Journal section: Oral Surgery
Publication Types: Research
doi:10.4317/medoral.15.e782

Thermal increment due to ErCr: YSGG and CO_2 laser irradiation of different implant surfaces. A pilot study

Laila Gómez-Santos [1], José Arnabat-Domínguez [2], Alejandro Sierra-Rebolledo [3], Cosme Gay-Escoda [4]

[1] DDS. Resident of the Master in Oral Surgery and Implantology. Barcelona University Dental School
[2] MD, DDS. Associate professor of Oral Surgery and Professor of the Master of Oral Surgery and Implantology. University of Barcelona Dental School. Investigator of the IDIBELLO
[3] DDS. Master in Oral Surgery and Implantology. Barcelona University Dental School
[4] MD, DDS, PhD. Chairman of Oral and Maxillofacial Surgery. Director of the Master of Oral Surgery and Implantology. University of Barcelona Dental School. Coordinating investigator of the IDIBELL Institute. Head of the Service of Maxillofacial Surgery, Teknon Medical Center. Barcelona, Spain

Correspondence:
Centro Médico Teknon
Instituto de investigación IDIBELL
C/ Vilana 12
08022 - Barcelona (Spain)
cgay@ub.edu

Received: 11/07/2009
Accepted: 21/02/2010

Gómez-Santos L, Arnabat-Domínguez J, Sierra-Rebolledo A, Gay-Escoda C. Thermal increment due to ErCr:YSGG and CO_2 laser irradiation of different implant surfaces. A pilot study. Med Oral Patol Oral Cir Bucal. 2010 Sep 1;15 (5):e782-7.
http://www.medicinaoral.com/medoralfree01/v15i5/medoralv15i5p782.pdf

Article Number: 3020 http://www.medicinaoral.com/
© Medicina Oral S. L. C.I.F. B 96689336 - pISSN 1698-4447 - eISSN: 1698-6946
eMail: medicina@medicinaoral.com
Indexed in:
-SCI EXPANDED
-JOURNAL CITATION REPORTS
-Index Medicus / MEDLINE / PubMed
-EMBASE, Excerpta Medica
-SCOPUS
-Indice Médico Español

Abstract

Objective: An evaluation and comparison is made of the thermal increment at different implant surfaces during irradiation with CO_2 and ErCr:YSGG lasers.

Study design: Five threaded and impacted implants with four types of surfaces were inserted in an adult pig rib: two implants with a hydroxyapatite surface (HA)(impacted and threaded, respectively), a machined titanium surface implant (TI mach), a titanium plasma spray surface implant (TPS), and a sandblasted, acid-etched surface implant (SBAE). A 0.5-mm diameter bone defect was made in the implant apical zone, and a type-K thermocouple (Termopar)® was placed in contact with the implant. The implants were irradiated in the coronal zone of each implant with a CO_2 (4 W continuous mode) and an ErCr:YSGG laser (1.5 W, pulsed mode) first without and then with refrigeration. The temperature variations at the implant apical surface were recorded.

Results: An apical temperature increase was recorded in all cases during CO_2 and ErCr:YSGG laser irradiation without refrigeration. However, when the ErCr:YSGG was used with a water spray, a decrease in temperature was observed in all implants. The acid-etched and sandblasted surfaces were those most affected by the thermal changes.

Conclusions: The ErCr:YSGG laser with a water spray applied to the sealing cap or coronal zone of the implants does not generate thermal increments in the apical surface capable of adversely affecting osseointegration and the integrity of the peri-implant bone tissue.

Key words: *Dental implant, laser, ErCr:YSGG laser, CO_2 laser, osseointegration, implant surfaces, temperature.*

Introduction

In the last 30 years many laser systems have been shown to constitute an effective alternative in application to a range of oral surgery procedures. The easy handling characteristics of these systems, the shortening of surgical time, and increased patient comfort both during the intervention and in the postoperative period constitute some of the advantages of these systems. In effect, laser systems allow precise sectioning of both soft and hard tissues, as a result of interaction of the laser beam with the water present in the irradiated tissues. The underlying mechanism of action is mainly based on thermal action resulting from laser energy absorption by the tissues, with heating, dehydration, coagulation, carbonization and vaporization, according to the thermal increment produced.

In oral surgery, laser systems with great thermal effects such as the CO_2 laser have been successfully used for the exeresis of soft tissue lesions, though the associated thermal increments can possibly cause irreversible damage upon coming into contact with bone. In 1983, Eriksson et al. (1) demonstrated that a temperature of over 47ºC maintained for one minute causes irreversible bone damage. Consequently, and considering a baseline tissue temperature of 37ºC, temperature increments of over 10ºC during laser application may suffice to cause irreparable damage to bone.

In oral implantology, laser is indicated (2) for second-step surgery (3), the exeresis of mucosal hyperplasias (4), and for the decontamination of peri-implantitis affected surfaces (5,6). However, the possibility of causing peri-implant bone and implant surface damage capable of placing osseointegration at risk constitutes an important disadvantage of laser irradiation.

The CO_2 laser has been one of the most widely used laser systems in both oral surgery and implantology. Its advantages in second-step surgery and in the decontamination of peri-implant surfaces have been confirmed by a number of authors (5-8).

Other laser systems with a lesser thermal effect, such as the Er:YAG laser (2, 9-11) have also been proposed for implant surgery (12). The ErCr:YSGG laser emits coherent light at a wavelength of 2.78 µm. Its morphological effects in the irradiated zone are similar to those observed with the Er:YAG laser, at a wavelength of 2.94 µm (13). The ErCr:YSGG laser allows precise bone sectioning and ablation, with minimal thermal effects upon the adjacent tissues (13-16). Its use has been proposed for the preparation of cavities and in caries removal (13,16), the surgical treatment of soft tissue lesions, and biopsies (15). However, to date few studies have evaluated its use in implant surgery.

The present study was carried out to evaluate and compare the thermal increment produced at different implant surfaces during irradiation with the CO_2 and ErCr:YSGG laser, both with and without refrigeration in the form of a water spray.

Material and Methods

In the present in vitro study, impacted and threaded titanium implants with different surfaces were used: impacted hydroxyapatite (HA) (IMZ, Friatec, Mannheim, Germany), threaded hydroxyapatite (HA) (Steri-Oss Inc., Anaheim, USA), machined titanium (TI mach) (Branemark System Mk III, NobelBiocare, Goteborg, Sweden), titanium plasma spray (TPS) (Osseotite 3i, West Palm Beach, USA) and sandblasted and acid-etched (SBAE) (Defcon TSA Series 3, Impladent, Barcelona, Spain). Five implants were placed in an adult pig rib employing the usual surgical technique. The implant characteristics are reflected in (Table 1). Posteriorly, rotary instrumentation was used to drill holes measuring 0.5 mm in diameter in the cortical bone at the apical third level of each implant, simulating fenestration. A type K thermocouple (Termopar®, TM 1300K, T Equipment, Hazlet, NY, USA) was placed in contact with the apical zone of each implant and fixed and insulated with Utility® wax (Dentalwax, Reus, Barcelona, Spain). The entire system was then isolated by positioning a rubber dam in the coronal third of the implants, fixed with sealing caps.

Two types of laser were used: CO_2 (Satelec®, Bordeaux, France) with a wavelength of 10.6 µm and a power rat-

Table 1. Laser irradiated implant designs and surfaces.

No.	Code	Surface material	Design	Texture
1	HA impacted	Hydroxyapatite	Impacted	Rough
2	TI mach	Machined titanium	Threaded	Smooth
3	TPS	Titanium plasma spray	Impacted	Rough
4	HA threaded	Hydroxyapatite	Threaded	Rough
5	SBAE	Sandblasted and acid-etched	Impacted	Rough

ing of 4 W (continuous mode), and an ErCr:YSGG laser (Waterlase®, Biolase, San Clemente, CA, USA.) with a wavelength of 2.78 µm and a power rating of 1.5 W (pulsed mode, frequency 20 Hz) and a Tip-Z6 600 µm tip; in one group irradiation was applied with 12% air - 6% H_2O refrigeration. The lasers were used to irradiate the sealing cap of each implant at a focal distance of 1.5 mm and an angle of 90 degrees during 60 seconds. Recordings were made of the temperature variations at the implant apex during irradiation with the CO_2 laser, the ErCr:YSGG laser with refrigeration, and the ErCr:YSGG laser without refrigeration. Measurements were made immediately before irradiation [Temp. 1], after 60 seconds of continuous irradiation, upon stopping irradiation [Temp. 2], 30 seconds after the end of irradiation [Temp. 3], and again 60 seconds after terminating laser application [Temp. 4]. A descriptive analysis was made of the behavior recorded for each irradiated surface according to the duration of irradiation, the laser power rating, and the application or omission of water spray refrigeration, using the SPSS version 9.0 statistical package for Microsoft Windows (license no. 7116391).

Results

On applying the CO_2 laser, an increase in temperature was recorded at all the implant surfaces (Fig. 1). The mean thermal increment after 60 seconds of irradiation was 8.56ºC (range 4.30-13.10). In the concrete case of the SBAE and TPS surfaces, the temperature increase exceeded 10ºC at the time of interrupting irradiation. Of all the surfaces tested, the threaded HA implant showed the least thermal increment: 4.3ºC during irradiation and 3.5ºC one minute after discontinuing irradiation. In the case of the ErCr:YSGG laser without refrigeration, all surfaces showed a temperature rise (Fig. 2). The mean thermal increment was 5.02ºC (range 2.70-7.50), the greatest temperature increases corresponding to the threaded HA and SBAE implants (7.50ºC and 6.70ºC, respectively).

In this case the TI mach surface showed the smallest temperature rise at apical level during irradiation (2.7ºC). When the ErCr:YSGG was applied with refrigeration, the surface temperature was seen to decrease for all implants (Fig. 3). The mean temperature drop was 0.6ºC (range -0.20 to -1.30). At the end of irradiation the most manifest decrease in temperature corresponded to

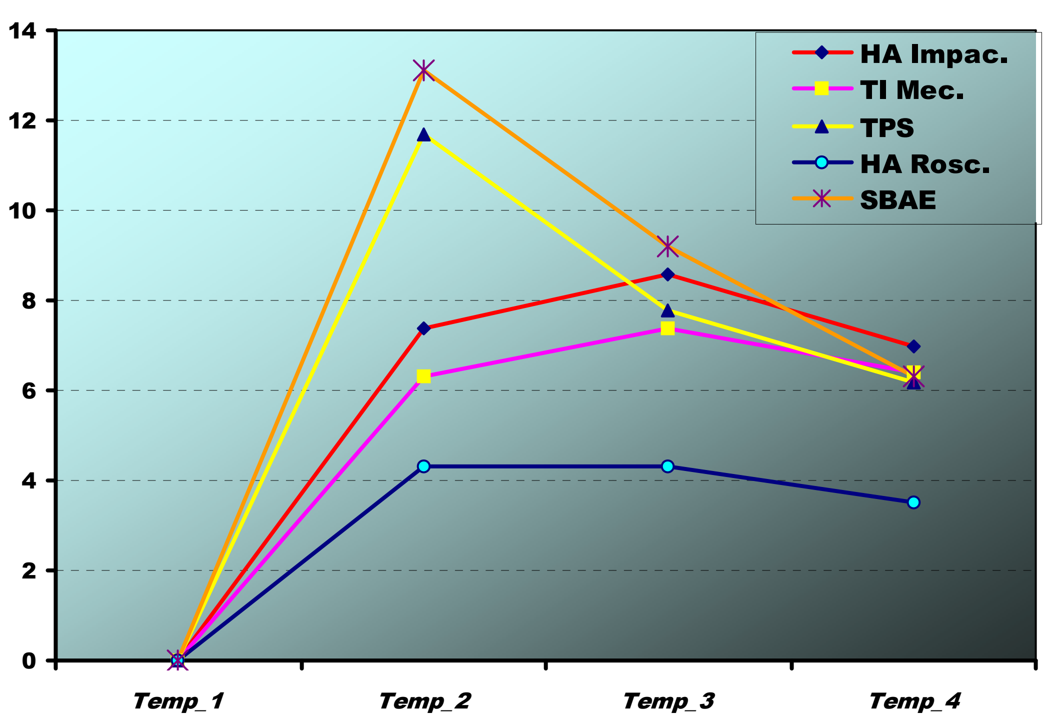

Fig. 1. Thermal increment during application of the CO_2 laser to the different implant surfaces.

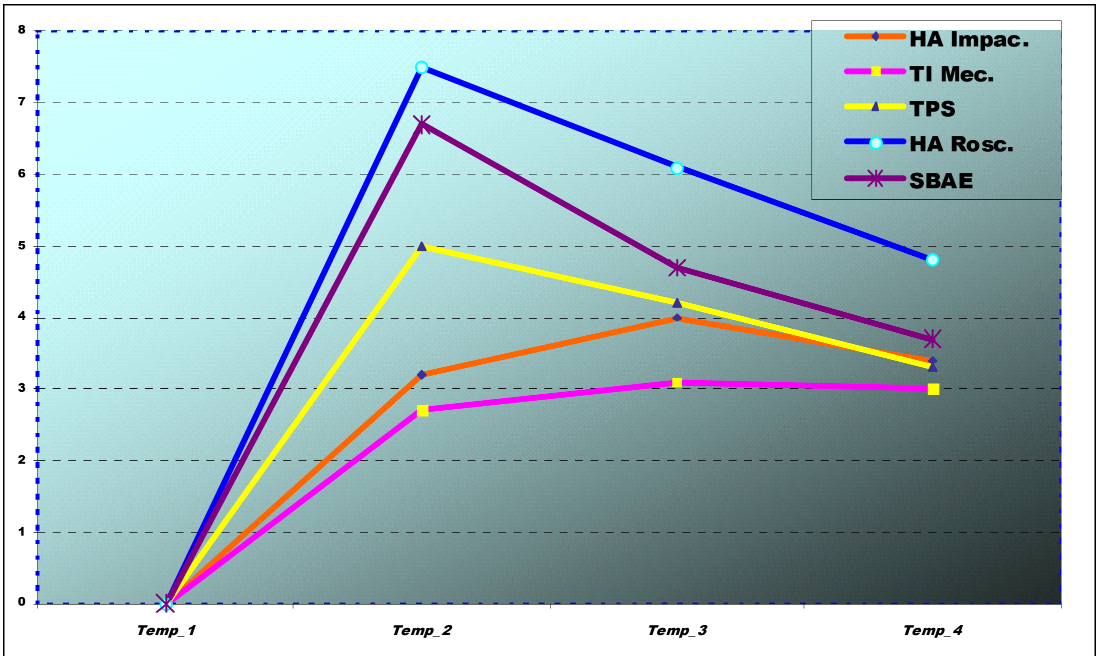

Fig. 2. Thermal variation during application of the ErCr:YSGG laser without refrigeration.

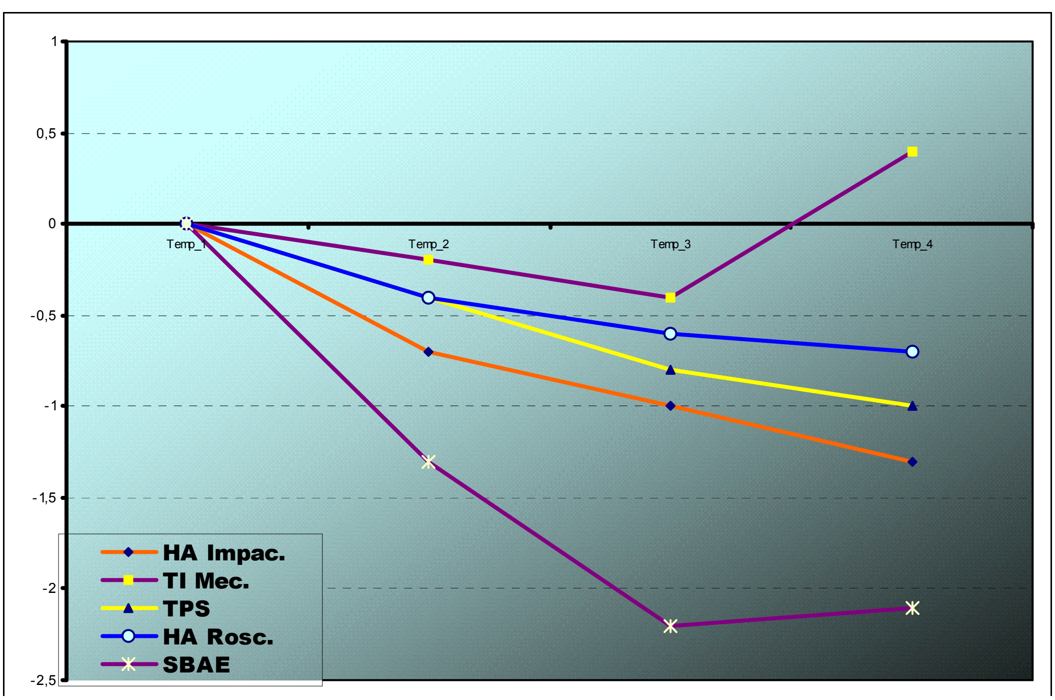

Fig. 3. Thermal variation during application of the ErCr:YSGG laser with refrigeration.

the SBAE surface, with -1.30ºC. The TI mach surface showed the smallest temperature drop during irradiation (-0.20ºC)- this being followed by an increase of 1ºC after terminating laser irradiation.

Discussion

The present study investigated the temperature variations at different implant surfaces irradiated with two lasers widely used in dental practice: the CO_2 laser and the ErCr:YSGG laser. When lasers are used in vivo, their thermal effects upon the adjacent tissues must be taken into account. In this sense, a bone temperature rise to over 47ºC for one minute can cause irreversible bone damage (1). Thus, with respect to the physiological tissue temperature of 37ºC, this leaves a margin of 10ºC which must not be exceeded during laser application. However, according to some authors such as Haider et al. (17) the effects of temperature are influenced by bone structure and vascularization. Accordingly, cancellous bone exhibits an increased regenerative capacity compared with cortical bone following laser heat-induced damage, due to its greater vascularization (17).

The CO_2 laser is one of the most widely used lasers in oral surgical practice. Its use has been described by different authors in numerous procedures such as the resection of benign soft tissue lesions, frenectomies, biopsies and the vaporization of precancerous lesions (leukoplakia). However, caution is required when using these systems in implant surgery, due to their thermal effects. Kreisler et al. (8) showed that the above mentioned 47ºC temperature barrier is exceeded after 15 seconds of application of the CO_2 laser at a power rating of 2.5 W in TPS surface implants. Its use therefore requires limitation of the power rating involved.

In contrast, Barak et al. (18) found that CO_2 laser power ratings of under 4 W in continuous mode, and under 8 W in pulses of 0.05 seconds, do not generate thermal increments of over 10ºC at the sealing cap and in the body of implants with TPS and HA surfaces. In the present study we have seen that the temperature increments of implants with SBAE and TPS surfaces irradiated for 60 seconds with the CO_2 laser exceed 10ºC; thus, the use of this system in second-step surgery or in surface decontamination procedures is not advisable, since the thermal rise in the adjacent tissues could adversely affect osseointegration. Nevertheless, some authors have used this type of laser in second-step implant surgery and for decontaminating implant surfaces in cases of periimplantitis, without recorded alterations of either the implants or the osseointegration process (5,18).

Other lasers such as the Nd:YAG and Ho:YAG lasers have also been evaluated in implantology, though their use has been disadvised in view of the thermal damage to bone and the structural damage inflicted upon the titanium surface (10).

The Er:YAG laser has been proposed for second-step implant surgery, based on its advantages when compared with the traditional cold scalpel. Its scant heat-induced alterations, lack of implant surface damage, and good postoperative comfort for the patient are among the advantages shown by this system (3). Since the studies by Eversole et al. (16) in 1995, this laser has been shown to be effective in cutting enamel, dentin and bone, and has been introduced in dental surgery, where it has been seen to be effective in preparing dental cavities – causing only minimum pulp and surrounding tissue damage. Prior to human studies of ErCr:YSGG laser irradiation, in vitro evaluations were made of its safety and effects upon pulp tissue. In this context, it has been reported that the temperature increments in cavity preparations are smaller than when a conventional turbine-driven instrument is used (16).

Following a study of 44 patients involving 50 dental cavity preparations, Matsumoto et al. (13) concluded that the ErCr:YSGG laser is efficient, effective and safe for caries and cavity preparations. Patient acceptance was excellent, and no side effects were observed. In the present study the ErCr:YSGG laser did not induce implant temperature increments during or after irradiation capable of damaging the neighboring tissues, provided refrigeration was used. The use of this laser without refrigeration led to an average temperature increase of 5ºC, with a maximum of 7.5ºC. While this does not exceed the temperature barrier associated with irreversible bone damage, it is advisable not to use the system without a water spray.

As to the behavior of the different types of implant surfaces, Kreisler et al. (9) found implants with HA surfaces to experience increased thermal increments compared with TPS and SBAE surfaces, during application of the Er:YAG laser for 120 seconds. Posteriorly, in another study evaluating the thermal increments of different implants during GaAlAs laser application, these same authors found no significant differences between these same surfaces when using the diode laser. In our study the SBAE surface was the surface most affected by thermal variation, yielding higher values than the other surfaces in terms of both temperature increase and decrease.

The findings of the present pilot study indicate that the ErCr:YSGG laser with refrigeration, applied to the sealing cap and coronal zone of the implants, does not generate thermal increments at the apical surface capable of compromising osseointegration or the integrity of the peri-implant bony tissues. These features may be useful in second-step implant surgery, the resection of mucosal hyperplasias, and the treatment of periimplantitis. However, we consider it necessary to conduct further studies to more fully assess the associated implant surface structural damage, and to assess the bactericidal action of the laser.

References

1. Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital-microscopic study in the rabbit. J Prosthet Dent. 1983;50:101-7.
2. Wilcox CW, Wilwerding TM, Watson P, Morris JT. Use of electrosurgery and lasers in the presence of dental implants. Int J Oral Maxillofac Implants. 2001;16:578-82.
3. Arnabat-Domínguez J, España-Tost AJ, Berini-Aytés L, Gay-Escoda C. Erbium:YAG laser application in the second phase of implant surgery: a pilot study in 20 patients. Int J Oral Maxillofac Implants. 2003;18:104-12.
4. Garg AK. Lasers in dental implantology: innovation improves patient care. Dent Implantol Update. 2007;18:57-61.
5. Romanos GE, Nentwig GH. Regenerative therapy of deep peri-implant infrabony defects after CO_2 laser implant surface decontamination. Int J Periodontics Restorative Dent. 2008;28:245-55.
6. Takasaki AA, Aoki A, Mizutani K, Kikuchi S, Oda S, Ishikawa I. Er:YAG laser therapy for peri-implant infection: a histological study. Lasers Med Sci. 2007;22:143-57.
7. Mouhyi J, Sennerby L, Van Reck J. The soft tissue response to contaminated and cleaned titanium surfaces using CO_2 laser, citric acid and hydrogen peroxide. An experimental study in the rat abdominal wall. Clin Oral Implants Res. 2000;11:93-8.
8. Kreisler M, Al Haj H, Götz 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. 2002;30:233-9.
9. 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. 2002;15:582-7.
10. Kreisler M, Götz H, Duschner H. Effect of Nd:YAG, Ho:YAG, Er:YAG, CO_2, and GaAIAs laser irradiation on surface properties of endosseous dental implants. Int J Oral Maxillofac Implants. 2002;17:202-11.
11. Matsuyama T, Aoki A, Oda S, Yoneyama T, Ishikawa I. Effects of the Er:YAG laser irradiation on titanium implant materials and contaminated implant abutment surfaces. J Clin Laser Med Surg. 2003;21:7-17.
12. Ishikawa I, Aoki A, Takasaki AA. Clinical application of erbium:YAG laser in periodontology. J Int Acad Periodontol. 2008;10:22-30.
13. Matsumoto K, Hossain M, Hossain MM, Kawano H, Kimura Y. Clinical assessment of Er,Cr:YSGG laser application for cavity preparation. J Clin Laser Med Surg. 2002;20:17-21.
14. Wang X, Ishizaki NT, Suzuki N, Kimura Y, Matsumoto K. Morphological changes of bovine mandibular bone irradiated by Er,Cr:YSGG laser: an in vitro study. J Clin Laser Med Surg. 2002;20:245-50.
15. Rizoiu IM, Eversole LR, Kimmel AI. Effects of an erbium, chromium: yttrium, scandium, gallium, garnet laser on mucocutanous soft tissues. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1996;82:386-95.
16. Eversole LR, Rizoiu IM. Preliminary investigations on the utility of an erbium, chromium YSGG laser. J Calif Dent Assoc. 1995;23:41-7.
17. Haider R, Watzek G, Plenk H. Effects of drill cooling and bone structure on IMZ implant fixation. Int J Oral Maxillofac Implants. 1993;8:83-91.
18. 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;13:666-71.

Acknowledgements
This study has been carried out by the research group in "Dental and Maxillofacial Pathology and Treatment" of the Institut d´Investigació Biomèdica de Bellvitge (IDIBELL), with financial support from the oral surgery teaching-healthcare agreement among the University of Barcelona, the Consorci Sanitari Integral and the Servei Català de la Salut of the Generalitat de Catalunya.