dental laser has several advantages such as minimal surgical wound, no flaps, no sutures, disinfection, no or minimal postop pain/discomfort, quality-of-life improvement (pain, eating, speaking), and no antibiotic use. Several clinical examples are shown below (◘ Figs. 11.18a–f, 11.19a–c, and 11.20a–g).

◘ **Fig. 11.18** Mesiodens **a**, **b** extracted at age 5 years and 10 months, causing delayed eruption of UL1, which has not erupted 1.5 years after extraction of the mesiodens **c**. The exposure was performed under no local anesthesia with an Er:YAG laser, at low repetition rate (5 Hz), 150 mJ, VLP (1000 μs) pulse de-focussed non-contact, spot size 600 um diameter **d**. A linear opening at the incisal ridge of the crown is sufficient **e**. One week **f** and 1 month F/U **g**

Fig. 11.19 Er:YAG exposure of upper lateral permanent incisors was requested by the orthodontist to accelerate orthodontic treatment **a**. With minimal amount of local anesthesia which can be applied either at the mucobuccal fold or only around the incision site, a higher repetition rate can be used, such as 20 Hz, 150 mJ, and very long pulse de-focussed non-contact, spot size 600 um diameter. Following a minimal incision that runs the length of the incisal edge of the crown **b**, within 3 weeks, the orthodontist was able to bond orthodontic brackets **c**

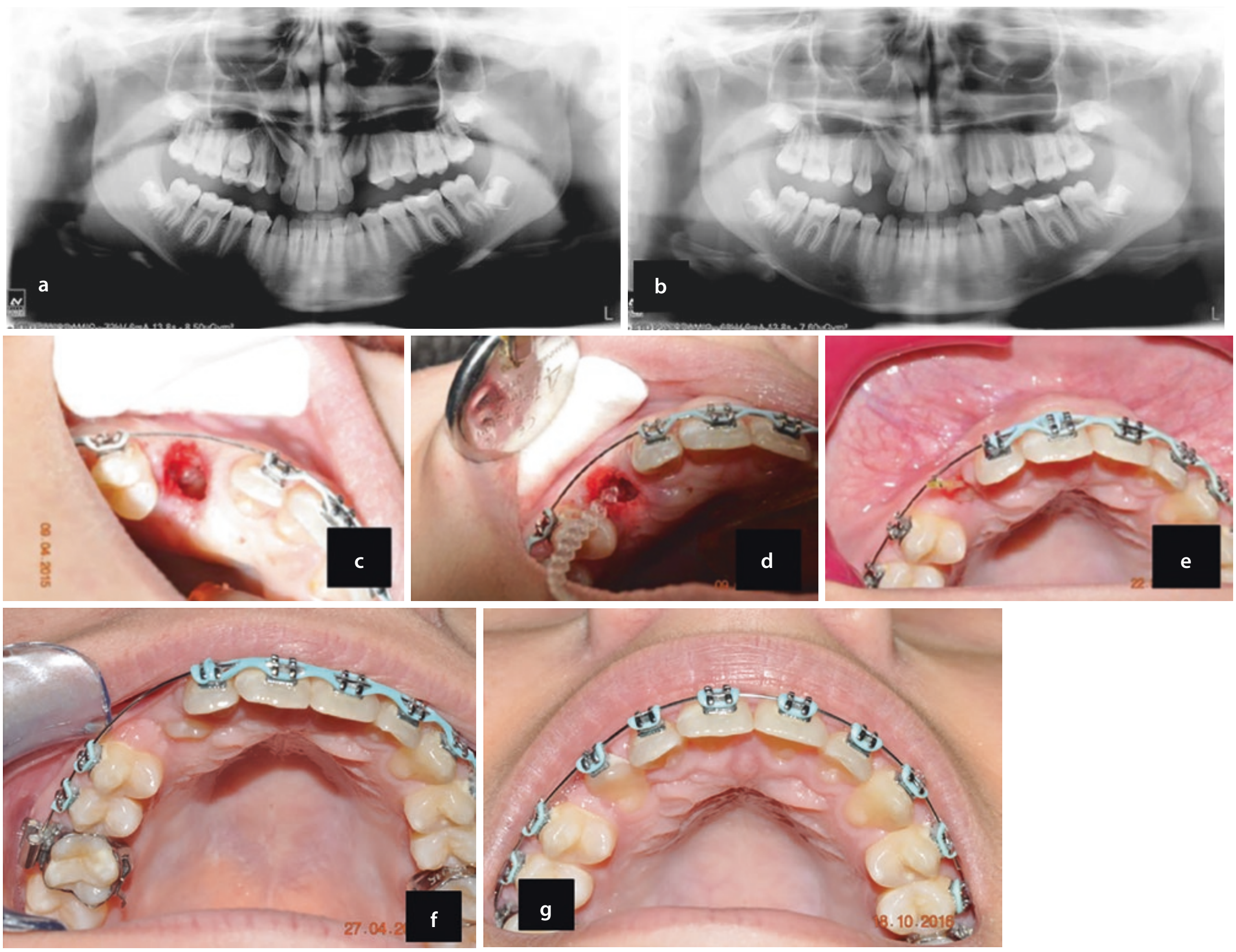


Fig. 11.20 Initial OPG before extraction of the upper right primary canine **a**. One year later, the upper right permanent canine is still impacted **b**. Using a simple SLOB (same lingual opposite buccal) method, it was determined that the distal aspect of the crown lies below the alveolar crest (not shown). All access was performed by an Er:YAG laser. Soft tissues were removed at 150 mJ, 20 Hz, and VLP (1000 μs), with and RO7 handpiece with a sapphire tip, in contact mode without water irrigation. Bone was removed with the same handpiece and tip, but at 200 mJ, 20 Hz, and VSP (100 μs) **c**. Note the minimally invasive surgical access and the dry field with good coagulation **c**. A bracket was bonded to the distal aspect of the crown with a pre-attached elastic chain **d**. In minimal access cases without a surgical flap, it is advisable that a chemically cured resin is used, as limited access does not always allow adequate light curing of the resin material under the orthodontic bracket or button. Note optimal healing in less than 2 weeks **e**; no analgesics were used. One year later **f**, the tooth emerges and is re-bracketed and brought to the arch in 1.5 years after the initial surgery **g**

Fig. 11.21 Pyogenic granuloma—fibroma. Exophytic lesion of normal mucosal color on the gingivae between lower central and lateral. Using a pulsed Nd: YAG laser with a 300-μm fiber at 3.2 W, 80 Hz, 40 mJ in contact mode. Primary incisors, causing tooth displacement and bothersome to this 2-year-and-10-month-old boy **a**, **b**. Ten months later, the lesion is causing further displacement of the teeth, and parents agreed to have the lesion removed by laser in the dental office setting **c**, **d**

Exophytic Lesion Laser Excision

See Figures 11.21a–d, 11.22a–d, 11.23, 11.24a–c, 11.25a–c, 11.26a–c, and 11.27a–t.

11.6.2 Pain Management and Wound Healing

Aphthous Ulcers

Aphthous ulcer treatment using proper technique and protocols (Table 11.4) with a dental laser has several advantages such as immediate relief of symptoms, improves quality of life (pain, feeding, speech), accelerates wound healing mechanism, is fast and simple, and requires no use of local or systemic medications (Fig. 11.28a, b).

Soft Tissue Trauma (Figs. 11.29a–c and 11.30a, b)

An unfortunate but all too common interlude to everyday pediatric dental practice is the child who has sustained dental or facial trauma. For both patient and parent, the presenting features may often amount to an impression of greater damage than actually sustained, but, nevertheless, the ability to provide support and initial treatment to combine positive action with empathetic care will go some way to calm the anxious situation. Table 11.5 provides an overview of the advantages offered through the adjunctive use of a dental laser.

Fig. 11.22 Irritation fibroma removal with Nd:YAG laser in an 18-year-old male. Lesion **a** was excised using a pulsed Nd:YAG laser with a 300-μm fiber at 3.2 W, 80 Hz, 40 mJ in a contact mode holding the lesion by its base with forceps and placing the tip parallel to the tissue base. **b** Immediately postop. **c** Two weeks f/u. **d** One year f/u. Note the quality of healing and the absence of scar tissue

Dentin Hypersensitivity

Dentin hypersensitivity (DHS) is a common condition, described as pain or unpleasant sensation upon intake of cold food or liquids, even with breathing cold air. It occurs as the cervical dentin, and the root may be exposed to external stimuli secondary to periodontal inflammation, gingival recession, iatrogenic (scaling and root planning) causes, abfraction, aggressive toothbrushing, and/or consumption of soft, erosive drinks. It is a rather uncomfortable or debilitating condition that may influence chewing, drinking, and performing oral hygiene and may also have emotional consequences. Its management includes the use of desensitizing agents for office or home use (GLUMA desensitizer, fluoride varnish, HA paste, bioglass) and desensitizing toothpastes (Sensodyne, Emoform KNO_3, Colgate Sensitive Pro-Relief).

The use of Nd:YAG for DHS has more than 20 years of research. Er:YAG was also studied with some success, but Nd:YAG remains the laser of choice for DHS [36–38].

Its mode of action has been attributed to the following:

1. Surface modification and sealing of dentinal tubules to some extent (5–25%)
2. Blocking Aβ and C nerve fibers

Note The same protocol may be used for pulpal analgesia and for alleviating hypersensitivity in teeth with molar incisor hypomineralization (MIH) both for minimizing discomfort between dental appointments and for making dental work better tolerated by the young patient [39]. Teeth with MIH, owing to their porous structure, have been shown to be in a state of continuous mild pulpal inflammation [40].

An 8-year-old patient with MIH shares his experience: "I am Triantafyllos and I am 8 years old. My teeth hurt. I could not eat anything or drink water; neither could I wash my teeth. When I drank cold water, it hurts a lot; when I drank hot water, it hurts a little less, and when I ate food, it hurts even less. When I brushed my

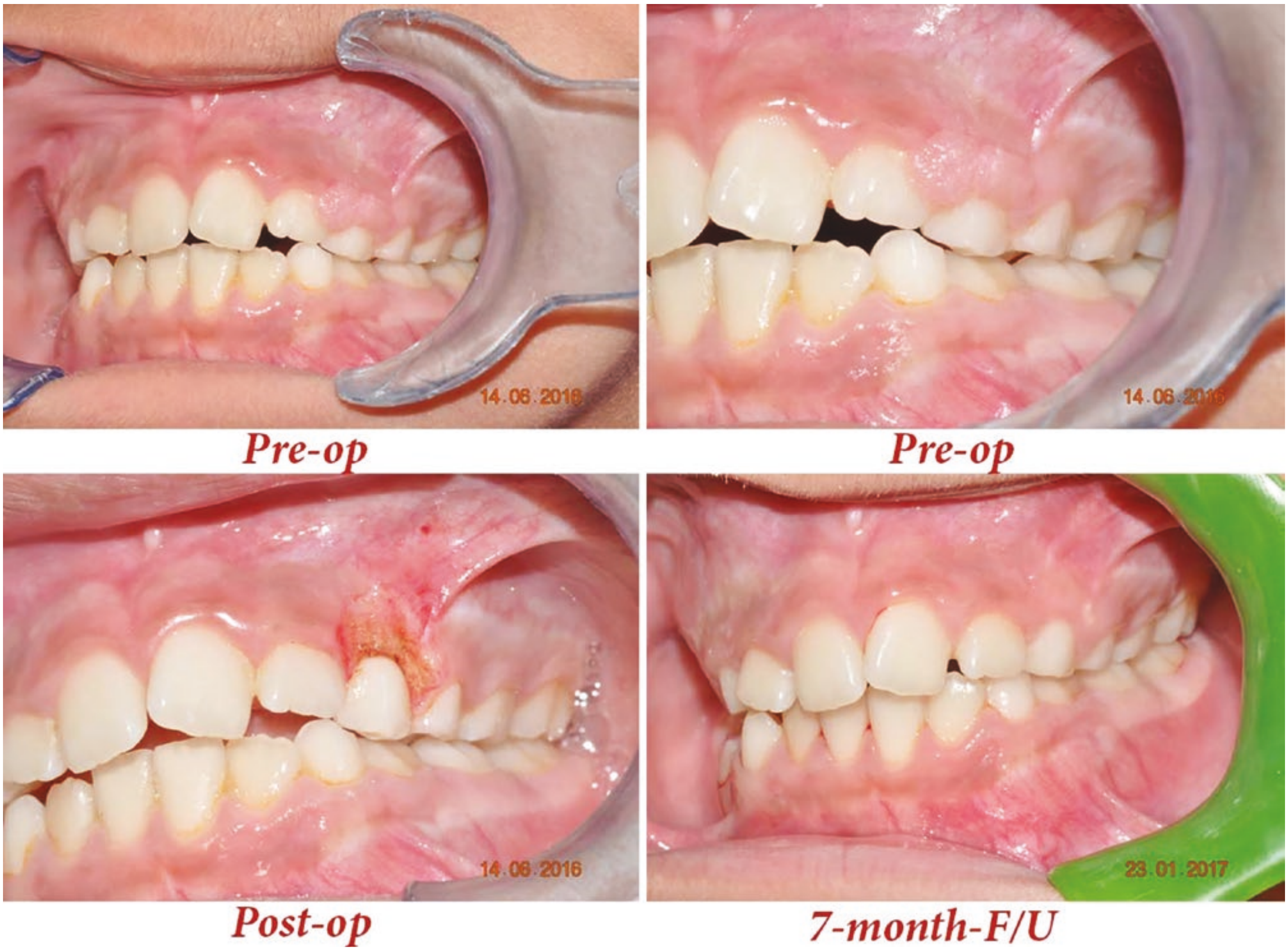


Fig. 11.23 (Published in LAHA (▶ www.laserandhealthacademy.com) 2017 as is). Oral warts: a 10-year-old girl noticed a "peculiar growth on her gums" that was growing during the last month and was not bleeding upon brushing. On intraoral examination, a 1-cm exophytic band-like lesion following the attached gingiva contour of the left upper primary canine. The lesion was of irregular surface, pedunculated on its base, and differential diagnosis consisted of oral papilloma (oral wart) and pyogenic granuloma. The lesion was removed under local anesthesia with 20-mg lidocaine and 0.11-µg epinephrine infiltration at the mucobuccal fold. The lesion was held with forceps and removed with an Nd:YAG laser (Fotona) at a setting of 4 W, 100 Hz, 40 mJ, VSP (100 µs), and 300-µm fiber from its base. Fluence was 56.6 J/cm^2; peak power was 400 W. There was no bleeding and no need for suturing, and no antibiotics or analgesics were prescribed. Healing was excellent without scarring, no pain or swelling was reported, and no recurrence was noted after 6 months F/U. The biopsy report confirmed the diagnosis of oral papilloma. Figure. Preoperative (Pre-op) and immediately postoperative (Post-op) views of the surgical site. Excellent healing at 7 months without scarring or recurrence

teeth though, I was crying because it hurts a lot when the toothbrush touched my teeth.

Dr. Dimitris did something to my teeth, and they immediately stopped hurting, and I am happy."

It is strongly discouraged to increase the power to 1.5 W or the time of application >1 min as this poses significant risk for thermal damage, microcracking, and carbonization [36].

Case A 15-year-and-8-month male complained of sensitivity only in the front lower teeth. On clinical examination, he showed calculus deposits (grade 1 scale) on upper first permanent molars and lower incisors with mild localized gingival inflammation. Air syringe test for sensitivity was negative on the upper molars but positive on all lower incisors. After running the following laser protocol, the air test was negative immediately after, and scaling was performed without any significant discomfort. The protocol used was with a pulsed Nd:YAG laser, at 100 mJ, 10 Hz, 1 W, 300-µm fiber, and 100-µs pulse duration, for 1 min in a scanning motion around the cervical area of the tooth, noncontact. It is very important to always move the fiber tip during laser emission, as there is evidence that keeping the probe still may result in irreversible damage to the pulp and ultimately necrosis. The sensitivity did not recur after 5 months follow-up. Because of the nature of such cases, the only evidence that can be provided is the patient's testimony, which is hereafter quoted in exact

Fig. 11.24 **a** Seventeen-year-old girl presented with an exophytic lesion on the soft palate mucosa. The lesion was pedunculated and whitish, and the clinical impression was oral wart. **b** The lesion was removed under local anesthesia and an Nd:YAG laser at 3.5 W, 100 Hz, 300 µm fiber, and 100 µs pulse duration from its base. No minor salivary gland was detected at the vicinity of the lesion, and the specimen was sent for histopathologic diagnosis, which confirmed the viral origin of the lesion. Postoperative instructions included rinses with mild antiseptic solutions, such as chamomile and Unisept (activated oxygen-based solution). **c** Healing after 9 days

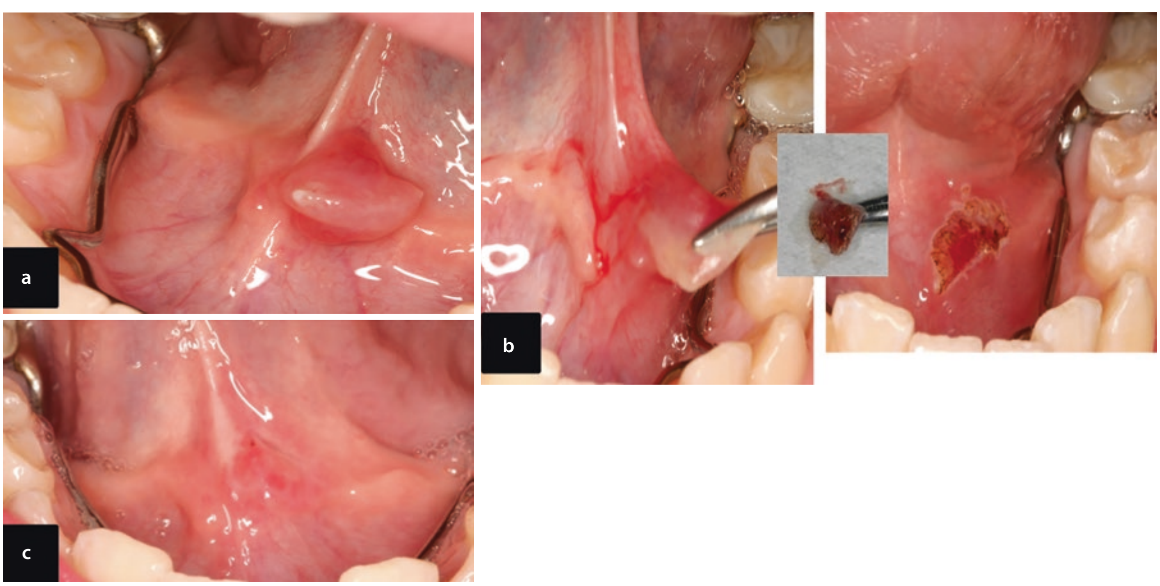


Fig. 11.25 Traumatic fibroma attached to the left sublingual duct removal, 11-year-old boy. **a** Initial intraoral view. **b** Surgical excision using a CO_2 laser [3 W, continuous mode, 200-µm spot area at focus, speed of movement 1.5 mm/s, cooling with water every 10 s for 5 s, and charring removal with gauze]. Extra caution to avoid traumatizing the duct or causing postsurgical edema, which may result in blocking the sublingual duct. No carbonization and no bleeding can be observed. Thus, suturing can be avoided, which is an advantage, since sutures on this area may, too, block the duct. **c** Follow-up after 1 week. Uneventful healing and free sublingual duct

Fig. 11.26 Marsupialization of two mucoceles on the mucosa of the vestibular region of the left lip, 12-year-old boy. **a** Initial situation. Traumatic injury due to orthodontic brackets resulting in superficial blocking of the salivary glands (normal texture under palpation). Major concerns which exclude surgical excision: (a) the number of mucoceles [extended surgical area], (b) the use of sutures [can cause blocking on the surrounding small saliva glands], (c) an excessive postsurgical edema [may increase the traumatic effect of the brackets and result in relapse]. **b** Marsupialization of the two saliva submucosal cysts using the CO_2 laser 10,600 nm with minimal surgical trauma [2 W, CW, speed of movement 1.5 mm/s, at focus, 200 μm, total working time 1 min]. **c** Follow-up after 1 week. Uneventful healing and normal function of the small salivary glands

translation. "For a long period of time, I had big difficulty drinking cold beverages, because of my tooth sensitivity. However, with the use of lasers, Dr. Velonis made that sensitivity a distant memory" (*EM, 15-year-old*).

Dry Socket

In cases where a dry socket develops after a difficult tooth extraction, the Er:YAG can offer immediate relief from the pain by removing the necrotic tissue from the socket. The settings used are similar to those of dentin removal, i.e., 150–200 mJ, 10–15 Hz, and 100-μs pulse duration, with water irrigation and a contact handpiece. It does not need local anesthesia. Light bleeding occurring after removal of the necrotic tissue is beneficial for the healing process. Usually, a single application is adequate to manage a dry socket.

Incision and Drainage of Abscess and Fistula

Drainage of an abscess of dental/periodontal origin can be performed by a laser with minimal topical or local anesthesia and minimally invasive access.

With an Er:YAG laser, the opening can be performed with 80–120 mJ, 10–15 Hz, and 50–1000-μs pulse duration. If the abscess is under the periosteum, adequate local anesthesia is required, and the Er:YAG is the laser of choice to proceed with 150–200 mJ, 10–20 Hz, and 100-μs pulse duration with a contact or noncontact handpiece.

When using near-infrared laser, local anesthesia is required. With an Nd:YAG, laser settings range from 4 to 5 W, 70 to 100 Hz, and 100 μs to 300 μm fiber. With a diode 810/980-nm laser, use 4–6-W in continuous wave.

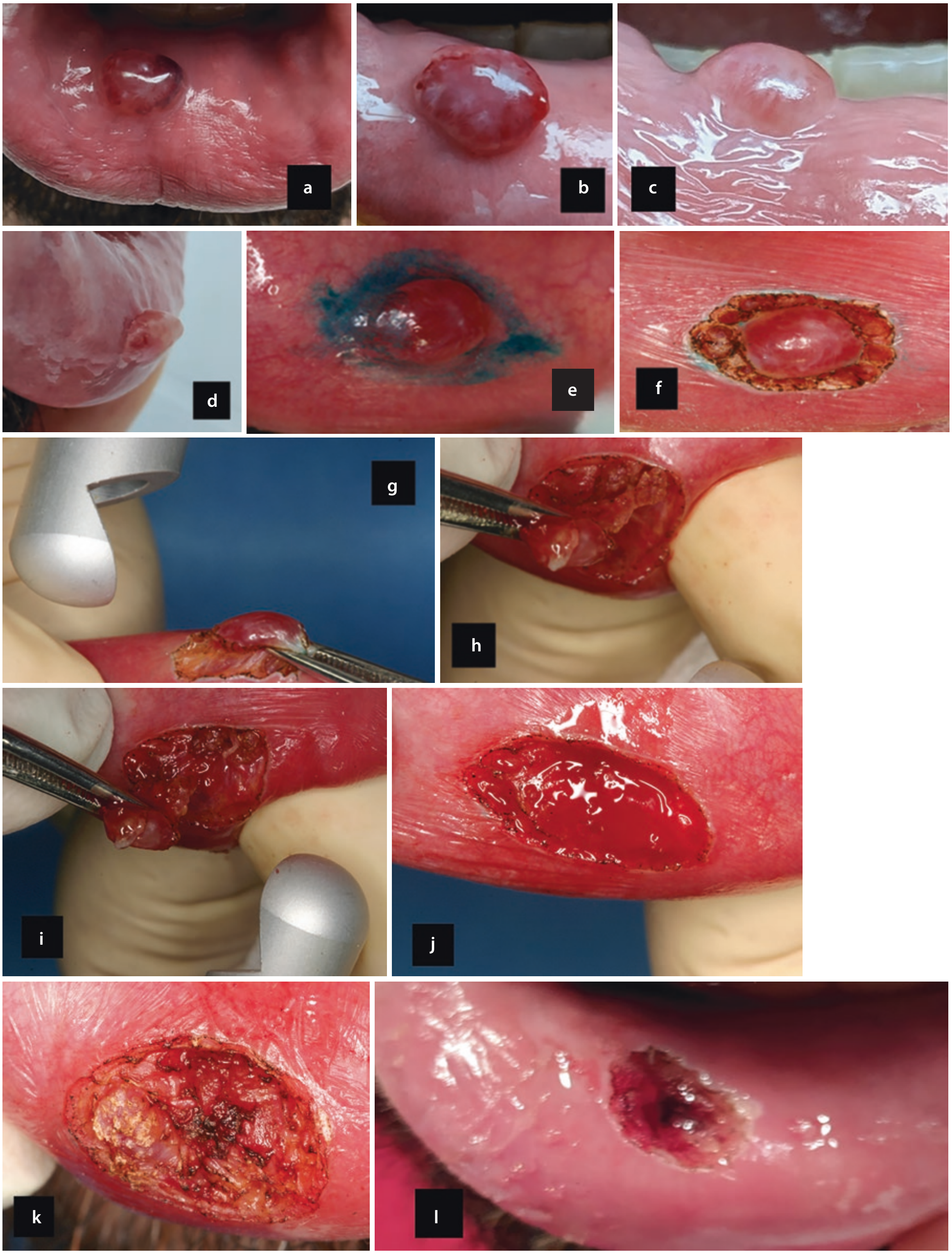


Fig. 11.27 Excision of one traumatic medium-size mucocele located superficially on the oral mucosa of the lower lip, 16-year-old boy. **a**–**d** Intraoral view. **e** Drawing the line of the incision. **f**–**j** Step-by-step surgical procedure: laser excision using a CO_2 laser 10,600 nm [2 W, CW, 200-μm spot area at focus, speed of movement 1.5 mm/s, total irradiation time 4 min], avoiding the direct irradiation of the mucocele. Every 20 s of irradiation, 40 s water cooling. **k** Coagulation for bleeding control using the CO_2 laser [same as above only on bleeding spots] and immediate postop view. **l**–**t** Day-by-day healing up to 3 months: 12 h **l**, 24 h **m**, 2 days **n**, 5 days **o**, 7 days **p**, 10 days **q**, 2 weeks **r**, 3 weeks **s**, and 3 months **t**. No scar formation

Fig. 11.27 (continued)

Table 11.4 Protocols of aphthous ulcer treatment

	Nd:YAG laser	Diode 810/940	Er:YAG, Er,Cr:YSGG
Power	2 W	Power: 1–2 W	Power: 0.45–0.75 W
Pulse E	100 mJ	CW (continuous wave)	30–50 mJ—no H_2O
Pulse frequency	20 Hz		15 Hz
Pulse duration	100 µs		
Fiber diameter	300 µm	Fiber diameter: 300 µm	Mirror or sapphire tip 0.8–1 mm
Mode	8–12 mm defocused	8–12 mm defocused	8–12 mm defocused
Movement	30 s/cm^2	30 s/cm^2	2–3×, white superficial layer

Fig. 11.28 Nd:YAG, before **a** and 1 day F/U **b**. Note beginning of fibrin formation to heal the ulceration

Fig. 11.29 Seven-year-old girl collided with schoolmate and sustained only a soft tissue injury. She was asked to not take any anti-inflammatories, or other topical ailments, to see the effect of photobiomodulation (PBM) treatment over the course of 3 days. A pulsed Nd:YAG laser was used with a fiber of 6-mm-diameter (R24 handpiece and fiber, Fotona). The settings were 75 mJ, 20 Hz, and 100-µs pulse duration. Average power was 1.5 W and peak power was 750 W, but energy density (fluence) was 0.27 J/cm^2 because of the large spot size of 6 mm. **a** Day 0, **b** day 1, **c** day 3

Fig. 11.30 **a**, **b** Five-year-old sustained intraoral lacerations at the swimming pool. Settings for aphthous ulcers were used, high-intensity laser treatment (HILT) to accelerate wound healing with a pulsed Nd:YAG laser, at 2 W, 20 Hz, with a 300-μm fiber, following the aphthous ulcer protocol described earlier in this chapter. Note the healing of the lacerations after 4 days

Table 11.5 Summary of laser advantages

Soft tissue trauma using proper technique with a dental laser has several advantages
• Immediate relief of symptoms
• Improves quality of life (pain, feeding, speech)
• Accelerates wound healing mechanisms
• Fast and simple
• No use of local or systemic medications
• Can be done with a number of less expensive diode lasers

11.6.3 Oral Infection Management

Herpetic Gingivostomatitis

Primary herpetic gingivostomatitis (PHGS) is caused primarily by HSV I and II, Herpesviridae that can cause latent or lytic infections. The first encounter with the virus usually occurs between ages 5 months and 6 years. It is common in children and 95% is caused by HSV 1 and 5% by HSV 2. While 90% of infections can have a subclinical course, 10% exhibit a symptomatic infection with 7–14-day duration and of varying severity.

The clinical characteristics are intense gingival erythema and bleeding; oral vesicles, which rupture leaving painful ulcers; and lip fissuring. Common locations are the gingivae, tongue, palate, lips, buccal mucosa, and floor of the mouth. General symptoms include fever (38–40 °C), lymphadenopathy, malaise, headache, weakness, oral malodor, anorexia, irritability, and difficulty eating and swallowing even liquids. As the lesions may start near the stomato-pharynx, it is often mistaken for pharyngitis or tonsillitis and often is mistreated with antibiotics and antifungals. As it is contagious, caution must be taken to avoid autoinoculation to the eye, cornea, and hand. Inoculation in the eye can be very painful and may lead to permanent ocular damage. Other conditions that may be included in the differential diagnosis are herpetiform ulcerations and aphthous ulcers, herpangina, hand-foot-mouth disease, ANUG, erythema multiforme, Stevens-Johnsons, and infectious mononucleosis.

Treatment is usually palliative, symptomatic, and supportive with fluids, anti-fever, and anti-inflammatory medication (paracetamol, ibuprofen). For the lesions, numerous topical agents have been used: dyclonine HCl rinse, viscous lidocaine, Mundisal, methylene blue (ink), Pyralvex, Tantum Verde (benzydamine HCl), with varying success. Antivirals per os are also used: aciclovir, 200 mg 4–6×/day, children 200 mg 4×/day until resolution, rinse and swallow, effective in the prodromal phase. Other antivirals, such as valaciclovir, femciclovir, penciclovir, and ganciclovir, are also being prescribed (Figs. 11.31 and 11.32).

After the initial infection, the virus enters a latency phase in 70–90% of cases in Gasser's ganglion to reemerge as herpes labialis ("cold sore" or "fever blister").

An alternate management/treatment of PHGS can be done with a laser. With an Nd:YAG laser (Table 11.6), the parameters and settings are shown.

Mode of Action Early in vitro studies have indicated that the laser energy may activate leukocytes to inactivate the

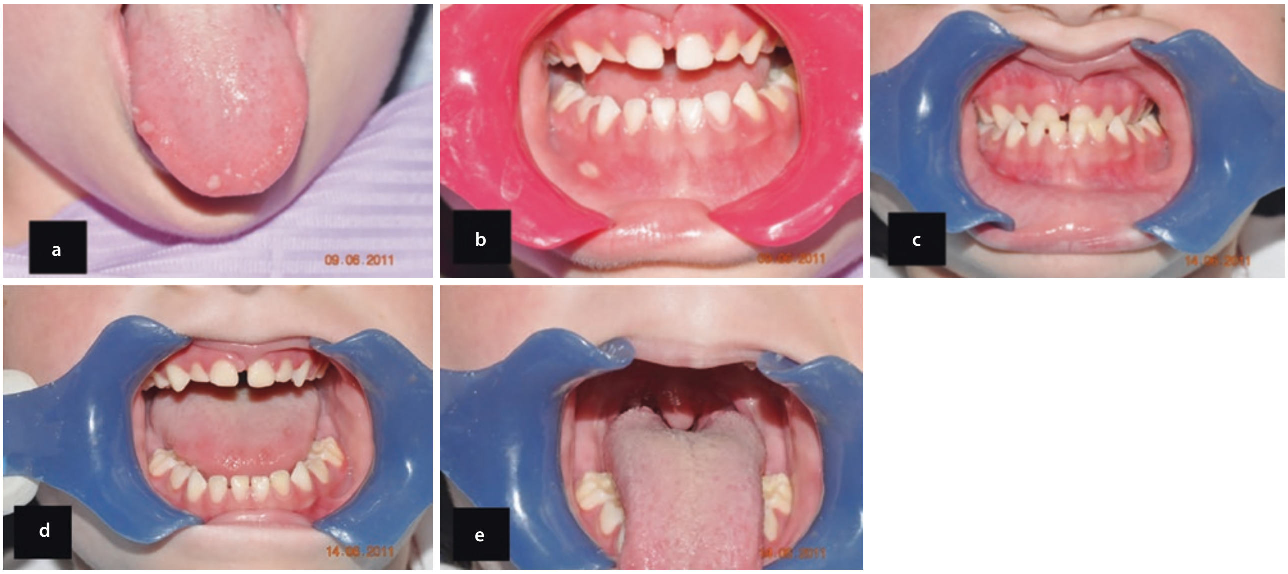


Fig. 11.31 Case #1. Four-year-and-2-month-old female presented to my private practice on September 6, 2011, with her mother. Chief complaint (CC) and HCC: her mouth and gums hurt for 2 days; she has fever 38.5 °C and does not want to eat or drink or brush her teeth. Her gums bleed easily and there is halitosis. Patient was referred from her pediatrician who had prescribed topical antifungals and antibiotics, which she did not yet take. PMHx and PDHx: no significant medical history. Diagnosis: clinically (not microbiologically or serologically) documented primary herpetic gingivostomatitis with appearance of painful vesicles and bullae that ulcerate in the labial mucosa, dorsum of the tongue, and swelling and bleeding of the gums. Mother had recently had an episode of recurrent herpes labialis. Treatment plan: laser (Nd: YAG) irradiation of oral lesions. No use of antibiotics or antifungals or antivirals. **a**, **b** Day 3 of primary herpetic gingivostomatitis, initial exam. **c**, **d** Day 8 of primary herpetic gingivostomatitis, 5 days post-laser irradiation. **e** Day 8 of primary herpetic gingivostomatitis, 5 days post-laser irradiation—only mild difficulty swallowing secondary to lesion in the palatal pillar which was not seen at the first visit. Irradiated this lesion at this appointment, and the patient felt immediate relief

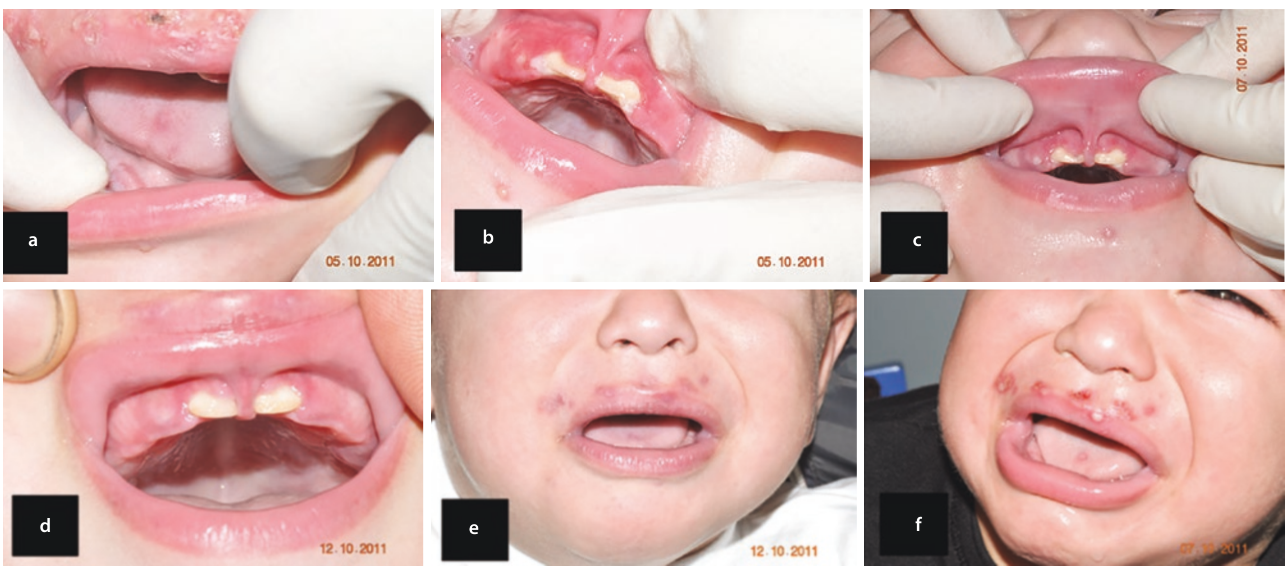


Fig. 11.32 Case #2. Primary herpetic gingivostomatitis treatment with Nd:YAG laser (DEKA). **a**, **b** Seven-month-old male presented on ca. Day 9 of infection. He does not drink water or milk and cries most of the time; parents and child do not sleep well; still fever >38 °C and was prescribed Daktarin gel. May 10, 2011: first laser treatment. Pre-cooperative (Frankl 1). Peak power 1500 W. **c**, **d** July 10, 2011: second laser treatment for few new blisters. Improving, parents reporting that he finally smiled on the night of the first treatment and slept well and started talking again. Difficult with water on that same day but drank water the next day. **e**, **f** December 10, 2011, F/U

Table 11.6 Laser (Nd:YAG 1064 nm) parameters for herpetic gingivostomatitis

Laser parameters for herpetic gingivostomatitis
• Operational mode: pulsed Nd:YAG
• Repetition rate: 20 Hz
• Pulse energy: 150 mJ
• Average power: 3.00 W
• Pulse duration: 100–350 μs
• Fiber diameter: 300 μm–6 mm
• Treatment duration: 30 s/cm^2
• Mode: noncontact, defocused at 8–10-mm distance

Table 11.7 Advantages of laser-assisted treatment of herpetic gingivostomatitis

Advantages of herpetic gingivostomatitis treatment using proper technique with a dental laser
• No medication use
• Immediate relief from pain
• Immediate resuming of eating and drinking
• Afebrile since day 1 of treatment
• Fast healing of lesions, no full-blown development
• Avoidance of dehydration and possible hospitalization
• Fast, painless, acceptable treatment
• Parents do not lose their sleep, family, and work benefits

virus [41]. Further studies have shown that epithelial cells are able to respond to HSV-1 presence inducing the expression of IL-6, IL-1, TNF-α, and IL-8, important in the acute-phase response mediation, chemotaxis, inflammatory cell activation, and antigen-presenting cells [42]. It has been hypothesized that laser irradiation acts in two ways, (a) in the final stage of HSV-1 replication by limiting viral spread from cell to cell and (b) on the host immune response unblocking the suppression of proinflammatory mediators induced by accumulation of progeny virus in infected epithelial cells (Table 11.7).

11.7 Pulp Treatment in Primary Teeth

Pulp treatment in primary teeth is usually required due to deep dentine caries or dental trauma. Indirect pulp capping, direct pulp capping, and pulpotomy are the treatment options for vital teeth, while pulpectomy is the recommended treatment for necrotic or irreversible pulpitis in primary teeth. The treatment choice is based on well-known clinical and radiographic criteria: history of pain and signs or symptoms of pulp degeneration are indications of necrotic pulp or irreversible pulpitis [43]. The use of the erbium family laser is beneficial for cavity preparation, especially in cases of teeth with deep dentin caries, due to (a) the selective and minimal tooth structure removal aiming to avoid unnecessary mechanical pulp exposure and (b) the facility of dentine decontamination and smear layer removal (see Tables 11.1 and 11.2 for energy parameters). In many cases, no local anesthesia is required when erbium family lasers are used. In addition, for all the above reasons, when interim therapeutic restorations (ITR) [44] is the choice of contemporary treatment in order to prevent the progression of dental caries on uncooperative patients, the use of lasers could be beneficial.

11.7.1 Indirect Pulp Capping

The goal of the technique is to preserve the integrity of the vital pulp and also activate the repairing mechanism for the formation of tertiary dentine. All decayed enamel and dentine except the decayed dental tissue located next to the pulp have to be removed. The pulpal wall is covered with a biocompatible protective base (usually mineral trioxide aggregate (MTA) or Portland cement (PC) or Biodentine or calcium hydroxide or glass ionomer), and the final restoration follows (glass ionomer restorative material or resin-modified glass ionomer or composite resin or preformed crowns). It has the same indications to pulpotomy on primary teeth [45], presenting success rates up to 83–100% using the traditional preparation techniques [46, 47], but there is no clinical study involving the use of laser at the indirect pulp capping on primary teeth. However, it is speculated that the laser-assisted technique (erbium family or/and near-infrared laser wavelengths) could be more predictable and successful due to decontamination of the cavity, the remaining carious dentine, and the positive effect on pulpal tissue healing and recovery [48]. See ◘ Tables 11.1 and 11.2 for laser wavelength parameters for deep dentine removal (erbium family) and decontamination.

11.7.2 Direct Pulp Capping

When the vital pulp is exposed because of mechanical caries removal or trauma, direct pulp capping could be performed. However, direct pulp capping is not recommended for primary teeth [43]. The success rate of the traditional techniques is 70–80%, using MTA or PC or Biodentine or calcium hydroxide as pulp dressing material, while usually there are acute edema and pain after 7–15 days in case of failure [33]. Therefore, there is a general recommendation to avoid direct pulp capping in primary teeth and perform pulpotomy, in case of any size of pulp exposure [43, 49]. Successful laser-assisted direct pulp capping cases have been reported [48], but there is no clinical study involving the use of any laser wavelength in such a treatment on primary teeth. Following cavity preparation using a diamond bur or a laser from the erbium family, the laser-assisted technique (erbium family, diode, Nd:YAG, CO_2) is introducing pulp tissue coagulation (erbium family: 50 mJ, 10 Hz, no water, 40% air, defocus for 5–10 s) along with decontamination before the placement of pulp dressing [48]. After laser-assisted direct pulp capping, it is expected that better pulpal healing occurs than with the transitional technique; the pulp will retain its vitality and perform the formation of tertiary dentine. See ◘ Tables 11.1 and 11.2 for laser wavelength parameters for decontamination.

11.7.3 Pulpotomy

The traditional technique of pulpotomy has clinical success rates up to 98–100% (MTA/PC/Biodentine or ferric sulfate (FS)) and is the most common technique performed after pulp exposure on vital primary teeth with deep carious dentine lesions. The technique involves the removal (amputation) of the coronal pulp tissue with burs and spoon excavator, achievement of hemostasis using sterile cotton pellets, and placement of MTA/PC/Biodentine or FS over the pulp stumps [43]. When the bleeding from the pulp stumps could not be controlled, it is an indication of irreversible pulpitis beside the absence of clinical and radiographical symptoms, and pulpectomy is indicated. Formocresol had been used for several years (before the wide use of FS) with great success, but its use is not currently recommended due to possible carcinogenic effect. The MTA/PC/Biodentine is covered by glass ionomer, while in the case of FS, a fast-setting zinc oxide and eugenol paste (IRM) is placed over the pulp stumps before the placement of the final restoration. FS forms a ferric ion and protein complex on contact with blood, providing a bridge between the vital root canal pulp tissues, and the paste contains eugenol (IRM), while the biocompatible and also bioinductive MTA/PC/Biodentine has to be in contact to the pulp tissue.

Alternatively, instead of using medicaments like FS, laser (erbium family, diode, Nd:YAG, CO_2) could be used for the pulp tissue coagulation over the pulp stumps before the placement of IRM (◘ Fig. 11.33a–g). Clinical studies show that either there is no significant difference in success rate (clinical or radiographically) between laser-assisted and traditional pulpotomy or the result is in favor for the laser-assisted method [50–57]. After coronal pulp was removed with burs and spoon excavator and hemorrhage was controlled, a type of laser [diode (five studies), Er:YAG (one study), Nd:YAG (three studies), CO_2 (one study)], using a variation in laser application parameters (power, frequency, exposure time) and capping materials (MTA, zinc oxide eugenol, IRM) report success rate of *laser-assisted pulpotomy* (follow-up period from 1 to 66 months) ranged from 71.4% to 100% clinically and 71.4% to 100% radiographically. The amputation through vaporization of the coronal pulp tissue using lasers (erbium family, diode, Nd:YAG, CO_2) is not recommended because they create coagulation and necrotic tissue which may camouflage possible inflammation or necrosis of the root canal pulp. See ◘ Tables 11.1 and 11.2 for laser wavelength parameters for decontamination (erbium family).

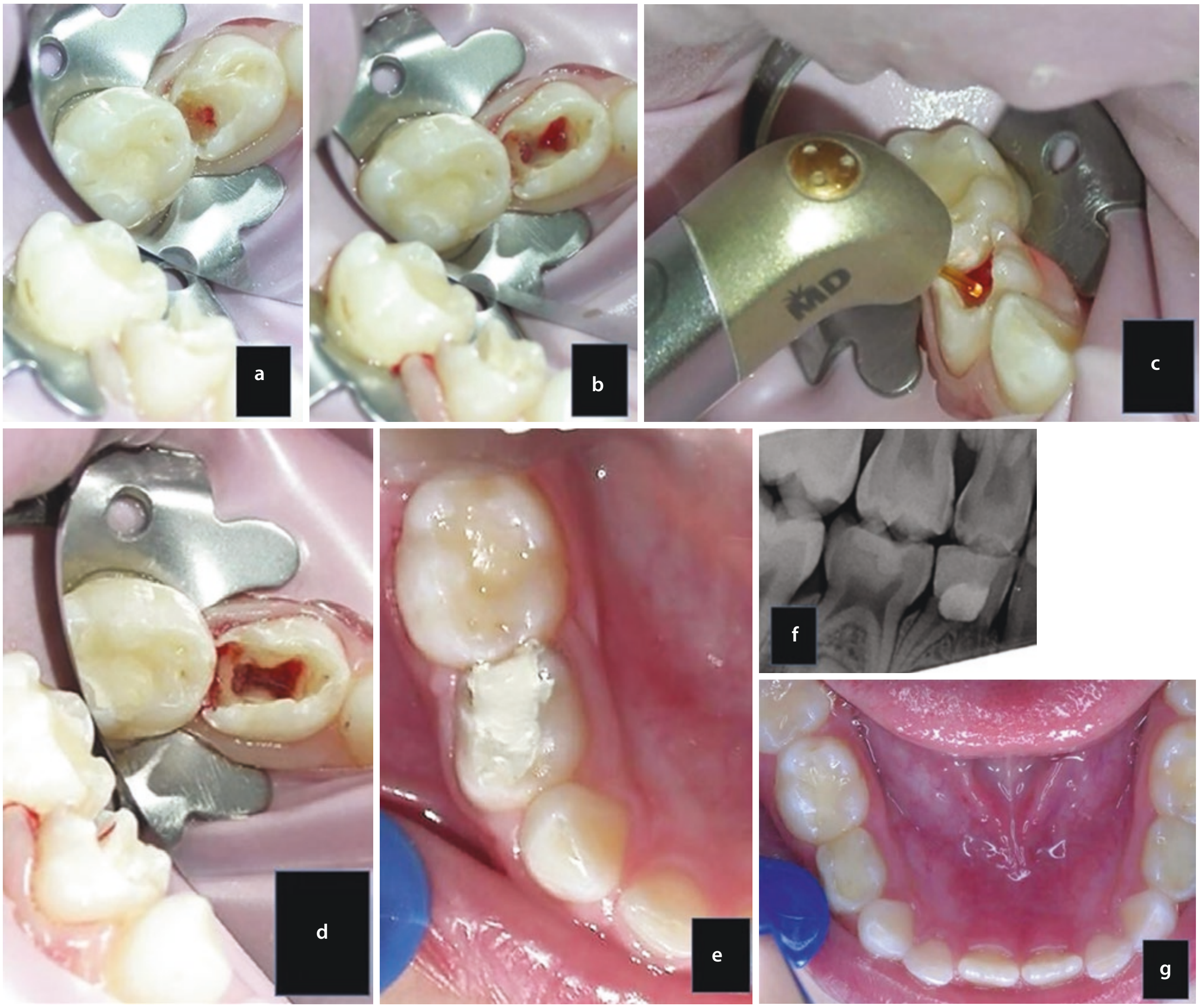
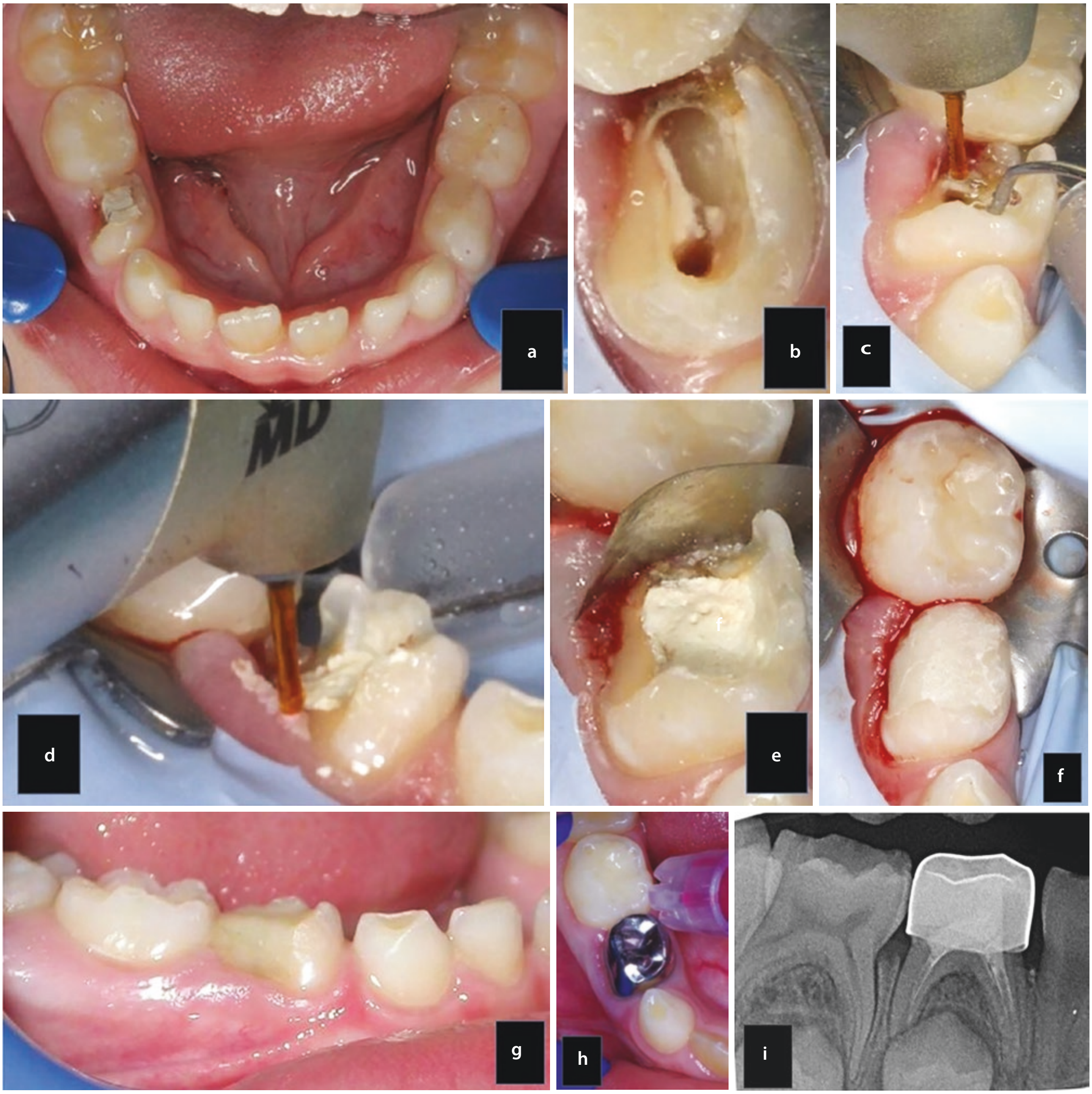


Fig. 11.33 Laser-assisted pulpotomy on a first primary molar of a 5.5-year-old girl. Block anesthesia (4% articaine, 1:200,000 epinephrine) and placement of rubber dam. **a** Pulp exposure during caries removal. **b** Removal of the coronal pulp tissue (diamond bur and spoon excavator). Hemorrhage was controlled. **c** Er,Cr:YSGG (2780 nm) was applied at 50 mJ, 10 Hz, (0.5 W), no water, 40% air, defocus for 5–10 s (gold handpiece, 0.6-mm MZ tip, S tissue mode) over the canal orifices **d**. Complete coagulation after laser application. **e** The cavity was filled up with IRM (fast-setting zinc oxide eugenol paste). Clinical view after 15 days. The placement of RMGI restoration was followed. **f**, **g** Radiographic and clinical pictures 16 months after treatment

11

11.7.4 Pulpectomy

It is the endodontic treatment for primary teeth and is indicated for teeth without or minimal pathological (internal or external) root resorption due to irreversible pulpitis or necrotic pulp. The traditional technique involves removing of all coronal and root pulp tissue, limited mechanical instrumentation, root canal disinfection using the appropriate irrigants, and filling the root canals with resorbable material (pure zinc oxide eugenol paste or iodoform-calcium hydroxide paste). Several protocols have been developed using lasers (erbium family, diode, Nd:YAG,) with great results for better decontamination of the main and the lateral canals on permanent teeth [58–62] (see ► Chap. 9). These same protocols for permanent teeth, using the same parameters, are also recommended for primary teeth, but there are only four studies (one in vivo, one in vitro, and two case reports) for deciduous teeth, all using photodynamic therapy, leading to satisfactory results [63–66]. In addition to the traditional technique, a laser-assisted disinfection method could be performed before the final conclusion of the endodontic treatment (Fig. 11.34a–i). Laser-assisted disinfec-



■ **Fig. 11.34** Laser-assisted pulpectomy and gingivoplasty on a first primary molar of a 6.5-year-old boy. Endodontic therapy of #84 due abscess. The patient returned 10 days after the initiation of treatment with a subgingival crown fracture. **a** Intraoral view of lower teeth. **b** Block anesthesia (4% articaine, 1:200,000 epinephrine) and placement of rubber dam. Occlusal view of #84. **c** Laser-activated irrigation (Er,Cr:YSGG 2780 nm) was applied at 33 mJ, 30 Hz, (1.0 W), no water, no air, tip inside the tooth chamber, saline solution for 5 s each root canal (gold handpiece, 0.6-mm MZ tip, H tissue mode). **d** Obstruction of the root canals with pure zinc oxide and eugenol paste and filling the tooth chamber with fast-setting zinc oxide and eugenol paste (IRM). Gingivoplasty (see laser energy parameters on ■ Fig. 11.3b) and cavity preparation followed (see ■ Table 11.2 for energy parameters). **e** After gingivoplasty and cavity preparation and decontamination. **f** Final restoration with RMGI. **g** Pulpectomy and restoration after 3 months. SSC was placed on #84 at that visit. **h**, **i** Periapical radiograph and clinical views 16 months after treatment

tion could have better results on primary teeth where there are more complex, with variable morphology, root canals making instrumentation and disinfection complicated. Irrigation with sodium hypochlorite should be avoided, especially when the laser-activated irrigation protocol is used, because if extruded from the open or resorbed root apex it could be irritant to the surrounding tissues.

11.8 Conclusion

All dental laser wavelengths (KTP, diode, Nd:YAG, erbium family, CO_2) could be used as alternative and/or complementary treatment methods of soft and hard tissue management for the pediatric dentistry patients. The main advantages of laser use in pediatric dentistry are (a) patient and parent's acceptance, (b) the administration of no or less local anesthesia, (c) the absence of vibration during cavity preparation, (d) the selectivity of dental caries, (e) the decontamination effect, and (f) making it easier for the dentist to perform several procedures in the same appointment. In addition to these advantages, the use of lasers can often offer an alternative strategy in children's behavior management along with the appropriate child's psychological management. Laser treatment can be used to introduce dentistry, gain the trust of the child, and perform needle-free and also no painful procedures using laser analgesia, especially for children who refused traditional dental treatment. However, children who do not finally cooperate or the mental status does not allow them to comply cannot be candidates for laser therapy.

Laser-assisted treatment in pediatric dentistry includes, among others, the removal of the infected dental tissue, the cavity preparation, and, depending on the case severity, the indirect or direct pulp capping, pulpotomy, and pulpectomy, followed by tooth restoration. Several studies conclude that laser abrasion is a safe, useful, and highly accepted by patients as an alternative method for caries removal and cavity preparation on primary teeth (erbium family). All dental restorative materials (composite resin, compomers, resin-modified class ionomer, glass ionomer) could be placed after laser cavity preparation on primary teeth revealing high success. Laser-assisted indirect and direct pulp capping techniques for primary teeth (erbium family or/and near-infrared laser wavelengths) could be more predictable and successful, than the transitional techniques, due to decontamination of the cavity, the remaining dentine, and the positive effect on pulpal tissue healing and recovery in order to form tertiary dentine. Instead of using medicaments (like ferric sulfate) during primary teeth pulpotomy, laser (erbium family, diode, Nd:YAG, CO_2) could be used, with great clinical and radiographical success, for the pulp tissue coagulation over the pulp stumps before the placement of the fast-setting zinc oxide and eugenol paste (IRM).

Laser-assisted disinfection, before the final root canal obstruction, could have better results on primary teeth pulpectomy where there are more complex, with variable morphology, root canals making instrumentation and disinfection complicated.

11

References

1. Koch G, Poulsen S. Pediatric dentistry. A clinical approach. 1st ed. Copenhagen: Munksgaard; 2001.
2. AAPD Oral health Policies. Policy on the use of lasers for pediatric dental patients. http://www.aapd.org/research/oral-health-policies--recommendations/.
3. AAPD Clinical Practice Guidelines on guideline on behavior guidance for the pediatric dental patient. http://www.aapd.org/policies/quidelines.
4. Poli R, Parker S. Achieving dental analgesia with the Erbium Chromium Yttrium Scandium Gallium Garnet laser (2780 nm): a protocol for painless conservative treatment. Photomed Laser Surg. 2015;33(7):364–71.
5. Olivi G, Magnolis FS, Genovese MD. Treatment considerations, Chapter 4. In: Pediatric laser dentistry. A user's guide. Quintessence Publishing Co, Inc; 2011.
6. Katsouda M, Tollili C, Coolidge T, Simos G, Kotsanos N, Arapostathis KN. Gagging prevalence and its association with dental fear in 4–12-year-old children in a dental setting. Int J Paediatr Dent. 2018;29:169. https://doi.org/10.1111/ipd.12445.
7. Katsouda M, Coolidge T, Simos G, Kotsanos N, Arapostathis KN. Gagging and cooperation in 4–12-year-old children over a series of dental appointments. Eur Arch Paediatr Dent. 2021;22(5):937–46. https://doi.org/10.1007/s40368-021--00654-x.
8. Moritz A. Oral laser application. Berlin: Quintessenz Verlags-GmbH; 2006.
9. Fisher JC. Photons, physiatrics, and physicians: a practical guide to understanding interaction of laser light with living tissue: Part II: Basic mechanisms of tissue destruction by laser beams. J Clin Laser Med Surg. 1993;11(6):291–303.
10. Vitale MC, Caprioglio C. Lasers in dentistry. Practical text book. Edizioni Martina s.r.l; 2010.
11. Kato J, Moriya K, Jayawardena JA. Clinical application of Er:YAG laser for cavity preparation in children. J Clin Laser Med Surg. 2003;21(3):151–5.
12. Genovese MD, Olivi G. Laser in paediatric dentistry: patient acceptance of hard and soft tissue therapy. Eur J Peadiatr Dent. 2008;9:13–7.
13. Jacobsen T, Norlund A, Sandborgh Englund G, Tranaeus S. Application of laser technology for removal of caries: a systematic review of controlled clinical trials. Acta Odontol Scand. 2011;69:65–74.
14. Martens LC. Laser physics and a review of laser applications in dentistry for children. Eur Arch Paediatr Dent. 2011;12(2):61–7.
15. Bahrololoomi Z, Kabudan M, Gholami L. Effect of Er:YAG laser on shear bond strength of composite to enamel and dentin of primary teeth. J Dent. 2015;12(3):163–70.
16. Monghini EM, Wanderley RL, Pecora JD, Palma-Dibb RG, Corona SAM, Borsatto MC. Shear bond strength to dentine of primary teeth irradiated with varying Er:YAG laser energies and SEM examination of the surface morphology. Lasers Surg Med. 2004;24:254–9.
17. Wanderley RL, Monghini EM, Pecora JD, Palma-Dibb RG, Borsatto MC. Shear bond strength to enamel of primary teeth irradiated with varying Er:YAG laser energies and SEM examination of the surface morphology: an in vitro study. Photomed Laser Surg. 2005;23(3):260–7.
18. Lessa FC, Mantovani CP, Barroso JM, Chinelatti MA, Palma-Dibb RG, Pécora JD, Borsatto MC. Shear bond strength to

primary enamel: influence of Er:YAG laser irradiation distance. J Dent Child (Chic). 2007;74(1):26–9.
19. Scatena C, Torres CP, Gomes-Silva JM, Contente MM, Pécora JD, Palma-Dibb RG, Borsatto MC. Shear strength of the bond to primary dentin: influence of Er:YAG laser irradiation distance. Lasers Med Sci. 2011;26(3):293–7.
20. Flury S, Koch T, Peutzfeldt A, Lussi A. Micromorphology and adhesive performance of Er:YAG laser-treated dentin of primary teeth. Lasers Med Sci. 2012;27(3):529–35.
21. Stiesch-Scholz M, Hannig M. In vitro study of enamel and dentin marginal integrity of composite and compomer restorations placed in primary teeth after diamond or Er:YAG laser cavity preparation. J Adhes Dent. 2000;2(3):213–22.
22. Hossain M, Nakamura Y, Yamada Y, Murakami Y, Matsumoto K. Microleakage of composite resin restoration in cavities prepared by Er,Cr:YSGG laser irradiation and etched bur cavities in primary teeth. J Clin Pediatr Dent. 2002;26(3):263–8.
23. Yamada Y, Hossain M, Nakamura Y, Murakami Y, Matsumoto K. Microleakage of composite resin restoration in cavities prepared by Er:YAG laser irradiation in primary teeth. Eur J Paediatr Dent. 2002;3(1):39–45.
24. Kohara EK, Hossain M, Kimura Y, Matsumoto K, Inoue M, Sasa R. Morphological and microleakage studies of the cavities prepared by Er:YAG laser irradiation in primary teeth. J Clin Laser Med Surg. 2002;20(3):141–7.
25. Borsatto MC, Corona SA, Chinelatti MA, Ramos RP, de Sá Rocha RA, Pecora JD, Palma-Dibb RG. Comparison of marginal microleakage of flowable composite restorations in primary molars prepared by high-speed carbide bur, Er:YAG laser, and air abrasion. J Dent Child (Chic). 2006;73(2):122–6.
26. Baygin O, Korkmaz FM, Arslan I. Effects of different types of adhesive systems on the microleakage of compomer restorations in Class V cavities prepared by Er,Cr:YSGG laser in primary teeth. Dent Mater J. 2012;31(2):206–14.
27. Ghandehari M, Mighani G, Shahabi S, Chiniforush N, Shirmohammadi Z. Comparison of microleakage of glass ionomer restoration in primary teeth prepared by Er:YAG laser and the conventional method. J Dent. 2012;9(3):215–20.
28. Baghalian A, Nakhjavani YB, Hooshmand T, Motahhary P, Bahramian H. Microleakage of Er:YAG laser and dental bur prepared cavities in primary teeth restored with different adhesive restorative materials. Lasers Med Sci. 2013;28:1453–60.
29. Bahrololoomi Z, Heydari E. Assessment of tooth preparation via Er:YAG laser and bur on microleakage of dentine adhesives. J Dent. 2014;11(2):172–8.
30. Arapostathis KN. An in vitro study comparing cavity preparation by Er:YAG, Er,Cr:YSGG lasers and diamond bur on primary molars: effect on microleakage of three different restorative materials and scanning electron microscopy examination of the cavity preparation. Thesis of Master of Science in Lasers Dentistry, Genoa, Italy; 2014.
31. Mirko P, Miroslav S, Lubor M. Significance of the labial frenum attachment in periodontal disease in man. Part 1. Classification and epidemiology of the labial frenum attachment. J Periodontol. 1974;45(12):891–4.
32. Walsh J, Links A, Boss E, Tunkel D. Ankyloglossia and lingual frenotomy: national trends in inpatient diagnosis and management in the United States, 1997–2012. Otolaryngol Head Neck Surg. 2017;156(4):735–40.
33. Hazelbaker AK. The assessment tool for lingual frenulum function (ATLFF): use in a lactation consultant private practice. California, Pacific Oaks College: Pasadena; 1993.
34. Ingram J, Johnson D, Copeland M, et al. The development of a tongue assessment tool to assist with tongue-tie identification. Arch Dis Child Fetal Neonatal Ed. 2015;100:F344–8.
35. Kotlow L. Diagnosis and treatment of ankyloglossia and ties maxillary frenum in infants using Er:YAG and 1064 diode lasers. Eur Arch Pediatr Dent. 2011;12(2):106–12.
36. Gutknecht N, Moritz A, Dercks HW, Lampert FJ. Treatment of hypersensitive teeth using neodymium:yttrium-aluminum-garnet lasers: a comparison of the use of various settings in an in vivo study. Clin Laser Med Surg. 1997;15(4):171–4. https://doi.org/10.1089/clm.1997.15.171.
37. Lopes AO, Aranha AC. Comparative evaluation of the effects of Nd:YAG laser and a desensitizer agent on the treatment of dentin hypersensitivity: a clinical study. Photomed Laser Surg. 2013;31(3):132–8. https://doi.org/10.1089/pho.2012.3386. Epub 2013 Feb 19.
38. Farmakis ET, Beer F, Kozyrakis K, Pantazis N, Moritz A. The influence of different power settings of Nd:YAG laser irradiation, bioglass and combination to the occlusion of dentinal tubules. Photomed Laser Surg. 2013;31(2):54–8. https://doi.org/10.1089/pho.2012.3333. Epub 2012 Dec 16. PMID: 23240877.
39. Orchardson R, Whitters CJ. Effect of HeNe and pulsed Nd:YAG laser irradiation on intradental nerve responses to mechanical stimulation of dentine. Lasers Surg Med. 2000;26(3):241–9. https://doi.org/10.1002/(sici)1096--9101(2000)26:3<241::aid-lsm1>3.0.co;2-i.
40. Lygidakis NA, Wong F, Jälevik B, Vierrou AM, Alaluusua S, Espelid I. Best clinical practice guidance for clinicians dealing with children presenting with Molar-Incisor-Hypomineralisation (MIH): an EAPD Policy Document. Eur Arch Paediatr Dent. 2010;11(2):75–81. https://doi.org/10.1007/BF03262716.
41. Körner R, Bahmer F, Wigand R. The effect of infrared laser rays on herpes simplex virus and the functions of human immunocompetent cells. Hautarzt. 1989;40(6):350–4.
42. Donnarumma G, De Gregorio V, Fusco A, Farina E, Baroni A, Esposito V, Contaldo M, Petruzzi M, Pannone G, Serpico R. Inhibition of HSV-1 replication by laser diode-irradiation: possible mechanism of action. Int J Immunopathol Pharmacol. 2010;23(4):1167–76.
43. AAPD Clinical Practice Guidelines on pulp therapy for primary and immature permanent teeth. http://www.aapd.org/policies/quidelines.
44. AAPD Oral health Policies on Policy on Interim Therapeutic Restorations (ITR). http://www.aapd.org/policies/quidelines.
45. AAPD Oral health Policies. Use of vital pulp therapies in primary teeth with deep caries lesions. http://www.aapd.org/policies/quidelines.
46. Farooq NS, Coll JA, Kuwabara A, Shelton P. Success rates of formocresol pulpotomy and indirect pulp therapy in the treatment of deep dentinal caries in primary teeth. Pediatr Dent. 2000;22(4):278–86.
47. Parisay I, Ghoddusi J, Forghani M. A review on vital pulp therapy in primary teeth. Iran Endod J. 2015;10(1):6–15. Epub 2014 Dec 24. Review.
48. Olivi G, Magnolis FS, Genovese MD. Endodontics, Chapter 8. In: Pediatric laser dentistry. A user's guide. Quintessence Publishing Co, Inc; 2011.
49. Konstanos N, Arapostathis KN, Arhakis A, Menexes G. Direct pulp capping of carious primary molars. A specialty practice based study. J Clin Pediatr Dent. 2014;38(4):307–12.
50. De Coster P, Rajasekharan S, Martens L. Laser-assisted pulpotomy in primary teeth: a systematic review. Int J Paediatr Dent. 2013;23(6):389–99. Epub 2012 Nov 22. Review.
51. Uloopi KS, Vinay C, Ratnaditya A, Gopal AS, Mrudula KJ, Rao RC. Clinical evaluation of low level diode laser application

for primary teeth pulpotomy. J Clin Diagn Res. 2016;10(1):ZC67–70.
52. Liu JF. Effects of Nd:YAG laser pulpotomy on human primary molars. J Endod. 2006;32:404–7.
53. Saltzman B, Sigal M, Clokie C, Rukavina J, Titley K, Kulkarni GV. Assessment of a novel alternative to conventional formocresol-zinc oxide eugenol pulpotomy for the treatment of pulpally involved human primary teeth: diode laser-mineral trioxide aggregate pulpotomy. Int J Paediatr Dent. 2005;15:437–47.
54. Gupta G, Rana V, Srivastava N, Chandna P. Laser pulpotomy—an effective alternative to conventional techniques: a 12 months clinicoradiographic study. Int J Clin Pediatr Dent. 2015;8(1):18–21.
55. Durmus B, Tanboga I. In vivo evaluation of the treatment outcome of pulpotomy in primary molars using diode laser, formocresol, and ferric sulphate. Photomed Laser Surg. 2014;32(5):289–95.
56. Yadav P, Indushekar K, Saraf B, Sheoran N, Sardana D. Comparative evaluation of ferric sulfate, electrosurgical and diode laser on human primary molars pulpotomy: an "in-vivo" study. Laser Ther. 2014;23(1):41–7.
57. Niranjani K, Prasad MG, Vasa AA, Divya G, Thakur MS, Saujanya K. Clinical evaluation of success of primary teeth pulpotomy using mineral trioxide aggregate(®), laser and Biodentine(TM)—an in vivo study. J Clin Diagn Res. 2015;9(4):ZC35–7.
58. Subbaiah R. Bacterial efficacy of Ca(OH)2 against E. faecalis compared with three dental lasers on root canal dentin—an In vitro study. J Clin Diag Res. 2014;8(11):ZC135–7.
59. Rebecca G, et al. Er:YAG 2,940-nm laser fiber in endodontic treatment: a help in removing smear layer. Lasers Med Sci. 2014;29(1):69–75.
60. Pedullà E, et al. Decontamination efficacy of photon-initiated photoacoustic streaming (PIPS) of irrigants using low-energy laser settings: an ex vivo study. Int Endod J. 2012;45:865–70.
61. Shoaib H. Bactericidal efficacy of photodynamic therapy against Enterococcus faecalis in infected root canals: a systematic literature review. Photodiagn Photodyn Ther. 2013;10(4):632.
62. Vahid Z. Antimicrobial efficacy of photodynamic therapy and sodium hypochlorite on monoculture biofilms of Enterococcus faecalis at different stages of development. Photomed Laser Surg. 2014;32(5):245–51.
63. Pinheiro SL, et al. Photodynamic therapy in endodontic treatment of deciduous teeth. Lasers Med Sci. 2009;24(4):521–6.
64. Pinheiro SL, et al. Manual and rotary instrumentation ability to reduce Enterococcus faecalis associated with photodynamic therapy in deciduous molars. Braz Dent J. 2014;25(6):502–7.
65. Giselle de Sant'Anna, Photodynamic therapy for the endodontic treatment of a traumatic primary tooth in a diabetic pediatric patient. J Dent Res Dent Clin Dent Prospect. 2014; 8(1): 56–60.
66. da Silva Barbosa P, et al. Photodynamic therapy in pediatric dentistry. Case Rep Dent. 2014;2014:217172.