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Laser Applications in Prosthodontics: A Review

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ABSTRACT

Lasers are now part of our lives in many ways. Lasers have also revolutionized many surgical procedures, minimizing bleeding, swelling, scarring, and pain. And now they are beginning to blaze a new trail in dentistry. The potential benefits of laser use in dentistry include procedures done on soft tissues of the mouth. Because laser techniques cause less pain than traditional methods, they are also likely to reduce the fear that many people have of the dentist. At the very least, lasers in some dental applications would eliminate the noise of the instruments that to some patients are nearly as disturbing as the physical discomfort[1].

Key Words: Laser, Prosthodontics, Implant Dentistry, Fixed Partial Dentures, Soft Tissue, Crown Lengthening

INTRODUCTION

It was not until 1990 that the field of laser dentistry began its earnest in clinical terms. In May 1990, the FDA cleared for intraoral soft tissue surgery a pulsed Nd: YAG laser. Developed by Myers and Myers, it was recognized as the first laser designed specifically for general dentistry called the **dLase 300**, it was manufactured by Sunrise technologies California. Other noteworthy firsts in FDA dental laser marketing clearances include the Curing of composite materials (1991), Tooth whitening(1995), Sulcular debridement(1997), Caries removal and cavity preparation(1997), Removal of coronal pulp(1998), Selective ablation of enamel caries.[1,2,3]

Laser Wavelengths Used In Dentistry

There are several laser manufacturers with various product offerings, and the reader should consult other sources for specific information for current details about companies and their instruments. The following are the brief descriptions of laser devices that have dental application. The lasers are named according to their active medium, wavelength, delivery system, emission modes, tissue absorption, and clinical applications.

Two categories of lasers are used in medicine and dentistry:

Laser types: Soft and hard

Soft lasers (cold or athermic lasers). These lasers provide cold (athermal) low energy at wavelengths believed to stimulate circulation and cellular activity (tissue regeneration, enhancement of healing). [4,5]

Hard lasers (Hot or thermal lasers) are used in surgical procedures to cut, coagulate, vaporize, composite polymerization and for welding purposes.[4,5]

Laser Application in Prosthodontics

1. Lasers in Complete Denture and Removable Partial Dentures: Prosthodontic problems that frequently occur with ill fitting dentures are high frenum attachments, scarred and keratotic tissue formations, and a shallow vestibule. Preprosthetic surgery is advisable in these situations to provide a better soft tissue bearing base. Conventional surgical procedures commonly produce extensive bleeding, which limits visualization and often requires suturing. When the area involved is large, there is often significant postoperative pain, and grafting is sometimes necessary to cover the wound but the laser offers the advantage of negotiating curves and folds easily, no bleeding during and after the procedure, a dry field, speed, minimal scarring, contracture, and reduced to absent postoperative pain and swelling for the patient.

1.1 Removing an inflammatory hyperplasia: first an area is lased with 4 to 6 W of indicated powering the defocused mode. For the; larger preprosthetic lesions such as those of inflammatory papillary hyperplasia, the CO2 laser is recommended due to its speed and effectiveness in vaporization.[6]

1.2 Frenectomy: The **argon** laser is a valuable tool in performing frenectomy procedures. While the argon laser is very effective in cutting fibrous tissue at higher energies, it is also particularly beneficial for lingual frenectomies because of the haemostatic properties of argon laser light. The use of argon laser during these procedures results in efficient tissue removal with a bloodless field. With the laser set at 1 to 2.25W, continuous wave delivery, the laser scalpel is placed on the frenular tissue, which is excised. Water spray may be used, but evacuation is always provided in the surgical site to remove the plume. This will result in power densities of 1,400 to 3,200 W/cm^{2}and result in tissue temperatures of 100^{0}C to 175^{0}C. The tissue is removed with conventional standards for incision design. The frenum can literally be cut away. Excellent haemostasis occurs, sutures are not required, and the patient experiences minimal discomfort during the healing period.[7,8]

1.3 Tuberosity reduction: Frequently the maxillary tuberosity area approximates the retromolar pad and is composed primarily of fibrous connective tissue. This condition needs to be altered to allow adequate space for the prosthesis. Also, although the maxillary tuberosity may not approximate the retromolar pad, it can be pendulous and not offer a stable base for the prosthesis. The choice of laser is one that can remove a large amount of tissue relatively quickly. The CO2laser is recommended for larger preprosthetic surgery because of its speed and effectiveness in vaporization. With the new 600µ and 1000µ fibers and sculpted tips and the paint brush like strokes allows the operator to vaporize or cut away tissue carefully and only as needed until the desired end result is achieved. Careful planning using impressions and mounted casts that can be altered and used to fabricate a splint are recommended. The splint then can be carried to the mouth to verify sufficient removal.[7,8]

1.4 Treatment of denture-induced mucosal lesions: The traumatic factors in the dentures may lead to chronic denture induced mucosal lesions. Patients belonging to these groups can go for the laser irradiation of the particular lesion with device. The therapeutic dose to treat inflammation is maximum optimal peak power, 12W, with a frequency modulation of 2.82 Hz, infrared wavelength of 904nm, and impulse duration of 200 nsec, according to the manufacture's recommendations. Each lesion is exposed to laser treatment for 90 sec once every other day for 3 weeks.[8,9]

1.5 Concept and development of a computerized positioning of prosthetic teeth for complete dentures: The complete transfer of the actual static articulator situation into a virtual, computer world is considered as data acquisition. This comprises three complexes; 3 D digitization, 3D referencing, and transferring individual structural points. Models of the edentulous jaws can be acquired sufficiently with conventional denture scanner system. Laser scanners, time of flight laser scanners; structured light scanners etc are conceivable. The acquisition accuracy should be +/- 0.25 mm. Maxilla and mandible casts are clearly assigned spatially by determining the jaw relation. It is important that the relation will be reproducible after removing from articulator and during scanning. This can be assured by attaching a hinge in the articulator on the back of the casts. If the joint is opened by approximately 180^0 after removal, both jaws can be scanned in one plane at the same time, including the hinge axis. The virtual models can be swung back on a circular path around the scanned hinge axis into the original position of the bite registration[8,9]

2. LASERS IN FIXED PARTIAL DENTURES

The use of lasers in dental treatment often is adjunctive to the fabrication of fixed prosthesis and, among many patients; this may be their first experience of such devices. Although an explanation of the use and the benefits of laser treatment often enhances the patient's appreciation of the standard of care being delivered, care needs to be exercised so as to not to engender expectations that are difficult to meet. One of the essential elements of success in fixed prosthodontics is the care and the accuracy of the component treatment stages and the laser often can confer minimal collateral tissue damage through proper consideration of the use of minimal laser energy of the correct wavelength.[10]

The final aspect of treatment planning is to guard against any claim or expectation that is unachievable. For example, employing a near infrared wavelength laser such as a diode or Nd: YAG laser to perform a frenectomy with very fibrous target tissue might require so much incident energy that the risk of periosteum or bone damage is high. In such a case, it may be prudent to use a scalpel to severe the fibrous band first and then complete the procedure with a laser. The correct use of laser wavelength as an adjunct to prosthetic restorative procedures can enhance the predictability, accuracy, and speed of case management.[10,11]

2.1 Gingival tissue retraction: Application of lasers on gingival tissue was made possible particularly by the use of flexible optical fibers (320-400microns for prosthetic applications) ensuring high precision of laser action at crevicular sulcus level. Sulcus conditioning with laser is an innovative method in the process of restoration with a fixed prosthesis, and the ever increasing operator interest in its atraumatic properties has made its development possible.

Argon laser energy has peak absorption in hemoglobin, thus lending itself to providing excellent hemostasis and efficient coagulation and vaporization of oral tissues. These characteristics are beneficial for retraction and hemostasis of the gingival tissue in preparation for an impression making during a crown and bridge procedure (Kutsch, 1993).[12,13,14]

2.2 Crown lengthening: Lasers can be very efficaciously used for crown lengthening due to excessive soft tissue or a passive eruption problem thus causing problem for tooth preparation during fixed partial denture procedures. When patients have clinical crowns that appear too short or when they have an uneven gingival line producing an uneven smile, excessive tissue can be easily and quickly removed without the need for blade incision. In **CO2** laser the power setting are usually from 3 to 6 watts of indicated power with a beam moving from a focused to a defocused mode as necessary. To protect the underlying tooth structure, a no 7 wax spatula is used in the sulcus. As lasing continues, the spatula moves in conjunction with the laser.

One first sound the area to determine the position of cementoenamel junction relative to the crest of the tissue. If this distance is short, there is a good chance that the clinical crown and the anatomical crown are approximately the same. Therefore when the situation arises, conventional crown lengthening must be performed to assure that the biologic width is not violated.[13,14,15]The **argon** laser can also be used to perform crown lengthening with osseous resection to establish the biologic width which absorbs hemoglobin, producing excellent hemostasis. The gingival flap is raised and 515.4nm argon laser with a 300μ-fiber, along with water and air spray and high speed evacuation, is used at 1.25 W of power with the pulse duration of .25 second, pulse interval of .10 second.

2.3 Soft tissue management adjunctive to crown placement: A case illustrates the treatment and accuracy of 810nm diode laser treatment and Nd: YAG in removing gingival in growth relative to a projected finished margin for a full veneer crown. In this case the coronal fracture has occurred with an existing indirect restoration, the small yet intrusive amount of soft tissue relative to the mesial aspect of the root face will compromise the management and accuracy of recording of the proposed new margin of the indented crown preparation. The soft tissue incursion represents significant problems for temporization, and for final prosthetic replacement of the lost tissue.[16]

The laser operating parameters are:

Parameters	Diode laser	Nd: YAG laser
Wavelength:	810 nm	1064 nm
Beam diameter:	320μm	320μm
Emission mode:	continuous wave	free running pulsed
Delivery:	quartz fiber contact	quartz fiber contact
Average power:	1.5W	2 W
Exposure time:	30 sec	45 sec per site

2.4 The use of an Nd: YAG laser in defining the emergence profile of abutment and pontic space in a combined natural tooth/ implant fixed prosthesis: The potential for direct damage to implant surfaces with the 1064 nm wavelength has been shown to be greater compared to other commonly used wavelength. So it is important to minimize heat transfer to the metal implant and to access radiographically the relationship of the pontic alveolus to the clinically evident profile of the overlying soft tissue. The management of the latter demands corrects power levels of the laser beam, whereas the former allows an innovative use of acrylic copings to insulate the implant and trans mucosal elements from direct laser exposure.With the gold and the acrylic copings in place the laser was used to excise excess marginal gingival tissue to leave cuff that would allow ease of hygiene. The 1064 nm Nd: YAG laser parameters are as follows:

Delivery: quartz fiber contact, Beam diameter: 320μm, Pulse width: 150 microseconds, Implant abutments; Energy: 150mJ, Pulse rate: 20 Hz, Average power: 3.0 W, Exposure time: 45 sec per site. Following laser treatment, the healing caps and provisional restorations were refitted, impressions made at 1 week, and final abutments constructed and fitted.[17,18]

3. LASERS AND IMPLANT DENTISTRY

An implant that integrates with biologic tissue and has perimucosal fixtures that can pass through the soft tissue and simulate near- ideal periodontal health should be chosen. All dental implants must pass through the submucosa and the covering stratified squamous epithelium into the oral cavity. Misch considers this the weak link between the prosthetic attachment and the predicted bony support of the implant. Typically, this is the zone where initial tissue breakdown begins that can result in tissue necrosis and implant destruction. The gingival epithelium or the biologic seal becomes an important factor in implant longevity. The seal must be effective enough to prevent the ingress of bacterial plaque, toxins, oral debris, and other deleterious substances. [18,19]

3.1 Use of laser technology in implant dentistry: The advantages of using laser in implant dentistry are the same as for any other soft tissue dental procedure. These advantages include increased hemostasis, minimum damage to the surrounding tissue, reduced swelling, reduced infection, and reduced pain postoperatively. Due to the hemostasis provided by the lasers, there is a significant advantage of improved visibility during surgery. 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.[20]

3.2 The use of laser impact the success or failure of the implant:

Nd: YAG has been a popular wavelength to use for soft tissue second stage surgery but some investigators contraindicate its use. Walsh (1992) and Block et al (1992) studied the effects of this laser 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.[17,21]

CO2 laser energy is reflected away from the metal surface, and hence the failure of implants to absorb the energy is the major advantage of this wavelength. Use of CO2 wavelength minimizes the risk of temperature induced tissue damage as a result of lasing the implant surface. It is generally accepted that the threshold for bone cells to remain viable is a temperature increase from 37^0C to 47^0C. An article by Mouhyi et al(1999) demonstrated that a CO2laser on a wet implant surface in pulsed mode at 8 watts(10 milliseconds pulse duration, 20 Hz for 5 sec) induced a temperature increase of less than 3^0C, well within the 10^0C safety margin from 37^0C-47^0C. The haemostatic properties of CO2 are excellent, which is a tremendous advantage for its use on soft tissues. The fact that CO2laser energy does not alter the implant surface because it is reflected away is also a benefit.[23,24]

The Erbium family of lasers is similar to the CO2 wavelength in some aspects. There is minimal depth of penetration in soft tissue and reflection away from the implant surface. The erbium lasers don not have a significant haemostatic capability as CO2 or Nd: YAG. By using the 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. All types of lasers can be used to excise or vaporize periodontal tissues as needed to expose dental implants. [22,24]

One advantage of 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 haemostatic effect of 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 laser can eliminate the trauma to the tissue of flap reflection and suture placement.[25]

3.3 The significance, in the short- and long- term, of laser use in implantology: During the laser therapy there is also a potential for obliteration of the attached gingiva if the 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 patients where the same bacteria reside in the implant sulcus as in the sulci of natural teeth. Although there is a hemidesmosomal attachment around the implant abutment to create a biologic seal, attached gingiva serves as a barrier to exposure of implant body due to recession over time, just as around natural teeth. 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.[26,27]

3.4 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. Diode laser were used in a study by Bach et al (2000) who found a significant improvement when integrating laser decontamination into the approved treatment protocol. Dortbudak et al (2001) found that the use of a low level laser therapy with a diode soft laser(690nm) for 60 seconds after the placement of toluidine blue O for 1 minute on the contaminated surface reduced the counts of bacteria by minimum of 92%. This reduction was significant but not complete and hence the same group was studied using the wavelength of 905 nm on all types of implant surfaces (i.e. Machined, plasma-flamed-sprayed, etched, and hydroxyappatite coated). Their data on several implant surfaces suggest that lethal photosensitization, through the use of toluidine blue O to sensitize the cell membrane to laser light, may have potential in the treatment of peri-implantitis.[25]

CO2 lasers have been successful in decontaminating implant surfaces. Kato et al in 1998 have found that irradiation with an expanded beam may be useful in removing bacterial contaminants from implant surfaces.

Er: YAG laser also has been proposedforsurface decontamination of dental implants. Schwarz et al in 2003 stated that this laser wavelength was found to be effective for removing sub gingival calculus from titanium implants without leading to any thermal damage. Even at low energy densities, the Er: YAG laser has a high bactericidal potential on common implant surface, with no morphologic implant surface alterations detected.[27,28]

Nd: YAG laser did not sterilize the plasma sprayed titanium or plasma sprayed hydroxyappatite coated titanium dental implants. In addition it causes melting, loss of porosity, and other surface alterations.[24,25]

3.5 Immediate implant and decontamination using aNd: YAG laser:

3.6 Osteoblast attachment on titanium after laser irradiation: Osteoblast attachment on titanium surfaces is necessary to achieve new bone formation and Osseo integration. Romanos et al in 2006 conducted a study to examine the attachment of osteoblasts on titanium surfaces after laser irradiation using titanium discs and divided into 2 groups which were machined, hydroxyapatite coated, sandblasted and titanium plasma sprayed. One group was irradiated with CO2 laser and the other with Er: YAG laser. The CO2 laser was used with a spot size of 1.5 mm.[27]

4. LASERS AND MAXILLOFACIAL PROSTHODONTICS

A considerable number of people are afflicted with a some degree of facial defect or anomaly each year thus causing the emotional pressure. Advancements in the modern surgical procedures, instruments, and equipments have provided some afflicted with facial disfigurement with new opportunities to be reintegrated into society through corrective/ restorative or plastic surgery.[46]Recently, as a result of advances in the digitized imaging technology, it has become possible to obtain non-contact 3- dimensional facial measurements and 3- D anatomic models.[47]

To avoid the disadvantages of CT scanning or MRI an optical modeling process for extra oral defects and body areas was developed. The development was based on the experience in the collection of digitized data for tooth related model dependant representations. The optical 3- dimensional scanning unit provides a point cloud or virtual model of face.The use of lasers holds good in the maxillofacial prosthodontics for the data acquisition and mold fabrication with the use of stereo lithography. So the role of lasers in the maxillofacial prosthesis can be grouped into:

- Collection of 3- D anatomical data using 3-D lasers scanning system.
- Manufacture of the physical prototype **(Rapid Prototyping)**.[16,19,20]

DISCUSSION

Soft lasers and hard lasers, depending upon the various wavelengths used. The common lasers used in the prosthodontic view of point are commonly carbon dioxide laser, argon laser, Nd: YAG laser, Er: YAG laser, Ho: YAG laser, Diode laser, KT laser and He-Cd laser. For the complete denture and the removable partial denture the lasers are commonly used in the Preprosthetic surgery especially the CO2 lasers. The CO2 lasers have the property of charring the layer thus giving the bloodless field. The other lasers used are the argon laser (due to its affinity to hemoglobin) and the Nd: YAG laser (attracted to pigmented tissue and have various degrees of optical scattering and penetration in tissue, minimal absorption and no reflection).So these lasers are basically used for the frenectomies, tuberosity reduction, and various soft tissue lesions. These lasers are now a days offering their application into the prosthetic arrangement of the teeth. Lasers have also contributed into the field of fixed prosthodontics by the application of lasers on gingival tissue made possible particularly by the use of flexible optical fibers (320-400microns for prosthetic applications) ensuring high precision of laser action at crevicular sulcus level.

The commonly used lasers are the diode laser, Argon laser and the Nd: YAG lasers so as to ensure the proper demarcation of the finish lines during the impression making. CO2 laser and the argon laser have found its use in the crown lengthening procedures so as to expose as much as tooth surface for crown preparation. The advantages of using laser in implant dentistry are the same as for any other soft tissue dental procedure. These advantages include increased haemostasis, minimum damage to the surrounding tissue, reduced swelling, reduced infection, and reduced pain postoperatively. Due to the haemostasis provided by the lasers, there is a significant advantage of improved visibility during surgery. Each specific wavelength has its own absorption characteristics. Nd: YAG has been a popular wavelength to use for soft tissue second stage surgery and CO2 laser energy is reflected away from the metal surface, and hence the failure of implants to absorb the energy is the major advantage of this wavelength. The Erbium family of lasers is similar to the CO2 wavelength in some aspects. There is minimal depth of penetration in soft tissue and reflection away from the implant surface.

The erbium lasers do not have a significant haemostatic capability as CO2 or Nd: YAG. By using the 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. All types of lasers can be used to excise or vaporize periodontal tissues as needed to expose dental implants. One advantage of 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 haemostatic effect of 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 laser can eliminate the trauma to the tissue of flap reflection and suture placement. The use of lasers holds good in the maxillofacial prosthodontics for the data acquisition and mold fabrication with the use of stereo lithography. Laser surface digitizing relies on a laser projector and a detector system to accurately capture 3-D topographic data of the external surfaces of the physical objects. Data produced are 3-D point cloud data set stored in various formats. Specialized CAD software is used to reconstruct the surfaces of the scanned object from the output digitized data to yield a computer model of the object.[20,23,25,]

CONCLUSION

Lasers have been investigated for potential use in working with dental materials since the mid 1960's.Laser welding can help solve the technical problems encountered in the repair of various dental alloys. Laser welding belongs to the field of melt weld processing. The efficiency of the laser beam treatment is determined by the absorbed optical energy of the material in use and is proportional to the degree of absorption of the material. Metals with a high reflection have a small degree of absorption in the visible and infrared spectral areas.Following the recent advances in high temperature, vacuum casting technology, it is now possible to use titanium as a prosthetic material (e.g. partial dentures, crowns and bridges). Within the dental field, soldering has generally used to join metallic materials. Titanium, however, is very difficult to solder because of its high melting point. As an alternative method, laser welding of titanium is more practical.

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