Cutting and coagulation during intraoral soft tissue surgery using Er:YAG laser

ABSTRACT

Aim To find the optimal techniques and parameters that enable Er:YAG laser to be used successfully for small intraoral soft tissue interventions, in respect to its cutting and coagulation abilities.

Case report In vitro pre-tests: 4 different Er:YAG laser units and one CO₂ unit as the control were used for incision and coagulation on porcine lower jaws and optimal parameters were established for each type of intervention and each laser unit: energy, frequency, type, pulse duration and distance.

Case series: 3 different types of intervention using Er:YAG units are presented: crown lengthening, gingivoplasty and maxillary labial frenectomy with parameters found in the in vitro pre-tests.

Results The results showed a great decrease of the EMG activity of masseter and anterior temporalis muscles. Moreover, the height and width of the chewing cycles in the frontal plane increased after therapy.

Conclusion Er:YAG is able to provide good cutting and coagulation effects on soft tissues. Specific parameters have to be defined for each laser unit in order to obtain the desired effect. Reduced or absent water spray, defocused light beam, local anaesthesia and the most effective use of long pulses are methods to obtain optimal coagulation and bleeding control.

Keywords Chewing cycles; Deep bite; EMG activity; Functional appliance; masticatory muscles.

Introduction

The advantages of using lasers for soft tissue surgery in dentistry have been well described in the literature.
Materials and method

In vitro study

For the first part of the study, in vitro tests were performed on porcine oral mucosa and skin in order to find the most adequate parameters for each of the Er:YAG laser units used. Porcine oral tissues were chosen due to their similarities to those of humans [Cercadillo-Ibarguren, 2010]. Half of porcine lower jaws were sectioned immediately after animal sacrifice and stored at -4°C. They were put at 2-4°C one day before using in the present study and laser-irradiated at room temperature.

A total of 5 different laser units were used for the in vitro pretests: four Er:YAG lasers and one CO₂ as the control. Table 1 contains the names, manufacturers and batch numbers of each laser unit.

Different laser parameters were taken into consideration: energy, frequency, type, pulse duration and distance of irradiation. Parameters were chosen from those indicated by manufacturers for soft tissue surgery or by investigators’ observations concerning the efficacy and speed control of lasers’ effects. There is one variable that stayed unchanged for all the 5 units: irradiation time of 5 s for each laser application.

Two series of parameters were chosen for each laser: one for incision and the other for coagulation of soft tissues. There is a detailed description of these ideal parameters obtained with each unit in Table 2, some of the parameters being limited by the laser machine. Figure 1 illustrates the effect on a porcine lower lip of the 5 laser machines for the chosen parameters, both for incision and coagulation.

Case series

In the second part of the study, some clinical soft tissue applications of Er:YAG are described and illustrated.

<table>
<thead>
<tr>
<th>NAME</th>
<th>MANUFACTURER</th>
<th>BATCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elexxion (Er:YAG)</td>
<td>ELEXION AG Radolfzell am Bodensee, Germany</td>
<td>SN : IEC 825-1: 10.2003</td>
</tr>
<tr>
<td>Opus Duo (Er:YAG)</td>
<td>LUMENIS Ltd. Yokneam, Israel</td>
<td>Model : SA56 01000 SN : 001-09191</td>
</tr>
<tr>
<td>Kavo Key Laser Plus (Er:YAG)</td>
<td>KaVo Biberach, Germany,</td>
<td>Type: Key-Laser 1243 SN: 0000115</td>
</tr>
<tr>
<td>Lightouch (Er:YAG)</td>
<td>Orcos Medical AG Künsnacht, Switzerland</td>
<td>SN: 002-00096</td>
</tr>
<tr>
<td>Opus Duo (CO₂)</td>
<td>LUMENIS Ltd. Yokneam, Israel</td>
<td>Model : SA56 01000 SN : 001-09191</td>
</tr>
</tbody>
</table>

### Table 1 Description of the laser units.

<table>
<thead>
<tr>
<th>LASER UNIT</th>
<th>EFFECT</th>
<th>ENERGY</th>
<th>FREQUENCY</th>
<th>TYPE</th>
<th>PULSE DURATION</th>
<th>DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elexxion</td>
<td>incision</td>
<td>250 ml</td>
<td>20 Hz</td>
<td>0.8 mm</td>
<td>600 µs</td>
<td>5 mm</td>
</tr>
<tr>
<td></td>
<td>coagulation</td>
<td>250 ml</td>
<td>20 Hz</td>
<td>0.8 mm</td>
<td>600 µs</td>
<td></td>
</tr>
<tr>
<td>Opus Duo Er:YAG</td>
<td>incision</td>
<td>150 ml</td>
<td>20 Hz</td>
<td>0.6 mm</td>
<td>240-404 µs</td>
<td>2 mm</td>
</tr>
<tr>
<td></td>
<td>coagulation</td>
<td>150 ml</td>
<td>20 Hz</td>
<td>0.6 mm</td>
<td>240-400 µs</td>
<td>10 mm</td>
</tr>
<tr>
<td>Kavo Key Laser Plus</td>
<td>incison</td>
<td>180 ml</td>
<td>25 Hz</td>
<td>non contact hand piece 2060</td>
<td>250 µs</td>
<td>20 mm</td>
</tr>
<tr>
<td></td>
<td>coagulation</td>
<td>180 ml</td>
<td>25 Hz</td>
<td>non contact hand piece 2060</td>
<td>250 µs</td>
<td>50 mm</td>
</tr>
<tr>
<td>Lightouch</td>
<td>incison</td>
<td>100 ml</td>
<td>30 Hz</td>
<td>0.8 mm</td>
<td>163 µs</td>
<td>2 mm</td>
</tr>
<tr>
<td></td>
<td>coagulation</td>
<td>100 ml</td>
<td>30 Hz</td>
<td>1.2 mm</td>
<td>163 µs</td>
<td>10 mm</td>
</tr>
<tr>
<td>Opus Duo CO₂</td>
<td>incision</td>
<td>Power 4 W</td>
<td>without</td>
<td>continuous</td>
<td>2 mm</td>
<td>SN : IEC 825-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power 4 W</td>
<td>without</td>
<td>continuous</td>
<td>10 mm</td>
<td>SN : IEC 825-</td>
</tr>
</tbody>
</table>

### Table 2 Description of the ideal parameters used for each laser unit.
Case 1: Crown lengthening
A 15-year-old patient with Geroderma Osteodysplastica was referred to our clinic with the diagnosis of multiple caries lesions. Tooth number 47 was still undergoing eruption with a deep dentinal caries on its buccal side, ¾ of the cavity covered by gingiva (Fig. 2a). For the comfort of the patient, anaesthesia by local infiltration was carried out prior to the intervention. The Er:YAG LighTouch laser unit was used to remove the bucco-distal gingival tissue and to expose the carious lesion completely (Fig. 2b). The “laser wound” was coagulated at the surface to control bleeding and to offer a dry field for the hard tissue treatment. Caries was then ablated with the same Er:YAG laser, only choosing different parameters (Fig. 2c). In this way the tooth was ready to receive a GIC temporary restoration for the time it completes its eruption and when a rubber dam can be placed in order to perform an adhesive restoration under optimal conditions.

Case 2: Gingivoplasty
An 18-year-old patient was referred to our clinic for aesthetic reasons. Besides the agenesis of both lateral incisors, the patient presented also an asymmetric gingival level in the two central incisors and a hypertrophic papilla between the teeth 11 and 13 (Fig. 3a). Gingivoplasty was performed using the LighTouch laser unit. Prior to intervention, a minimal local anaesthesia by infiltration was done. After that, the bone level of tooth 11 was detected using a periodontal probe and the level of the desired gingival level was marked on the vestibular gingiva (Fig. 3b). In order to protect the tooth from possible laser damage, a metal matrix was slid on the vestibular side of the gingival sulcus up to the bone level (Fig. 3c). After the reduction of the gingiva, the surface of the “laser wound” was smoothed using lower pulse energy (Fig. 3d). One week after the procedure the gingiva was completely healed (Fig. 3e).

Case 3: Maxillary labial frenectomy
An 8-year-old patient presented a hypertrophic maxilla frenulum with fibers that went down until the palatal side of the incisive papilla (Fig. 4a). As the lateral incisors were delayed in their eruption, the frenectomy could facilitate the mesialisation of the central incisors when the lateral ones would make their way out from the upper jaw. A local anaesthesia was done from both sides of the frenulum and completed with a palatal infiltration. After that, the frenulum was sectioned perpendicularly to its fibers, all along the vestibular side of the upper
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jaw, until the palatal side of the papilla. The laser used was the Key Laser Plus from Kavo with the settings shown in Table 2. The procedure was not completely bloodless, so there was the need for haemostasis with gauze compresses at the end of the incision part. After that, a coagulation of the wound surface was made with the same laser and the same parameters, only working in a defocused way (Fig. 4b). As the distance needed to defocus the light of Key Laser Plus is quite large (5 cm), it was important to have a pilot laser beam that indicated the exact place for the laser application. The patient left without any sutures and the recommendation to keep a good oral hygiene and to avoid acidic food that could create discomfort during eating. One week later, the wound was clean and covered by a layer of fibrin that is part of the healing process (Fig. 4c). At one month from the procedure the wound was completely healed (Fig. 4d).

Discussion

The mechanism of action for Er:YAG lasers on soft tissues is the same as that on hard tissues: micro explosions induced by abrupt vaporisation of water molecules that had absorbed the laser energy converted into local thermal energy [Hibst, 2002; van As, 2004]. Er:YAG targets the water molecules rather than the collagen matrix [Venugopalan, 1995]. That is the reason why the depth of penetration of this wavelength of laser is somewhere between 5 and 40 µm only. This is quite negligible comparing to other types of laser, like Nd:YAG laser, which can reach down to 5 mm of penetration [White et al., 2002; van As, 2004]. Also the residual thermal damage of the Er:YAG laser is no bigger than 5µm [Lanigan, 2002]. From here comes the fast and complication-free healing after Er:YAG soft tissue interventions, but also its disadvantage concerning the control of bleeding. That is why, when using Er:YAG, a compromise has to be established in order to have the least thermal damage with the best haemostatic effect. There are three parameters that have to be taken into consideration in order to obtain the best compromise: quantity of water spray, defocused light beam and pulse width.

Olivi [2010] noticed that water spray during erbium lasers irradiation functions as a cooling system and cleaning agent, but that the control of bleeding is reduced. He also found that incisions made by erbium laser require low levels of energy in the order of 50-75mJ. The presence of water contained in soft tissues and the additional water from the water spray together with the low depth of penetration of an Er:YAG laser confers to this wavelength a minimal thermal effect on the irradiated tissues.

Increasing the pulse energy will have a mechanical effect, meaning that the speed and the proportions of the incision will be less controllable but not necessarily the bleeding during the laser intervention. For this, the amount of water that covers or is contained in the target tissue has to be minimal. Reducing/eliminating the water spray may help haemostasis, because of the increased thermal effect of the laser light. Histological tests have to be done in order to see the exact depth of the tissue damage when laser is applied without water spray. For the in vitro pretests, none of the Er:YAG lasers and parameters used delivered a more important thermal effect that the control CO₂ laser. In the same context, using air during laser irradiation may be an
option to reduce the amount of water at the surface of the target tissue and thus have a “cleaner” operation field. Intentionally drying the soft tissues makes them more fragile, without the consideration of the cooling effect on these tissues. That is why using air during laser treatment may enhance bleeding at the end of the intervention. For the present study, for all the in vitro tests and clinical cases, Er:YAG laser was used without any air or water spray added. Post-operative healing was rapid and pain-free.

By increasing the working distance between the laser type and the target tissue, at one point the operator can see that the effect of the light beam is no longer incision or ablation, but coagulation at the surface. This effect, due to the defocusing of the light beam, is very superficial comparing to other wavelengths, but still it can be used any time bleeding becomes too important, in order to have a clean vision of the operating field. It is also useful to use this effect at the end of the intervention to coagulate the surface of the “laser wound” and to create a “natural bandage-like layer”. From the three cases presented, case 2, the gingivoplasty, was the one that did not need the bandage layer because the wound surface was reduced and almost bloodless. For this particular case the defocused light beam effect was used to “smooth” the surface of the gingiva at the end of the intervention. To make it easier to use this effect during and after the surgery, practitioners may keep the same laser parameters and only change the distance to obtain the desired result. For some of the lasers, for example Key Laser Plus with the non-contact hand piece, the threshold distance for the light beam to defocus is quite important (at 5 cm distance). For this laser it is thus imperative to have a target beam laser during the intervention and standby mode in order to be in permanent control of the area where the laser light will be applied, and to avoid collateral damages of hard and soft tissues.

One of the advantages of Er:YAG lasers for hard tissue applications is the possibility to pulse the energy and even to use super pulses as short as 150-200μs. The shorter the pulse duration, the higher the energy that may be applied. All these have the purpose to obtain an important mechanical effect and very small collateral thermal effect. The concept is perfect for hard tissue applications. In contrast, when working with soft tissues, which have higher water content and thus a more important absorption of laser light, the energy needed for ablation must be reduced. It permits also to increase the pulse width and to have a more important thermal effect which is useful for hemostasis. From our in vitro tests we observed that the most important parameter for bleeding control is pulse duration.

From the four Er:YAG units used in the present study, the one that had the longest pulse duration offered also the most important coagulation (Fig. 1, Table 2). It was the case for Elexxion laser, the only laser in the study that offers the possibility to modify the pulse width. For the other units, this parameter is fixed or determined by the laser machine. Other laser units with modifiable pulse duration are nowadays available on the market. The frequency with which these pulses are applied is also important, but it cannot be too high in order to let time to the irradiated tissue to cool down between pulses. Optimal individual parameters have to be found for each laser for ablation and coagulation.

Another way to reduce bleeding that is not dependent on laser parameters is the administration of local anaesthesia. The local vasoconstriction effect obtained together with the infiltration is not negligible especially in case of inflamed tissues. For all our clinical cases we used local anaesthesia and this for several reasons: first of all in the studies published so far it was reported that the acceptance of erbium laser therapy is 90% for hard tissue and only 63% to 75% for soft tissue [Keller et al., 1998; Boj et al., 2005; Genovese and Olivi, 2008]. In certain cases local anaesthesia is required also for additional reasons or manipulations other than the surgical intervention itself: the patient from case 1 was a child with medical problems that needed a quick, precise and completely painless intervention. That is why he accepted well a small pain at the beginning and complete tranquility during surgery.

For case 2, more painful than the laser intervention itself might have been the periodontal probing and insertion of the metallic matrix to protect the tooth during gingivoplasty. That is why the patient preferred to have all this manipulations performed under local anaesthesia.

For case 3, the age of the patient and the nature of the procedure (close to the periosteum) were indications for local anaesthesia from the beginning in order to avoid uncontrollable reactions of the little patient during intervention.

Er:YAG’s effect in the three cases described was different in function of the target tissue, laser parameters and desired result. In the first case, crown lengthening, the effect was incision followed by surface coagulation. In the second case marginal gingiva was reduced and reshaped and finally smoothened by laser irradiation. In the third case, frenectomy, the effect was incision followed by coagulation and sealing of the blood vessels to obtain a “laser bandage”.

It is important for the dental practitioner to know the properties of target tissues and also the possibilities and limits of laser. The ideal parameters are those that work well for the laser unit but also for the user. At the beginning of the intervention, laser operator will chose parameters that permit a better control of the laser application and adjust them in function of the desired effect and patience’s acceptance.

From the five laser units used for the pretests on porcine oral tissues, CO2 unit was the one that offered
the best coagulation all along the incision line. The coagulation effect is shown in Figure 1 by a round spot next to the incision. For the four Er:YAG lasers, the incision was quick and precise, but the coagulation was different in function of the laser and its parameters. The one that offered the best coagulation was Elexxion for a maximal machine dependent pulse width of 600 microseconds. It was also the only one that had an adjustable pulse duration.

Conclusions

- Er:YAG is currently the laser type that offers dental practitioners excellent performance on hard tissue preparations and the possibility to execute a variety of soft tissue interventions with all the advantages that laser technology brings to dentistry.
- Reducing/eliminating the water spray, a defocused light beam, long pulses and local anaesthesia are methods to control bleeding during Er:YAG laser surgery.
- As the most effective method to reduce bleeding was the use of long pulses, Er:YAG lasers should offer the possibility to modify pulse duration in function of the target tissue and desired effects.
- Ideal parameters have to be found for every laser but also for every practitioner in order to obtain the best results with minimal collateral damage.
- Further histological studies are needed to visualise the thermal effect of Er:YAG application on soft tissues when different parameters are used.

References