Photonics (Er,CR:YSGG and photobiomodulation) versus conventional surgery for impacted lower third molar tooth extraction: a split-mouth, controlled randomized clinical study

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Abstract

Purpose  Impacted third molars occur commonly and often require surgery for tooth extraction. As consequence, postoperative complications of varying degrees of severity are commonly seen. Thus, searching for less traumatic surgeries protocols is of importance. The aim of this study was to evaluate the outcome of impacted lower third molar teeth extraction using traditional protocol (scapples and surgical burs) or photonics protocol [Er,CR:YSGG associated with photobiomodulation therapy (PBMT)].

Methods Thirty-five patients with bilateral impacted mandibular third molars were included in this split-mouth, controlled, and randomized clinical study. Seventy impacted third molars were divided into control group: extraction using traditional surgical scapples for soft tissue and burs for bone cutting or photonics group: extraction using Er,CR:YSGG laser (2780 nm) for soft tissue and bone cutting followed by PBMT (940-nm diode laser). The maximum mouth aperture (MMA) before and after extraction was used for comparing the surgeries’ outcomes.

Results Immediately after surgery, the MMA for the control group remained unchanged and decreased significantly at 7 days after surgery. In the photonics group, the MMA remained unchanged during whole experimental time.

Conclusion The presented photonics protocol (Er,CR:YSGG laser plus PBMT) for third molar extraction prevents impairment of the maximum mouth aperture.

Keywords  Er,CR:YSGG laser · 904-nm diode laser · Photobiomodulation therapy · Tooth extraction

Introduction

Most surgeries lead to outcomes that are directly related to the extent of trauma caused by the surgical procedures. Therefore, surgeons are looking for surgical procedures that could minimize the trauma of bones and soft tissues. A very common surgery in dentistry is the extraction of impacted third molars [1, 2]. This surgery is often required due to the presence of symptoms and or for association to oral disorders, such cysts or odontogenic tumors. Postoperative complications of varying degrees of severity are commonly seen in third molar impaction surgery. These complications are mainly postoperative pain, swelling, and trismus, but also fractures, postoperative infection, hemorrhage, damage, or displacement of adjacent teeth can occur [3]. These complications can compromise mouth opening, among others, impacting the life quality of the patients [4–6].

The conventional impacted third molar removal is based on the opening of the soft tissue with blades to access the bone, followed by removal of the bone with burs at high speed to
access the impacted tooth, and sometimes sectioning the teeth with burs. An alternative for this traumatic type of surgery is the use of high-power lasers able to cut soft tissue and ablate hard tissues. Lasers have been established to ablate dental hard tissues without thermal damage throughout the ablation of enamel, cementum, and bone. In 2002, the Er, Cr:YSGG (2780 nm) laser was presented for hard tissue surgical procedures, such as osseous cutting, shaving, contouring, and resection after compliance of safety and effectiveness [7]. Additionally, for controlling some of the postoperative complications of impacted third molar extraction, an adjunctive laser therapy, done with lasers in low intensity, known as photobiomodulation (PBM) therapy can be applied intra- and/or extra-orally. PBM has biostimulatory effects, and it is able to modulate the inflammatory process, resulting in less pain and swelling promoting faster tissue regeneration [8, 9].

Based on the above, our hypothesis was that our proposed protocol based on photonics (Er, Cr:YSGG laser followed by application of PBM) for impacted third molar removal would have lesser postoperative complications than convention surgery (traditional scaples for soft tissue and surgical burs for bone cutting). To test this hypothesis, the aim of this split-mouth controlled clinical study was to evaluate the outcome of these both surgery techniques. Pain and edema are the most common undesirable outcomes of impacted tooth extraction. And they, in turn, impairs mouth opening. Thus, in this study, the measurements of the maximum mouth aperture before and after extraction of impacted lower third molar teeth were assessed to compare both surgery protocols.

Material and methods

Study design and inclusion/exclusion criteria

This split-mouth, controlled randomized clinical trial was carried out at the private dental office in London. For that, 35 healthy outpatients, age 19 years old to 39 years old, of both gender (16 males and 19 females) with two contralateral impacted lower third molars that need to be removed, were selected (Fig. 1a) and were included in the study. Pregnant women and patients with uncontrolled diabetes were excluded. A full medical and dental history and panoramic radiographs (Fig. 1b) were taken. The sample size was calculated with the G*Power 3.0.10 [10]. Third molars were classified according to the Winter’s classification. In the total of 70 third molars, 61 of the third molars were in horizontal angulation to inclination to the long axis of the second molars and nine of the third molars were in mesioangular angulation to inclination to the long axis of the second molars.

Clinical procedures

All the procedures and analyses were performed by a single researcher; the procedures were done under local anesthesia consisting of 2% lidocaine hydrochloride with 1:80,000 adrenaline (Lignospan Special, Septodont, UK).

The randomization was performed with a patient indication which side (left or right hand side) they preferred to be treated first. The first patient of the day was treated with laser, the second one with conventional tooth extraction and so on. The second surgery occurred between 3 and 4 weeks after the first surgery, depending on the total recovery of initial maximum mouth opening.

Seventy impacted third molars were divided into the following:

- **Control group**: extraction of impacted lower third molar teeth using traditional surgical scaples for soft tissue and burs for bone cutting.
- **Photronics group**: extraction of impacted lower third molar teeth using Er, CR:YSGG laser (2780 nm) for soft tissue and bone cutting followed by PBMT.

![Fig. 1](a) Intra-oral photograph showing the upper third molars partially erupted and (b) panoramic radiograph showing these impacted teeth
Conventional tooth extraction

Figure 2 illustrates the impacted third molar extraction with the conventional protocol (control group). After mouth washing and anesthesia, immediately before the surgery, the initial maximum mouth opening (MMA), in mm, was recorded using a caliper (Boley Gauge Caliper Vernier BG HU FRIEDY) (Fig. 2a). Then, a mucoperiosteal flap was reproduced with scalpel NO:15 and with periosteal elevator to uncover the impacted third molar tooth and nearby bone. With a carbide round bur (fixed on a straight handpiece was used at 35,000 rpm), the buccal and distal sides of the tooth were cut (Fig. 2b). A straight fissure bur was used to divide the tooth (Fig. 2c). At all times, cutting of bone and tooth was irrigated with chilled saline solution. After removal of the tooth (Fig. 2d), the extraction socket was debrided (Fig. 2e), irrigated with saline solution, and the wound was sutured with proline sutures (Fig. 2f). Immediately after surgery and 7 days later, the maximum mouth aperture was measured as described above. Surgical time from incision to suturing for conventional third molar removal was between 30 and 45 min.

Photonics tooth extraction

Figure 3 illustrates the impacted third molar extraction using the photonics protocol. After mouth washing and anesthesia, similarly, as in the control group, the initial maximum mouth opening in mm was recorded using a caliper (Fig. 3a). The photonics protocol was applied with the Er,Cr:YSGG laser, followed by PBMT (904-nm diode laser) (both lasers from Biolase, USA) with the parameters presented in Tables 1 and 2, respectively. The Er,Cr:YSGG laser device used a pulsed energy basis that is provided across an optic fiber transfer system linked to a straight handpiece with an end-cutting tip. The tip has a diameter of 750 μm. Through the surgical process, the tip of the laser was situated 1 to 2 mm from the target tissue, and it is washed by an air–water spray mist over to escape burning of tissues.

The parameters of irradiation were different for raising a flap in the soft tissue (Fig. 3b) and for osteotomy (Fig. 3c, d). To reduce the operating time of the process, a conventional fissure bur handpiece was used for sectioning of the third molar (Fig. 3e). Following tooth removal, the Er,Cr:YSGG laser was used for bone debridement (Fig. 3f). Surgical time from incision to suturing for laser-assisted third molar removal was between 40 and 60 min. After wound closing by using proline sutures (Fig. 3g), the laser group received PBM therapy (Fig. 3h, i). PBM therapy was done in the scanning mode. Extroral, the tip was positioned perpendicularly to the face on the extraction side with movement covering the side of the face where the extraction was done. Intra-orally, irradiation was done occlusal, vestibular, and lingually over the dental socket. Immediately after surgery and 7 days later, the maximum mouth aperture was measured as described above.

All patients received an antibiotic postoperative therapy with Amoxicillin 500 mg or Metronidazole 400 mg every 8 h up to 5 days. The patients were advised to take paracetamol if necessary.
Analyses

The primary outcome variable was the maximum mouth aperture (mm) that was obtained with a caliper (Boley Gauge Caliper Vernier BG HU FRIEDY) before, immediately after surgery, and in 1 week after surgery.

Ethical issues and statistical analysis

All patients were treated in agreement with the Declaration of Helsinki (1964), where all patients were informed about the entire process and signed a comprehensive consent form. The sample size was calculated with the G*Power 3.0.10. [10]
By comparing the effect of both tooth extraction protocols, the data of maximum mouth aperture from the three periods within the same experimental group were compared with ANOVA complemented by Tukey’s test. The level of significance was set at 5% ($p \leq 0.05$).

**Results**

**Maximum mouth aperture**

Figure 4 illustrates the results. The maximum mouth aperture was taken before, immediately after surgery, and 7 days later (Fig. 4a). Immediately after the conventional surgery, the mouth aperture remained unchanged irrespective to the experimental group. At 7 days, there was a significant decrease in this aperture ($< 0.01$) for the control group. For the photonics group, the maximum mouth aperture means remained unchanged during whole experimental time (Fig. 4b).

**Discussion**

Impacted third molar removal can be very traumatic. For this reason, less traumatic procedures and adjuvant therapies to improve the outcomes of such surgeries have been suggested. Among these procedures, the use of lasers has been studied with positive results. High power lasers can be used for cutting both soft and hard tissues, and low power lasers can have a biostimulatory and analgesic effect. With the hypothesis that the use of a proposed protocol based on photonics (Er,Cr:YSGG laser followed by application of PBMT) for impacted third molar removal would have lesser postoperative complications than conventional surgery, this split-mouth controlled clinical study evaluated the outcome of these both surgery techniques by comparing the measurements of the maximum mouth aperture before and after extraction of impacted lower third molar teeth. The results confirmed our hypothesis, once the mouth aperture that could be impaired due to edema or traumatic procedures during tooth extraction in the laser group was maintained unchanged during whole experimental time, whereas after conventional tooth extraction, at 7 days post-surgery, this aperture decreased significantly.

Throughout the previous three decades, lasers have been generally used in many medical specialties [11, 12]. Lasers were primary used in dentistry to remove dental caries and as a further for mechanical cutting with the air-turbine, high-speed handpiece to ablate teeth and bone with the argon, CO$_2$, and Nd:YAG lasers. Traditionally, in oral and maxillofacial surgery, the laser application has been restricted to soft tissue surgery. Carbon dioxide and neodymium:YAG lasers in hard tissue (bone and teeth) have been used; however, these lasers trigger considerable thermal destruction involving carbonization and cracking [1, 3], resulting in belated or reduced recovery [13–15]. On the other hand, Er,Cr:YSGG laser, with a wavelength of 2780 nm, has shown the capability to ablate teeth and bone with no harm to the pulp or to the underneath bone [7, 16]. The cutting with this type of lasers occurs by thermal ablation process. This process relies on the absorption of energy delivered by the laser by the water present in the target tissue. Then, the water temperature increases leading to increase of the pressure inside the tissue, leading to micro explosions with tissue removal.
resulting in an ablation crater [17] Knowing that the 2780-nm wavelength is greatly absorbed in water creates the possibility to change the parameters in such a way to cut soft tissue, cut bone, and remove smear layers and decontaminate the extraction site. The machine of cutting hard tissue is different than any other laser system and is capable by an interaction of the laser energy with the water spray, which has been named a “hydrokinetic effect.” Absorption of laser energy by the water fog makes violent micro explosions on the end tissue, which is accountable for eliminating calcified hard tissues such as enamel, cementum, and bone [16, 18]. Eversole et al. showed that osseous wound repair in response to surgery with the Er,Cr:YSGG laser was similar to that of surgery completed with the conventional fissure bur in a high-speed air-turbine handpiece operating at 25,000 rpm, with no adverse thermal changes to the beagle dogs with the Er,Cr:YSGG laser [19].

The Er,Cr:YSGG 2780-nm laser has confirmed to be a surgical device capable of ablating hard tissues for gaining of bone in cutting processes and in the extraction of impacted third molars. Intraoperatively, the laser beam allowed exact clean cutting of hard tissues exclusive of necrosing osseous tissues and has not produced extra harm to the nearby soft tissues and teeth. This is because of the water spray that surrounds the laser beam [18]. In fact, no injuries were witnessed during the third molars extracted from the mandible with this laser. The mouth aperture after the application of the proposed photonics protocol was not affected by the surgery. Moreover, all patients up to now approved that the extent of postoperative mouth aperture opening was better with laser use. This was in relationship with removing the third molar with a fissure bur handpiece. The outcomes showed that all patients were satisfied with treatment and wished the use of the laser to the high-speed handpiece. The only drawback with laser use is the extended working time. On the other hand, the patients reported that they need to take painkillers only after some of the conventional surgeries. None of the patients took painkillers after the tooth extraction using the photonics protocol (data not shown). This could be explained based on both the tooth extraction with 2780-nm laser and on the photobiomodulatory effects of the 940-nm laser applied in low intensity. The positive effects of PBMT on tissue repair are well known [20]. The extra-oral infrared laser irradiation reaches deep tissues like bone, where the inflammatory process is modulated resulting in control of pain and edema, among other positive effects for tissue repair. In fact, Santos et al. [21] had already reported that a single session of extra-oral infrared laser irradiation improved postoperative mouth opening after third molar extraction. Moreover, recently, Cheng et al. review the pathways and mechanisms of pain modulation and the therapeutic application of different wavelengths on pain control showing foundation for understanding this novel treatment for pain [22].

This study showed an efficient effect of the 2780-nm wavelength laser-assisted third molar surgery combined with PBMT on mouth aperture that was achieved even with a single application of 940-nm diode laser intraorally and extra-orally. Thus, it remains to be determined if the better outcome observed in the photonics group was mostly due to the Er,Cr:YSGG laser-assisted surgery or to the PBM effect. Anyway, the proposed surgery technique combining high- and low-intensity lasers was successful in maintaining the maximum mouth aperture unchanged after surgery.
Based on the results of this split-mouth controlled clinical study, even taking into account its limitations (e.g., the small number of patients), we can conclude that the presented photonics protocol (Er,Cr:YSGG laser plus PBMT) for third molar extraction prevents impairment of the maximum mouth aperture. Then, one can infer that laser-assisted surgery protocol here presented has potential for being a future routine treatment for impacted third molar removal. Then, it gives support for making this technology an extremely significant treatment choice for patients in the near future.

**Author contribution** Saleh Aria: conception and design of the study, clinical procedures, data analysis, and manuscript drafting. Thiago Pal-lin Gomes: data analysis and critical review of the manuscript. Norbert Gutknecht: conception and design of the study. Marcia Marques: conception and design of the study, data analysis, and critical review of the manuscript.

**Declarations**

**Competing interests** The authors declare no competing interests.

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