Comparative Study on CW- Mode Versus Pulsed Mode in AlGaAs-Diode Lasers.

Claus P. Neckel*

Bad Neustadt, Germany

ABSTRACT

In the last six years AlGaAs- Diodelasers have become more and more popular. Due to their small size, their good electro-optical coupling and delicate glass fibers this type of laser fits into most dental offices. The first diode lasers and still most of the devices still on the market work in a continuous wave mode or in a gated mode up to 50 Hz. Using this setting high temperatures in the tissue are inevitable.
In this randomized study we tried to evaluate the difference in clinical cutting efficiency, post operative outcome and the histological findings of the excisional biopsies using a new diode laser Ora- laser Jet 20.
We preformed 40 biopsies:
Group I: in CW mode. Group II: Pulsed mode 10000 Hz gated (1:1). Group III Pulsed mode 10000 Hz gated (1:3).
Group IV: Pulsed mode 10000 Hz gated (1:10).
The macroscopic results and postoperative outcome of the patients in group IV were best. Scarring and postoperative pain was more intense in the cw group and high pulsed group with an on off relation of 1:1. The histological evaluation showed more thermal damage the longer the laser pulse lasted.

Keywords: Laser, diode, CW- Mode, pulsed Mode, gated on off relation,

1. INTRODUCTION

A surgical diodelaser in dentistry was first introduced in 1994 by Oralia , Germany [1]. Since that time many companies have seen its potential and brought many new products to the market, due to the main advantages of this lasertype as are, small size, good electro-optical coupling and the use of delicate glass tips or fibers. On the other hand there still are some technical pitfalls that have to be overcome.

Diode lasers deliver their energy in a continuous wave mode or a gated pulsed mode. Thermal interaction with the lased tissue is largely dependant on the wave length, the target tissue, the output power at the fiber tip and the application time. Heat dissipation or diffusion from the site is a function of the thermal conductivity of the tissue and laser time. Collateral damage in the surrounding structures can ultimately be observed after laser application. Minimal thermal side effects are the aim of laser application to differentiate from sheer thermal cutting using electro- surgery.

Due to technical problems diode lasers run either on a continuous wave mode or gated[2], mostly in an one to one on off fashion. Using this kind of application parameters we experience a high thermal interaction and a continuous temperature rise in the target tissue. Low output powers are necessary the keep charring and thermal damage minimal. Cutting efficiency is reduced and intraoperativ anesthesia is mandatory.

*Correspondence: Email: cpneckel@t-online.de; Telephone: 011 49 9771 4775; Fax: 011 49 9721 75149

In 1999 a high pulsed diode laser (Ora- Laser Voxx 08) as introduced, that could achieve a gated pulse frequency of up to 10000 Hz. With a laser diode with 8 Watt output power at the fiber tip the cutting efficiency[3] could be accelerated not without giving users problems in finding the right parameters for a sufficient application of the laser.

Aim of this study was to use fixed parameters of a new diode laser for excisional biopsies of the oral mucosa and to evaluate the clinical, individual and histological outcome of the patients and specimens.

2. MATERIAL AND METHOD

In the study we included 28 female and 12 male patients in an age range between 34 and 71 years. All 40 Patients were randomly selected. The excisional biopsies were preformed under local anesthesia, using 3% Articain with 1: 200 000 Adrenaline (Ultrcain® DS). Aim of the therapy was to obtain a histological diagnosis and to remove the entire tumor.

2.1. Clinical diagnosis of the Biopsies:

26 fibroma
14 epulides fissurata

The dimensions of the tumors were in a range of 5cm to 8mm and were primarily situated in the cheek or the vestibule. After excision no sutures were used and no wound dressing was applied. If necessary the denture of the patients with epulides fissurata was relined.

2.2. Laser of us:

The laser we used in the study was a Ora- laser Jet 20 of the Oralia GmbH, Konstanz, Germany. It is an AlGaAs- Diodelaser emitting 810 nm. Maximum output power was 25 Watt. Continuous wave mode and pulsation of up to 10000 Hz. Gating with an on off ratio between 1:1 and 1:10.

2.3. Clinical Parameters in the study:

Group I:
400μ glass fiber; Continuous wave mode; 1.5 Watt output power at the fiber tip.

Group II:
400μ glass fiber; Pulsed mode 10000 Hz, gated 1:1 on off relation; a peak output power of 5 Watt at the fiber tip.

Group III:
400μ glass fiber; Pulsed mode 10000 Hz, gated 1:3 on off relation; a peak output power of 20 Watt at the fiber tip.

Group IV:
400μ glass fiber; Pulsed mode 10000 Hz, gated 1:10 on off relation; a peak output power of 25 Watt at the fiber tip.

Cutting efficiency and intraoperative appearance was monitored. All patients were followed up after 3 days, 1 week and 4 weeks. We evaluated all patients for their individual postoperative pain, clinical aspects of wound healing and the histology of the specimens in respect of thermal damage to the tissue.

3. RESULTS

3.1. Operative findings:

Cutting efficiency:
The comparison of cutting speed showed that the continuous wave mode with 1.5 Watt output power at the tip had the lowest preparation rate. It was followed by the biopsies of group IV with the on off ration of 1:10. The difference between both groups was significant where as the speeding up between group IV and III (1:3 on off relation) was only subjective. The significantly fastest group were the biopsies of group II.

Clinical aspect of the donor site:
The parameters we looked at doing the excisional biopsies were charring and blanching of the tissue. Group I (CW mode) showed some charring of the epithelial lining. The tissue had a very dry aspect and about 0.5mm blanching around the excision. Group II looked very similar to group I. Charring was also significantly present. Both Group III and IV presented different features. Charring was significantly less visible and the surface of the wound had a raw less dry aspect.

Coagulation:
All groups showed sufficient coagulation in excision region. No bleeding occurred during the procedure or the wound healing phase even in patients with bleeding disorders (N: 6 ; 5 Acetylsalicylic Acid, 1 Coumarintherapy). The wound surface was totally dry in group I and II and showed a raw aspect with bleeding spots in group III and IV. These bleeding spots did not require any treatment and showed no bleeding tendency even after vigorous rinsing.

3.2. Postoperative findings:

Individual patient outcome:
All patients reported of no or minimal postoperative discomfort. In those cases where the excisions were in direct contact to the margin of the dentures the patients observed discomfort during masticatory function. No significant difference between the groups could be evaluated.

Clinical postoperative follow-up:
At the three day postoperative inspection in Group I we found a slight redness of the direct surroundings of the excision. The wound had a grayish- white layer of fibrin on the surface. Wound sensitivity was minimal. One week postoperative we found closing of the wound from the margins. Even small wounds of 8mm in diameters had not yet filled in. Redness was not present. After four week all wounds had closed in. In most cases it was very difficult to distinguish the excision site. Scarring was minimal.

Group II showed significant redness of the surrounding tissue after three days. Wound sensitivity was minimal even with the showing redness. The fibrin layer on the surface of the wound showed typical structure. At one week in three cases redness of the surrounding tissue still with out sensitivity was present. No wound had yet closed in. The wound healing seemed to be delayed in comparison to Group I. After four weeks all wounds had healed. The identification of the excision site was easier as little scarring was detectable. The scarring was a visible mark without functional changes as induration or tissue augmentation.

Group III displayed minimal redness around the excision after three days. Fibrin layer and wound sensitivity were normal. After one week the wounds were closing in. No wound, even small ones, had totally reepithelialized. After four weeks all wounds had healed. Almost no scarring was distinguishable.

Group IV presented only in two cases redness in the periphery of the wound after three days. Sensitivity was minimal. All wound had a fibrin layer. At the one week follow up we found good wound healing with a significantly faster epithelisation rate. A small wound had almost closed in. At four weeks the excision sites could not be distinguished. Scarring was not visible.

3.3. Histological findings:

The histological evaluation of the biopsies confirmed in most cases our clinical diagnosis. Only in one case the diagnosis fibroma had to be specified as ossifying fibroma. In the specimen you could find osteoclastes and osteoblasts with mineralized and nonmineralized osseoid. The tumor had no hint for malignancy and was removed totally.

In group I with continuous wave mode the histology showed a thermal damage zone of up to 125 μ. The range found lay between 80 an 125 μ. The target tissue for thermal damage is connective fibrous tissue. Very little muscle cells are effected. Dehydration of all damaged cells is prominent. Signs of coagulation and protein denaturation are predominant. Some superficial charring adjacent to deeper thermally deteriorated zone could be found.

Group II exhibited similar results only that the thermal effects were significantly more drastical. The thermal alteration showed a depth of 250 to 800 μ. Muscle cells and fibrous tissue showed dehydration and cellular disintegration. Charring was an often found site with very deep thermal damage.

In Group III the histological changes exhibited a thermally damaged zone of 45 to 65 μ. Connective tissue again was the main target. Dehydration of the damaged cells was prominent. Charring was found very seldom and the thermal destruction zone was more constant in depth.

Group IV displayed a maximum of thermal damage of 25 μ. The depth ranged between 15 and 25 μ. Charring was not visible. The thermal damage zone was very consistent in depth.

All specimen could be evaluated by the pathologist. Total marginal evaluation was only possible in the specimen of groups III and IV and of group I in 50% of all cases.

4. DISCUSSION

Photothermal interaction with tissue is the basis of surgical lasers. In this process radiant light is absorbed by the tissue and becomes transformed to heat energy changing tissue structures[4]. The amount of laser light that is absorbed is dependent on a number of factors such as: wave length of the laser radiation, power output at the laser tip or focus, pulse or nonpulse, if applicable pulse character and the optical properties and composition of the target tissue[5]. Every single parameter of the laser beam can significantly alter the thermal interaction of the laser radiation in the tissue. The wave length by large determines the heat generation in tissue as the absorption of the radiation in a specific tissue is dependent on the emitted photon character. The CO_2 laser beam is highly absorbed by intracellular water within soft tissue. Because of this 90% of its energy is absorbed within the first 100μm of penetration of the tissue surface[3]. The high absorption of the laser energy leads to rapid vaporization of water and pyrolysis of organic material in the target tissue. High superficial carbonization and charring can be can be observed even using low energy densities. Diode lasers emitting 810 nm are well absorbed in dark pigment as in hemoglobin, melanin pigment and other dark tissue components. The absorption rate in water is by far lower than in a CO_2 laser[6,7].

Laser light is primarily absorbed by the tissue inducing a molecular excitation[8]. Important is that the target molecules have a similar energy level structure as the laser wave length. Later the thermal energy is dissipated to the surrounding tissue structures by thermal diffusion and conduction. Heat dissipation is dependent on the thermal conductivity of the target tissue and will determine the extent of collateral damage in the adjacent tissue. This process which is highly influenced by the vascularity of the tissue is characterized by the thermal relaxation time of a specific tissue. The degree of collateral damage is dependent on the target tissue properties such as tissue composition , water content, vascularity, volume of radiated tissue and tissue surface[9]. Further more radiated energy and length of radiation are important factors in this process. Thermal relaxation time is the time that is required for a specific tissue to cool down from an accumulated temperature to 37% of the maximum value[10].

Using a continuous wave mode for surgery thermal dissipation is minimal other than by blood flow. Constant motion of the fiber tip is therefore mandatory to avoid over heating of the tissue[11]. Although low power output is recommended tissue dehydration and charring is observed. Using a pulsed approach, in a gated 1:1 on off mode, tissue has time to dissipate heat and to keep the temperature from rising continuously. In our clinical setting using a 10000 Hz pulsation we encountered more clinical, individual and histological damage than the CW mode group showed. This is due to the fact that the time of the off phase was too short for a sufficient heat conduction, leading to a continuous increase of temperature. This also explains the clinical signs of mild inflammation in the postoperative phase and the scarring of the healed tissue. By lengthening the off phase heat dissipation is much more sufficient and thermal damage can be controlled much better. This can only be achieved at the expense of cutting speed. Therefore the pulsed mode with an on off relation of 1:1 had the best cutting momentum, an on off ratio of 1:3 was similar and the on off ration of 1:10 showed a slightly slower speed. High output power at the fiber tip helps cutting efficiency and with clinical parameters of 20 or 25 Watt the cutting is comparable with a CO_2 laser.

Important comparing diode lasers is the fact that we defined the output power as power at the fiber tip and not as output power of the laser diode. Due to the ovoid outlet the optical coupling is very difficult and often we find a significant loss of energy between laser diode and fiber tip[12].

In the histological specimen we found equivalent results to the clinical findings. Using a very high pulsation rate and short relaxation time a thermal effect in the tissue is prominent. Charring can be found readily. This carbonized tissue is an example of laser induced modification of target tissue. By burning the superficial tissue a new extremely high absorbing agent is created that can create excessive high temperatures of up to 3200° C. This temperature is thereafter dissipated and conducted into the surrounding tissue damaging its structures irreversibly. All specimen showing charring simultaneously exhibited a deeper concentric thermal damage zone. By using a very high power output and longer off period in the gated pulsed mode thermal interactions in the tissue could be controlled. Charring was minimal and therefore unintended side effects of excessive heating as could be found in the gated one to one on off relation.

By controlling the thermal side effects the laser application this treatment stands out again electro- surgery. In this therapy thermal destruction is by far more prominent. A further advantage of both treatments is their coagulating ability. Even in group IV with minimal thermal destruction of the target tissue the coagulation was absolutely sufficient to achieve a stable wound over the period of healing. This therapy can also be used for patients with bleeding disorders[3].

5. CONCLUSION

After introduction of high pulsed diode lasers it has become very difficult to distinguish the right clinical parameters for the surgical use of these machines. For excisional biopsies, with the diode laser Ora- laser Jet 20, we recommend using a continuos wave mode with low output power and low cutting efficiency or to excise with high output power, high pulsation rate and at least an on off ratio of one to three better one to ten. Clinically and histologically 25 Watt peak output power at the tip, 10000 Hz and on off ration of one to ten gave the best results. The difference in cutting momentum was not significant. 10000 Hz combined with an on off ratio of one to one brought the largest thermal destruction zone and should not be used. All clinical parameter apply to the Ora- laser Jet 20 and do differ from other diode lasers on the market. They should be adapted adequately.

6. REFERENCES

1. Bach, G.: "Der Dioden- Hardlaser in der Zahnheilkunde". *ZMK*:**11**/ 7:16- 19, 1995.
2. Albers, P.: "Physik des Dioden- hardlasers." *Persönliche Mitteilung*, I/ 1995
3. Neckel,CP.: "Laser assisted treatment of patients with hemorhagic diathesis." *Proc Spie,* **3910,** 18- 23, 2000.
4. Carruth, JA, Mc Kenzie, AL.: "The production of surgical laser lesions." *Science and Clincal Practice, Adam Higer Ltd;*51- 80, 1986
5. Fischer, JC.: "Qualitative and quantitative tissue effects from important surgical lasers."*Laser Surg Gyn.* **1**, 58- 81, 1993.
6. Moritz,A. et al .:"Mikrobiolgische und infrarotspektroskopische Untersuchungs-ergebnisse und Farbpenetrationsversuche nach in- vitro- Bestrahlung infizierter Wurzelkanäle mit dem Diodenlaser." *Quintessence International* : **3**, 205- 210, 1997
7. Moritz, a. and Gutknecht, N.: "Keimreduzierung in Zahnfleischtaschen durch Bestrahlung mit einem Diodenlaser." *Journal of Clinical Laser in Medicine and Surgery* :**1**, 33- 40, 1997
8. Dereich, DN.: "Laser Tissue Interaction." *Alpha Omega,* **84**, 33-36, 1991

9. Mierendino, LJ.: "Lasers in Dentistry." *Quintessence,* 39-55, 1995.
10. Harris, DM, Werhaven, JA.: "Biophysiks and application of medical lasers." *Adv Otolaryngol Head Neck Surg,* **3**, 91-123, 1989.
11. Bach, G., Gutknecht, N., Schneider, H.: "Lasertherapie in der Zahnheilkunde. Diodenlaser in der Praxis." *Apollonia Verlag, Linnich*, 1998
12. Gutknecht, N, Van Gogswaardt, D, Conrads, G, Apel, C, Schubert, C, Lampert, F,: "Diode Laser irradiation and ist effect in root canal wall dentin." *J Clin Laser Med Surg,* **18**, 57- 60, 2000