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Review

A Scoping Review of the Efficacy of Diode Lasers Used for Minimally Invasive Exposure of Impacted Teeth or Teeth with Delayed Eruption

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Abstract: Background: The use of diode lasers for oral surgery soft tissue procedures is associated with less pain and bleeding, quick recovery, and better surgical site visibility. Objectives: This scoping review identifies and analyses the evidence evaluating the efficacy of the diode laser surgical exposure of impacted teeth or teeth with delayed eruption (both with no overlaying bone) vs. conventional scalpel surgical exposure. Materials and Methods: The PubMed/Medline, SCOPUS, and Google Scholar databases were searched up to January 2022 for randomized clinical trials and case-control studies comparing diode laser impacted-tooth surgical exposure vs. conventional surgical methods. Furthermore, the surgical exposure of an impacted mandibular canine or premolars with a 940 nm (InGaAsP) diode laser was presented. Results: The literature search revealed no high-quality evidence. However, four prospective studies were identified. Diode laser application was associated with less pain or analgesic need, minimal/no bleeding, and no need for suturing after surgery. The laser wavelengths used were 808, 810, 935, and 980 nm. A comparison of the study outcomes was not possible; all the studies had methodological issues and their funding sources were not mentioned. Conclusions: Adequately powered clinical trials are needed for comparing outcomes from diode laser surgical exposure vs. conventional methods, identifying the ideal laser characteristics, and assessing the long-term periodontal health of laser-exposed teeth and any potential risks.

Keywords: diode laser; 940 nm; impacted canine; impacted premolars; surgical orthodontics

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1. Introduction

Excluding the third molars, the impaction of permanent teeth is reported with a prevalence of 2.9% [1,2] to 13.7% [1–8], with canines and second premolars being the most involved [1,3–8]. Failure of eruption or tooth impaction can be due to local or systemic factors [9,10]. The impaction of mandibular canines and premolars occasionally occurs and it is often associated with crowding in the dental arches [1]. Mandibular second premolars can become impacted, leading to complications such as root resorption of the adjacent first molars or continued root development in close proximity to the inferior dental alveolar nerve, which is a surgical challenge [11]. The impaction of mandibular canines is less common compared to the maxillary canines, with an incidence between 0.92% and 5.1% [12]. Impacted mandibular canines may be associated with odontomas (up to 20%) and lateral incisor anomalies (16%) [12]. Surgical extraction (89% in some studies) and orthodontic traction (20–32%) are cited as the suggested treatment modalities, with the orthodontic traction showing a failure rate of about 17% [12].

For uncovering superficially impacted teeth with no overlying bone layer, the conventional surgical exposure and orthodontic traction often involve reflecting the surgical flap with a scalpel, releasing incisions apical to the adjacent teeth, and managing surgical site bleeding, pain, and postoperative swelling. The management of impacted teeth is

time-consuming (two to three years) and expensive. Surgical exposure requires the retraction of soft tissues, allowing for adequate visualization of the surgical site, bonding of the impacted tooth with a bracket or attachment, and, if possible, simultaneous orthodontic traction [13]. Surgical site bleeding complicates the orthodontic bonding process, and clinicians should deal with intra- and post-operative pain, swelling, and the possible risk of site infection [13].

Where applicable, the alternative approaches are to use the diode lasers or elecrosurgery for surgical exposure of impacted teeth if they are not deeply impacted and covered by bone [14,15]. Diode lasers produces a surrounding zone of thermal necrosis and healing, promoting healing and sterilization of the surgical site (14,15). Electrocautery produces adequate hemostasis, but results in greater and deeper thermal damage and has no self-sterilizing properties (14,15). Compared to conventional exposure using a scalpel, patients who received laser exposure showed little need for intra-operative local anaesthesia, experienced reduced post-surgical pain (fewer took analgesics), and did not show any post-surgical side effects such as bleeding and oedema [16]. Compared with a scalpel, the initiated fibre-optic tip of the diode laser device easily cuts, ablates, and reshapes the oral soft tissues, with no or reduced bleeding and less pain, as well as no or less need for suturing [15–18]. This is mainly due to laser penetration in the surrounding tissues during high-level laser treatment, stimulating tissues and cells without producing irreversible thermal changes in the tissues (photobiomodulation), resulting in wound healing in the surrounding tissues [17].

However, it is not clear what type of information is available for clinicians when comparing the surgical exposure of impacted teeth or the management of teeth with delayed eruption using diode laser surgical exposure or the conventional scalpel method. Therefore, the purpose of this scoping review was to systematically map the available evidence and identify the gaps in our knowledge on the efficacy of impacted-tooth laser surgical exposure compared to conventional scalpel surgical exposure in terms of the reduction in pain, bleeding, oedema, and the need for infiltration anaesthesia.

In addition, two cases were presented—an impacted mandibular canine or impacted second premolars, respectively—in which diode laser surgical exposure was used, as well as simultaneous orthodontic bonding and traction.

2. Methodology

The present scoping review was based on the PRIRMA extension for scoping reviews [19,20] and was conducted to provide an overview or map of the evidence that is available.

2.1. PICOS

For this scoping review, the following PICOS QUESTION was formulated to assess whether it generates enough high-quality evidence. The following definitions were used:

Population: patients presenting with impacted teeth needing surgical exposure or teeth with delayed eruption that would benefit from surgical exposure.

Intervention: diode laser surgical exposure.

Comparison/Control: conventional scalpel surgical exposure.

Outcome/Result: reduction in pain, bleeding, oedema, and the need for infiltration anaesthesia.

Study design: randomized clinical trials (RCT) or case-control studies (retrospective or prospective).

2.2. Eligibility Criteria and Information Sources

Using the PubMed/Medline, SCOPUS, and Google Scholar databases, a literature search was conducted for peer-reviewed English journal papers (up to January 2022) reporting on clinical trials or case-control studies with human participants (retrospective

or prospective) comparing the outcomes (pain, bleeding, need for anaesthesia and local infiltration) of conventional surgical tooth exposure and diode laser exposure.

The following MeSH terms were identified and searched for:

"Tooth, Impacted", "Cuspid", "tooth, unerupted/diagnosis", "tooth eruption/physiology", "Tooth Eruption, Ectopic", "Tooth Eruption", "Orthodontics", "orthodontics, preventive", "orthodontics, interceptive", "orthodontics, corrective", "Prospective Studies", "Retrospective Studies", "Randomized Controlled Trials as Topic", "Case-Control Studies", "Treatment Outcome", "Lasers, Semiconductor", "Laser Therapy", "Surgery, Oral", "Surgical Flaps".

3. Results

Our database search identified 212 studies. The literature search revealed no high-quality evidence in the form of RCTs. However, four prospective studies were identified (Table 1). A recent study used a 980 nm laser wavelength [16] (pulsed mod, power = 1.5 W, fibre diameter tip = 320 µm) for the exposure of impacted teeth, reporting less pain, bleeding, or analgesic needs during or after diode laser surgery compared to the conventional method (scalpel). The surgical procedure was completed in 8–23 min in the laser group vs. 21–43 min in the conventional surgery group [16]. Brackets or attachments were bonded to the impacted teeth for all the impacted teeth during the exposure procedure in the laser group as opposed to only 60% in the conventional group [16].

The list of other studies and their findings are shown in Table 1. One study sample was diverse [21], including cases of aesthetic recontouring, maxillary frenectomy, operculectomy, and gingivectomy; another [22] compared laser exposure with a control group that did not receive any surgical intervention. Finally, the RCT by Yossif et al. [23] lacks some vital information such as laser exposure site locations.

Overall, diode laser application was associated with less pain or analgesic need, minimal/no bleeding, and no need for suturing during or after diode laser surgery. The laser wavelengths used were 808, 810, 935, and 980 nm. A comparison of the study outcomes was not possible, and all the studies had methodological issues; funding sources were not mentioned for all the identified studies.

Table 1. Summary of identified evidence comparing diode laser surgical exposure with conventional scalpel surgical exposure.

Authors	Study Design/Groups/Funding Source	Exposed Tooth/Region	Diode Laser Characteristics	Main Findings/Adverse Events
Migliario et. al. [16]	Prospective study. Funding source not clear. 16 orthodontic patients (overall, 20 impacted teeth, 4 patients had 2 impacted teeth). 9 males and 7 females. Age range = 10 years and 7 months to 24 years and 4 months. Control group (N = 10) received exposure of impacted teeth by scalpel. Experimental group (N = 10) received laser exposure to uncover the impacted teeth, including 60 s of laser biostimulation of tissues covering impacted tooth crown to reduce pain. 15% Lidocaine spray was used as topical anaesthsia. Pain assessed using a numerical rating scale (NRS, 1–10). 14-day follow-up.	Impacted teeth Mainly maxillary canines, maxillary lateral incisors, and mandibular 2nd molars	980 nm diode laser Pulsed mode (20 s on/10 s off) Power = 1.5 W Fibre diameter tip = 320 µm	Of the 10 patients in the laser-treated group, only 3 needed infiltrative anaesthesia, and of those only 2 needed to take analgesics post-surgically (slight pain (NRS = 2)). None had bleeding or needed suturing. Brackets or attachments were bonded to the impacted teeth for all 10 impacted teeth. The laser surgical procedure was completed in 8–23 min. No adverse event was reported for laser use. All patients in the conventional group needed infiltrative anaesthesia and almost all (9/10) had pain for up to 5 days (average NRS = 4) and were treated with post-surgical analgesics. All had bleeding and 6 needed suturing. Only in 6 patients were brackets or the attachment bonded to the impacted teeth. The whole surgical procedure took 21–43 min.

Table 1. *Cont.*

Authors	Study Design/Groups/Funding Source	Exposed Tooth/Region	Diode Laser Characteristics	Main Findings/Adverse Events
Ize-Iyamu et al. [21]	Prospective study. Funding source not clear. 23 orthodontic patients (17 females and 6 males, age range = 10–30 years). A mixed sample of patients who had either conventional surgery or laser surgery for gingivectomy, aesthetic recontouring, maxillary frenectomy, operculectomy, or tooth impaction exposure surgery (all had conventional bone removal, i.e., palatally impacted canines, to uncover the tooth initially and to bond it with a bracket followed by flap closure). Control group (N = 11) received conventional surgical intervention (including 5 cases of tooth exposure). Experimental group (N = 12) received laser surgery (including 6 cases of tooth exposure). WHO bleeding scale (0–4) and Visual Analogue Scale (VAS, 0–10) were used and recorded. The length of follow-up not clear.	Sample included some impacted teeth but their locations were not clear	**810 nm diode laser** The laser brand, mode of laser delivery, and the tip diameter were not specified	None of the laser procedures required suturing, while 8 (72.7%) of the conventional surgical procedures required suturing. Only 2 (16.7%) of the laser surgical procedures required infiltration anaesthesia compared to 10 (90.9%) with conventional surgery ($p < 0.001$). Post-operative pain was significantly reduced in all cases treated with the diode laser ($p < 0.001$). There was a significant reduction ($p < 0.05$) in post-operative bleeding in all cases treated with the diode laser. About 83% (10/12) of the laser surgery cases took $\leq$ 20 min to finish vs. 27% (3/11) in conventional surgery group. No adverse event reported for laser use.
Seifi et al. [22]	Prospective study. Funding source not clear. 16 orthodontic patients with delayed tooth eruption and no sign of impaction. Female/male data only available for the laser group (6 females and 2 males, mean age = 14 $\pm$ 0.9 years). Control group (N = 8) did not receive any surgical (conventional or laser) intervention. Experimental group (N = 8) received laser exposure to uncover the unerupted 2nd premolars after the utilization of topical and local anaesthetic.	2nd premolars with delayed eruption	808 nm diode laser Continuous wave mode Power = 1.6 watt Fibre diameter tip = 0.3 mm	Laser intervention accelerated the tooth eruption significantly (11 $\pm$ 1.1 vs. 25 $\pm$ 1.8 weeks to be able to access the facial axis of the clinical crown). No significant bleeding during or immediately after the surgery. No adverse event reported for laser use.
Yossif et al. [23]	Randomized clinical trial study. Funding source not clear. Study sample size is not clear (two figures of 30 and 20 were cited in the paper). 18 females and 12 males. Mean age = 11.2 (2.2) years. Control group (N = 15) received exposure of delayed erupted tooth by conventional method (scalpel). Experimental group (N = 15) received laser exposure to uncover the unerupted tooth/teeth. 7-day follow-up.	Teeth with delayed eruption but their locations were not clear	935 nm diode laser Continuous wave mode Power = 1.6 watt Fibre diameter tip = 0.4 mm	The pain VAS score on days 1 and 7 were significantly lower in the laser group compared to the surgical group. The laser group showed less bleeding (the WHO bleeding criteria) than the conventional surgical group. Patients in the surgical group took more analgesics on the 1st day than patients in the laser group. No adverse event reported for laser use.

4. Case Reports

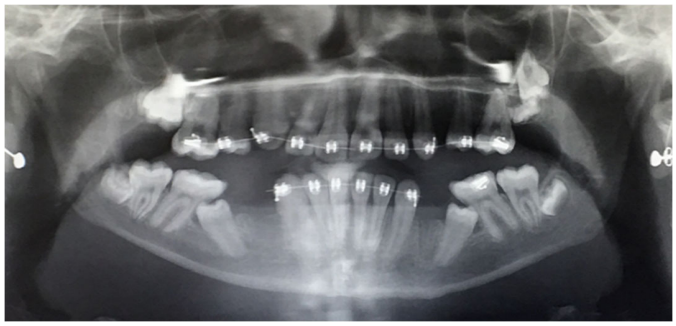
Diode laser surgical exposure of mandibular impacted teeth is presented. This was carried out with a 940 nm InGaAsP diode laser (Epic 10, Biolase, Irvine, CA, USA), with an initiated 400 µm diameter fibre-optic tip, in the contact mode (gated-CW mode). In both cases, brackets with the MBT prescription were used and an arch wire sequence began with 0.014 NiTi for the initial alignment after the laser surgical exposure.

4.1. Case Report 1

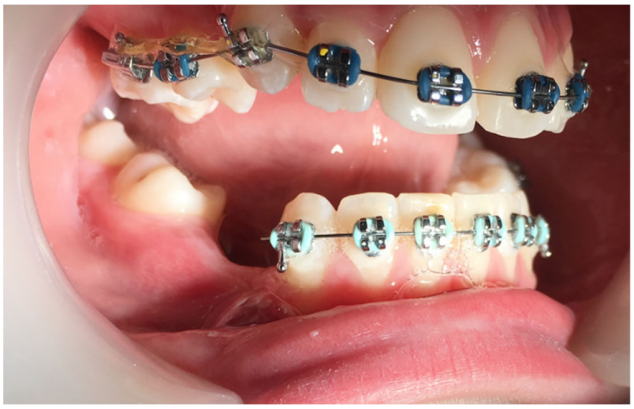
Impacted Mandibular Second Premolars

A female patient aged 13.5 years presented with Class II division 1 malocclusion complicated by impacted mandibular second premolars and severe crowding in the upper and lower dental arches, necessitating the removal of four premolars. After the removal of

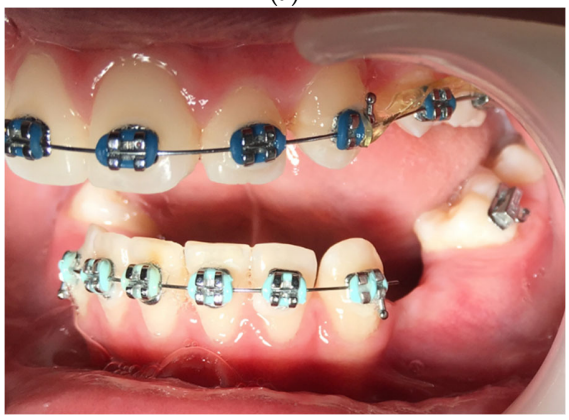
the four first premolars (Figure 1a) and space opening in the lower second premolar areas (Figure 1b,c), precise laser exposure of both mandibular second premolars was carried out. To achieve local anaesthesia, the site was injected with about a third of a lidocaine cartridge. The time spent on the laser exposure was about 10 min. This was followed by immediate bonding of the mandibular second premolars with small brackets (lower incisor bracket as attachment); simultaneous orthodontic traction was begun using elastomeric power chains (Figure 1d). The patient reported very mild discomfort during a one-day post-op follow-up and there was no swelling of the surgical site or the adjacent areas.



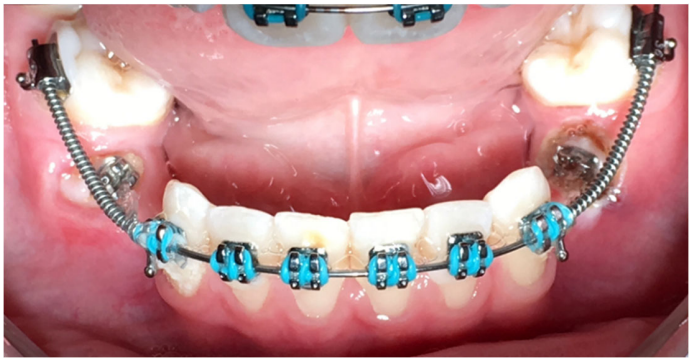
(**a**)



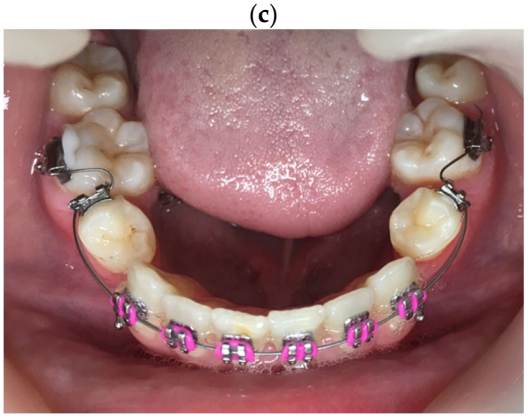
(**b**)



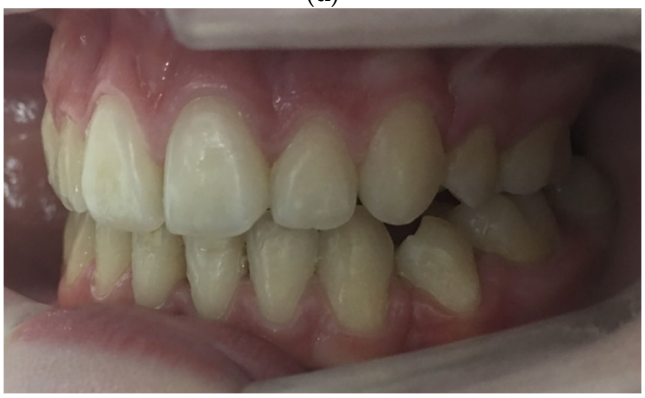
(**c**)



(**d**)

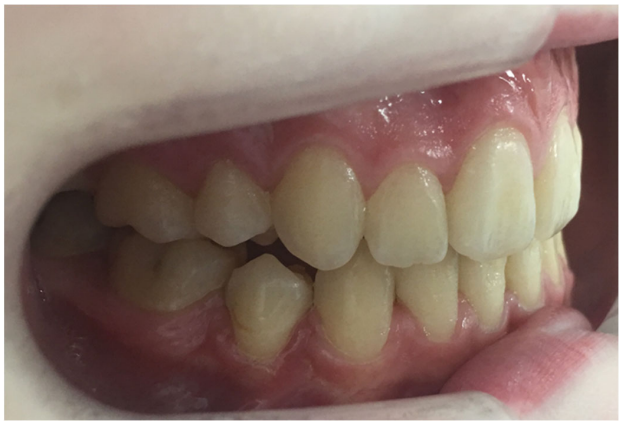


(**e**)



(**f**)

Figure 1. *Cont.*



(**g**)

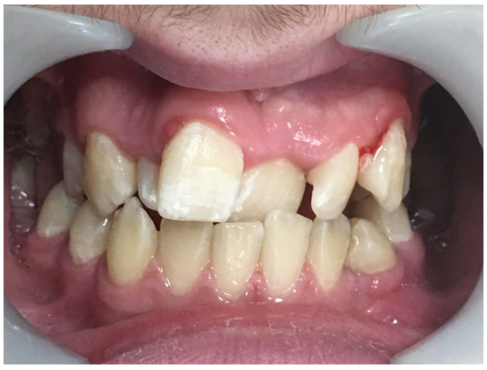
Figure 1. (**a**–**g**) The preoperative panoramic radiograph following the removal of the four first premolars, showing impacted and distally angulated mandibular second premolars (**a**) and the pre-operative views of the surgical exposure site (**b**,**c**), one week after diode laser exposure (940 nm). Bonding with simultaneous traction using power chain, absence of inflammation or swelling one week post-op (**d**), subsequent re-bonding with premolar brackets, and final result are shown (**e**–**g**).

Both mandibular second premolars were fully erupted and re-bonded again after 3 months (Figure 1e); photos from the end of the treatment can be seen (Figure 1f,g). The treatment took about 18 months.

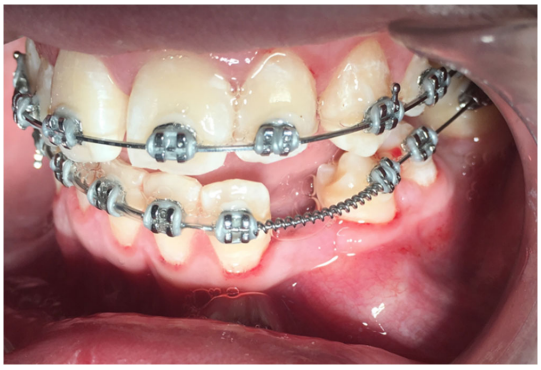
4.2. Case Report 2

Impacted Mandibular Left Canine

A 14-year-old male patient presented with a Class III malocclusion, anterior cross-bite, impacted mandibular left canine (LL3), dental centre line discrepancy, and severe crowding in the upper and lower dental arches. This required prior space opening in the LL3 area prior to laser exposure. Subsequent to the removal of the four first permanent molars, due to poor prognosis (Figure 2a), and a space opening in the LL3 area (Figure 2b,c), laser exposure of the mandibular left canine was carried out after the injection of about a third of a lidocaine cartridge in the surgical site (Figure 2d). This was followed by bonding of the mandibular left canine with a small bracket (lower incisor bracket), and simultaneous orthodontic traction was initiated using an elastomeric power chain (Figure 2d). The mandibular left canine was fully erupted and bonded again after 5 months (Figure 2e). Apart from mild discomfort for a few days and some food impaction in the surgical exposure site that needed some in-office irrigation, the patient reported no major issue in the surgical site and adjacent areas. The treatment was ongoing at the time the last photo was taken (Figure 2e).



(**a**)



(**b**)

Figure 2. *Cont.*

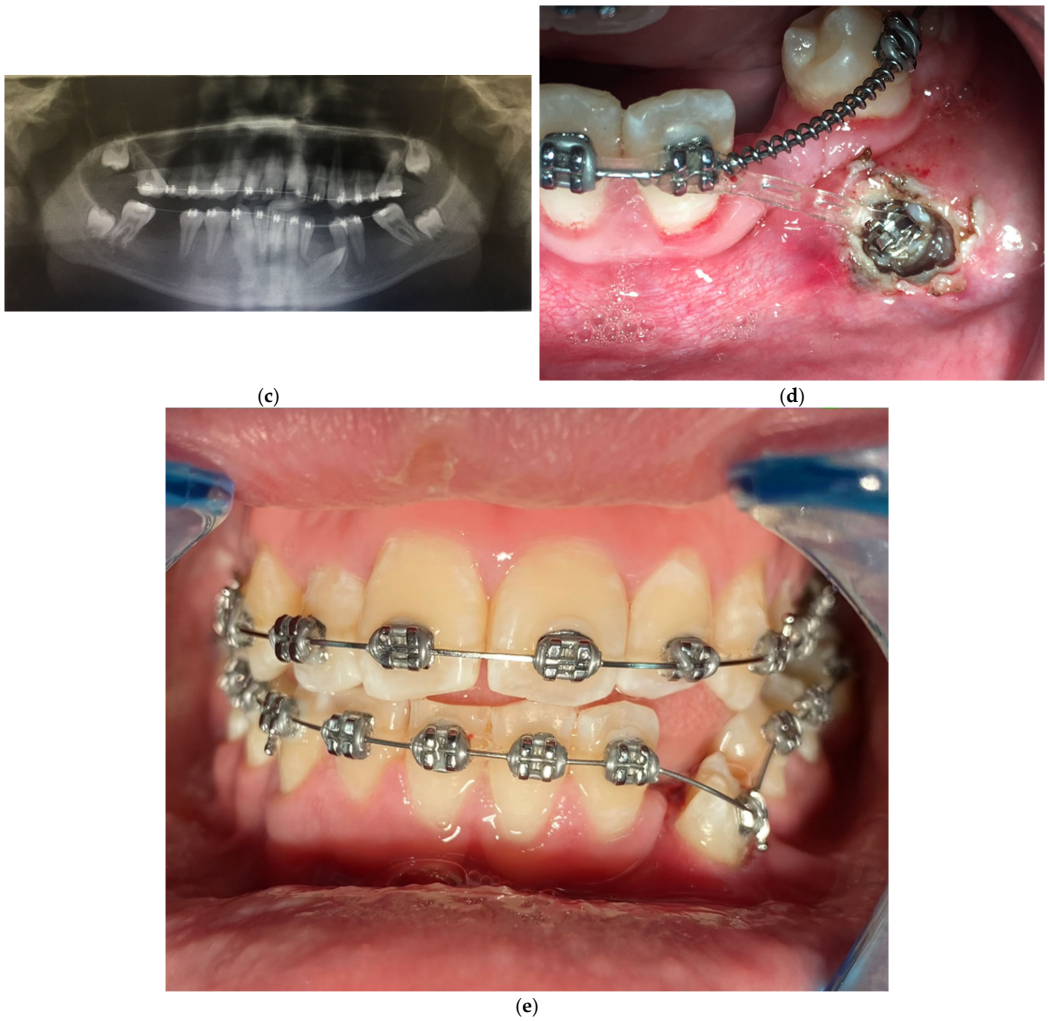


Figure 2. (**a**–**f**) Frontal intra-oral view with a Class III malocclusion anterior cross-bite, severe crowding in upper and lower dental arches, and impacted mandibular left canine (LL3), necessitating space opening in the area prior to laser exposure (**a**,**b**). In particular, the proximity to the mental nerve made the surgical exposure challenging. The preoperative panoramic view shows an impacted LL3 after space opening in the area and 4 extracted first permanent molars (**c**). Diode laser exposure (940 nm) with immediate bonding and orthodontic traction is demonstrated (**d**). Subsequent to further eruption (after about 5 months), the LL3 was rebonded with a canine bracket (**e**). Frontal view showing substantial correction of the Class III incisors, anterior cross bite, dental centre lines, and eruption of LL3 (treatment ongoing) (**e**).

5. Discussion

The review of the literature identified only one case-control study, suggesting a paucity of studies comparing conventional surgical tooth exposure (scalpel) and diode laser exposure. As explained earlier, based on the very limited available evidence, a scoping review of the literature was conducted [19]. The identified studies lacked sample size calculations, the study sample sizes were small, no long-term follow-up was carried out to assess the periodontal health of the exposed teeth, and full details of the case selection and surgical sites were not reported (Table 1). Of importance was the fact that laser exposure took less time and was associated with no bleeding and less use of infiltration anaesthetics and analgesics. Diode laser surgical exposure did not need suturing and allowed for immediate bonding of attachment to the crown of the impacted tooth, compared to 60% in the conventional scalpel group.

One of the aims of scoping reviews is to clarify key concepts or definitions in the literature. The definition for impacted teeth or unerupted teeth was not quite clear; there were variations among the identified studies. It was not clear how cases that needed surgical exposure were selected or whether they had any CBCT examination prior to inclusion in the study. This is important, as teeth covered by bone are not candidates for diode laser exposure. The methodologies of the identified studies were not similar enough to allow for comparison across studies. This highlights the importance of better standardization in assessments and methods for future research [19]. The review identified gaps in our knowledge such as of the ideal laser characteristics (wavelength, power, continuous or pulsed mode), the best anaesthetic formula/usage (topical or infiltration) for diode laser exposure, or data on the long-term periodontal status of exposed teeth. The review also identified two main approaches when using a diode laser for the exposure of impacted/unerupted teeth; one was with simultaneous orthodontic bonding [16] and the other involved laser exposure without immediate orthodontic bonding [22,23].

Most reports of the surgical laser exposure of impacted teeth involve maxillary canines and incisors, which are relatively safe to operate on. However, reports on the laser exposure of mandibular impacted teeth close to vital nerves such as the mental nerve are limited [24]. The present report highlights the benefits of using in-office diode lasers for the exposure of mandibular impacted teeth near the mental nerve, where a precise surgical exposure is needed. This provides better surgical site visibility, is less traumatic and minimally invasive, and eliminates scalpel surgery complications (i.e., possible nerve damage, infection, and swelling). Ideally, soft tissue laser surgery involves the right combination of ablating, incising, and excising the soft tissue, the provision of the much-needed coagulating effect, and no or very limited interaction with hard tissue [15,18].

Frequently used dental soft tissue lasers are mainly diode lasers due to their smaller devices and lower cost [15,18]. Diode lasers (800–980 nm) provide deep soft tissue penetration and very good coagulation/haemostasis, with minimal dental hard tissue interaction [15,17,18]. Carbon dioxide lasers (10,600 nm) offer good ablation of both hard and soft tissues, with shallow soft tissue penetration of 0.2 mm, superficial carbonization and coagulation at a much higher cost, and less control over bleeding, necessitating the use of surgical dressing [25]. Erbium lasers (Er:YAG laser (2940 nm) and Er,Cr:YSGG laser (2780 nm)) are relatively expensive; they penetrate soft tissues as shallow as 5 μm, creating precise ablation with minimal thermal effects and a low inflammatory response, but with weak coagulation properties and bleeding at the surgical site [15,17,18]. The Nd:YAG laser (1064 nm), a deeply penetrating type of laser with a relatively thick coagulation layer on the lased soft tissue surface and with strong haemostasis, is another laser with minimal dental hard tissue interaction [15,18].

There is growing evidence that photobiomodulation with diode laser light (808–940 nm), which is associated with the use of most diode lasers, results in a greater number of newly-formed osteoblasts and matrices, increases in collagen synthesis, and microvascular re-establishment [19,26]. Diode lasers are the ideal choice for the orthodontic set-up because of the smaller size of the laser device, good penetration (photobiomodulation) and haemostasis, as well as the relatively lower cost involved [15,18].

When hard tissue lasers (erbium (Er:YAG; 2940 nm) and neodymium (Nd:YAG; 1064 nm)) were used after tooth extraction (to degranulate, disinfect, de-epithelialize, clot stabilize, and photobiomodulate the extraction socket), improved post-extraction bone healing/density and considerably less pain, bleeding, or swelling were observed [27].

The conventional surgical exposure of teeth involves making apically positioned flaps, releasing incisions apical to the adjacent teeth and managing intra- and post-operative bleeding, post-operative pain, and suturing, as well as any post-operative infections [1,13]. The conventional flap procedures are relatively aggressive in nature and associated with a degree of alveolar bone loss, compromising the integrity of periodontium. The full-thickness mucoperiosteal flap often requires suturing and the placement of a protective dressing (pack) over the surgical site while it heals [28], and the patient may need sedation

or general anaesthesia. This is costly and stressful for patients. The use of a scalpel may involve suturing that comes with a risk of suture loss or loosening, and sutures often need to be removed 1–2 weeks post-operatively [28–31]. The diode laser creates a bloodless surgical site that allows for immediate orthodontic bonding of the impacted tooth without the need for surgical dressing, as highlighted in this review. This reduces the treatment time and provides an open exposure method that is associated with less pain during orthodontic treatment, shorter treatment time, and fewer complications post-surgery [18,32]. There is also less need for infiltration anaesthesia, with an improved postoperative comfort and healing potential [16].

Aside from the management of gingival enlargement/hyperplasia, cosmetic gingival contouring, and the exposure of impacted teeth [15,18], diode lasers are used to uncover temporary anchorage devices. Diode lasers are also used for frenectomy, operculum removal of mandibular molars, to facilitate banding or bracket bonding, or the treatment of post-orthodontic minor aphthous ulceration [18,33–35]. In addition, when a precise and stable soft tissue position after surgery is needed, a diode laser has been shown to be more reliable, offering a more stable tissue margin compared to a scalpel [36].

When using a laser to expose the impacted teeth, it is important to keep the exposed crown in the keratinised mucosa and preserve the keratinized mucosa as much as possible to avoid future complications such as the development of a thin gingival biotype [15,17,18]; this will make cleaning of the site much easier, preventing complicating food accumulation afterwards [15,17,18]. In both cases presented, the option of the apically repositioned flap, involving hospital admission and a much longer referral/treatment time, was provided to patients; however, the families decided to opt for the in-office laser exposure. Adjunctive use of a 940 nm diode laser in orthodontics for soft tissue procedures is limited [15,18,34,35] in the literature, and there are few studies comparing diode laser surgical exposure and conventional methods of tooth surgical exposure [16,20,22,32]. Considering the minimally invasive nature of diode laser exposure, there is a need for clinical trials to further investigate and identify the right wavelength, power, and anaesthesia method for using diode lasers. This review and case report further highlights the use of a diode laser for precise, minimally invasive, and bloodless surgical exposure that is associated with ease of immediate bonding, faster recovery, and minimal pain compared to conventional surgery using a punch or scalpel [37].

6. Conclusions

High-quality clinical trials are needed to compare outcomes from diode laser surgical exposure vs. the conventional method to identify the ideal laser characteristics and provide data on any potential risks and the long-term periodontal health of laser-exposed teeth.

Funding: No funding was obtained for this study.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The author declares no conflict of interest.

Abbreviations

RCT	Randomized clinical trial
LL3	Mandibular left canine

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