Erbium:YAG Laser Application in the Second Phase of Implant Surgery: A Pilot Study in 20 Patients

Josep Arnabat-Domínguez, DDS, MD[1]/Antonio Jesús España-Tost, DDS, MD[1]/
Leonardo Berini-Aytés, DDS, MD, PhD[2]/Cosme Gay-Escoda, DDS, MD, PhD[3]

Purpose: Conventional implant dentistry implies 2 surgical stages. In this context, pain is often present in the second stage, despite the fact that it is comparatively less aggressive for the patient. The present pilot study proposes application of Erbium:YAG (Er:YAG) laser for second-stage implant surgery. **Materials and Methods:** Twenty patients were studied with a total of 50 implants in which osseointegration was complete. The subjects were divided into 2 groups: a control group (10 patients with 25 implants), subjected to conventional second-stage surgery; and a group of 10 subjects (also with 25 implants) treated with the Er:YAG laser at second-stage implant surgery. **Results:** The use of Er:YAG laser obviated the need for local anesthesia and minimized postoperative pain and time needed before starting the second stage. With regard to surgical duration, quality of hemostasis, and success in implant treatment, no differences were reported. **Discussion:** In the second stage of implant surgery, different types of laser have been used, taking advantage of their bacteridal effect; disadvantages arise from inducing damage to the implant surface and adverse thermal effects. **Conclusion:** The advantages afforded by laser treatment include technical simplicity, the possibility of obviating local anesthesia, absence of postoperative pain and edema, and complete tissue healing by day 5, thus facilitating rapid prosthetic rehabilitation. The technique described can be used in all cases except situations where esthetic considerations prevail in anterior areas, or in the event of a lack of keratinized gingiva surrounding the implant. (INT J ORAL MAXILLOFAC IMPLANTS 2003;18:104–112)

Key words: dental implants, endosseous dental implantation, lasers

One of the most important considerations during second-stage endosseous implant surgery is the correct manipulation of peri-implant soft tissues to ensure adequate esthetic results and the maintenance of good health. Depending on the technique employed, the implant can be surrounded by either keratinized gingiva or free mucosa. The former consists of collagen-rich connective tissue covered by keratinized epithelium, while free mucosa comprises a lamina propria with little collagen but abundant elastic fibers covered by a non-keratinized epithelium.[1,2]

The need to retain keratinized gingiva around the peri-implant surface is the subject of considerable debate.[3–11] While some authors consider the presence of this type of tissue to be essential for implant success,[4,5,9,11] others are of the opinion that the presence of keratininzed gingiva does not affect implant survival or peri-implant status, although more thorough hygiene of these implants is indicated.

The elimination of peri-implant keratinized tissue must therefore be considered with caution. In the authors' clinical experience, second-stage implant surgery, while usually not as aggressive as first-stage surgery, may involve almost as much postoperative discomfort for the patient. The authors have generally found the postoperative period to be much more comfortable when different lasers are used in oral surgery.

[1]Physician and Stomatologist, Barcelona, Spain; Associate Professor of Oral Surgery and Professor of the Master (Postgraduate Program) in Oral Surgery and Implantology, University of Barcelona Dental School, Barcelona, Spain.

[2]Assistant Professor of Oral and Maxillofacial Surgery and Professor of the Master in Oral Surgery and Implantology, University of Barcelona Dental School, Barcelona, Spain.

[3]Professor of Oral and Maxillofacial Surgery and Director of the Master in Oral Surgery and Implantology, University of Barcelona Dental School, Barcelona, Spain; Maxillofacial Surgeon, Teknon Medical Center, Barcelona, Spain.

Reprint requests: Dr Cosme Gay-Escoda, Ganduxer 140, 4, 08022 - Barcelona, Spain. E-mail: cgay@bell.ub.es

The carbon dioxide (CO_2) laser is one of the most widely employed lasers in oral surgery. Its use has been extensively described by many authors.[12–14] However, application of the CO_2 laser to implant surgery may by inadvisable because of the thermal effects generated. Direct irradiation of the bone should be avoided, since bone necrosis may result. Although laser energy is reflected by polished metal surfaces, the associated temperature rise in adjacent tissues can be transmitted to the implant, thus possibly affecting osseointegration.[15] Nevertheless, some authors have used this type of laser for both second-stage implant surgery and for decontaminating the implant surface in cases of peri-implantitis, with no alterations being reported in either the implant or in the osseointegration process.[16–20]

The erbium:YAG (Er:YAG) laser is a pulsed laser with no thermal effect that can be applied to both soft and hard tissues.[21] Since the beam is reflected by polished metal surfaces, it has no effects upon titanium implant surfaces. The effect of the Er:YAG laser on the implant surface depends on the energy fluence. When certain energy fluences are exceeded, the laws of linear optics do not apply and plasma formation can be detected on the superficial layers of metals.[22]

In second-stage implant surgery, bone is often seen to form above the healing cap or at the implant margins upon removal of the sealing cap. Elimination of this bone can be performed using rotary or manual instruments. In either case, caution is essential to avoid damage to the implant surface. In such situations, the Er:YAG laser can eliminate soft tissue as well as ablate bone without damaging the implant surface.[23]

Recent studies[24–26] have found osseointegration to be expedited when using the Er:YAG laser compared to employing conventional rotary instruments. The laser is well absorbed by bone, without a rise in temperature, and good healing is facilitated. The present pilot study was conducted to evaluate the advantages of the Er:YAG laser versus conventional surgery in second-stage endosseous implant surgery of the jaws.

MATERIALS AND METHODS

This pilot study comprised 20 consecutive patients subjected to second-stage implant surgery at the Master (Postgraduate Program) in Oral Surgery and Implantology of the Dental School of the University of Barcelona. Patients with single anterior-zone implants were excluded, as were those with keratinized gingiva that failed to cover the entire implant perimeter.

The patients were randomized according to Efron's method[27] and divided into 2 groups: (1) a control group of 10 patients with 25 implants, subjected to conventional second-stage surgery; and (2) an experimental group of 10 subjects (also with 25 implants) treated with an Er:YAG laser at second-stage implant surgery, based on the technique described below (Table 1). In the control group, surgery was performed as follows: Following anesthetic infiltration with 4% carticaine and 1:100,000 epinephrine, a small mucoperiosteal flap was raised and the healing caps were replaced by healing posts. The surgical zone was subsequently sutured using 3/0 silk.

In all patients, sufficient keratinized gingival tissue was present to completely surround the implant, with a variable tissue thickness (0.5 to 3.0 mm) between the healing cap surface and the gingival surface.

An Er:YAG laser (wavelength 2,940 nm) (Key laser II, KaVo, Biberach, Germany) was used. The treatments were performed employing the 2051 and 2056 handpieces, with the former operating in non-contact mode and the latter in contact mode with a quartz prism tip.

Implant Location

In those patients where the healing cap was not visualized by transparency, a surgical guide was used with radiologic control to precisely determine the implant location.

Surgery

In all cases, surgery was started using the 2051 non-contact handpiece under a water spray (0.3 mL/minute) at a frequency of 2 Hz and a pulse power rating of 250 mJ, without anesthesia. The handpiece was used at a focal distance of 14 mm. In those patients who reported no perioperative pain, the parameters were modified, increasing the frequency and/or pulse energy. In 2 cases, a maximum of 500 mJ and 4 Hz was reached (the maximum dose afforded by the Key laser), without using anesthesia (Figs 1 and 2).

Anesthesia

Anesthesia was performed when the intraoperative discomfort or bleeding prevented the continuation of surgery. In one case it was requested by the patient because of a painful sensation during lasing (patient #2) and in another case, anesthesia was delivered to control bleeding, which did not allow adequate visualization of the cover screw (patient #8). One milliliter of 4% carticaine solution with 1:100,000 epinephrine was used via infiltration

Table 1	Clinical Data of Patients Included in the Experimental and Control Groups			
Patients (in surgical order)	Group	No. of implants	Edentulism	Anesthesia
1	Control	1	Single (Maxillary right first premolar)	1 mL of 4% carticaine + 1:100,000 epinephrine
2	Experimental	3	Mandibular distal extension	1 mL of 4% carticaine + 1:100,000 epinephrine
3	Experimental	1	Single (Maxillary right second molar)	None
4	Control	2	Total mandibular	1.2 mL of 4% carticaine + 1:100,000 epinephrine
5	Control	5	Total mandibular	1.8 mL of 4% carticaine + 1:100,000 epinephrine
6	Experimental	1	Single (Maxillary left second premolar)	None
7	Experimental	3	Maxillary distal extension	None
8	Experimental	4	Total maxillary	1 mL of 4% carticaine + 1:100,000 epinephrine
9	Experimental	2	Mandibular distal extension	None
10	Control	3	Mandibular distal extension	1.5 mL of 4% carticaine + 1:100,000 epinephrine
11	Experimental	5	Mandibular distal extension (left and right)	None
12	Experimental	2	Total mandibular	None
13	Control	1	Single (Maxillary left second premolar)	1 mL of 4% carticaine + 1:100,000 epinephrine
14	Experimental	3	Mandibular distal extension	None
15	Control	2	Mandibular distal extension (Maxillary left second premolar)	1 mL of 4% carticaine + 1:100,000 epinephrine
16	Control	3	Maxillary distal extension	1.8 mL of 4% carticaine + 1:100,000 epinephrine
17	Experimental	1	Single (Maxillary right first premolar)	None
18	Control	1	Single (Mandibular right second premolar)	1 mL of 4% carticaine + 1:100,000 epinephrine
19	Control	4	Maxillary (four maxillary incisors)	1.8 mL of 4% carticaine + 1:100,000 epinephrine
20	Control	3	Maxillary distal extension	1.8 mL of 4% carticaine + 1:100,000 epinephrine

Fig 1   Second-stage implant surgery in a patient receiving 4 Brånemark System implants in the maxilla. The periodontic handpiece with quartz crystal fiber and water spray was used (patient #8).

Fig 2   Appearance of the implant heads after removal of the healing posts, 1 week after surgery (patient #8).

Fig 3 Elimination of soft tissue above the implant. All soft tissue removal could be performed without anesthesia. Bleeding is seen, since the Er:YAG laser exerts very little thermal effect (patient #11).

Fig 4 Immediate postoperative situation following healing post placement (patient #11).

around the implant. The amount of anesthetic solution never exceeded 0.2 mL per exposed implant. Despite the vasoconstrictive action of the epinephrine when bleeding continued to obstruct action of the laser beam, the 2056 (Kavo) handpiece was used, since this is the instrument used for periodontal surgery, with the quartz prism tip under water drip for contact working. The handpiece was not used, because it generates a slight thermal effect.

When the tissues were anesthetized, a frequency of 15 Hz and a pulse power rating of 250 mJ were selected, thus allowing a shortening of surgical time because of the increased ablation effect. After the tissues covering the implant were eliminated, the healing cap was replaced by the corresponding transepithelial post, allowing healing by secondary intention (Figs 3 and 4).

In the control group, the technique usually employed in the Unit of Oral Surgery and Implantology, Master of the Dental School of the University of Barcelona, was performed. This consisted of a crestal incision with connection of the transepithelial abutment and suturing.

Postoperative Treatment

All patients operated on by both techniques received the same analgesia (acetaminophen 650 mg, for a maximum of 4 doses daily, spaced 6 hours apart). The patients were instructed to take the medication only when necessary, and a visual analog scale (VAS) was provided to allow the patients to score pain daily for the first 7 days. Pain was scored on a scale of 1 to 5 (1 = total absence of pain; 5 = worst pain imaginable). The patients were also asked to record their use of analgesic medication during the postoperative period.

Evaluation of the Surgical Technique

The patients were asked about their degree of satisfaction with the perioperative and postoperative management received.

To evaluate the technique employed, the duration of surgery and the need for local anesthesia were recorded. The appearance of intraoperative (eg, bleeding) and postoperative complications (pain or any kind of discomfort) was also documented. The time to healing was recorded, with a clinical assessment of the peri-implant tissues at the end of surgery and again 7 days after the operation. Absence or presence of soft tissue inflammation, edema, gingival bleeding, crevicular exudates, and pain was assessed. Finally, the minimum time required to commence prosthetic treatment was recorded. A single observer visited all patients. This observer had been previously calibrated by reviewing all abutment connection surgeries at the Unit of Oral Surgery and Implantology.

Statistical Analysis

A descriptive study was conducted, together with a comparative analysis based on the Pearson chi-square test for the comparison of qualitative variables and the Student t test for the comparison of means. Statistical significance was considered for $P < .05$. The SPSS statistical package (version 10.0; SPSS, Chicago, IL) was used throughout.

RESULTS

The 20 patients included in the study (11 men and 9 women; mean age 41.6 years, range 27 to 65 years, median age 41 years) received a total of 50 implants (Mark II, Brånemark System, Nobel Biocare, Göteborg, Sweden).

Fig 5 Appearance of the implant head and soft tissue healing 1 week after second-stage implant surgery (patient #11).

Fig 6 Healing abutment and soft tissue 1 week after second-stage implant surgery, in a patient of the control group (patient #16), immediately after removing the suture.

Eight of the 10 laser-treated patients (80%) needed no anesthesia, while all the control patients required carticaine infiltration (Table 1). The difference was significant (chi-square test, $P < .001$). Moreover, the 2 patients in the laser treatment group who required anesthesia received only 0.1 to 0.2 mL of solution, versus 0.2 to 0.4 mL in the control group.

In the experimental group, the mean duration of surgery was 6.28 minutes per implant (range 3.6 to 12), versus 7.44 minutes per implant (range 5 to 14) among the controls. The intergroup difference was not significant ($P = .069$).

Intraoperative bleeding was controlled without the need for additional measures, although abundant hemorrhage was the reason for local anesthetic-epinephrine administration in 1 of the 10 laser-treated subjects.

With respect to pain, none of the patients subjected to Er:YAG laser treatment required analgesia, and the corresponding VAS scores were all between 1 and 2 (8 patients responded with score 1 and two with score 2). However, of the 10 patients subjected to conventional surgery, 8 required analgesia, and the VAS score was between 1 and 4 (two patients scored 1, three scored 2, four scored 3, and one patient responded with a score of 4). The difference between the 2 groups was statistically significant ($P = .032$).

Peri-implant soft tissue evaluation was performed 7 days after surgery. In the laser-treated group, the clinical appearance was of complete healing, without bleeding or signs of inflammation. In all patients, prosthetic rehabilitation could be started on day 7 after surgery (Fig 5). In the control group, sutures were removed after 7 days of the surgery. Impression-making was postponed until swelling and edema had disappeared (Fig 6). In the laser-treatment group, prosthetic rehabilitation could be started on day 7.3 on average, versus on day 13.6 in the control group. The difference between the means was 6.3 days (95% confidence interval, 4.79 to 7.81) and reached statistical significance ($P < .005$).

All implants were followed up for a minimum of 6 months after second-stage implant surgery. There were no failures in either group.

DISCUSSION

The use of lasers in implant surgery is seldom mentioned in the literature, and long-term clinical trials conducted to date are insufficient to either confirm or reject the applicability of this new technology. The present study involving the Er:YAG laser is a pilot survey designed to establish the validity of the technique for second-stage implant surgery.

Other types of lasers have also been used in implant dentistry, with different advantages or inconveniences compared to the Er:YAG laser. In this sense, Walsh[13] was of the opinion that the CO_2 and Er:YAG lasers were best suited for this type of surgery. The indications for both lasers are specified in Table 2.

Since 1999, various authors have conducted in vitro studies with the Er:YAG laser and CO_2 laser (wavelength 9.6 nm) for preparing the bone bed and facilitating posterior implant placement.[28] Application of the surgical laser to the soft tissues surrounding or covering the implant offers a series of potential advantages[13]: improved control of possible bleeding, less mechanical trauma to the soft and hard tissues, prevention of local infection, less postoperative inflammation and pain, improved healing, and a lesser risk of postoperative bacteremia.

The type of laser used is an important consideration, since the effects upon the tissues vary substantially from one type to another. Pick and Colvard[29] in some cases used the CO_2 laser for second-stage implant surgery, since it can vaporize the overlying mucosa. However, they did not recommend the Neodymium:YAG (Nd:YAG) laser, since its thermal effect is comparatively much greater and can therefore damage both the implant and the surrounding tissues.

To understand these differences, it must be taken into account that each of the laser systems on the market operates at a different wavelength, which gives rise to different absorption coefficients. The CO_2 laser operates at a wavelength of 10,600 nm and is well absorbed by water, while the Nd:YAG laser, with a wavelength of 1,064 nm, is barely absorbed by water.

The oral tissues exposed to laser irradiation contain water in proportions of 70% to 90%. Consequently, CO_2 laser absorption is very effective in these tissues. Practically all the energy is absorbed in the first 0.2 mm beneath the surface. In contrast, the absorption coefficient in water of the Nd:YAG laser is lower, and the energy is therefore able to penetrate to a depth of about 3 mm.[13] This indicates that all the heat generated by the laser beam dissipates superficially when the CO_2 laser is used, but it is distributed more deeply by the Nd:YAG laser, reaching temperatures that can even damage bone.

The Er:YAG laser used in the present study operates at a wavelength of 2,940 nm and is largely absorbed by water. Since penetration of the beam is very superficial, the thermal effect upon the surrounding tissues is limited.[23,24,26] Although application of the Er:YAG laser was initially basically restricted to hard dental tissues, it is now increasingly used upon soft tissues.[30]

The present study took advantage of the good absorption of the Er:YAG laser to ablate the soft tissues overlying the implant. The laser was also used in some cases where bone had grown over the implant, since a number of studies have documented appropriate bone healing when using this type of laser.[26]

During laser application, some of the energy may be delivered to the implant; therefore, the consequences of such implant exposure should be known. When Er:YAG or CO_2 laser beams are applied to metal, energy reflection occurs. As a result, when the implant surface is irradiated by these lasers, no alterations are to be expected, as noted by Oyster and coworkers[17] after irradiating a titanium surface at a power rating of 20 W for 30 seconds. Nevertheless, Chu and associates[31] found the Nd:YAG laser to behave differently, with energy absorption by the

Table 2 Surgical Laser Indications in Implant Dentistry	
Clinical procedure	Laser indicated
Preparation of bone bed	Carbon dioxide 9.6 Er:YAG
Implant exposure (second-stage surgery)	Carbon dioxide or Er:YAG
Gingival surgery	Carbon dioxide or Er:YAG
Control of bacterial plaque	None
Removal of bacteria around ailing implants	Carbon dioxide, diode

metal and a considerable increase in irradiated implant temperature. Thus, these authors have discontinued the use of Nd:YAG lasers in proximity to implants. On the other hand, Block and colleagues[32] demonstrated fusion and alteration at the surface of plasma-sprayed and hydroxyapatite-coated titanium dental implants when using the Nd:YAG laser.

Rechmann and coworkers[33] lased different kinds of dental implants with different lasers. They observed that with Er:YAG there were micromorphologic changes with an average fluence of 7 Jcm[2], while with the CO_2 laser, there were neither changes nor ablation on the implant.[33] Kreisler and associates also assessed the effects on different implant surfaces of Nd:YAG, holmium:YAG, Er:YAG, and CO_2 lasers and concluded that the first 2 types should not be used for implant decontamination, because they harm the surface of all kinds of implants. The CO_2 and Er:YAG lasers can be used only at low power, because they can affect the implant surface. On the other hand, with the 890-nm GaAlAs diode laser, there are no changes on the implant surface.[22]

A study in dogs has shown that the CO_2 laser, alone or in combination with abrasive powder and membranes, can be used for implant decontamination, with no effect on osseous regeneration.[34]

The temperature rise associated with the Er:YAG laser has been found to be no greater than 47ºC, this being the threshold above which bone damage results from exposures lasting more than 1 minute.[35] The studies designed to measure such temperature increments have been conducted when the laser is applied in combination with the water spray of the laser unit. When this spray is not used, the temperature can rise to the point of bone damage. Barak and coworkers[36] have shown that the temperature rise resulting from CO_2 laser application to different implant types varies according to the laser power rating and exposure time. Accordingly, no thermal damage was observed when operating at a continuous 4 W for a period of less than 5 seconds. Likewise, the CO_2 laser at 0.05

seconds/pulse may yield 8 W in 5 seconds. With the Nd:YAG laser applied to soft tissues, Spencer and colleagues[18] found that important bone damage may occur. When similar energy levels are compared, the temperature increases are much greater with the Nd:YAG laser than with the CO_2 laser (from 8°C to 11°C and 1.4°C to 2.1°C, respectively).

In a recent study,[16] Mouhyi and associates evaluated temperature rise during the decontamination of implant surfaces using the CO_2 laser. They concluded that when implants were irradiated with a humid or wet surface at operating parameters of 8 W/10 ms/20 Hz for 5 seconds, the temperature increase was a mere 3°C. Therefore, the risk of altering osseointegration was minimal. However, when the irradiated surface was dry, the temperature rise was seen to be greater, exceeding the minimum threshold required for inflicting bone damage. Other clinical studies[37] involving the Er:YAG laser also support use of the water spray, since it prevents temperature elevation in the adjacent tissues.

Another postulated advantage of laser treatment is its bactericidal action. Many studies have evaluated this effect with the Er:YAG laser,[38] CO_2 laser,[20,39] Nd:YAG laser,[32] and soft laser.[40] Over 20 years ago Adrian and Gross described the use of CO_2 lasers for sterilizing metal surfaces.[41] However, these studies involved very high energies and prolonged exposure times (1.5 to 2.0 minutes), which are far too extreme for intraoral use.

Block and coworkers[32] used the Nd:YAG laser to irradiate implants contaminated by *Bacillus subtilis*. They found that although irradiation reduced the bacterial count on the implant surface, complete sterilization was not achieved. Kato and associates[20] in turn demonstrated the usefulness of the CO_2 laser for eliminating bacteria from the implant surface, with no associated surface alterations or temperature increases capable of damaging the connective and bony tissues. The soft laser also has a bactericidal effect. Haas and colleagues[40] reported that the combination of a 905-nm diode laser for 60 seconds and toluidine blue had a bactericidal effect on *Actinobacillus actinomycetemcomitans*, *Porphyromonas gingivalis*, and *Prevotella intermedia*.

The present study involved the performance of minimally invasive second-stage implant surgery, with minimal soft tissue ablation. The mucosa was penetrated to allow removal of the locking screw and enable placement of the transepithelial healing post. This ensured patient comfort during the postoperative period and rapid healing. Bernhart and coworkers,[42] in application to single implants, likewise proposed minimally invasive incisions to ensure rapid healing.

In the control group, the second-stage surgeries were carried out in the conventional manner. As Moy and associates reported,[43] it is preferred that an incision be made on the ridge crest when uncovering the implants. Punch incisions are not preferred because there is certain loss of attached gingiva. If in some cases of this study, the punch technique had been used, then the healing process may have been faster, and the time elapsed before impression taking would have been similar to the study group, because the punch technique does not usually require suture placement.

No flaps were prepared in the experimental group, and only the soft tissue above the implant was removed. This could give rise to a problem of insufficient attached gingiva to surround the full implant perimeter.[44] The technique employed may thus be contraindicated in 2 situations: *(1)* application to zones where esthetic considerations are important, since laser treatment does not allow mucogingival papilla reconstruction techniques; and *(2)* in patients in whom little keratinized gingival tissue is available.[42] This latter contraindication may be only relative, since authors such as Delgado and colleagues[45] have pointed out that peri-implant health is more dependent upon patient observation of good implant hygiene than on the presence of ketratinized gingival tissue. In this context, appropriate implant maintenance resulted in a similar success rate, regardless of the existence or absence of attached gingival tissue.[45]

Wennström and coworkers[1] and Krekeler and associates[4] compared different peri-implantitis indicators such as Plaque Index, gingivitis, bleeding upon probing, probing depth, and marginal tissue mobility for implants with and without keratinized gingival tissue. They found that the absence of such keratinized tissue around the implant did not place maintenance of peri-implant soft tissue health at risk. In all of the present patients subjected to Er:YAG laser treatment, as much keratinized gingival tissue as possible was maintained to facilitate implant hygiene.

One of the main drawbacks of the laser is its high cost, although it has to be taken into account that the Er:YAG is a multidisciplinary device and as such, it can be used in operative dentistry, periodontics, endodontics, and oral surgery, which can compensate clinicians for the investment.

CONCLUSIONS

The results of this pilot study show that Er:YAG laser utilization can minimize surgical trauma. As a result, it was possible to obviate local anesthesia in

many of the second-stage implant operations performed (80%). Furthermore, when anesthesia proved necessary, the amount required was smaller than in the patients who underwent the conventional surgical technique. The patients in the experimental group reported comfort both during and after the operation, which was practically painless. The healing time following second-stage implant surgery was substantially shortened, thus allowing earlier prosthetic rehabilitation. Finally, it should be noted that the indications for the technique are limited by the need to maintain gingival keratinization and by esthetic requirements that involve flap techniques or gingival tissue enhancement.

REFERENCES

1. Wennström JL, Bengazi F, Lekholm U. The influence of masticatory mucosa on the peri-implant soft tissue condition. Clin Oral Implants Res 1994;5:1–8.
2. Buser D, Weber HP, Donath K, Fiorellini JP, Paquette DW, Williams RC. Soft tissue reactions to non-submerged unloaded titanium implants in beagle dogs. J Periodontol 1992;63:226–236.
3. Bower RC, Radny NR, Wall CD, Henry PJ. Clinical and microscopic findings in edentulous patients 3 years after incorporation of osseointegrated implant-supported bridgework. J Clin Periodontol 1989;16:580–587.
4. Krekeler G, Schilli W, Diemer J. Should the exit of the artificial abutment tooth be positioned in the region of the attached gingiva? Int J Oral Surg 1985;14:504–508.
5. Artzi Z, Tal H, Moses O, Kozlovsky A. Mucosal considerations for osseointegrated implants. J Prosthet Dent 1993;70:427–432.
6. Piñera M, Paredes J, Gargallo J, et al. Implantología. Revisión bibliográfica 1991–1992. Arch Odontoestomatol 1993;9:589–600.
7. Sánchez MA, Alaejos C, Valmaseda E, et al. Revisión de los artículos de implantología bucal publicados durante 1993 y 1994. Arch Odontoestomatol 1996;12:459–469.
8. Rodriguez P, Castro J, Ibero I. Importancia clínica de la encía insertada en periodoncia, ortodoncia, odontología restauradora e implantología. Av Periodontol 1998;10:121–133.
9. Jemt T, Book K, Börjesson T. Mucosal topography around implants in edentulous upper jaws. Photogrammetric three-dimensional measurements of the effect of replacement of a removable prosthesis with a fixed prosthesis. Clin Oral Implants Res 1994;5:220–228.
10. Strub JR, Gaberthöel, Grunder U. The role of attached gingiva in the health of peri-implant tissue in dogs. Part I. Clinical findings. Int J Periodontics Restorative Dent 1991;11:317–331.
11. Han TJ, Klokkevold PR, Takei HH. Strip gingival autograft used to correct mucogingival problems around implants. Int J Periodontics Restorative Dent 1995;15:405–411.
12. España AJ, Velasco V, Gay-Escoda C, Berini L, Arnabat J. Aplicaciones del Láser de CO_2 en Odontología. Madrid: Ergon, 1995.
13. Walsh LJ. The use of lasers in implantology: An overview. J Oral Implantol 1992;18:335–340.
14. Wigdor H, Walsh J, Featherstone J, Visuri S, Fried D, Waldvogel J. Lasers in dentistry. Lasers Surg Med 1995;16:103–133.
15. Adell R, Lekholm U, Rockler B, et al. Marginal tissue reactions at osseointegrated implants: A 3-year longitudinal prospective study. Int J Oral Surg 1986;15:39–52.
16. Mouhyi J, Sennerby L, Nammour S, Guillaume P, Van Reck J. Temperature increases during surface decontamination of titanium implants using CO_2 laser. Clin Oral Implants Res 1999;10:54–61.
17. Oyster DK, Parker WB, Gher ME. CO_2 lasers and temperature changes of titanium implants. J Periodontol 1995;66:1017–1024.
18. Spencer P, Cobb CM, Wielczka D, Glaros A, Morris P. Change in temperature of subjacent bone during soft tissue laser ablation. J Periodontol 1998;69:1278–1282.
19. 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 1998;13:666–671.
20. Kato T, Kusakari H, Hoshino E. Bactericidal efficacy of carbon dioxide laser against bacteria-contaminated titanium implant and subsequent cellular adhesion to irradiated area. Lasers Surg Med 1998;23:299–309.
21. Li ZZ, Reinisch L, Van de Merwe WP. Bone ablation with Er:YAG and CO_2 laser: Study of thermal and acoustic effects. Lasers Surg Med 1992;12:79–85.
22. Kreisler M, Götz H, Duschner H, Hoedt B. Effect of Nd:YAG, Ho:YAG, Er:YAG, CO_2 and GaAlAs laser irradiation on surface properties of endosseous dental implants. Int J Oral Maxillofac Implants 2002;17:202–211.
23. Hibst R, Keller U. Heat effect of pulsed Er:YAG laser radiation. Laser surgery: Advanced characterization of therapeutics and systems. Proc SPIE 1990;1200:379–386.
24. Hibst R. Mechanical effects of erbium:YAG laser in bone ablation. Lasers Surg Med 1992;12:125–130.
25. Lewandrowski KU, Lorente C, Schomacker KT, Flotte TJ, Wilkes JW, Deutsch TF. Use of the Er:YAG laser for improved plating in maxillofacial surgery: Comparison of bone healing in laser and drill osteotomies. Lasers Surg Med 1996;19:40–45.
26. Keller U, Hibst R, Mohr W. Tierexperimentelle untersuchungen zur laserosteotomies mit dem Er:YAG laser. Dtsch Z Mund Kiefer Gesichtschir 1991;15:197–199.
27. Efron B. Forcing a sequential experiment to the balanced. Biometrika 1971;58:403–417.
28. El-Montaser M, Devlin H, Dickinson MR, Sloan P, Lloyd RE. Osseointegration of titanium metal implants in erbium-YAG laser-prepared bone. Implant Dent 1999;8:79–85.
29. Pick RM, Colvard MD. Current status of lasers in soft tissue dental surgery. J Periodontol 1993;64:589–602.
30. Keller U. Erbium-YAG laser in der oralchirurgie. Dtsch Zahnärztl Z 1997;52:439–42.
31. Chu RT, Watanabe L, White JM, Marshall SJ, Hutton JE. Temperature rises and surface modification of lasered titanium cylinders [abstract]. J Dent Res 1992;71:144.
32. Block CM, Mayo JA, Evans GH. Effects of the Nd:YAG dental laser on plasma-sprayed and hydroxyapatite-coated titanium dental implants: Surface alteration and attempted sterilization. Int J Oral Maxillofac Implants 1992;7:441–449.
33. Rechmann P, Sadeg HM, Goldin DS, Henning T. Zur Oberflächenmorphologie von Implantaten nach Laserbestrahlung. Dtsch Zahnärztl Z 2000;55:371–376.
34. Deppe H, Horch HH, Henke J, Donath K. Peri-implant care of ailing implants with the carbon dioxide laser. Int J Oral Maxillofac Implants 2001;16:659–667.

35. Eriksson R, Albrektsson T. Temperature threshold levels for heat induced bone tissue injury: A vital microscopy study in the rabbit. J Prosthet Dent 1983;50:101–107.

36. Barak S, Horowitz I, Katz J. 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 1998;13:666–671.

37. Hibst R, Keller U. Effects of water spray and repetition rate on the temperature elevation during Er:YAG laser ablation of dentine. Proc SPIE 1995;2623:139–144.

38. Ando Y, Aoki A, Watanabe H, Ishikawa I. Bactericidal effect of Erbium:YAG laser on periodontopathic bacteria. Lasers Surg Med 1996;19:190–200.

39. Purucker P, Romanos GE, Bernimoulin JP, Nentwig GH. Effect of cw-CO_2 laser irradiation on the viability of two pathogenic bacteria covering titanium implants [abstract]. J Dent Res 1998;77:967.

40. Haas R, Dörtbudak O, Mensdorff-Pouilly N, Mailath G. Elimination of bacteria on different implant surfaces through photosensitization and soft laser. An in vitro study. Clin Oral Impl Res 1997;8:249–254.

41. Adrian JC, Gross A. A new method of sterilization: The carbon dioxide laser. J Oral Pathol 1979;8:60–61.

42. Bernhart T, Haas R, Mailath G, Watzek G. A minimally invasive second-stage procedure for single-tooth implants. J Prosthet Dent 1998;79:217–219.

43. Moy PK, Weinlaender M, Keenney EB. Soft tissue modifications of surgical techniques for placement and uncovering of osseointegrated implants. Dent Clin North Am 1989;33:665–681.

44. Lázaro PJ, Herrero M, Aranda JJ, Herrero F. Enfoque periodontal de la segunda fase quirurgica (II): Proceso de toma de decisiones en los tejidos blandos peri-implantarios. Periodoncia 1999;9:369–380.

45. Delgado E, Sánchez MA, Berini L, Gay-Escoda C. Manejo clínico y tratamiento de la infección periimplantaria. Presentación de 6 casos. Av Periodontol 1998;10:143–153.