

Thermographic monitoring of wound healing and oral health-related quality of life in patients treated with laser (aPDT) after impacted mandibular third molar removal

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G. Batinjan, Z. Zore, A. Čelebić, M. Papić, D. Gabrić Pandurić, I. Filipović Zore: Thermographic monitoring of wound healing and oral health-related quality of life in patients treated with laser (aPDT) after impacted mandibular third molar removal. Int. J. Oral Maxillofac. Surg. 2014; xxx: xxx–xxx. © 2014 International Association of Oral and Maxillofacial Surgeons. Published by Elsevier Ltd. All rights reserved.

Abstract. The objective of this study was to assess the impact of low-level laser therapy on wound swelling, wound temperature changes, and oral health-related quality of life (OHRQoL) after surgical removal of impacted lower third molars. Forty patients with impacted lower third molars requiring surgical removal participated in this study; all were Pell–Gregory class IIB or IIC. The patients were divided randomly into two groups for post-extraction therapy. One group received antimicrobial photodynamic therapy (aPDT) and the other received no additional therapy (placebo group). Temperature measurements were done using an infrared thermographic camera on days 3 and 7 postoperative. OHRQoL was assessed in both groups on day 7 using the Oral Health Impact Profile questionnaire translated into Croatian (OHIP-14-CRO). Prior to surgical treatment, there was no difference in patient characteristics between the two groups. A significantly lower temperature and less wound swelling were recorded on day 3 postoperative in the aPDT group compared to the control group ($P < 0.001$). Participants in the aPDT group also had significantly lower OHIP-14-CRO summary scores ($P < 0.01$). The present study showed beneficial effects of the aPDT modality of low-level laser therapy: postoperative wound swelling was reduced and wound temperature decreased, and OHRQoL was better through the 7-day postoperative period in comparison to the placebo group.

Key words: thermography; diode laser; third molar extraction; quality of life.

Accepted for publication 5 September 2014

The extraction of impacted lower third molars is followed by an inflammatory reaction, pain, swelling, and often by limitations in mouth opening and mouth movements.¹⁻³ It has been reported that about a third of subjects experience a significant deterioration in quality of life (QoL) after routine tooth extraction.⁴ With regard to the extraction of mandibular third molars, one study showed a decrease in QoL immediately after the procedure, which returned to the initial preoperative levels after the sixth postoperative day.⁵ In studies using the Oral Health Impact Profile (OHIP) questionnaire, those domains with significantly higher scores have been physical pain, psychological discomfort, and physical disability. Impacted mandibular third molars may be difficult to extract,⁵⁻⁷ and significantly higher OHIP scores and worse oral health-related quality of life (OHRQoL) have been registered after their extraction in comparison to the extraction of non-impacted third molars.⁸

Laser therapy has been reported to be an effective tool for the treatment of postsurgical conditions, due to its analgesic and anti-inflammatory effects, as well as to the stimulating effect on tissue healing.⁹⁻¹¹ Infrared thermography is a diagnostic method based on the ability to record infrared radiation emitted by the skin and to convert this into electronic video signals. Infrared thermography is unique in its ability to show physiological and/or pathological temperature changes.¹²

The objective of this study was to assess post-extraction wound swelling and wound temperature after surgical removal of impacted lower third molars in patients subjected to treatment with a low-level laser modality; in this study, a group of patients treated with antimicrobial photodynamic therapy (aPDT) was compared to a placebo group. A further aim was to assess OHRQoL in both groups using the OHIP-14 questionnaire translated into Croatian (OHIP-14-CRO). The null hypothesis was that there would be no significant difference between subjects who received placebo therapy and patients who received aPDT after surgical removal of an impacted lower third molar.

Materials and methods

The study was approved by the ethics committee of the dental school.

Forty patients who had impacted lower third molars that required surgical removal participated in the study; all were Pell-Gregory class IIB or IIC.¹³⁻¹⁵ There were 20 males and 20 females, ranging in age from 19 to 32 years. The following

exclusion criteria were applied: systemic diseases, smoking habit, pregnancy or breastfeeding, oral contraception, antibiotics or analgesics taken before or after the surgical procedure, and overweight (high body mass index (BMI)). The height and weight of each participant were recorded and the BMI calculated using the formula weight/height squared (kg/m^2). Participants with a BMI ≥ 24 were not included in the study. All participants had BMI values within the normal range.

Before the surgical removal of the impacted lower third molar, all patients were informed in detail about the laser therapy, its application, effects, indications, and side effects, and also about the thermographic procedures. All participants signed an agreement in which they accepted laser therapy after tooth extraction. They were divided randomly into two groups, the study aPDT group who received real laser therapy ($n = 20$) and the placebo group ($n = 20$) who did not receive laser therapy. There were 34 participants with class IIB molar impaction, who were distributed equally in each group (17 participants in each group). Six participants had class IIC impaction and these patients were also distributed equally in each group (three participants in each group).¹³⁻¹⁵ None of the patients were taking antibiotics or had undergone a prior surgical procedure, nor did they do so after the impacted tooth removal.

All surgical procedures were performed under local anaesthesia with articaine hydrochloride and adrenaline hydrochloride (Ubistesin; 3M ESPE AG, Seefeld, Germany). Impacted lower third molars were removed using the surgical technique of mucoperiosteal flap and osteotomy. All third molars were sectioned during surgical removal in order to preserve as much bone as possible. In order not to influence the level of tissue damage related to the surgical experience of the operator, the surgeon performing the operations had more than 10 years of experience. All cases underwent wound closure with sutures and healing by primary intention; the sutures were removed on the seventh postoperative day at the follow-up appointment.

A high frequency laser (LaserHF; Hager and Werken GmbH & Co., Duisburg, Germany) was used in the study. Participants were divided randomly into two groups: one group of 20 participants received adequate laser therapy and the other group (also 20 participants) received only placebo laser therapy. Patients were completely unaware of whether they had

received laser therapy or placebo. The study group received laser therapy before suturing. A photosensitive substance consisting of toluidine chloride powder ($155 \mu\text{g}/\text{ml}$), water, sodium phosphate, and hydroxymethylcellulose (LaserHF Paro-PDT solution; Hager & Werken GmbH and Co.) was applied to the post-extraction socket. After 60 s, the Paro-PDT solution was thoroughly rinsed using saline solution and a laser light was applied directly to the surgical site for 60 s (2×30 s) with constant laser beam irradiation over the surgical area. The laser probe was used in non-contact mode and was set at a distance of approximately 5 mm from the tissue surface. The irradiation intensity was 50 mW, with a wavelength of 660 nm. In the control (placebo) group, the saline solution (0.9% NaCl) was applied before suturing. The laser probe was held above the wound, but without any irradiation.

All patients received identical postoperative instructions. They were told to eat a soft food diet on the day of surgery and the following day, not to drink alcoholic beverages or sparkling drinks during the same period, and to avoid tooth brushing, rinsing, or spitting on the day of surgery. They were instructed to brush their teeth on the day after surgery, but to avoid any brushing near the surgical site for 3 days. They were asked to apply ice to their face for the first 24 h and to keep their head elevated in order to reduce wound swelling. Irrigating and rinsing of the wound was not allowed for the first 2 days.

Thermographic procedure

Temperature measurements were done using an infrared (IR) thermographic camera (FLIR T335; FLIR Systems Pty Ltd, Australia) with a detection range of -20°C to $+650^\circ\text{C}$, a thermal sensitivity of <50 mK, and IR resolution of 320×240 pixels. Analysis of the recorded data was performed using the FLIR Tools software (FLIR Systems, Inc., North Billerica, MA, USA). Prior to the surgical procedure (extraction of the impacted mandibular third molar), standardized thermographic images of the patient's face in profile (dependent on the site of extraction) were obtained by the thermographic operator. Before imaging, the patient was left in the recording room for a minimum of 15 min. The temperature and humidity of the room were always the same due to controlled conditions (air conditioning). The camera was set up on a tripod at a fixed distance

Table 1. Temperature differences between the aPDT and control groups and significance of the differences.

| | Group | Temperature, °C | | <i>t</i> | <i>P</i> -value |
|---|----------|-----------------|------|----------|-----------------|
| | | Mean | SD | | |
| Before surgical removal of the lower third molar | aPDT | 35.09 | 0.63 | −0.117 | 0.908 NS |
| | Controls | 35.11 | 0.44 | | |
| Day 3 after surgical removal of the lower third molar | aPDT | 35.36 | 0.62 | −4.64 | 0.001* |
| | Controls | 36.29 | 0.64 | | |
| Day 7 after surgical removal of the lower third molar | aPDT | 35.02 | 0.76 | −1.86 | 0.071 NS |
| | Controls | 35.45 | 0.69 | | |

aPDT, antimicrobial photodynamic therapy; SD, standard deviation; NS, not significant. Degrees of freedom = 38.

*Significant at 99% probability, $P < 0.01$.

(30 cm from the patient's head), and the settings were always the same. All patients were seated in an upright position. During measurements, they looked straight ahead. Further thermographic images were obtained at the postoperative follow-ups on the third and seventh postoperative days.

The skin projection of the region of interest (ROI) was marked and the mean temperature of the ROI was obtained in degrees Celsius. The superior ROI border represented a line connecting the commissure of the lips and the point where the frontal part of the earlobe turns into facial skin. The frontal border was the line intersecting the superior border and perpendicular to the lower border of the mandible. The inferior border represented the lower border of the mandible, and the posterior border was a line drawn from the point where the ear lobe meets the facial skin to the gonion.

All temperatures were measured at the same time of the day, between 9:00 and 11:00 a.m.

Assessment of wound swelling

Wound swelling was assessed by one experienced surgeon (with more than 15 years of experience) who did not perform the impacted lower molar removal. Before assessing the study patients, the same specialist in oral surgery assessed 25 wound images of different degrees of swelling twice, with an interval period of 7 days between the two assessments. These images were presented in a different order on the two occasions. The kappa test revealed a high level of agreement between the two assessments (kappa value = 0.921), which proved the uniformity of evaluation. Assessments of the patients who participated in the study were performed on postoperative days 3 and 7, using a four-point scale: 0 = no swelling, 1 = mild swelling, 2 = moderate swelling, and 3 = severe swelling. The surgeon who assessed wound swelling did not know to

which group the patient was allocated (laser therapy or placebo) and was completely unaware of the purpose of the study.

OHRQoL

OHRQoL was assessed for both groups of patients on day 7 after surgery. All participants completed an OHIP-14-CRO questionnaire.¹⁶ The questions related to the period from the surgical removal of the lower third molar to day 7 after the procedure. Patients answered each question on a 0–4 Likert scale (0 = absence of problems; 4 = the most severe problems). The OHIP summary score was calculated for the statistical analysis.

Statistical analysis

The statistical analysis was performed using SPSS ver. 19 statistical software (IBM Corp., Armonk, NY, USA). Descriptive parameters (mean values and standard deviations) were calculated. The significance of the difference for the registered temperature and for the OHIP summary scores between the laser and placebo groups was assessed by independent samples *t*-test. The level of significance was set at 0.05. The significance of the difference in wound swelling was assessed by Fisher's exact test. Correlation between the degree of wound swelling and the observed temperature on the third and the seventh postoperative days was assessed by Spearman's rho correlation coefficient.

Results

Temperature differences

There was no significant difference in temperature between the aPDT group and the placebo group before the surgical procedure. Both groups had almost the same temperature in the region of the impacted lower third molar (Table 1, $P = 0.76$).

A significantly higher temperature (almost 1 °C higher) was recorded on the third postoperative day in the placebo group than in the laser aPDT group ($P = 0.001$) (Table 1). On postoperative day 7, there was no statistically significant difference between the groups, although the placebo group still had a slightly higher temperature ($P = 0.071$, Table 1).

Assessment of wound swelling

The aPDT group had significantly more participants with mild wound swelling on day 3 after the surgical procedure in comparison to the placebo group, which had a higher number of moderate and severe wound swelling cases (Fig. 1; Fisher's exact test, $P < 0.001$).

On postoperative day 7 (Fig. 2), there was no significant difference in the degree of wound swelling between the groups ($P = 0.826$).

OHRQoL

Participants in the laser aPDT group had significantly lower OHIP-14 summary scores (mean value 13.0) (Table 2) than participants in the placebo group. The aPDT study group maintained significantly better OHRQoL during the postoperative period in comparison to the placebo group ($P < 0.01$, Table 2).

Correlation between wound swelling and observed temperature

The correlation between wound swelling and the observed temperature on the third postoperative day was significant ($P < 0.001$) and the rho coefficient was 0.725. The correlation was also significant on the seventh postoperative day (rho = 0.618, $P < 0.001$).

Discussion

A deterioration in OHRQoL after routine single tooth extraction has been described

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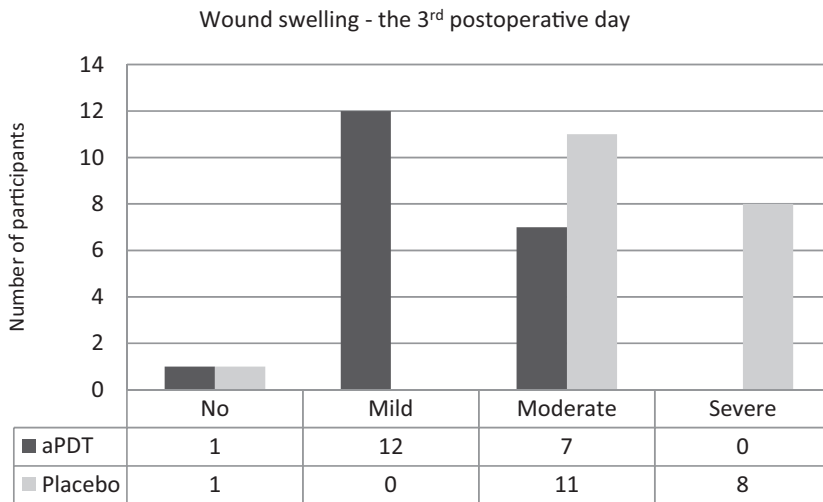


Fig. 1. Intensity of swelling on postoperative day 3 in the two examined groups: aPDT (antimicrobial photodynamic therapy group) and placebo (control group).

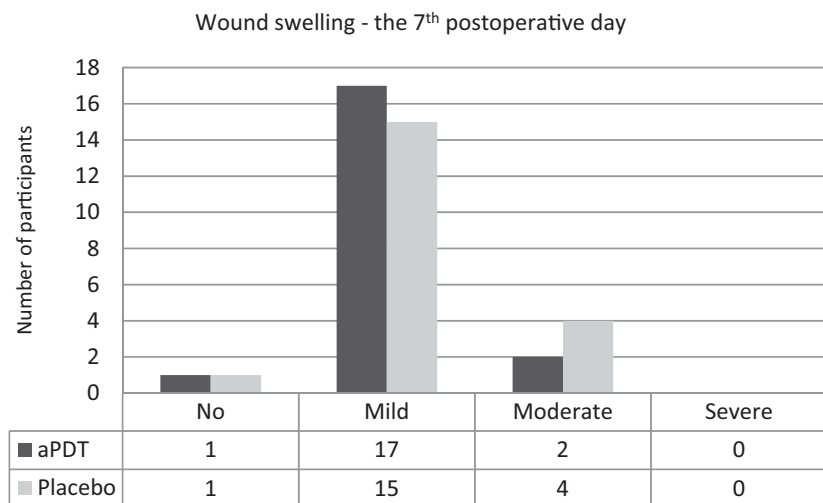


Fig. 2. Intensity of swelling on postoperative day 7 in the two examined groups: aPDT (antimicrobial photodynamic therapy group) and placebo (control group).

in the recent literature,^{3-6,17} but data concerning OHRQoL after the surgical removal of impacted mandibular third molars are scarce.⁵ Increased pain and wound swelling,^{2,18} increased halitosis,¹¹ and limited jaw opening and limited jaw movements,¹⁹ as well as reduced chewing ability, have been reported following extraction of the impacted mandibular third

molar. All of these factors have been evaluated individually in different papers.^{2-6,11,17-19} However, all of them may contribute to a decreased OHRQoL, including the physical, psychological, and social aspects.^{2,5,6}

The OHRQoL was established as an important area when evaluating the impact of a disease and/or efficacy of different

treatment modalities and related factors. It is based on a conceptual framework derived from the International Classification of Impairments, Disabilities, and Handicaps (ICIDH) developed by the World Health Organization (WHO) in 1980.^{20,21} It was assumed that the impairment that develops soon after extraction of the impacted lower molar would lead to a deterioration in the individual's quality of life. Therefore the OHIP-14-CRO questionnaire was chosen as a tool for the assessment of OHRQoL.¹⁶ It has already been validated in Croatia and has demonstrated excellent psychometric properties.^{16,17} Moreover, the OHIP is an internationally accepted questionnaire, so the data obtained can be compared with those of other authors.²² OHRQoL and oral health were evaluated from the surgical intervention to the seventh postoperative day using the OHIP-14-CRO questionnaire.

Some studies have shown a beneficial effect of laser on wound healing and reduced postoperative discomfort after laser therapy.^{10,11} Although each laser therapy modality has been proven to be advantageous, one study has shown the aPDT modality to have the best effects.¹¹ For this reason it was used in the present study. All of the patients were unaware of whether they had received real aPDT laser therapy or placebo therapy.

There are only a few papers in the recent literature that have reported temperature changes after the surgical removal of the impacted third molar with assessment by means of thermography.^{12,23,24} One was a study in which two patients were compared – one receiving laser therapy and the other receiving placebo therapy after the surgical removal of the lower third molar.¹² The thermographic abnormalities caused by extraction of the molar remained longer in the patient who was treated with the placebo laser.

Another study reported significantly higher postoperative temperatures on the operated side than on the control side at 2 days after surgery, while the temperature of the operated site, although much higher, was not significantly different from the preoperative temperature at the same site.²³ However, no temperature difference was reported between groups when methylprednisolone drugs or placebo were given.²⁴ As the assessment of wound swelling may be rather subjective, we aimed to collect thermographic data as well, measuring the wound temperature as an indicator of tissue swelling.

Infrared thermography is a method able to precisely quantify clinical and subclinical inflammatory changes.^{25,26} However,

Table 2. Difference in the OHIP-14 summary scores between the aPDT and control groups and significance of the difference.

| Group | OHIP score | | <i>t</i> | <i>P</i> -value |
|---------------|------------|------|----------|-----------------|
| | Mean | SD | | |
| aPDT | 13.00 | 3.84 | -6.776 | <0.01* |
| Control group | 26.50 | 8.29 | | |

OHIP, Oral Health Impact Profile; aPDT, antimicrobial photodynamic therapy; SD, standard deviation. Degrees of freedom = 38.

*Significant at 99% probability, $P < 0.01$.

the limitation of this method is the inability to detect temperature changes far from the surface of the body, as the method measures heat emission from the skin. Therefore pathological conditions located deep within the tissues will not be detected. The wound resulting from surgical removal of the mandibular impacted molar was not far from the skin and the temperature changes were easy to monitor using the thermal camera.

Thermographic recordings may also be affected by the type of tissue being imaged. Fat tissue is an effective insulator, causing lower temperature readings. Therefore, thermography can be difficult or impossible in overweight subjects.²³ It was for this reason that we included only subjects with normal BMI values in the present study. At baseline (prior to the surgical intervention), no temperature difference was found between the groups. On the third postoperative day, the temperature was increased in both groups, but it was significantly higher in the placebo group than in the aPDT group. This was attributed to more increased wound swelling in the placebo group than in the aPDT group, which was also confirmed by the wound swelling assessment performed by the experienced operator, who was unaware of the purpose of the study. Christensen et al. observed higher temperatures measured on the second postoperative day in comparison to the preoperative temperature, but the difference between the two measurements did not reach statistical significance.²³ There are several possible reasons for the difference between our study and that of Christensen et al. The ROI in the above-mentioned study was approximately twice as large as that in our study and included non-inflamed tissues, which would have decreased the mean temperature. Moreover, they also prescribed 600 mg ibuprofen, which is a drug known to reduce body temperature and also acts as an anti-inflammatory; our patients were not allowed to take any drugs to relieve the pain. Nevertheless, our study is in agreement with the pilot study carried out by Christensen et al.,²³ who reported a temperature increase at 2 days postoperatively compared with the baseline temperature.

According to the results of our study, the temperature had decreased in both groups on the seventh postoperative day. At this stage there was no significant difference between the groups, although the aPDT group still had a lower temperature than the placebo group.

None of the patients took antibiotics or analgesics during the observation period,

and no patient was a smoker, so the interference of other therapeutic modalities and other factors on wound healing/swelling was excluded. As body temperature shows small oscillations throughout the day,²⁷ all temperatures were measured within a 2-h range (between 9:00 and 11:00 a.m.).

We also found a significant correlation between wound swelling and the observed temperature, which was stronger on the third day postoperative than on the seventh postoperative day. This was attributed to the fact that on the seventh day, the wound had started to heal and there were no patients with the worst grade of swelling.

OHRQoL deteriorated more in the placebo group, who had significantly higher OHIP summary scores, as expected. The reduced OHRQoL in the placebo group was attributed to increased wound swelling, the consequent increase in wound temperature, and probably more pain than in the laser group.

The present study showed beneficial effects of the aPDT modality of low-level laser therapy on OHRQoL, reduced postoperative wound swelling, and decreased wound temperature as registered by means of thermography.

Funding

None.

Competing interests

None declared.

Ethical approval

The study was approved by the Ethics Committee of the School of Dental Medicine, University of Zagreb, Croatia.

Patient consent

Not required.

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