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Lasers in dental implantology

Emile Martin, DDS, MAGD[a,b,*]

[a] *Martin and Winkler, DDS, PC, 3150 Erie Boulevard East, Syracuse, NY 13214, USA*
[b] *Treatment Planning Section, St. Joseph's Hospital GPR Program, 301 Prospect Avenue, Syracuse, NY 13203, USA*

The origins of implant dentistry can be traced back to China 4000 years ago when bamboo was inserted into the jaw bone for fixed tooth replacements [1]. Humans have striven to replace missing teeth predictably throughout the centuries. Many attribute the article by Goldberg and Ghershkoff in 1949 [2] as the beginning of modern implant dentistry, with the description of the technique for the subperiosteal implant. Further progress was achieved in the 1960s with the blade-vent implant developed by Linkow [3], Roberts and Roberts [4], and Weiss [5], among others. Until 1983, dentists who performed implant procedures were considered to be "on the fringe" of the dental profession. In 1985, the publication of *Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry* by Branemark et al [6] ushered in the era of osseointegration. Although many of the dogmas espoused in his text have since been proved wrong, the concept of a gentle surgical insertion technique and the use of a root replacement device made of the highly biocompatible metal titanium have stood the test of time. Add to that the willingness of the profession, an American public of baby boomers who wish to retain or restore their youthfulness, and a patient pool that can afford this type of therapy, and you have a recipe for the success of new treatment modalities.

In 1960, Maiman published work on the ruby laser [7]. The carbon dioxide (CO_2) laser has been used in oral and maxillofacial surgery since its development in 1964 [8]. Lasers were brought to general practice in 1989 by Drs. William and Terry Myers, who modified an ophthalmic Nd:YAG laser for dental use. This unit (dLase 300, American Dental Laser, Southfield, Michigan) pioneered the development of lasers dedicated to the field of dentistry rather than medicine. In the 15 years since, a number of laser wavelengths have been brought to the profession for various procedures. The

* Martin and Winkler, DDS, PC, 3150 Erie Boulevard East, Syracuse, NY 13214, USA.
E-mail address: emartin@choiceonemail.com.

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CO_2, Nd:YAG, diode, argon, and holmium wavelengths are primarily soft tissue lasers. The enthusiasm by laser users has been significant; however, actual market penetration by the technology has been slow. The introduction of the erbium family of wavelengths, with its ability to safely remove hard tissue, has stimulated a new wave of interest in laser therapy in the dental profession. Continuing research on all of these wavelengths has brought new opportunities for use in the clinical environment.

The parallel in the expansion of implant dentistry and laser dentistry in clinical practice is apparent. As advocates for laser dentistry continue to seek new ways to use the technology and as more practitioners become involved in implant dentistry, it is logical to see the concurrent use of both technologies in clinical practice.

The following questions should be asked:

1. Why use laser technology in implant dentistry?
2. How does the use of a laser impact the success or failure of the implant?
3. What is the significance, in the short- and long-term, of laser use in implantology?
4. What are the potential benefits of using lasers to repair ailing implants?
5. Are there clinical situations in which the use of a laser is the best choice?
6. What impact can laser use have on the prostheses that are manufactured for implant restorations?

Why use laser technology in implant dentistry?

The advantages of using lasers in implant dentistry are the same as for any other soft tissue dental procedure. These advantages include increased hemostasis, minimal damage to the surrounding tissue, reduced swelling, reduced infection, and reduced pain postoperatively. Due to the hemostasis provided by lasers, there is the significant advantage of improved visibility during surgery [9]. The increasing popularity of the erbium family of lasers, with their hard tissue ablation capability, has added the potential for its use for osteotomy and decontamination of infected and ailing implant bodies.

How does the use of a laser impact the success or failure of the implant?

In the past, controversy has surrounded the use of lasers on dental implants. Each specific wavelength has its own absorption characteristics. As such, although Nd:YAG has been a particularly popular wavelength to use for soft tissue second-stage surgery, several investigators contend that it is contraindicated. Walsh [10], Block et al [11], and Chu et al [12] studied the effects of this wavelength on implants. The specific issues that were studied were the transmission of heat to the bone from the heated implant surface, effects of this wavelength on the metal surface, the potential for pitting and melting, and the porosity of the implant surface.

CO_2 laser energy, on the other hand, is reflected away from metal surfaces. The failure of implants to absorb the energy of the CO_2 laser is a major advantage of this wavelength. Use of the CO_2 wavelength minimizes the risk of temperature-induced tissue damage as a result of lasing the implant surface. It generally is accepted that the threshold for bone cells to remain viable is a temperature increase from 37°C (normal body temperature) to 47°C [13]. An article by Mouhyi et al [14] demonstrated that a CO_2 laser on a wet implant surface in pulsed mode at 8 W (10 milliseconds pulse duration, 20 Hz for 5 seconds) induced a temperature increase of less than 3°C, well within the 10°C safety margin from 37°C to 47°C. It also should be noted that the hemostatic properties of CO_2 are excellent, which is a tremendous advantage for its use on soft tissue. The fact that CO_2 laser energy does not alter the implant surface because it is reflected away also is of benefit. For osseous procedures, however, the CO_2 laser is not the instrument of choice because it has the potential to cause thermal changes to bone [10].

The erbium family of lasers is similar to the CO_2 wavelength in some respects. There is minimal depth of penetration in soft tissue and reflection away from the implant surface. The erbium lasers do not have as significant a hemostatic capability as CO_2 or Nd:YAG. By using the erbium:yttrium-aluminum-garnet (Er:YAG) laser with small diameter tips and pulse repetitions of 8 to 10 Hz without water spray, it is possible to perform mucosal ablation without bleeding. Dry ablation with Er:YAG lasers produces more precise cuts in the oral mucosa [15]. It should be noted that despite concerns about overheating and surface changes during laser usage, the experience of the past few years seems to support the idea that the risks can be minimized with proper technique and control of laser parameters [16]. All types of lasers can be used to excise or vaporize periodontal tissue as needed to expose dental implants. One advantage of the use of lasers in implantology is that impressions can be taken immediately after second-stage surgery because there is little blood contamination in the field due to the hemostatic effect of the lasers. There also is minimal tissue shrinkage after laser surgery, which assures that the tissue margins will remain at the same level after healing as they are immediately after the surgery. In addition, the use of the laser can eliminate the trauma to the tissue of flap reflection and suture placement (assuming adequate zones of keratinized tissue and the knowledge of where the implant has been placed).

What is the significance, in the short- and long-term, of laser use in implantology?

One of the main reasons dentists cite for using lasers during implant recovery is that there is less postoperative pain, less bleeding, and faster healing [16]; however, there also is the potential for obliteration of the attached gingiva if this technology is overused. It is important to maintain and preserve attached gingiva around implants whenever possible. This practice is especially true in the partially edentulous patient where the same bacteria reside in the implant sulcus as in the sulci of the natural teeth. The flora are different in the fully edentulous patients in whom no sulci exist except for those around the implants [17]. Although there is a hemidesmesomal attachment around the implant abutment to create a biologic seal, attached gingiva serves as a barrier to exposure of the implant body due to recession over time, just as around natural teeth [18]. If the attached gingiva is violated during the second-stage procedure, then a graft or a soft tissue repositioning procedure may be needed to restore keratinized tissue around the implant abutment.

What are the potential benefits of using lasers to repair ailing implants?

One of the most interesting uses of lasers in implant dentistry is the possibility of salvaging ailing implants by decontaminating their surfaces with laser energy. A number of clinical studies have been done to examine how, when, and whether lasers can be used successfully to help these situations.

Diode lasers were used in a study by Bach et al [19] who found a significant improvement in the 5-year survival rate when integrating laser decontamination into the approved treatment protocol. Dortbudak et al [20] found that the use of low-level laser therapy with a diode soft laser (690 nm) for 60 seconds after the placement of toluidine blue O for 1 minute on the contaminated surface reduced the counts of bacteria by a minimum of 92%. This reduction was a significant improvement, but complete elimination of bacteria was not achieved with this wavelength. The same group was able to obtain complete bacterial elimination in a study using the 905-nm diode (also a soft tissue laser) with toluidine blue O on all types of implant surfaces (ie, machined, plasma-flame–sprayed, etched, and hydroxyappatite coated). Shibli et al [21] found a positive correlation in the use of a diode laser and toluidine blue O on experimentally produced peri-implantitis in dogs before guided tissue regeneration procedures. Their data on several implant surfaces suggest that lethal photosensitization, through the use of toluidine blue O to sensitize the cell membranes to laser light, may have potential in the treatment of peri-implantitis.

CO_2 lasers have been successful in decontaminating implant surfaces. Kato et al [22] found that this wavelength did not cause surface alteration, rise of temperature, or serious damage of connective tissue cells located outside the irradiation spot or cause inhibition of cell adhesion to the irradiated area. They concluded that irradiation with an expanded beam may be useful in removing bacterial contaminants from implant surfaces.

Mouhyi et al [23] found that a combination of citric acid, hydrogen peroxide, and CO_2 laser irradiation seems to be effective for cleaning and re-establishing the oxide structure of contaminated titanium surfaces. The highly biocompatible titanium oxide surface is corrosion resistant, which contributes significantly to the strength of the bone–implant interface during osseointegration [6]. A study on dogs performed by Deppe et al [24] concluded that peri-implant defects can be treated successfully by CO_2 laser decontamination without damaging the surrounding tissues. Romanos [25] was able to treat successfully 18 ailing implants in 14 patients using mechanical debridement followed by implant surface decontamination with the CO_2 laser and subsequent grafting of the bony defects with a resorbable barrier.

The Er:YAG laser also has been proposed for surface decontamination of dental implants. In an article by Schwarz et al [26], this wavelength was found to be effective in removing subgingival calculus from titanium implants without leading to any thermal damage. Kreisler et al [27], after evaluating 72 titanium blocks in vitro with three different surfaces, concluded that even at low energy densities, the Er:YAG laser has a high bactericidal potential on common implant surfaces, with no morphologic implant surface alterations detected.

The previous articles are contrasted with the findings in a study on Nd:YAG by Block et al [11], which found that this wavelength did not sterilize the plasma-sprayed titanium or plasma-sprayed hydroxyapatite-coated titanium dental implants that were used in the study. In addition, melting, loss of porosity, and other surface alterations were observed on both types of implants, even at the lowest settings. Kreisler et al [28] performed a study on various wavelengths including Nd:YAG, holmium:yttrium-aluminum-garnet (Ho:YAG), Er:YAG, CO_2, and gallium-aluminum-arsenide for implant surface decontamination. They concluded that Nd:YAG and Ho:YAG lasers are not suitable for decontamination of dental implant surfaces at any power output. With Er:YAG and CO_2, the power output must be limited so as to avoid surface damage. The gallium-aluminum-arsenide laser seems to not cause any surface alterations.

Are there clinical situations in which the use of a laser is the best choice?

The use of a laser in clinical practice would have the same advantages in implant dentistry. A patient with potential bleeding problems could be treated with a laser to provide essentially bloodless surgery in the bone. This practice could be particularly useful in the placement of mini-implants. Using the autoadvance technique advocated by Balkin et al [29], a small opening could be placed into the soft tissue and approximately 3 mm into the bone. These mini-implants, 1.8 mm in diameter with a self-tapping thread, can be rotated slowly and autoadvanced into the soft cancellous bone. Although there is little concern in the literature about possible contamination of the osteotomy site by the use of drills in the oral cavity, there is the potential benefit of the laser sterilizing the bone as it penetrates and creates an osteotomy site. The prosthesis is stabilized using the "O" ball heads that come on these implants. Other attachments also are available.

It has been proposed by some clinicians who use lasers that it is possible to create the entire osteotomy site for conventional-sized implants. Although it may be possible on an individual-case basis, it has yet to be shown that this would be a superior technique to be used in everyday practice.

What impact can laser use have on the prostheses that are manufactured for implant restorations?

One of the hallmarks of the osseointegration technique is a passive fit of the prosthesis on the implants [6]. It has been proposed that one of the ways to obtain a true passive fit is by the elimination of the casting technique. The expansion and contraction during casting can lead to a nonpassive fit of the implant prosthesis when placed onto multiple implants. To that end, the proposed laser welding of titanium components has been advocated and used with some mixed success. Iglesia and Moreno [30] stated that the aim of the use of a Nd:YAG laser welder technique is to allow the use of titanium as the best suited material. They concluded that by using high-precision machined abutments and titanium bars to connect the abutments with a laser welding machine, a passive fit was achieved. Bergendal and Palmqvist [31] found that there was a tendency for more fractures of artificial teeth and acrylic resin in the titanium-welded framework group. They also believed that one of the issues was the learning curve for the technicians and that as familiarity with the procedure increased, success rates improved. In a recent study, Jemt et al [32] concluded that except for a minor tendency for small chips of porcelain veneers, laser-welded titanium frameworks presented an overall similar clinical performance to conventional, cast frameworks in implant-supported, fixed partial denture situations after 5 years. Reidy et al [33] concluded that the laser-welded framework exhibited a more precise fit than the one-piece casting. Finally, a study done by Ortorp et al [34] concluded that the cast frameworks had a higher overall success rate, but the titanium framework treatment results were well in accordance with the results of the control group. Their assessment was that laser-welded frameworks were a viable alternative in the edentulous mandible.

Clinical cases

The following clinical cases demonstrate the use of dental lasers for a variety of procedures including second-stage uncovering, implant site preparation, and removal of diseased tissue around the implant.

The first case shows the second-stage uncovering and tissue retraction for the restoration of a maxillary right central incisor. A 55-year-old woman had fractured the tooth and root, and after the oral surgery procedures, presented with the fully integrated implant that had healed for 6 months (Fig. 1). Local anesthesia was obtained and a CO_2 laser (emission wavelength of 10,600 nm) was used at 5 W, continuous wave. The overlying soft tissue was removed, and a healing abutment was placed (Figs. 2 and 3). The patient returned 12 days later. The soft tissue had healed well (Fig. 4), and the final restoration was completed a short time later (Fig. 5).

The second case shows a similar second-stage uncovering and tissue retraction for the restoration of the maxillary left first bicuspid. A 50-year-old woman presented with an edentulous area in the upper first bicuspid area, shown on the radiograph (Fig. 6). The implant was placed and, 6 months later, was ready for uncovering (Fig. 7). Because the area of the implant placement was known precisely and there were adequate zones of keratinized tissue, it was agreed that the laser would be used to expose the implant for the second stage.

An Ho:YAG laser (emission wavelength of 2100 nm) was used with a light water spray and the parameters of 2 W and 10 Hz to open the implant (Fig. 8). Care was taken to aim the beam only at the soft tissue and to avoid hitting the implant. The patient returned approximately 2 months later. The soft tissue had healed well (Figs. 9 and 10). Fig. 11 shows the abutment fitted to the fixture, and then a crown was fabricated according to the patient's desires (Fig. 12). Fig. 13 is a 1-year follow-up radiograph indicating that the restoration is stable and functional.

Case 3 shows a 52-year-old man who had been missing the lower right first and second molar for some time. Two single-tooth implants were planned (Fig. 14). A surgical stent was fabricated for guidance in preparing the gingival and osseous tissue. Local anesthesia was obtained, and an Er:YAG laser (emission wavelength of 2940 nm) was used with a water spray. The laser parameters were 350 mJ per pulse, 10 pulses per second, and

Fig. 1. Implant fixture in place, healed for 6 months. (Courtesy of Stuart Coleton, DDS, Westchester, NY.)

Fig. 2. A CO_2 laser was used to uncover the implant. (Courtesy of Stuart Coleton, DDS, Westchester, NY.)

Fig. 3. The healing abutment immediately placed. (Courtesy of Stuart Coleton, DDS, Westchester, NY.)

Fig. 4. Twelve days later. (Courtesy of Stuart Coleton, DDS, Westchester, NY.)

Fig. 5. Final restoration. (Courtesy of Stuart Coleton, DDS, Westchester, NY.)

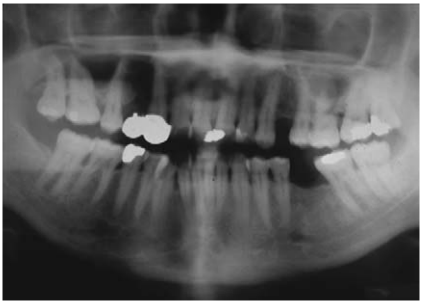

Fig. 6. Preoperative radiograph.

Fig. 7. Six-month postimplant placement. Note the adequate zone of keratinized tissue.

Fig. 8. Ho:YAG second-stage surgery.

Fig. 9. Healing of second-stage laser surgery with healing abutment in place.

Fig. 10. Note the quality of the tissue after the removal of the healing abutment.

Fig. 11. Single-tooth abutment mounted on the implant platform.

Fig. 12. Completed crown cemented into position on the implant abutment.

Fig. 13. Follow-up radiograph 1 year in function.

Fig. 14. Preoperative view. (Courtesy of Pablo Schilman, DDS, Ramat Hasharon, Israel.)

a pulse duration of 400 microseconds. An 800-μm diameter tip was placed through the alignment hole on the stent to ablate the soft tissue above the area where the implants were to be placed (Fig. 15). The tip was switched to a 200-μm diameter to place a pilot hole in the bone for the conventional implant drills (Fig. 16). The stent was removed, revealing the finished preparations with the precise soft tissue removal that is the hallmark of laser-tissue interaction (Fig. 17). The implants were placed (Fig. 18), and a 6-month radiograph (Fig. 19) depicts successful osseous integration.

The fourth case shows inflammation around an already-osseointegrated fixture of the lower right first molar. A small surgical incision was made, and granulation tissue was present around the implant (Fig. 20). A 980-nm diode laser was used with an irrigating solution of sterile saline solution flowing around a 400-μm activated bare fiber. The gated pulse mode setting was 8.0 W, with 0.05 seconds on and 0.05 seconds off, and the total exposure time was 2 minutes. The fiber was moved quickly around the metallic fixture to avoid heat build-up, and all granulation tissue was removed (Fig. 21). The affected area was limited to less than the full two polished threads of the

Fig. 15. The erbium laser positioned on the surgical stent. (Courtesy of Pablo Schilman, DDS, Ramat Hasharon, Israel.)

Fig. 16. Both soft and hard tissue were instrumented with the erbium laser, and conventional drills finished the intraosseous preparations. (Courtesy of Pablo Schilman, DDS, Ramat Hasharon, Israel.)

Fig. 17. Immediate postoperative view of the preparations. Note the precise ablation of the soft tissue. (Courtesy of Pablo Schilman, DDS, Ramat Hasharon, Israel.)

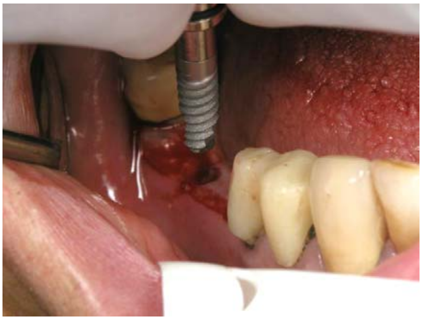

Fig. 18. Implant fixture being placed into preparation. (Courtesy of Pablo Schilman, DDS, Ramat Hasharon, Israel.)

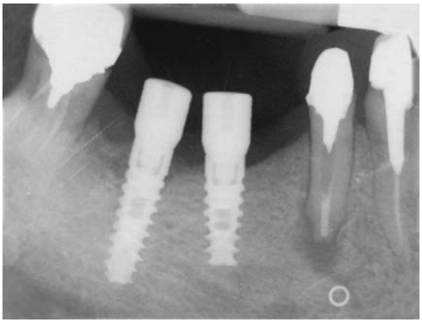

Fig. 19. Six-month postoperative radiograph showing complete healing. (Courtesy of Pablo Schilman, DDS, Ramat Hasharon, Israel.)

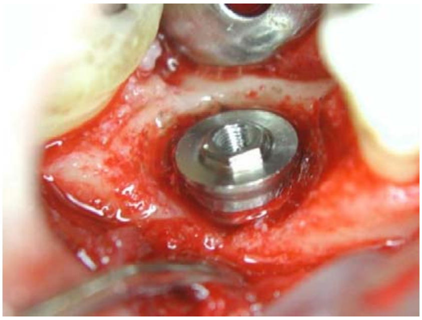

Fig. 20. Granulation tissue and exudate around implant fixture. (Courtesy of Kenneth Luk, BDS, Hong Kong, China.)

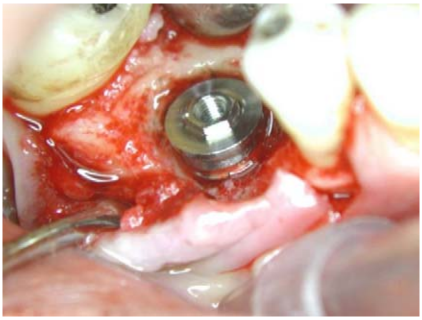

Fig. 21. All inflammation removed with diode laser. (Courtesy of Kenneth Luk, BDS, Hong Kong, China.)

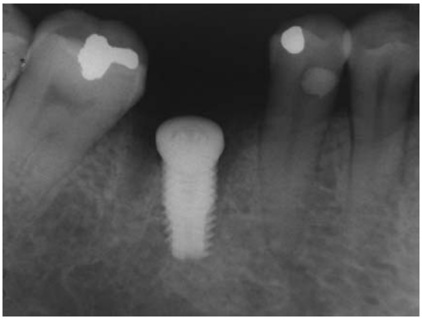

Fig. 22. Postoperative radiograph shows healing. (Courtesy of Kenneth Luk, BDS, Hong Kong, China.)

implant, and it was not necessary to contour the osseous crest. The flap was closed with the healing abutment in place. Fig. 22 is a 1-month radiograph that demonstrates good healing.

Summary

It is clear from the available data that dental lasers can be useful in the practice of implant dentistry. The challenge for the practitioner is the same as for any other area of dentistry: knowing when, where, and what armamentarium to use in any given situation. Not every dental laser wavelength is necessarily useful for all dental implant situations. After clinicians know the characteristics of the wavelengths available to them, the application of this technology to the specific situation certainly is warranted. Dental implant surfaces and geometry also may affect the success of lasers in an attempt to bring ailing implants back to health. A comprehensive knowledge of these implant characteristics also is needed. As dental laser therapy continues to expand into the mainstream of dental practice, practitioners will examine the use of lasers in more procedures, which in turn will provide new impetus for further research into these fields to provide more and better therapy for dental patients.

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