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REVIEW PAPER

Diode Laser Applications for Muco-Gingival Surgical Orthodontics; A Case Series

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Abstract

Background Diode lasers are highly effective adjuncts in surgical orthodontics. This paper highlights the in-office use of diode lasers for common muco-gingival surgical orthodontic procedures. This paper demonstrates four common soft tissue orthodontic applications of the diode laser that orthodontists can master to reduce the need for lengthy referrals and minimize delays in orthodontic treatment.

Methods A retrospective series of case reports were presented, demonstrating the use of a 940-nm (InGaAsP) diode laser in contact cutting mode. Procedures included: Laser gingivectomy to improve oral hygiene or facilitate bracket positioning; esthetic gingival recontouring following the removal of fixed braces and laser exposure of superficially impacted teeth. Additionally, an interesting case of a maxillary impacted canine in a 39 year-old female patient—fully covered by bone—was presented. The treatment combined diode laser soft tissue exposure to control the bleeding along with surgical bur ostectomy to remove covering alveolar bone, expose the impacted canine crown, and facilitate simultanious bonding.

Results The use of diode lasers resulted in enhanced healing following minor oral surgeries; bloodless surgical sites, improving patient comfort, and improved visibility during bracket bonding procedures.

Conclusion This paper underscores the advantages of diode lasers, including their popularity, compact size, and cost-effectiveness. The combined use of diode laser soft tissue exposure and surgical bur ostectomy for tooth exposure shows promise and warrants further investigation.

Keywords Diode laser · 940 nm · Impacted canine · Impacted premolars · Surgical orthodontics

Introduction

Conventional muco-gingival surgical orthodontics often involves scalpel incisions for two prime groups of procedures. This is gingivectomy for removal of excess or fibrotic and hypertrophic gingival tissue [1] or reflection of the surgical flap and making releasing incisions apical to the adjacent teeth to expose impacted teeth in an open or closed eruption technique [2]. These require managing surgical site bleeding, pain, and postoperative swelling.

The healthy gingival margin is typically positioned 1–2 mm coronal to the cemento-enamel junction [3]. However, this ideal gingival architecture does not always manifest at the end of orthodontic treatment, necessitating surgical alteration of the gingival margins to achieve satisfactory smile esthetics [4–7].

Muco-gingival surgery, first proposed by Friedman in 1957, is a type of surgery “designed to preserve attached gingiva, remove fraenum or muscle attachment, and increase the depth of the vestibule” [8–10]. Muco-gingival surgery, also known as ‘muco-gingival therapy, ’ aims to correct defects in the morphology, position, and/or amount of soft tissue and underlying bone support around teeth and implants [10]. In the context of surgical orthodontics, it is employed to correct the morphology, position, and/or amount of soft tissue around teeth through procedures such as gingivectomy, apically repositioned flaps, or frenectomy to achieve esthetically pleasing gingival architecture and to surgically expose impacted teeth [4, 5].

Laser incision or excision has established a significant role in modern muco-gingival surgery [11]. Compared to a

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surgical scalpel, a laser beam or the delivery tip of a laser device can more easily cut, ablate, and reshape oral soft tissues with minimal or reduced bleeding, less pain, and reduced need for suturing [11]. Various soft tissue lasers have been used for muco-gingival surgical procedures such diode, erbium, and CO2 lasers. A histological investigation by Kazakova et al. [12] showed that the diode laser produced one of the deepest hemostasis and thickest coagulation layer widths compared to Erbium and CO2 lasers or a surgical scalpel. Within the context of orthodontics, laser excision to uncover impacted teeth offers advantages for delicate procedures by providing a bloodless surgical site, facilitating precise bonding of orthodontic attachments, and promoting faster healing.

Diode laser applications in muco-gingival surgical orthodontics primarily involve laser gingivectomy, removal of fibrotic and hypertrophic gingival tissue, or soft tissue uncovering of unerupted or impacted teeth [4, 5]. Most muco-gingival surgical orthodontic laser procedures involve gingivectomy or the removal of soft tissue [4, 5]. However, as it was explained, this can be combined with a surgical bur to remove a small amount of alveolar bone when necessary. Utilizing lasers provides several benefits, such as sterilizing the surgical site, reducing bleeding, enhancing visibility, and allowing for more precise incisions [1, 7, 13–15]. The coagulated tissue layer aids in healing and can eliminate the need for a dressing in procedures such as open exposure of impacted teeth and the removal of hyperplastic fibrotic soft tissue [1, 7, 13–15]. Compared to scalpel gingivectomy, laser use results in faster healing times due to quicker epithelialization, less post-operative pain, and may be viewed as a less invasive method [1, 7, 13–15].

Methods

Diode Laser Applications for Muco-Gingival Surgical Orthodontics

In the following section, four common soft tissue orthodontic applications of the diode laser are demonstrated with treated cases. The diode laser has been used for the surgical exposure of impacted teeth or the removal of excess gingival tissue (gingival recontouring). These procedures were carried out with a 940-nm diode laser (Epic 10, Biolase, Irvine, CA) using an initiated 400-µm-diameter fiber-optic tip in contact mode (Power = 2 Watts; gated-CW mode). In all patients, brackets with the MBT prescription were used, and the archwire sequence started with 0.014 NiTi for initial alignment following the diode laser surgical exposure of impacted teeth.

To achieve local anesthesia, topical anesthetic (lidocaine) was initially applied, followed by an injection of approximately one-third of a lidocaine cartridge at the surgical site. The laser exposure procedure took about 10 to 15 min. This was followed by the immediate bonding of the impacted tooth with a small bracket (using a lower incisor bracket as an attachment). Orthodontic traction was either initiated simultaneously or delayed for a week, as necessary. All patients reported very mild discomfort at the 1-day postoperative follow-up, and there was no swelling or infection at the surgical site or adjacent areas.

Results

Laser Exposure of Superficially Impacted Teeth

Case Report 1

Diode Laser Exposure of Buccally Impacted Left Maxillary Canine The simplest form of laser exposure involves removing the minimum amount of keratinized tissue over an impacted tooth to facilitate its eruption. A Caucasian male adolescent patient initially presented with a Class II Division 1 malocclusion, complicated by a buccally impacted left maxillary canine (Fig. 1a). Buccal diode laser exposure was performed (Fig. 1b) to surgically expose the impacted canine after waiting for nearly 5 months for eruption of the canine. The patient was advised to brush the exposed area to prevent tissue reclosure over the tooth. Four months after laser uncovering, the canine began to erupt spountaneously supported by healthy keratinised tissue (Fig. 1c) and subsequently bonded with a canine bracket (Fig. 1d).

Case Report 2

Diode Laser Exposure of Palatelly Impacted Left Maxillary Canine A 14 years old female patient initially presented with Class II division 1 malocclusion, complicated by a palatally impacted left maxillary canine as shown in the panoramic x-ray (Fig. 2a). Palatal diode laser exposure was performed (Fig. 2b), and the left maxillary canine was bonded with a small bracket (lower incisor backet). One week later, orthodontic traction was initiated (Fig. 2c, d), and Fig. 2e and f show the almost aligned canine (2d) and following removal of brackets (2f).

Case Report 3

Diode Laser Exposure of buccally Impacted Right Maxillary Canine A female adolescent patient initially presented with Class II division 1 malocclusion, characterized by increased overjet, a buccally impacted right maxillary canine, and crowding in the maxillary and mandibular arches. As shown in Fig. 3a–d, she underwent laser exposure of the impacted

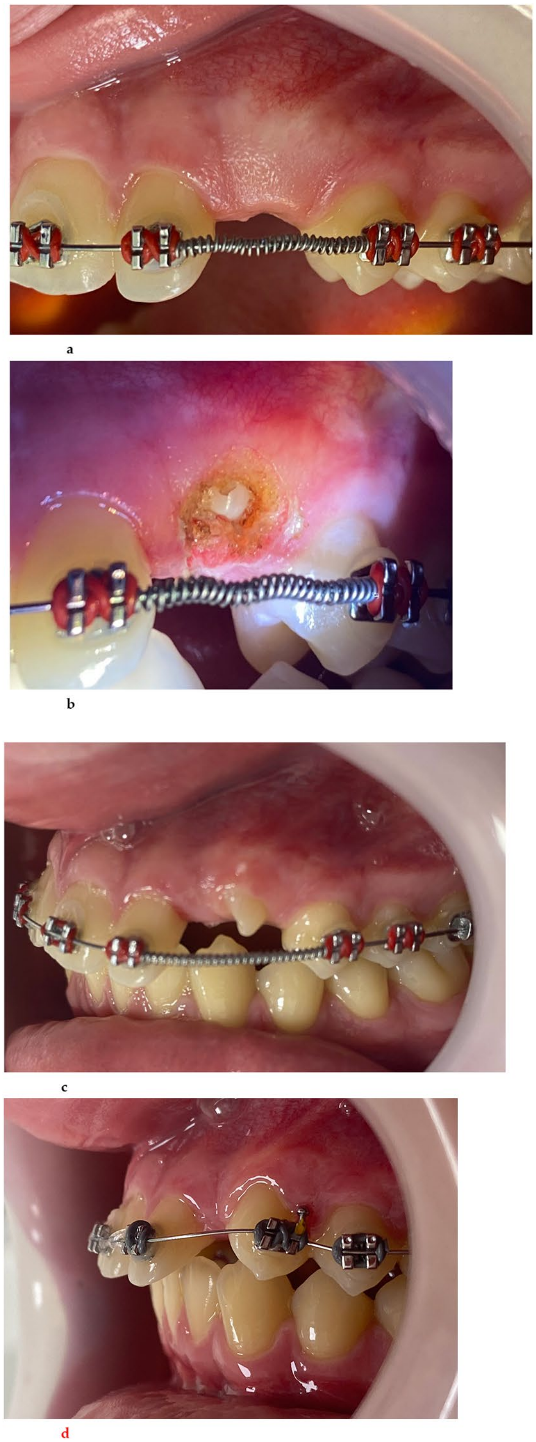

Fig. 1 **a**-Buccally impacted left maxillary canine, **b**-The tip of impacted left maxillary canine was surgicaly laser exposed, **c**-Four month after laser exposure the canine gradually started to erupt, **d**-The canine was bonded with a canine bracket

maxillary canine. Figure 2d shows excellent healing at the 1-week follow-up.

Combined Use of Surgical Bur and Diode Laser to Expose Impacted Teeth Covered by Bone

Case Report 4

Combined Use of Diode Laser and Surgical Bur for Exposure of Impacted Maxillary Right Canine A 39-year-old female patient initially presented with Class I malocclusion, missing upper and lower lateral incisors, retained primary right maxillary B and C teeth, missing maxillary and mandibular lateral incisors, spacing in the upper and lower arches, impacted upper right and lower wisdom teeth, extracted lower right second molar, and an impacted maxillary right canine covered by bone. The maxillary right canine was initially exposed using a combination of diode laser to remove the soft tissue covering the bone and achieve hemostasis (Fig. 4a–f), along with simultaneous ostectomy with round tungsten carbide bur to remove the cortical bone and access the tooth crown. The diode laser was used as an adjunct to control bleeding. Immediately after exposure, the maxillary right canine was bonded with a small bracket, and orthodontic traction was initiated.

However, as demonstrated in Fig. 4g–m, about 8 months after the initial canine exposure, the site was completely covered by soft tissue, necessitating a second diode laser exposure and re-bracketing with a maxillary lateral incisor bracket. Overall, the treatment from the first canine exposure and ostectomy to the end took about 2 years. It should be noted that impacted teeth at this age (39 years) respond poorly to orthodontic traction, resulting in a low success rate, often leading to their surgical removal.

Esthetic Laser Gingival Recontouring

Case Reports 5 & 6

Diode Laser Gingival Recontouring Figure 5a–c presents the post-orthodontic treatment photographs of a Caucasian female adolescent patient who initially presented with a Class II malocclusion, moderate crowding in the upper and lower dental arches, and increased overjet and overbite. After the removal of the brackets, a significant gingival margin discrepancy in the upper canine-to-canine area was evident, necessitating laser recontouring.

Figure 6a–d displays the post-treatment photographs of a female adult Chinese patient who initially presented with a Class I malocclusion. At the end of the treatment, she exhibited increased gingival coverage of the upper front teeth (maxillary canines to canines) and a gingival margin discrepancy. Diode laser gingival recontouring was performed to create more esthetic gingival margins and improve crown exposure.

Fig. 2 **a**-Panoramic radiographic view showing the impacted maxillary left canine, **b**-Diode laser exposure of the left maxillary canine, **c**-Placement of a small bracket (a bracket suitable for lower incisors), **d**-Starting orthodontic traction 1 week after the laser exposure, with a clean healing exposure site, **e**-Placement of a canine bracket, **f**-At debond

Laser Gingivectomy to Improve Oral Hygiene

Case Report 7

Diode Laser Surgical Removal of Palatal Hypertrophic Gingival Tissue Figure 7a–d shows photographs of a female adult African patient with fixed braces, presenting with excessive palatal gingival hyperplasia of unknown etiology despite maintaining good oral hygiene in the upper front maxillary area. The excessive gingival overgrowth was removed using a diode laser.

Discussion

This case series provides insights into the use of diode lasers for managing common muco-gingival issues in orthodontics. This paper presented seven cases in four common scenarios that can delay treatment due to lengthy oral surgery/periodontic referrals. The delay may arise from the need to expose an impacted tooth or the delayed provision of an orthodontic retainer, following removal of fixed braces, due to unsightly gingival overgrowth requiring surgical recontouring. Diode lasers are frequently utilized in dental practices due to their compact size and cost-effectiveness [4–7, 16–18]. These lasers, mainly operating in the 800–980 nm range, offer deep soft tissue penetration and effective coagulation with minimal interaction with hard tissues [4–7, 16–18]. The low absorption of diode laser light by dental hard tissues, such as enamel and bone, makes it ideal for soft tissue procedures. This includes exposure of unerupted or impacted teeth, gingivectomy, frenectomy, as well as the excision of fibro-epithelial oral lesions, hyperplastic gingival tissue, or benign and premalignant oral lesions, such as leukoplakia, erythroplakia, or lichen planus [4–7, 16–21].

Diode lasers are part of the deeply penetrating laser category (visible and near-infrared spectrum, 450 nm–1100 nm), which allows transmission through water and results in a lower absorption coefficient in water [6, 16]. This characteristic enables diode lasers to penetrate deeply into healthy soft tissue, with the laser light scattering extensively within the tissue [6, 16]. However, these lasers are selectively absorbed in inflamed areas by blood components and tissue pigments, making them particularly suitable for soft tissue procedures. Compared to Nd:YAG lasers (1064 nm), diode

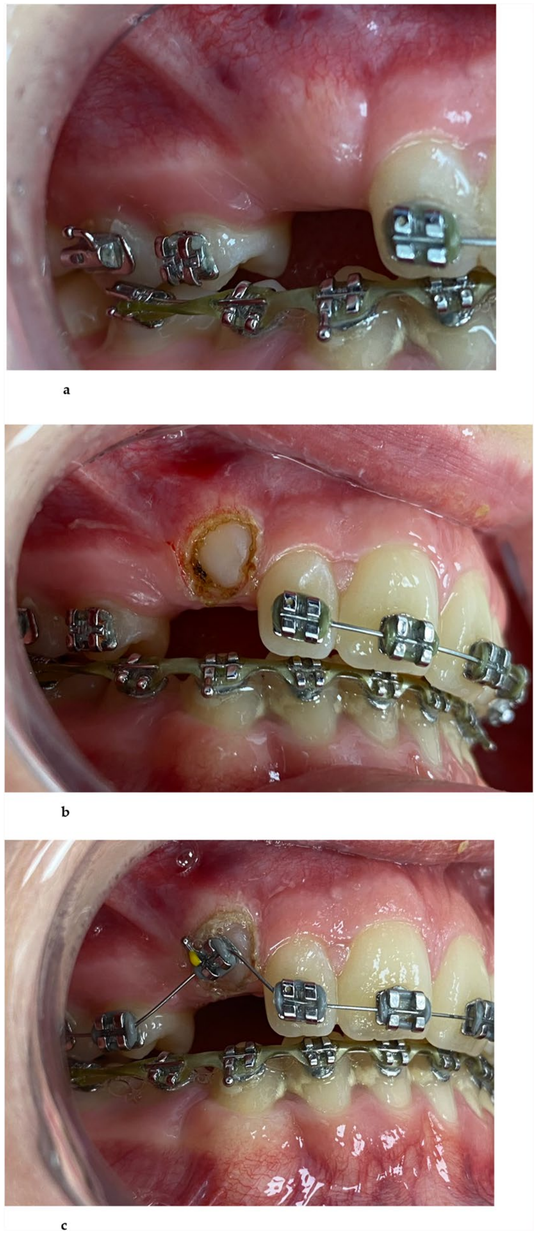

Fig. 3 **a**-Impacted right maxillary canine with ample keratinized tissue coverage, **b**-Immediately after diode laser exposure, **c**-Placement of the maxillary right canine bracket and initiation of orthodontic traction, **d**- Excellent healing and regeneration of gingival tissue one week post-laser exposure

lasers have a shallower penetration depth, reducing the likelihood of causing pulpal damage [6, 18].

Laser-tissue interactions may induce tissue warming, welding, coagulation, protein denaturation, drying, and even vaporization (ablation) and carbonization, where soft tissues are evaporated or incised [6, 11, 17]. This latter process also provides hemostasis, microbial inhibition and destruction [6, 11, 17, 22–24]. Increasing evidence suggests that the appropriate use of lasers is associated with reduced intraoperative and post-operative pain, as well as enhanced wound healing or tissue regeneration, compared to conventional scalpel surgery [6, 11, 15, 17, 22–25]. Diode lasers can be operated in continuous-wave or gated-pulsed mode [5]. Continuous-wave mode produces higher levels of heat which can result in soft tissue damage [26]. Overall, the laser-tissue interaction is determined by interplay between the incident photonic power density and exposure time [26].

Orthodontists often refer patients for the exposure of impacted teeth, removal of frenum, or excision of hyperplastic gingival tissue. These issues can delay orthodontic treatment, increase the risk of complications, and affect patient satisfaction [27, 28]. They can also be detrimental to the cost efficiency and productivity of a practice [27, 28]. The adjunct in-office use of a diode laser can improve the esthetic outcomes of orthodontic treatment, decrease treatment duration for patients requiring surgical exposure of superficially impacted teeth, reduce the number of appointments, and collectively increase patient satisfaction [4].

When performing gingival recontouring, as illustrated in Figs. 5 and 6, it is crucial to leave at least 1 mm of pocket depth and preserve at least 2 mm of keratinized tissue to prevent further soft tissue complications, such as gingival recession or absence of protective keratinized tissue [4, 18]. Gingival hyperplasia is common in orthodontic patients, occurring in about 10% of cases [4, 29, 30]. This condition impedes oral hygiene maintenance leading to esthetic and functional issues [4, 29, 30]. Extensive and fibrotic gingival hyperplasia often does not respond to conventional treatments, such as oral hygiene instructions, scaling, root planing, and prophylaxis, compromising patient self-care [4, 29].

The adjunctive use of diode laser gingivectomy can significantly improve gingival health in patients with gingival enlargement [6]. As shown in Figs. 7a–d, a patient with palatal gingival hyperplasia who did not respond to conventional treatment was successfully managed with diode laser gingivectomy. The purpose of this paper is not to discuss the combined gingivectomy and ostectomy, such as cases with ‘altered passive eruption’ or ‘crown lengthening’ that involves alveolar bone removal with surgical burs or hard tissue lasers such as ER:CR:YSGG laser (2780 nm) [31–33]. Instead, this paper focuses on gingivectomy procedures within soft tissue boundaries after exclusion of other causes of excessive gingival display [34]. Various lasers such as ER:CR:YSGG laser (2780 nm) [31–33], CO_2 [35, 36], and Nd:YAG [36] laser have been used for gingivectomy. However, diode lasers appear to be becoming the popular option. Diode lasers (wavelengths of 808, 810, 940, and 980 nm) were compared to scalpel surgery in the literature [4–7, 24, 34–37]. A recent systematic review revealed that diode laser gingivectomy results in lower levels of pain and bleeding compared to conventional scalpel surgery [34].

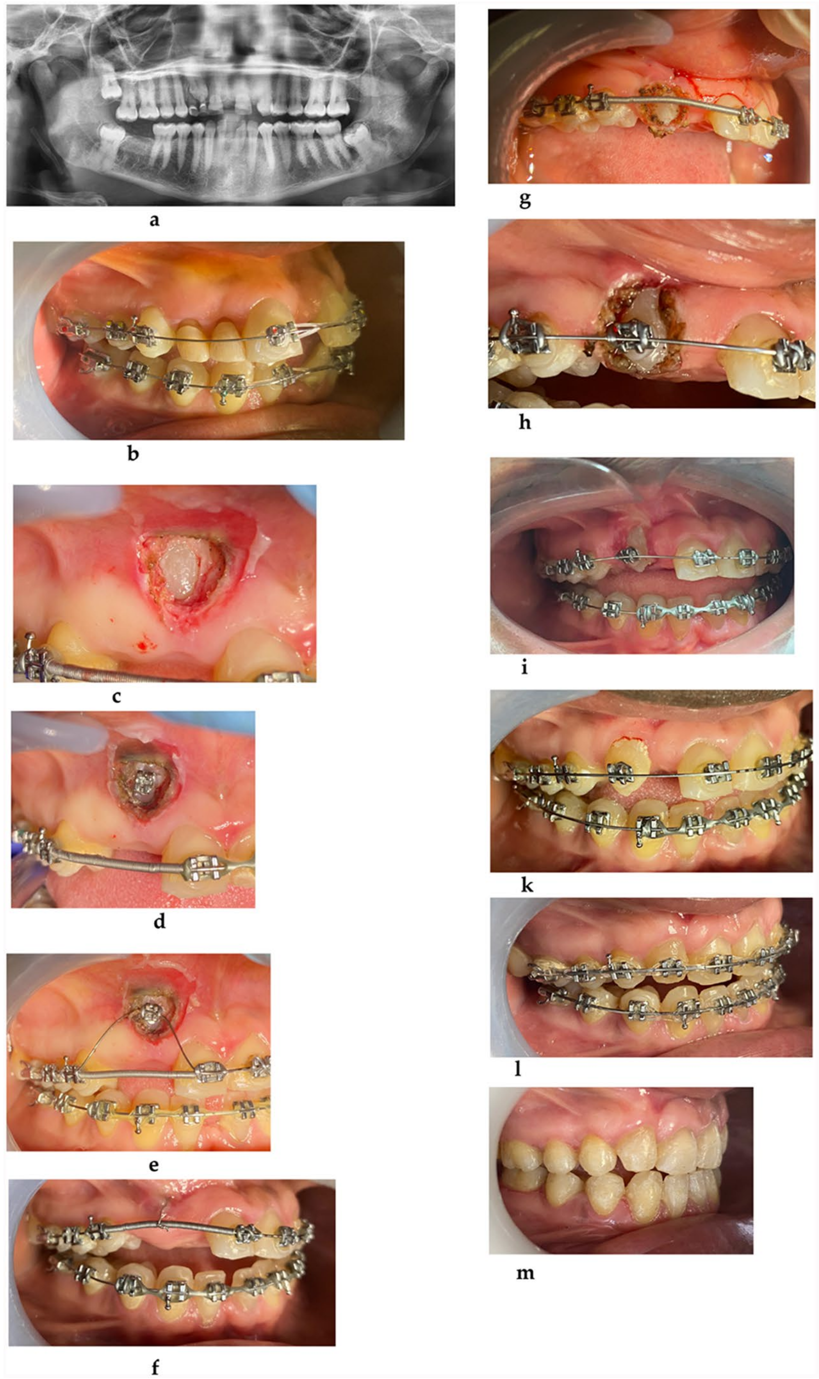

Fig. 4 **a**-Panoramic radiograph of the patient showing an impacted right maxillary canine and retained right maxillary primary teeth B and C, **b**-Beginning of fixed appliance treatment, **c**-After uncovering soft tissue and ostectomy with round tungsten carbide bur to remove the cortical bone and access the canine crown. Good hemostasis was achieved with diode laser use, which facilitated orthodontic bracket bonding following ostectomy, **d**-Placement of a small incisor bracket for the impacted right maxillary canine, **e**-Start of orthodontic traction with auxiliary 0.014 NiTi wire, **f**-At the 8-month follow-up after the first canine exposure, the upper right canine has descended and is close to eruption. However, the bracket is completely covered by overgrowth of the soft tissue, and a second laser exposure was planned immediately, **g**-Second diode laser soft tissue uncovering performed to expose the right maxillary canine and facilitate proper bracket bonding, **h**-A maxillary right lateral incisor bracket (for canine substitution) was placed and tied to a 0.016 NiTi wire, **i**-Follow-up 1 week after the second diode laser exposure, showing a healing exposure site with no signs of infection, **k**-At five-month follow-up after the second diode laser exposure, **l**-At the 15-month follow-up after the second diode laser exposure (about 2 years after the first canine exposure and ostectomy), canine substitution and space closure are in progress and nearing the end of treatment, **m**-Following removal of braces, note the approximately 2 mm supporting keratinized tissue for the upper right canine. Patient suffers from tooth size discrepancy, missing maxillary and mandibular lateral incisors and was not interested in any form of esthetic dentistry

Diode lasers can facilitate the exposure of superficially impacted teeth, either with (Figs. 2, 3 and 4) or without (Fig. 1) simultaneous bonding of the exposed tooth. The bloodless exposure site created by the diode laser enables the bonding of brackets or attachments, which is difficult to achieve when using a punch or scalpel. When using a laser to expose impacted teeth, as depicted in Fig. 3a–d, it is important to keep the exposed crown within the keratinized mucosa and preserve the protective keratinized as much as possible [4–7, 38–40]. This approach helps avoid future complications, such as developing a thin periodontal biotype, the combination of gingival phenotype (three-dimensional gingival volume) and bone morphotype (thickness of the bone plate) [4–7, 38–40].

A recent scoping review revealed that laser exposure of impacted teeth is more efficient, with reduced treatment time, no bleeding, and less need for infiltration anesthetics and analgesics [41]. Diode laser surgical exposure eliminates the need for suturing and allows for immediate bonding of an attachment to the crown of the impacted tooth, compared to only 60% in the conventional scalpel group [41]. This method not only shortens treatment time but also results in less pain during orthodontic treatment, a shorter overall treatment duration, and fewer post-surgical complications [13, 24, 52]. For all reported cases, we initially used topical lignocaine anesthetic gel, applied for 3–5 min, followed by small amount of local infiltration (e.g., 2% lidocaine) approximately 5 min before the procedure to enhance postoperative comfort [41].

As illustrated in Fig. 4a–l, author introduced the concept of using a diode laser in combination with a surgical bur to remove bone and control excessive bleeding at the surgical site. While hard tissue lasers, such as Erbium lasers [Er:YAG (2940 nm) and the Er, Cr:YSGG (2780 nm)] can also perform these tasks, they are costly, require larger equipment setups, and are less effective at hemostasis due to poor absorption in pigmented chromophores [42].

Conventional surgical exposure of impacted teeth covered by bone typically involves making apically positioned flaps, performing releasing incisions apical to the adjacent teeth, cortical bone removal, and managing intra- and post-operative bleeding. This method often requires suturing, which can result in post-operative pain and potential infection. Conventional full-thickness mucoperiosteal flap procedures are relatively aggressive, often leading to minimal alveolar bone loss that can potentially compromise the integrity of the periodontium, particularly with thin alveolar bone thickness (< 2 mm) [43]. A full-thickness mucoperiosteal flap usually necessitates suturing and the placement of a protective dressing (pack) over the surgical site during healing. This process can be costly and stressful for patients [43]. Additionally, sedation or in rare situations general anesthesia may be required, and sutures typically need to be removed 1–2-week postoperatively [44–47].

Kokich [48] suggested three main methods for exposing labially impacted maxillary canines based on the position of their cusp relative to the muco-gingival junction. These are:

1. The "closed eruption technique," where the canine cusp is significantly above the muco-gingival junction and located intra-alveolarly high within the buccal sulcus.
2. The "excisional uncovering or gingivectomy" when the canine cusp is below the muco-gingival junction, as seen in Case 2. The excisional uncovering can be accompanied with removal of any bone covering the crown of the impacted canine (48).
3. If the canine cusp is above the muco-gingival junction, an "apically positioned flap" is suggested.

In Case 4, a combination of ostectomy, soft tissue removal, and subsequent gingivectomy was successfully employed, resulting in a healthy periodontal profile with adequate (2 mm) (48) keratinized tissue coverage. Considering that the canine crown was positioned partially below the mucogingival junction, any of the 3 techniques could be used to uncover the tooth (48), which might have involved raising a flap and significant bone removal; therefore, a more conservative approach was chosen to preserve alveolar bone during surgical exposure, given the patient's age and the uncertain outcome of the procedure. Ectopic maxillary canines that are most favorable for alignment typically exhibit a mesial inclination and are located within 14 mm of the canine site on the occlusal plane, as observed in this patient [49, 50]. However, in adult patients over 30 years of age, the risks associated with surgical exposure and alignment must be carefully evaluated, as treatment outcomes can be compromised due to an increased incidence of ankylosis and slower rates of tooth movement [50, 51].

Previous research has shown that the success rate of orthodontic treatment for impacted maxillary canines in adults is lower than in adolescents [51]. For instance, research indicates a success rate of 69.5% in adults aged 20–47 years, compared to 100% in younger individuals aged 12–16 years [51]. The reduced success in older patients is attributed to factors such as increased bone density and decreased cellular activity, which can impede tooth movement. Consequently, orthodontic traction in adults may require longer treatment durations and carries a higher risk of failure, often leading to the consideration of surgical removal of the impacted teeth.

Nevertheless, surgical removal of the impacted teeth carries the risk of creating a significant bony defect in an esthetically critical area, which may necessitate bone grafting and complicate both orthodontic space management and subsequent dental implant placement [50–52]. As illustrated, the

Fig. 5 **a**-Gingival level discrepancy in the maxillary canine-to-canine area after removal of fixed braces, **b**-Gingival recontouring performed with diode laser, **c**-At 1-week follow-up

Fig. 6 **a**-Gingival margin discrepancy and increased soft tissue crown coverage at removal of the fixed braces, **b**-A periodontal probe was used to assess the false pocketing and excess gingival cover, **c**-Immediately after diode laser gingival recontouring, **d**-At 1-day follow-up post-laser gingivectomy

combined use of a diode laser and surgical bur to expose the crowns of impacted teeth located below or partically above the muco-gingival junction can be performed in carefully selected cases. Future research can investigate the long-term periodontal status of impacted teeth exposed in this manner compared to conventional exposure using apically repositioned flap or closed eruption technique.

In addition to managing gingival enlargement or hyperplasia, cosmetic gingival contouring, and exposing impacted teeth, diode lasers are used to uncover temporary anchorage devices (TADs) [52–55]. They are employed for frenectomy, operculum removal for mandibular molars to facilitate banding or bracket bonding, and for treating post-orthodontic minor aphthous ulceration [42].

Given the minimally invasive nature of diode laser and its superior healing properties, there is a need for clinical trials to further investigate and determine the optimal wavelength, power settings, optimal selection critria, and anesthesia methods for diode lasers.

Fig. 7 **a**-Palatal gingival hypoplasia of unknown cause, making maintenance of oral hygiene challenging, **b**-Immediately following palatal laser gingivectomy, **c**-At 1-week follow-up, showing healthy tissue regeneration, **d**-At 6-week post-laser gingivectomy follow-up, healthy regenerated palatal gingival tissue is visible

Conclusions

The in-office use of diode laser for gingivectomy and exposing impacted teeth covered by soft tissue or thin layer of alveolar bone can be a valuable technique for orthodontists. Randomized clinical trials are warranted to compare the outcome of impacted teeth laser surgical exposure in combination with surgical bur ostectomy versus conventional surgical exposure, and to identify the ideal selection criteria, laser parameters and potential risks.

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