

APPLICATION OF LASER TECHNOLOGIES IN DENTAL PROSTHETICS

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Abstract: *Laser technologies are widely used in various areas of contemporary practice - not only in engineering but also in medicine. Owing to them, more accurate and precise results are achieved in making objects of unique shape and size for various purposes. In recent years, these technologies have entered rapidly into dental prosthetics. Several processes are mainly used: laser cutting, laser welding, laser sintering, rapid prototyping, laser cladding and laser surface structuring. Laser cutting and laser welding are mainly used in dental laboratories for production of large bridge prostheses ensuring high construction accuracy. By laser sintering and laser prototyping, individual crowns, dentures and implants are made from 3D models for each patient. Laser cladding and laser nanostructuring are used for surface treatment of implants to enhance their biocompatibility and osteoblast integration.*

Keywords: LASER CUTTING, LASER WELDING, LASER SINTERING, LASER CLADDING, DENTAL PROSTHETICS

1. Introduction

The laser is a generator of electromagnetic radiation with distinct properties - coherence, monochromaticity, directionality and high brightness. Laser radiation can convey vast energy for a short time. Moreover, the electric and magnetic fields generated in the points where the laser beam falls are as strong as the fields in the atoms. On account of that, mediums begin to exhibit unusual properties: two or more photons are absorbed simultaneously, the medium itself focuses the laser beam and reduces its cross section, and sometimes the substance is ionized or heated considerably.

With the widespread introduction of lasers nowadays it has become possible to achieve faster, more accurate and more precise results. They are most helpful in making objects of unique shape and size for various purposes [1,2,3]. Laser light, a powerful high-energy photon radiation, is increasingly applied in different areas and aspects of science, technology and medicine [3-6]. In recent years, various technologies for laser processing of materials have been more and more widely used, such as: laser cutting, laser welding, laser sintering, laser nanostructuring and laser prototyping of complex details. With their help, production time and costs have been significantly reduced. The great potentials of these technologies render it possible to use them in medicine as well for making of unique components - prototypes, dental implants, whole and partial dentures, implants of joints and whole limbs [2-6]. The purpose of this article is to review the application of different laser technologies in dental medicine and particularly in dental prosthetics.

2. Laser technologies in dental prosthetics

The proper make of an elaborate detail or part thereof, requires accurate, sensitive and high-quality equipment. Lasers, with their potentials to operate at high speeds in hard-access environments and to be incorporated in CAD-CAM systems, are the perfect candidate to this end.

2.1 Laser cutting

Because of their high levels of power, CO₂ lasers are commonly used in industry for cutting and welding, while low power lasers are

used primarily for engraving [7,8]. In dental prosthetics, the contraction of metal alloys results in errors when making large bridge constructions. This can easily be corrected by cutting in certain points and subsequent welding (Fig.1). The use of laser in these operations ensures both accuracy and speed in making the construction [9].

In recent years, CO₂ lasers have also been used for making of miniature plastic products with high precision because the polymethyl-metacrylate (PMMA) plastic absorbs infrared (IR) light with a wavelength in the range of 2,8-25µm and creates mikrofluidni devices from it, with channel widths of a few hundred micrometers [8].

2.2 Laser welding

Laser light is a powerful high-energy beam, which can produce quality welds at high speed and high efficiency [10-14]. The intensity of the laser beam is approximately 10 000 times greater than the intensity of the electric arc. It can evaporate any known material. The high-speed processes in the narrow working area of the focused laser beam result in obtaining weld joints of smooth surface, homogeneous microstructure and small deformations. It is recommended that laser welding be performed with a high-energy laser, as losses are smaller, the compression force is greater and the

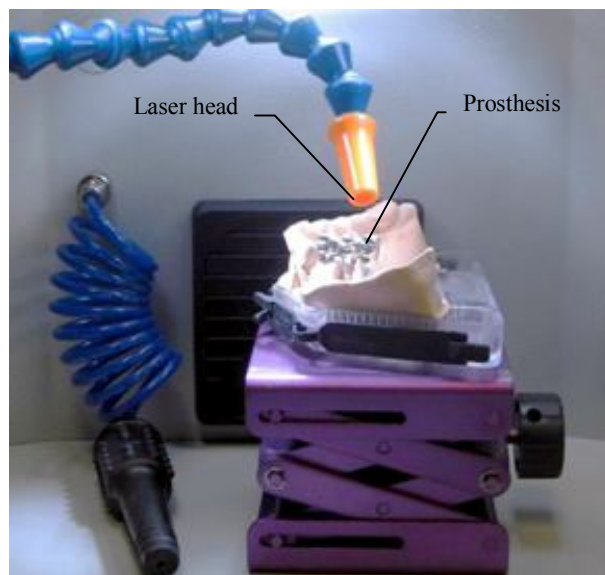


Fig. 1 Laser cutting of dental prosthesis.

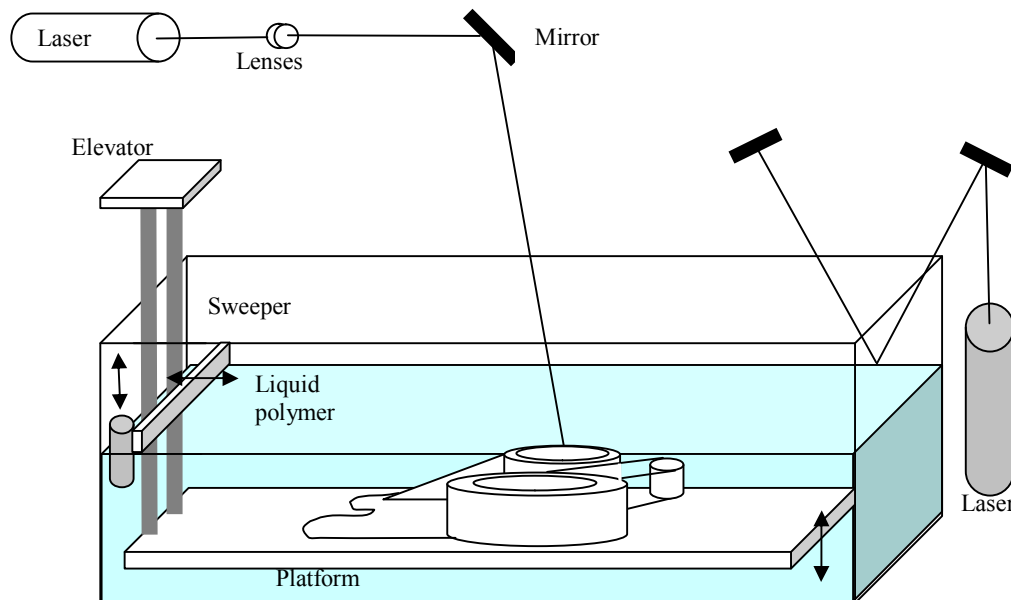


Fig.2 Scheme of the laser stereolithography method (SLA).

fusion between two heterogeneous materials is easier [11].

Laser welding is becoming increasingly important in dental prosthetics because of the high speed of the processes and the minimal deformations. The high-powered and precisely directed laser light in laser welding is emitted in a point with a diameter of 0.5 to 1mm – a prerequisite for creation of very high temperatures that can easily melt alloys. In dental prosthetics, laser welding is used mainly for correcting longer metal skeletons in metal-ceramic bridge prostheses. This is necessary in order to increase the accuracy of casting. Larger constructions are hard to fit onto bridge supports due to the great contraction of alloys; therefore, they are cut in certain points, corrected and then welded. Laser welding is also used in combined prostheses for highly precise welds of various holding elements, such as different types of locks.

2.3 Laser sintering and laser prototyping

Prototyping or layered manufacturing combines different methods, materials and technologies for producing three-dimensional objects directly from the data source - a computer with CAD system, by eliminating the need for tools. Most rapid prototyping processes are additive. They involve building of one layer at a time from a powder or liquid that is bonded by means of melting, fusing or polymerization, often with the aid of a laser.

The first techniques for rapid prototyping date from the end of 1980s; they were used to make models and prototype parts of plastic. Today they are used in a much wider range and are even used to produce products of unique quality and parts in relatively small series [15-19]. They offer a number of advantages over traditional methods of production:

- The objects thus obtained may sometimes be quite complex, without the need for any complex machinery setup or final assembly;
- The objects can be made of the same or different materials. Their composition may be altered in a controlled manner, regardless of the location of the object;
- The method of production involves a controllable, easy and relatively quick process.

The most common principles for laser prototyping are methods involving stereolithography (SLA), selective laser sintering (SLS), direct metal deposition (DMD), fused deposition modelling (FDM),

laminated object manufacturing (LOM), inkjet-based systems and three dimensional printing (3DP). [3, 4, 14, 15]

In SLA, the ultraviolet energy is typically emitted by Nd:YAG, Ar, or HeCd laser that activates a liquid photopolymer to solidify it the next moment into the desired 3-D model (Fig.2). Parts, produced by SLA, are known for their durability, functionality, resolution and surface quality [4].

One of the machines creating rapid prototypes uses selective laser sintering (SLS). It typically uses a high-power beam of a CO₂ laser. The high temperature created by this laser causes polymer or metal powders to melt and deposit layer over layer thus building a strong, durable form of a certain design (Fig.3).

In this way the properties of the material can be improved – by taking one type of powder, such as steel, and mixing it with another type, copper for example, to achieve 100% steel in one area, 100% copper in another, and a combination thereof in between. This is helpful in testing materials and plays an important role in creating new kinds of parts, such as ceramic-coated metals. Therefore, the reliability and durability of material can greatly be improved compared to traditional materials.

SLS is the most advanced technology for laser fusion. It uses a laser beam to scan the surface and detect areas of agglomerates and particles bondage. The rest of the layer remains as powder. To build the next layer, a layer of powder is applied on top of the layer that is



Fig.3 Basis for dental prosthesis made of PMMA by selective laser sintering (SLS).

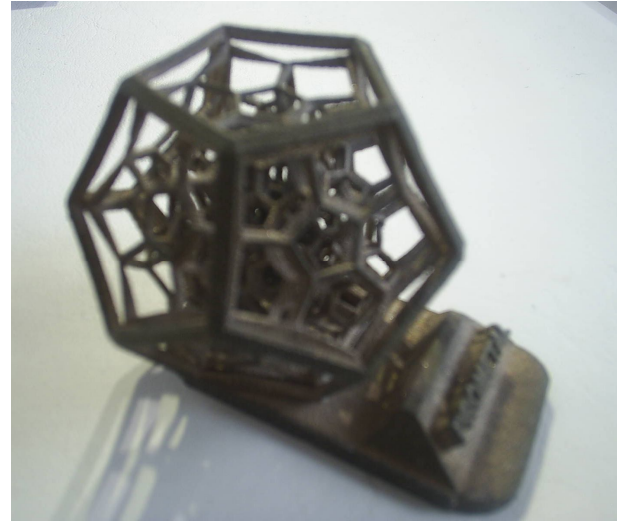
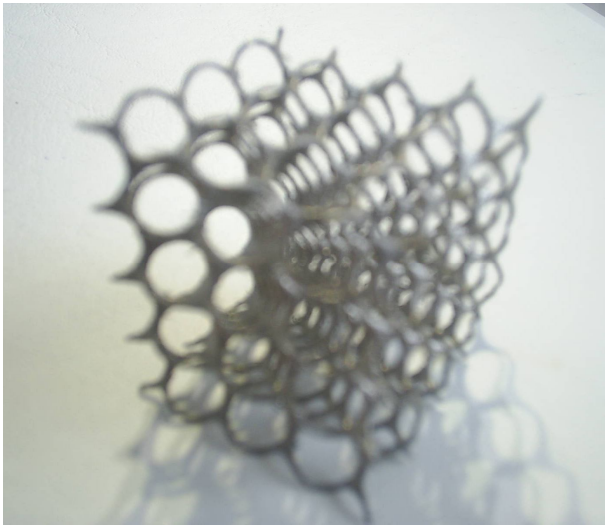


Fig.4 Steel details made by selective laser sintering (SLS).

already built. The laser is used to process the next layer, the one applied on top of the previous. The procedure is repeated until the product is ready (Fig. 4). It is believed that traditional sintering techniques can be used to “compact” various kinds of materials - Al_2O_3 , SiC and Zr composites for example.

Professionals in the field of laser prosthetics are increasingly interested in designing and manufacturing prostheses and implants, improving and streamlining the process using a three-dimensional biomodel particularly in the field of dental implants. The process of dental prosthetics in SLS includes the following procedures:

1. Computer tomography of the patient [3, 20, 21]
2. Computer 3D simulation for separation of hard and soft tissues.
3. Making of a layer-by-layer stereolithographic biodental model from a photopolymer resin using a laser beam. The model thus created can be used for making a diagnosis and a treatment plan.
4. Making of a treatment plan using the created model.

In direct metal deposition (DMD), the material is applied by injecting metal powder in a molten pool created on the surface of the detail by CO_2 laser beam, where the powder melts and deposits. As a result of the melting process, the coating is free of pores and cracks, and the bond with the base material is extremely strong. Different powders can be mixed or alternately deposited in order to create customized layered constructions. This method is commonly used for creating of different metal or ceramic coatings on orthopaedic and dental implants which enhance wear-resistance, biocompatibility and osseoblast integration.

2.4 Laser nanostructuring

Titanium and its alloys are increasingly used in biomedical applications because of their physical, structural and mechanical properties. Ti-6Al-4V alloy is widely used for making implants (orthopedic and dental) because of its low cytotoxicity and high biocompatibility, as well as corrosion resistance, durability and fatigue resistance [22]. In most applications, surface grooves and porous coatings are made over the implants of this alloy to improve osseointegration. Typically, the desired area of implant is blasted with Al_2O_3 and SiC particles to create a micron-sized roughness on the surface [23]. These mechanical techniques may lead to significant changes in the chemical composition of the surface

layer. This can lead to deformation, mechanical degradation and increase in the local concentration of cytotoxic elements, such as Al or V [24]. Therefore, diode-pumped solid-state (DPSS) lasers appear to be an alternative for processing materials with UV and IR lasers based on Nd:YAG and Nd:YVO₄. They can control pulse rate, scanning speed and lens focal length, which in turn controls the location and size of roughness [22,23,24]. Laser processing helps to achieve surface roughness in the nanorange, leading to improved biocompatibility between materials and tissues. Nanostructured surfaces improve cellular attachment and direct the cells to grow into defined structures [22-28].

3. Conclusion

In recent years, laser technologies have widely entered into dental prosthetics. Several processes are mainly used: laser cutting, laser welding, laser sintering, rapid prototyping, laser cladding and laser surface structuring. Laser cutting and laser welding are mainly used in dental laboratories for making of large bridge prostheses while ensuring high construction accuracy. By means of laser sintering and laser prototyping individual crowns, dentures and implants are made from 3D models for each patient. Laser cladding and laser nanostructuring are used for surface treatment of implants to enhance their biocompatibility and osteoblast integration.

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