Laser Use in Minor Oral Surgery

Omar Hamadah

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_13

Core Message

The initial experimentation and early clinical practice of laser use have been reported in the mid-1960s [1] and one of the first initial clinical surgeries was documented in 1977 [2]. Nowadays, adjunctive laser use is defining the standard of care for many oral surgeries, offering many advantages for both the surgeon and the patient. The purpose of this chapter is to explain those therapies and to demonstrate those benefits.

13.1 Introduction

In 1960, Maiman published his pioneering work on the ruby maser [3]. This was based on the theoretical statements of Einstein dated in 1917 [4] and the work of Schawlow and Townes 1958 [5]. Based on this breakthrough, many groups working on different laser types published their studies in the 1960s. Those articles led to the development of the main laser types in use today such as the CO_2 laser, the Nd:YAG laser, or the diode laser [6–11]. Within clinical dentistry, the long sought after goal was to replace the pain and vibration of the drill with a laser. This quest for the drill substitute held up the introduction of lasers in the dental field as it took until 1989 for the Er:YAG laser [12, 13] to be studied and then developed for practice a few years later. At this time, lasers were in widespread use in medicine working mainly on soft tissue. Beginning in 1990, laser therapy began to establish its place in dentistry.

Prior to lasers, there were three main methods of oral surgical treatment available:

- The conventional scalpel.
- Electro surgery [12].
- Cryotherapy (in use since the mid-1970s) [13].

13

For treatment of dental hard tissue, there are only a few wavelengths that may be used (Er:YAG, Er,Cr:YSGG, CO_2). However, in soft tissue surgery, up to ten different wavelengths are applicable. The oral/maxillofacial surgeon has a choice of a fiber-based delivery system (Nd:YAG, diode lasers) or a non-contact optical system (CO_2, erbium family).

- Diode lasers (445–1064 nm) are suitable for most oral soft tissue surgery procedures, especially on pigmented tissue. They are small, compact instruments whose portability can be an advantage for short procedures. They are delivered through a small diameter flexible optical fiber with an optional tip that can access small areas of tissue. Using a gated mode with digitally modulated pulse width and high output power diode laser have become very much more efficient than the early generations.
- Nd:YAG (1064 nm) has similar interaction with soft tissue although the free running pulse mode can produce very high peak powers for efficiency. Its delivery system is the same as the diode.
- The KTP laser emits at 532 nm and can be used similar to diode and Nd:YAG laser. Historically, the KTP was a frequency doubled FRP Nd:YAG. Now, the 532 nm “green” laser is a diode GaN semiconductor.
- Ho:YAG laser (2100 nm) is mostly used in soft tissue surgery. It utilizes an articulated delivery system and non-contact application.
- The argon laser (488 nm, 514 nm) has its indications in the use for pigmented lesions or vascular malformations.
- The carbon dioxide lasers (9300 and 10,600 nm) have been used traditionally in oral surgery; the latter wavelength having a very long history of clinical success. A higher average power than diode is readily available with very rapid tissue cutting speed, but there is a possibility of more tissue carbonization when used in continuous wave emission mode. A non-contact delivery mode and the use of an articulated arm makes the application of the 10,600 nm laser more demanding.
- The Er:YAG (2940 nm) and the Er,Cr:YSGG (2780 nm) lasers are readily absorbed in water. Their main indication is with hard tissue (osseous) surgery. Soft tissue surgery is also possible but much slower. Hemostasis is not as prominent due to poor absorption in pigmented chromophores and the coolant effect of co-axial air/water to assist in ablation site debridement. Depending on the particular laser, there is a choice of either contact or non-contact mode with the tissue, using delivery tips or a tip-less handpiece.

The main indications in selecting a laser for use in oral surgery:

- Hemostasis.
- Maintaining a decontaminated operation field.
- Controllable penetration depth of laser-tissue interaction.
- Minimal need for wound dressing/sutures.
- Less need for local anesthetic.
- Less postoperative pain.
- Less wound contraction and scarring.
- Uneventful wound healing.

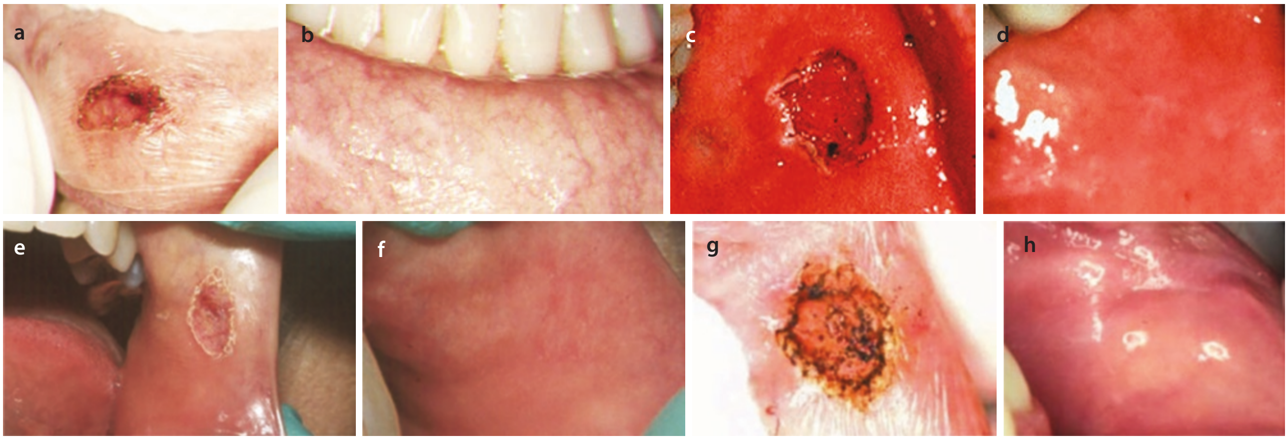


Fig. 13.1 **a** An immediate postoperative view of an excision of an irritation fibroma on the lower lip. An 810 nm diode was used with a 400 μm glass fiber in contact with the tissue at 1.2 W continuous wave. Fluence 149 J/cm^2. **b** A 3-week postoperative view of the healed area. **c** An immediate postoperative view of an excision of an irritation fibroma on the buccal mucosa. An Nd:YAG laser was used with an 320 μm glass fiber in contact with the tissue at an average power of 3 W (100 mJ, 30 Hz) Fluence 915 J/cm^2. **d** A 3-week postoperative view of the healed area. **e** An immediate postoperative view of an excision of an irritation fibroma on the inner lip mucosa. An Er:YAG laser was used with an 600 μm glass tip in contact with the tissue at an average power of 2.4 W (80 mJ, 30 Hz, without water spray.) Fluence 263 J/cm^2. **f** Two-week postoperative view of the healed area. **g** An immediate postoperative view of an excision of an irritation fibroma on the buccal mucosa. A 10,600 nm Carbon Dioxide laser was used with a 0.8 mm diameter hollow tubular tip that was focused on the lesion at 5 W continuous wave. Fluence 146 J/cm^2. **h** Three-week postoperative view of the healed area. (Courtesy of Dr. Donald Coluzzi)

Hemostasis is one of the most sought-after advantages that the laser provides. Depending on the target tissue, the laser wavelength and emission mode selected, an almost totally dry operation field is produced. This can also be achieved in patients with hemorrhagic diatheses [14]. The use of sufficiently matched energy for cutting will produce little carbonization leaving the wound unchanged in color and structure. This makes orientation during the procedures easier, even for the surgically inexperienced dentist. When using the laser not only is the wavelength important, but also parameters such as temporal emission mode (continuous wave or pulsed), pulse duration, emission cycle, exposure time, and the speed of the incision [15, 16]. All this in the right proportions will lead to a clean cut with little carbonization and contraction of proteins resulting in scarring [17–20].

As mentioned, all of the dental wavelengths currently available can be used for soft tissue oral surgery. As mentioned in ► Chap. 3, the laser-tissue interaction can vary because of the different absorption characteristics of the applied incident photonic energy. However, with careful technique and prudent choice of operating parameters, healing from laser surgery should be uneventful. Figure 13.1a–h depicts examples of an excisional procedure performed with four different wavelengths.

13.2 Benign Lesions and Tumors of the Oral Cavity

13.2.1 Leukoplakia

A color change from normally pale pink oral mucosa to white is one of the most often discovered abnormalities in the oral cavity. Failure to identify and recognize the cause of this alteration can be an omission with serious consequences since early squamous cell carcinomas may appear in early stages as a white lesion.

Clinically, the term leukoplakia has been used differently by many authors that it now presents a "white patch that cannot be rubbed away" [21]. As defined by the World Health Organization, leukoplakia is "a white patch or plaque that cannot be characterized clinically or pathologically as any other disease" [22, 23]. As such, leukoplakia should be used only as a clinical term; it has no specific histopathological connotation and should never be used as a microscopic diagnosis. Subsequently, the World Health Organization WHO (2005) changed the definition of leukoplakia to "A predominantly white plaque of questionable risk having excluded (other) known diseases or disorders that carry no increased risk for cancer" [24].

In clinical practice, the Malmö protocol of 1983 [25, 26] has been helpful in differentiating between potentially precancerous and benign lesions. The distinction of these is purely clinical, based on surface color and morphological (thickness) characteristics, and does have some bearing on the outcome or prognosis. Since leukoplakia has been and still is an exclusion diagnosis, it is mandatory to perform a biopsy to verify the diagnosis. Clinically, there are two types of leukoplakia: homogenous and nonhomogeneous. Homogeneous lesions are uniformly flat, thin, and exhibit shallow cracks of the surface keratin. The risk of malignant transformation in the homogenous type lesion is similar to any other normal mucosa tissue, whereas nonhomogeneous lesions exhibit oral cancer transformation rates ranging between 2.2% and 35%, especially when its biopsy reveled dysplastic entities [27–30]. In the therapeutic treatment protocol of leukoplakia, it is mandatory to excise all areas of the lesion that showed surface morphology that could warrant dysplasia. In conventional surgery, a flap procedure is usually employed, and the result can be scarring and prolonged and painful healing. Several treatment modalities have been suggested to manage this lesion including scalpel excision, electrosurgery, cryosurgery, laser surgery, and chemoprevention medications. A particularly difficult group of patients to manage are those with multiple oral, potentially premalignant lesions in whom extensive areas of mucosa may show signs of dysplastic change. Widespread leukoplakias have been shown to have higher rates of malignant transformation than more localized lesions [31]. The introduction of laser technology, for example, using the CO_2 laser, offers the option of vaporizing the lesion and leaving it to heal with no-to-minimal scar formation [32, 33]. However, the ability to analyze the submitted laser-excised specimen for pathology was soon questioned. Conventional excision produces a serial section of the whole specimen, and spot biopsies were criticized as insufficient. In the eyes of traditional surgeons, the pathologic evidence was being (literally) vaporized. Therefore, the standard of care before ablation of an oral potentially premalignant lesion is still to obtain an incisional biopsy for histopathological assessment.

The CO_2 laser manifests strong absorption ability in soft tissues, causing a superficial evaporation with minimal thermal damage to the surrounding tissue and maximum selectivity to remove targeted lesion. It works with a non-contact mode, using a handpiece attached to an articulating arm delivering the laser beam to the target tissue.

For procedures performed under general anesthesia, an endotracheal intubation with a cuffed ETT tube is recommended to be used as it provides significantly protection against ignition in comparison to conventional PVC endotracheal tubes [33]. Saline moistened gauze also should be used to protect the pharynx, endotracheal tube, and facial skin. Preferably, no metal instruments should be used during CO_2 lasing for safety measure. Instead, wooden or plastic spatulas can be used to manipulate the oral tissues when irradiated with CO_2 laser.

All staff within the operating theater must wear safety glasses for this laser wavelength. An evacuation system must be used to remove smoke and debris from the surgical site.

Oral potentially premalignant lesions can be managed under local or general anesthetic according to lesion size, location, and health status of the patient.

Oral leukoplakia without dysplastic histopathological features can be removed utilizing an ablation technique. The peripheral margins of the lesion are outlined with single mode pulse and vaporized with CO_2 laser in continuous mode at 4–6 W average power, with scanning mode covering the extension of the lesion. A second pass may be required to achieve a complete vaporization with adequate depth [34].

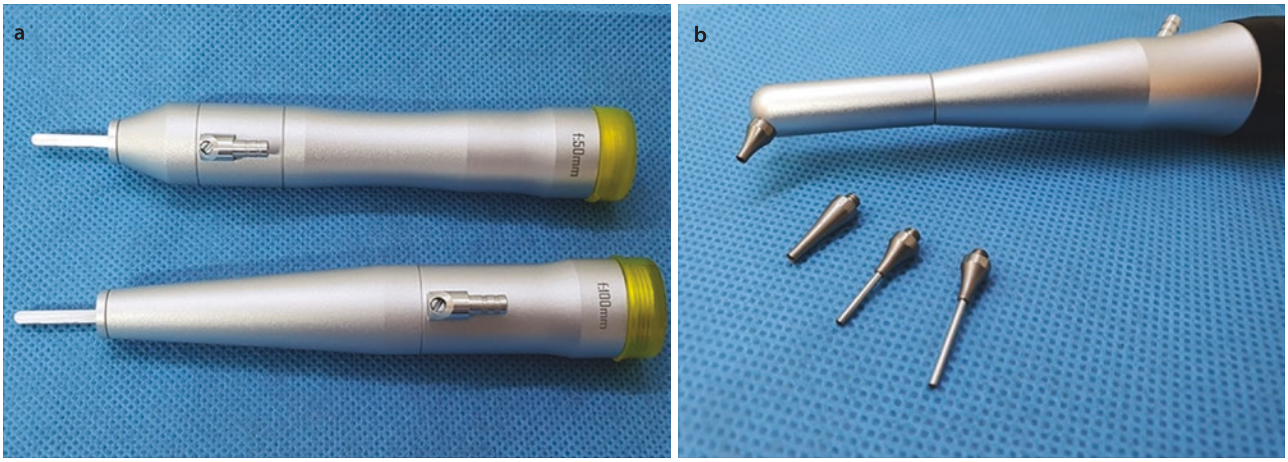
A complete resection of oral leukoplakia becomes mandatory when incisional biopsy of such lesion revealed dysplastic changes [34].

For lesion resection, the power levels vary between 5 and 15 W in continuous mode according to the thickness and extension of the lesion. For devices offering pulsed mode, the following parameters were suggested to facilitate resection of hyperkeratotic lesions: a power of 4.5 W on PW, 80 Hz, fluence of 44.78 J/cm^2, and a spot diameter of 400 μm [35].

Initially, a single pulse mode is used to outline the resection margins, situated at least 5–10 mm beyond the apparent clinical margin of the target lesion. Subsequently, the laser is adjusted to continuous mode and the peripheral marks are connected at the submucosal level. The whole specimen is then excised by undercutting at approximate 5 mm constant depth [34, 36]. However, when resecting mucosa overlying alveolar bone, the undercutting depth should be shallower.

It is recommended that the resected area and all peripheral margins should be vaporized using a defocused beam to eliminate residual disease and to facilitate hemostasis. The wound is left to heal by secondary intention, with no need for sutures, dressing, or grafting. Several studies demonstrated that the CO_2 laser offers precise cutting ability of the oral mucosa with less bleeding and scar formation in the surgery field.

All excised specimens should be preserved and fixed in 10% formalin and sent for histopathology examination. Large biopsies must be orientated by sited sutures to define the involved margin with the disease.



■ **Fig. 13.2** Surgical and dental CO_2 laser handpieces used in the oral cavity. **a** Straight handpieces with different focal lenses (50/100 mm) used for resection of extended and bulk lesions. **b** Dental CO_2 laser handpiece with multiple tips facilitating treatment of small mucosal and gingival lesions within the oral cavity

As the wound will heal by secondary intention, postoperative instructions include using a mouth rinse such as chlorhexidine 0.12% and avoiding spicy and coarse food. Tranexamic acid 5% can be used as mouthwash if oozing happens. Augmentin antibiotic is prescribed as 1000 mg twice a day and paracetamol or ibuprofen for pain relief as required. Complete healing and mucosal re-epithelialization of the resected area is usually achieved within 4–6 weeks. Follow-up sessions usually are organized at 1, 3, and 6-month intervals thereafter.

Finally, although the CO_2 laser has been proven to be the treatment of choice of oral potential premalignant lesions, recurrence or malignant transformation is still unavoidable [31, 35].

Recurrence of a white lesion is a serious development. Studies show that the use of laser treatment has at least a similar if not better outcome than the conventional therapy [37–39]. In functionally sensitive regions as the lips, a laser excision demonstrated significant improvement in outcome [40].

Most of the studies regarding laser treatment of oral leukoplakia were performed with the 10,600 nm carbon dioxide wavelength. However, it is also possible in some small lesions, especially those located in the anterior part of the oral cavity to use a fiber-based delivery system of an Nd:YAG laser or a diode laser, depending on the accessibility of the lesion [41–44].

Two different types of handpieces used with CO_2 laser device in the oral cavity (■ Fig. 13.2).

■ Figure 13.3 shows a case of leukoplakia on the lateral border of the tongue. A 50-year-old female presented with an inconspicuous medical history except for smoking. An Nd:YAG was used to vaporize the lesion. Six months later, a small area has recurred.

Verrucous leukoplakia extending from the interior aspect of the upper left mucosa to the tuberosity (■ Fig. 13.4). An incisional biopsy was performed which revealed the presence of severe dysplasia. Lesion resection was performed using the CO_2 laser. Exposed alveolar bone was covered by a platelet-rich fibrin PRF membrane which was stitched to resection margins. The healing was uneventful, and no recurrence was detected at 6 months postoperatively.

13.2.2 Lichen Planus

Lichen planus is a chronic inflammatory mucocutaneous disorder; it generally affects middle aged to elderly females and the lesions mostly appear in the buccal mucosa, tongue, gingiva, and vermillion border of the lower lip [45]. It is a T-cell mediated autoimmune disease in which the cytotoxic CD8+ T cells trigger apoptosis of the basal cells of the oral epithelium. Several antigen-specific and nonspecific inflammatory mechanisms have been proposed to explain the accumulation and homing of CD8+ T cells subepithelially, and the subsequent keratinocyte apoptosis [46].

Clinically, oral lichen planus (OLP) may appear in six forms: Reticular (Wickham striae), erosive, atrophic, plaque-like, papular, and bullous. The reticular shape is the most common type which is usually asymptomatic exhibiting localized or generalized extension with no need for treatment [47]. However, other clinical patterns such as erosive or atrophic forms may cause variable amounts of pain or discomfort, especially when the patient is consuming spicy or hot foods. Additionally, oral function and patient's quality of life may be affected [48].

The clinical diagnosis of OLP should be associated with a histopathological examination to rule out the presence of any associated sinister elements such as dysplasia or neoplasia [49]. The microscopic features of

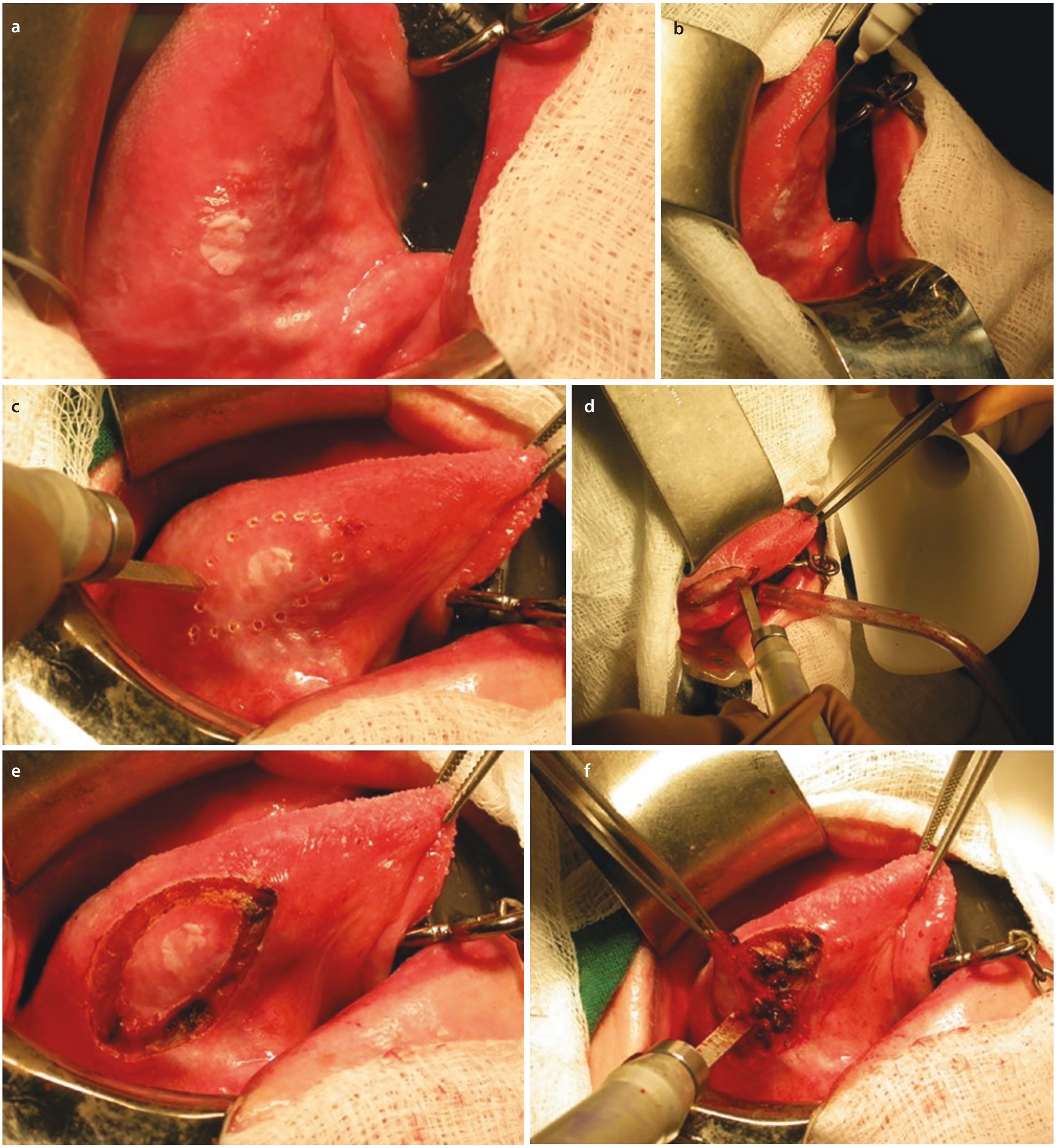


Fig. 13.3 **a** A 48-year-old male with severe dysplasia located on ventral tongue. **b** This procedure was performed under general anesthesia; however, local anesthesia was also provided to aid hemostasis during the resection. The CO_2 laser was used with power levels varying from 10 to 15 W **c**. **d**, **e** The outlined margins were first determined using single pulse mode which served as surgical boundaries, extending 0.5 cm beyond the apparent clinical margins of the lesion. Subsequently, the laser was set to continuous mode, and the peripheral marks were connected at the submucosal level. **f** The whole specimen was then resected by undercutting at approximate 5 mm constant depth. **g** The surgical bed and all peripheral margins were vaporized using a defocused beam to eliminate residual disease and to facilitate hemostasis. The wound surface was left, without closure or dressing, to heal by secondary intention. **h** The excisional specimen was oriented by placing multilength sutures at the margins and fixed in 10% formalin and transferred for histopathology evaluation. **i** Healing and resection field re-epithelialization was achieved within 4–6 weeks

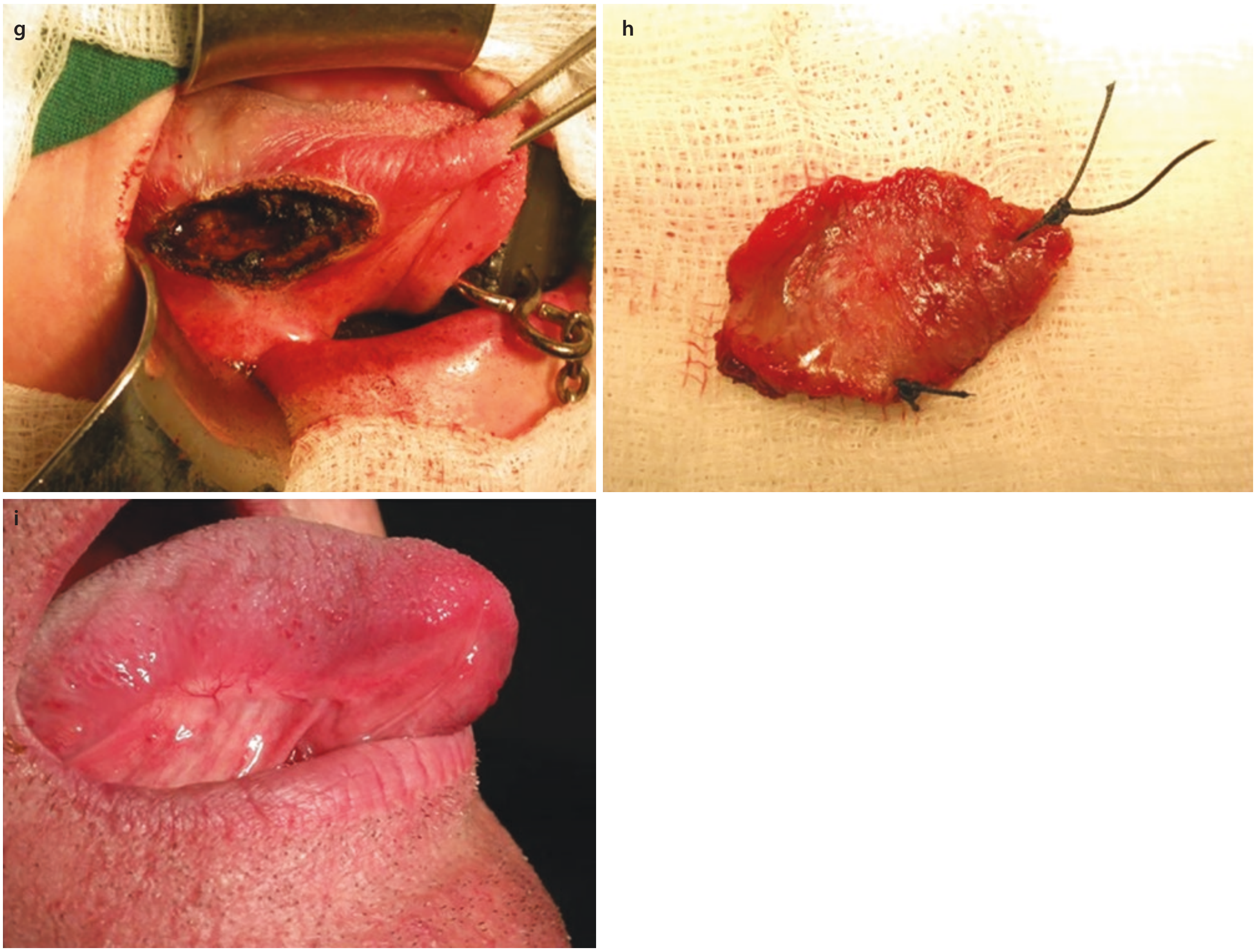


Fig. 13.3 (continued)

OLP usually include plasma cells, subepithelial band-like infiltration of lymphocytes and acanthosis [46, 50].

Bearing in mind that the risk of malignant transformation is higher in erosive and atrophic lesions, treatment of these types should be considered mandatory. Several treatment methods are available and topical corticosteroids are mostly considered the treatment of choice; in the light of side effects such as thinning of the oral mucosa and secondary candidiasis, it has been preferable to find alternative pharmacological treatments, including retinoids and immunosuppressive agents, especially cyclosporine and tacrolimus. Low level laser therapy (photobiomodulation) and high-power (surgical) laser may be considered as alternative tools for OPL treatment, especially for those unresponsive lesions to traditional pharmacological regimes [51, 52]. Surgical removal of affected mucosa may be performed either by a scalpel or high-power laser. Elimination of OLP with a laser offers complete resection of the lesion usually in one session with minimal postoperative complications such as pain, bleeding, or scar formation. Tarasenko et al. reported in their randomized controlled trail the superiority of Er:YAG and Nd:YAG on scalpel surgery in ablation of erosive lichen planus [52]. The Er:YAG laser was applied in a contact mode using reciprocal movements of 15 s per cm^2 with the following parameters: average power: 2 W, frequency: 10 Hz, pulse duration: 230 μs, spot size: 0.9 mm, water/air: on. The Nd:YAG laser was also applied in a contact mode using reciprocal movements of 15 s per cm^2 with the following parameters: average power: 1.5 W, frequency: 40 Hz, pulse duration: 350 μs, spot size: 300 μm. Coagulation was achieved by applying the two lasers with a non-contact mode using an average power of 3 W with circular movements of unfocused beam 1–3 mm far away from the treated area. The findings of this research showed that high-level laser intervention exhibits a superior clinical outcome compared to the scalpel excision for the surgical treatment of oral erosive lichen planus. Taking into consideration that the Er:YAG causes less thermal damage to the oral mucosal tissue, it has been considered as the most effective laser type in this study at the end of the first postoperative month [45].

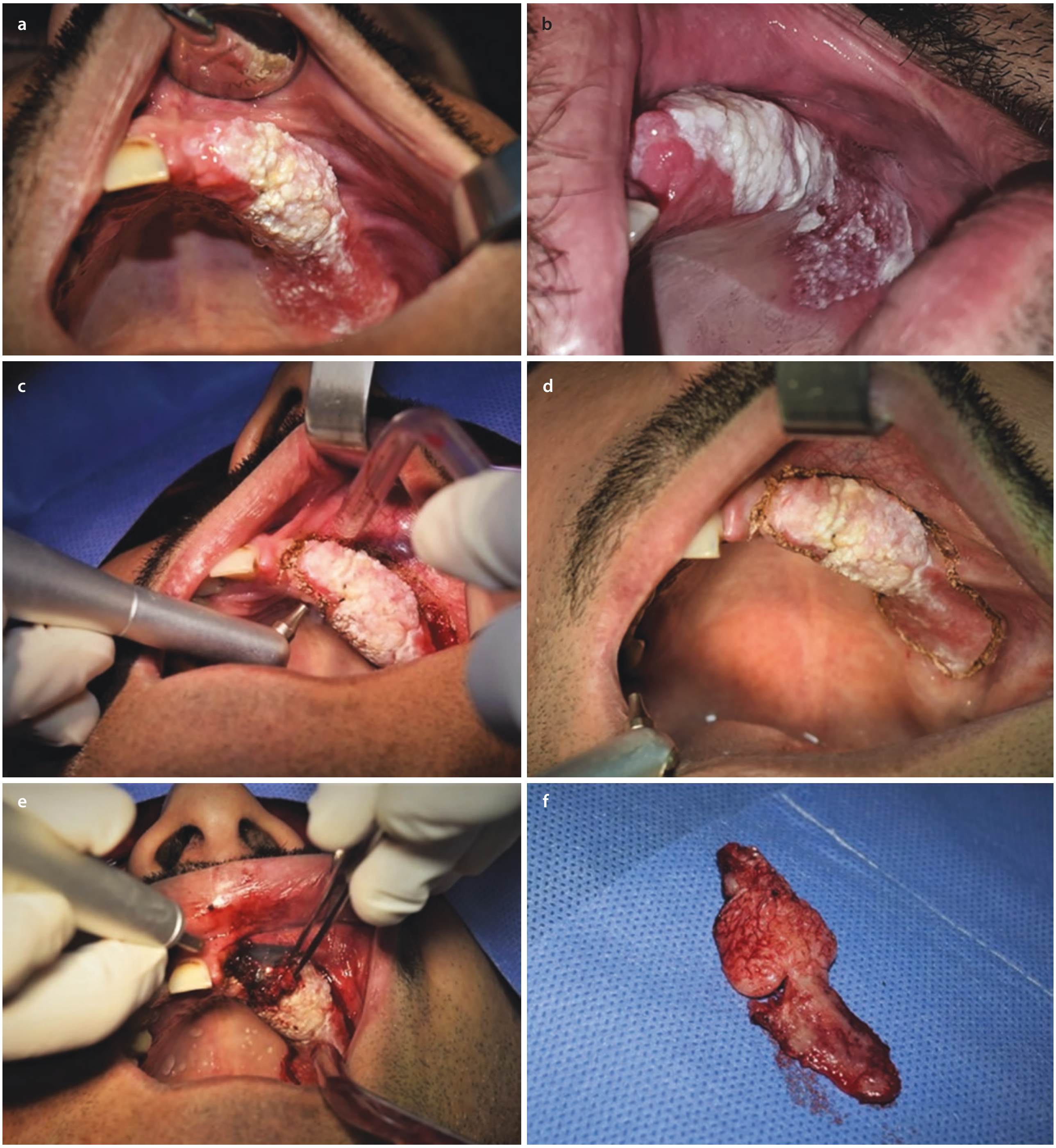


Fig. 13.4 **a**, **b** A 39-year-old male presented with a recurrent verrucous leukoplakia. The lesion extends clinically from the interior aspect of the upper left mucosa to the tuberosity. **c**–**f** Lesion peripheral outlining and resection were performed by applying CO_2 laser using both dental and straight handpieces. A periosteum elevator was used to facilitate the lesion dissecting. **g**, **h** The exposed upper alveolar maxillary bone was covered by a PRF membrane which was stitched to resection margins. A partial pressure denture was placed to support the membrane and to aid hemostasis control. The healing was uneventful, and no recurrence was detected 6 months post intervention

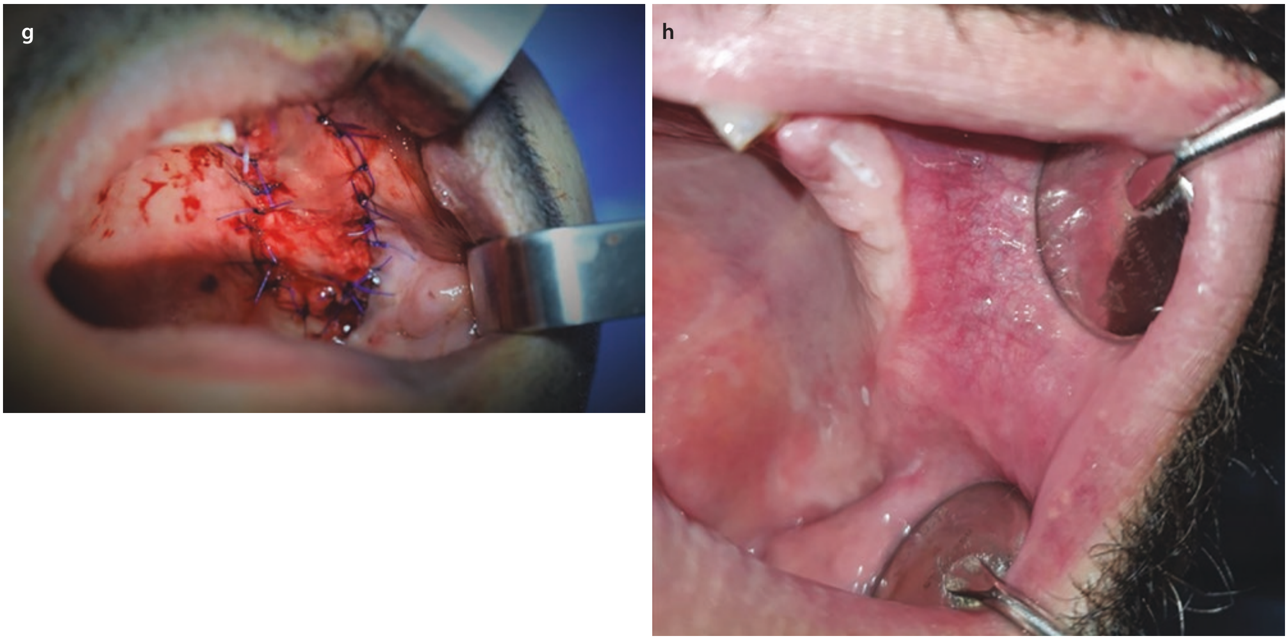


Fig. 13.4 (continued)

The CO_2 laser (10,600 nm) manifests a high absorption in the water component of oral mucosa which facilities a precise resection of oral mucosal lesions with post-surgery coagulation. It also can be used in a defocused mode enabling evaporation of superficial tissues even when the lesion exhibits a large extension thus the evaporated area will heal by secondary intention [53].

Treating of lichen planus using the CO_2 laser was reported in several studies with an advantage of reducing the lesion size and pain severity. The operation is performed after administration of local anesthesia using defocused continuous CO_2 laser (10,600 nm) with power range reported from 2 to 20 W. The lesion is irradiated to achieve superficial vaporization with a slow gliding motion, until the lesion is completely removed. The ablation should not reach the connective tissue level. Although a study suggested using CO_2 laser with defocused continuous mode, others recommended super pulsed mode [54–56].

OLP recurrence rate differs according to follow-up period, lesion extension, type of OLP, and technique of laser application and parameters used [54].

A 27-year-old male presented with pan-oral lichen planus (Fig. 13.5). Multiple incisional biopsies were performed, and the histopathological report confirmed the clinical entity of the lesions. A surgical CO_2 laser (λ = 10,600 nm) was used applying a continuous defocused mode with an output power of 3 W. The spot diameter was 0.5 mm, the speed of movement was approximately 3 mm/s, and the power density was 1527.8 W/cm^2. The procedure was conducted under local anesthesia.

The same patient presented with reticular and atrophic-shape lichen planus on the left buccal mucosa (Fig. 13.6). The lesion was vaporized using the CO_2 laser defocused beam with scanning mode covering the extension of the lesion. Similar laser parameters were used as in the abovementioned case.

13.2.3 Fibroma

The lesion most commonly found in the oral cavity is the fibroma. It occurs as a discrete, superficial, pedunculated mass commonly found on the buccal mucosa. It is usually of non-neoplastic nature and arises as a response to persistent mechanical irritation such as calculi, foreign bodies, chronic lip or check biting, overhanging margins restoration, sharp spicules of bones, and overextended borders of appliances [57, 58]. The irritation fibroma is also termed a traumatic fibroma, peripheral fibroma, fibrous nodule, fibroepithelial polyp, focal fibrous hyperplasia, and inflammatory fibrous hyperplasia [59]. It is composed of collagenous, fibrous connective tissue covered with keratinized or parakeratinized squamous epithelium. In the lesion, there can be myxomatous degeneration or pathological weakening of the connective tissue along with bone formation and in growth of fatty tissue. Affected patients often notice the lesion only after masticating on the area

Fig. 13.5 **a** A 27-year-old male presented with a symptomatic lichenoid lesion on ventral tongue. **b** Immediately after CO_2 laser vaporization. **c** Four weeks postoperative view showing complete healing with no sign of recurrence

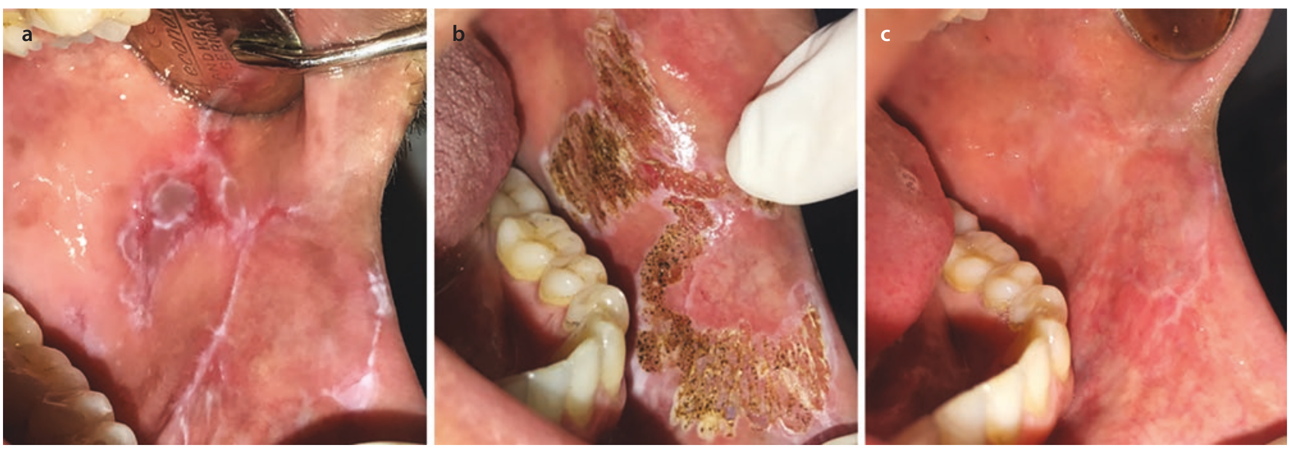


Fig. 13.6 **a** The same abovementioned patient exhibiting reticular and atrophic shape lichen planus lesions on the left buccal mucosa. **b** Lesion ablation using CO_2 laser with continuous mode. **c** Uneventful healing of the oral mucosa 3 weeks postoperatively

and then experiencing post traumatic pain and swelling. At this point, the fibroma will have grown to at least 2–3 mm in size depending on the region and would be visible in a mirror. The lesion will generally continue to grow, becoming a nuisance, and should be removed. When a scalpel is used, postoperative bleeding often makes the procedure difficult, especially if the lesion is inflamed with increased vascularization. Moreover, suturing is often necessary. Laser surgery allows both excision and hemostasis simultaneously [20, 57].

Treatment protocol includes injection of local anesthesia peripherally and underneath the lesion. A tissue forceps or a suture is used to grasp the lesion away from its base. Employing a contact mode, laser choice of Nd:YAG or diode laser with wavelength of 450, 810, 940, and 980 nm can be used to perform the resection [60]. Depending on the lesion size and location, it is outlined about 2 mm outside its border using an initiated 320–400 μm quartz optic fiber. As the tip contacts the base of the lesion, activate the laser to make an incision circumscribing the lesion, then move the tip in quick gentle 2–3 mm strokes to achieve complete resection of the lesion. It is important while performing the cutting to direct the tip at the base of the resected specimen and not toward the oral mucosa. This allows a precise resection without damaging underlying tissues. The area is left to heal in secondary intention with no need for dressing.

Figure 13.7 is a case of an asymptomatic fibroma present on a 45-year-old female patient, nonsmoker, with an inconspicuous medical history. A diode laser performed the excisional biopsy and the tissue healed without any scarring or residual lesion.

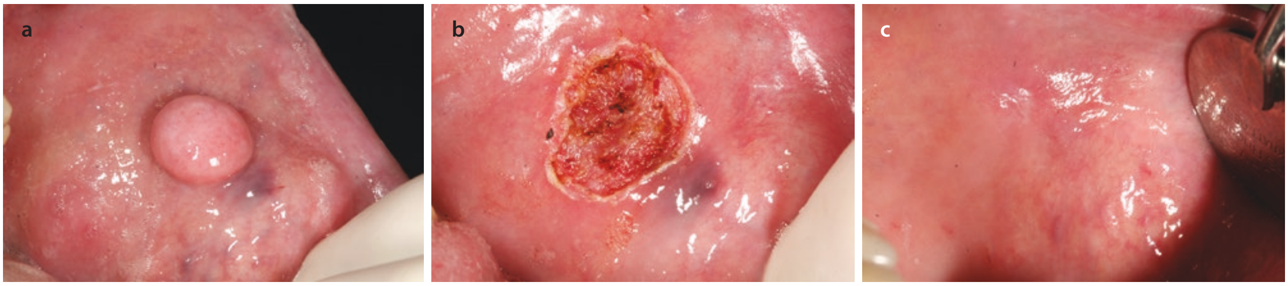


Fig. 13.7 **a** Pre-operative view of a fibroma in the buccal vestibule. **b** Immediate postoperative view of the excision. An 810 nm diode laser was used with a 200 μm glass fiber in contact with the tissue at 30 W, 12,500 Hz, and a 9 μs pulse duration, 200 μm glass fiber, contact mode. Average power 3.38 W. Fluence 554 J/cm^2. **c** A 4-week postoperative photo shows complete healing

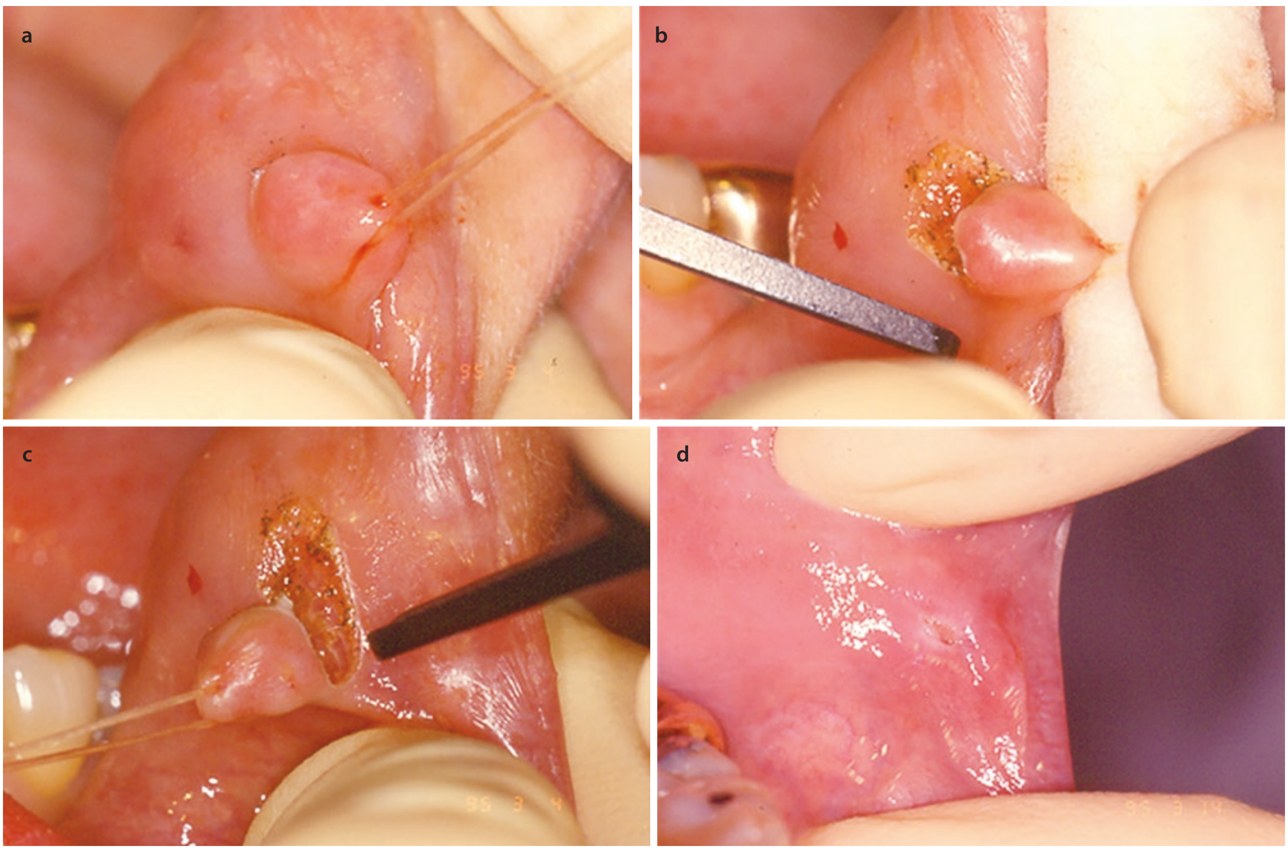


Fig. 13.8 Traumatic fibroma left buccal mucosa in a 50-year-old female. **a** Lesion secured with suture to stabilize the tissue and facilitate accurate estimation of the level of incision. **b**, **c** Using a CO_2 10,600 nm laser with non-contact, fixed focal length delivery: 1.0 W CW 800 μm beam diameter × 30 s. Incisional hemostasis achieved. **d** Postoperative uneventful early healing at 10 days. (Clinical case courtesy of Prof. Steven Parker)

Figure 13.8 depicts an irritation fibroma present inner mucosal lining of the lip of a (50-year-old female patient with a non-contributory medical history?) A superpulsed 10,600 nm carbon dioxide laser performed the excision, while a suture kept tension on the lesion. Clinical case courtesy of Prof. Steven Parker.

Figure 13.9 is that of a 38-year-old female, non-smoker, presented with multiple areas of fibromas. Her medical history included hypertension and cardiac dysrhythmia, which are drug controlled. She has a bruxism habit which could contribute to the presence of the lesions.

Figure 13.10 depicts a fibroepithelial polyp localized on the left buccal mucosa as a result of chronic irritation. The lesion was excised using the diode laser and complete re-epithelization was achieved after 3 weeks.

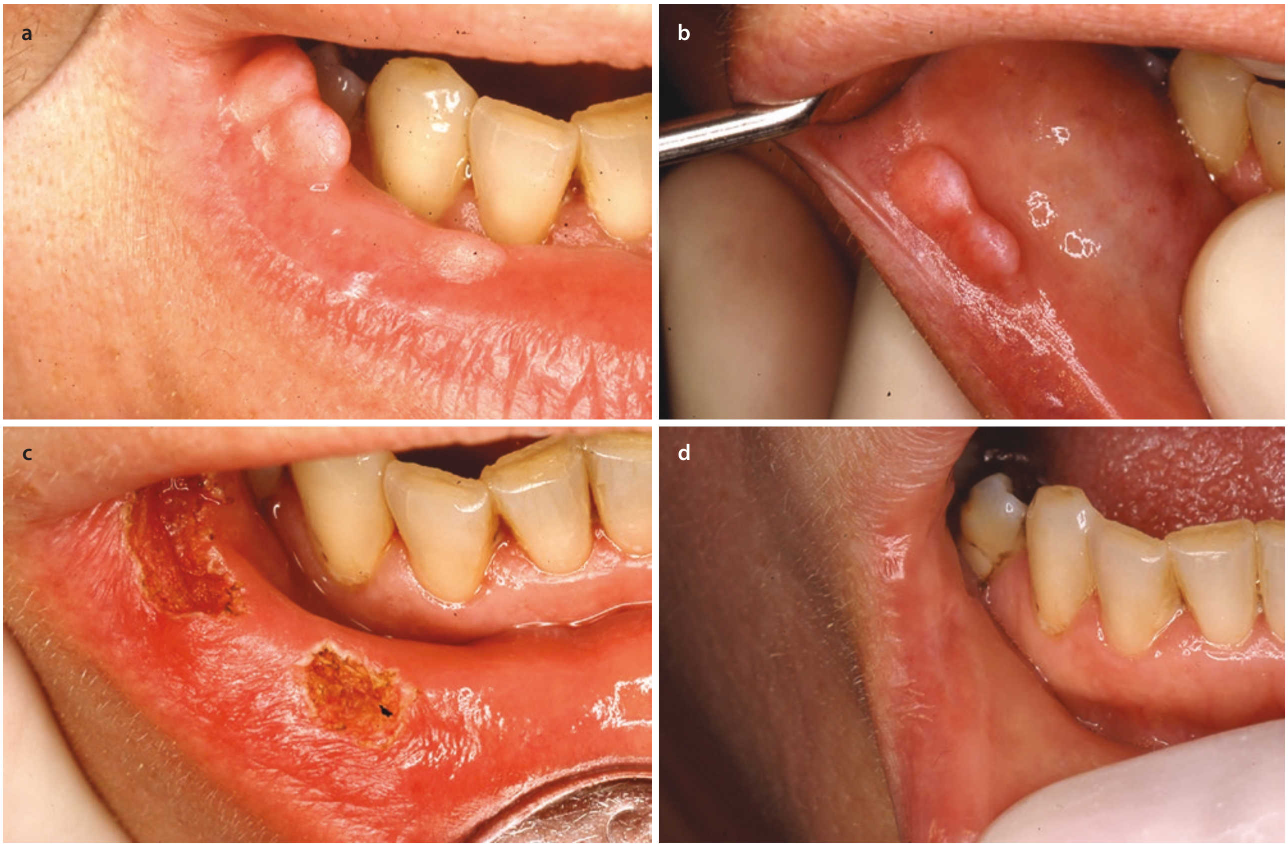


Fig. 13.9 **a** Pre-operative view of multiple fibroma lesions on the lower right lip. **b** A similar view showing that the lesions are contained in the keratinized portion of the tissue. **c** An immediate post-operative view of the excision areas. An Nd:YAG laser was used with a 320 µm glass fiber in contact with the tissue at an average power of 4 W (100 mJ, 40 Hz). Fluence 637 J/cm^2. **d** A 4-week postoperative photo showing complete healing with no residual lesion present

13.2.4 Papilloma

Several papillomatous lesions presented in the oral cavity are usually related to the infection with the human papilloma virus (HPV). These lesions include squamous cell papilloma, verruca vulgaris, condyloma acuminatum, and focal epithelial hyperplasia. HPV is also responsible for malignant lesions that occur in oropharyngeal cancer. A papilloma presents as an arborescent growth of numerous squamous epithelial finger-like projections. Each branch contains a well-vascularized fibrous connective tissue core. It can be seen throughout the oral cavity with a preference on the tongue and the periuvular region. The etiology of the lesion is generally viral and is thought to be induced by the human papilloma virus [61, 62]. Since human papilloma viruses infect basal cells that is the only dividing cells of the epithelium, it is necessary to remove the entire epithelial layer where the papilloma occurred. The treatment of papillomatous lesions comprises complete excision, including the base of the lesion with apparently free margins to avoid recurrence. This procedure can be performed with a conventional scalpel, an electrosurgery, or using a laser [63]. Diode and CO_2 lasers were reported in several studies as an acceptable choice to remove a papilloma from the oral cavity and aerodigestive tract offering precise resection with minimal thermal damage to surrounding tissues [64]. For small or solitary lesions, a diode laser can be used to achieve complete resection. For instance, diode laser of different wavelengths (450, 810–980 nm), with an average power of 2.1 W, in continuous wave mode, using 300–320 µm optical fibers has been recommended [65, 66]. However, for multiple and extended lesions ablation mode preferably using CO_2 laser is the treatment of choice to manage these lesions taking into consideration that several sessions be needed to achieve complete eradication of the lesion. A recurrence can occur even though laser treatment has shown lower reappearance rates than conventional therapy. However, any therapy could be limited since the latent behavior of infection of HPV in the apparently normal mucosa around papilloma which explains the frequent recurrence after surgical removal of a visible lesion [67, 68].

Fig. 13.10 **a** Fibroepithelial polyp seen on the left buccal mucosa caused by regular biting of the check. **b** The 980 diode laser with 3 W peak power and duty cycle 50% was used to excise the lesion. Complete hemostasis was achieved with no need for dressing or sutures. **c** Three weeks postoperative view showing complete healing. **d** The polyp after excision was fixed in 10% formalin and sent for histopathology examination

Figure 13.11 is a clinical case of an oral papilloma. The patient is a 36-year-old male, smoker with an inconspicuous medical history. A diode laser performed the excision and excellent healing is anticipated.

A 14-year-old female presented with extensively distributed nodules and papules, which appeared when she was 6 years old (Figs. 13.12 and 13.13). The size of the lesions ranges from 2 to 30 mm. The diagnosis of Heck's disease was confirmed depending on clinical characteristics, histopathological examination, and immunohistochemical staining. Depending on the extensive clinical situation, the decision was made to treat the patient using CO_2 laser at wavelength: 10,600 nm, continuous mode and power of 6 W. It showed good function and aesthetic results. Five treatment sessions were required to manage all regions in the oral cavity.

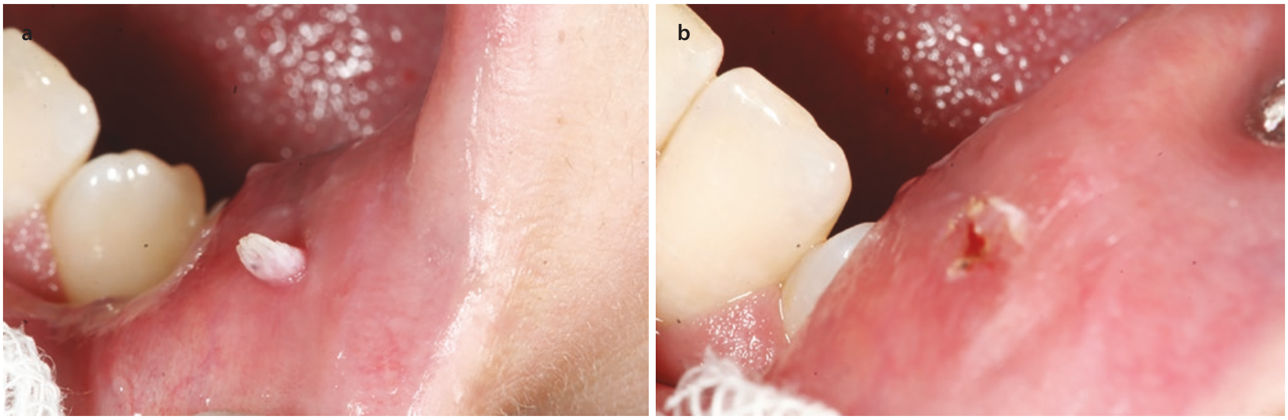


Fig. 13.11 **a** Pre-operative photo of a small oral papilloma on the buccal mucosa. **b** An immediate postoperative view of the excision of the lesion. An 810 nm diode laser was used with a 200 μm glass fiber in contact with the tissue at 30 W, 12,500 Hz, and a 9 μs pulse duration. Average power 3.38 W. Fluence 554 J/cm^2. Complete healing is expected

Fig. 13.12 **a** A 14-year-old female presented with an extensive case of pan-oral focal epithelial hyperplasia covering most of her lining oral mucosa. **b**, **c** Immediate postoperative view of the labial aspect of the upper lip after resection of lesions using the CO_2 laser with 6 W continues mode, which minimized the time of resection and reduced the thermal damage of the oral mucosa. **d** The labial aspect of the upper lip 1 month following CO_2 laser intervention with no sign of relapse or new primary lesions

13.2.5 Lipoma

Lipomas are the most common benign tumors of the human body. They can be solitary or in multiple clusters. They vary extensively in size from minute to large growths with weight in kilograms. They occur mostly between 40 and 50 years of age. In the oral cavity, they appear as soft, slightly elastic, and painless lesions and usually are noticed by the patients if they are of large dimension. They are normally found in the buccal, sub-

Fig. 13.13 **a** The same patient exhibiting multiple papillomatous lesions on the lining mucosa of the lower lip extending to the commissure in both sides. **b** Immediate postoperative view of the labial aspect of the lower lip after ablation of lesions using the CO_2 laser with continuous mode. **c** Uneventful healing of the oral mucosa 10 days postoperatively

mandibular, and vestibular region. The development of a lipoma is not necessarily hereditary although hereditary conditions, such as familial lipomatosis can stimulate its growth [69]. Genetic studies support prior epidemiologic data in humans showing a correlation between high mobility group proteins (HMG I-C) and mesenchymal tumors [70]. When the patient's complaint is the size of the lesion, or to verify the diagnosis, the treatment is excision. The laser's ability to achieve instant hemostasis offers a good view of the site, which is important in some areas of the mouth, for example, in direct proximity to the mental nerve [71]. While any laser wavelength will perform the surgery, a fiber delivered laser that has better maneuverability could be an advantage in the depth of the wound [72]. Depending on the dimension of the lesion, sutures would be placed to avoid food impaction. For bigger and subdermal lesions, irradiation with the Nd:YAG laser is performed by inserting a 600 μm optical fiber within a cannula through a 1 mm incision after applying local anesthesia underneath the tumor. The fiber is passed through the proximal end of the clamp, in order for the fiber to be a little longer than the cannula. The fiber is pouched no more than 2–3 mm beyond the end of the cannula while laser emission is activated. The recommended parameters to be used to treat subjects in a single session using Nd:YAG include average power 6 W, pulse repetition rate 30 Hz, energy per pulse 200 mJ, and pulse width 100 μs [73, 74].

Figure 13.14 is that of a 48-year-old male patient, nonsmoker with a non-contributory medical history presented with a slow growing mass in the mandibular vestibule. It was beginning to annoy the patient. A diode laser was used for an excisional biopsy and a diagnosis of lipoma was confirmed. Sutures were placed because of the large size of the excised tissue and the depth of the wound. Healing proceeded uneventfully.

Figure 13.15 is a clinical case of a lipoma on the lateral border of the tongue. The 58-year-old male patient presented because of his concern with the growing size of the tumor although it has not yet caused any functional impairment. His hypertension and diabetes are controlled with medication. A diode laser was used for the excision. A 15-year postoperative photo shows excellent healing and no recurrence.

13.2.6 Pyogenic Granuloma

Pyogenic granuloma is a vascular lesion of skin and oropharyngeal mucosa. It appears as reddish overgrowth due to mechanical, physical, chemical, or hormonal trauma [51]. It is generally located in the anterior of the maxilla and can be painful if it is constantly irritated. The lesion can grow rapidly and will often bleed profusely after little or no trauma, and it has the appearance of a highly vascular granulation tissue with inflammation on histologic examination. Special variants of the pyogenic granuloma are the epulis granulomatosum and the granuloma gravidarum. Treatment is not necessary except in cases of excessive bleeding or pain and ulceration. After pregnancy, the lesion normally regresses. [1, 52]. As expected, any surgical laser that achieves good control of bleeding may be used [45, 53]. A biopsy must be taken for histological verification of the lesion.

Pyogenic granuloma (PG) is one of the common inflammatory nonneoplastic vascular hyperplasias seen in the oral cavity. It occurs in response to many factors, for example, long-term irritation, traumas, or hormonal factors. It often arises in the second decade of life in young females, probably due to the effects of female hormones [75].

Clinically, oral PG is a smooth or lobulated pedunculated or sessile exophytic lesion which enlarge rapidly and easily bleeds. It is recognized as small pink to red to purple papules depending of the persistence of the

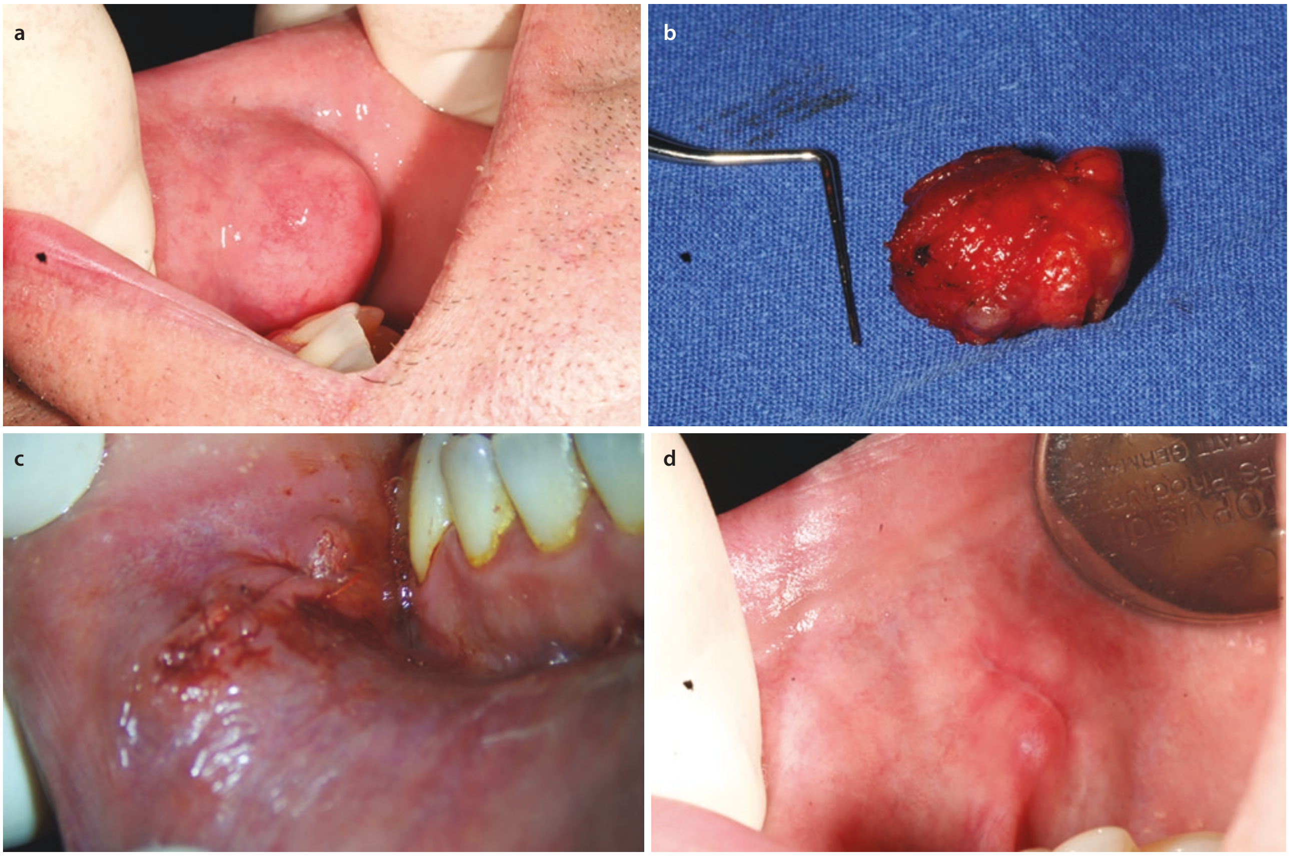


Fig. 13.14 **a** Pre-operative photo of a lipoma lesion in mandibular vestibule. It is soft and elastic, but firmly attached to the underlying and covering tissue. There is no sign of any inflammatory process. An 810 nm diode laser was used with a 300 µm glass fiber in contact at 30 W, 13,000 Hz, and a 9 µs pulse duration. Average power 2.93 W. Fluence 967 J/cm^2. **b** The excised specimen has an irregular lobular surface, and the histologic diagnosis was that of a common lipoma. **c** Immediate postoperative view showing closure of the deep wound with sutures. **d** One-week postoperative view depicts good healing

lesion. It is most likely to appear in the gingiva and less common in the palate, oral mucosa, tongue, and lips [76].

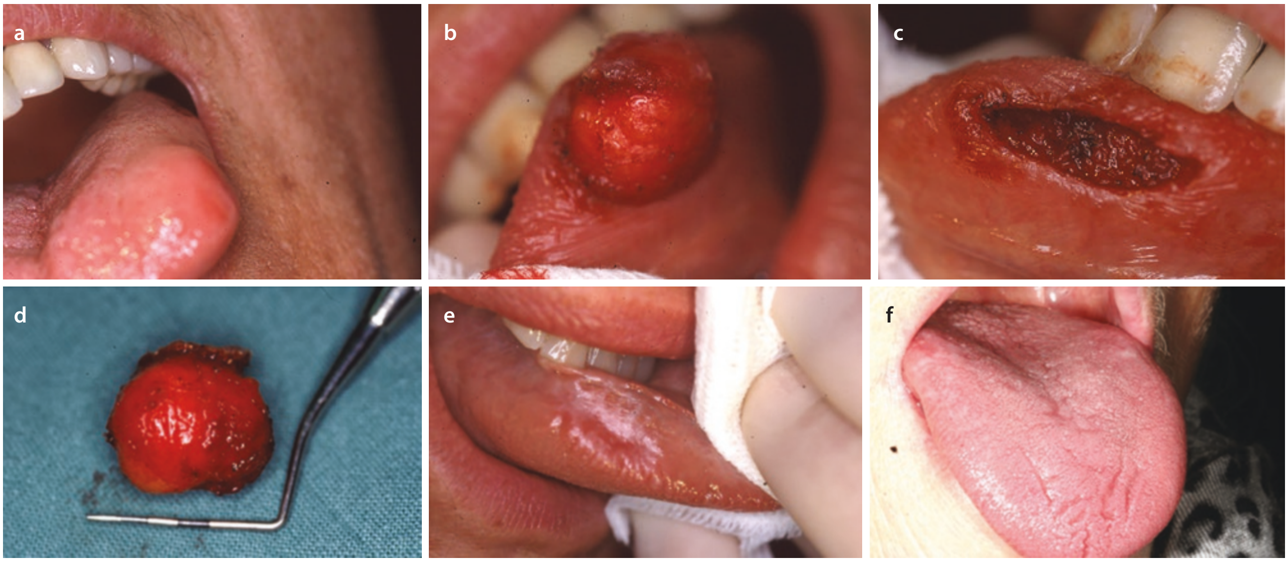
Histologically, PG comprises a highly vascular proliferation that resembles granulation tissue with a dense inflammatory infiltrate of neutrophils, plasma cells, and lymphocytes. The surface of chronic lesions becomes ulcerated and replaced by a thick fibrinopurulent membrane showing more fibrous entities. Long-standing PGs may progress to gingival fibromas as a result of fibrous maturation [77].

Differential diagnosis of PG includes peripheral giant cell granuloma, a peripheral odontogenic or ossifying fibroma, and less commonly Kaposi's sarcoma, bacillary angiomatosis, and non-Hodgkin's lymphoma. Thus, biopsy is the most decisive way to confirm the diagnosis. Radiographic findings are absent in most cases [77].

Scaling and curettage usually are the initial treatment, and the patient is instructed to improve his/her oral hygiene. In addition, all expected irritants like foreign bodies, calculus, and sharp restorations should be eliminated [78].

Complete surgical resection of PG is considered the treatment of choice. This could be performed using a scalpel as a conventional treatment or preferably using laser with indicated wavelengths [79]. The Nd:YAG, CO_2, Er:YAG, and high-power diode laser have been reported in several studies as a suitable tool for surgical removal of PG offering a precise excision with minimal bleeding [80, 81]. The wavelengths of diode 980 nm and Nd:YAG 1064 nm laser are well absorbed by oral lesions which exhibit a high amount of melanin and hemoglobin such PG. Therefore, they consider the ideal lasers for PG management [82].

The procedure is performed after infiltration of local anesthesia usually with a fiber lasing in a contact mode with average power ranging between 2 and 3.75 W. According to specifications of available laser device, continuous/interrupted or pulse mode can be used. The fiber tip (320–400 µm diameter) is pointed at an acute angle of about 15°, moving it circumferen-



■ **Fig. 13.15** **a** A pre-operative view of the swelling in the left portion of tongue. **b** The tissue overlying the area is excised and the mass can be seen. It is adhered deeply in the underlying tissue. **c** An immediate postoperative view of the excision area. An 810 nm diode laser was used with a 400 µm glass fiber in contact with the tissue at 1.6 W continuous wave. Fluence 199 J/cm^2. The lesion does show some carbonization because of the emission mode, but the hemostasis is excellent. **d** A photo of the large sized lesion. **e** Three-week postoperative photo shows healing with a substantial tissue defect. **f** Fifteen-year postoperative view of the completely healed area with no sign of recurrence or a functional defect

■ **Fig. 13.16** **a** A discrete nodular, erythematous, sessile overgrowth covering the cervical third of the crowns #11 and #12. **b** Complete removal of the lesion using 2 W super pulse CO_2 laser. The clinical diagnosis was a pyogenic granuloma which was confirmed histopathologically. **c** Three weeks postoperative view showed uneventful healing

tially around the base of the lesion. Whenever the lesion starts to detach from its adjacent tissues, the fiber tip is directed toward the base of lesion itself to avoid cutting deeply within the tissues underneath resected lesion. For PG located on gingiva and for aesthetic and functional request, the proper gingival contour is better to be achieved during laser resection and interdental papilla should be preserved when it is possible.

If PG is around an implant, then Er:YAG/Er,Cr:YSGG lasers have the advantage of removing the lesion with minimal thermal effects to the implant surface and surrounding bone [83]. The following parameters may apply safely in the field of intervention: Er:YAG laser 2940 nm with average power: 3 W, energy per pulse: 300 mJ, frequency: 10 Hz, short pulse, with contact headpiece, with 50% water and 50% air, Tip Ø = 1 mm) [84].

To avoid recurrence, the excision should extend down to the periosteum. Nonetheless, recurrence rate was reported in 8% of PGs resected with lasers in comparison to 15% for those undergoing conventional treatments [85].

■ Figure 13.16 is a healthy 48-year-old female complaining of a recurrent gingival overgrowth associated with the area of teeth 12/11. The patient manifested bad oral hygiene with interproximal open margin restorations. The lesion was about 1 cm in diameter with a sessile base. The clinical diagnosis displayed a pyogenic granuloma. It was asymptomatic and bled easily with light contact. The CO_2 laser was used to excise the lesion offering a precise cutting with good hemostasis.

13.3 Pre-prosthetic Surgery

13.3.1 Epulis Fissurata and Pre-prosthetic Vestibuloplasty of the Edentulous Patient

The epulis fissuratum or denture-induced fibrous hyperplasia is a trauma or inflammation caused lesion in patients with partial or full dentures [86]. Ill-fitting and overextended dentures can irritate the mucosal tissue and create a hyperplastic tissue flap that can develop signs of secondary inflammation [87, 88]. Due to constant irritation, the lesions can progressively grow, compromising the support for the denture, which in turn causes more irritation. Often these epulis are combined with alveolar ridge atrophy and diminished or missing vestibular depth [89]. During conventional surgery, hemostasis is difficult to achieve, especially for patients with bleeding dyscrasias. Furthermore, in most cases, suturing the incision can result in a diminished vestibular depth. Since laser surgical wounds show a reduced number of myofibroblasts, there will be a diminished contraction the tissue when healing by secondary intension [90, 91]. Secondary wound healing is ordinarily uneventful and significantly less painful than with a conventional surgical protocol. Therefore, excision of the epulis fissurata should be performed with a laser to achieve adequate hemostasis even in patients with bleeding disorder. If there are very large tissue flaps, a fiber-delivered laser can easily undercut them for excision [92].

Several dental lasers have been used with the following recommended protocols and parameters in the treatment of epulis fissuratum:

Laser	CO_2
Wavelength	10,600 nm
Power	5–6 W
Emission mode	Pulsed
Frequency	50 Hz
Spot size	0.9 mm
Local anesthesia	As needed
Application technique	Firstly, a gentle tension should be applied to pull the lesion away from its base and get clean cut with clear borders, then the clinician starts cutting the lesion with the focused mode and finally the mode is defocused to achieve the tissue vaporization with keeping the tip away from the tissue for about 6 mm during the operation, and finally the wound will stay exposed to heal in the second intention in the site, the excised mass should be sent to the pathological examination to confirm the diagnosis [93]

Laser	Diode
Wavelength	810 nm
Average power	2 W
Emission mode	Pulsed
Local anesthesia	As needed
Application technique	Firstly, the lesion is grasped with Adson forceps or any other helpful toothless forceps to fix the lesion and keep it under tension then the excision starts at the base of the mass in order not to over cut the tissues in the site with continuous removing and until the lesion is detached and until we reach a healthy connective tissue then the removed mass should be fixed in 10% formalin and sent to the histopathologist, neither sutures nor dressings are needed in the site [94]

Figure 13.17 is that of a 68-year-old female patient, nonsmoker, presents with an ill-fitting denture and a very painful epulis fissuratum lesion in the midline lingual vestibule. Her medical history is significant for hypertension, cardiac dysrhythmia, and Coumarin anticoagulant medication. A diode laser excised and contoured the tissue. Two weeks later, the area had healed, facilitating a new lower full denture, correctly extended.

Vestibular depth can be very challenging with elderly patients, and a vestibuloplasty can be planned. After losing their teeth at a young age, many of these patients show a profound progressive atrophy of the skeletal bone. This atrophy has anatomical limitations in the mandible due to the structure of the self-supporting bone; thus, the patient seldom presents with less than 8 mm of residual bone height. In the maxilla, the limitations are the nasal cavity with an apertura piriformis and the floor of the maxillary sinus. If the alveolar ridge is lost, the bony configuration of the maxillary sinus takes over to function as the ridge. In the anterior segment, the alveolar ridge can recede and disappear. Considering these anatomical situ-

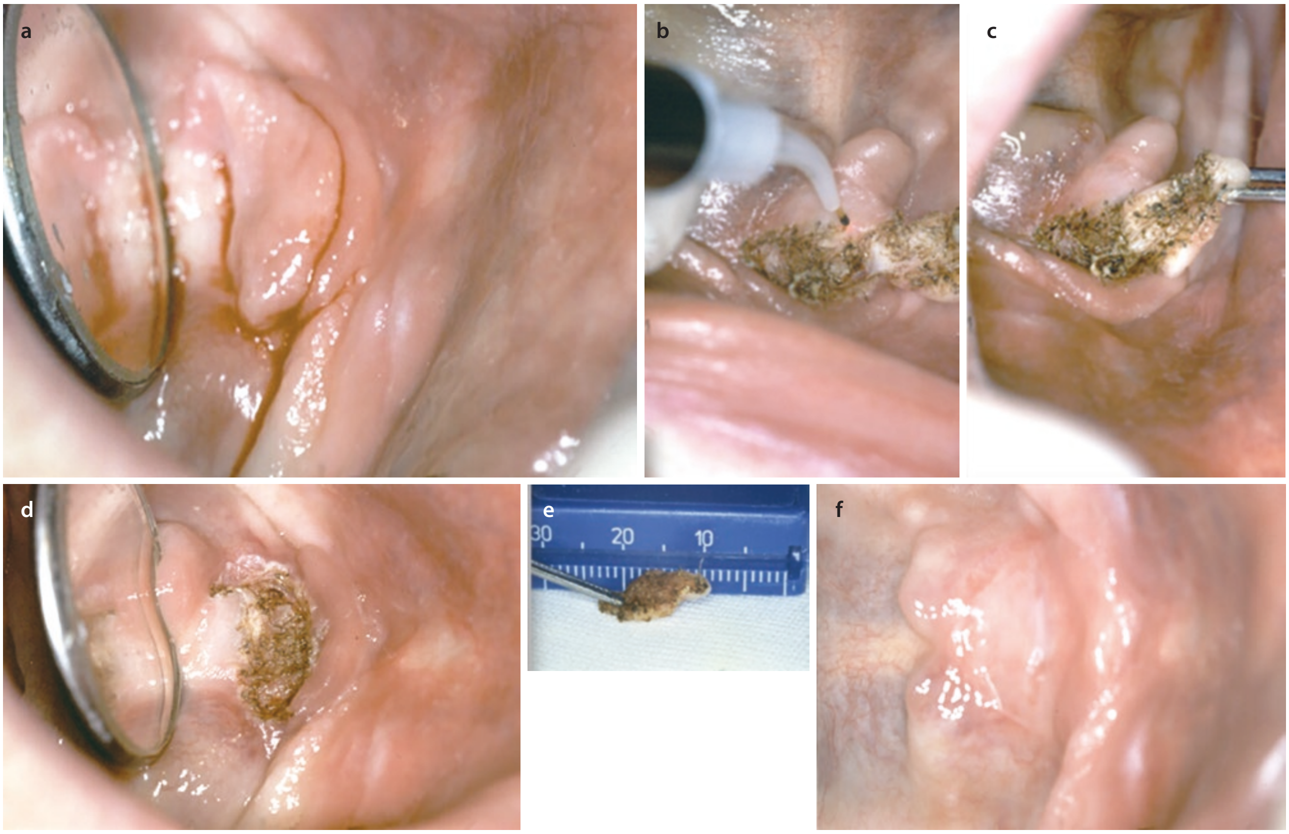


Fig. 13.17 **a** Pre-operative photo of an epulis fissuratum lesion in the midline lingual vestibule. The slight bleeding is due to administration of local anesthesia. A 980 nm diode laser was used with a 320 μm quartz fiber in contact at 1.5 W, CW. **b**, **c** The hypertrophic tissue is carefully dissected from the underlying tissue bed, with the advantage of incisional hemostasis. **d** Immediate postoperative view. **e** Excised tissue and histological confirmation of provisional diagnosis. **f** Healing at 2 weeks. (Case courtesy Prof. Steven Parker)

ations, experience has shown that, in a mandible with a residual height of approximately 10 mm, it is impossible to expect a satisfactory prosthodontic outcome. In the maxilla a vestibular extension in the premolar and molar region is possible. However, the vestibule can only extend to a certain height without compressing the residual soft tissue, so relapse can occur. It is possible to stabilize the wound healing by inserting a free gingival graft [95].

Figure 13.18 is that of a 68-year-old male with a medical history of cardiac insufficiency, hypertension, and nephrolithiasis, presents with insufficient vestibular depth. A diode laser was used for a vestibular excision and a free gingival graft was inserted. The border of the existing denture was extended apically to aid the graft in healing. Six months postoperatively, the vestibular depth is now adequate.

Atrophy of the alveolar ridge leads to the appearance of pre-existing frenula that can subsequently interfere with the denture flange or the periodontal tissue. Laser surgery offers benefits for frenum revision and vestibuloplasty and suturing, such as for conventional Z- or VY-plasty procedures, which are not necessary.

Gingival recession is normally located in the anterior mandible, due to a high insertion point of the mandibular frenulum and a mis-aligned mental muscle with mobility of the periodontal soft tissue under function. Treatment of this recession accompanied by a malalignment of the mental muscles should be carefully planned ahead of time so that patient can care for the healing edentulous area. The objective of the surgery is to divert the muscle movement away from the periodontium and establish a neutral zone in the affected anterior vestibule [96]. One option is called the Kazanjian technique. An incision line is made on the mucosa in the lip from canine to canine; or, it can be extended to the premolar region, depending on the patient's muscle activity zone [97]. A thin mucosal flap is prepared to the periosteum at the mucogingival border by using a laser with a 200 μm fiber. Then the mental muscle is excised away from the periosteum into the vestibule. When sufficient vestibular depth is achieved, the mucosal flap is placed back onto the periosteum, and fixed there with two or three resorbable sutures to spread out the flap. The muscle and wound in the lip are prone to secondary granulation. The postop-

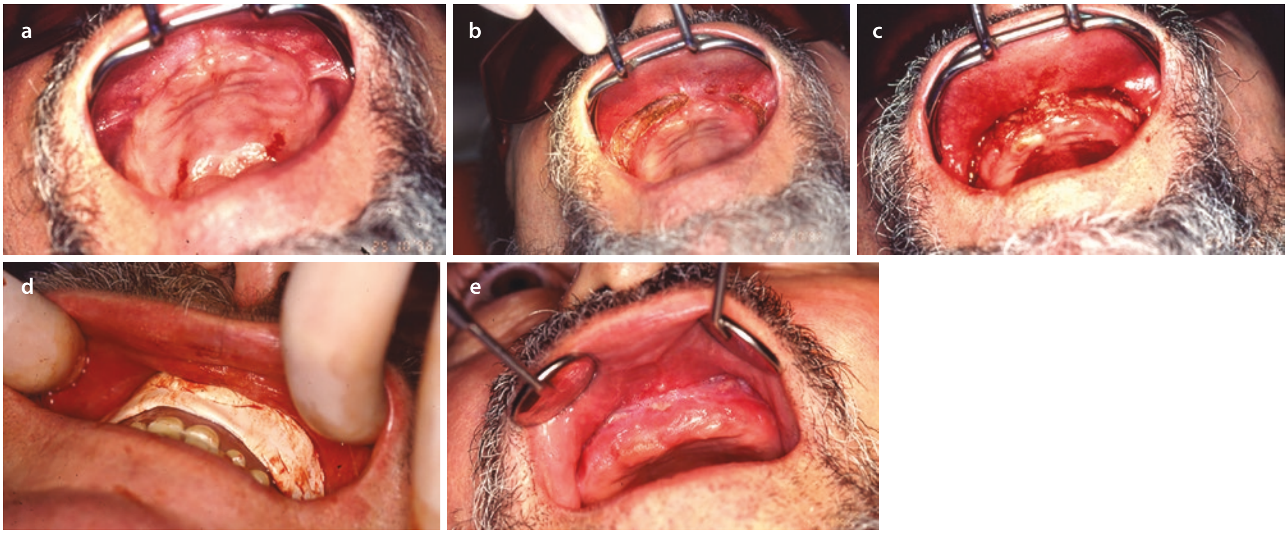


Fig. 13.18 **a** Pre-operative view of the very short maxillary anterior vestibule extension, which is inadequate for a stable denture. **b** An incision was made to the periosteum with 810 nm diode laser employing a 400 μm glass fiber in contact with the tissue at 1.6 W continuous wave. Fluence 199 J/cm^2. **c** A free gingival graft is placed, covering the periosteum. **d** An extension was placed on the denture border for a scaffold enabling the graft material to adapt and heal. **e** A 6-month postoperative view shows the new vestibular depth with healed tissue

Fig. 13.19 **a** Pre-operative view of a maxillary anterior frenum whose attachment is embedded in the gingiva. **b** Immediate postoperative photo of the completed frenum revision. A 10,600 nm Carbon Dioxide laser was used in the SP mode at an average power of 1.5 W with an 800 μm beam diameter in non-contact mode. Fluence 135 J/cm^2. The incision's extension was well into the gingival tissue to eliminate the muscle pull. No sutures were placed. **c** Postoperative view of the revised frenum, showing completely healed tissue (Clinical case courtesy of Dr. Charles Hoopingarner)

13

erative outcome is generally uneventful, and patients report minimal bleeding with tolerable discomfort which is eased with mild oral pain medication. Some swelling could occur. Over time, a relapse of recession can occur; however, good oral hygiene measures can produce some stable reattachment. If the recession persists, a connective tissue graft can be placed to re-establish an adequate zone of attached gingiva.

Figure 13.19 shows the revision of the maxillary frenum of a 65-year-old male with no significant medical history. The maxillary anterior frenum attachment must be revised to allow improved periodontal health and further treatment planning for tooth restoration, which may involve a maxillary denture. Clearly, the revised frenum would also allow an adequate extension of the denture flange. A carbon dioxide laser in superpulsed mode was used for the surgery. A 2-month postoperative photo shows total healing and a stable position of the frenum's attachment.

A prosthetic treatment in an edentulous patient can be a real challenge to the dentist especially when the vestibular depth is shallow, also epulis fissuratum which is a soft tissue overgrowth related with a long-term irritation in the site or poorly adapted or over extended denture can make the case more complicated [98, 99].

Vestibuloplasty and removing the fibrous hyperplasia are mainly performed by conventional scalpel but recently, many lasers such as CO_2, Er:YAG, Nd:YAG, and diode lasers are considered as appropriate alternative tools because of their advantages in reducing the postoperative complications and acceleration the healing [98, 99].

Achieving adequate vestibular depth has an essential role to improve the retention of the complete denture and leads to a good oral hygiene; alternatively, inadequate vestibular depth will produce poor plaque control, gingival resection, and poor aesthetics, so that vestibuloplasty can be a necessary procedure in order to deepen the oral vestibule and increase the keratinized gingiva [100]. However, this may be achieved using a range of dental lasers following the instructions based on previous research as follows:

Laser	CO_2
Wavelength	10,600 nm
Average power	3 W
Emission mode	Pulsed
Focal spot size	0.25 mm
Local anesthesia	As needed
Application technique	The incision is horizontal across the muscle attachment by moving the hand parallel to the mucogingival junction line with pulling the lip outward to keep it under tension, the procedure is performed with an angled tipless handpiece which is 1–3 mm away from the tissue during the cutting procedure removing layer by layer in sweeping motions, moving it at the “hand-speed” for a few seconds until we reach the periosteum [101]

Laser	Er:YAG
Wavelength	2940 nm
Pulse energy	200 mJ
Frequency	2 Hz
Local anesthesia	As needed
Application technique	Ablating the strong attached tissues starting from the mucogingival junction and 2 mm from the bottom of the vestibule, removing the tissue by moving the laser tip until we reach the ideal depth and after finishing the procedure we can coagulate the surface with a very long pulse defocused mode, finally the wound will remain exposed to heal in the second intention without any sutures [98, 102]

Laser	Diode
Wavelength	940 nm
Average power	3 W
Emission mode	Pulsed
Local anesthesia	As needed
Application technique	Incising the tissues using an initiated 400 μm fiber tip extending all over the mucogingival junction with a horizontal stroke parallel to the bone relieving the muscle fibers from the periosteum until we reach the desired depth [103]

13.4 Frenulae Revision for Children and Adults

A frenulum attachment positioned within the attached gingiva can lead to gingival recession and accompanying periodontal problems. The revision of this attachment can be easily performed with a laser. The wound is usually not sutured and the secondary intention healing generally proceeds uneventfully [104]. This same treatment method can be performed on children at any age with no negative influence on the development of the mucogingival complex.

Similarly, lingual frenulum the so-called Tongue-Tie can be easily released using any available diode laser wavelength, CO_2 laser, or Er:YAG/Er,Cr:YSSG laser. Early recognition and management of an abnormal tongue frenulum attachment, especially Type III and IV frenula can help prevent, breast feeding difficulty, airway and sleep disturbance, snoring, speech, and orthodontic problems [105].

Midline diastema caused by a hypertrophic maxillary frenulum may interfere with orthodontic therapy and increase the possibility of post-orthodontic relapse. If the space between the upper ► central incisors is more than 2–3 mm, frenectomy will become essential to facilitate its closure, as it is less likely to close spontaneously [106].

Using laser to remove a prominent frenum is a simple, quick, and efficient method in both contact and non-contact laser application modes. A small amount of local anesthesia is infiltrated then the frenum is incised using a focused beam to lyse the fibrous band. This is accomplished by grasping the tissue with a fine ► hemostat or forceps at its inferior and superior attachment. The frenum is then excised by directing the laser along the hemostat outer levels. No sutures are need, and to

Fig. 13.20 **a** Pre-operative photo of a mandibular anterior frenum causing the beginning of clinical attachment loss. **b** A perioperative view. An Er:YAG laser (2940 nm) was used with a 400 µm contact tip at an average power of 2 W (40 mJ, 50 Hz) with a water spray for the incision. Fluence 57 J/cm^2. **c** Another peri-operative view showing the final incision dimensions. Subsequent to this photo, the same laser tip and parameters were used to score the underlying periosteum. No sutures were placed. **d** One-month post-operatively, the tissue is completely healed and the frenum is attached into the mucosal tissue. Case courtesy Dr D. Coluzzi

ensure hemostasis the bed of resected area is scanned by defocusing the beam [107].

Figure 13.20 depicts a mandibular anterior frenum of a 35-year-old female patient with no significant medical history. The frenum inserts at the base of the gingiva and is causing a developing loss of clinical attachment to the anterior teeth. One-month postoperatively, the frenum's attachment has been repositioned on the mucosa to eliminate the muscle pull on the gingival tissues.

Figure 13.21 demonstrates the advantage of laser soft tissue surgical management in the revision of a failed earlier upper labial frenectomy. Anecdotal evidence provides a potential for re-insertion of resected fibrous bands, where the underlying periosteum remains contiguous to the alveolar osseous tissue. Where indicated, the use of either scalpel or suitable laser wavelength to score the periosteum dissuades such complication and "finger-like" multiple frond reinsertion.

Figure 13.22 shows a clinical case of a 15-year-old female patient undergoing orthodontic treatment presented with the anterior impinging mandibular frenulum causing gingival recession. An incision for a mucosal flap procedure was performed with a diode laser and tissue was repositioned. One-year postoperatively, the attached tissue has regenerated, and periodontal health is restored.

■ **Fig. 13.21** **a** The case of a 33-year-old female patient who was referred by her general dentist for a developing periodontal problem with her frenum. Her history involved a previous scalpel frenectomy during teen years, that shows signs of fibrous reinsertion in the attached gingiva. Anecdotal reasons are offered that omission to score the periosteum during the surgical procedure may predispose to re-insertion. **b** Er:YAG 2940 laser was used to dissect all fibrous banding, using parameters: 1.5 W Average Power/150 mJ pp/10 Hz + water spray and air. Time taken 30 s. **c** Immediate post-operative appearance—a final pass with no water spray allows a tenacious plasma coagulum to protect the wound. No sutures required. **d** Early healing at 2 weeks. (Case courtesy Prof. Steven Parker)

Fig. 13.22 **a** A pre-operative view of gingival recession of the lower central incisor caused by the mandibular anterior frenum's attachment. **b** An 810 diode laser was used with a 400 µm glass fiber in contact with the tissue at 1.6 W continuous wave for an incision in the mucosa for a flap procedure. Fluence 199 J/cm^2. **c** The flap is completed and adequate vestibular depth is created as shown in **d**. **e** A 1-week postoperative view shows fibrin covering the wound as it heals by secondary intention granulation. **f** A 3-week postoperative photo depicts good healing. **g** One-year postoperative view shows complete healing with a healthy frenal attachment revision and resolution of the gingival recession

13.5 Other Conditions

13.5.1 Vascular Lesions

Acknowledgment to Antoni J. España (Former Associate Professor at the Faculty of Medicine and Health Sciences. University of Barcelona) For his valuable contribution in this section.

Vascular Malformations

Vascular Lesions of the Oral Cavity

Vascular anomalies are a highly heterogeneous group of congenital disorders of the blood vessels. These types of lesions are classified as tumors and vascular malformations (which represent a localized defect in vascular morphogenesis) although each anomaly is characterized by a specific morphology, pathophysiology, and clinical behavior.

Most vascular tumors are malformations or hamartomas. Thus, they do not constitute a true neoplasm, but rather a congenital anomaly characterized by increased cell proliferation. Hemangiomas are the most common vascular tumors. Other tumors include hemangioendotheliomas, hemangiopericytomas, and less commonly angiosarcomas.

Vascular malformations, on the other hand, are the result of the abnormal development of vascular elements during embryogenesis and fetal life, these can be simple (capillary, arterial, lymphatic, or venous) or combined (arteriovenous malformations).

Hemangiomas

Hemangiomas are usually seen in newborns or at an early age. It is common for a regression to occur during puberty. There are also senile hemangiomas, usually secondary to a traumatic event. This pathology is more frequent in women. The most common locations are the lips, buccal mucosa, tongue, and palate. The size is highly variable, from a few millimeters to very extensive lesions, and they occur in approximately 10% of the population. Identifiable risk factors include female gender, prematurity, low birth weight, and fair skin

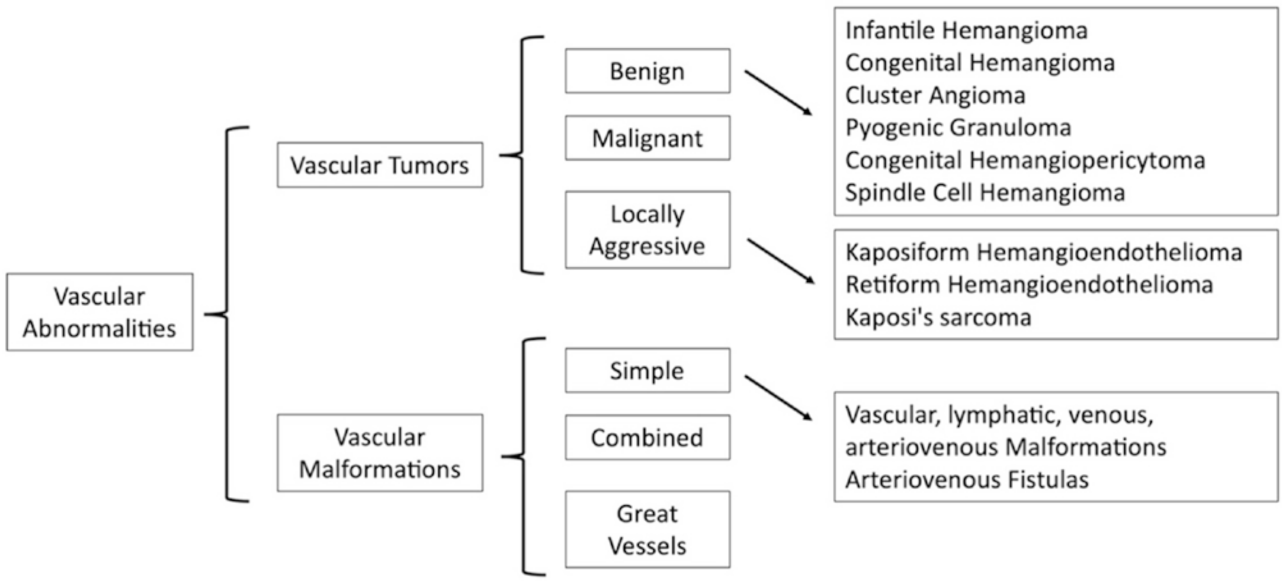


Fig. 13.23 Vascular abnormalities classification

[108]. Their growth is attributed to endothelial cell hyperplasia, they are classified as "children" or "congenital."

Another subclassification for hemangiomas is focal and segmental. Focal hemangiomas are localized and unilocular. Multifocal hemangiomatosis also exists, and newborns with more than five lesions should undergo a study to rule out visceral involvement [109]. Segmental hemangiomas are more diffuse in the form of a plaque and can lead to dysfunction and cosmetic alterations. The extremities and face are common places of appearance.

The current classification of vascular lesions can be consulted on the website of the International Society for the Study of Vascular Anomalies (ISSVA) [110–113]. As a summary, we can classify the vascular anomalies as seen in Fig. 13.23.

The presentation of hemangiomas is variable in terms of size, extent, and morphology. When there is superficial dermal involvement, the skin takes on a raised, firm appearance with a vivid crimson color. If the hemangioma is confined to the deeper dermis, subcutaneous tissue, or muscle, the overlying skin may be slightly raised and appear bluish in color. Hemangioma may present with a macular, telangiectatic appearance.

However, spontaneous involution may be incomplete, and ~15–20% of the residual lesion may remain. In cases of complete involution, scarring, replacement with fibrofatty tissue, tissue discoloration, and telangiectasia are generally observed. A total of 65.3% of affected patients are children. These lesions are more common among Caucasians, who have a prevalence of 10–12% [114].

Several treatment modalities were suggested for management of hemangiomas and vascular malformations. This will differ depending on the lesion's type, size, depth, and location [115]. Surgery has been the main form of treatment for these lesions although total removal is sometimes not possible due to the extent of the lesion, which may involve vital structures, significant deformity, prolonged pain, skin necrosis, nerve damage, systemic toxicity, and hemorrhagic phenomena [116].

Other possibilities include embolization, steroid therapy, cryosurgery, electrodessication, and laser therapy. High-power density laser treatment is an alternative, becoming one of the main treatment options for vascular lesions [117].

The mechanism of laser therapies in treating hemangiomas is achieved by targeting intravascular oxyhemoglobin, resulting in vascular injury. In general, laser irradiation is indictable for the treatment of early superficial hemangiomas or the superficial portion of a compound hemangioma, due to the limited penetration depth which is less than 5 mm [115]. However, Nd:YAG laser is more suitable for larger hemangiomas measuring up to 2 cm in depth. Percutaneous interstitial irradiation is another treatment modality that can be used for deep hemangiomas to avoid skin damage and to diminish lesions effectively. It is very frequent that vascular lesions are included between different planes, which makes it impossible to completely remove them due to the risk of injuring other structures. For this reason, when it is suspected that their anatomical relationship may pose problems, a detailed study of their location must be carried out. Nuclear magnetic resonance and selective arteriography, among others, are tests that can help us make the most appropriate therapeutic decision.

The use of different lasers for treatment of vascular lesions has been recommended in the literature. Any high-power density laser can be used, but it is convenient to know the effect the wavelength used will have, as well as the parameters applied on irradiated tissues. The most commonly used lasers are Nd:YAG and infrared diode lasers.

In the oral cavity, it is common to see isolated lesions that can be easily removed, but on some occasions their proximity to bone structures can hide a vascular shunt that could complicate the intervention and even jeopardize the patient's life.

Once the topographic scope of the lesion has been established, we can opt for different techniques; excisional biopsy, transmucosal thermocoagulation, or intralesional photocoagulation. However, before utilizing any interventional technique to manage a vascular lesion, a precise diagnosis should be obtained to determine the extent and flow pattern of the lesion. This will include having a thorough history of the present complaint and an accurate clinical examination. The extent and flow patterns of vascular malformations are usually confirmed depending on the findings of color Doppler ultrasound, MRI, or angiography.

13

For transmucosal thermocoagulation and intralesional photocoagulation techniques, it is recommended to infiltrate the bed of target lesions with local anesthesia without adrenalin to avoid vessel contraction. This will facilitate a homogeneous delivery of laser to the whole lesion.

Excisional Biopsy

In the case of excisional biopsies, any surgical laser that can emit a sufficient power density can be used. The most widely used lasers for this purpose are the CO_2 laser, Er:YAG, Er,Cr:YSGG and diode lasers. It is essential to consider that the fiber in infrared diode lasers must be activated to obtain the cutting effect. The emission parameters will vary depending on the laser which will be used. The lesion is removed by cutting through the healthy tissue that surrounds the visible lesion.

Unlike the other techniques—which will be discussed later, histological information can be obtained from an excisional biopsy.

Transmucosal Photothermal Coagulation

Another therapeutic option is transmucosal photothermal coagulation. This technique takes advantage of the mucosa's poor absorption of the applied laser wavelength, so that the energy accumulates in the hemoglobin contained in the vascular lesion.

This technique can be considered the least invasive of the three techniques proposed with the use of laser.

It is of high value to know the optimum wavelength absorbed by target tissue since this will be the basis of the success of the treatment. Figure 13.24 shows wavelength absorption peaks of different biological chromophores. It is important to note that it is a logarithmic graph and having a good understanding is paramount to anticipate the behavior of laser used.

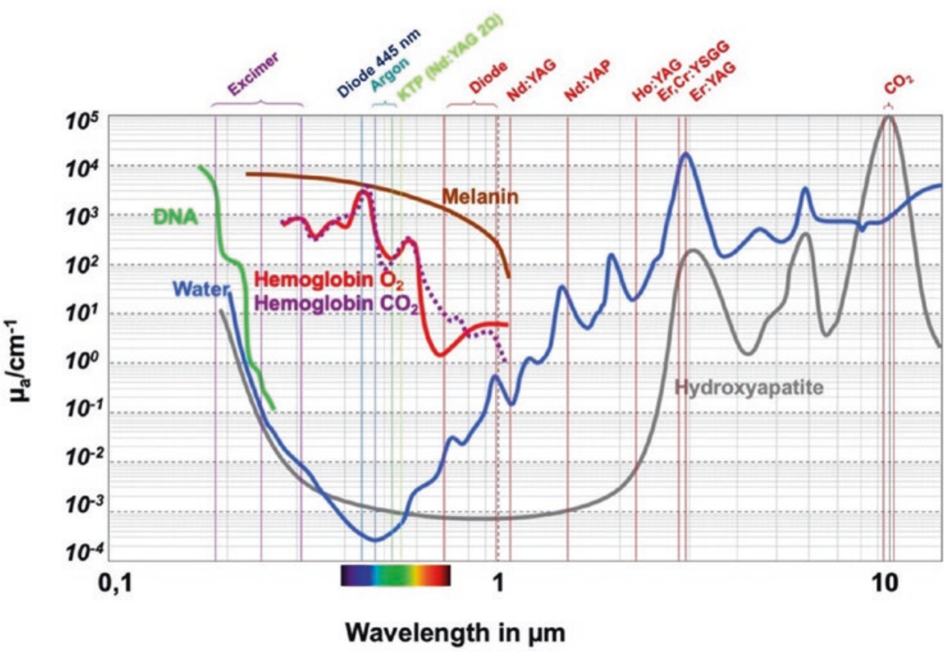


Fig. 13.24 Absorption graph according to laser wavelength for some tissue chromophores

The Nd:YAG laser is the laser of choice due to its high penetration depth of up to 5–6 mm in tissue, also being selectively absorbed by hemoglobin and poorly absorbed by water, which reduces the harmful effects on the surrounding connective tissue [118–124].

Near-infrared emitting diode lasers obtain similar absorption to Nd:YAG lasers and can also be used for the same purpose. Diode lasers (semiconductor lasers) have a range of wavelengths, which are in the visible and near-infrared spectrum. However, the 800–980 nm wavelengths are often used to treat superficial oral vascular lesions due to their good absorption by hemoglobin. The laser beam penetrates deeply into the tissue, down to a depth of 4–5 mm causing coagulation in the lesion that extends 7–10 mm because of the generated heat [125–128].

The penetration will be greater for the least absorbed wavelength, which will provide greater safety and a higher chance of completely eliminating the lesion. For this indication, the fiber should always be used without initiation.

Transmucosal photothermal coagulation (PHC) includes delivering the laser beam through a flexible quartz fiber, without contact between the fiber tip and the surface of the lesion (1–4 mm in distance). Also, a microscopic glass slide can be used to allow greater penetration of the laser beam into the lesion. Continuous wave mode can be used with a power of 2–6 W, or pulsed wave mode with a power of 6–12 W. Sweeping movements are applied from the circumference to the center of the lesion until blanching and shrinkage of the surface become clear [114, 129–133].

Transmucosal photothermal coagulation is indicated in the treatment of small to moderate vascular lesions in anticoagulated patients since the risk of bleeding is greatly reduced. By using this technique, no specimen will be available for histopathological evaluation. Another drawback is the lack of knowledge of the lesion being completely irradiated since the intraoperative appearance can be confusing, which would demand carrying out additional treatment sessions if the lesion has not disappeared in the following weeks.

Intralesional Photocoagulation

In some cases, the size and anatomical relationships of the lesion make excision or transmucosal photocoagulation unfeasible. Lesions that extend from the cutaneous plane to the mucosa, crossing subcutaneous tissue and muscle, or lesions of close proximity to the bone, can pose a risk to the patient's life. Accordingly, when a complete removal of large or extended vascular lesions is not achievable, partial removal or volume reduction of the lesion may help improve the patient's quality of life.

Intralesional photocoagulation (ILP) also called the "interstitial technique," depends on the direct puncture of the lesion by a needle connected to the end of the fiber. It should be inserted to cover the entire thickness of the lesion and moved in a radial pattern as photocoagulation is proceeded within the tissue. Continuous or pulsed wave modes can be used with a power of 9–13 W. The endpoint of treatment is obtaining pallor of the lesion, but the effectiveness of mentioned technique is limited when dealing with large and thick lesions [116]. The considerations in relation to the wavelength to be used are similar to wavelengths applied in transmucosal photothermal coagulation [130, 134–138].

In order to achieve optimal results, each clinical situation must be evaluated, as well as the wavelength and the parameters to be used. The clinician must select the best wavelength, from those available, to design the treatment strategy. In the same intervention, all the techniques described can be used when the injury requires it.

▣ Figure 13.25 depicts a clinical case of a large vascular formation that was present on the lip of a 72-year-old female patient with an inconspicuous medical history. The patient reported that the lesion had been slowly growing over a period of 10 years, but she was given medical advice to not treat it. A diode laser was used in a non-contact mode, and 4 weeks postoperatively, the lesion had disappeared.

▣ Figure 13.26 is that of a 78-year-old patient with a medical history consisting of hypertension, cardiac insufficiency, and cardiac dysrhythmia was taking Coumarin for anticoagulation therapy. A diode laser performed an excisional biopsy, and the tissue was determined to be a non-malignant vascular malformation. A 5-day postoperative photo shows the wound healing satisfactorily and that is expected to continue.

▣ Figure 13.27 shows a 65-year-old female patient with a medium size vascular lesion on the central part of her lower lip. Her medical history is non-contributory. The patient recalls biting her lip several months ago and she is concerned about the aesthetic appearance. A carbon dioxide laser was used for an excision. One month later, the tissue healed. Clinical case courtesy of Dr. Rick Kava.

▣ Figure 13.28 depicts a non-aesthetic hemangioma on the lower lip of a 72-year-old female, with a non-contributory medical history. The large lesion extends from the vermillion border to the mucosa. A diode laser was used in a non-contact mode to allow the laser radiant energy to penetrate into the lesion. A 3-month postoperative view shows complete healing. Clinical case courtesy of Dr. Giuseppe Iaria.

▣ Figure 13.29 depicts a clinical case of a large vascular formation that was seen on the upper lip of a 4-year-old male patient with no remarkable medical history. The parent reported that the lesion was observed since birth and had been slowly growing over the years. The patient was first prescribed Propranolol 3 mg/kg (beta-blocker) for 4 months before the laser application. This can effectively control the proliferation of heman-

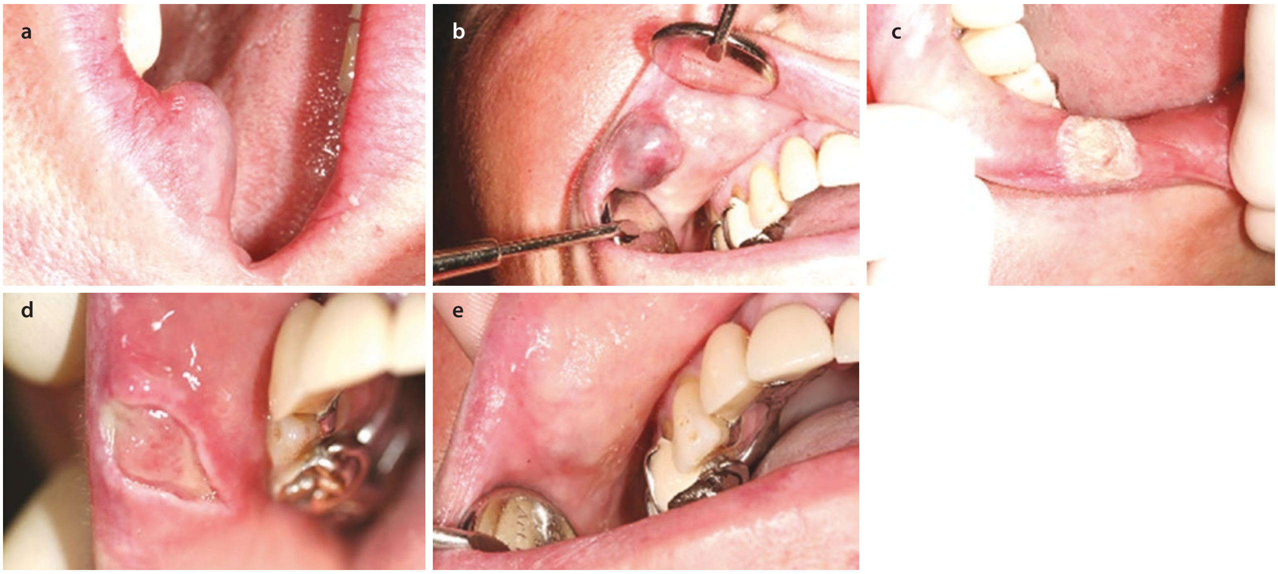


Fig. 13.25 **a**, **b** Two pre-operative views of a vascular malformation on the upper right lip. **c** Immediate postoperative view. An 810 nm diode laser was used with a non-initiated 600 μm glass fiber out of contact with the tissue at 2.5 W continuous wave. Fluence 128 J/cm^2. The laser was activated until the tissue appeared blanched, and then the laser was turned off. **d** A 1-week postoperative view shows granulation is proceeding. **e** Four-week postoperatively, the area is healed and the lesion disappeared

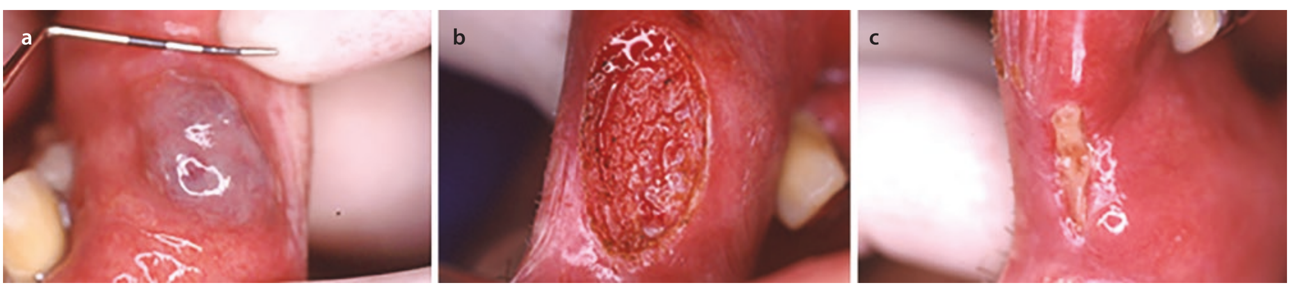


Fig. 13.26 **a** Pre-operative view of a large vascular malformation lesion on the lower lip. **b** An 810 nm diode laser was used with a 400 μm glass fiber in contact with 30 W, 12,500 Hz, and a 10 μs pulse duration. Average power 3.75 W. Fluence 928 J/cm^2. **c** A 5-day postoperative photo shows normal wound healing

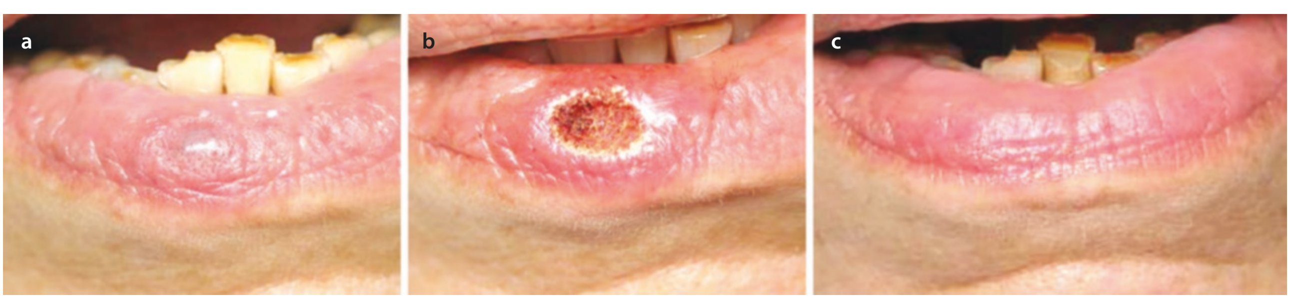


Fig. 13.27 **a** Pre-operative view of the hemangioma on the central area of the lower lip. **b** Immediate postoperative view of the lesion ablation. A 10,600 nm Carbon Dioxide laser was used with an average power of 2 W in SP mode with a 400 μm non-contact tip. Fluence 289 J/cm^2. **c** A 6-week postoperative photo showing complete resolution of the vascular lesion

gioma and promote its regression. The Nd:YAG laser was used in the transmucosal photothermal coagulation technique, in which the laser was applied in non-contact mode through a glass slide placed with added compression over the lesion. This will prevent the laser from penetrating the lining mucosa above the lesion and help in

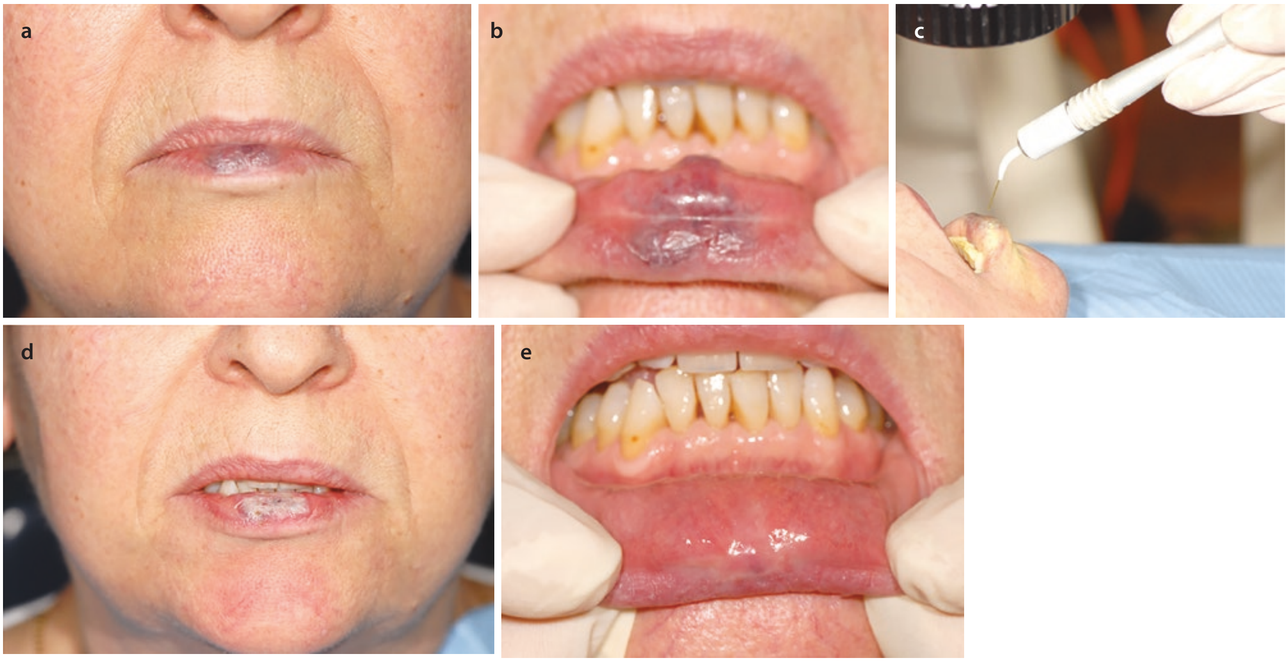


Fig. 13.28 **a** Pre-operative view of a hemangioma on the lower lip from the extraoral view. **b** The intraoral view showing the extent of the lesion to the inner mucosa. **c** An 808 nm diode laser was used with a 400 μm non-initiated fiber in non-contact, approximately 2 mm from the tissue surface. Average power 3.0 W CW. Fluence 154 J/cm^2. The handpiece was in constant movement with a circular motion, covering the extent of the lesion. No anesthesia was used, and the patient was comfortable. **d** The immediate postoperative view after 1 min shows the tissue is light gray color. Ice was applied for 2 min to reduce edema of the surrounding tissues. **e** Three-month postoperative view shows complete tissue healing. (Clinical case courtesy of Dr. Giuseppe Iaria)

Fig. 13.29 **a** The initial clinical appearance of a hemangioma affecting the upper lip and philtrum. The lesion gradually increased in size since birth. **b** An irradiation session, in which the transmucosal photothermal coagulation technique was applied, used Nd:YAG laser with pulse mode to facilitate vessels shrinkage inside the lesion without damaging the superficial surface of the lesion. This was achieved by delivering the laser in non-contact mode through a glass slide placed with added compression over the lesion. **c**, **d** A complete resolution of the vascular lip lesion after five irradiation sessions. The patient is set to undergo a surgical intervention to correct the lip asymmetry after puberty

lasing the lump homogenously. Obviously, the Nd:YAG laser was applied in pulse mode with following operating parameters: 3 W, 60 Hz, and 50 mJ. Five sessions were required. The case requires cosmetic correction after puberty and complete development of the lip.

The clinical appearance of multiple vascular lesions noticed on the right buccal mucosa which were treated previously without complete resolving (◘ Fig. 13.30). An Er,Cr:YSGG laser with the following parameters was used: 2 W (100 mJ per pulse), 20 Hz, pulse duration 140 μs with a fiber tip of 800 μm, 12% water, and 12% air for irrigation. No anesthesia was used in this procedure. All lesions were resected in the same session and left to heal by secondary intention. Complete re-epithelization was achieved after 3 weeks.

A 32-year-old woman who presented with a deformity in the lip/nose area on the right side of her face (◘ Fig. 13.31). It was a congenital lesion that increased

◘ **Fig. 13.30** **a** Multiple vascular lesions appearing on the buccal mucosa. **b**, **c** Lesions removal using Er:Cr:YSGG. Cutting was performed about 1–2 mm outward of the lesion margin to avoid lesion penetration and incidental bleeding. **d** Immediate postoperative. **e** Healing process after 1 week of treatment. **f** Three weeks post laser application view showing uneventful healing

Fig. 13.31 **a**, **b** A vascular lesion affecting the right upper lip producing facial asymmetry. **c**, **d** Intraoral view of the lesion which measures about 2 cm in diameter. **e**–**g** The intralesional lasing technique was used by inserting a 320 µm optical fiber within a cannula through the lesion wall to the center of the lump, passing 2–3 mm beyond the end of the cannula, while laser emission is activated. The 980 nm diode laser, 1 W in continuous mode was used in this case. **h** Three weeks post laser application showing significant reduction in lesion size with no sign of scaring or discoloration

slowly in size over time, which was prominent over the last year. The pre-operative study showed a vascular lesion that extended from the cutaneous plane to the mucosa, crossing the levator labii superioris muscle, the zygomaticus minor muscle, the risorius muscle and, partially, the orbicularis oris muscle. In her previous consultation visits, she had been advised against carrying out any treatment due to the high risk of a worse unsightly result. As there being a possibility to reduce the volume of the lesion, the intralesional technique was performed with the help of a 980 nm laser, 1 W in a CW. One cartridge of 0.5% articaine anesthetic solution with 1:200,000 epinephrine was infiltrated, half the amount near the infraorbital nerve and the other half on the anterior superior alveolar nerve. The procedure was performed by inserting a 320 µm optical fiber within a cannula, through the lesion wall. The fiber was passed through the proximal end of the clamp no more than 2–3 mm beyond the end of the cannula while laser emission was activated. Clinical case courtesy of Prof Antoni J. España.

A 14-year-old female was diagnosed with an upper lip congenital hemangioma, exhibiting consistent enlargement overtime (◘ Fig. 13.32). The patient presented complaining of her lip asymmetry. Surgical resection of the lesion was excluded as it would cause unfavorable deformity of the lip. The transmucosal photothermal coagulation technique was used to reduce the volume of the vascular lesion using the Nd:YAG laser with a wavelength of 1064 nm, offering a penetration depth of 4–6 mm by non-contact mode. The following parameters was applied: 3 W, 50 Hz, and 60 mJ. The laser beam was delivered using a 320 µm fiber tip and laser irradiation was applied 2 mm away from the visible

13

◘ **Fig. 13.32** **a**, **b** Initial clinical appearance of a hemangioma affecting the right upper lip. The lesion showed a persistent increase in size especially over the last year. MRI was organized to determine the extent and the flow pattern of the lesion. **c**, **d** First irradiation session. For aesthetic and function purposes, transmucosal photothermal coagulation technique using Nd:YAG laser with pulse mode was applied to facilitate vessels shrinkage inside the lesion without damaging the superficial surface of the lesion. Immediately after radiation, the treated area turned off-white, with a surrounding erythematous flare with a slight swelling. **e**, **f** A 2 weeks view post laser irradiation showing a good recovery with fibrin residues. **g**, **h** A complete resolution of the lip vascular lesion after seven irradiation sessions. **i**, **j** The patient underwent a surgical intervention to correct the lip asymmetry. **k**, **l** Six weeks post-surgery, whereby the final result was remarkable with no sign of scaring or discoloration

Fig. 13.32 (continued)

Fig. 13.32 (continued)

margins of the lesion toward its center in a spiral mode. Treatment was repeated at an interval of 4 weeks for seven treatment sessions. Subsequently, the patient underwent a surgical correction to re-contour the residual deformity and hypertrophied tissues in the lip, in order to improve cosmetics and competency.

13.5.2 Mucocele

A mucocele is considered the most common minor salivary gland disorder with a high incidence rate among older children or young adults in both genders, nonetheless, mucoceles have been reported in patients of all ages [139]. It is caused by accumulation of mucus following rupture of a salivary gland or a traumatic injury to its duct in which the saliva spills into the oral cavity's subepithelial tissue [77]. Clinically, it appears as a round, well-circumscribed, asymptomatic dome-like swelling that ranges from a few millimeters to several centimeters in size. Depending on the persistency and the amount of mucosa accumulated inside the lesion, the outer surface may exhibit deep blue to pinky-pale color [140]. Mucoceles are usually painless, however, in some persistent long-standing cases, the size of mucoceles can cause discomfort and interfere with speech, chewing and swallowing and even causes a concern to the patients from being sinister lesion [141]. Although the lower lip is the most common site for a mucocele, it is also present on the ventral tongue, the floor of the mouth, and check mucosa [142].

According to its cause, mucoceles are classified as retention cysts and extravasation accumulations. Extravasation mucoceles are considered pseudo-cysts as no epithelial lining is detected histopathologically. In contrast, retention mucoceles are true cysts with cubic or squamous cell epithelial linings [77]. They are less common but more frequent among major salivary gland ducts as a result of ductal obstruction by a calculus or scar that interferes with the normal salivary flow causing mucosal lump and ductal dilatation.

In some cases, extravasation mucoceles can regress spontaneously with no sign of recurrence. Treatment is only necessary when the patient's function is impaired. Several treatment modalities of mucoceles have been described in the literature including: cryosurgery, intra-lesion injection of corticosteroid, micro-marsupialization, conventional surgical removal, and laser ablation [142, 143].

Excision can be performed by scalpel which can be challenging since there is no true cystic capsule. Similarly, a laser can also lacerate the lesion; but, with a fiber delivery, it is possible to weld the injured and now overlapping wound edges together. This can conserve some of the form of the cyst and gland without blindly dissecting too much tissue. In deep excisions, two or three sutures are placed to avoid food impaction and allow healing to occur. Patients report very little pain or loss of function. Wound healing is by secondary intention.

Ramkumar et al. suggested using diode laser in wavelength of 940 nm, with fiber tip 400 μm at 1.5 W in continuous mode. The initial incision was performed on the uppermost site of the swelling and then the lesion was resected completely down to the muscular layer [144].

Choi et al. depending on available data of 164 patients found that oral mucocele recurrence is significantly higher on the ventral tongue (50%) than on the labial/buccal mucosa. In addition, patients aged under 30 years old exhibited a higher recurrence rate (16.0%), compared with older individuals (aged >30 years, 4.4%). With respect to intervention method, both surgical procedures using scalpels and those using laser showed similar recurrence rate [145].

Figure 13.33 is a 16-year-old female who has a recent history of biting her lower lip. A rounded swelling with semi-translucent appearance suggested the development of a mucocele. Under local anesthesia, the lesion was surgically dissected, taking advantage of laser hemostasis and using a diode 980 nm laser. The lesion was removed intact, to facilitate histological examination. Early (5 days) and later (1 month) indicate uneventful healing, attributable in part to wavelength-associated PBM.

Figure 13.34 is a 22-year-old patient who had a sublingual retention cyst for more than 2 months. The swelling appeared after a traumatic injury to the floor of the mouth, causing a scar in the salivary gland duct which obstructed saliva flow. The occlusal view was negative with no sign of calcified stones. The outer surface of the swelling was removed by a diode laser with a wavelength of 810 nm and power of 2.5 W. The patient showed a good recovery after 1 month postoperatively.

Figure 13.35 is a healthy, non-smoking 26-year-old female, was concerned about a lump on her lower lip that had been growing for 3 months, measuring about 5 mm in diameter. It was soft on palpation with a bluish color, nonetheless, blanching test was negative. The

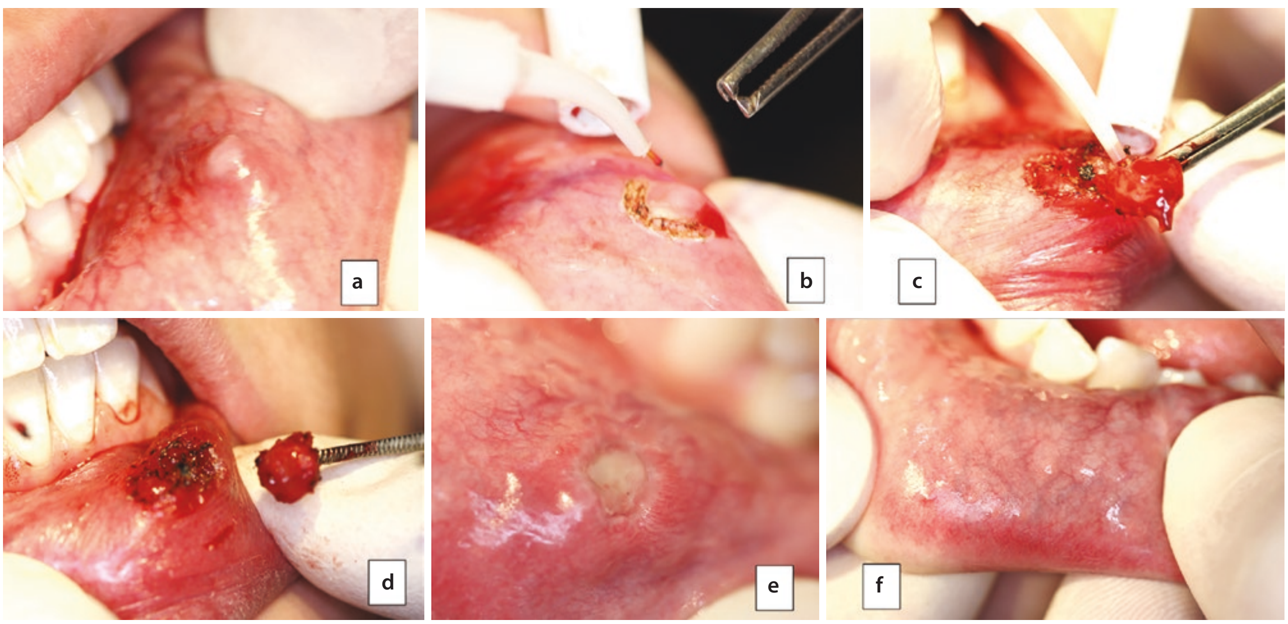


Fig. 13.33 **a** Pre-operative appearance of rounded translucent swelling lower lip in a 16-year-old female. History of recent biting trauma. **b**, **c** Using a 980 nm diode laser and 320 µm quartz fiber 1.2 W CW power parameters, together with incisional hemostasis, it was possible to dissect the lesion. **d** Immediate postoperative appearance. No sutures required. **e**, **f** Early (5 days) and later (1 month) uneventful healing and complete resolution of the surgical site. (Case courtesy Prof. Steven Parker)

Fig. 13.34 **a** A well-defined retention cyst on the on the floor of the mouth expanding for more than a month. **b** The cyst was excised using the 810 nm diode laser. **c** No relapse was seen after 1 month and the operation bed showed good recovery

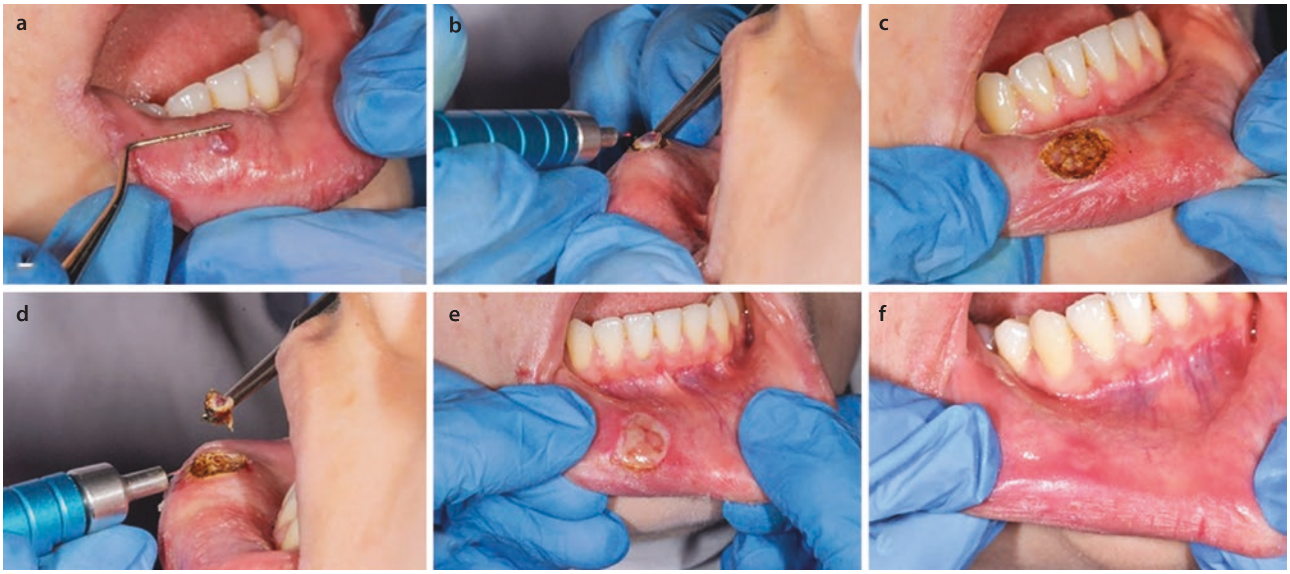


Fig. 13.35 **a** Mucocele of the right lower lip was recognized at 3 months. **b** The 810 nm diode laser with initiated 300 mic tip was used to remove the lesion. **c**, **d** Excision area extended down to the muscular layer and the surgery bed was left to heal with secondary intension. **e** Ten days postoperatively. **f** One-month post laser surgery with no sign of recurrence or scaring

810 nm diode laser was used to excise the lesion, which was identified as a retention cyst. The excision area was left to heal with secondary intention with no need for dressing or closure sutures.

13.5.3 Sialolithiasis

Sialolithasis is the occurrence of a salivary stone or calculus and is a frequent cause of inflammatory changes within the large salivary glands. Statistics show that over 78% of salivary stone formation affect the submandibular gland and 81% appear in the parotid gland; but is a rare occurrence in the sublingual gland, though not totally unknown [146]. Clinical practice detects signs of stone formation in 1 out of 10,000 patients. The incidence in male patients is 2–3 times higher than in females. The greatest presence can be found in the age range of 50–70 years, but sialiths have been reported in children. Some reports assume a correlation between sialolithiasis and other stone diseases as urinary or biliary stones, but large multicenter studies show no correlation at all [146, 147]. Major salivary gland stones are usually measured between 5 and 10 mm in size. Giant sialoliths is a term used to describe those stones exceeding 15 mm in any one dimension [148].

The typical symptoms include a painful swelling of the affected salivary gland which is intensified by chewing and at mealtimes. The diagnosis is based on the clinical symptoms, ultrasound examination, radiographic imaging, and endoscopic evaluation. Other symptoms can be due to an obstruction such as one in Wharton's duct in the floor of the mouth resulting in an infection of the gland. Chronic inflammation may lead over time to an atrophic replacement of the acinar cells by scar and fatty tissue [149]. An acute inflammation is often the first sign of a sialolithiasis even in the presence of an extensive calculus formation. Instead of extirpating the gland, a different therapeutic concept has been developed nowadays which analyzes the location and size of the stones [150]. In cases of normally small size parotid stones, a basket extraction shows promising results. Also extracorporeal sonographically controlled lithotripsy plays a major role in therapy. Endoscopic techniques can more precisely locate the stones. Although extra- and intracorporal lithotripsy show excellent results, that method is not often used due to accessibility and cost of the apparatus.

A trans oral approach has been established as an alternative; as a result, more than 90% of all submandibular stones can be removed preserving the gland. After sounding the duct to locate the stone, it is easy to incise the tissue and locate the stone which can be mobilized and removed. Following the incision using a 320–400 μm surgical fiber, a dissecting scissors is used to dilate the incision wound and expose the sialolith. After the exposure, the sialolith is grasped with the mosquito hemostat or forceps and removed from the duct. Once the stone is retrieved, the duct is marsupialized into the floor of the mouth with 5/0 vicryl sutures [151]. Checking duct patency is an essential step after sialolithotomy, in

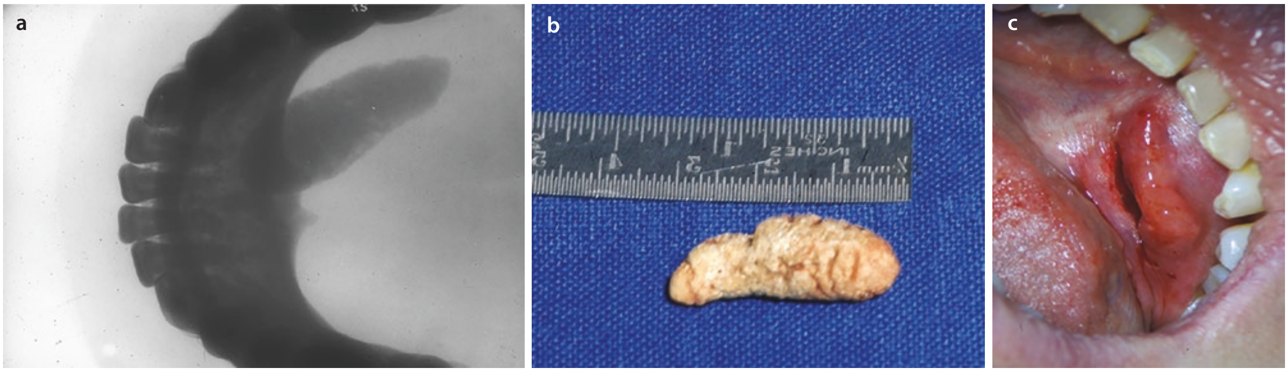


Fig. 13.36 **a** A radiograph of the area showing a large sialolith in the Warton's duct. X-ray shows a large sialolith in the Wharton's duct. **b** A photo of the excised sialolith. An 810 nm diode laser was used for the incision with a 200 µm glass fiber in contact with the tissue at 30 W, 12,500 Hz, and a 9 µs pulse duration. Average power 3.38 Watts. Fluence 554 J/cm^2. **c** Immediate postoperative view shows good hemostasis. No sutures were placed and healing is expected to be normal

some cases, a micro-drainage may be placed in the duct to avoid scar formation and blockage of the duct. Conventional instrumentation offers no control of bleeding and with the flow of saliva, visibility can be extremely difficult during the surgery. A laser insures good hemostasis and therefore a good overview of the operation site. Sutures are not usually placed, and the healing is uneventful healing with little scaring [152–154]. Accordingly, several laser wavelengths have been employed to treat sialolithiasis, including carbon dioxide, diode, Ho:YAG, and Nd:YAG lasers.

▶ Angiero et al. reported the efficacy of 810 nm diode laser as an alternative surgical tool to remove stones from the submandibular duct even those over 4.5 cm in size. The laser was used in continuous mode at 2.5 W power, and the beam was delivered using a 320-µm flexible fiber [152].

Figure 13.36 shows a clinical case of a 48-year-old male smoker presented with a painful swelling submandibular which intensifies during chewing and eating. His medical history includes hypertension and hyperlipidemia. A radiograph was taken and the diagnosis was made as sialolithiasis. A diode laser performed the incision, and the stone was removed. No sutures were placed and the healing is expected to be normal.

Figure 13.37 is a 56-year-old female complained of firm painful swelling in the right floor of the mouth. The clinical and radiological examination confirmed the presence of a 1 cm stone in the submandibular gland. The 980 nm diode laser was used to create an incision over the stone. A dissecting scissor was used to dilate the incision wound to facilitate the stone's removal. A micro-drainage was placed in the duct for 3 days after stone retrieval to avoid scar formation and blockage of the duct. The patient was seen in 1 month time with no sign of swelling or salivary flow disturbance.

13.5.4 Excessive Gingival Display (Gummy Smile)

A smile is the most essential expression on a person's face. It has a vital role in facial attractiveness, and it can positively affect the patient's social interactions. However, an ideal smile comes from a balance between three mutually related main factors: teeth, gingiva, and lips [155]. Increased interest has been shown to rectify excessive gingival display in growing numbers of individuals. Reports demonstrate a prevalence of 7% in males and 14% in females. Several factors may take part in producing this aesthetic issue. For instance, delayed tooth eruption, a short or hypermobile upper lip, gingival hyperplasia, and skeletal reasons [156]. Nevertheless, lip repositioning surgery had seen the light for the first time by Rubinstein and Kostianovsky in 1973, and it was considered as an effectual, safe, and predictable approach to manage gummy smiles with an average of 2.71 mm of exposed gingiva [157]. However, gummy smiles can be managed using several treatment approaches. For example, orthognathic surgery, orthodontic intrusion, crown lengthening, botulinum toxin, and lip repositioning. Thus, the underlying causing factor should be identified decisively in order to determine the appropriate treatment plan accurately [158]. The concept includes the removal of a partial-thickness mucosal strip from the vestibular alveolar mucosa of the internal upper lip, then suturing the apical edge of the exposed wound to the mucogingival margin aiming to shorten the vestibule and reduce lip movements. Whereas various modifications were dissimilar to the original technique, some of them described a full-thickness flap excluding the frenum by creating a V-shape in the middle of the flap [156].

Fig. 13.37 **a** Painful swelling associated with the right submandibular gland duct. The location of the stone was confirmed radiographically. **b** Incision was performed using the 980 nm diode laser which helped in stone removal. Then a micro-drainage was placed inside the duct and sutured to adjacent mucosa to enhance saliva flow and prevent scar formation. **c** 1 cm sialolith was removed from the duct. **d** One-month view of the floor of the mouth showed uneventful healing with normal saliva flow from the salivary gland orifices

Laser surgery is considered as a proper alternative tool in soft tissue oral surgeries due to its recorded advantages in decreasing the postoperative complications and in accelerating the healing process. Putting in mind the fact that the CO_2 laser is the laser of choice in the majority of soft tissue oral surgeries, consequential to its efficient role in providing coagulation and an extraordinary visual surgical field during the procedure even in the extremely vascularized tissues [159, 160].

Lip repositioning using laser surgery is an effective, safe, and predictable approach to manage excessive gingival display caused by soft tissue disorders (short upper lip or hyperactive elevator muscles). The procedure is explained step by step in the related photos in Fig. 13.38.

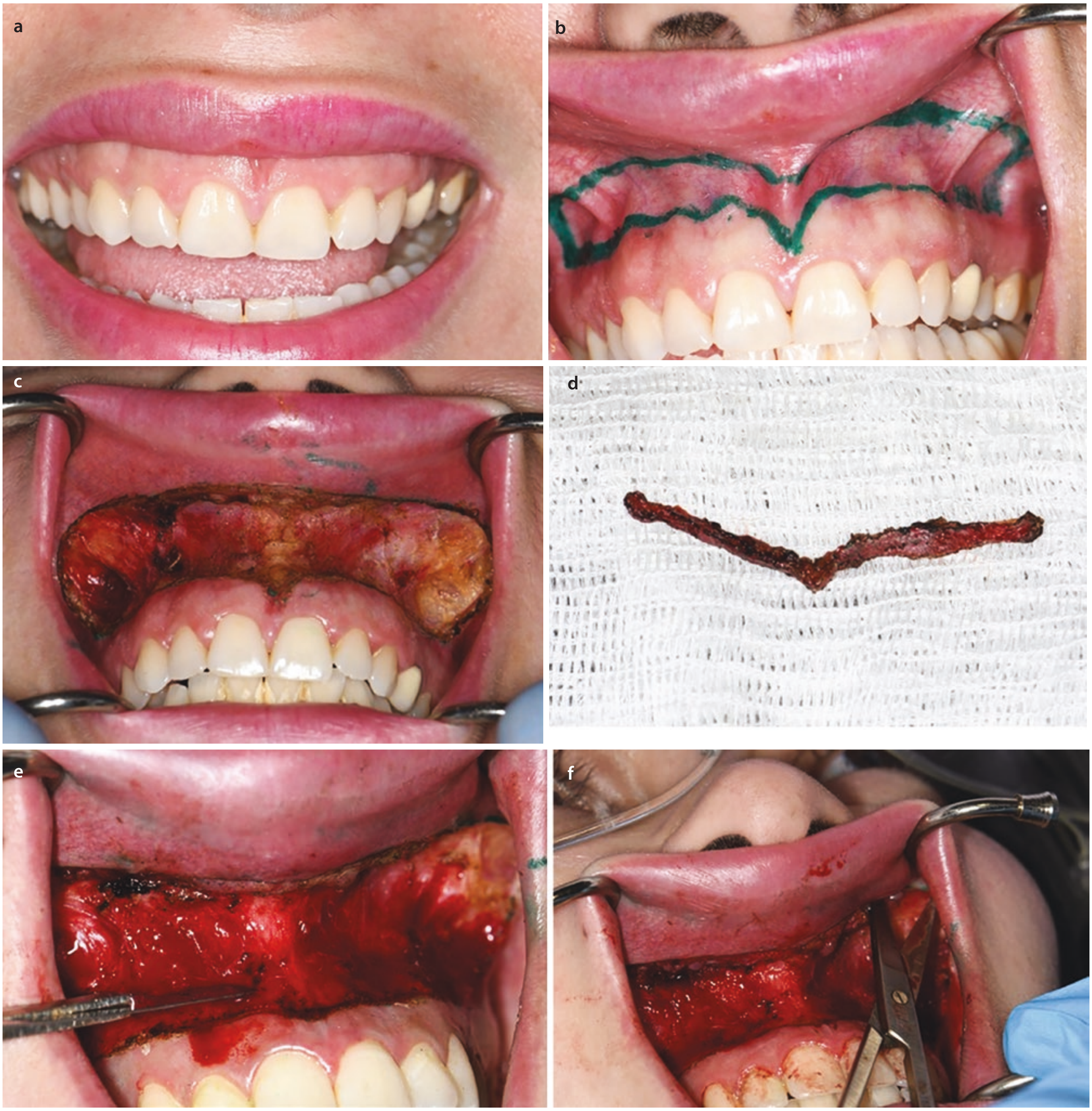


Fig. 13.38 **a** A 24-year-old female presented complaining of an excessive gingival display while smiling. **b** The tissue was dried prior to marking of the incision outlines using a sterile surgical marking pen, the margins were made 1 mm coronal to the mucogingival line in order to achieve accurate suturing from the distal line of the second premolar in both of the right and the left sides, in addition, a V-shape was made in the area of the upper lip frenum. Thus, the lip midline was punctually determined and the symmetry was well achieved. Then the second incision was made in the labial mucosa parallel to the first incision and 10–12 mm apical to it, the two incisions were connected. **c** A partial thickness epithelial strip was carefully removed utilizing 10,600 nm CO_2 laser with 4 W in continuous mode, this facilitated complete resection of the strip without bleeding. **d** A strip of mucosa removed by CO_2 laser demonstrates a partial-thickness flap removed without bleeding. **e**, **f** A 15 blade was used in peeling movements to encourage a slight bleeding which helps in accelerating the wound recovery, also the margins were dissected about 2 mm around to minimize tension during wound suturing. **g** Subsequently, the wound's borders were sutured with interrupted technique using 4/0 silk sutures. The first one was performed in the midline in order to ensure the symmetry of the lip. **h** A couple of indicative sutures in the midpoint of the canines areas in each side, so that two windows were made in order to compare the symmetry of the lip. Additional sutures were used in the rest of the two regions. **i** Follow-up appointment illustrates the punctual midline and crystal-clear lip symmetry

Fig. 13.38 (continued)

13

13.6 Conclusion

The use of lasers in oral soft tissue surgery is beneficial for patient and surgeon. The good hemostasis provided offers a better view of the operation site and can help to make the procedure more straightforward and even easier for both the accomplished and the novice surgeon. Treatment for patients with bleeding problems becomes possible. Wound healing is mostly uneventful. Conventional biopsies, so necessary for histological verification, can be easily taken. Depending on the choice of parameters, soft tissue surgery can be performed with all available wavelengths. On some instruments, a fiber-based delivery system facilitates accessibility in areas with challenging anatomy, such as undercuts. All told, for many indications laser treatment is superior to conventional therapy in many instances and can help to deliver safe and effective dental care.

Acknowledgment To Dr. Claus Neckel for his valuable contribution in the first edition of this chapter. The author would like to thank: Prof. Peter J. Thomson for the encouragement and advice he has provided throughout my time as his PhD student at Newcastle University, especially his advice on how to use the CO_2 laser in oral and maxillofacial surgery. I also wish to express my appreciation to all the members of staff and my postgraduate students in the Oral Medicine department and the Higher Institute of Laser Research and Application at Damascus University-Syria.

References

1. Gaspar L. The use of high-power lasers in oral surgery. J Clin Laser Med Surg. 1994;12(5):281–5. PMID: 10150673.
2. Shafir R, Slutzki S, Bornstein L. Excision of buccal hemangioma by carbon dioxide laser beam. Oral Surg Oral Med Oral Pathol. 1977;44(3):347–50. https://doi.org/10.1016/B978-0-08-013320-1.50016-6.
3. Maiman TH. Stimulated optical radiation in ruby. Nature. 1960;187:493–4. https://doi.org/10.1038/187493a0.
4. Einstein A. Zur quantentheorie der strahlung. [Article in German]. Phys Z. 1917;18:121–8.
5. Schawlow A, Townes C. Proposal of laser. Phys Rev. 1958;112(6):1940.
6. Snitzer E. Optical maser action of Nd^{+3} in a barium crown glass. Phys Rev. 1961;7(12):444. https://doi.org/10.1103/PhysRevLett.7.444.
7. Lobene RR, Fine S. Interaction of laser radiation with oral hard tissues. J Pros Dent. 1966;16(3):589–97. https://doi.org/10.1016/0022-3913(66)90066-7.
8. Hall RN, Fenner G, Kingsley J, Soltys T, Carlson R. Coherent light emission from GaAs junctions. Phys Rev. 1962;9(9):366. https://doi.org/10.1016/B978-0-08-013320-1.50022-1.

9. Nathan MI, Dumke WP, Burns G, Dill FH Jr, Lasher G. Stimulated emission of radiation from GaAs pn junctions. Appl Phys Lett. 1962;1(3):62–4. https://doi.org/10.1063/1.1777371.
10. Holonyak N Jr, Bevacqua S. Coherent (visible) light emission from Ga ($As_{1-x}P_x$) junctions. Appl Phys Lett. 1962;1(4):82–3. https://doi.org/10.1063/1.1753706.
11. Quist T, Rediker R, Keyes R, Krag W, Lax B, McWhorter AL, et al. Semiconductor maser of GaAs. Appl Phys Lett. 1962;1(4):91–2. https://doi.org/10.1063/1.1753710.
12. Hibst R, Keller U, Steiner R. Die wirkung gepulster Er:YAG Laserstrahlung auf zahngewebe. Laser Med Surg. 1988;4:163–5.
13. Hibst R, Keller U. Experimental studies of the application of the Er:YAG laser on dental hard substances: I. Measurement of the ablation rate. Lasers Surg Med. 1989;9:338–44. https://doi.org/10.1002/lsm.1900090405.
14. Das S, Mohammad S, Singh V, Gupta S. Neodymium:Yttrium aluminum garnet laser in the management of oral leukoplakia: a case series. Contemp Clin Dent. 2015;6(Suppl 1):S32–5. https://doi.org/10.4103/0976-237x.152934. PMID: 25821371.
15. Parker S, Cronshaw M, Grootveld M, George R, Anagnostaki E, Mylona V, Chala M, Walsh L. The influence of delivery power losses and full operating parametry on the effectiveness of diode visible-near infra-red (445–1064 nm) laser therapy in dentistry-a multi-centre investigation. Lasers Med Sci. 2022;37(4):2249–57. https://doi.org/10.1007/s10103-021-03491-y.
16. Farah C, Savage N. Cryotherapy for treatment of oral lesions. Aust Dent J. 2006;51(1):2. https://doi.org/10.1111/j.1834-7819.2006.tb00392.x.
17. Parker S, Cronshaw M, Anagnostaki E, Mylona V, Lynch E, Grootveld M. Current concepts of laser-oral tissue interaction. Dent J (Basel). 2020;8(3):61. https://doi.org/10.3390/dj8030061.
18. Parker S. Lasers and soft tissue: 'loose' soft tissue surgery. Br Dent J. 2007;202(4):185–91. https://doi.org/10.1038/bdj.2007.128.
19. Luomanen M, Meurman J, Lehto VP. Extracellular matrix in healing CO_2 laser incision wound. J Oral Pathol Med. 1987;16(6):322–31. https://doi.org/10.1111/j.1600-0714.1987.tb00702.x.
20. Zeinoun T, Nammour S, Dourov N, et al. Myofibroblasts in healing laser excision wounds. Lasers Surg Med. 2001;28(1):74–9. https://doi.org/10.1002/1096-9101(2001)28:1%3C74::aid-lsm1019%3E3.0.co;2-b. PMID: 11430446.
21. Gáspár L, Tóth J. Comparative study on wound healing in the oral cavity following experimental surgery using a scalpel, electrocauterization and CO_2 laser beam. Fogorv Sz. 1991;84(11):339–43. PMID: 1773835.
22. Neckel CP. Comparative study on cw mode versus pulsed mode in AlGaAs-diode lasers. In: Proc SPIE 4249, Lasers in dentistry, vol. VII. Bellingham, WA: BiOS 2001 The International Society for Optical Engineering; 2001. p. 44–9. https://doi.org/10.1117/12.424515.
23. Warnakulasuriya S, Johnson N, Van der Waal I. Nomenclature and classification of potentially malignant disorders of the oral mucosa. J Oral Pathol Med. 2007;36(10):575–80. PMID: 17944749.
24. Warnakulasuriya S, Kujan O, Aguirre-Urizar JM, et al. Oral potentially malignant disorders: a consensus report from an international seminar on nomenclature and classification, convened by the WHO Collaborating Centre for Oral Cancer. Oral Dis. 2021;27:1862–80. https://doi.org/10.1111/odi.13704.
25. Brouns E-R, Baart JA, Bloemena E, et al. The relevance of uniform reporting in oral leukoplakia: definition, certainty factor and staging based on experience with 275 patients. Med Oral Patol Oral Cir Bucal. 2013;18(1):19–26. https://doi.org/10.4317/medoral.18756.
26. Abidullah M, Kiran G, Gaddikeri K, et al. Leukoplakia—review of potentially malignant disorder. J Clin Diagn Res. 2014;8:ZE01–4. https://doi.org/10.7860/jcdr/2014/10214.4677.
27. Thomson PJ, Hamadah O. Cancerisation within the oral cavity: the use of 'field mapping biopsies' in clinical management. Oral Oncol. 2007;43(1):20–6. https://doi.org/10.1016/j.oraloncology.2005.12.019.
28. Axell T, Holmstrup P, Kramer I, Pindborg J, Shear M. International seminar on oral leukoplakia and associated lesions related to tobacco habits. Commun Dent Oral Epidemiol. 1984;12(3):145–54. https://doi.org/10.1111/j.1600-0528.1984.tb01428.x.
29. Odell E, Kujan O, Warnakulasuriya S, Sloan P. Oral epithelial dysplasia: recognition, grading and clinical significance. Oral Dis. 2021;27:1947–76. https://doi.org/10.1111/odi.13993.
30. Brouns ER, Evren I, Wils LJ, Poell JB, Brakenhoff RH, Bloemena E, de Visscher JGAM. Oral leukoplakia classification and staging system with incorporation of differentiated dysplasia. Oral Dis. 2022; https://doi.org/10.1111/odi.14295. Epub ahead of print. PMID: 35765231.
31. Hamadah O, Goodson M, Thomson PJ. Clinicopathological behaviour of multiple oral dysplastic lesions compared with that of single lesions. Br J Oral Maxillofac Surg. 2010;48(7):503–6. https://doi.org/10.1016/j.bjoms.2009.08.027.
32. Thomson PJ, Goodson ML, Cocks K, Turner JE. Interventional laser surgery for oral potentially malignant disorders: a longitudinal patient cohort study. Int J Oral Maxillofac Surg. 2017;46(3):337–42. https://doi.org/10.1016/j.ijom.2016.11.001.
33. Doroshenko M, Guerra A, Vu L. Airway for laser surgery. [Updated 2022 Oct 20]. In: StatPearls [Internet]. Treasure Island, FL: StatPearls Publishing; 2022.
34. Thomson PJ, Wylie J. Interventional laser surgery: an effective surgical and diagnostic tool in oral precancer management. Int J Oral Maxillofac Surg. 2002;31(2):145–53. https://doi.org/10.1054/ijom.2001.0189.
35. Romeo U, Mohsen M, Palaia G, Bellisario A, Del Vecchio A, Tenore G. CO_2 laser ablation of oral leukoplakia: with or without extension of margins? Clin Ter. 2020;171(3):e209–15. https://doi.org/10.7417/CT.2020.2215. PMID: 32323707.
36. Hamadah O, Thomson PJ. Factors affecting carbon dioxide laser treatment for oral precancer: a patient cohort study. Lasers Surg Med. 2009;41(1):17–25. https://doi.org/10.1002/lsm.20733.
37. Hazrati E, Horch H, Gerlach K, Schaffer H. CO_2 laser surgery of oral premalignant lesions. Plast Reconstruct Surg. 1988;82(2):378. https://doi.org/10.1016/s0300-9785(86)80006-0.
38. Van der Hem P, Nauta J, Van der Wal J, Roodenburg J. The results of CO_2 laser surgery in patients with oral leukoplakia: a 25 year follow up. Oral Oncol. 2005;41(1):31–7. https://doi.org/10.1016/j.oraloncology.2004.06.010.
39. Chandu A, Smith A. The use of CO_2 laser in the treatment of oral white patches: outcomes and factors affecting recurrence. Int J Oral Maxillofac Surg. 2005;34(4):396–400. https://doi.org/10.1016/j.ijom.2004.10.003.
40. Gooris P, Roodenburg J, Vermey A, Nauta J. Carbon dioxide laser evaporation of leukoplakia of the lower lip: a retrospective evaluation. Oral Oncol. 1999;35(5):490–5. https://doi.org/10.1016/s1368-8375(99)00022-6.

41. Vivek V, Jayasree RS, Balan A, Sreelatha KT, Gupta AK. Three-year follow-up of oral leukoplakia after neodymium:yttrium aluminum garnet (Nd:YAG) laser surgery. Lasers Med Sci. 2008;23(4):375–9. https://doi.org/10.1007/s10103-007-0500-8.
42. Montebugnoli L, Frini F, Gissi DB, Gabusi A, Cervellati F, Foschini MP, Marchetti C. Histological and immunohistochemical evaluation of new epithelium after removal of oral leukoplakia with Nd:YAG laser treatment. Lasers Med Sci. 2012;27(1):205–10. https://doi.org/10.1007/s10103-011-0941-y.
43. Sagalow ES, Kumar AT, Banoub RG, Xiao KB, Zhan T, Luginbuhl A, Curry JM. Recurrence of premalignant oral cavity and oropharynx lesions after pulsed diode laser treatment. Am J Otolaryngol. 2022;43(5):103556. https://doi.org/10.1016/j.amjoto.2022.103556. PMID: 35952526.
44. Bombeccari GP, Garagiola U, Candotto V, Pallotti F, Carinci F, Giannì AB, Spadari F. Diode laser surgery in the treatment of oral proliferative verrucous leukoplakia associated with HPV-16 infection. Maxillofac Plast Reconstr Surg. 2018;40(1):16. https://doi.org/10.1186/s40902-018-0156-2.
45. Tarasenko S, Stepanov M, Morozova E, Unkovskiy A. High-level laser therapy versus scalpel surgery in the treatment of oral lichen planus: a randomized control trial. Clin Oral Investig. 2021;25(10):5649–60. https://doi.org/10.1007/s00784-021-03867-y. PMCID: PMC8443509.
46. Lavanya N, Jayanthi P, Rao UK, Ranganathan K. Oral lichen planus: an update on pathogenesis and treatment. J Oral Maxillofac Pathol. 2011;15:127. https://doi.org/10.4103/0973-029x.84474.
47. Silverman S, Griffith M. Studies on oral lichen planus: II. Follow-up on 200 patients, clinical characteristics, and associated malignancy. Oral Surg Oral Med Oral Pathol. 1974;37(5):705–10. https://doi.org/10.1016/0030-4220(74)90135-2. PMID: 4524378.
48. Sonawane S, Sawane H, Pasalkar L, Khare V. Diode laser—a cure for obstinate oral lichen planus: a case series and review of the literature. Indian J Case Rep. 2022;8:120–2. https://doi.org/10.32677/ijcr.v8i5.3403.
49. Idrees M, Farah CS, Khurram SA, Firth N, Soluk-Tekkesin M, Kujan O. Observer agreement in the diagnosis of oral lichen planus using the proposed criteria of the American Academy of Oral and Maxillofacial Pathology. J Oral Pathol Med. 2021;50(5):520–7. https://doi.org/10.1111/jop.13170.
50. Rad M, Hashemipoor MA, Mojtahedi A, Zarei MR, Chamani G, Kakoei S, Izadi N. Correlation between clinical and histopathologic diagnoses of oral lichen planus based on modified WHO diagnostic criteria. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;107(6):796–800. https://doi.org/10.1016/j.tripleo.2009.02.020.
51. Mutafchieva MZ, Draganova-Filipova MN, Zagorchev PI, Tomov GT. Effects of low level laser therapy on erosive-atrophic oral lichen planus. Folia Med. 2018;60(3):417–24. https://doi.org/10.2478/folmed-2018-0008.
52. Trehan M, Taylor CR. Low-dose excimer 308-nm laser for the treatment of oral lichen planus. Arch Dermatol. 2004;140(4):415–20. https://doi.org/10.1001/archderm.140.4.415.
53. Dalirsani Z, Seyyedi SA. Treatment of plaque-like oral lichen planus with CO_2 laser. Indian J Dermatol. 2021;66(6):698–703. https://doi.org/10.4103/ijd.ijd_1170_20.
54. Mücke T, Gentz I, Kanatas A, Ritschl LM, Mitchell DA, Wolff KD, Deppe H. Clinical trial analyzing the impact of continuous defocused CO_2 laser vaporisation on the malignant transformation of erosive oral lichen planus. J Craniomaxillofac Surg. 2015;43(8):1567–70. https://doi.org/10.1016/j.jcms.2015.06.044.
55. de Magalhaes-Junior EB, Aciole GT, Santos NR, dos Santos JN, Pinheiro AL. Removal of oral lichen planus by CO_2 laser. Braz Dent J. 2011;22(6):522–6. https://doi.org/10.1590/s0103-64402011000600014.
56. Mozaffari HR, Ziaei N, Nazari H, Amiri SM, Sharifi R. Oral lichen planus treatment by CO_2 laser: a systematic review. Asian J Sci Res. 2017;10:1–9. https://doi.org/10.3923/ajsr.2017.1.9.
57. Bakhtiari S, Taheri JB, Sehhatpour M, Asnaashari M, Attarbashi Moghadam S. Removal of an extra-large irritation fibroma with a combination of diode laser and scalpel. J Lasers Med Sci. 2015;6(4):182–4. https://doi.org/10.15171/jlms.2015.16.
58. Singh A, Vengal M, Patil N, Sachdeva SK. Traumatic fibroma—a saga of reaction against irritation. Dental Impact. 2012;4(1):49–52.
59. Halim DS, Pohchi A, Yi EEP. The prevalence of fibroma in oral mucosa among patient attending USM dental clinic year 2006–2010. Indonesian J Dent Res. 2010;1(1):61–6. https://doi.org/10.22146/theindjdentres.9991.
60. Sotoode SM, Azimi S, Taheri SA, Asnaashari M, Khalighi H, Rahmani S, Jafari S, Elmi Rankohi Z. Diode laser in minor oral surgery: a case series of laser removal of different benign exophytic lesions. J Lasers Med Sci. 2015;6(3):133–8. https://doi.org/10.15171/jlms.2015.08. PMID: 26464782.
61. Yamaguchi T, Shindoh M, Amemiya A, Inoue N, Kawamura M, Sakaoka H, et al. Detection of human papillomavirus type 2 related sequence in oral papilloma. Anal Cell Pathol. 1998;16(3):125–30. https://doi.org/10.1155/1998/705216. PMID: 9699941.
62. Eversole L. Papillary lesions of the oral cavity: relationship to human papillomaviruses. J Calif Dent Assoc. 2000;28(12):922–7. PMID: 11323946.
63. da Cunha W, Souza A, Pina P, Azevedo L. Efficacy of diode laser in treating oral papilloma: a case report. Open Dent J. 2021;15:262–5. https://doi.org/10.2174/1874210602115010262.
64. Omi T, Numano K. The role of the CO_2 laser and fractional CO_2 laser in dermatology. Laser Ther. 2014;23(1):49–60. https://doi.org/10.5978/islsm.14-re-01.
65. Angiero F, Buccianti A, Parma L, Crippa R. Human papilloma virus lesions of the oral cavity: healing and relapse after treatment with 810–980 nm diode laser. Lasers Med Sci. 2015;30(2):747–51. https://doi.org/10.1007/s10103-013-1401-7.
66. Boj JA, Hernandez M, Espasa E, Poirier C. Laser treatment of an oral papilloma in the pediatric dental office: a case report. Quintessence Int. 2007;38(4):307–12. PMID: 17432786.
67. Shim J, Choi S, Jung K, Baek S. Treatment of laryngotracheal papilloma with 532-nm diode laser. Med Lasers. 2020;9(2):190–3. https://doi.org/10.25289/ML.2020.9.2.190.
68. Toledano-Serrabona J, López-Ramírez M, Sánchez-Torres A, España-Tost A, Gay-Escoda C. Recurrence rate of oral squamous cell papilloma after excision with surgical scalpel or laser therapy: a retrospective cohort study. Med Oral Patol Oral Cir Bucal. 2019;24(4):e433–7. https://doi.org/10.4317/medoral.22943.
69. Leffell DJ, Braverman IM. Familial multiple lipomatosis: report of a case and a review of the literature. J Am Acad Dermatol. 1986;15(2):275–9. PMID: 3745530.
70. Toy BR. Familial multiple lipomatosis. Dermatol Online J. 2003;9(4):29. PMID: 14594582.

71. Misir AF, Demiriz L, Barut F. Laser treatment of an oral squamous papilloma in a pediatric patient: a case report. J Indian Soc Pedodont Prevent Dent. 2013;31(4):279. https://doi.org/10.4103/0970-4388.121833. PMID: 24262405.
72. Capodiferro S, Maiorano E, Scarpelli F, Favia G. Fibrolipoma of the lip treated by diode laser surgery: a case report. J Med Case Rep. 2008;2:301. https://doi.org/10.1186/1752-1947-2-301.
73. Piccolo D, Mutlag MH, Pieri L, Fusco I, Conforti C, Crisman G, Bonan P. Lipoma management with a minimally invasive 1,444 nm Nd:YAG laser technique. Front Med (Lausanne). 2022;9:1011468. https://doi.org/10.3389/fmed.2022.1011468.
74. Lee SH, Jung JY, Roh MR, Chung KY. Treatment of lipomas using a subdermal 1,444-nm micropulsed neodymium-doped yttrium aluminum garnet laser. Dermatol Surg. 2011;37(9):1375–6. https://doi.org/10.1111/j.1524-4725.2011.02084.x. PMID: 22988996.
75. Kamal R, Dahiya P, Puri A. Oral pyogenic granuloma: various concepts of etiopathogenesis. J Oral Maxillofac Pathol. 2012;16(1):79–82. https://doi.org/10.4103/0973-029X.92978. PMID: 22434943.
76. Jafarzadeh H, Sanatkhani M, Mohtasham N. Oral pyogenic granuloma: a review. J Oral Sci. 2006;48(4):167–75. https://doi.org/10.2334/josnusd.48.167. PMID: 17220613.
77. Neville BW, Damm DD, Allen CM, Chi AC. Oral & maxillofacial pathology. 4th ed. Philadelphia, Pa: Saunders; 2016. p. 604–5.
78. Bugshan A, Patel H, Garber K, Meiller TF. Alternative therapeutic approach in the treatment of oral pyogenic granuloma. Case Rep Oncol. 2015;8(3):493–7. https://doi.org/10.1159/000441839.
79. Rai S, Kaur M, Bhatnagar P. Laser: a powerful tool for treatment of pyogenic granuloma. J Cutan Aesthet Surg. 2011;4(2):144–7. https://doi.org/10.4103/0974-2077.85044.
80. Raulin C, Greve B, Hammes S. The combined continuous-wave/pulsed carbon dioxide laser for treatment of pyogenic granuloma. Arch Dermatol. 2002;138(1):33–7. https://doi.org/10.1001/archderm.138.1.33.
81. Karandeep SA, Prabhpreet K, Kasper DH, Rupinder DK, Shrawan KS. Efficacy of Er,Cr:YSGG Laser in treatment of unusual presentation of Pyogenic Granuloma in a 9 year old girl. S Afr Dent J. 2016;71(5):218–21.
82. Khan MK, Jindal MK. Diode laser as minimal invasive treatment modality for oral pyogenic granuloma in a pediatric patient: a case report. J Pediatr Dent. 2021;7(3):178–83. https://doi.org/10.14744/JPD.2021.09_67.
83. Fekrazad R, Nokhbatolfoghahaei H, Khoei F, Kalhori KA. Pyogenic granuloma: surgical treatment with Er:YAG laser. J Lasers Med Sci. 2014;5(4):199–205. PMID: 25653822.
84. Burgess DK, Levi PA Jr, Kim DM. The management of an oral pyogenic granuloma around osseointegrated dental implants. Clin Adv Periodontics. 2022;13:50. https://doi.org/10.1002/cap.10219. PMID: 35908249.
85. Hasanoglu Erbasar GN, Senguven B, Gultekin SE, Cetiner S. Management of a recurrent pyogenic granuloma of the hard palate with diode laser: a case report. J Lasers Med Sci. 2016;7(1):56–61. https://doi.org/10.15171/jlms.2016.12.
86. Iinuma T, Arai Y, Abe Y, Takayama M, Fukumoto M, Fukui Y, Iwase T, Takebayashi T, Hirose N, Gionhaku N, Komiyama K. Denture wearing during sleep doubles the risk of pneumonia in the very elderly. J Dent Res. 2015;94(3 Suppl):28S–36S. https://doi.org/10.1177/0022034514552493. PMID: 25294364.
87. Mohan RP, Verma S, Singh U, Agarwal N. Epulis fissuratum: consequence of ill-fitting prosthesis. BMJ Case Rep. 2013;2013:bcr2013200054. https://doi.org/10.1136/bcr-2013-200054.
88. Ibrahim AH, Merzouk N, Abdelkoui A. Prosthetic and surgical management of a sizeable epulis fissuratum: a case report. Pan Afr Med J. 2022;41:49. https://doi.org/10.11604/pamj.2022.41.49.31339. PMID: 35317487.
89. Veena K, Jagadishchandra H, Sequria J, Hameed S, Chatra L, Shenai P. An extensive denture-induced hyperplasia of maxilla. Ann Med Health Sci Res. 2013;3(Suppl 1):S7–9. https://doi.org/10.4103/2141-9248.121208. PMID: 24349860.
90. de Freitas AC, Pinheiro AL, de Oliveira MG, Ramalho LM. Assessment of the behavior of myofibroblasts on scalpel and CO(2) laser wounds: an immunohistochemical study in rats. J Clin Laser Med Surg. 2002;20(4):221–5. https://doi.org/10.1089/104454702760230555.
91. Zeinoun T, Nammour S, Dourov N, Aftimos G, Luomanen M. Myofibroblasts in healing laser excision wounds. Lasers Surg Med. 2001;28(1):74–9. https://doi.org/10.1002/1096-9101(2001)28:1/74:AID-LSM1019>3.0.CO;2-B. PMID: 11430446.
92. Tamarit-Borrás M, Delgado-Molina E, Berini-Aytés L, Gay-Escoda C. Removal of hyperplastic lesions of the oral cavity. A retrospective study of 128 cases. Med Oral Patol Oral Cir Bucal. 2005;10:151–62. PMID: 15735548.
93. Monteiro LS, Mouzinho J, Azevedo A, Câmara MID, Martins MA, La Fuente JM. Treatment of epulis fissuratum with carbon dioxide laser in a patient with antithrombotic medication. Braz Dent J. 2012;23:77–81. https://doi.org/10.1590/s0103-64402012000100014.
94. Agrawal AA, Mahajan M, Mahajan A, Devhare S. Application of diode laser for excision of non-inflammatory vascular epulis fissuratum. Int J Case Rep Images. 2012;3(9):42–5. https://doi.org/10.5348/ijcri201209182CR12.
95. Kumar JN, Bhaskaran M. Denture-induced fibrous hyperplasia. Treatment with carbon dioxide laser and a two year follow-up. Indian J Dent Res. 2007;18(3):135. https://doi.org/10.4103/0970-9290.33791. PMID: 17687178.
96. Neckel CP. Vestibuloplasty: a retrospective study on conventional and laser operation techniques. In: Proc SPIE 3593, Lasers in dentistry, vol. V. Bellingham, WA: International Society for Optical Engineering; 1999. p. 76–80. https://doi.org/10.1117/12.348330.
97. Kazanjian VH. Surgical operations as related to satisfactory dentures. Dent Cosmos. 1924;66:387. https://doi.org/10.12691/ijdsr-3-6-3.
98. Kacarska M, Dimitrovski O, Popovic-Monevska D. Preprosthetic laser assisted mandibular vestibuloplasty. Balkan J Dent Med. 2016;20(3):182–5. https://doi.org/10.1515/bjdm-2016-0030.
99. de Arruda Paes-Junior TJ, Cavalcanti SCM, Nascimento DFF, Saavedra GDSFA, Kimpara ET, Borges ALS, Niccoli-Filho W, Komori PCDP. CO_2 laser surgery and prosthetic management for the treatment of epulis fissuratum. Int Scholar Res Notices. 2011; https://doi.org/10.5402/2011/282361.
100. Blessing EP, Adlin RS. Vestibuloplasty using diode laser—a case report. Int Org Sci Res J Dent Med Sci. 2019;18(8):43–7. https://doi.org/10.9790/0853-1808084347.
101. Levine R, Vitruk P. The use of a 10,600-nm CO_2 laser mandibular vestibular extension in a patient with a chromosomal disorder. Compend Contin Educ Dent. 2016;37(9):527–33. PMID: 27608196.
102. Pisevska SG, Simjanovska L, Markovska M, Petreska MP, Chadikovska E. ER:YAG LASER: minimal invasive tech-

nique for vestibuloplasty in the lower jaw. J Morphol Sci. 2019;2(2):37–42.
103. Bhullar SK, Goel V, Bhullar A, Goyal L, Mehta V, Nanda T, Sethi M. Comparative evaluation of pain in vestibular depth extension procedure using scalpel, electrocautery and diode laser. J Dent Specialities. 2017;5:148–51. https://doi.org/10.18231/2393-9834.2017.0033.
104. Kalakonda B, Farista S, Koppolu P, Baroudi K, Uppada U, Mishra A, Savarimath A, Lingam AS. Evaluation of patient perceptions after vestibuloplasty procedure: a comparison of diode laser and scalpel techniques. J Clin Diagn Res. 2016;10(5):ZC96–ZC100. https://doi.org/10.7860/jcdr/2016/17623.7820.
105. Fioravanti M, Zara F, Vozza I, Polimeni A, Sfasciotti GL. The efficacy of lingual laser frenectomy in pediatric OSAS: a randomized double-blinded and controlled clinical study. Int J Environ Res Public Health. 2021;18(11):6112. https://doi.org/10.3390/ijerph18116112.
106. Messner AH, Ha JF. Ankyloglossia and tight maxillary frenula. In: Lesperance MM, editor. Cummings pediatric otolaryngology. 2nd ed. Elsevier; 2021. p. 473–82. https://doi.org/10.1016/b978-0-323-69618-0.00033-0.
107. Fürchtgott N, Paterson BC, Bernard J, Costello BJ. The use of lasers in maxillofacial surgery. In: Fonseca RJ, editor. Oral and maxillofacial surgery, vol. 19. 3rd ed. Elsevier; 2018. p. 336–63.
108. Elias G, McMillan K, Monaghan A. Vascular lesions of the head and oral cavity—diagnosis and management. Dent Update. 2016;43:859–66. https://doi.org/10.12968/denu.2016.43.9.859.
109. Richter GT, Friedman AB. Hemangiomas and vascular malformations: current theory and management. Int J Pediatr. 2012;2012:645678. https://doi.org/10.1155/2012/645678.
110. Steiner JE, Drolet BA. Classification of vascular anomalies: an update. Semin Intervent Radiol. 2017;34:225–32. https://doi.org/10.1055/s-0037-1604295. PMID: 28955111.
111. Kunimoto K, Yamamoto Y, Jinnin M. ISSVA classification of vascular anomalies and molecular biology. Int J Mol Sci. 2022;23:2358. https://doi.org/10.3390/ijms23042358. PMID: 35216474.
112. Oomen KPQ, Wreesmann VB. Current classification of vascular anomalies of the head and neck. J Oral Pathol Med. 2022;51:830–6. https://doi.org/10.1111/jop.13353. PMID: 36066308.
113. ISSVA Classification. Accessed 9 Jan 2023. https://www.issva.org/classification.
114. Angiero F, Benedicenti S, Romanos GE, Crippa R. Treatment of hemangioma of the head and neck with diode laser and forced dehydration with induced photocoagulation. Photomed Laser Surg. 2008;26:113–8. https://doi.org/10.1089/pho.2007.2143.
115. Zheng JW, Zhang L, Zhou Q, Mai HM, Wang YA, Fan XD, Qin ZP, Wang XK, Zhao YF. A practical guide to treatment of infantile hemangiomas of the head and neck. Int J Clin Exp Med. 2013;6(10):851–60. PMID: 24260591.
116. Vesnaver A, Dovsak DA. Treatment of vascular lesions in the head and neck using Nd:YAG laser. J Craniomaxillofac Surg. 2006;34(1):17–24. https://doi.org/10.1016/j.jcms.2005.07.009. Epub 2005 Dec 13. PMID: 16352435.
117. Azma E, Razaghi M. Laser treatment of oral and maxillofacial hemangioma. J Lasers Med Sci. 2018;9:228–32. https://doi.org/10.15171/jlms.2018.41. PMID: 31119015.
118. Cadavid AMH, de Campos WG, Aranha ACC, Lemos-Junior CA. Efficacy of photocoagulation of vascular malformations in the oral mucosa using Nd:YAG. J Craniofac Surg. 2018;29:e614–7. https://doi.org/10.1097/scs.0000000000004676.
119. Bastos JT, Balassiano LKA, Mariano da Rocha CR, Freitas BMP, Bravo LG, Bravo BSF. Treatment of vascular lesions located in the lip and in the oral cavity with Nd:YAG laser. J Cosmet Laser Ther. 2017;19:256–8. https://doi.org/10.1080/14764172.2017.1314503.
120. Parisi D, Ciancio F, Cagiano L, Rucci M, Annacontini L, Portincasa A. Hemangioma of the oral and perioral region: Nd:YAG vs surgery. Ann Ital Chir. 2016;2016:2578. PMID: 27830673.
121. Medeiros R Jr, Silva IH, Carvalho AT, Leão JC, Gueiros LA. Nd:YAG laser photocoagulation of benign oral vascular lesions: a case series. Lasers Med Sci. 2015;30:2215–20. https://doi.org/10.1007/s10103-015-1764-z.
122. Asai T, Suzuki H, Takeuchi J, Komori T. Effectiveness of photocoagulation using an Nd:YAG laser for the treatment of vascular malformations in the oral region. Photomed Laser Surg. 2014;32:75–80. https://doi.org/10.1089/pho.2013.3594.
123. Yang HY, Zheng LW, Yang HJ, Luo J, Li SC, Zwahlen RA. Long-pulsed Nd:YAG laser treatment in vascular lesions of the oral cavity. J Craniofac Surg. 2009;20:1214–7. https://doi.org/10.1097/SCS.0b013e3181acdd9f. PMID: 19553836.
124. Vesnaver A, Dovsak DA. Treatment of large vascular lesions in the orofacial region with the Nd:YAG laser. J Craniomaxillofac Surg. 2009;37:191–5. https://doi.org/10.1016/j.jcms.2008.10.006.
125. Bacci C, Sacchetto L, Zanette G, Sivolella S. Diode laser to treat small oral vascular malformations: a prospective case series study. Lasers Surg Med. 2018;50:111–6. https://doi.org/10.1002/lsm.22737.
126. Voynov PP, Tomov GT, Mateva NG. Minimal invasive approach for lips venous lake treatment by 980 nm diode laser with emphasis on the aesthetic results. A clinical series. Folia Med. 2016;58:101–7. https://doi.org/10.1515/folmed-2016-0017. PMID: 27552786.
127. Dementieva N, Jones S. The treatment of problematic hemangiomas in children with propranolol and 940nm diode laser. J Pediatr Surg. 2016;51:863–8. https://doi.org/10.1016/j.jpedsurg.2016.02.038.
128. Favia G, Tempesta A, Limongelli L, Suppressa P, Sabbà C, Maiorano E. Diode laser treatment and clinical management of multiple oral lesions in patients with hereditary haemorrhagic telangiectasia. Br J Oral Maxillofac Surg. 2016;54:379–83. https://doi.org/10.1016/j.bjoms.2015.08.260.
129. Jasper J, Camilotti RS, Pagnoncelli RM, Poli VD, da Silveira Gerzson A, Gavin Zakszeski AM. Treatment of lip hemangioma using forced dehydration with induced photocoagulation via diode laser: report of three cases. Oral Surg Oral Med Oral Pathol Oral Radiol. 2015;119:89–94. https://doi.org/10.1016/j.oooo.2014.03.005.
130. Romeo U, Del Vecchio A, Russo C, Palaia G, Gaimari G, Arnabat-Dominguez J, España AJ. Laser treatment of 13 benign oral vascular lesions by three different surgical techniques. Med Oral Patol Oral Cir Bucal. 2013;18:e279–84. https://doi.org/10.4317/medoral.18156.
131. Fekrazad R, Am Kalhori K, Chiniforush N. Defocused irradiation mode of diode laser for conservative treatment of oral hemangioma. J Lasers Med Sci. 2013;4:147–50. PMID: 25606323.
132. Azevedo LH, Del Vechio A, Nakajima E, Galletto V, Migliari DA. Lip and oral venous varices treated by photocoagulation with high-intensity diode laser. Quintessence Int. 2013;44:171–4. https://doi.org/10.3290/j.qi.a28926. PMID: 23444183.

133. Azevedo LH, Galletta VC, Eduardo Cde P, Migliari DA. Venous lake of the lips treated using photocoagulation with high-intensity diode laser. Photomed Laser Surg. 2010;28:263–5. https://doi.org/10.1089/pho.2009.2564.
134. Abukawa H, Kono M, Hamada H, Okamoto A, Satomi T, Chikazu D. Indications of potassium titanyl phosphate laser therapy for slow-flow vascular malformations in oral region. J Craniofac Surg. 2017;28:771–4. https://doi.org/10.1097/scs.0000000000003445.
135. Miyazaki H, Kato J, Watanabe H, Harada H, Kakizaki H, Tetsumura A, Sato A, Omura K. Intralesional laser treatment of voluminous vascular lesions in the oral cavity. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;107:164–72. https://doi.org/10.1016/j.tripleo.2008.08.004.
136. Derby LD, Low DW. Laser treatment of facial venous vascular malformations. Ann Plast Surg. 1997;38:371–8. https://doi.org/10.1097/00000637-199704000-00011.
137. Miyazaki H, Ohshiro T, Romeo U, Noguchi T, Maruoka Y, Gaimari G, Tomov G, Wada Y, Tanaka K, Ohshiro T, Asamura S. Retrospective study on laser treatment of oral vascular lesions using the "leopard technique": the multiple spot irradiation technique with a single-pulsed wave. Photomed Laser Surg. 2018;36:320–5. https://doi.org/10.1089/pho.2017.4410.
138. Álvarez-Camino JC, España-Tost AJ, Gay-Escoda C. Endoluminal sclerosis with diode laser in the treatment of orofacial venous malformations. Med Oral Patol Oral Cir Bucal. 2013;18:e486–90. https://doi.org/10.4317/medoral.18528.
139. Khandelwal S, Patil S. Oral mucoceles—review of the literature. Minerva Stomatol. 2012;61(3):91–9. PMID: 22402300.
140. More CB, Bhavsar K, Varma S, Tailor M. Oral mucocele: a clinical and histopathological study. J Oral Maxillofac Pathol. 2014;18(Suppl 1):S72–7. https://doi.org/10.4103/0973-029X.141370. PMID: 25364184.
141. Nagar SR, Fernandes G, Sinha A, Rajpari KN. Mucocele of the tongue: a case report and review of literature. J Oral Maxillofac Pathol. 2021;25(Suppl 1):S37–41. https://doi.org/10.4103/jomfp.jomfp_396_20. PMID: 34083968.
142. Bagher SM, Sulimany AM, Kaplan M, Loo CY. Treating mucocele in pediatric patients using a diode laser: three case reports. Dentistry J. 2018;6(2):13. https://doi.org/10.3390/dj6020013.
143. Sinha R, Sarkar S, Khaitan T, Kabiraj A, Maji A. Nonsurgical management of oral mucocele by intralesional corticosteroid therapy. Int J Dent. 2016;2016:2896748. https://doi.org/10.1155/2016/2896748.
144. Ramkumar S, Ramkumar L, Malathi N, Suganya R. Excision of mucocele using diode laser in lower lip. Case Rep Dentistry. 2016;2016:1746316, 4 pages. https://doi.org/10.1155/2016/1746316.
145. Choi YJ, Byun JS, Choi JK, Jung JK. Identification of predictive variables for the recurrence of oral mucocele. Med Oral Patol Oral Cir Bucal. 2019;24(2):e231–5. https://doi.org/10.4317/medoral.22690.
146. Zenk J, Constantinidis J, Kydles S, et al. Clinical and diagnostic findings of sialolithasis. HNO. 1999;47(11):963–9. https://doi.org/10.1007/s001060050476. PMID: 10602786.
147. Huoh KC, Eisele DW. Etiologic factors in sialolithiasis. Otolaryngol Head Neck Surg. 2011;145(6):935–9. https://doi.org/10.1177/0194599811415489. PMID: 21753035.
148. Gupta A, Rattan D, Gupta R. Giant sialoliths of submandibular gland duct: report of two cases with unusual shape. Contemp Clin Dentistry. 2013;4:78–80. https://doi.org/10.4103/0976-237X.111599. PMID: 23853458.
149. Iro H, Zenk J, Koch M. Stenosis and other non-sialolithiasis-related obstructions of the major salivary gland ducts. HNO. 2010;58(3):211–7. https://doi.org/10.1007/s00106-009-2076-z. PMID: 20213107.
150. Rzymska-Grala I, Stopa Z, Grala B, Gołębiowski M, Wanyura H, Zuchowska A, Sawicka M, Zmorzyński M. Salivary gland calculi—contemporary methods of imaging. Pol J Radiol. 2010;75(3):25–37. PMID: 22802788.
151. Kılınç Y, Çetiner S. Surgical removal of a giant sialolith by diode laser. Open J Stomatol. 2014;4:484–8. https://doi.org/10.4236/ojst.2014.410065.
152. Yang SW, Chen TA. Transoral carbon dioxide laser sialolithectomy with topical anaesthesia. A simple, effective, and minimally invasive method. Int J Oral Maxillofac Surg. 2011;40:169–72. https://doi.org/10.1016/j.ijom.2010.09.020.
153. Angiero F, Benedicenti S, Romanos GE, Crippa R. Sialolithiasis of the submandibular salivary gland treated with the 810- to 830-nm diode laser. Photomed Laser Surg. 2008;26:517–21. https://doi.org/10.1089/pho.2007.2226.
154. Martellucci S, Pagliuca G, de Vincentiis M, Greco A, Fusconi M, De Virgilio A, Gallipoli C, Gallo A. Ho:YAG laser for sialolithiasis of Wharton's duct. Otolaryngol Head Neck Surg. 2013;148:770–4. https://doi.org/10.1177/0194599812451438a34.
155. Younespour S, Yaghobee S, Aslroosta H, Moslemi N, Pourheydar E, Ghafary ES. Effectiveness of different modalities of lip repositioning surgery for management of patients complaining of excessive gingival display: a systematic review and meta-analysis. Biomed Res Int. 2021;2021:9476013. https://doi.org/10.1155/2021/9476013. PMID: 34660802; PMCID: PMC8516537.
156. Tatakis DN. Lip repositioning techniques and modifications. Dent Clin N Am. 2022;66(3):373–84. https://doi.org/10.1016/j.cden.2022.02.002. Epub 2022 Jun 1. PMID: 35738733.
157. Ardakani MT, Moscowchi A, Valian NK, Zakerzadeh E. Lip repositioning with or without myotomy: a systematic review. J Korean Assoc Oral Maxillofac Surg. 2021;47(1):3–14. https://doi.org/10.5125/jkaoms.2021.47.1.3. PMID: 33632971; PMCID: PMC7925163.
158. Alammar A, Heshmeh O, Mounajjed R, Goodson M, Hamadah O. A comparison between modified and conventional surgical techniques for surgical lip repositioning in the management of the gummy smile. J Esthet Restor Dent. 2018;30(6):523–31. https://doi.org/10.1111/jerd.12433. Epub 2018 Nov 9. PMID: 30412347.
159. Luke AM, Mathew S, Altawash MM, Madan BM. Lasers: a review with their applications in oral medicine. J Lasers Med Sci. 2019;10(4):324–9. https://doi.org/10.15171/jlms.2019.52. Epub 2019 Oct 1. PMID: 31875126; PMCID: PMC6885906.
160. Levine R, Vitruk P. Use of a 10,600-nm CO_2 laser mandibular vestibular extension in a patient with a chromosomal abnormality. Compend Contin Educ Dent. 2016;37(8):527–533; quiz 534. PMID: 27608196.