elexxion

powered by technology

selected surgery studies

Rev. 1.0 / Oct. 2009

Table of contents

Dental lasers for soft tissue surgery and periodontics

What we know and what we've learned

author_Donald J. Coluzzi, USA

Fig. 1_Immediate post operative view of an Nd:YAG laser gingivectomy, using high power.
Fig. 2_Seven month post operative view with final restorations in place.
Fig. 3_Immediate post operative view of another gingivectomy using a newer laser with less power and better technique.
Fig. 4_One week post operative view at the restoration try-in appointment. Note tissue healing.

_About 1975 medical surgeons began using a new device that complemented and, in some cases, replaced the scalpel. That instrument was a laser, and during the 1980's a Carbon Dioxide model was a common component in the operating suite. In 1989 the first laser specifically designed for dental use became available. Today there are two dozen indications for use with various dental laser devices; and the clinical applications continue to increase, making the laser one of dentistry's most exciting advances with unique patient benefits. This article will attempt to summarize those laser applications for dental soft tissue and treatment of periodontal disease.

Surgical lasers produce energy that can be absorbed by a target tissue, and this absorption proceeds as a photo-thermal reaction; that is the radiation produces a thermal reaction in that tissue. While other effects are possible, including true photo-disruption where molecular bonds are broken without vaporization to very low level use of laser energy producing a bio-stimulatory or bio-modulation effect.[1] Depending on the instrument's parameters and the optical properties of the tissue, the temperature will rise and various effects will occur. In general, most non-sporulating bacteria, including anaerobes, are readily deactivated at temperatures of 50 °C.[2] Proteins begin to denature at temperatures of approximately 60 °C without any vaporization of the underlying tissue.[3] This is a clinically useful effect because, if the temperature can be controlled, diseased granulomatous tissue will be removed while the biologically healthy portion can remain intact. Coagulation, also occurring at this temperature, refers to the irreversible damage to tissue, congealing liquid into a soft semi-solid mass.[4] This process produces the desirable effect of hemostasis, by the contraction of the wall of the vessel. At 70 to 80 °C uniform heating will produce adherence of the layers because of stickiness due to the collagen molecule's helical unfolding and intertwining with adjacent segments, a process sometimes termed tissue welding.[5]

Laser excisional or incisional surgery is accomplished at 100 °C, where vaporization of intra- and extracellular water causes ablation or removal of biological tissue.[6] Thus excision of soft tissue can begin at this temperature, but the apatite crystals in dental hard tissue will not be ablated. However water molecules dispersed throughout mineral structure are vaporized and the resulting jet of steam expands and then explodes, removing the tooth structure. This water mediated explosive removal transfers minimal heat to the adjacent tissue.[7] Thus, cavity preparation, calculus removal, and osseous contouring can proceed.

Continued application of energy will raise the tissue temperature. At about 200 °C dehydration is complete and the tissue carbonizes. Carbon as the end product absorbs all wavelengths. Thus, if laser energy continues to be applied, the surface carbonized layer absorbs the incident beam, becoming a heat sink. Collateral thermal damage can spread rapidly preventing normal tissue ablation and causing tissue necrosis.[8]

Some of the general benefits of the use of lasers in dental soft tissue include:
_Lasers reduce pathogens
_Lasers provide hemostasis
_Lasers can offer better post operative courses in healing
_Lasers can offer biostimulatory effects
_Lasers can have advantages over scalpels and electrosurgery.

For pathogen reduction several studies point out that every wavelength is effective, which is clearly a different effect than when a scalpel is used.[9-12] Moreover there is an advantage in reduce the need for prescription antimicrobials for a wide range of patients including children and pregnant women. Additionally, without medications, the patient will not experience allergic reactions, bacterial resistance or untoward side effects.

The ability to control bleeding during surgery enables much better visualization of the area. Some wavelengths achieve better hemostasis than others. The erbium family whose radiation is emitted in a free running pulse mode offers less sustained energy so soft tissue surgery may not be totally bloodless.[13-16] There are some conflicting results from studies comparing the post operative healing from lasers versus other modalities. Some authors point out that the healing can be faster, slower or the same as conventional instrumentation.[17-21] At the same time lasers have been shown to have offer bio-stimulatory effects. These are not clearly understood, but are clinically significant during and after treatment, adding to the value of health care.[22-23]

Other advantages include the lessening need for sutures[24], less painful treatment and reduced swelling post-operatively[25], less wound contraction[26], easier contouring of gingival tissues compared to a scalpel[27], safer around dental implants[28], and generally better patient acceptance of a procedure[29].

For treatment of periodontal disease, once again all wavelengths show usefulness. After scaling of the root surface with other instrumentation diode, Nd:YAG and Carbon Dioxide lasers are used can be used on the soft tissue side of the periodontal pocket to remove the inflamed soft tissue and to reduce the pathogens.[30-34] The erbium family of lasers can also be employed to remove calculus and other accretions on cementum with results similar or better than conventional scalers.[35-37]

The first twenty years of dental laser technology have been accompanied by sophistications in the instruments themselves, as well as improved surgical techniques. Figure 1 shows one of the author's first cases of gingival contouring in an immediate post-operative view and Figure 2 shows the restorations in place several months later with good tissue health. Retrospectively the soft tissue in the first figure received an excessive amount of laser power, as evidenced by the dark and almost charred areas; however, the healing progressed with a beneficial result. The immediate post-operative consequence of the author's use of a newer pulsed instrument with much more controlled thermal interaction is shown in Figure 3. Figure 4 illustrates the trial fitting of the restorations with the tissue practically healed. The conclusion to be drawn from these two cases is that the surgeon must observe the photothermal events carefully and employ proper instrument parameters.

In summary although lasers cannot totally replace conventional instrumentation, the overwhelming evidence from published studies and clinical cases provide assurance that lasers are a beneficial treatment modality for dentistry._

The literature list can be requested from the editorial office.

_contact laser

Donald J. Coluzzi, DDS
15 Navajo Place
Portola Valley, CA 94061, USA
don@laser-dentistry.com

Lasereinsatz als Therapieoption

Laserchirurgie *stellt eine ideale Behandlungsoption für zweizeitiges Vorgehen in der Implantologie und die Freilegung nach gedeckter Einheilung dar.*

Von DDr. Franziska Beer, Bernhard Gottlieb Uniklinik, Wien

In der modernen Implantologie ist die Minimierung der notwendigen chirurgischen Eingriffe der Trend der Zeit. Single-stage-Implantation oder transgingivale Implantation sind das Resultat. Ist dennoch ein zweizeitiges Vorgehen notwendig und die gedeckte Einheilung gewünscht, ist es erklärtes Ziel der Implantologen, den Zweiteingriff so klein wie möglich zu halten. Laserchirurgie stellt hier eine ideale Behandlungsoption dar.

Die chirurgischen Indikationen waren die ersten zahnärztlichen Einsatzgebiete, in welchen die neu entwickelten Laser ihren Einsatz fanden. Mittlerweile ist das Indikationsspektrum im zahnärztlich-kieferchirurgischen Sektor ebenso vielfältig wie die zur Auswahl stehenden Wellenlängen. Unzählige Publikationen haben sich mit verschiedensten Teilaspekten beschäftigt, der Hardlaser wird in der oralen Chirurgie mittlerweile routinemäßig eingesetzt und stellt eine gangbare Alternative zur konventionellen Chirurgie dar. Mit zunehmender Bedeutung der Forensik in unserem Fach ist sicherlich auch auf Belange der Aufklärungspflicht, den Sicherheitsaspekt (Laserschutzbeauftragter) und die nachgewiesene Ausbildung in diesem Bereich Rücksicht zu nehmen.

Die Vorteile der Laserchirurgie im Vergleich zur konventionellen Chirurgie sind dabei vielfältig:

- Bei Verwendung des Lasers lassen sich durch einfache Veränderung von Pulsdauer, durchschnittlicher Leistung und Repetitionsrate mit ein und demselben Laser völlig verschiedene Effekte erzielen, das heißt, ein Gerät gibt mehrere „Instrumente" in die Hand. Schneiden, Koagulieren, Vaporisieren und Desinfizieren des Gewebes werden mit nur einem Instrument durchgeführt.
- Koagulation des Wundbereiches, kombiniert mit einer präzisen Schnittführung, die jener des Skalpells durchaus vergleichbar ist. Die kollateralen Nekrosezonen sind minimal. Dabei ist sicher zu beachten, dass die unterschiedlichen Laser in ihrer koagulativen Kapazität sehr unterschiedlich zu beurteilen sind.
- Meist kann selbst bei großen Wundflächen auf einen chirurgischen Wundverschluss oder eine plastische Schleimhautdeckung verzichtet werden. Ein weiterer Vorteil bei der Anwendung des Lasers als „optisches Skalpell" ist die Minimierung der Ausdehnung des postoperativen Ödems.
- Schon lange ist die Bakterizidie chirurgisch genutzter Laser schon bei Energiedichten weit unterhalb der operativen Parameter bekannt. Bereits bei Energiedichten von 0,3-0,4J/cm² fanden sich Hemmzonen des bakteriellen Wachstums.[12]
- Dokumentiert ist die Senkung des Schmerzniveaus intra- und postoperativ, ein nahezu blutungsfreies Operationsfeld sowie eine geringe Inzidenz von Nachblutungen.
- Die wünschenswerte Reduktion der Hämatome und damit der Infektgefährdung reduziert den Antibiotikaeinsatz.
- Die Anwendung des Lasers hat auch Einfluss auf die Wundheilung. Einerseits werden unterschiedliche Laser als sogenannte Hardlaser (=„optische Skalpelle") verwendet, andererseits besteht die Möglichkeit, dieselben Laser mit niedriger Energie im Sinne der „low level laser therapy" (LLLT) oder auch Softlasertherapie einzusetzen. Letztere hat durch die Stimulation von Stoffwechselvorgängen im Wundbereich einen positiven Einfluss auf die Wundheilung.

Vorteile des Lasers in der Chirurgie

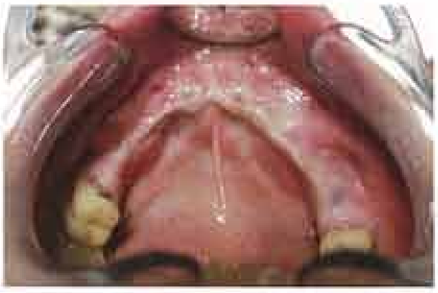
- Aufrechterhaltung steriler Bedingungen
- Reduktion von Blutungen
- Kalkulierbare Eindringtiefen
- Präzision der Schnittführung
- Reduktion der notwendigen Instrumente
- Selten Wundverschluss notwendig
- Schmerzreduktion intra- und postoperativ
- Keine Beeinträchtigung oder sogar Förderung der Wundheilung
- Geringere Narbenbildung
- Kostensenkung durch Material-, Personal- und Zeitersparnis

Von besonderer Bedeutung bei der Verwendung des Lasers als Instrument zur Implantatfreilegung sind die kalkulierbare Eindringtiefe sowie die möglichen Interaktionen mit der Implantatoberfläche. Das Wissen um den Temperaturanstieg in verschiedenen, aneinander grenzenden Geweben ist von essenzieller Bedeutung für die Risikominimierung thermischer Schäden. In der Regel zeigen die Gewebe einen linearen Temperaturanstieg mit zunehmender Dauer der Bestrahlung[1].

Laserbeschreibung

Laser, welche eine geringe optische Eindringtiefe aufweisen und damit an der Oberfläche der behandelten Gewebe sehr hohe Effizienz zeigen (somit geringe Kollateralschäden), sind für die Durchführung der Implantatfreilegung besonders gut geeignet. Dazu gehören der Er:YAG-Laser, der Er,Cr:YSGG-Laser und der CO_2-Laser. Der Er:YAG-Laser (2940nm) weist eine hohe Absorption in Wasser, bei äußerst geringer Eindringtiefe in das Gewebe auf (etwa 1µm); es gelingt die selektive Photo-Ablation von unterschiedlichen Geweben. Einen besonderen Stellenwert erhält dieser Laser in der Implantologie; sind mit ihm doch sowohl die Inzisionen im Mucoperiost, Implantatfreilegungen als auch die Pilotbohrungen für Implantate problemlos durchführbar[3].

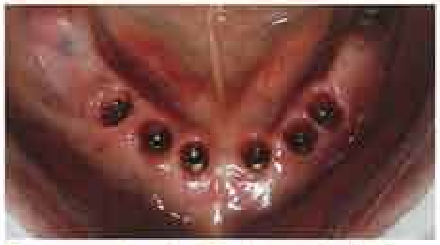
Ähnlich reagiert der Er,Cr:YSGG-Laser (2780nm) mit dem Gewebe. Dieser Laser ist ähnlich dem Er:YAG sowohl in der Weichteilchirurgie[14] als auch zur Bearbeitung von knöchernen Strukturen einsetzbar[4]. Als eher junger Vertreter des chirur-



Implantation im UK, unmittelbar vor Freilegung

Schrittweise Freilegung der Implantate mit CO_2-Laser, superpulsed mode, 2 W, keine Anästhesie

Gingivaformer in situ, nach zwei Tagen reaktionslose Verhältnisse



Gut ausgeformte Gingiva, vor technischer Versorgung, zwischenzeitlich wurden auch die Zähne 36, 37, 47 extrahiert, Wunden reaktionslos

Eingegliederte technische Versorgung

gischen Laserspektrums hat er bereits seinen Platz im klinischen Routinebetrieb gefunden.

Bei CO_2-Lasern (10600nm) liegt das Absorptionsmaximum im Bereich derselben Spektrallinie wie das von Wasser, daher erfolgt der Einsatz vornehmlich in der Weichgewebschirurgie[3].

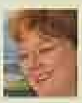
Technische Parameter

Maßgeblich für die Prognose ist auch die möglichst geringe thermische Alteration des das Implantat umgebenden Knochens. Barak et al. fanden bei Verwendung des Co_2-Lasers bis zu einer Grenze von 4W im cw-mode bzw. 8W im pulsed mode – beide Grenzwerte liegen deutlich über der therapeutisch verwendeten Energie – keine bedenkliche Temperaturerhöhung im Bereich der Knochen/Implantat - Grenze[9]. Kreisler et al. verglichen den Temperaturanstieg am Implantat-Knochen-Interface-Ti-Plasma-gesprayter Implantate unter Verwendung von CO_2 bzw. Diodenlasers (GaAlAs). Der kritische Treshold wurde beim Diodenlaser bei 2,5W nach 8 sek erreicht, nach 13 sek bei 2,0W,nach 18 sek bei 1,5W. Der CO_2 Laser erreicht die kritische Temperatur etwas später (15 sek – 2,5W; 23 sek – 2,0W;35 sek – 1,5 W) Obwohl bei Verwendung von Standardparametern der zeitliche Spielraum relativ groß erscheint, ist Rücksicht auf eine mögliche Schädigung des Knochens zu nehmen[10]. Die Temperaturveränderungen an der Implantat-Knochen-Grenze untersuchten Kreisler et al. auch anhand von Ti-plasma sprayed, sandgestrahlten und geätzten Implantatoberflächen für den Er:YAG Laser; bei Verwendung von Energien von 60–120 mJ und 10 pps. Selbst bei ununterbrochener Bestrahlung für 120 Sekunden überschritt die Temperatur nie die Grenze von 47°C, welche von den Autoren als kritisch angesehen wurde[11]. Bevorzugt bleibt der CO_2 Laser, falls eine sehr dicke mucoperiostale Schicht zu durchtrennen ist und die hämostatische Potenz des CO_2-Lasers gewünscht wird[12]. Arnabat et al. verwenden für Second-stage-Eingriffe den Er,Cr: YSGG-Laser in der Implantologie.

Die Implantatfreilegung ist ohne Anästhesie möglich; sie beobachten eine komplette Wundheilung nach nur fünf Tagen und damit ideale Voraussetzungen für eine rasche prothetische Versorgung[5].

Conclusio

Die Verwendung des Lasers im Rahmen der Second-stage-Chirurgie in der Implantologie stellt keineswegs eine andere Art der Chirurgie dar, sie gibt uns lediglich ein neues, sehr wertvolles Instrument in die Hand, welches bei sachgerechter Anwendung für mehr Patientenkomfort, raschere chirurgische Intervention und ein ästhetisch sehr anspruchsvolles Ergebnis garantiert.



DDr. Franziska Beer
Bernhard-Gottlieb-Universitätszahnklinik, Wien
Beamed – interdisziplinäres Zentrum für laserunterstützte Medizin und Zahnmedizin, Wien
SOLA-International Laser Academy, c/o VMA, Wien
E *franziska.beer@meduniwien.ac.at*

Literatur:

1) Ando Y., Aoki A., Watanabe H., Ishikawa I.: Bactericidal effect of Erbium YAG laser on perodontopathic bacteria. Lasers Sug Med 19: 190-200 (1996)
2) Schoop U., Kluger W., Moritz A., Sperr W.: The bactericidal Effect of Different Laser Systems in Deep Dentin Layers. Laser Congress Florence (2003)
3) Wilder-Smith P., Arrastis A.M., Liaw L.H., Berns M.: Incision properties and thermal effects of three CO_2 lasers in soft tissue. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 79(6); 685-691 (1995)
4) Salina S., Maiorana C., Piattelli A., Lezzi G., Colombo A., Fontana F.: Analysis of the Implant Site Prepared with the Er:YAG Laser Compared to ones Prepared with Traditionell Bur and Following Analysis of the Osteointegration of Mini Implants in Rabbits Fibula. Laser Congress Florence 2003.
5) Arnabat J., Espana A., Satorres M., Berini L., Gay-Escada C.: Er,Cr:YSGG laser application in the second phase of implant surgery: a pilot study in 30 patients. Lecture Laser Congress Florence 2003
6) Rizoiu I.M., Eversole L.R., Kimmel A.I.: Effects of an Er,Cr:YSGG Laser on mucocutaneous soft tissues. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 82(4); 386-395 (1996)
7) Wang X., Ishizaki N.T., Suzuki N., Kimura Y., Matsumoto K.: Morphological changes of bovine mandibular bone irradiated with Er,Cr: YSGG laser: an in vitro study. J Clin Laser Med Surg 20(5); 245-250 (2002)
8) Beer F., Porteder H., Moritz A.: Introduction of the CO_2 Laser in Cleft Lip and Palate Surgery. J Oral Laser Appl 1(2);135-141 (2001)
9) Barak S., Horowitz I., Katz J., Oelgiesser D.: Thermal Changes in Endosseous Root-Form Implants as a Result of CO_2 Laser Application: an in vitro and in vivo study. Int J Oral Maxillofac Implants 13(5), 666-671 (1998)
10) Kreisler M., Al Haj H., Gotz H., Duschner H., d'Hoedt B.: Effect of simulated CO_2 and GaAlAs Laser surface decontamination on temperature changes in Ti-plasma sprayed dental implants. Lasers Surg Med 30(3), 233-239 (2002)
11) Kreisler M., Al Haj H., d'Hoedt B.: Temperature changes at the implant-bone interface during simulated surface decontamination with an Er:YAG laser. Int J Prosthodont. 15(6), 582-587 (2002)
12) Chryssikopoulos S.: Er:YAG and CO_2-Lasers in oral implantology: a study on 83 implants. J Oral Laser Applic 3, 97-103 (2003)

Mit der Kraft des Lichts

Redaktion

Laser ist das Akronym für Light Amplification by Stimulated Emission of Radiation (= Lichtverstärkung durch Induzierte Emission). Bereits 1917 beschrieb Albert Einstein die stimulierte Emission. Praktische Umsetzung fand diese Theorie jedoch erst 1960 durch den Amerikaner Theodore Maiman, der den ersten Laser, einen Rubinlaser, baute. Inzwischen haben sich Laser für unzählige Anwendungsgebiete in technischen und medizinischen Bereichen erfolgreich durchgesetzt. Hierzu gehört auch der medizinische Bereich.
In der Allgemeinmedizin werden Laser hauptsächlich zu Diagnosezwecken, z. B. für die Messung von Blutstrom und -zirkulation, eingesetzt. In der Augenheilkunde beispielsweise werden mithilfe von Lasern sich ablösende Netzhäute wieder mit dem Augenhintergrund verschweißt. Häufige Anwendung finden Laser in den verschiedensten Fachrichtungen nicht nur als Skalpellersatz – so auch in der Zahnmedizin.

Dr. Hubert Stieve ist begeisterter Laser-Anwender.

Vor allem in den letzten zehn Jahren wurde die Entwicklung von Lasern für zahnmedizinische Behandlungen erfolgreich vorangetrieben. Dr. Hubert Stieve ist seit 2004 überzeugter Laser-Anwender und diesbezüglich auch als Referent tätig. Seine 1976 in Rendsburg gegründete Praxis trägt mittlerweile den Namen „Laserzentrum und Praxis für Zahnheilkunde“. Hier werden sämtliche Anwendungsmöglichkeiten von Lasern voll ausgeschöpft. Dr. Stieves Interesse an digitalen Technologien für die Zahnheilkunde zeigt sich auch daran, dass er unter anderem Mitglied der Deutschen Gesellschaft für Computergestützte Zahnheilkunde (DGCZ), der Academy for Computerized Dentistry of North America (ACDNA), der Academy of Laser Dentistry (ALD) und der European Society of Oral Laser Application (ESOLA) ist.

Laser ist nicht gleich Laser

Laserlicht bewirkt eine gezielte Gewebeinteraktion. Je nach maximaler Absorption durch die Chromophore (Teil eines Farbstoffs, in dem anregbare Elektronen verfügbar sind) koppeln Laser an verschiedenen Geweben unterschiedlich an. Die diversen Laserwellenlängen beziehungsweise -typen haben jeweils abhängig von beispielsweise Wassergehalt und Pigmentierung unterschiedliche Auswirkungen auf das Zielgewebe. Deshalb kann nicht ein einzelner Laser für alle dentalmedizinischen Behandlungen geeignet sein.

Laser werden häufig in harte und weiche Laser unterteilt. Bei Letzteren handelt es sich um sogenannte Softlaser, mit denen kein Gewebeabtrag bewirkt werden kann. Die harten Laser umfassen sowohl Hartgewebe- als auch Weichgewebelaser. Um Missverständnisse zu vermeiden, empfiehlt sich die Unterscheidung von Hartgewebe-, Weichgewebe und Therapie- beziehungsweise LLLT-Lasern (Low-Level-Light-Therapie).

Therapielaser

Im Laserzentrum ist der Einsatz von Lasern fest in den alltäglichen Arbeitsfluss integriert. Therapielaser werden vor, während und nach chirurgischen Eingriffen verwendet, da sie die Mikrozirkulation, das heißt den Zellstoffwechsel, anregen und schmerzreduzierend wirken. Daher eignet sich ihr Einsatz auch beispielsweise bei akuten Kiefergelenkbeschwerden. Patienten, die an Herpes leiden, empfiehlt Dr. Stieve, gleich nach Auftreten der ersten Symptome in Form von Juckreiz das Laserzentrum aufzusuchen, da durch die Lasereinwirkung der Ausbruch des Herpes unterbunden und eine schnelle Heilung gefördert werden kann. Außerdem wird im Rahmen der Parodontitis-Behandlung eine sogenannte fotoaktivierte Desinfektion durchgeführt. In die Zahnfleischtaschen wird eine Farblösung appliziert, die von den Bakterien während einer Einwirkzeit von etwa einer Minute aufgenommen wird. Dann erfolgt eine rund einminütige Bestrahlung pro Parodontium mit einem Therapielaser mittels feiner Lichtfaserleitern bei einer Wellenlänge von 660 nm, durch die sich der Sauerstoff in der Lösung abspaltet. Da die Leitkeime Anaerobier sind, werden sie durch den Sauerstoff abgetötet – eine äußerst minimalinvasive und für die Patienten angenehme Methode. Auch schwierige und konventionell therapieresistente Fälle konnten laut Dr. Stieve im Laserzentrum auf diese Weise schon erfolgreich behandelt werden. In der Endodontie werden Diodenlaser (Wellenlänge 810 nm oder 980 nm) zur Dekontamination der Kanäle und Seitenkanäle nach klassischem „shaping and cleaning“ verwendet. Dr. Stieve: „Die Wirkung des Laserlichts reicht deutlich weiter als die herkömmliche Spülung mit NaHCl wie Untersuchungen von Gutknecht und anderen gezeigt haben. Die elastische Spitze aus Glasfaser kann leicht in den Wurzelkanal eingeführt und das Licht vom Apex aufsteigend nach koronal appliziert werden.“ Weitere Einsatzmöglichkeiten von Diodenlasern sind das „Kürettieren“ von Weichgewebe, die Entfernung von Reizfibromen, das präprothetische Durchtrennen von hochansetzenden Bändern beziehungsweise die Trocknung des Sulcus vor Abdrucknahme etc.

Dr. Stieve verfügt in seinem Laserzentrum über verschiedene Therapielaser wie unter anderem den LABpen® MED 50 (Medizin Technik Behounek, A-Graz) und den LASOTRONIC Med-200 DUO (LASOTRONIC, H-Budapest). Der LABpen® MED 50 arbeitet mit einer Leistung von 50 mW und mit der Wellenlänge 660 nm. Nur bei dieser Wellenlänge wird Sauerstoff abgespalten. Der LASOTRONIC Med-200 DUO bietet sowohl die Emittierung von sichtbarem roten Licht (Wellenlänge 660 nm) als auch von unsichtbarem infrarotem Laserlicht (Wellenlänge 805 nm) und somit zwei unterschiedliche Eindringtiefen.

Im Laserzentrum kommen verschiedene Therapielaser zum Einsatz, unter anderem der LABpen® MED 50.

Weichgewebelaser

CO_2- beziehungsweise Gaslaser sind Weichgewebelaser. Sie werden auch als „Laser der Chirurgen“ bezeichnet und sind schon seit den 1970er Jahren im Einsatz. Je nach Bedarf kann mit ihm Weichgewebe sowohl geschnitten als auch flächig abgetragen werden – und dies blutungsfrei. Aufgrund von fokussiertem Energieeintrag und eng begrenzter Temperaturerhöhung wird das Weichgewebe verdampft und die Blutgefässe werden verschlossen. Daher muss bei der Behandlung von Lippen- und Zungenbändchen mit einem Laser nicht – wie nach Verwendung eines Skalpells erforderlich – genäht werden. Der Fokus befindet sich beim CO_2-Laser (Wellenlänge 10.600 nm) 1 mm vor der Spitze des Handstücks.

Wird der CO_2-Laser defokussiert angewendet, kann flächig koaguliert oder abgetragen werden.

Warze am rechten Oberlippenrand einer 45-jährigen Patientin.

Es erfolgte eine Oberflächenanästhesie mit EMLA Creme (AstraZeneca, D-Wedel), eine örtliche Infiltrationsanästhesie und dann die Excision der Warze mit einem CO_2-Laser bei 3 Watt CW Superpulsed. Die Dauer des Eingriffs betrug etwa zwei Minuten.

Die Situation direkt nach der OP.

Hartgewebelaser

Er:YAG-Laser, also Hartgewebelaser, die eine Wellenlänge von 2.940 nm aufweisen, bieten zahlreiche Anwendungsmöglichkeiten. Hierzu gehören

Das Ergebnis sieben Wochen post OP.

beispielsweise Kavitätenpräparation, Schmelz-Konditionierung, schonende pulpennahe Präparation, Wurzelspitzenresektion, Knochenablation und Entfernung kariöser Defekte. Die Kariesentfernung durch Laser ist für den Patienten sehr viel angenehmer als mit herkömmlichen Bohrern, da Vibration und Wärmeentwicklung wegfallen. Bei Frontzähnen kann in circa 70 % der Fälle auf eine Anästhesie verzichtet werden. Durch die Einwirkung des Er:YAG-Lasers wird das interkristalline beziehungsweise interstitielle Wasser, das auch in Schmelz und Dentin enthalten ist, so erhitzt, dass es schlagartig verdampft. Durch die plötzliche Volumenzunahme wird die Hartsubstanz-Struktur auseinandergerissen und herausgeschleudert. Da kariöses Dentin einen höheren Wasseranteil als gesundes aufweist, findet auf diesem Wege eine selektive, minimalinvasive und schonende Exkavation statt. Gleichzeitig erfolgt durch die Wasserdampfbildung eine Keimreduktion im betreffenden Dentin. Die Gefahr einer rezidivierenden Karies wird somit reduziert. Amalgam- und Goldversorgungen können mit Lasern nicht entfernt werden. Dr. Stieve entfernt diese daher zunächst konventionell und wechselt anschließend auf den Einsatz von Lasern, da die Karies hiermit schonend und flächig abgetragen werden kann.

Wer sowohl Hart- als auch Weichgewebe mit der „Kraft des Lichts" behandeln will, benötigt somit mindestens zwei unterschiedliche Laser. Es bietet sich daher an, Geräte zu erwerben die zwei Wellenlängen bieten. Es muss dabei mit Investitionssummen zwischen 40.000,- und 60.000,- Euro gerechnet werden. Dem Laserzentrum stehen das Er:YAG- und SuperPulse™-CO_2 Duallasersystem OpusDuo (Lumenis, D-Dreieich) und elexxion delos (elexxion, D-Radolfzell), eine Kombination aus Er:YAG- und Diodenlaser, zur Verfügung.

Laserbehandlungen werden von den Patienten sehr gut angenommen.

Laserschnitt mit Er:YAG-Laser für Wurzelspitzen-resektion.

Der elexxion delos bietet eine Kombination aus Er:YAG- und Diodenlaser.

Erstgespräch

Aber im Laserzentrum von Dr. Stieve sind Laser nicht die einzigen digitalen Technologien, die zum Einsatz kommen. Mit jedem neuen Patienten wird ein Erstgespräch geführt, bei dem die Ausgangssituation unter anderem durch Fotografien der einzelnen Zahngruppen als auch durch Röntgenbilder dokumentiert wird. Die Fotoaufnahmen erfolgen mit einer digitalen Intraoralkamera (Orangedental, D-Biberach) und werden gemeinsam mit dem Patienten für eine „Co-Diagnostik" begutachtet. Hierbei hilft eine entsprechende Software mit Lupenfunktion, mit der beispielsweise defekte Füllungsränder deutlich sichtbar werden. Durch diese Methode wird bei dem Patienten größeres Vertrauen in die vorgeschlagene Behandlung erzielt, denn er hat mit eigenen Augen gesehen, dass Handlungsbedarf besteht. Röntgenbilder werden mit einem Gerät der Orthoralix-Serie von Gendex (KaVo Dental, D-Biberach), das nachträglich digital aufgerüstet wurde, erstellt. Farbausdrucke der Fotografien und Röntgenaufnahmen werden dem Patienten nach dem Erst-Gespräch in einer Beratungsmappe mitgegeben. Terminerinnerungen erhalten Patienten auf Wunsch übrigens per SMS.

Das Konzept der „Co-Diagnostik" stärkt das Vertrauen des Patienten in die Behandlung.

Behandlung

Für die Dokumentation von Behandlungen, beispielsweise mit Invisalign® Alignern (Align Technology, US-Santa Clara), transparenten Kunststoffschienen für kieferorthopädische Maßnahmen, wird die Digitalkamera Nikon D1 (Nikon, D-Düsseldorf) verwendet. Das Laserzentrum von Dr. Stieve ist seit März 2007 zertifizierte Invisalign-Praxis.

Seit 1994 haben Patienten des Laserzentrums die Möglichkeit, vollkeramische Versorgungen in nur einer Sitzung zu erhalten. Damals begann Dr. Stieve, mit dem CAD/CAM-System CEREC 2 (Sirona Dental Systems, D-Bensheim) zu arbeiten. Er ist als Erprober für Sirona tätig und hat daher stets Kenntnis über neueste Software-Versionen. Das Laserzentrum verfügt über zwei CEREC 3D Aufnahmeeinheiten sowie über

Mit einer professionellen Kameraausrüstung werden Behandlungen dokumentiert.

die Fertigungseinheiten CEREC 3 und inLab, sodass bei Quadrantensanierungen ein zügiger Arbeitsfluss gewährleistet ist. Aktuell werden die Software-Versionen 3.04 für CEREC und 2.6 für inLab verwendet. Die Restaurationen werden aus VITABLOCS Mark II (VITA Zahnfabrik, D-Bad Säckingen) geschliffen. Die Individualisierung erfolgt im praxiseigenen Labor durch eine Zahntechnikerin, die ebenfalls in die CAD/CAM-Verfahren eingearbeitet ist.

Im Laserzentrum erhalten Patienten auch CAD/CAM-Versorgungen.

CMD

Da der Ursprung von etwa 60 % der chronischen Schmerzen im Kopf-, Nacken- und Schulterbereich zumindest teilweise in einer Funktionsstörung des Kausystems liegt, hat sich Dr. Stieve auch auf die Behandlung von Cranio-Mandibulären Dysfunktionen (CMD) spezialisiert. In diesem Zusammenhang nimmt er beispielsweise eine digitale Axiografie mit CADIAX® Compact (Gamma, A-Klosterneuburg) vor. Cadiax bietet 3D- und Slow Motion-Ansichten sowie die grafische Darstellung der Kurven an, wodurch sehr präzise Rückschlüsse durch den Anwender gezogen werden können.

Die digitale Befund-Aufzeichnung und Diagnostik erfolgt mithilfe der Software CMDfact von PD Dr. M. Oliver Ahlers. Diese bietet unter anderem viele Hilfs- und Hinweisfunktionen an, sodass auch der weniger geübte Anwender schnell die Umsetzung eines reproduzierbaren Befundungsprotokolls erlernen kann. Hat ein Patient Schienen erhalten oder soll okklusal äquilibriert werden, erfolgt eine exakte Analyse der zeitlichen Entwicklung der Lastverteilung der Okklusions- und Artikulationskontakte mit T-Scan III (Cumdente, D-Tübingen). Entsprechend dieser Analyse werden die Schienen beziehungsweise die natürliche Dentition eingeschliffen. Die so erzielten Informationen gehen weit über das hinaus, was mit dem Einsatz von herkömmlichem Okklusionspapier und durch die Beschreibung des Patienten erreicht werden kann.

Voll vernetzt

Im Laserzentrum stehen neun Computer und zwei Laptops bereit, die alle untereinander sowie mit der Heim-PC-Station von Dr. Stieve vernetzt sind. Für die Praxisorganisation, betriebswirtschaftliches Controlling etc. wird das Praxis-Management-System Charly (solutio, D-Holzgerlingen) eingesetzt. Businessplan und Controlling der Praxis werden mithilfe des Unternehmens Dent-Vision (D-Rendsburg) und deren Spezialsoftware durchgeführt. Dr. Stieve wird in allen Hardware-, Software- und Administrationsfragen von einem IT-Berater unterstützt. Auch von seinen Mitarbeitern wird die Auseinandersetzung mit digitalen Technologien erwartet. Jede Zahnmedizinische Fachangestellte im Laserzentrum hat mehrere Schwerpunktbereiche, die beispielsweise auch die Stuhlassistenz bei Behandlungen mit CEREC oder Lasern, die Vorbereitung oder Durchführung von T-Scans sowie die Assistenz bei der digitalen Axiografie mit Cadiax umfasst.

Kontakt

Laserzentrum und Praxis für Zahnheilkunde
Lancasterstraße 42
D-24768 Rendsburg
Tel.: +49 (0) 43 31 / 52 05
Fax: +49 (0) 43 31 / 54 00
info@digital-dentistry.com
www.digital-dentistry.com

Comparison of Diode Lasers in soft- tissue surgery using cw- and superpulsed mode: an in vivo study.

by

Dr. Ralf Borchers

for the degree of

Master of Science in Lasers in Dentistry

(Master Thesis)

2008

RWTH Aachen University

AALZ Aachen Dental Laser Institute

Prof. Dr. Norbert Gutknecht

Table of contents

Acknoledgement

The author wishes to express his special gratitude to Prof. Dr. Norbert Gutknecht, Dr. Rene Franzen and Dr. Jörg Meister for their throughout efforts and patience to guide us on our way to the Master of Science and let us participate in scientific laser dentistry.

Abstract

Purpose :

Dental soft tissue surgery by diode lasers in cw- mode often causes carbonization of the tissues with following necrosis and a delay of wound healing.

In vitro studies have already shown, that superpulsed diode laser surgery has much less disadvantages for the tissues in histological approach.

Purpose of this study is to investigate in vivo, if superpulsed mode of operation can realize an improvement for surgeon and patient in soft tissue surgery.

Materials and methods :

26 patients were treated by diode lasers in different modes of operation for soft tissue surgery. 12 patients were treated by superpulsed Elexxion Claros diode laser :

810 nm; 10- 50 W P_{peak} ; 10- 20 μs pulse duration; 12000- 20.000 Hz; 400 μm fiber and 14 patients were treated by Vision MDL-10 diode laser : 980 nm; 2,5 W; cw- mode and also 400 μm fiber.

Clinical treatment was documented by photos and questionnaires for patients and surgeons. Questions concerned: carbonization, coagulation, cutting speed, pain, swelling, bleeding, need for drugs, functional reduction and fibrine layer on wounds- during treatment, directly after treatment, after 1 day, after 3 days and after 1 week.

Results :

The clinical observations and the questionnaires showed in most cases significant differences between cw- mode and superpulsed diode laser treatment in surgery.

There was less carbonization in the superpulsed group.

The cutting speed was higher and the cut itself more defined and deeper by using superpulsed mode.

Superpulsed laser treatment had a shorter healing time than cw- mode treatment; the fibrine layer was build faster and also the removal of it was faster.

There was often no swelling after superpulsed diode laser treatment; and if a swelling occured it was smaller and quicker gone as in cw- mode treatment.

The duration of pain was shorter and the amount of pain smaller in the superpulsed group, therefore the patients in the superpulsed group needed less analgetic drugs.
There was less functional reduction in time and amount for the superpulsed group.
Only coagulation ability was better in the cw- mode group.

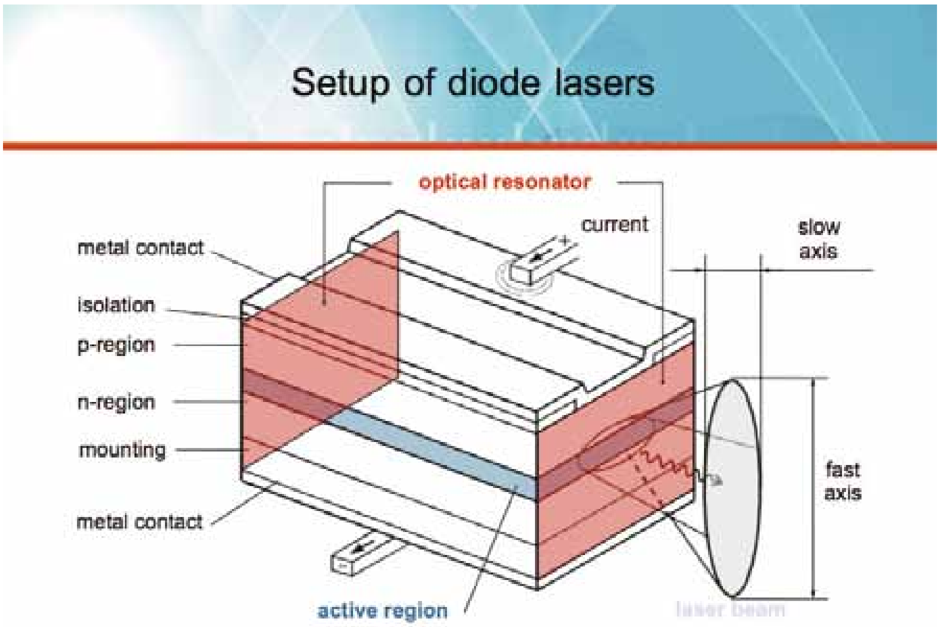
Conclusion :

Clinical studies have shown that superpulsed diode laser surgery is superior to continuous wave done treatment. Carbonization and thermal damage of the tissues can be reduced to a minimum, therefore healing is faster as in cw- mode surgery. Generation of a soft tissue cut is faster and more precise. Patients have less pain; in amount and time period. The need of drugs is reduced. There are less functional restrictions and there is less swelling. The advantages of superpulsed mode of operation for soft tissue diode laser surgery are evident. Continuous wave mode should no longer be implemented in diode laser surgery.

1. Introduction

1.1 Diode lasers

Diode lasers are semiconductors, mainly with *GaAs* compounds and mixed crystals.
The composition of the mixed crystals, the kind of *GaAs* compound and the temperature determine the wavelength. In diode lasers the laser beam is generated directly at the p-n junction out of electrical energy; no arc- or flashlamps are needed for pumping, therefore the efficiency is about 35- 50 % (76,141).

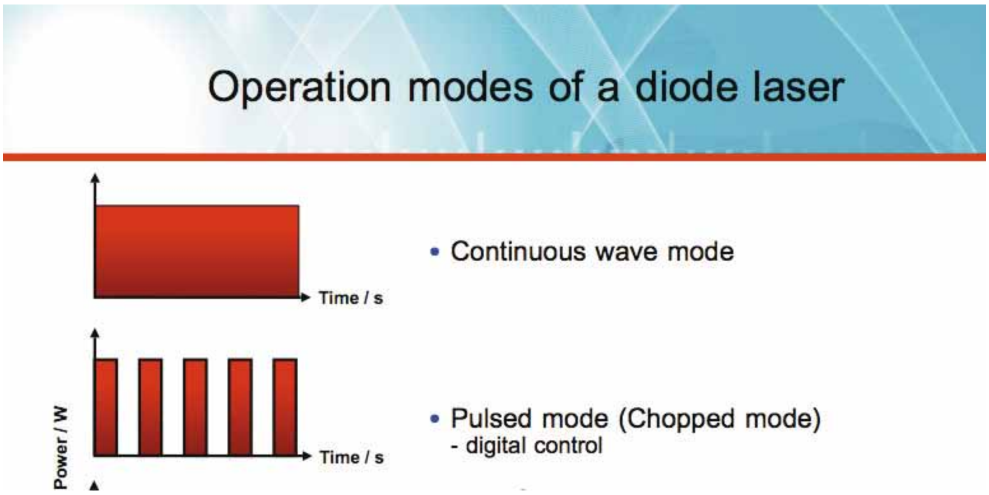


(Meister J,Franzen R: Diode Lasers, Aachen Institute for Laser Dentistry, M4, ED2006)

There are no real resonators in common sense, the dimensions are particularly small (0,1 dm^3/ kw). Because of the slit- diffraction at the p-n junction of the semiconductor the beam profile is elliptical and highly divergent. It has to be collimated before use. The output power from a diode is only in the mW region, so several diodes have to be arranged in arrays, bars and stacks to achieve an output power in the W range.
The focussed intensity can reach 10^4- 10^6 W/ cm^2.

Diode lasers for dentistry operate in the near infrared region. The most commonly used wavelengths are 810, 940 and 980 nm (141), because these wavelengths are very well absorbed by pigmented tissues, haemoglobine and melanin, which makes the diodes suitable for soft tissue surgery, endodontics, periodontics and LLLT (57,72,141).
The history of diode lasers started 1962 with the first *GaAs* diode laser, 840 nm, pulsed in fluid *He* or N_2. It was developed by IBM, General Electric and Lincoln Laboratories.(155).
The first red diode laser was introduced.
1966 the first fiber to guide the laser beam was created.
In 1970 the Bell Laboratories produced the first cw- mode diode laser (155).
In 1995, on the IDS, the first diode laser for dentistry was shown. It was an 810 nm diode laser with cw mode. (133). Peak power was 6 W.
1999 diode lasers with 10- 15 W followed.
2000 a short pulsed diode laser with 810 nm, 20 W, 50 μs pulse and an average power of 2,0- 6,7 W was introduced, which showed a faster cutting and only 50 % of the necrosis zone of an cw- mode diode laser. (156).
2002 the peak power reached 30 W with a pulse duration of 9 μs, a frequency of 20000 Hz and a limited average power of 10 W. Today frequencies up to 30000 Hz and peak powers of 50 W are possible. To gain a sufficient result the peak power has to be more than 8 W in this case. (141).

During the first years of diode laser treatment in dentistry only cw mode was possible. Several studies at that time showed that cw mode and 1 W was enough to reach a bactericidal effect on and in roots and root canals, so as on implant surfaces.
(13- 16,51,88,106,118,120,156). Application of 3- 4 W in cw mode led very fast to carbonization of the soft tissue; the carbonization caused higher absorption followed by a heavy thermal damage and necrosis of the tissue. (71,146,149,150,156).
To approach better results in soft tissue treatment without much carbonization it was necessary to interrupt the cw mode. That was done by chopping the cw mode. Pulses down to several 100 μs were realized. (141,97,145). The peak power of the pulses was in fact not higher than the peak power of the cw mode pulse, but the applied dose was decreased and the carbonization and thermal damage was reduced.



(Meister J,Franzen R: Diode Lasers, Aachen Institute for Laser Dentistry, M4, ED 2006)

A further progress were pulse durations of 9 μs, a frequency of 20000 Hz and a peak power of 50 W, which could only be generated by DPL (digital pulse technique).
Using these parameters could generate a fast, sharply edged cut nearly without thermal damage of the surrounding tissue and only minimal carbonization at the cutting edges. (17,24,26,34,35,109,153,154,156).
To make a statement about the laser - tissue interactions something about the general mechanisms of laser irradiation has to be said.
If a laser beam hits the tissue surface 4 different effects can be noticed. (67,68)

1. Reflection
2. Transmission
3. Scattering
4. Absorption

Very important for a surgical effect on the tissue is the absorption of laser light. The kind of tissue and the wavelength are essential for absorption. There are some more factors been involved in laser- tissue interactions, so as the frequency, the dose applied, the pulse duration, power density and very important: the mode of operation (cw, pulsed, superpulsed) which is a main question of the in vivo studies done here.
Dependend on the just mentioned factors there are different effects to be watched in the tissue. (52,67,68,151,152)

Photodynamical effects

Photochemical effects

Thermal effects

(34,64,67,68,71,146,147,148,149,150,151,152)

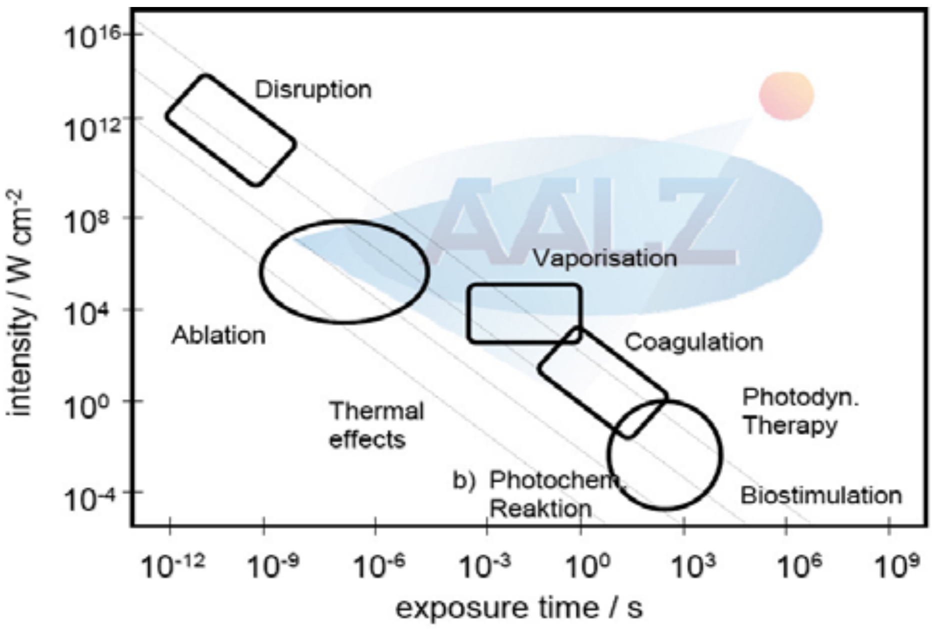
T= 40- 60 °C: oedema, functional imbalance of metabolism
(up to 50°C reversibel)

T= 60- 100°C: denaturation of the proteins, coagulation, contraction
because of dehydration

T > 100°C : disruption, evaporation of water, ablation

T > 150°C : vaporisation, ablation

T > 300°C : carbonisation



(Franzen R, Meister J: Dosimetry. Aachen Institute for Laser Dentistry, M3, ED 2006)

1.2 Diode lasers in dentistry

As mentioned above diode lasers were used in dentistry since1995.
Mostly with a wavelength of 810 nm. Later the wavelength 980 nm follows and recently a wavelength of 940 nm is in progress.
In comparison to other lasers the diodes are more economical, the construction is more simple, laser light is generated directly from electrical energy, service periods are rare (maintainance only in intervals of 10000 hours) and the efficiancy is high. The laser beam is guided through a quarz- fiber, which makes it easier to reach problematic zones in the oral cave. Unfortunately diode lasers are only applicable in soft tissue procedures, endodontics, periodontics and LLLT, but not practicable for the ablation of hard tissues.
In soft- tissue treatment the diode lasers have similar effects than the Nd:YAG laser, which is not so far away regarding to the wavelength (1064 nm).
Diode lasers are established in endodontical treatment because of the good bactericidal effect (2,13-15,26,28,29,57,72,98).
Diodes are implemented in periodontal treatments and periimplantitis to remove granulated tissue and to sterilize the surface of root and implant (2,11,13,16,18-23,40,50,57,60,72,80,82,85,104,105,134-136,139,140,144).
Also in little surgery diodes are used because of several advantages:

- efficient cutting
- good haemostasis
- nearly without bleeding and therefore good visibility of the op site
- mostly no sutures needed
- no or only small post op oedema
- bactericidal effect
- pain reduction post and intra op treatment
- no secondary bleeding
- precision of cut
- calculated depth of cut
- reduced application of drugs (antibiotics, analgetics..)
- only minimal destruction of adjacent tissues
- uncomplicated handling

- high patient acceptance
- low level of scar forming
- use on patients with haemorrhagic diathesis without or only with little substitution
- good handling due to fiber optics
- reduction of needed instruments (change of parameters- different effects)
- treatment duration shorter (no suture, not often change of instrument..)
- biostimulation of the surrounding tissue

(1,3-10,12,17,25-27,30-39,42-49,57-69,72,74,77,81,86-89,91-97,106, 109-114,116,119-132,138,141,142,145-154,156)

In the beginning soft tissue surgery by diodes was limited because of the low peak powers and the cw- mode as only mode of operation. The doses which were applied to the soft tissue led very fast to carbonization, thermal damage and necrosis of the tissue if the power exceeds 3-4 W in cw- mode. To achieve a better result the dose had to be reduced.

This can be done by decreasing the power, but then there will be no sufficient cutting ability. Another way is to shorten the treatment time, or to split the continuous wave into pulses; and change the frequency of the pulses.

By using mechanical shutters the cw- mode of the diode was changed into a chopped mode, the dose was reduced, but the peak powers of the pulses equaled the peak powers of the cw- mode. Carbonization was reduced for a certain degree but no efficient cutting could be done. The peak power of the pulses was not sufficiently high enough. So the management of the pulses was changed from mechanical to digital. (DPL). Now very short pulses with high peak powers could be generated to avoid carbonization and thermal damage as good as possible. Several studies in the recently past years have shown, that short pulses with high peak powers could generate a much better result than lower powers with longer pulse duration. (17,24,26,34,35,109,153,154)

Already Bach et al. (109) could show 2008 in vitro, that different modes of operation; cw- pulsed- superpulsed; led to different effects.

Result of the study was the suggestion that cw- mode diodes should no longer be used in soft tissue surgery because of the high amount of thermal damage and necrosis of the adjacent tissue. The superpulsed diode had much less carbonization and thermal damage as side effect. Interestingly 980 nm and 810 nm diodes have been used in that study-- but histologically there was no difference between the 810 nm and 980 nm diode; only the mode of operation was responsible for the grade of cell damage.

Case reports of Maiorano et al. (153) from 2006 could show in vivo that superpulsed diode lasers caused only minimal involvement of the adjacent tissue during surgery, that there was a clean cut without thermal side effects, but still coagulation. Result was an excellent postoperative condition with minimal swelling and pain.

Until now there are unfortunately no clinical or in vivo studies to show the different results of diode laser soft tissue surgery with different modes of operation. Theoretically the difference in treatment results with cw- mode and pulsed is comprehencible; in vitro it is shown already (109) but in vivo it is still unproven. It would be very nice to have no more carbonization during surgical treatment, because carbonization causes a higher grade of absorption and due to that a higher thermal damage of the tissue, which will lead to more discomfort of the patient and a delayed wound healing.

Therefore it is a major task of this thesis to answer the question if highly pulsed diode lasers are more suitable for soft tissue surgery than cw- mode diode lasers and how the achievable results differ.

Of course a number of noticed parameters in the following study, so as patient`s pain, influence on oral hygiene, reduced masticatory or lingually function etc. are subjective criteria, but at least it can show a tendency for the right direction to go.

2. Materials and methods

Within a period of 5 months 26 dental surgery treatments have been done by diode laser. Predominantly simple laser cuts, but also removal of hyperplasia and fibromas, exposure of teeth and implants, abscess incision and gingivo- and vestibuloplasty.

14 patients have been treated by ***Vision MDL-10*** diode laser :

- Vision Lasertechnik GmbH, Lügensteinweg 27, 30890 Göxe, Germany

- cw- mode or 20 Hz mode
- max. 2,5 W
- 200 µm and 400 µm fiber
- 980 nm

All procedures have been done with: **cw mode; 2,5 W; 400 µm fiber**

Treatment	P_{peak}	Mode
Single cut (4x)	2,5 W	cw
Incision abscess (1x)	2,5 W	cw
Hyperplasia (1x)	2,5 W	cw
Exposure implant (3x)	2,5 W	cw
Exposure tooth (1x)	2,5 W	cw
Fibroma (2x)	2,5 W	cw
Gingivoplasty (1x)	2,5 W	cw
Vestibuloplasty (1x)	2,5 W	cw

12 patients were treated by ***Elexxion Claros*** diode laser :

- Elexxion AG, Schützenstraße 84, 78315 Radolfzell, Germany
- 810 nm
- 10 mW- 50 W P_{peak}
- 2,5 μs- cw pulse duration
- 200 μm, 300 μm, 400 μm and 600 μm fiber
- digitally superpulsed (8- 20.000 Hz)

Treatment	P_{peak}	Frequency	Pulse duration	P_{avg}
Single cut (3x)	50,0 W	20.000 Hz	11 μs	11,0 W
Incision abscess (2x)	10,0 W	20.000 Hz	20 μs	4,0 W
Hyperplasia (1x)	50,0 W	12.000 Hz	10 μs	6,0 W
Frenectomy (1x)	15,0 W	20.000 Hz	16 μs	4,8 W
Exposure implants (2x)	15,0 W	15.000 Hz	10 μs	2,25 W
Exposure tooth (1x)	25,0 W	15.000 Hz	10 μs	3,75 W
Fibroma (2x)	50,0 W	12.000 Hz	10 μs	6,0 W

All treatments have been done with the 400 μm fiber for better comparison.
Both lasers have been used with fibers in contact to tissue.
The fibers had been under permanent control for tidiness, because contaminated fibers decrease the applied energy, the cutting speed drops down, the treatment time prolongs and more thermal energy is given to the tissue (145).
After sufficient anesthesia, for abscess incision only superficial, in all other cases infiltration anesthesia, the treatment was done in consideration of the laser safety directions given for laser treatment of class 4 lasers.
Before, during and directly after laser treatment photos were taken and the patients had to fill in a questionnaire. Another questionnaire had to be done by the surgeon. 1 day, 3 days, 1 week, 2 weeks and sometimes 3 month later there was a recall to control the op sites clinically and to take some more photos. The patients had to fill in their questionnaires until 1 week after surgery. Asked subjects were intra- and postoperative pain, need of analgetic drugs, difficulties in oral hygiene or mastication. The surgeons questionnaire asked about cutting speed of the laser, bleeding intra- and post op, swelling, carbonization, coagulation and fibrine layer covering. Time schedule was the same as for the patients.

Questionnaire

for patient

Name: **Subject : Laser treatment**

Pain :

During laser treatment :

0	1	2	3	4	5	6	7	8	9

No pain **Unbearable pain**

Directly after laser treatment :

0	1	2	3	4	5	6	7	8	9

No pain **Unbearable pain**

1 day after laser treatment :

0	1	2	3	4	5	6	7	8	9

No pain **Unbearable pain**

3 days after laser treatment :

0	1	2	3	4	5	6	7	8	9

No pain **Unbearable pain**

1 week after laser treatment :

0	1	2	3	4	5	6	7	8	9

No pain **Unbearable pain**

Analgesic drugs needed :

only 1 day **3 days** **the first week** **more than a week**

Reduced masticatory or lingually function :

only 1 day **3 days** **the first week** **more than a week**

Difficulties in oral hygiene :

only 1 day **3 days** **the first week** **more than a week**

Questionnaire

for surgeon

Name: **Subject : Laser treatment**

<u>During laser treatment</u>

Speed of cutting

0	1	2	3
very slow	slow	fast	very fast

Carbonization

0	1	2	3
no carbonization	little carbonization	carbonization	heavy carbonization

Coagulation

0	1	2	3
no coagulation	little coagulation	good coagulation	very good coagulation

<u>Directly post OP</u>

Bleeding

0	1	2	3
No bleeding	little bit	bleeding	heavy bleeding

1 day post OP

Bleeding

0	1	2	3
No bleeding	**little bit**	**bleeding**	**heavy bleeding**

Turgor, swelling

0	1	2	3
No swelling	**little swelling**	**swelling**	**large swelling**

Fibrine layer :

0	1	2	3
No layer	**small region**	**mostly covered**	**completely covered**

3 days post OP

Bleeding :

0	1	2	3
No bleeding	**little bit**	**bleeding**	**heavy bleeding**

Turgor, swelling :

0	1	2	3
No swelling	**little swelling**	**swelling**	**large swelling**

Fibrine layer :

0	1	2	3
no layer	**small region**	**mostly covered**	**completely covered**

<u>1 week post OP</u>

0	0	0
bleeding	**swelling**	**fibrine layer**

As already mentioned in the introduction the purpose and aim of this in vivo study is to show, that superpulsed diode lasers are more suitable for oral surgery than cw- mode diode lasers, because it is expected that there is nearly no carbonization and thermal damage of the adjacent soft tissue because of the very short pulse durations, the high peak power and high frequency.

Until now there are not enough data from in vivo studies available to support the supposed results, but in vitro studies already came to a similar resume.

(24,34,35,109,132,153)

The diode lasers used in this study are not of the same wavelength; on the one hand there is an 810 nm diode (Elexxion Claros) on the other hand a 980 nm diode (Vision MDL- 10).

According to the wavelength it must be said that normally there is a stronger thermal effect using the 980 nm diode (72) but as shown in a recent in vitro study (109) from 2008, the mode of operation is much more responsible for the clinical results on soft tissue as the diode`s wavelength.

3. Results

3.1 Clinical results

To show the visual results of a soft tissue surgery treatment by diode laser in cw and superpulsed mode 2 similar cases were taken as example for all clinical cases. Treatment procedure was the same in both cases and the local sites were comparable.
In both procedures a fibroma was removed out of the inner lip.
Once on the right and once on the left side of the lower jaw.
For better comparison it would have been perfect if both treatments had been done on the same patient, but there was no such case during the investigation period.

3.1.a 1st case : as example for Vision MDL- 10; cw

Removal of fibroma by Vision MDL 10 diode laser:

980 nm; cw mode; 2,5 W; 400 μm fiber; contact mode

Female patient, 60 years old, hypertonia. No other general deseases.
18, 15, 25, 28, 36, 48 missing. Bridge 14- 16.
Fair oral care. General horizontal loss of bone. No periodontal problems.

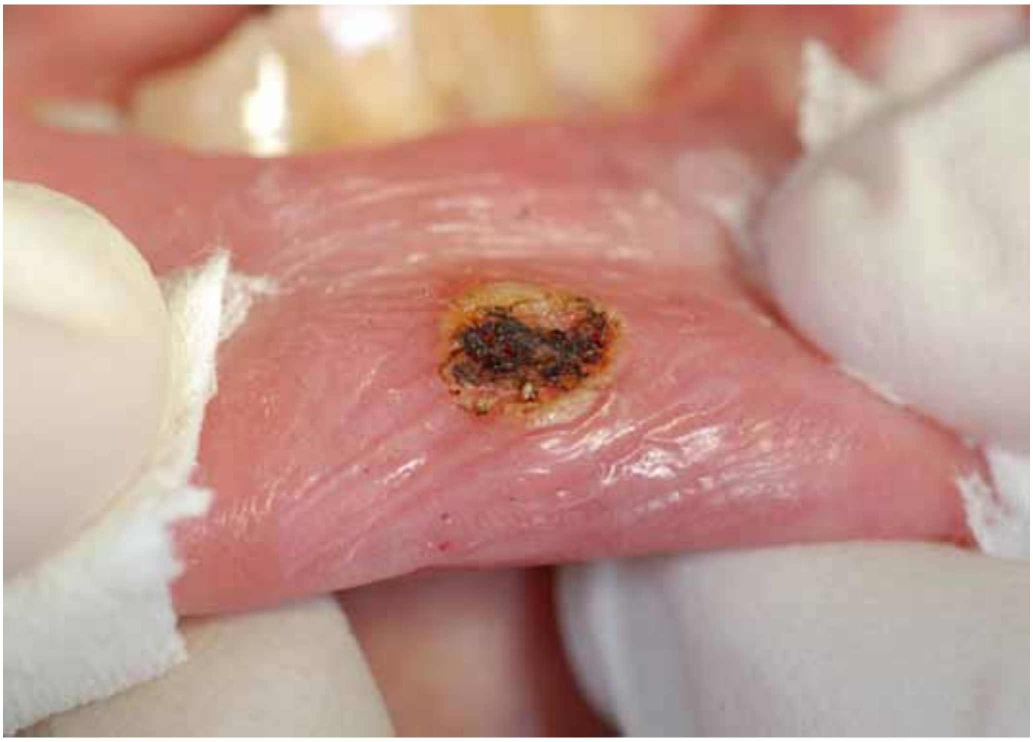
Patient was often sucking on the fibroma.
Fibroma was situated at regio 43, inner lip. Diameter about 8 mm.

After little infiltration anesthesia with Ultracain DS® the fibroma was removed under permanent tension with the 400 μm fiber in contact.

Before treatment.

During treatment (980 nm; cw; 2,5 W; 400 μm fiber)

Because of the good absorption of the 980 nm wavelength in melanin and haemoglobine there was a sufficient cutting ability and no bleeding.



Directly after treatment.

The treatment procedure took a little longer because the cutting speed of the 980 nm diode in cw mode with only 2,5 W peak power was slow.
No bleeding because of the very good coagulation of the 980 nm diode, but strong carbonization of the soft tissue was seen.
No sutures needed.
There was no pain or discomfort for the patient during the surgical procedure.
1 day after surgical treatment no secondary bleeding, but a little swelling and a fibrine layer that covered the wound was seen. The patient had no pain but the mastication, the lingual function and the oral hygiene was influenced.

1 day after surgical treatment.

3 days after surgical treatment

No bleeding, a little swelling and a fibrine covered wound was seen.
The patient had no longer functional limitations. No pain.

1 week after treatment

No bleeding and no more fibrine layer was seen.

3 months later. No rezidiv. Total recovery. No scar.

3.1.b 2nd case : as example for Elexxion Claros; superpulsed

Removal of fibroma by Elexxion Claros diode laser.

810 nm; 50 W $P_{peak,}$; 12000 Hz; 10 μs pulse duration; 6 W P_{avg} ;
400 μm fiber; contact mode
Female patient, 72 years old, diabetic disorder. No other general deseases.
18- 28, 38- 35, 32-48 missing.
Total upper denture. Lower partial denture with clasps at 33, 34.
General horizontal and vertikal loss of bone. Fair oral care.
Fibroma was situated at regio 35, inner lip, lower jaw. Diameter about 11 mm.
After sufficient anesthesia with Ultracain DS® the fibroma was removed under good tension with the 400 μm fiber in contact.

Before treatment (little bleeding spot from injection of anesthesia)

During treatment

(810 nm; 50 W P_{peak}; 12000 Hz; 10 μs pulse; 6 W P_{avg}; 400 μm fiber)

No bleeding because of good coagulation of 810 nm wavelength (good absorption in haemoglobine and melanin).
Extremly fast cutting speed because of high power, short pulses and high frequency.
The patient felt no discomfort or pain during the surgical treatment time.

Directly after treatment no bleeding of the wound, no sutures needed.
Good coagulation and only a little carbonization zone was seen.

Directly after treatment

1 day after treatment

3 days after treatment

No bleeding, no swelling. Wound is completely covered by fibrine layer.
Patient had no discomfort or pain.

1 week after treatment

No bleeding, no swelling, partial fibrine layer. Patient without any discomfort.

2 weeks after treatment

Nearly full recovery. Only a little impression of the soft tissue remained.
No rezidiv, no scar. Healing much quicker than with cw diode laser.

4. Results of questionnaires

In total there were 52 questionnaires to analyse.
26 from the patients and 26 from the surgeons.

4.1 Patient`s questionnaire :

4.1.a VISION MDL- 10 treatment ➡ 14 patients; cw

During laser treatment

All patients felt no **pain** during laser treatment (100 %)

Directly after laser treatment

All patients without any **pain** (100 %)

1 day after laser treatment

Number of patients	Pain: scale 0- 9	Percentage of total number of patients
3	0 (no pain)	21,43%
3	1	21,43%
5	2	35,71%
2	3	14,29%
1	7 (strong pain)	7,14%

3 days after laser treatment

Number of patients	Pain: scale 0- 9	Percentage of total number of patients
10	0 (no pain)	71,43%
3	1	21,43%
1	7 (strong pain)	7,14%

1 week after laser treatment

Number of patients	Pain: scale 0- 9	Percentage of total number of patients
13	0	92,86%
1	5	7,14%

Analgesic drugs needed

Number of patients	Analgesic drugs needed	Percentage of total number of patients
8	No	57,14%
5	Yes, 1 day	35,71%
0	Yes, 3 days	0%
1	Yes, 1 week	7,14%

Reduced masticatory or lingually function

Number of patients	Time of reduction	Percentage of total number of patients
0	No reduction	0%
4	1 day	28,57%
8	3 days	57,14%
1	1 week	7,14%
1	more than a week	7,14%

Difficulties in oral hygiene

Number of patients	Time of handicap	Percentage of total number of patients
0	No	0%
5	1 day	35,71%
8	3 days	57,14%
0	1 week	0%
1	more than a week	7,14%

4.1.b ELEXXION CLAROS treatment ➡ 12 patients; superpulsed

During laser treatment

All patients felt no **pain** during laser treatment. (100 %)

Directly after laser treatment

All patients without any **pain** (100 %)

1 day after laser treatment

Number of patients	Pain: scale 0- 9	Percentage of total number of patients
5	0 (no pain)	41,67%
3	1	25%
3	2	25%
1	3	8,33%

3 days after laser treatment

Number of patients	Pain: scale 0- 9	Percentage of total number of patients
8	0 (no pain)	66,67%
4	1	33,33%

1 week after laser treatment

Number of patients	Pain: scale 0- 9	Percentage of total number of patients
12	0 (no pain)	100%

Analgesic drugs needed

Number of patients	Analgesic drugs needed	Percentage of total number of patients
8	No	66,67%
3	Yes, 1 day	25%
1	Yes, 3 days	8,33%

Reduced masticatory or lingually function

Number of patients	Time of reduction	Percentage of total number of patients
2	No reduction	16,67%
4	1 day	33,33%
6	3 days	50%

Difficulties in oral hygiene

Number of patients	Time of handicap	Percentage of total number of patients
1	No	8,33%
5	1 day	41,67%
6	3 days	50%

4.2. Surgeon`s questionnaire

4.2.a VISION MDL- 10 treatment ➡ 14 patients; cw

During laser treatment

Speed of cutting was all time low (100 %)

Carbonization

Number of patients	Degree of carbonization	Percentage of total number of patients
0	no carbonization	0%
2	little carbonization	14,29%
7	carbonization	50%
5	heavy carbonization	35,71%

Coagulation

Number of patients	Degree of coagulation	Percentage of total number of patients
0	no coagulation	0%
0	little coagulation	0%
8	good coagulation	57,14%
6	very good coagulation	42,86%

Directly post op

Number of patients	Degree of bleeding	Percentage of total number of patients
11	no bleeding	78,57%
3	little bleeding	21,43%

1 day post op

There was no recognizable **bleeding** (100 %)

Swelling

Number of patients	Degree of swelling	Percentage of total number of patients
4	no swelling	28,57%
9	little swelling	64,29%
1	swelling	7,14%

Fibrine layer

Number of patients	Size of fibrine layer	Percentage of total number of patients
4	no layer	28,57%
5	small region	35,71%
5	mostly covered	35,71%

3 days post op

There was no recognizable **bleeding** (100 %)

Swelling

Number of patients	Degree of swelling	Percentage of total number of patients
8	no swelling	57,14%
6	little swelling	42,86%

Fibrine layer

Number of patients	Size of fibrine layer	Percentage of total number of patients
2	no layer	14,29%
3	small region	21,43%
3	mostly covered	21,43%
6	completely covered	42,86%

1 week post op

No **bleeding** (100 %) left; no **swelling** (100 %) left.
6 patients of 14 still had a little **fibrine layer** (42,86 %).

4.2.b ELEXXION CLAROS treatment ➡ 12 patients; superpulsed

During laser treatment

Speed of cutting

Number of patients	Speed of cutting	Percentage of total number of patients
0	slow	0%
3	fast	25%
9	very fast	75%

Carbonization

Number of patients	Degree of carbonization	Percentage of total number of patients
4	no carbonization	33,33%
4	little carbonization	33,33%
4	carbonization	33,33%
0	heavy carbonization	0%

Coagulation

Number of patients	Degree of coagulation	Percentage of total number of patients
0	no coagulation	0%
2	little coagulation	16,67%
10	good coagulation	83,33%
0	very good coagulation	0%

Directly post op

Bleeding

Number of patients	Degree of bleeding	Percentage of total number of patients
7	no bleeding	58,33%
5	little bleeding	41,67%

1 day post op

There was no recognizable **bleeding** (100 %)

Swelling

Number of patients	Degree of swelling	Percentage of total number of patients
5	no swelling	41,67%
7	little swelling	58,33%
0	swelling	0%

Fibrine layer

Number of patients	Size of fibrine layer	Percentage of total number of patients
2	no layer	16,67%
6	small region	50%
4	mostly covered	33,33%

3 days post op

There was no recognizable **bleeding**. (100 %)

Swelling

Number of patients	Degree of swelling	Percentage of total number of patients
11	no swelling	91,67%
1	little swelling	8,33%

Fibrine layer

Number of patients	Size of fibrine layer	Percentage of total number of patients
0	no layer	0%
4	small region	33,33%
5	mostly covered	41,67%
3	completely covered	25%

1 week post op

No **bleeding** (100 %); no **swelling** (100 %) left.

4 of 12 patients still had a little **fibrine layer** (33,33 %)

5. Summary of results

5.1 Surgeon`s results

The visible clinical results could be described as followed :
During surgical treatment and directly after treatment the soft tissues at the involved area were more carbonized by the Vision MDL- 10 laser, which ran in cw- mode;
35,71 % heavy carbonization.
The superpulsed laser , Elexxion Claros, showed sometimes carbonization too, but the amount of carbonization was much smaller, the color of the carbonized zones was more brown than black and in a third of all cases there was no carbonization at all.

Carbonization	cw- mode	superpulsed
no	0%	33,33%
little	14,29%	33,33%
medium	50%	33,33%
heavy	35,71%	0%

Coagulation was good with both lasers, in some situations (a patient with anticoagulant therapy - Marcumar® - INR > 2,5 ; not substituted) the 980 nm diode in cw- mode (Vision MDL- 10) had a better coagulation.

Coagulation	cw- mode	superpulsed
little	0%	16,67%
good	57,14%	83,33%
very good	42,86%	0%

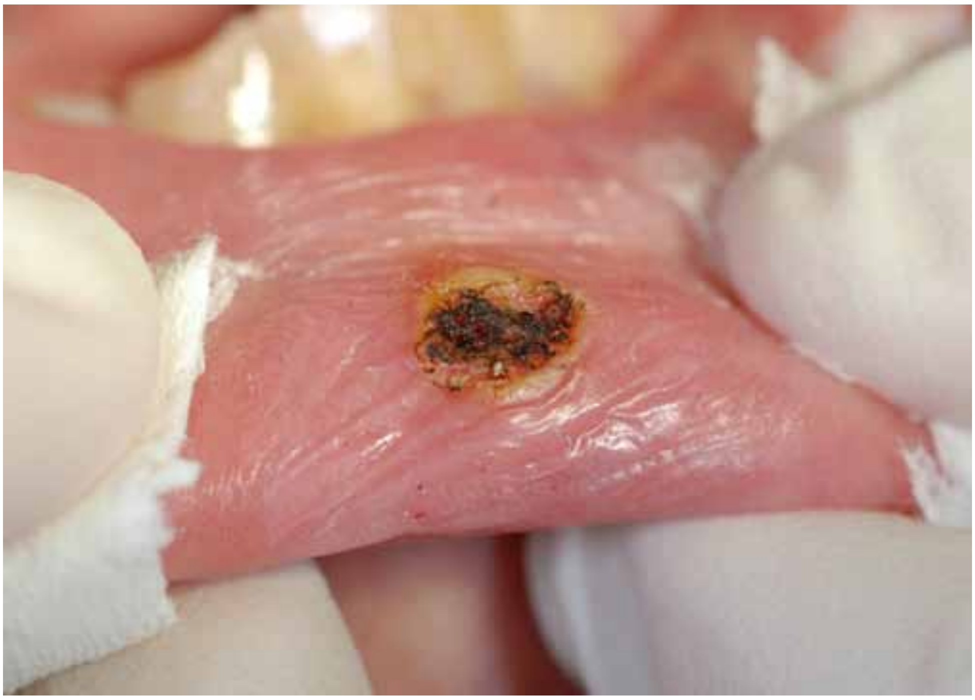
Both lasers did not allow common bleedings post op, but in some cases there was a little oozing bleeding; more after superpulsed laser therapy than after cw- mode treatment.

Bleeding	cw- mode	superpulsed
post op : no	78,57%	58,33%
post op : little	21,43%	41,67%

The **speed of cutting** was very different, the superpulsed Elexxion diode laser cutted much easier and faster than the Vision diode laser.
The surgical procedure was done much faster by using the superpulsed laser.

Speed of cutting	cw- mode	superpulsed
low	100%	0%
fast	0%	25%
very fast	0%	75%

On pictures taken after the surgical procedure the wound areas looked much nicer when the treatment was done by superpulsed Elexxion laser.
The cutting margins had sharper edges, the cut was more straight and seemed to go deeper into the tissue with one movement.



cw mode

superpulsed

The following days there was a swelling of the treated soft tissue in different sizes noticed for both laser systems.

Swelling 1 day post op	cw- mode	superpulsed
no swelling	28,57%	41,67%
little swelling	64,29%	58,33%
swelling	7,14%	0%

The swelling tendency of the superpulsed diode laser was lower and there was no swelling in significant more cases.

Swelling 3 days post op	cw- mode	superpulsed
no swelling	57,14%	91,67%
little swelling	42,86%	8,33%

After 3 days there was only in 8,33 % a little swelling left after superpulsed diode laser treatment but in the cw- mode group 42,86 % of the patients still had a recognizable swelling. One week after laser treatment there was no swelling left in both laser groups.

Another phenomenon to be watched was the fibrine layer.

Fibrine layer 1 day post op	cw- mode	superpulsed
no layer	28,57%	16,67%
small region	35,71%	50%
mostly covered	35,71%	33,33%

Including 4 osteotomy cuts for cw- mode and 3 for superpulsed mode.
In total there was more fibrine layer after superpulsed treatment.

Fibrine layer 3 days post op	**cw- mode**	**superpulsed**
no layer	14,29%	0%
small region	21,43%	33,33%
mostly covered	21,43%	41,67%
completely covered	42,86%	25%

3 days post op the fibrine covering of the wound areas had increased in both groups.

Fibrine layer 1 week post op	**cw- mode**	**superpulsed**
no more layer	57,14%	66,67%
still little layer	42,86%	33,33%

1 week post op there was more reduction of fibrine layer in the superpulsed group, while the cw- mode group still had a partial fibrine covered area in 42,68 % of the patients.

5.2 Patient`s results

During laser treatment and directly after laser treatment no patient felt pain or discomfort because there was anesthesia given in every treatment case.

Pain 1 day post op: 0= no pain 9= unbearable	cw- mode	superpulsed
0	21,43%	41,67%
1	21,43%	25%
2	35,71%	25%
3	14,29%	8,33%
7	7,14%	0%

There were more patients without pain and the pain strength was on a lower level in the superpulsed group.

Pain 3 days post op: 0= no pain 9= unbearable pain	cw- mode	superpulsed
0	71,43%	66,67%
1	21,43%	33,33%
7	7,14%	0%

Now there were more patients without any pain in the cw- mode group and also patients with very mild pain were less in the cw- mode group. But still there was a special patient with continued heavy pain.

Pain 1 week post op: 0= no pain 9= unbearable pain	cw- mode	superpulsed
0	92,86%	100%
5	7,14%	0%

After 1 week all patients in both groups were free of pain, the only exception was the special patient of the cw- mode group.
For better understanding it has to be said that the mentioned patient was very algesic; a vestibuloplasty had been done and the extended denture was incorporated directly after laser treatment, so the healing was inhibited for a certain degree and the denture was grinding on the wound area all the time.

Analgesic drugs needed	cw- mode	superpulsed
No	57,14%	66,67%
Yes, 1 day	35,71%	25%
Yes, 3 days	0%	8,33%
Yes, 1 week	7,14%	0%

The need for analgesic drugs was higher in the cw- mode group, 42,85 %.
Need for medication in the superpulsed group: 33,33 % .
The above mentioned special patient needed a week of medication.

Reduced masticatory or lingually function.

Reduced function	cw- mode	superpulsed
No	0%	16,67%
1 day	28,57%	33,33%
3 days	57,14%	50%
1 week	7,14%	0%
more than 1 week	7,14%	0%

The influence of the laser treatment on functional aspects as e.g. mastication lasted in average 3 days.

In the cw- mode group even longer in 2 cases.

Only in the superpulsed group 16,67 % were without any functional limitations.

Difficulties in oral hygiene	cw- mode	superpulsed
No	0%	8,33%
1 day	35,71%	41,67%
3 days	57,14%	50%
1 week	0%	0%
more than 1 week	7,14%	0%

Nearly the same result for difficulties in oral hygiene.

Average was as well 3 days.

Even here there were patients without difficulties in the superpulsed group; 8,33 %.

6. Discussion

Classical surgical soft tissue treatment by scalpel has it`s relevancy, but in the last years soft tissue surgery by diode laser is in progress.

There are a lot of advantages for the surgeon:

- efficient and precise cutting with a calculated depth of cut
- good haemostasis- so nearly or completely without bleeding- and therefore better visibility of the place of interest.
-mostly no sutures needed
-only minimal destruction of the adjacent tissue (in pulsed mode)
-uncomplicated handling due to fiber and variety of parameters
-shorter treatment time.

The patients have a lot of advantages also:

-they mustn`t be sutured
-no or only little post op oedema
-bactericidal reduction of the wound area
-no secondary bleeding
-low level of scar forming
-patients with haemorrhagic diathesis can be treated without or with only little substitution
-shorter treatment time
-biostimulation of the surrounding area
-reduced application of drugs because of pain reduction intra- and post op (1,3-10,12,17,25-27,42,43,57,72,106,129,141,145,146,153).

The reduction of pain during laser treatment and the better acceptance of laser treatment in comparison to conventional treatment could be proofed yet for restorative dentistry (Matsumoto 1996, Keller- Hibst 1997-1998, Evans 2000, Takamori 2003) but in this cases the used lasers were not diode lasers.

Discussing the results from the study one certain thing has to be remembered.

The cw mode laser (Vision MDL- 10) had always been used with 2,5 W and cw- mode.

So peak- and average power had always be the same; in every procedure.
That`s the main difference to the superpulsed laser (Elexxion Claros) which had been used with different parameters ; 10- 50 W peak power; 2,25- 11,00 W average power ; 12000- 20000 Hz; 10- 20 µs pulse duration.

The precise treatment parameters of the Elexxion Claros laser were :

P_{peak}	P_{avg}	frequency	pulse duration
6x 50 W	3x 11,00 W	6x 20000 Hz	6x 10 µs
1x 25 W	3x 6,00 W	3x 15000 Hz	3x 11 µs
3x 15 W	1x 4,80 W	3x 12000 Hz	1x 16 µs
2x 10 W	2x 4,00 W		2x 20 µs
	1x 3,75 W		
	2x 2,25 W		
∅ 32,5 W	**∅ 6,00 W**	**∅ 16750 Hz**	**∅ 12,42 µs**

The used peak power was sometimes 20 times higher than the peak power of the cw mode laser; and even the average power was more than double (2,4 times higher). Regarding to this there was no doubt that the Elexxion laser would cut much easier and faster than the Vision laser. On the other hand the used powers were so high that normally a cw mode diode laser user would expect terrible thermal damage and necrosis of the tissue with a lot of carbonization (71,146,149,150,156). But thanks to the superpulsed mode of operation there was less carbonization and less damage of the adjacent tissue, which had been proven histologically in vitro by Bach et al. in 2008 (109). Bach used a cw mode diode laser, a pulsed mode diode laser and a superpulsed diode laser with P_{peak} 30 W; P_{avg} 9,99 W; 20000 Hz to make soft tissue cuts in pig jaws . Unfortunately he didn`t mention the pulse duration. Peak power was nearly the same as in this study, average power 1,67 times higher as in this study and the average frequency also higher. Still the results were much better for the superpulsed laser than for the cw- mode laser.

Maiorana and Salina (153) did a clinical study with a superpulsed laser on 3 patients in 2006. Parameters were: 23,33 W peak power in average; 16667 Hz in average; 10 μs pulse duration in average; P_{avg} not mentioned.
The conclusion was : clean cut without thermal side effect; instant coagulation; excellent post op conditions with minimal pain and swelling; minimal involvement of the adjacent tissues during surgery.

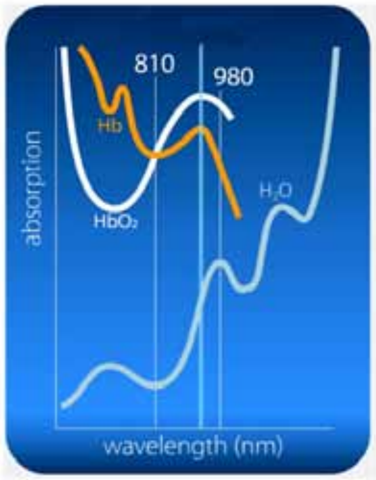
The parameters were similar to this study, only the peak power was significantly lower and the number of patients was only 3. But the summary of both studies correspond with the results achieved in this study.

The results out of this comparative in vivo study are sometimes not very different for the used lasers, but sometimes very significant, so in case of the

cutting speed :

The use of high powers, short pulse durations and high frequencies offered a high speed for cutting and a deeper cut as it did in cw-mode. The margins of the cut were more defined and more straight using superpulsed mode. This was already described several times in literature. (26,34,145). When using the superpulsed diode with high power and frequency for cutting the first time, the normal treatment behaviour had to change; the movement speed of the fiber had to be increased because of the rapid cutting velocity. When using the cw- diode laser the cut was flattish and the cutting speed was low. Certainly the low peak power of the Vision MDL- 10 was one great inhibition factor for speed. Another one may have been the wavelength of 980 nm. As known the cutting efficiancy of an 810 nm diode laser is better than it is with a 980 nm diode
(Gutknecht N; script M6- Master of Science in Lasers in Dentistry,ED2006; AALZ- Aachen; 02/2008).

The 810 nm diode has less penetration into the depth, a lower absorption in water, a lower absorption in HbO_2 and nearly the same absorption in Hb as a 980 nm diode. The 980 nm diode creates more thermal energy at the surface and penetrates more into depth. The zone of necrosis is larger and it is more dangerous for cutting.



(Pict. from Ezlase brochure; Biolase Technologie Inc. 2007)

Surprisingly Bach et al. (109) could prove 2008 in in vitro studies, that there was no difference from the histological point of view between 810 nm and 980 nm diode lasers, when both are used in the same mode of operation.

If we assume that Bach`s results were correct and we neglect the difference between in vitro and in vivo studies, we can conclude together with the attained results from this study that superpulsed mode of operation will lead to faster cutting speed and a more precise cut with less tissue damage.

There are a lot more parameters apart from the wavelength, power, frequency, pulse duration, fiber diameter and mode of operation that will influence the cutting ability, so as e.g. : kind of tissue, pigmentation, race, blood circulation in tissue, applied dose, treatment time etc. but these parameters are of subsidiary relevance in this study.

The above shown reference cases are done with patients of the same race and same gender. The soft tissue region was the same, both patients with similar pigmentation. The treated sites were mirror- inverted at the inner lip of the lower jaw.

Carbonization :

Next point to view is the carbonization of the tissue. If there is a lot of carbonization the destruction of the surrounding tissue is large (37,45,71,109).
Carbonization is changing the absorption of the treated tissue; it is increasing due to the dark color which absorbs the diode laser light much better than light colors do.
This means there is more thermal energy applied in the surface and necrosis of the adjacent structures is created.
As we can see from the study the changing of parameters could influence the degree of carbonization and coagulation; which had already been described in literature(145).
In 1999 Goharkhay et al.(7) stated that the horizontal and vertikal dimension of the tissue destruction is neither addicted to the diameter of the fiber, nor related to the mode of operation (cw or pulsed) but is only depending on the average power used.
Both assumptions could be rebut until today. Using the same power settings the dose applied in a defined treatment time is lower with a larger fiber diameter. In using smaller fiber diameters the applied energy is distributed in a smaller area, the dose is higher, the effect is larger, there is more thermal energy brought into the tissue.
The risk of carbonization is increasing.
So the tissue destruction is certainly related to the diameter of the fiber.

The used average power in case of the Vision MDL-10 laser was 2,5 W; in case of the Elexxion Claros 6,0 W.
According to Goharkhay the tissue damage must be larger when using the Elexxion Claros

because of the higher average power, but it was just the opposite, because the mode of operation was changed.

Also in literature a much smaller degree of carbonization and destruction is described when using pulsed instead of cw- mode (24,26,34,35,41,61,62,109,145,153).
This can be consolidated by the results achieved here.
The cw- mode laser produced carbonization in every treatment case, 100 % .
The superpulsed diode laser only in 66,66 % of the cases.
No patient with heavy carbonization in the superpulsed group.
In the cw- mode group, 35,71 % had severe carbonization,
The total amount of carbonization was much higher in the cw- mode group.

Maybe carbonization could have been less in the superpulsed group regarding to the treatment practice, because the fiber had to be moved much faster as in cw- mode and the surgeon had to adapt to the new procedure technique.

The fiber diameter is another factor for the applied dose and perhaps the carbonization could have been decreased by using a larger fiber; but for better comparison both lasers were used with 400 μm fibers. All other parameters which could influence the degree of carbonization, such as peak power, average power, frequency, pulse duration etc. were accepted in the way the manufacturers had programmed the diode laser units.
Exception was, as just said, only the fiber diameter of 400 μm which was prescribed by the manufacturer of Vision MDL-10 diode laser for surgery. In case of the Elexxion Claros the prescribed fiber diameters should have been changed from 200 to 400 or 600 μm according to the planned surgical treatment.

Coagulation :

Next aspect to discuss is the coagulation ability of both modes of operation.
In literature the coagulation efficiancy is described as good (17,30,42,67,68,131,145) to very good (7,37,51,72,142) for cw- mode.

For superpulsed mode the coagulation mentioned is very good (17,35,143) and good with minimal bleeding (34).

Geldi C et al. (35) described 2006 in a study, that superpulsed diode lasers have a larger coagulation area but smaller carbonization area as cw- mode diode lasers.
In this study the gained results from the surgeons questionnaire demonstrated in direct comparison that coagulation was stronger by using cw- mode.
During treatment the coagulation was very good in 42,86 % of the treated patients and good in 57,14 %. For superpulsed there was no very good coagulation, but 83,33 % good and 16,67 % little coagulation which meant that a few patients had a minimal bleeding.
In cw- mode there was none.
In literature often no bleeding after surgical treatment is mentioned (17,26,29-31,37,72) but in this study there was an oozing bleeding in 21,43 % of the cw- group patients after surgery and also in 41,67 % of the superpulsed group after finishing the surgical treatment , which is a significant difference.
This might have been a derivation of the higher thermal damage of the cw- mode laser.
The blood vessels were sealed better by the influence of the larger amount of thermal energy delivered by the cw- mode of operation.
Therefore a patient with anticoagulant therapy (Quick 20 %; INR > 2,5) was treated with the cw- mode diode laser without any substitution; and there was no bleeding at all.
Mentionable in comparison to other studies is that 7 of 26 patients have been treated with a simple diode laser cut for a following osteotomy.
These patients were sutured after osteotomy and therefore a minimal oozing bleeding occured. This has to be kept in mind for better understanding of the given results.

Swelling :

Swelling of the wound area and adjacent tissue 1 day after surgery was significantly less in the superpulsed group, 41,67 % with no swelling.
Only 28,57 % with no swelling in the cw- group.
The size of swelling didn`t differ much in both groups.

3 days after treatment there were :
Already 91,67 % of the patients free of swelling in the superpulsed group.
Only 57,14 % of the cw-mode group; which is a significant difference.
The reason for this could be the degree of tissue damage caused by laser irradiaton. Regarding to the lower degree of carbonization and thermal damage in the superpulsed group it was explainable that there was less swelling.

The literature review showed different kinds of results which varied from no swelling (17,72) to little swelling (26,37,41,46,142,145,153) for both kinds of lasers.

Swelling is a result of the inflammation reaction of the body and, often described in literature, the inflammation reaction is more serious using diode laser surgery than it is by using a traditional scalpel (26,31,32).

Pain :

A second characteristic sign for inflammation is pain.
During and directly after laser treatment there was no pain because all patients had been given local anesthesia before surgery. Surgical treatment with a diode laser always requires anesthesia, because the thermal energy applied always generates pain.
In literature classifications as mild pain (37), less pain (26,34,145), reduced pain (30,41,46,72,142,145), minimal pain (153) and no pain (17) are found and all authors agree that the degree of pain is reduced after laser treatment in comparison to classical treatment by scalpel.
Looking to the results of the questionnaire a recognizable larger percentage of patients had no pain 1 day post op in the superpulsed group: 41,67 % .
Only 21,43 % in the cw group had no pain.
Nearly double of the patients in the superpulsed group were painfree.
The remaining 58,33 % of the superpulsed group only had pain on the 1^{st} - 3^{rd} niveau.
In the cw group 78,57 % of the patients were also on the 1^{st} - 3 rd niveau.
Only 1 patient (the very algesic one, as described above) was on the 7^{th} niveau of pain.

After 3 days the situation was completely different.
Now more patients without pain could be found in the cw group, 71,43 %,
while only 66,67 % of the superpulsed group were painfree.
But the difference of the percentages was not as significant as it was after the first day.
The rest of the patients could be found on pain niveau 1 in both groups, exception, of course, the very algesic patient, still on pain niveau 7.

Saaleh et al. (37) noticed an average of 3 days of pain for all patients in their study after cw- mode treatment.

1 week after surgical laser treatment no patient felt pain any longer
(exception: the very algesic patient on niveau 5).

Need for drugs :

After laser treatment the patients had been supplied by an analgesic drug,
Ibuprofen 400 mg.
42,85 % of the patients in the cw group needed medication, but
only 33,33 % of the patients in the superpulsed group.
With a high percentage only 1 day.
That corresponded to the findings for pain that have been done before.

In general we can say that the pain sensation was less in the superpulsed group.

These results and the following conclusions for reduced masticatory and lingually function so as the difficulties in oral hygiene were subjective and will differ by treating other patients because the degree of sensation is very different from person to person.
There will be no reproducable results but only a hint to the right direction.

Reduced masticatory and lingually function :

In order to the traumata set during laser treatment there was a functional reduction for masticatory and/ or lingually function in both groups.
In the cw group every patient was affected.
In the superpulsed group at least 16,67 % of the patients had no functional limitations.
50- 57,14 % of the patients were handicapped for 3 days in both groups.
That corresponded once again to the study of Saaleh et al. (37), who described a 3 day period of painful mastication and speech after cw- mode treatment.

Difficulties in oral hygiene :

Nearly the same results for oral hygiene.
In average 3 days of limitation, but this time
only 8,33 % of the patients in the superpulsed group without any difficulties.
In the cw group all patients with difficulties.

Now three of the five signs for inflammation were reviewed. (dolor, tumor, functio laesa)
2 others, calor and rubor were not registered during the study.
But a sign of healing, better secondary healing, should be discussed subsequently.

The **Fibrine layer :**

The building of fibrine is a part of the secondary haemostasis, a part of the plasmatic haemostasis. The thrombocytes were connected by a dense network of fibrinous fibers.
The grade of fibrine layer relies in a certain extent to the grade of healing.
The faster the fibrine layer is removed, the faster the wound healing is in progress.
2- 4 hours after trauma the extravasation starts , a coagulum is build
with blood- and plasmacells on the wound surface. Fibrin fibers are connecting the thrombocytes and build a dense network of fibers. This normally lasts to the 4th day .
Then proliferation starts, granulated tissue is build and the fibrin fibers are reduced.

From the 5th day on regeneration starts and there is no more fibrine layer.
The faster the fibrine layer is removed, the faster the wound healing is in progress.

The observed results regarding the fibrin layer differed from the normally seen wound healing after classical treatment by scalpel.

In this study 26 patients were treated, but 7 of them only by simple laser cut for osteotomy. The cut was sutured afterwards, so there was primary wound healing and no visible fibrine layer could be seen.
The first day no fibrine layer was seen on the wounds in 28,57 % of the cw group and only 16,67 % of the superpulsed group.
A small region was covered in 50 % of the superpulsed, but only in 35,71 % of the cw group.
Mostly covered wounds were noticed in 33,33 % (superpulsed) and 35,71 % (cw) in both groups.
This meant that in the superpulsed group already 83,33 % of the wounds had a fractional fibrine layer. In the cw group only 71,42 % of the wounds were partially covered with fibrine.
After 3 days all wounds; 100 % were covered with fibrine in the superpulsed group: 41,67 % were mostly covered; 33,33 % partially and 25 % completely.
In the cw group already 42,86 % were completely covered; 21,43 % mostly; 21,43 % partially, but still 14,29 % were not covered yet.
So far fibrine layer building was faster and more complete in the superpulsed group.

In comparison to healing after conventional surgical treatment there was a delay of healing time, because fibrine layer building started later and needed more time to cover the wounds. In consequence of delayed wound healing there was still a fibrine layer seen after 1 week in 33,33 % of the superpulsed group and in 42,86 % of the cw group.
Delayed wound healing after surgical diode laser treatment has been described in literature already (26,31,32) and as we could see from the results above the wound healing of the cw group started later and lasted even longer as the prolonged wound

healing of the superpulsed group.
This might have been an effect of the stronger thermal damage and increased carbonization in the cw group. The cells and blood vessels in the adjacent tissue were much more damaged and needed longer to reorganize for healing.
Superpulsed treatment left more intact tissue at the wound margins, so healing could begin earlier as in cw mode.
Even if there was an improvement in healing time there was still a difference to normal healing, where fibrine layer removal begins already at the end of the 4th day.
So the intactness of the tissue seemed to be essential for regular wound healing.
Superpulsed diode laser treatment did not cause much carbonization, but there was as well coagulation, which meant applied thermal energy on the blood vessels and cells; causing damage and therefore delayed healing.

As option for surgical laser treatment an Er:YAG laser with waterspray and air can be used instead. The Er:YAG laser also generates a soft tissue cut, but with a resulting bleeding. There will be no carbonization and nearly no coagulation, therefore no or only minimal damage of the tissue and as effect a much quicker and nicer wound healing and less discomfort for the patient as after diode laser treatment.

In summary we can say that superpulsed diode laser treatment is contrary to cw- mode diode laser treatment much more gentle for the tissue (less damage, quicker healing), more comfortable for the patient (less pain and swelling) and an improvement for the surgeon (more precise and deeper cut, less burnt smell, shorter treatment time).
Only the coagulation ability of the superpulsed diode laser seems to be minimal inferior of the cw- mode diode laser.
In combination with the findings of the Bach study (109) and the case reports of Maiorana and Salina (153) we can conclude that superpulsed diode lasers should be the state- of-art treatment nowadays if there is spoken about surgical diode laser treatment.

Of course these are only 2 further studies and the results have to be reconfirmed by various studies with a larger amount of patients, but the direction to go is clearly given.

7. Conclusion

Clinical in vitro and in vivo studies have shown that soft tissue surgery done by superpulsed diode lasers is more reasonable as doing the same procedures by cw- mode diode lasers. Carbonization and thermal damage of the adjacent tissue can be reduced to a minimum, the soft tissue cut can be generated faster, the cut is more precise.
Because of the lower amount of tissue destruction the healing is faster as in cw- mode.
It is more comfortable for the patients regarding to the post op pain and swelling, the patients will need less drugs and the functional abilities are not reduced as much as in continuous wave mode.

In terms of Bach`s histological investigation of the treated soft tissue (109) we probably have to share his opinion, that cw- mode diode lasers are no longer suitable for soft tissue cutting in dentistry.

The advantages of the superpulsed diode lasers in soft tissue surgery are evident and with the meanwhile achieved peak powers, the very short pulse durations and the high frequency the surgical treatment can be improved and probably the range of treatment can be expanded.

8. Literature

001. Gouw- Soares S, Tanji E, Haypek P, Cardoso W, Eduardo CP: The use of Er:YAG, Nd:YAG, and Ga-Al-As-Lasers in Periapical Surgery: a three year clinical study. J Clin Lasers Med Surg 19(4): 193-198,2001

002. Schoop U, Kluger W, Moritz A, Sperr W: The bactericidal Effect of Different Laser Systems in Deep Dentin Layers. Laser Congress, Florence 2003

003. Wigdor HA, Walsh JT, Featherstone JDB, Visuri SR, Fried D, Waldvogel JL: Lasers in Dentistry. Laser Surg Med 16: 103-133, 1995

004. Pick RM, Colvard MD: Current status of Lasers in soft tissue dental surgery. J Periodontol 64(7): 589-602, 1993

005. Horch HH: Laser in der oralen Chirurgie. Vortrag beim 11. Internationalen Jahreskongress der DGL. Berlin 2002

006. Luomanen M, Virtanen I: Healing of laser and scalpel incision wounds of rat tongue mucosa as studied with cytoceratin antibodies. J Oral Pathol 16: 139-144, 1987

007. Goharkhay K et al.: Effects on oral soft tissue produced by a Diode laser in vitro. Laser Surg Med 25: 401-406, 1999

008. Goharkhay K, Moritz A, Schoop U, Pattera C, Rumetzhofer A, Wernisch J, Sperr W: Auswirkung unterschiedlicher Laserwellenlängen auf die orale Schleimhaut- eine inVitro Studie. Stomatol 97: 173-179, 2000

009. Stock K, Hibst R: Comparative in vitro study of Diode Laser (940 nm) and Nd:YAG laser for oral surgery. Lecture Laser Congress, Florence 2003

010. Rosenberg C, Tadir Y et al.: Endometrial laser ablation in rabbits : a comperative study on three laser types. Laser Surg Med 10: 66-73, 1990

011. Romanos G et al.: Laseranwendung in der Parodontologie- aktueller Stand. Parodontologie 4: 299-312, 1998

012. Gaspar L : The use of high power lasers in oral surgery. J Clin Laser Med Surg 12(5): 281-285, 1994

013. Moritz A, Gutknecht N, Dörtbudak O, Schoop U, Schauer P, Sperr W: Bacterial reduction in periodontal pockets through irradiation with a Diode laser: a pilot study. J Clin Laser Med Surg 15(1): 33-37, 1997

014. Moritz A, Gutknecht N, Goharkhay K, Schoop U, Sperr W: In-vitro Irradiation of infected Root Canals with a Diode Laser: Results of Microbiologic, Infrared Spectrometric and Stain Penetration Examination.
Quintessence Int 28(3): 205-209, 1997

015. Gutknecht N, Moritz A, Conrads G, Lampert F: The Diode Laser and its bactericidal effect in root canals: an in vitro study.
Endodontie 3: 217-222, 1997

016. Hartmann HJ, Bach G: Diodenlaser- Oberflächen- Dekontamination in der Periimplantitistherapie. Eine Drei- Jahres- Studie. ZWR 106: 524-526, 1997

017. Romanos G, Nentwig GH: Diode Laser (980 nm) in oral and maxillofacial surgical procedures: observations based on clinical applications.
J Clin Laser Med Surg 17(5): 193-197, 1999

018. Romanos GE: Treatment of periimplant lesions using different laser systems.
J Oral Laser Appl 2: 75-81, 2002

019. Romanos GE, Everts H, Nentwig GH: Effects of the diode (980 nm) and Nd:YAG (1064 nm) laser irradiation on titanium discs. A SEM examination.
J Periodontol 71: 810-815, 2000

020. Salina S, Beretta M, Speroni S, Maiorana C: Treatment of peri- implantitis with Diode Laser and GBR: preliminary results.lecturs.
Laser Congress, Florence 2003

021. McDavid VG, Cobb CM, Rapley JW, Glaros AG, Spencer P: Change in temperature of subjacent bone during soft tissue laser ablation.
J Periodontol 69: 1278-1282, 1998

022. Soibelmann M: Verwendung dentaler Lasersysteme in der zahnärztlichen Praxis.
Laser Journal (4): 30-33, 2007

023. Moritz A, Gutknecht N, et al.: Keimreduzierung in Zahnfleischtaschen durch Bestrahlung mit einem Diodenlaser. J Clin Laser Med Surg 15(1): 33-37, 1997

024. Neckel C: Eine klinische und histologische Untersuchung zum Thema CW-Mode oder 10.000- Hertz- topgepulster Ga-Al-As- Diodenlaser. DZW 9, 2001
025. Bach G, Gutknecht N, Schneider H: Lasertherapie in der Zahnheilkunde. Diodenlaser in der Praxis. Apollonia Verlag, Linnich, 1998
026. Moritz A, et al.: Orale Lasertherapie. Quintessence Verlag, Berlin 2006
027. Frentzen M, Koort HJ: Lasertechnik in der Zahnheilkunde Dtsch Zahnärztl Z 1991(46): 443-454
028. Gutknecht N, Franzen R, Schippers M, Lampert F: Bactericidal effect of a 980-nm diode- laser in the root canal wall dentin bovine teeth J Clin Laser Med Surg 2004(22): 9-13
029. Kreisler M, Kohnen W, Beck M, Al Haj H, Christoffers AB, Gotz H, Duschner H, Jansen B, D'Hoedt B. Efficacy of NaOCl/H2O2 irrigation and GaAlAs laser in decontamination of root canals in vitro. Laser Surg Med 2003: 32(3): 189-196
030. Capodiferro S, Maiorano E, Loiudice AM, Scarpelli F, Favia G: Oral laser surgical pathology: a preliminary study on the clinical advantages of diode laser and on the histopathological features of specimens evaluated by conventional and confocal laser scanning microscopy. Minerva Stomatol 2008(1-2),57: 1-7
031. D'Arcangelo C, Di Nardo Di Maio F, Prosperi GD, Conte E, Baldi M, Caputi S: A preliminary study of healing of diode laser versus scalpel incisions in rat oral tissue: a comparison of clinical, histological, and immunohistochemical results. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007 Jun;103(6):764-73. Epub 2006 Nov
032. Taylor DL, Schafer SA, Nordquist R, Payton ME, Dickey DT, Bartels KE: Comparison of a high power diode laser with the Nd:YAG laser using in situ wound strength analysis of healing cutaneous incisions. Lasers Surg Med 1997,21(3): 248-254
33. Grigorian AS, Grigoriants LA, Kasparov AS: Experimental- morphological study of the effects of diode laser scalpel with different irradiation parameters (wave length 0.97 mm) on oral mucosa. Stomatologiia(Mosk) 2006,85(1): 8-13

034. Stübinger S, Saldamli B, Jürgens P, Ghazal G, Zeilhofer HF: Soft tissue surgery with the diode laser- theoretical and clinical aspects. Schweiz Monatsschr Zahnmed 2006, 116(8): 812-820

035. Geldi C, Bozkulak O, Tabakoglu HO, Isci S, Kurt A, Gulsoy M: Development of a surgical diode- laser system: controlling the mode of operation. Photomed Laser Surg 2006,Dec.,24(6): 723-729

036. Gulsoy M, Dereli Z, Tabakoglu HO, Bozkulak O: Closure of skin incisions by 980 nm diode laser welding. Lasers Med Sci 2006, Apr,21(1): 5-10.Epub 2006 Mar 17

037. Saleh HM, Saafan AM: Excision biopsy of tongue lesions by diode laser. Photomed Laser Surg 2007 Feb, 25(1): 45-49

038. Magid KS, Strauss RA: Laser use for esthetic soft tissue modification. Dent Clin North Am 2007, Apr, 51(2): 525-545

039. Sano F: Present status and future prospects of laser surgery—advantages of the laser scalpel. Nippon Rinsho 1987, Apr, 45(4): 710-715. PMID : 3302355

040. Barr RE : Laser periodontal treatment and surgical procedures : part1 Pract Proced Aesthet Dent 2004, Nov-Dec,16(10): 747-748. PMID: 15739915

041. Sarver DM: Use of the 810 nm diode laser: soft tissue management and orthodontic applications of innovative technology. Pract Proced Aesthet Dent 2006, Oct, 18(9): suppl 7-13. PMID: 17139948

042. Walinski CJ: Irritation fibroma removal: a comparison of two laser wavelengths. Gen Dent 2004, May-Jun, 52(3): 236-238. PMID: 15206255

043. Tamarit- Borras M, Delgado- Molina E, Berini- Aytes L, Gay- Escoda C: Removal of hyperplastic lesions of the oral cavity. A retrospective study of 128 cases. Med Oral Patol Oral Cir Bucal 2005, Mar-Apr, 10(2): 151-162.

044. Kravitz ND, Kusnoto B: Soft- tissue lasers in orthodontics: an overview. Am J Orthod Dentofacial Orthop 2008, Apr, 133(4 Suppl): 110-114

045. Janda P, Sroka R, Mundweil B, Betz CS, Baumgartner R, Leunig A: Comparison of thermal tissue effects induced by contact application of fiber guided laser systems. Lasers Surg Med 2003, 33(2): 93-101

046. Fornaini C, Rocca JP, Bertrand MF, Merigo E, Nammour S, Vescovi P: Nd:YAG and diode laser in the surgical management of soft tissue related to orthodontic treatment. Photomed Laser Surg 2007, Oct, 25(5): 381-392

047. Deppe H, Horch HH: Laser applications in oral surgery and implant dentistry. Lasers Med Sci 2007, Nov, 22(4): 217-221. Epub 2007 Feb 1

048. Lee EA: Laser assisted gingival tissue procedures in esthetic dentistry. Pract Proced Aesthet Dent 2006, Oct, 18(9): suppl 2-6

049. Yeh S, Jain K, Andreana S: Using a diode laser to uncover dental implants in second-stage surgery. Gen Dent 2005, Nov- Dec, 53(6): 414-417

050. Romanos GE, Henze M, Banihashemi S, Parsanejad HR, Winckler J, Nentwig GH: Removal of epithelium in periodontal pockets following diode (980 nm) laser application in the animal model: an in vitro study. Photomed Laser Surg 2004, Jun, 22(3): 177-183

051. Judy MM, Matthews JL, Aronoff BL, Hults DF: Soft tissue studies with 805 nm diode laser radiation: thermal effects with contact tips and comparison with effects of 1064 nm Nd:YAG laser radiation. Lasers Surg Med 1993, 13(5): 528-536

052. Niemz MH: Laser- Tissue Interactions. Springer Verlag Berlin, Heidelberg, N.Y. 1996

053. Berlien HP, Müller G: Angewandte Lasermedizin. Bd 1. Ecomed Verlagsges. Landsberg , 1999

054. Berlien HP, Müller G: Angewandte Lasermedizin. Bd 2. Ecomed Verlagsges. Landsberg , 1999

055. Müller GJ, Ertl T: Angewandte Laser- Zahnheilkunde Ecomed Verlagsges. Landsberg/ Lech 1995

056. Vahl J, Van Benthem H: Laser in der Zahnmedizin. Quintessenz Verlag Berlin 1992

057. Gutknecht N: Lasertherapie in der zahnärztlichen Praxis. Quintessenz Verlag Berlin, Chicago, London 1999.

058. Miserendino LJ, Pick RM: Lasers in Dentistry. Quintessenz Verlag Berlin, Chicago 1995.

059. Widgor HA, Walsh Jr JT, Featherstone JDB, Visuri SR, Fried D, Waldvogel JL: Lasers in Dentistry. Laser Surg Med Vol 16, 103-133, 1995.

060. Hopp M, Schlar N: Laser in der täglichen Anwendung. Teil 2: Fasergestütze Laser Zahn Prax 6: 90-104, 2003

061. Hopp M, Schlar N, Perez-Canto A, Biffar R: Entfernung dystopischen Zungengewebes mittels Diodenlaser (980 nm) aus der Retromolarregion. Z Laserzahnheilkunde 3, 185-189, 2004

062. Hopp M, Bogusch G, Biffar R: Speicheldrüsenexstirpation aus der Unterlippe mittels Diodenlaser (980 nm). Z Laserzahnheilkunde 2, 99-104, 2004

063. Knappe V: Diode Lasers in Berlien H P, Müller G: Applied Laser Medicine. 1. Auflage, Springer Verlag, Berlin, New York, 61-71, 2003

064. Adams TC, Pang PK: Lasers in aesthetic dentistry. Dent Clin North Am 48: 833-860, 2004

065. Coluzzi DJ: Fundamentals of dental lasers: science and instruments. Dent Clin North Am, 48,: 751-770, 2004

066. Jesse K: Laser- Grundlagen und moderne Trends. 1. Auflage VDE Verlag, Berlin- Offenbach, pp 35-54, 1999

067. Meister J, Franzen R, Apel C: Grundlagen der Laserzahnheilkunde, Teil 1: Das Licht. Z Laserzahnheilkunde 1, 57-61, 2004a

068. Meister J, Franzen R, Apel C: Grundlagen der Laserzahnheilkunde, Teil 3: Die Licht- Gewebe-Wechselwirkung. Z Laserzahnheilkunde 3, 199-204, 2004b

069. Niemz MH: Laser- Tissue interactions- Fundamentals and applications. 3.Auflage, Springer Verlag, Berlin- New York, pp 45-149, 2003

070. Walsh LJ: The current status of laser applications in dentistry. Aust Dent J, 48, 146-155, 2003

071. Welch AJ: The thermal response of laser irradiated tissue. IEEE J Quant Electron 20, 1471-1481, 1984

072. Gutknecht N, et al.: Proceedings of the 1st International Workshop of Evidence Based Dentistry on Lasers in Dentistry. Quintessence Publishing Co.Ltd., 2007

073. Duck FA: Physical properties of tissue. Academic Press London- Toronto, 1990

074. Ishii J, Fujita K, Komori T: Laser surgery as a treatment for oral leukoplakia. Oral Oncol 39(8): 759-769, 2003

075. Katzir A: Lasers and optical fibers in medicine.
Academic Press, Inc, San Diego- Boston, 1993

076. Nathan MI, Dumke WP, Burns G, Dill Jr FH, Lasher G: Stimulated emission of radiation from GaAs p-n junctions. Appl Phys Lett 1(3): 62-64, 1962

077. Prahl SA: Optical absorption of hemoglobin.
Oregon Medical Laser Center: http://omlc.ogi.edu/spectra/hemoglobin/index.html

078. Strassl M, Kassenbacher A, Wintner E: Ultrashort laser pulses in dentistry.
J Oral Laser Appl 2(4): 213-222, 2002

079. Stabholz A, Zeltzser R, Sela M, Peretz B, Moshonov J, Ziskind D: The use of lasers in dentistry: principles of operation and clinical applications.
Compend 24: 811-824, 2003

080. Kreisler M, Daublander M, Willershausen-Zonnchen B, d`Hoedt B: Effect of diode laser irradiation on the survival rateof gingival fibroblast cell cultures.
Laser Surg Med 28(5): 445-450, 2001a

081. Rastegar S, Jacques SL, Motamedi M, Kim BM: Theoretical analysis of equivalency of high- power diode laser and Nd:YAG laser for coagulation.
Lasers in Dentistry, SPIE 1646: 150-160, 1992

082. Theodoro LH, Haypek P, Bachmann L, Garcia VG, Sampaio JE, Zezell DM, Eduardo C de P: Effect of Er:YAG and diode laser irradiation on the root surface: morphological and thermal analysis. J Periodontol 74(6): 838-843, 2003

083. White JM, Gekelman D, Shin K, Park X, Swenson T, Rouse B, Tran K, Bullard S, Scott- Beckles B, Oto MJSB, Yamamoto A: Laser interaction with dental soft tissues: What do we know from our years of applied Scientific research?
Lasers in Dentistry, SPIE 4610: 39-48, 2002

084. Adams TC, Pang PK: Lasers in Aesthetic Dentistry.
Dent Clin North Am 48: 833-860, 2004

085. Bach G, Neckel C, Mall C, Krekeler G: Conventional versus laser- assisted therapy of periimplantitis: a five year comparative study.
Implant Dent 9: 247-251, 2000

086. Clayman L, Kuo PC: Soft tissue excision techniques. In Clayman L, Kuo P : Lasers in Maxillofacial Surgery and Dentistry. Thieme Publ., Stuttgart:63-83, 1997

087. Convissar RA, Diamond LB, Fazekas CD: Laser treatment of orthodontically induced gingival hyperplasia. Gen Dent 44(1): 47-51, 1996
088. Goharkay K, Moritz A, Wilder –Smith P, Schoop U, Kluger W, Jakolitsch S, Sperr W: Effects on oral soft tissue produced by a diode laser in vitro. J Oral Surg 36: 932-937, 1978
089. Olbricht SM, Stern RS, Tang SV, Noe JM, Arndt KA : Complications of cutaneus laser surgery. A survey. Arch Dermatol 123(3): 345-349, 1987
090. Pinheiro AL, Limeira Jr FA, Gerbi MEM, Ramalho LMP: Effect of 830 nm Laser Light on the Repair of Bone Defects Grafted with Inorganic Bovine Bone and Decalcified Cortical Osseous Membrane. J Clin Laser Med Surg 21(6): 383-388, 2003
091. Romanos GE: Atlas der chirurgischen Laserzahnheilkunde. Urban und Fischer Verlag , München, 1999
092. Romanos GE, Nentwig GH: Present and future of lasers in oral soft tissue surgery: clinical applications. J Clin Laser Med Surg 14(4): 179-184, 1996
093. Strauss RA: Laser management of discrete lesions. In : Laser applications in Oral Maxillofacial Surgery. Eds. Catone G A, Alling C C, Saunders, Philadelphia, 1997
094. White JM, Goodis HE, Horton J, Gold S: Current status of lasers in soft tissue dental surgery. J Periodontol 65(7): 733-735, 1994
095. Yousuf A, Hossain M, Nakamura Y, Yamada Y, Kinoshita J, Matsumoto K: l Remova of gingival melanin pigmentation with the semiconductor diode laser :. a case report. J Clin Laser Med Surg 18: 263-266, 2000
096. Zeinoun T, Nammour S, Dourov N, Aftimos G, Luomanen M: Myofibroblasts in healing laser excision wounds. Lasers Surg Med 28: 74-79, 2001
097. Al-Watban FA, Zhang XY: The comparison of effects between pulsed and CW lasers on wound healing. J Clin Laser Med Surg 22(1): 15-18, 2004
098. Gutknecht N, Gogswaardt D, Conrads G, Apel C, Schubert C, Lampert F: Diode laser radiation and its bactericidal effect in root canal wall dentin. J Clin Las Med Surg 57: 57-60, 2000

099. Parkins F: Lasers in pediatric and adolescent dentistry. Dent Clin N Amer 44: 821-830, 2000

100. Santaella MR, Braun A, Matson E, Frentzen M: Effect of diode laser and fluoride varnish on initial surface demineralisation of primary dentition enamel : an in vitro study. Int J Paed Dent 14: 199-203, 2004

101. Tuner J, Hode L: The laser therapy handbook. Grängesberg, 231, 2004

102. Gherlone EF, Maiorana C, Grassi RF, Ciancaglini R, Cattoni F: The use of 980 nm diode and 1064 nm Nd:YAG laser for gingival retraction in fixed prostheses. J Oral Laser Applications 4: 183-190, 2004

103. Glauche CE, de Freitas PM, Vieira ND, Marques JL: Qualitative microanalysis of ions and ultrastructuralchanges in dentin exposed to laser irradiation. Lasers Surg Med 36(4): 334-339, 2005

104. Gutknecht N, Zimmermann R, Lampert F: Lasers in periodontology: state of the art. J Oral Laser Applications 1: 169-179, 2001a

105. Kreisler M, Haj HA, d`Hoedt B: Clinical efficacy of semiconductor laser application as an adjunct to conventional scaling and root planning. Lasers Surg Med 37: 350-355, 2005

106. Mester E, Spiry T, Szende B, Tota JG: Effect of laser rays on wound healing. Am J Surg 22: 532-535, 1971

107. Patruta S, Franz A, Beer F, Goharkhay K, Sperr W, Moritz A: In vitro stimulatory effect of diode laser on the secretion of tissue inhibitor of matrix mealloproteinases 1(TIMP-1) in human gingival fibroblast: A preliminary report. J Oral Laser Applications 4(3): 167-170, 2004

108. Silveira LB, Silveira JB, Ribeiro MS, Garrocho AA, Novelli MD, Marigo H, Growth EB, et al.: In vivo study on mast cells behavior following low intensity visible and near infrared laser radiation (abstract 304).Lasers Surg Med, 82, 2002

109. Bach G, Koch HK, Hellerich U, Venzke T: Konventionelle Diodenlaser versus Hochpulstechnik. Laser Journal 1/2008: 18-20

110. Deppe H, Horch HH: Laseranwendungen in der chirurgischen Zahn-,Mund- und Kieferheilkunde. Laser Zahnheilkunde 2007(4): 219-222, 2007

111. Horch HH, Deppe H: Laser anwendungen im Mund-Kiefer-Gesichtsbereich. In Horch HH: Mund-Kiefer-Gesichtschirurgie. München: Elsevier, 2007: 797-820
112. Roodenburg JL, Witjes MJ, deVeld DC; Tan IB, Nauta JM: Lasers in dentistry.8. Use of lasers in oral and maxillofacial surgery. Ned Tijdschr Tandheelkd 2002: 109:470
113. Maiorana C, Salina S: Oral soft tissue pathologies: long term evaluation after laser treatment. J Oral Laser Appl 2001(1):20
114. Crippa R: Report on 103 cases of precancerous and other oral lesions treated with a diode laser. J Oral Laser Appl 2001(1): 26
115. Bach G: Er:YAG versus Diode- Zwei Wellenlängen"made in Baden-Württemberg". Laser Zahnheilkunde 2007(4): 283-287
116. Andersen K: Laser technology- a surgical tool of the past, present and future. Aorn J 78: 794-802, 2003
117. Eichler J, Schneeweiss- Wolter C: Wirkung von Laserstrahlung auf Gewebe. MTA 14: 255, 1999
118. McKenzie AL: Physics of thermal processes in laser- tissue interaction. Phys Med Biol 35: 1175-1209, 1990
119. Sullins KE: Diode laser and endoscopic laser surgery. Vet Clin North Am Small Anim Pract. 32: 639-648, 2002
120. Svaasand LO, Boerslid T, Oeveraasen M: Thermal and optical properties of living tissue: application to laser-induced hyperthermia. Lasers Surg Med 5: 589-602, 1985
121. Welch AJ, Motamedi M, Rastegar S, LeCarpentier GL, Jansen D: Laser thermal ablation. Photochem. Photobiol. 53: 815-823, 1991
122. Lippert BM, et al. : Wound healing after laser treatment of oral and oropharyngeal cancer. Lasers Med Sci. 18(1): 36-42, 2003
123. Grossenbacher R: Laser surgery in the oral cavity. J Clin Laser Med Surg 10(1): 19-21, 1992
124. Guttenberg SA, Emery RW: Laser resurfacing and oral and maxillofacial. surgeons. Dermatol. Surg. 25(6): 519, 1999

125. Coleton S: Laser treatment of atypical oral pigmentation. A case report. N Y State Dent J. 72(2): 22-23, 2006
126. Damante CA, et al : Histomorphometric study of the healing of human oral mucosa after gingivoplasty and low-level laser therapy. Lasers Surg Med.35(5): 377-384, 2004
127. Eichler J, Eichler HJ: Laser. Springer Verlag, Berlin- Heidelberg- New York, 1991
128. Manni J: Surgical diode lasers. J Clin Laser Med Surg 10: 377-380, 1992
129. Pick RM, Powel GL: Lasers in dentistry, soft tissueprocedures. Dent Clin North Am 37: 281-297, 1993
130. Scherer H, Fuhere A, Hopf J: Current status of laser surgery of benign deseases in the area of soft palate. Laryngol Rhinol Otol 73: 14-18, 1994
131. Morita T, Okamura Y, Ookub K, et al. : A new instrument for hemostatic vascular management in endoscopic surgery: diode laser(STATLaser- SDL) and it`s hand piece. (Dual Hook). J Clin Laser Med Surg 17: 57-61, 1999
132. Claus PN: Comparative study on CW- mode versus pulsed mode in AlGaAs Diode lasers. SPIE Proc 4249: 44-49, 2001
133. Krause F, Frentzen M: Dioden- Laser in der zahnmedizinischen Anwendung. DGL Zeitschrift für Laserzahnheilkunde 3/07: 151-158, 2007
134. Coluzzi DJ: Lasers and soft tissue curettage. An update. Compend Contin Educ Dent 23: 1104-1111, 2002
135. Dederich DN: Laser curettage: an overview. Compend Contin Educ Dent 23: 1097-1103, 2002
136. Schwarz F, Sculean A, Berakdar M, Szathmari L, Geoerg T, Becker J: In vivo and in vitro effects of an Er:YAG laser, a diode laser, and scaling and root-planning on periodontally diseased root surfaces: a comparative histologic study. Lasers Surg Med 32: 359-366, 2003
137. Fontana CR, Kurachi C, Mendonca CR, Bagnato VS: Temperature variation at soft periodontal and rat bone tissue during a medium- power diode laser. exposure. Photomed Lasres Surg 22: 519-522, 2004

138. Gold SJ, Vilardi MA: Pulsed laser beam effect on gingiva.
J Clin Periodontol 21(6): 391-396, 1994
139. Borrajo JL, Varela LG, Castro LG, Rodriguez- Nunez I, Torreira MG: Diode laser (980 nm) as an adjunct to scaling and root planning.
Photomed Laser Surg 22: 509-512, 2004
140. Kreisler M, Al Haj H, Daublander M, Gotz H, Duschner H, Willershausen B, D`Hoedt B: Effect of diode laser irradiation on root surface in vitro.
J Clin Laser Med Surg 20: 63-69, 2002
141. Meister J, Franzen R: Dentale Lasersysteme Teil II: Der Dioden- Laser.
DGL Zeitschrift für Laserzahnheilkunde 3/07: 185-189, 2007
142. Alam T, Dawasaz AA, Thukral N, Jangam D: Surgical Diode Laser Excision for Peripheral Cemento-Ossifying Fibroma: A Case Report and Literature Review
J Oral Laser Applications 8: 43-49, 2008
143. Convissar RA: An overview of Laser wavelength used in dentistry.
Dent Clin North Am 44: 753-765, 2000
144. Kreisler M, Meier C, Stender E, Daubländer M, Willershausen- Zönnchen B, de Hoedt B : Effect of diode laser irradiation on the attachment rate of periodontal ligament cells : an in vitro study. J Periodontol Oct, 72(10): 1312-1317, 2001
145. Black P: Der Dentallaser in der oralen Chirurgie-Masterthese-Teil2
Laser Journal 1/2007: 16-21, 2007
146. Van Hillegersberg R: Fundamentals of Laser Surgery
Eur J Surg Jan 1997, 163(1): 3-12, 1997
147. Haina D, Landthaler M, Braun- Falco O, Waidelich W: Comparison of the maximum coagulation depth in human skin for different types of medical lasers.
Lasers Surg Med 7(4): 355-362, 1987
148. Sullins KE: Diode Laser and endoscopic laser surgery.
Vet Clin North Am Small Anim Pract May 32(3): 639-648, 2002
149. McKenzie AL: Physics of thermal processes in laser- tissue interaction.
Phys Med Biol Sep 35(9): 1175-1209, 1990
150. Reinisch L: Laser physics and tissue interaction.
Otolaryngol Clin North Am Dec 29(6): 893-914, 1996

151. Coluzzi DJ: Fundamentals of dental lasers: science and instruments.
Dent Clin North Am 48: 751-770, 2004

152. Niemz MH: Laser- tissue interactions- Fundamentals and applications.
2. Auflage Springer Verlag, Berlin- New York: 45-149, 2003

153. Maiorana C, Salina S: Versatility of Superpulsed Diode Laser in Oral Surgery:
A clinical report. J Oral Laser Appl 6: 193-199, 2006

154. Gold SI, Villardi MA: Pulsed laser beam effects on gingiva.
J Clin Periodontol 21: 391-396, 1994

155. Kamp M: Halbleiterlaser. Vorlesung WS 2006, Technische Physik,
Uni Würzburg, 2006

156. Schäfer O: Die Entwicklung des Diodenlasers bis zur Digitalpulstechnik.
Laser Journal 2/2008: 6-7, 2008

157. Nanami T, Shiba H, Ikeuchi S, Nagai T, Asanami S, Shibata T: Clinical applications and basic studies of laser in dentistry and oral surgery.
Keio J Med Dec.1993, 42(4): 199-201; 1993

Lasers Med Sci (2007) 22:217–221
DOI 10.1007/s10103-007-0440-3

REVIEW ARTICLE

Laser applications in oral surgery and implant dentistry

Herbert Deppe · Hans-Henning Horch

Received: 3 July 2006 / Accepted: 17 December 2006 / Published online: 1 February 2007

Abstract Lasers have been used for many years in oral surgery and implant dentistry. In some indications, laser treatment has become state of the art as compared to conventional techniques. This article is a comprehensive review of new laser applications in oral surgery and implant dentistry. One of the most interesting developments over the last years was the introduction of the 9.6-μm CO_2 laser. It has been shown in the recent literature that the use of this new device can preserve tissue with almost no adverse effects at the light microscopic level. In contrast, modifications of approved CO_2 laser therapies of premalignant lesions resulted in higher recurrence rates than the conventional defocused laser technique. However, several studies indicate that other wavelengths such as Nd–YAG (λ=1,064 nm) or diode lasers (λ=810 nm) may be also of value in this field. In many other indications, the use of lasers is still experimental. Intraoperatively used photodynamic therapy or periimplant care of ailing implants with the CO_2 laser seems to be more of value than conventional methods. However, further studies are required to assess standard protocols. Over the past years, research identified some new indications for laser treatment in oral surgery and implant dentistry. Moreover, well-known laser applications were defined as state of the art. Nevertheless, further studies are required for laser treatment in oral surgery and implant dentistry.

Keywords Laser · Oral surgery · Implant dentistry

This work was presented in part as a keynote lecture at the 10th Anniversary Meeting of the International Society for Lasers in Dentistry, Berlin/Germany, May 18–20, 2006.

H. Deppe · H.-H. Horch
Department of Oral and Craniomaxillofacial Surgery,
Klinikum rechts der Isar,
Ismaninger Strasse 22,
81675 München, Germany

H.-H. Horch
e-mail: horch@mkg.med.tum.de

H. Deppe (✉)
Klinik und Poliklinik für Mund-Kiefer-Gesichtschirurgie,
Technische Universität München,
Klinikum rechts der Isar,
Ismaninger Strasse 22,
81675 München, Germany
e-mail: herbert.deppe@mkg.med.tum.de

Introduction

This article is a comprehensive review of recent laser applications in oral surgery and implant dentistry, providing information for dentists and oral and maxillofacial surgeons. Therefore, the authors focus on new laser techniques in osteotomy, treatment of premalignant lesions, fluorescence spectroscopy and photodynamic therapy (PDT), periimplant care of ailing implants, and local hemostasis.

To understand the use of laser surgery, it is necessary to know the fundamental principles of laser light. Unlike other light sources, lasers emit coherent, monochromatic, and collimated electromagnetic radiation. These characteristics endow lasers with unique applications. The most common surgical lasers emit wavelengths in the infrared part of the spectrum: the neodymium:yttrium–aluminium–garnet laser (Nd–YAG, λ=1,064 nm), the erbium–yttrium–aluminum–garnet laser (Er–YAG, λ=2.94 μm), and the CO_2 laser (λ= 10.6 and 9.6 μm). Within the visible portion of the electromagnetic spectrum, argon lasers emit a light between 458 and 515 nm, and excimer lasers are located in the ultraviolet part of the spectrum (100 to 400 nm). Diode lasers emit wavelengths of λ=810 and 906 nm. In surgical indications, within the last years, the latter seem to be of increasing interest.

Whether a laser system is suitable for incisions, vaporization, or coagulation is determined by the wavelength, the energy fluence, the optical characteristics of the tissues, and how the laser is operated. In continuous mode, the laser provides a constant and stable delivery of energy. Pulsed laser systems, in contrast, provide bursts of energy. Lasers within the ultraviolet region (100 to 380 nm) are able to ionize tissues, a process known as photochemical desorption. Lasers of longer wavelengths, especially those within the infrared part of the spectrum (700 to 10,000 nm), cause significant tissue heating. Most of the surgical lasers are embedded in this group and comprised as thermal lasers. The light of these lasers is rapidly converted to thermal energy, causing denaturation of proteins, decomposition of tissue, microexplosion of cell water, and charring. However, recent studies showed that the CO_2 laser at 9.6 μm made an important step toward replacing conventional osteotomy techniques [1, 2].

New laser applications in oral surgery and implant dentistry

Laser osteotomy

For most patients, drills and hand pieces are the most inconvenient components in oral surgery. Therefore, laser osteotomy could be an elegant alternative [1–3]. Research was focused on most of the medically used laser systems. The major components of bone and dental hard tissues are inorganic structures such as water and hydroxyapatite as well as organic structures (collagen). Several authors described the critical temperature for bone and noted that temperature elevation between 44 and 47°C may lead to osteonecrosis [3]. The laser light emitted by the CO_2 and the Er–YAG laser are well absorbed by water. The wavelength of the Er–YAG laser, moreover, is well absorbed by water and hydroxyapatite. In addition to a high absorption coefficient for water and for hydroxyapatite with phosphate, carbonate, and hydroxyl groups, the energy emitted by the CO_2 laser at 9.6 μm is also highly absorbed by collagen. Therefore, this wavelength seems to play an increasingly important role in oral and maxillofacial surgery.

Eyrich [1] compared the super-pulsed CO_2 laser at 9.6 μm to the Er–YAG laser and the conventional drill with regard to their respective thermal effects on human bone. Therefore, temperature rise during ablation of human bone was measured. The results of the study suggested that a maximum rise of mean temperature to 1.88°C (well below the critical range of 7°C) demonstrated the safety and tissue-preserving capability of the super-pulsed 9.6-μm CO_2 laser. The laser caused an even lower temperature rise than conventional drilling when using this device for osteotomies on larger bone segments compared to small bone slices. Moreover, the laser showed acceptable efficacy with drilling times comparable to a conventional drill.

In another study [1], bony osteotomies were produced in six patients with 60-μs pulses of a pulsed 9.6-μm CO_2 laser and a scanning system. Histologic sections revealed no charring, but a very thin basophilic zone was seen next to the cut surface. Cutting trabecular structures resulted in a coagulation zone of 20–150 μm. The author concluded that clinical use of a 9.6-μm CO_2 laser as a cutting tool can be considered to preserve tissue with almost no adverse effects at the light microscopic level.

Lasers in premalignant lesions of the oral mucosa

According to the literature, malignant transformation of premalignancies such as oral leukoplakia and oral lichen planus occurs in up to 28% of these lesions [4]. Consequently, due to the high rates of malignant transformation and basically unchanged prognosis of head and neck cancer, early treatment of premalignant lesions is mandated. Even though there are some reports in the literature on laser-assisted tumor treatment, surgery is mostly performed conventionally. As an alternative to the scalpel, the CO_2 laser (λ=10.6 μm, continuous wave, defocused) is an established device which has been in use for more than 20 years. It has been demonstrated histologically that thermal laser energy carbonizes superficial parts of epithelium. Consequently, reepithelization is delayed for more than 2 weeks. This technique has been proven very effective being associated with recurrence rates of less than 20% [5].

However, a delay in healing caused by the thermal laser energy is an encumbrance for the patient. Therefore, new methods of applying laser energy, such as scanners or the use of very short laser pulses (the so-called super pulses, sp), could be of value. Scanners allow the focused CO_2 laser beam to sweep quickly over an area, thereby reducing the dwell time on each individual point to less than 1 ms which is shorter than the thermal relaxation of soft tissue (3.6 ms) [6]. Through the use of the sp-mode as well as the scanners, thermal laser effects such as delays in healing can be reduced but, on the other hand, a lesser degree of destruction of dysplastic cells could lead to an increased recurrence rate.

Accordingly, the aim of a recent study was to evaluate the recurrence rates resulting from different methods of CO_2 laser surgery in a prospective clinical study. Therefore, a total of 56 patients with a total of 68 premalignant lesions of the oral mucosa were treated with three different modes of CO_2 laser surgery [5]. In the group with defocused resection of oral leukoplakias, a recurrence rate of 23.1%

was seen, which is very similar to that found in the literature [4, 7]. In contrast, neither the application of scanner plus cw-irradiation nor the scanner plus sp-mode yielded results superior to those of the classic defocused technique. These results were explained by the pulsed mode of laser beam delivery and, furthermore, the geometry of the laser beam on the scanned area.

Oral lichen lesions were associated with very high recurrence rates. According to the literature, oral lichen is an autoimmune disease which is not amenable to healing by means of resection. Consequently, only erosive lesions should be treated to achieve pain relief for the patient.

Tissue effects resulting from different scanning systems were also assessed in an experimental study [8]. Therefore, healing of skin wounds after CO_2 laser resection was evaluated with the use of two different scanners (Swiftlase® and Silktouch®). Histologically and clinically, both scanners yielded better results with regard to progress of wound healing than those seen with the use of a defocused laser beam. Nevertheless, these differences could no longer be detected at 2 weeks after surgery. Due to the digitally generated mode of the laser beam on the irradiated area, smoother skin surfaces were yielded with the Silktouch® scanner.

In recent studies, very low recurrence rates were observed with the Nd–YAG laser (λ=1064 nm) [9] and a diode laser (λ=810 nm) [10]. At these wavelengths, laser energy is not absorbed to any significant extent in water. As a result, deleterious effects on sensitive structures such as the mental nerve might occur. Nevertheless, the use of these wavelengths for resection of premalignant lesions should be evaluated in subsequent studies.

Lasers in fluorescence spectroscopy and PDT

Laser-induced fluorescence (LIF) spectroscopy is a noninvasive technique that has been used in various fields to differentiate tissues and, therefore, might be an important tool for cancer diagnostics. In a recent pilot study, the ability of LIF spectroscopy to detect dysplasia or cancerous tissue was validated [11]. Therefore, a 337.1-nm nitrogen laser with a 600-µm fiber optic was used to induce fluorescence in human normal and pathological tissues. Fluorescence spectra were obtained by means of a spectrograph and analyzed by a computer program. The results of this study indicated that differentiation of benign and malignant tissues was possible with a sensitivity above 80%. The authors concluded that this method might be applicable for discrimination of benign and malignant tissues. It was stated that LIF spectroscopy may provide the clinician with a reliable technique for detecting malignancies. Nevertheless, the authors recommended further studies to verify the in vivo applicability of the method.

It has been shown in the past that PDT can optimize conventional surgery in squamous cell carcinoma [12–14]. In a recent animal study, PDT has also been performed intraoperatively next to vital structures like the carotid artery using a new photosensitizer meta-tetrahydroxyphenylchlorin (m-THPC) [14, 15]. As a result of the irradiation, complete necroses of muscles and connective tissue were found. Nerve tissues demonstrated demyelination (above 75%), however, without clinical symptoms.

Intraoperative PDT using m-THPC has also been performed in 22 patients with malignancies of the brain [16]. The authors concluded that m-THPC-mediated, intraoperative fluorescence-guided resection followed by PDT is a highly promising concept in improving the radicality of tumor resection combined with a therapeutic approach.

Nevertheless, more studies are necessary before these methods can be recommended as standard therapies in the treatment of oral carcinoma.

Periimplant care of ailing implants

A new indication of laser treatment might be the sterilization of exposed implant surfaces to rehabilitate ailing implants. However, apparently not all laser systems available in dentistry are of value in this regard. Park et al. [17] reported that the potential exists for Nd–YAG laser irradiation (λ=1064 nm) to melt the surface and even to remove the surface layer from plasma-coated titanium implants. From this study, it was concluded that the use

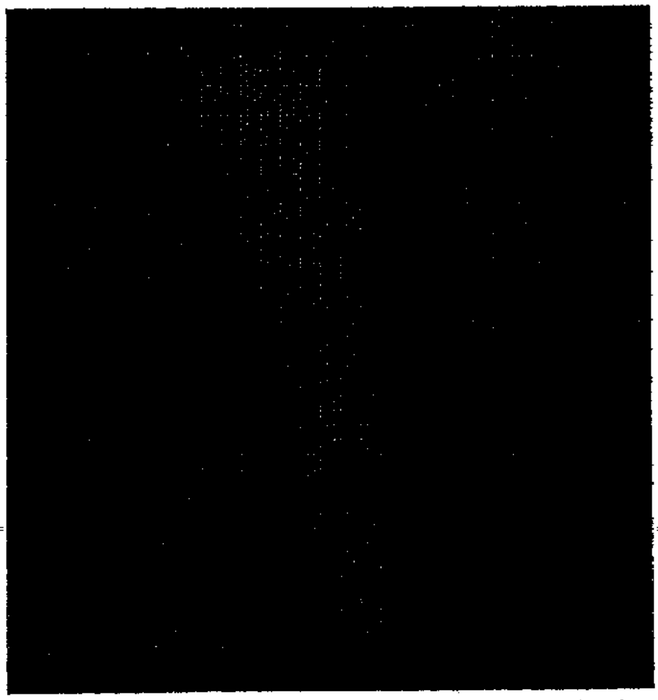


Fig. 1 Radiograph indicating chronically progressive periimplant bone resorption

Fig. 2 Surgical intervention: full thickness flaps and granulation tissue removal

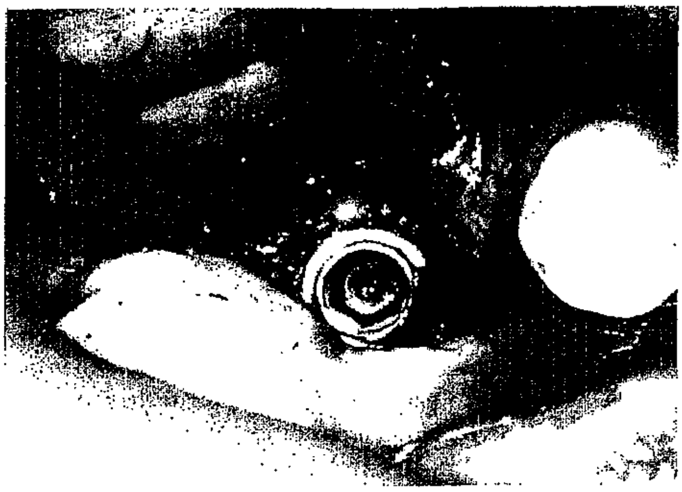


Fig. 4 Reentry 4 months after therapy. Complete closure of the defect

of Nd–YAG lasers in implant-uncovering procedures or periimplant gingival surgery should be considered inherently unsafe for such procedures.

Better results were seen with the use of a CO_2 laser (λ= 10.6 μm). The purpose of a study in a total of 16 patients with 41 ailing implants was to assess the reliability of the CO_2 laser-assisted implant decontamination vs a conventional decontamination procedure [18]. The results of the clinical study showed, 4 months after therapy, that implants treated with laser decontamination and soft-tissue resection exhibited statistically significant better clinical parameters than conventionally decontaminated implants followed by soft-tissue resection. From these results, it was concluded that treatment of periimplantitis can be optimized using a CO_2 laser-assisted decontamination (Figs. 1, 2, 3, 4, and 5).

There are several positive reports in the literature in which laser decontamination has been recommended including the use of diode lasers (λ=810 and 906 nm) [19–21] and Er–YAG laser (λ=2.94 μm) [22]. Application of a diode laser (λ=810 nm) resulted in recurrence rates of less than 7% [19]. In further studies, PDT with toluidine blue plus diode laser light (λ=906 nm) was used [20, 23]. Haas and coworkers [20] reported on a mean bony reapposition of 2 mm (±1.90 mm) after a 9.5-month observation period. However, reosseointegrations were demonstrated for the first time for the CO_2 laser [6]. Most

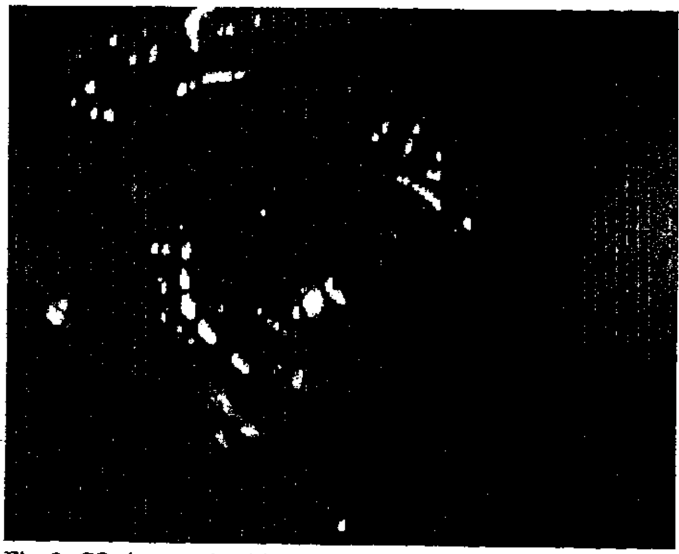


Fig. 3 CO_2 laser-assisted implant decontamination and augmentation with beta-TCP

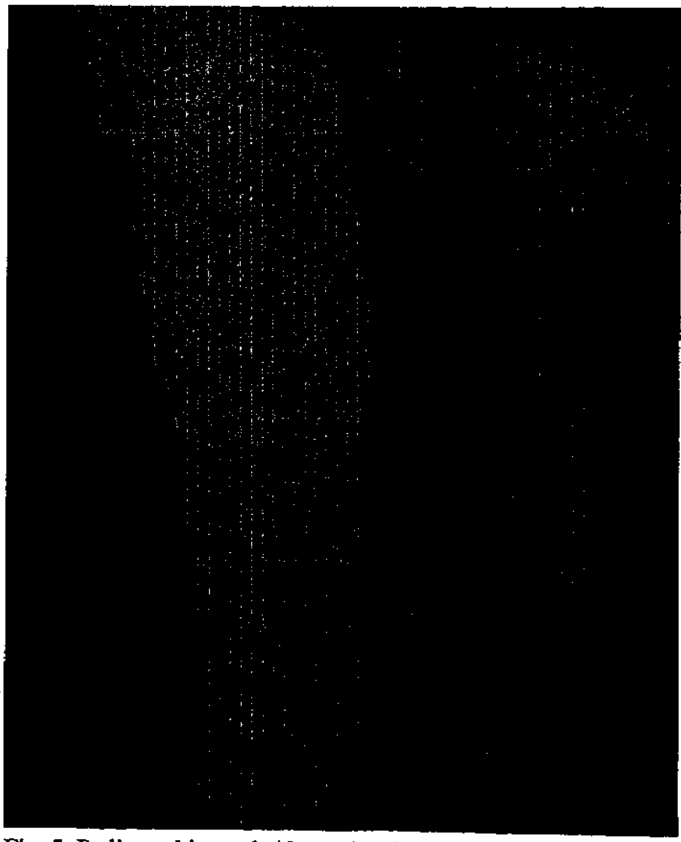


Fig. 5 Radiographic result 10 months after surgery

recent results from a study performed in beagle dogs have indicated that reosseointegration also occurred after irradiation with an Er–YAG laser [24]. Nevertheless, further studies are required in this field.

Bare fiber technique in local hemostasis

In modern societies, there is an increasing number of older patients, especially those treated with anticoagulation because of cardiologic indications. Over the past years, laser hemostasis has been established as an alternative to conventional techniques. Due to a penetration depth of more than 4 mm in soft tissue, cw Nd–YAG laser light (λ=1064 nm) applied with a hand piece has been very effective in this field [25].

However, if bleeding occurs massively from the apical region of the socket, the use of the bare fiber can be of interest. Therefore, in a clinical study in 44 patients, the bare fiber technique was studied in this indication [4]. Moreover, to reduce the thermal effects, a pulsed laser was used. It was concluded that intraalveolar application of pulsed Nd–YAG laser energy can be considered safe. It was demonstrated that optical characteristics of blood result in scattering and dispersion of laser light, thereby reducing the adverse effects on bony tissue.

Conclusion

Over the past years, research identified some new indications and techniques for laser treatment in oral surgery and implant dentistry. Moreover, well-known laser applications were defined state of the art. Nevertheless, further studies are required for laser treatment in oral surgery and implant dentistry.

References

1. Eyrich G (2004) Hard-tissue drilling and cutting with a 9.6 μm CO_2 laser. Med Habilitationsschrift, Zürich
2. Ivanenko M, Sader R, Afilal S, Werner M, Hartstock M, von Hanisch C, Milz S, Erhardt W, Zeilhofer H-F, Hering P (2005) In vivo animal trials with a scanning CO_2 laser osteotome. Lasers Surg Med 37:144–148
3. Horch H-H (1983) Laser Osteotomie und Anwendungsmöglichkeiten des Lasers in der oralen Weichteilchirurgie. Eine tierexperimentelle und klinische Studie. Berlin, Quintessenz
4. Horch H-H, Deppe H (2004) Laser in der Zahnärztlichen Chirurgie und Mund-, Kiefer-und Gesichtschirurgie. In: Berlien H-P, Müller G (Hrsg.): Angew. Lasermedizin. Lehr- und Handbuch für Praxis und Klinik. Losebl.-Ausg. Landsberg, Ecomed, III. 3.3.1, S. 1–28
5. Deppe H, Hillemanns M, Hauck W (2004) Recurrence rates of premalignant lesions after CO_2 laser vaporization. Med Laser Appl 19:55–60
6. Deppe H, Horch H-H, Henke J, Donath K (2001) Peri-implant care of ailing implants with the carbon dioxide laser. Int J Oral Maxillofac Implants 16:659–667
7. Horch H-H, Deppe H (2005) Lasers in oral and maxillofacial surgery. Med Laser Appl 20:47–59
8. Weibrich G, Wahlmann U, Kunkel M, Reichert T, Wagner W (1999) Tissue damage and regeneration after laser surgery using different scanning systems. Mund Kiefer Gesichtschir 3:200–204
9. Maiorana C, Salina S (2001) Oral soft tissue pathologies: long term evaluation after laser treatment. J Oral Laser Appl 1:20
10. Crippa R (2001) Report on 103 cases of precancerous and other oral lesions treated with a diode laser. J Oral Laser Appl 1:26
11. Broer NM, Liesenhoff T, Horch H-H (2004) Laser-induced fluorescence spectroscopy for real-time tissue differentiation. Med Laser Appl 19:45–53
12. Kübler AC, Scheer M, Zoller JE (2001) Photodynamic therapy of head and neck cancer. Onkologie 24:230–237
13. Kuebler AC, de Carpentier J, Hopper C, Leonard AG, Putnam G (2001) Treatment of squamous cell carcinoma of the lip using Foscan-mediated photodynamic therapy. Int J Oral Maxillofac Surg 30:504–509
14. Kuebler AC, Stenzel W, Ruhling M, Meul B, Fischer JH (2003) Experimental evaluation of possible side effects of intra-operative photodynamic therapy on rabbit blood vessels and nerves. Lasers Surg Med 33:247–255
15. Zimmermann A, Ritsch-Marte M, Kostron H (2002) In vitro investigation of pH dependence of the absorption and fluorescence properties of the photosensitizer mTHPC. Photochem Photobiol 75:335–338
16. Zimmermann A, Ritsch-Marte M, Kostron H (2001) MTHPC-mediated photodynamic diagnosis of malignant brain tumors. Photochem Photobiol 74:611–616
17. Park Ch-Y, Kim SG, Kim MD, Eom TG, Yoon JH, Ahn SG (2005) Surface properties of endosseous dental implants after NdYAG and CO_2 laser treatment at various energies. J Oral Maxillofac Surg 63:1522–1531
18. Deppe H, Horch H-H, Wagenpfeil S (2003) CO_2-Laser-assistierte versus konventionelle Implantat-Dekontamination-Eine klinische Dreijahresstudie. Z Zahnärztl Impl 19:73–81
19. Bach G, Neckel C, Mall Ch, Krekeler G (2000) Conventional versus laser-assisted therapy of peri-implantitis: a five-year comparative study. Implant Dent 9:247–251
20. Haas R, Baron M, Dortbudak O, Watzek G (2000) Lethal photosensitization, autogenous bone, and e-PTFE membrane for the treatment of peri-implantitis: preliminary results. Int J Oral Maxillofac Implants 15:374–382
21. Romanos GE, Everts H, Nentwig GH (2000) Effects of diode and Nd:YAG laser irradiation on titanium discs: a scanning electron microscope examination. J Periodontol 71:810–815
22. Schwarz F, Sculean A, Rothamel D, Schwenzer K, Georg T, Becker J (2005) Clinical evaluation of an Er:YAG laser for nonsurgical treatment of peri-implantitis: a pilot study. Clin Oral Implants Res 16:44–52
23. Neugebauer J (2005) Using photodynamic therapy to treat peri-implantitis. Interview. Dent Implantol Update 16:9–16
24. Schwarz F, Jepsen S, Herten M, Sager M, Rothamel D, Becker J (2006) Influence of different treatment approaches on nonsubmerged and submerged healing of ligature induced peri-implant lesions. An experimental study in dogs. J Clin Periodontol 33:584–595
25. Ackermann K (1984) Neodym–YAG-Laser in der Zahnmedizin. Münch Med Wschr 126:1119–1121

Versatility of a Superpulsed Diode Laser in Oral Surgery: A Clinical Report

Carlo Maiorana[a], Sergio Salina[b]

[a] Professor and Chair, Oral Surgery and Implantology, Dental Clinic ICP, University of Milano, Milano, Italy.
[b] Attending Doctor, Oral Surgery and Implantology, Dental Clinic ICP, University of Milano, Milano, Italy.

Purpose: A superpulsed diode laser (Claros; Elexxion) was used for different surgical procedures using various operative parameters.The possibility of reaching the target tissue with lower power than and equivalent efficacy of the conventional diode laser was clinically tested .

Materials and Methods: After setting local anaesthesia (Ecocain 1:100000), the superpulsed diode laser was used on patients to uncover impacted teeth, remove epulis, and treat intraoral hemangioma. No antibiotics were administrated and chlorhexidine rinses were prescribed for one week, twice a day, before surgery.

Results: In all cases, slight carbonization was observed. The postoperative healing ensued without inflamation or complications.

Conclusion: The use of a superpulsed diode laser allows the surgeon to operate using high energy and very short pulse duration (milliseconds). This allows the best control of incision depth and reduces the thermal damage to the target tissue.

Keywords: superpulsed laser, oral surgery.

J Oral Laser Applications 2006; 6: 193-199.

The use of diode laser in oral surgery is becoming very popular for several procedures that can be performed quickly, with low morbidity and excellent healing due to the biostimulating effect of this specific laser. As we know, the active medium is a solid-state semiconductor that uses a combination of gallium, aluminum, and arsenide to change electric energy into light energy. The available wavelengths place this laser in the invisible nonionizing infrared radiation portion of the electromagnetic spectrum. These wavelengths are very well absorbed by pigmented tissues, such as hemoglobin and melanin. This tendency to transmit depends on the wavelength and the absorption factor of the target tissue.[1-3] The poor absorption in the surrounding tissues (only 20% of the emitted energy penetrates deeper than 2 mm) allows the surgery to be performed safely.[4,5] Surgery is usually performed in continuous mode, but the recently produced superpulsed diode laser allows the surgeon to perform interventions with very high energy levels (up to 20,000 Hz) with a pulse duration in the millisecond range. In this way, the thermal damage to the tissue does not progress deeper than 50 µm, and carbonization is reduced to a minimum.

MATERIALS AND METHODS

Three patients, men and women, in good general health, were selected for oral surgery. They presented with different pathologies: epulis, fornex hemangioma, and impacted teeth. A superpulsed diode laser (Clar-

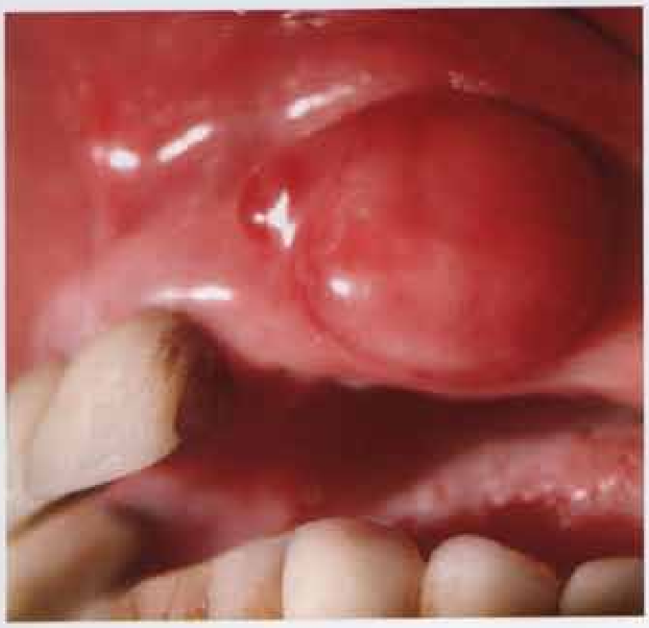


Fig 1 14-mm spheroidal epulis.

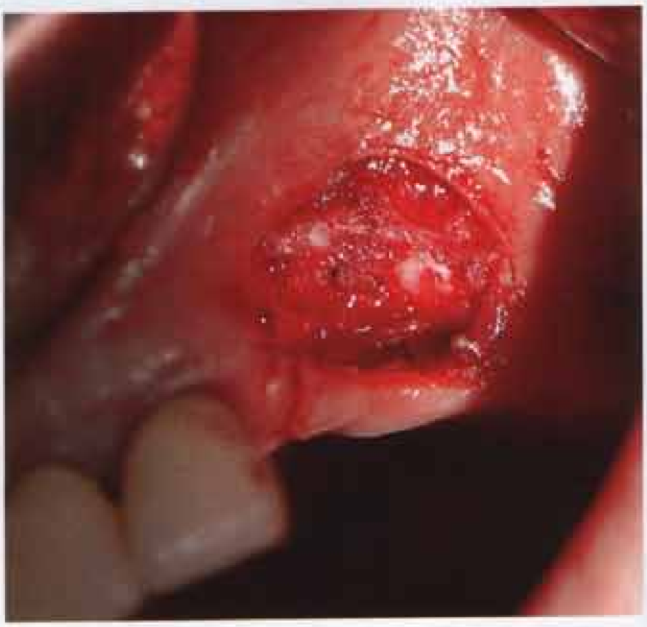


Fig 2 Immediate postoperative site.

Fig 3 Epulis removed and sent for histological analysis.

Fig 4 Surgical site 40 days postoperatively.

ion, Elexxion Medical Systems; Radolfzell, Germany) at 30 W and 20,000 Hz was used to excise the epulis and intraoral hemangioma, and uncover impacted the teeth.

CASE 1

This 62-year-old female patient had a large spheroidal durum epulis (14 mm) located on the gingival mucosa in dental area 23 (Fig 1). The most probable etiology was chronic trauma produced by an ill-fitting removable prosthesis.

After giving local anesthesia (Ecocain 1:100000, Molteni Dental; Scandicci, Italy), the lesion was removed using superpulsed 809-nm diode laser set at 20 W and 20,000 Hz, with 10 ls pulse duration (Fig 2). After removal, the epulis was sent in for the usual histological analysis (Fig 3).

The patient's removable prosthesis was immediately modified and relined with a soft tissue conditioner (Soft Liner, GC Europe NV; Leuven, Belgium). Chlor-

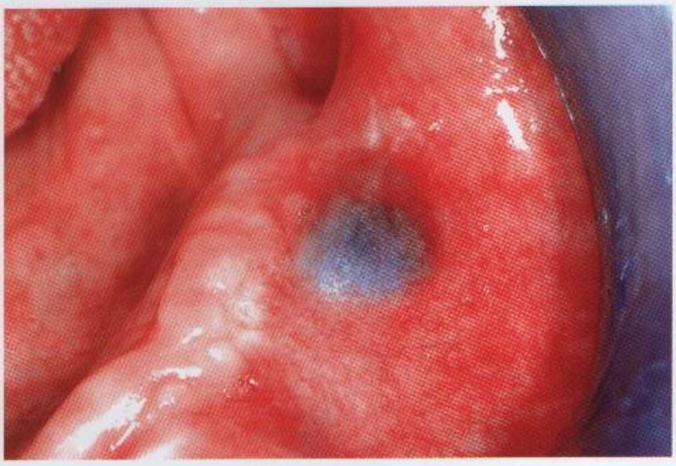


Fig 5 Intraoral 7-mm hemangioma.

Fig 6 Immediate postoperative view with a thin, stable scar.

Fig 7 After 7 days: the postoperative site appears covered by newly formed tissue.

hexidine (0.2%) rinses were prescribed for one week, twice a day.

After 40 days, the treated area looked completely healed without shrinkage (Fig 4).

CASE 2

A round, 7-mm-wide hemangioma was observed on the inner side of the lower lip of a 75-year-old female (Fig 5). Because of the size and location, this lesion was removed in toto under local anesthesia, using a superpulsed diode laser. The laser parameters were: pulse output 25 W, pulse frequency 15,000 Hz, and pulse duration 10 Ìs. This setting was enough to achieve the complete exeresis of the lesion and very effective coagulation with a stable scar (Fig 6). No sutures were necessary.

The patient was released without a prescription for antibiotics. Only chlorhexidine (0.2%) rinses for one week (twice a day) were suggested.

Healing proceeded rather quickly: just one week postoperatively, wound healing looked good (Fig 7): the epithelium defect due to the operation was already covered by newly formed tissue.

CASE 3

A 12-year-old male presented with both maxillary canines impacted. After a correct diagnosis and orthodontic preparation (bracket appliance for the maxilla) (Figs 8 to 12), the patient underwent a laser surgery session to uncover the buccally impacted teeth.

The superpulsed diode laser, set at 25 W and 15,000 Hz, with 10 μs pulse duration, permitted inci-

CASE REPORT

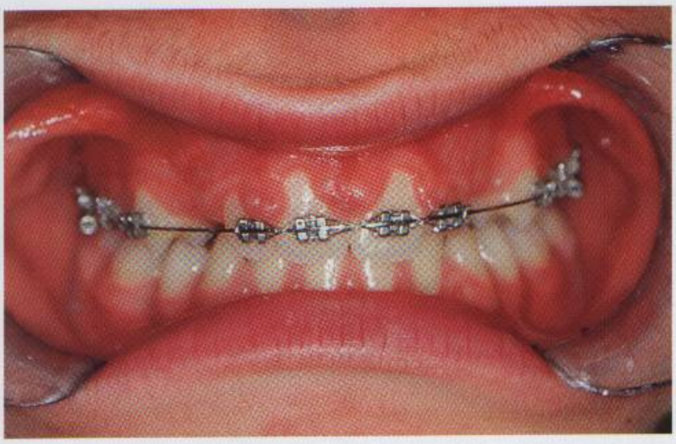


Fig 8 Maxillary orthodontic appliance: the two canines are not present.

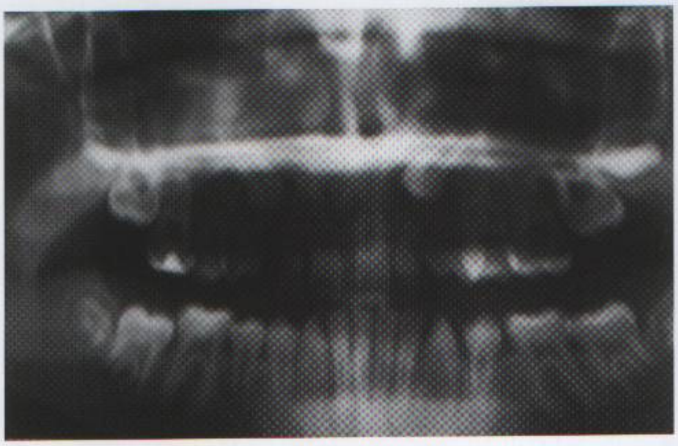


Fig 9 Panoramic radiograph: the two maxillary canines appears impacted.

Fig 10 Occlusal radiographic image: the two maxillary canines appears buccally impacted.

Fig 11 Canine area on the right side.

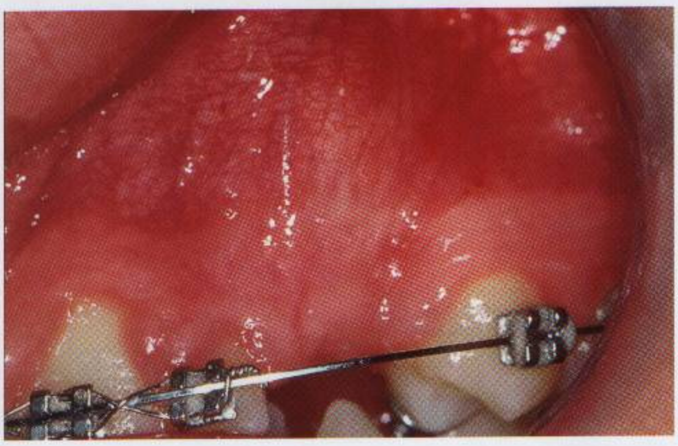


Fig 12 Canine area on the left side.

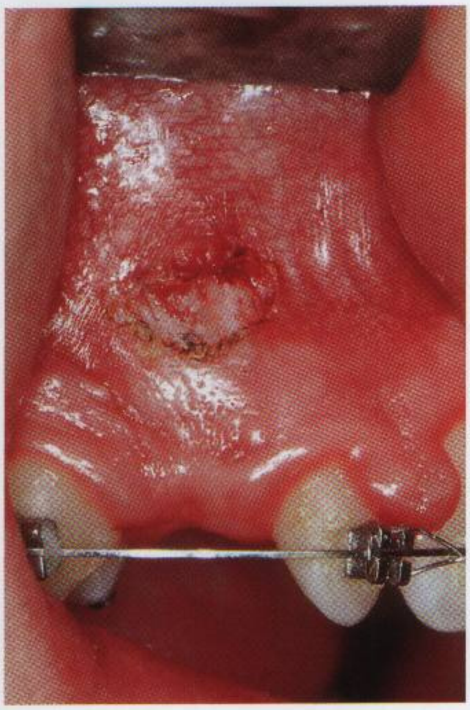


Fig 13 Canine area on the right side: first incision with superpulsed diode laser.

Fig 14 Canine area on the left side: first incision with superpulsed diode laser.

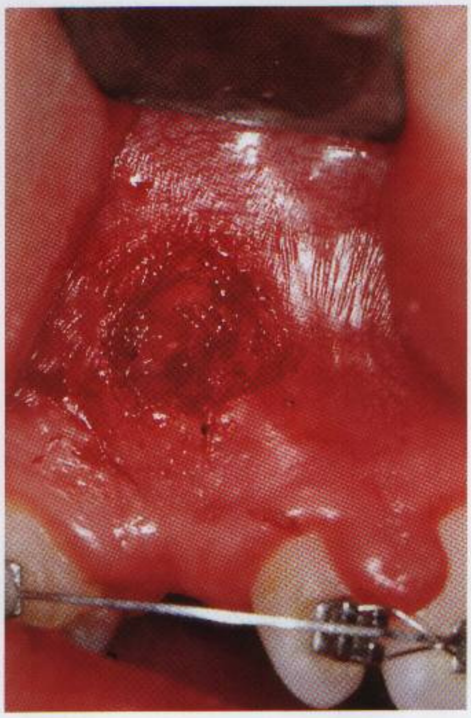


Fig 15 Uncovered right canine.

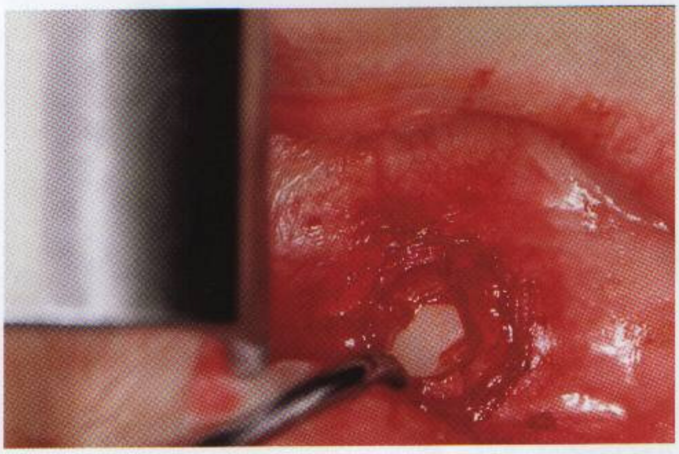


Fig 16 Uncovered left canine.

sion with immediately effective hemostasis (Figs 13 to 16), allowing establishment of a solid connection of the orthodontic brackets to the newly uncovered teeth (Figs 17 and 18).

The orthodontist joined the brackets to the arch, facilitating the correct eruption of the two canines. Four months later, the two teeth were completely erupted in the right position (Fig 19). A satisfactory amount of

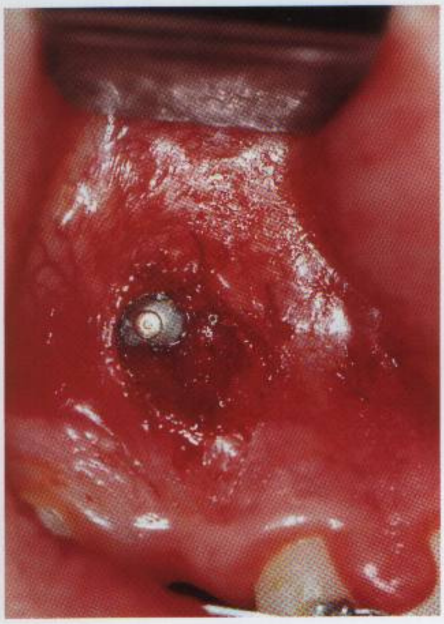


Fig 17 Orthodontic bracket linked to the right canine.

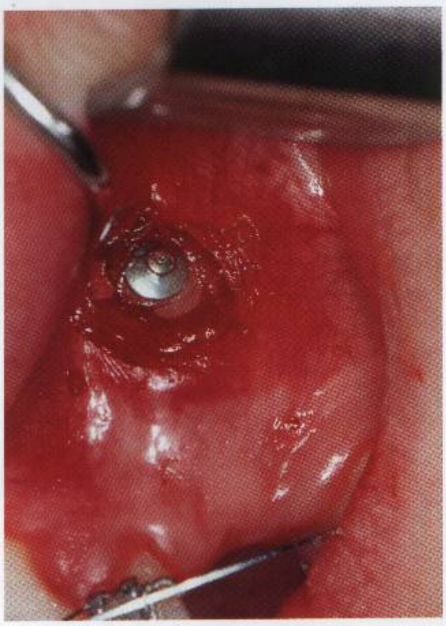


Fig 18 Orthodontic bracket linked to the left canine.

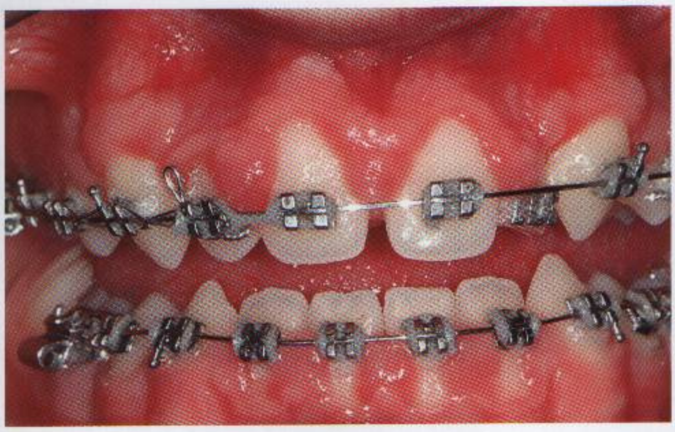


Fig 19 After 4 months: the two canines are in the correct position.

keratinized gingiva can be observed due to the suture of the follicular envelope to the oral epithelium, thus simulating the physiologic eruption process.

RESULTS

All patients experienced a predictable and satisfactory healing process, without complications or side effects.[6,7] No antibiotic prophylaxis was necessary, because laser surgery provided decontamination of the operating field[8] and led to stable scar-tissue formation.[9,10]

DISCUSSION AND CONCLUSION

The superpulsed 809 nm GaAlAs laser allows the excision of oral lesions of various consistency, such as epulides and hemangioma, with numerous advantages when compared to the conventional scalpel techniques:[2,11,12]

- Clean cut without thermal side effects
- Instant coagulation of the surgical site
- Minimal involvement of the adjacent tissues during surgery
- Easy and safe to use
- Excellent postoperative conditions, minimal pain and swelling

- Reduced surgical stress for both the patients and the operator

Based on these results and the literature, this laser surgery can be considered the first choice for the excision of intraoral benign tumors, impacted teeth, or implant uncovering surgery, frenectomy, gingivectomy, and gingivoplasty.[2, 9-12]

REFERENCES

1. Martelli FS, De Leo A, Zinno S. Laser in odontostomatologia: applicazioni cliniche. Milan: Masson Ed, 2000:59-60.
2. Maiorana C. Laser in the treatment of soft tissue lesions. J Oral Laser Applic 2003;2:7-14.
3. Moritz A. Orale Lasertherapie. Berlin: Quintessence, 2005:41-45.
4. Goharkhay K, Moritz A. Effects on oral soft tissue prodeuced by a diode laser in vitro. Laser Surg Med 1999;25:401-406.
5. Romanos G, Nentwig GH. Diode laser in oral and maxillofacial surgical procedures: clinical observations based on clinical applications. J Clin laser Med Surg 1999;17:193-197.
6. Maiorana C, Salina S, Censi R et al. Nd:YAG laser in soft tissue surgery: a two-year retrospective study on 130 patients. J Oral Laser Applic 2001;1:29-34.
7. White JM, Chaudhry SI, Kudler JJ, et al. Nd:Yag and CO2 laser therapy of oral lesions. J Clin Laser Med Surg 1998;16:299-304.
8. Moritz A, Schoop U, Goharkhay, et al. Treatment of periodontal pockets with a diode laser. Laser Surg Med 1998;22:302-311.
9. Gold SI, Vilardi MA. Pulsed laser bean effects on gingival. J Clin Periodont 1994;21:391-396.
10. Salina S, Maiorana C, Censi R, et al. Treatment of oral fibromata using the Nd:YAG laser. J Oral Laser Applic 2001;1:59-64.
11. Pick RM. Using lasers in clinical dental practice. J Am Dent Assoc 1993;124:37-47.
12. Maiorana C, Salina S. Laser a Diodi: applicazioni cliniche. Milano: Ariesdue, 2004.

Contact address: Prof. Carlo Maiorana, Via Torino 51, 20123 Milano, Italy. Fax: +39-0280-51204. e-mail: carlo.maiorana@unimi.it

Mehr Behandlungssicherheit bei der chirurgischen Anwendung von fasergestützten Lasersystemen

Die Anwendung von Lasern verschiedener Wellenlängen stellt seit über zwölf Jahren ein unter Praktikern geschätztes Verfahren zur Therapieergänzung in den verschiedenen Teilgebieten der Zahnmedizin dar.

DR. GERD VOLLAND/HEILSBRONN

Fasergestützte Systeme ermöglichen es, mit Wellenlängen des nahen Infrarot durch den Einsatz in Parodontaltaschen, Wurzelkanälen und bei kleinen Schnitten den Nutzungsgrad in der täglichen Praxis zu steigern. Gleichzeitig ist bei der Verwendung von Faserlasern der Wellenlängen 500 bis 1.200 nm die Gefahr, eine breite thermische Schädigungszone durch Verschmutzung der Faser und den Hitzestau zu beachten. Durch entsprechende Pulsung versucht man dem Hitzestau seit Jahren entgegenzuwirken (z.B. I.S.T.-Laser). Die Idee, durch Kühlung des Operationsgebietes, ähnlich wie bei der Turbine, für einen Abfluss der entstehenden Hitze zu sorgen, scheiterte auf Grund der Verwendung von langgepulsten Nd:YAG-Lasern, die bei Oberflächenkühlung zu Tiefennekrosen (Eindringtiefe bis 4 mm) führten (Abb. 1 und 2).

Grundlagen

Zu Beginn des Jahres 2002 wurden in Zusammenarbeit mit dem LMTB Berlin Temperaturstudien, Thermokameradokumentationen und Histologien bei der Verwendung der Wellenlänge 980 nm und einem Prototyp der zirkulären Spraykühlung durchgeführt. Diese zeigten eindrucksvoll, dass die Kühlung des umliegenden Gewebes tatsächlich zu einem Abtransport der entstehenden Hitze führt (Abb. 3). Bei der Aufzeichnung der Temperaturerhöhungen konnten mit Spraykühlung Leistungen bis 12 Watt im gepulsten Modus (0,01/0,01) verwendet werden, ohne eine Temperaturerhöhung über den für CW-Modus empfohlenen 3 Watt zu erreichen (Abb. 4 und 5). Ferner führten die Bestrahlung von Knochen zu keinerlei Nekrosewirkung.

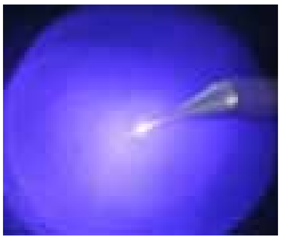


Abb. 1: Laserspitze mit Spray.


Abb. 2: Turbine mit Spray.

Durch einen Druckminderer wird die Pressluft der Dentaleinheit auf bis maximal 3 bar reduziert. Der Luftstrom betreibt eine Turbine, die die eingesetzte Spülflüssigkeit ansaugt und über ein Schlauchsystem in das Handstück leitet, in dessen Mitte die Faser austritt und ein zirkulärer Spülstrom entsteht (Abb. 6). Wir verwendeten bisher sterile Kochsalzlösungen, da Zusätze von CHX zu Schaumentwicklung führen. Behälter, Schlauchsystem, Faser und Handstück sind sterilisierbar.

Erste Praxiserfahrungen

Parodontologie
Beim Einsatz in der geschlossenen Kürettage verwendeten wir 5 Watt Leistung im gepulsten Modus (0,01/0,01).

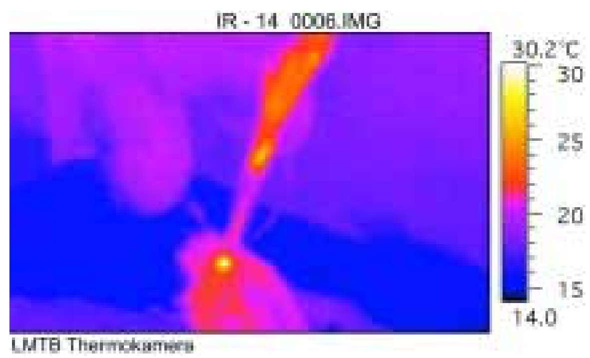


Abb. 3: Thermokamerabild.

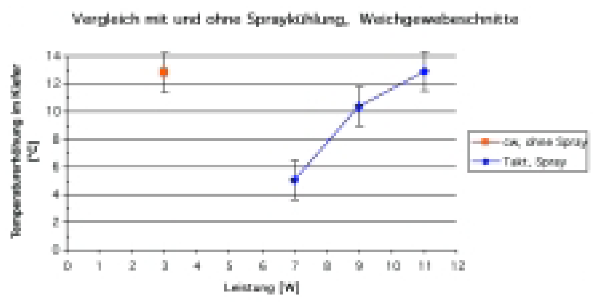


Abb. 4: Die Untersuchung der peripheren Nekrosezonen zeigte bei Anwendung des Sprays (7W/0,01/0,01) zufrieden stellende Ergebnisse, die in ihrer Breite mit 150 m denen eines Er:YAG-Lasers nahe kamen.

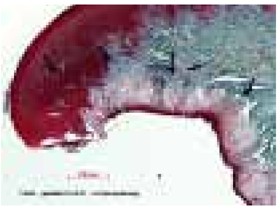



Abb.5: Histologie. — Abb. 6: Cool Pro.


Abb. 7: Vor der Behandlung. — Abb. 8: Nach der Behandlung — keinerlei Karbonisation sichtbar.

Das Vorgehen gestaltete sich wie bei der Anwendung ohne Spray: Lasereinsatz – Konkremententfernung – Lasereinsatz. Bei Taschen bis 5 mm Tiefe verzeichneten wir bei 19 Parodontalbehandlungen keine postoperativen Beschwerden, die Patienten waren durch das Fehlen der Geruchsbelästigung angenehm angetan (Abb. 7 und 8). Bei einer Patientin mit teilweise über 7 mm Taschentiefe zeigten sich bei den betroffenen Molaren postoperative Beschwerden, die auf die Hitzenekrose zurückzuführen sind. Durch Anwendung von Spülungen und Salbenbehandlung besserten sich ihre Beschwerden innerhalb von wenigen Tagen.

Folgerung

Die Spülung und der angestrebte Wärmeabtransport erfolgt auf Grund der anatomischen Verhältnisse nur bis zu der auch bisher gewohnten Taschentiefe von 5 mm bei geschlossener Kürettage.

Implantatfreilegung/Oralchirurgie

Zweiphasige Implantate sind trotz eines in den letzten Jahren zu verzeichnenden Trend zur transgingivalen Einheilung die am häufigsten angewandte Methode mit der höchsten Erfolgsquote. Für den Patienten stellt die Freilegung mit erneuten postoperativen Schmerzen eine Belastung dar. Da durch die Eindringtiefe von ca. 0,3 mm bei der Verwendung einer Wellenlänge von 980 nm eine ausreichende Koagulationszone und damit auch verbundene Blutstillung erreicht wird, verwendeten wir das Cool pro in den letzten Monaten in 53 Fällen standardmäßig (Leistung 5–11 Watt/0,01/0,01sec). Die Schleimhautdicke reichte von 0,5 bis 5 mm, die Messung erfolgte mit dem Implant Locator der Firma Steco. Die Patientenzufriedenheit war sehr hoch (49 von 53 postoperativ beschwerdefrei), vier Patienten hatten leichte Schmerzen, wobei die Schleimhautdicke von 2 und 3 mm keinen Rückschluss auf einen Hitzestau zuließen. Bei Schleimhautdicken bis 3 mm (n=32) ähnelte das Vorgehen dem mit einer kleinen Stanze, die umliegende Schleimhaut wurde mit Gingivaformern aufgedehnt (Abb. 9–11). In zehn Fällen mit 1mm wurde komplett freigelegt. Ab 4 mm verfolgten wir einen lingualen Schnitt und vernähten die Wundränder wie gewohnt. Nur bei Frontzahnimplantaten wurde der Abdruck nicht bei der Freilegung genommen und 7 Tage ein Gingivaformer verwendet (n=5). Die Ergebnisse waren somit mehr als zufrieden stellend und versprechen bei Entwicklung unterschiedlicher Faserspitzen gute Ansätze für die Zukunft. Daneben werden durch die Blutungsfreiheit auch die oralchirurgischen Eingriffe blutungsfrei möglich, wie im folgenden Fall einer kieferorthopädischen Eckzahnfreilegung und gleichzeitiger Aufklebung des Brackets (Abb. 12).

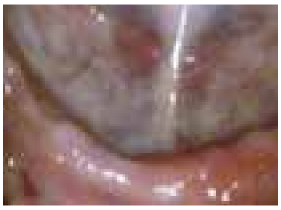



Abb. 9: Implantate vor Freilegung. — Abb. 10: Implantat nach Freilegung 8:15.


Abb. 11—Abb. 12: Aufgeklebtes Bracket.

Zusammenfassung

Die Spraykühlung Cool Pro scheint die Erwartungen zur Herabsetzung der Nekrosezonen und damit verbundenen Gewinnung von mehr Behandlungssicherheit bei der chirurgischen Anwendung vom fasergestützten Lasersystem mit 980 nm in der Praxis erfüllen zu können. Durch Entwicklung geeigneter Faserspitzen sollte die chirurgische Anwendung noch präziser werden, d.h. mit weniger Gewebeverlust, sodass in Zukunft auch Anwendungen in der Mukogingivalchirurgie möglich sein dürften. Insgesamt ist das vorhandene System gerade für Einsteiger und implantologisch/chirurgisch orientierte Praxen tauglich.

Wir bitten unsere Leser, die schlechte Qualität der Bilder zu entschuldigen! Nach Auskunft des Autors war durch die Aufnahmetechnik eine bessere Bildqualität nicht zu erreichen. – Die Redaktion.

Korrespondenzadresse:
Dr. Gerd Volland
Marktplatz 2, 91560 Heilsbronn
Tel.: 0 98 72/72 12, Fax: 0 98 72/95 56 96
E-Mail: dr.volland@t-online.de

Lasers in Surgery and Medicine 25:401–406 (1999)

Effects on Oral Soft Tissue Produced by a Diode Laser In Vitro

K. Goharkhay, MD, DMD,[1] A. Moritz, MD, DMD,[1]* P. Wilder-Smith, MD, DMD,[2]
U. Schoop, MD, DMD,[1] W. Kluger, MD,[1] S. Jakolitsch, MD,[1] and W. Sperr, MD, DMD[1]

[1]*Department of Conservative Dentistry, Dental School, University of Vienna, A-1090 Vienna, Austria*
[2]*Beckman Laser Institute and Medical Clinic, University of California, Irvine, Irvine, California 92697*

Background and Objectives: **This investigation determined incision characteristics and soft-tissue damage resulting from standardized incisions using a wide range of laser modes and parameters of a diode laser at 810 nm.**
Study Design/Materials and Methods: **Histologic examinations were performed to verify vertical and horizontal tissue damage as well as incision depth and width.**
Results: **Incision depth and width correlated strongly with average powers, but not with laser parameters or the used tips. No laser damage was visible to the naked eye in the bone underlying the incisions in the range between 0.5–4.5 W.**
Conclusion: **The remarkable cutting ability and the tolerable damage zone clearly show that the diode laser is a very effective and, because of its excellent coagulation ability, useful alternative in soft-tissue surgery of the oral cavity. Lasers Surg. Med. 25:401–406, 1999.**

Key words: incision depth; mucosa; collateral tissue damage

INTRODUCTION

The scalpel and the conventional electrosurgery unit are the instruments of choice for soft-tissue surgery. In addition, lasers are an alternative to conventional surgical systems. Scalpels have been used for many years because of their ease of use, accuracy, and minimal damage to the surrounding tissue. On the other hand, scalpels cannot provide the hemostasis that is helpful for use on highly vascular tissue [1].

One characteristic difference between a laser and a scalpel cut is the generation of a coagulated tissue layer along the walls of the laser incision [2]. All laser-tissue interactions produce some degree of tissue vaporization and a surrounding zone of thermal necrosis [3]. This zone of thermal damage should ideally be kept to a minimum, as it may impede wound healing and graft take, and reduce tensile strength [2]. Clinical experience suggests some advantages for laser over scalpel surgical procedures of the oral tissues. Advantages of this tool include greater precision, a relatively bloodless surgical and postsurgical course, sterilization of the surgical area, minimal swelling and scarring, coagulation, vaporization, and cutting, minimal or no suturing, and much less or no postsurgical pain [4–6]. Research has consistently demonstrated that laser surgery can be performed safely by using parameters which protect underlying bone and tooth structures [7]. The factors that determine the initial tissue effect include the laser wavelength, laser power, the available laser waveform (continuous wave, chopped, and pulsed beams), tissue optical properties, and tissue thermal properties [8]. At this time, oral laser applications do not replace the majority of

*Correspondence to: Prof. A. Moritz, Department of Conservative Dentistry, Dental School, University of Vienna, Waehringerstr. 25a, A-1090 Vienna, Austria.

Accepted 25 May 1999

traditional scalpel procedures or the high-speed drill. Certain lasers are ideal for specific oral procedures, but lasers cannot provide the same efficiency and efficacy as a scalpel for many different oral procedures [4]. Electrosurgery units produce adequate hemostasis but result in greater thermal injury and also have the disadvantage of causing muscle fasciculations. Reports suggest that healing is delayed for electrosurgery wounds when compared with scalpel wounds [1]. The thermal and histologic events resulting from soft-tissue incision with different CO_2 lasers have already been determined [2]. These examinations showed that incision depths correlate positively with the average power [9–11]. Diode lasers have been used successfully for conditioning enamel and dentin surfaces. Furthermore, the diode laser reveals a bactericidal effect and helps to reduce inflammation in the root canal and in the periodontal pocket in addition to scaling [12–14].

The aim of this study was to determine incision characteristics and soft-tissue damage resulting from standardized incisions using a wide range of laser modes and parameters of a diode laser at 810 nm.

MATERIALS AND METHODS

For this investigation, 17 fresh pig mandibles were used no later than 6 hours after the animals' death. Immediately after death, the mandibles were cooled until 1 hour before use and then returned to room temperature. Six standardized incisions per laser parameter combination, 3 cm in length, were made in the oral mucosa parallel to the border of the mandible. Three incisions per parameter were positioned 5 mm below the gingival margin, and three in the thicker soft tissue 5 mm from the lower border of the mandible. The average thickness of these tissues was 0.8–2 mm. A total of 198 incisions was made. The incisions were performed in the anterior, middle, and posterior third of the mandible. The incision length was standardized, with a template positioned 3 mm below the planned incision site during the performance of each incision. The laser handpiece was attached to a motorized device to standardize the incision and to control movements. Radiation was applied by the handpiece at a speed of 10 mm/second and was timed with a stopwatch. This experimental model has been used for many years in standardized studies [2,3,15].

Treatment was carried out with 33 different settings of the Dentek LD 15 diode laser (Dentek Austria GMBH, Gasselberg 53–54, A-8564 Gaisfeld, Austria). This laser has a wavelength of 810 nm. The laser output power ranges from 0.5–15 W. A pulse rate of 2–32 msec in pulsed mode and a frequency of 1.5–250 Hz can be used. The laser can also be operated in continuous wave mode. The target beam is generated by a helium-neon laser (533 nm, 1 mW).

The application occured with a 200- or 400-μm tip. Not only continuous wave (cw), but also pulsed modes with a frequency of 25 Hz and 30-msec pulse width, and 50 Hz and 10 msec, were used. The mentioned output powers do not correspond to the output powers described on the laser instrument, but were measured directly at the outflow of radiation with a wattmeter. The 400-μm tip was used in a measured range of 0.5–4.5 W, whereas a maximum of 2 W could be achieved for the thinner 200-μm tip.

Immediately after irradiation, incisions were dissected out with a margin exceeding 5 mm and divided with a scalpel. The bone underlying each incision was marked, labeled, and photographed. The chief evaluation factor for bone was charring, which was selected as a gross indicator of significant laser-induced thermal damage.

The soft-tissue samples were fixed directly in 10% neutral-buffered formalin for 15 days and were dehydrated for 8 days in a rising alcohol series. After treatment with terpineol and toluol for 10 days, the specimens were embedded in paraffin for another 8 days. A total of 198 wax blocks was prepared, and 6-μm sections were cut routinely with the microtome and stained with Serius red. Measurements were made from 15 slides per parameter and incision site. A photographic record of the results was made. Incision depth and width, as well as depth and width of adjacent tissue damage, were determined. A typical slide with measurement locations is shown in Figure 1.

RESULTS

Mean incision depths and widths, as well as mean collateral vertical and horizontal damage measurements and standard deviations, are presented in Tables 1 and 2. Mean incision depths using cw and a 400-μm tip measured from 217.5–647.5 μm, and mean incision widths from 78.8–357.5 μm. Using the 200-μm tip, mean incision depths of 405–605 μm and mean widths of 87.6–278.3 μm were measured. In the 50-Hz/10-msec pulsed mode, mean depths ranged from 295–737.5 μm. Mean widths of 162.5–400 μm were

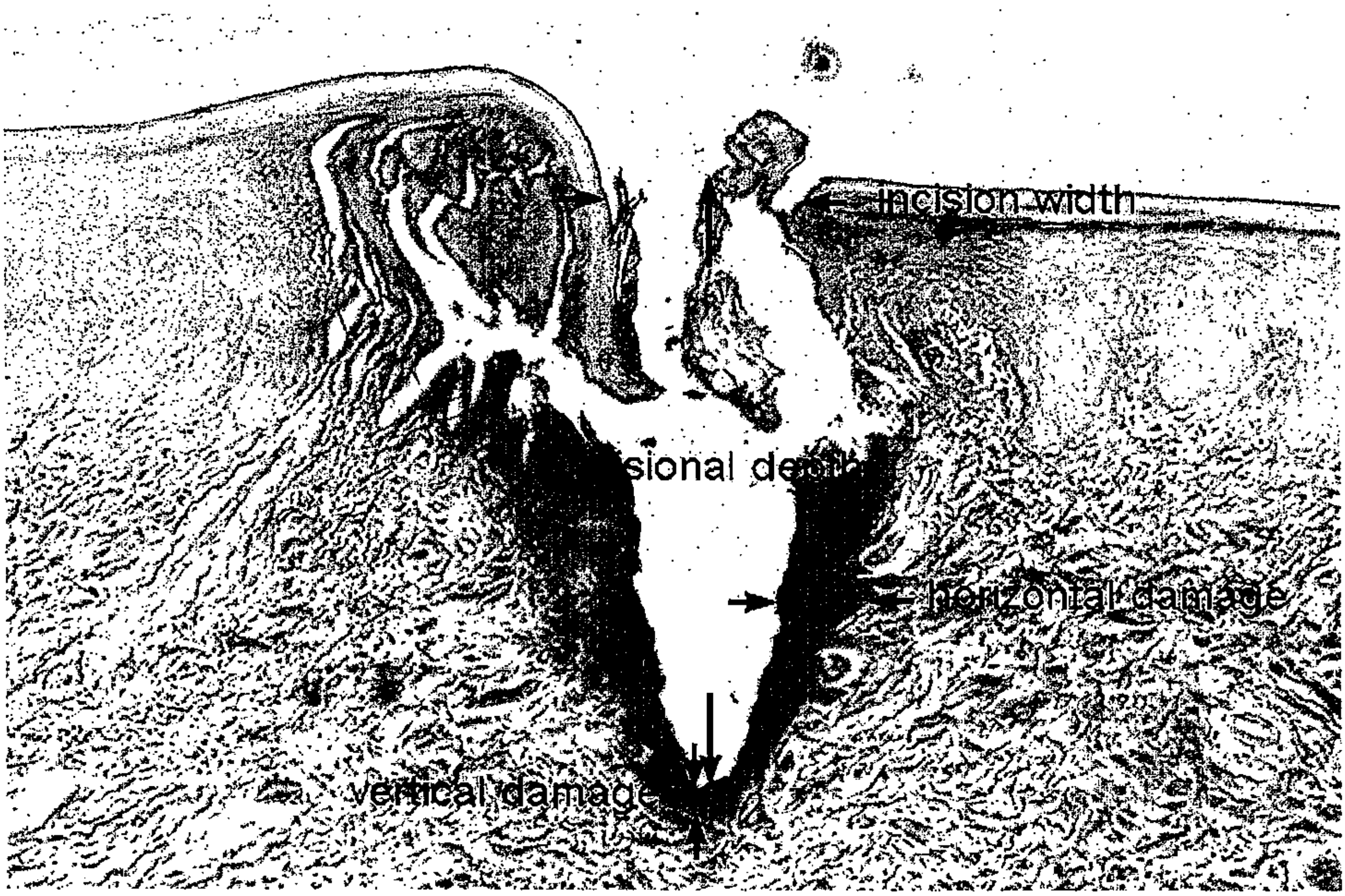


Fig. 1. Incisional and collateral effects of diode laser in oral soft tissue.

measured for the 400-μm tip, while mean incision depths from 240–614.3 μm and mean widths from 103.8–210.3 μm were determined for the 200-μm tip. The 25-Hz/30 msec pulsed mode revealed mean depths from 298.5–527 μm and mean widths from 138.8–377.5 μm for the thicker tip, and mean incision depths from 201.6–345 μm and widths from 115.2–244.3 μm for the thinner tip.

Mean vertical damage measured from 22.5–85.3 μm and mean horizontal damage from 28.3–98 μm, irrespective of the laser parameters and tips used.

The depth and width of incision correlated strongly and positively with average powers, but not with laser parameters or the tips used.

To the naked eye, no laser damage was visible in the bone underlying the incisions, either in the thicker soft tissue or in the thinner soft tissue.

DISCUSSION

Histologic events resulting from soft-tissue incisions with different CO_2 lasers have already been determined. Histologic effects are related to the parameters used and the beam characteristics rather than wavelength; greater damage to the collateral tissues has been observed with the use of the constant wave mode. This effect enhances thermocoagulation to achieve hemostasis and provide a bloodless surgical field. The desired results with the least risk of unwanted thermal damage can be achieved with very short pulses at the highest power density for the shortest time possible [2]. The extent of collateral thermal effects is smaller by a factor of about 2–3 for the superpulse mode in comparison to the cw mode [16,17]. A wide range of clinical effects can be achieved consistently and predictably in soft tissue, depending on the parameter configuration selected. The use of higher average powers correlates with increasing depths of incision. Incision width and collateral damage are the results of complex interactions between the different laser parameter variables, as mentioned. Incision shape and width are strongly mode-dependent. The cw mode produces

TABLE 1. Incisional and Collateral Effects of 400-μm Tip*

Average power (W)	Pulse width (msec)	Pulse repetition (Hz)	Mean ± SD incision depth in μm (n)	Mean ± SD incision width in μm (n)	Mean ± SD vertical damage in μm (n)	Mean ± SD horizontal damage in μm (n)
0.5		cw	217.5 ± 12.6 (15)	78.8 ± 19.3 (15)	30 ± 4.0 (15)	29.8 ± 1.3 (15)
1		cw	230 ± 18.7 (15)	119.3 ± 8.7 (15)	22.5 ± 6.5 (15)	37.5 ± 6.5 (15)
1.5		cw	272.3 ± 12.3 (15)	175 ± 23.8 (15)	44.5 ± 5.3 (15)	56.3 ± 25 (15)
2		cw	302.5 ± 22.2 (15)	205 ± 17.3 (15)	40 ± 8.2 (15)	77.5 ± 2.1 (15)
2.5		cw	421.3 ± 19.3 (15)	277.5 ± 20.6 (15)	48.8 ± 4.8 (15)	76.8 ± 4.6 (15)
3.5		cw	593 ± 9.5 (15)	300 ± 7.1 (15)	46.3 ± 5.1 (15)	73.3 ± 11.6 (15)
4.5		cw	647.5 ± 9.6 (15)	357.5 ± 30.3 (15)	55 ± 4.1 (15)	98 ± 33.4 (15)
0.5	30	25	298.5 ± 11.5 (15)	138.8 ± 8.5 (15)	35 ± 12.9 (15)	40 ± 4.1 (15)
1	30	25	380 ± 40.8 (15)	162.5 ± 6.5 (15)	28.3 ± 2.4 (15)	51.8 ± 16 (15)
1.5	30	25	416.3 ± 13.8 (15)	218.8 ± 1.7 (15)	23.3 ± 5.4 (15)	55.75 ± 4.3 (15)
2	30	25	488.7 ± 12.6 (15)	275.7 ± 14.1 (15)	48.6 ± 7.7 (15)	49 ± 2.6 (15)
2.5	30	25	476.3 ± 18 (15)	371.3 ± 8.5 (15)	44.9 ± 10.2 (15)	66.7 ± 5.8 (15)
3.5	30	25	497 ± 12.6 (15)	367 ± 15 (15)	57.5 ± 6.5 (15)	72.5 ± 32 (15)
4.5	30	25	527 ± 22.2 (15)	377.5 ± 45.7 (15)	56.3 ± 4.8 (15)	97.5 ± 12.6 (15)
0.5	10	50	295 ± 13 (15)	213.75 ± 4.8 (15)	28.8 ± 3 (15)	37.5 ± 2.9 (15)
1	10	50	477.5 ± 9.6 (15)	162.5 ± 8.7 (15)	23.8 ± 4.8 (15)	35 ± 5.8 (15)
1.5	10	50	492.5 ± 6.5 (15)	248.8 ± 9.8 (15)	43.8 ± 4.8 (15)	63.3 ± 7 (15)
2	10	50	590 ± 8.2 (15)	304.8 ± 12.7 (15)	34.5 ± 5.3 (15)	55 ± 5.8 (15)
2.5	10	50	587 ± 20.6 (15)	372.7 ± 20.2 (15)	75 ± 20.4 (15)	78.8 ± 29.5 (15)
3.5	10	50	707.5 ± 17.1 (15)	400 ± 8.2 (15)	70 ± 21.6 (15)	65 ± 12.9 (15)
4.5	10	50	737.5 ± 9.6 (15)	377.5 ± 48 (15)	80 ± 35.8 (15)	87.2 ± 8.6 (15)

*SD, standard deviation.

TABLE 2. Incisional and Collateral Effects of 200-μm Tip*

Average power (W)	Pulse width (msec)	Pulse repetition (Hz)	Mean ± SD incision depth in μm (n)	Mean ± SD incision width in μm (n)	Mean ± SD vertical damage in μm (n)	Mean ± SD horizontal damage in μm (n)
0.5		cw	405 ± 20.8 (15)	98.3 ± 9.3 (15)	52 ± 4.3 (15)	53.9 ± 8.1 (15)
1		cw	475.7 ± 8.9 (15)	87.6 ± 13.7 (15)	47.8 ± 4.7 (15)	55.5 ± 11.3 (15)
1.5		cw	520.5 ± 29.7 (15)	138.3 ± 9.3 (15)	60.3 ± 5.6 (15)	59.8 ± 7.5 (15)
2		cw	605 ± 16.38 (15)	278.3 ± 19.8 (15)	59.5 ± 8.6 (15)	62 ± 9.4 (15)
0.5	30	25	201.6 ± 6.3 (15)	195.8 ± 5.7 (15)	29.3 ± 3.3 (15)	28.3 ± 3.3 (15)
1	30	25	307.5 ± 9.6 (15)	115.2 ± 11.1 (15)	37.5 ± 6.5 (15)	31.5 ± 5 (15)
1.5	30	25	262.5 ± 6.5 (15)	204.3 ± 9.9 (15)	60.3 ± 5.6 (15)	48.8 ± 3 (15)
2	30	25	345 ± 12.9 (15)	244.3 ± 8.3 (15)	58.4 ± 11.6 (15)	42.7 ± 7.9 (15)
0.5	10	50	240 ± 18.3 (15)	103.8 ± 11.1 (15)	38.8 ± 6.3 (15)	49.5 ± 4.2 (15)
1	10	50	306.4 ± 7.7 (15)	111.8 ± 12.5 (15)	85.3 ± 8.5 (15)	60.6 ± 8.2 (15)
1.5	10	50	566.3 ± 12.5 (15)	157.8 ± 13.3 (15)	81.4 ± 9 (15)	53.1 ± 8.5 (15)
2	10	50	614.3 ± 11.8 (15)	210.3 ± 7.6 (15)	75.9 ± 6.9 (15)	56.2 ± 10.5 (15)

*SD, standard deviation.

relatively wide, straight-sided incisions. Therefore, this mode can cut or ablate large amounts of tissue. Comparable incisions in depth can be achieved equally quickly and efficiently at lower average powers with the superpulse mode [3].

Of the clinically common dental lasers, the CO_2 laser usually produces narrower zones of damage in soft tissues than does the Nd:YAG laser because of the greater absorption of the CO_2 wavelength by soft tissues [18–20]. The average zone of damage caused by CO_2 lasers after laser incision in soft tissues is less than 0.6 mm [16,18, 21–23]. This finding is directly relevant to clinical dentistry because of concerns regarding possible damage to neighboring structures, such as teeth or bone, during soft-tissue laser surgery. Comparisons of Nd:YAG and diode laser show that, when used in contact mode, these two lasers produce similar extents of tissue vaporization and zones of thermal necrosis [24]. With 10–12 W, values of 0.625 and 0.79, respectively, and 0.48 and 0.9 mm, respectively, are obtained with diode and Nd:YAG lasers [25,26]. Although the extent of tissue vaporization at low powers is less for the diode laser, these differences are not apparent at higher laser powers and energies that can be clinically applied with commercially available units [24].

However, the radiation of a diode laser shows a greater absorption and a smaller penetration depth than that of a Nd:YAG laser, especially in blood-rich tissue. The wavelength of the diode laser is considerably more absorbed due to hemoglobin than that of the Nd:YAG laser. This causes not only a better incision performance but also an excellent coagulation of tissue [27]. The thickness of the charring layer and the coagulation layer, and incision depth, are similar for the diode laser and the Nd:YAG laser with the same laser settings [25].

Advantages of the diode laser seen in our clinical routine are that it requires no anesthetics and that the wounds heal softly. Moreover, its simple use allows very good modeling of the gingiva.

Favorable results in other dental areas encouraged us to determine the surgical effects on soft tissue produced by a diode laser, using two different tips in continuous wave mode and two pulsed modes. According to our results, the incision depth correlates strongly and positively with the average power, whereas incision shape and width depend neither on the mode used, nor on the fiber. These results confirm the findings reported by Judy et al. [25], who investigated the Nd:YAG laser. A possible explanation may be the chopped operating mode of the diode laser.

The horizontal and vertical damage zone depends neither on the average power, nor on the mode used or fiber tip. When compared with the CO_2 laser, one characteristic difference from the diode laser can be found, namely that no trend of greater damage to lateral tissues with the constant wave mode at higher power levels can be observed. Also, no charring of bone underlying 0.8-mm-thick soft tissue was observed with the continuous wave mode, or with the pulsed mode at an average power of 4.5 W. Several authors have reported that the use of the CO_2 laser can result in possible damage to the underlying bone around teeth when cutting tissues with either pulsed or continuous wave CO_2 lasers [2,3,28]. Clayman et al. [29] described minimal damage to the bone under gingiva treated with a CO_2 laser, but the gingiva healed well, although over a longer period of time. It is possible that the laser wavelength is transmitted through the surface layer of the bone into the inner cancellous tissue. Simple observation of the surface does not preclude inner damage. However, in this study, low-power settings were used, so that the possibility of damage was extremely remote.

Blood circulation acts as a potential, not very significant coolant. One typical example of heat convection in tissue is heat transfer due to blood flow. Due to the low perfusion of most tissues, however, heat convection is negligible in a first approximation. Only during long exposures does it play a significant role [30]. Certainly an adverse cellular response will over time change the histological picture of the tissues affected. Yet the focus of this study was on the measurement of direct thermal damage, not on tissue response to irradiation.

Contrary to other investigations [3,7], deeper incisions could be achieved with the diode laser than were achieved by other authors with the CO_2 or Nd:YAG laser at the same power setting, even with fewer movements of the delivery system. Even the horizontal and vertical zones of thermal damage are in a comparable range. These findings, i.e., the remarkable cutting ability and the tolerable damage zone, clearly show that the diode laser is a very effective and, because of its excellent coagulation ability, useful alternative in soft-tissue surgery of the oral cavity.

REFERENCES

1. Liboon J, Funkhouser W, Terris D. Comparison of mucosal incisions made by scalpel, CO_2 laser, electrocautery and constant-voltage electrocautery. Otolaryngol Head Neck Surg 1997;116:379–385.
2. Wilder-Smith P, Arrastia AM, Liaw LH, Berns M. Incision properties and thermal effects of thoursee CO_2 lasers in soft tissue. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:685–691.
3. Wilder-Smith P, Dang J, Kurosaki T. Investigating the range of surgical effects on soft tissue produced by a carbon dioxide laser. J Am Dent Assoc 1997;128:583–588.
4. Pick RM, Colvard MD. Current status of lasers in soft tissue dental surgery. J Periodontol 1993;64:589–602.
5. Gold SI, Vilardi MA. Pulsed laser beam effects on gingiva. J Clin Periodontol 1994;21:391–396.
6. White JM, Goodis HE, Rose CL. Use of the pulsed Nd:YAG Laser for intraoral soft tissue surgery. Lasers Surg Med 1991;11:455–561.
7. Perry D, Goodis H, White J. In vitro study of the effects of Nd:YAG laser probe parameters on bovine oral soft tissue excision. Lasers Surg Med 1997;20:39–46.
8. Douglas N, Dederich NH. Laser/tissue interaction. Alpha Omegan 1991;84:33–36.
9. Matin NH, Orikasa N, Kusakari H. Effects of CO_2 laser irradiation to periodontal tissues. Int Soc Laser Dent 1995; Abstracts 9.
10. Walsh JT Jr, Deutsch TF. Pulsed CO_2 laser tissue ablation. measurement of the ablation rate. Lasers Surg Med 1988;8:3:264–275.

11. White JM, Goodis HE, Yessic MJ, Meyers TD. Histologic effects of a high repetition pulsed Nd:YAG laser on oral soft tissue. In: Wigor HA, Featherstone JDB, White JM, eds. Lasers in dentistry. International Society for Optical Engineering. Proc SPIE 2394; 1995. p 129–141.
12. Moritz A, Schoop U, Goharkhay K, Wernisch J, Sperr W. Procedures for enamel and dentin conditioning: a comparison of conventional and innovative methods. J Esthet Dent 1998;10:84–93.
13. Moritz A, Schoop U, Goharkhay K, Doertbudak O, Sperr W. Rapid report: irradiation of infected root canals with a diode laser in vivo. Lasers Surg Med 1997;21:221–226.
14. Moritz A, Schoop U, Goharkhay K, Wernisch J, Sperr W. Treatment of periodontal pockets with a diode laser. Lasers Surg Med 1998;22:302–311.
15. Wilder-Smith P, Dang J, Kurosaki T, Neev J. The influence of laser parameter configurations at 9.3 microns on incisional and collateral effects in soft tissue. Oral Surg Oral Med Oral Path Oral Radiol Endod 1997;84:22–27.
16. Fitzpatrick RE, Ruiz-Esparza J, Goldman MP. The depth of thermal necrosis using the CO_2 laser: a comparison of the superpulsed mode and conventional mode. J Dermatol Surg Oncol 1991;17:340–344.
17. Bar-Am A, Lessing JB, Niv J, Brenner SH, Peyser MR. High and low-power CO_2 lasers. Comparison of results for three clinical indications. J Reprod Med 1993;38:455–458.
18. Nelson JS, Berns MW. Basic laser physics and tissue interactions. Contemp Dermatol 1988;2:3–15.
19. Luciano AA, Frishman GN, Maier DB. A comparative analysis of adhesion reduction, tissue effects, and incising characteristics of electrosurgery, CO_2 laser, and Nd:YAG laser at operative laparoscopy: an animal study. Laparoendoscopic Surg 1992;2:287–292.
20. Scherer H, Fuhrer A, Hopf J. Current status of laser surgery of benign diseases in the area of the soft palate. Laryngol Rhinol Otol 1994;73:14–20.
21. Zweig AD, Meierhofer B, Muller OM. Lateral thermal damage along pulsed laser incisions. Laser Surg Med 1990;10:262–274.
22. McKenzie AL. A thoursee-zone model of soft-tissue damage by a CO_2 laser. Phys Med Biol 1986;31:967–983.
23. Polanyi TG. Laser physics: medical applications. Otolaryngol Clin North Am 1983;16:753–774.
24. Wyman A, Duffy S, Sweetland HM, Sharp F, Rogers K. Preliminary evaluation of a new high power diode laser. Lasers Surg Med 1992;12:506–509.
25. Judy MM, Matthews L, Aronoff B, Hults D. Soft tissue studies with 805 nm diode laser radiation: thermal effects with contact tips and comparison with effects of 1064 nm Nd:YAG laser radiation. Lasers Surg Med 1993; 13:528–536.
26. Schoursoder T, Brackett K, Joffe S. An experimental study of the effects of electrocautery and various lasers on gastrointestinal tissue. Surgery 1987;101:691–697.
27. Rastegar S, Motamedi M, Jacques SL, Kim MB. Theoretical analysis of equivalency of high-power diode laser (810 nm) and Nd:YAG laser (1064 nm) for coagulation of tissue. Predictions for prostate coagulation. [Proceedings of the Laser–Tissue Interaction III. 21–24 Jan (1992). Los Angeles] Washington, Soc of Photo-Optical Instrumentation Engineers.
28. Goldman L, Shumrick DA, Rockwell RJ, Meyer R. The laser in maxillofacial surgery. Arch Surg 1968;96:397—400.
29. Clayman L, Fuller T, Beckman H. Healing of continuous-wave and rapid superpulsed, carbon dioxide, laser induced bone defects. J Oral Surg 197836:932–937.
30. Niemz M. Laser tissue interactions. Springer, Berlin; 1996. p 69.

elexxion AG

Schützenstraße 84 · 78315 Radolfzell · Germany
Tel. 0049 (0) 7732-822 99 0 · Fax 0049 (0) 7732-822 99 77
info@elexxion.com · www.elexxion.com