Application of Fractional Co2 Laser Modification of PEEK in Dental Implants, *In vivo* Study

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Abstract

This study aimed to Modify the PEEK surface using Fractional CO2 laser in different range of parameters to change the surface topography regarding roughness and wettability to enhance osseointegration. A PEEK block (Ceramill PEEK 98X20 N -JUVORA dental innovations, UK) was used to prepare substrate. By CAD-CAM system, PEEK was cut into discs (2 mm thickness and 10 mm diameter). the discs were smoothed by silicon carbide paper of 500 grit and a rotation motion, polishing machine at 200 rpm for one minute used to polish the discs, finally cleaned with ethanol alcohol using ultrasonic cleaner. Different parameters were tested to study their effects on PEEK surface; therefore, several trails were done using Fractional CO2 laser device. Surfaces of the irradiated PEEK discs were examined microscopically at different magnification power. Then SEM was used. Then, PEEK samples were scanned by (EDS). Range of powers were used (2, 4, 6, 8, 10, 12) W The distance between spots was 0.2mm and 0.2 ms pulse duration to ensure maximum coverage of laser effect. The energy range was (4 - 25) which was n't enough to produce any effect. To test the effect of pulse duration different values were also studied starting from 0.2ms then increase the pulse duration. 0.4,0.6,0.8 ms to increase the energy per pulse accordingly. Starting from short pulse duration up to 0.6ms there was no effect even when the power increased. At 0.8 ms pulse duration, the effect was recognized on the specimen surface. The collected data of previous trials direct the operator to reduce pulse duration to have best criteria, including surface roughness, wettability, without carbonization or cracks.

Conclusions: Successful modification of PEEK surface can be done with fractional CO2 laser. Laser parameters as power, pulse duration, distance between spotes and number of scans are key factors induced different range of effect considering material's properties.

Keywords: *PEEK, Laser, SE, implants, Co2.*

Introduction

Dental implants serve as artificial roots for the fixation of dental prostheses. By restoring the masticatory function through dental implants, the quality of life and nutritional status of the affected patients can be markedly improved**.** Osseointegrated dental implant was described as structural and functional connection between living bone and the implant's surface, under light microscope[1]. In spite of well evidence- based implants made from titanium and titanium alloy,, it was observed that their usage can be associated with a variety of disadvantages, such as its light transmission lack, titanium can affect esthetic results**.** In cases of high smile line this can cause a darkness in neck of the periimplant soft tissue with thin gingival biotype or/and recession of gingivae surrounding a titanium implant . Also, hypersensitivity to titanium and other problem could occur because of the gradient difference in the titanium implant's elastic moduli and the bone surrounding it[2]. As a substitution to titanium, implants made from ceramics were suggested Dental implants made from zirconia, were biocompatible, tooth like-color, and low plaque affinity, which appeared to be a better convenient substitution to titanium **.** But, because of higher elastic modulus of zirconia than the bone, might result in higher peaks stress in comparison to titanium**.** Other biocompatible material closer in modulus of elasticity of bone, is polyetheretherketone (PEEK)**.** PEEK is a thermoplastic polymer with a high-performance capable of replacing components of metallic implant in the field of orthopedics**.** With such findings encouraged the suggestions for PEEK to be substitution for titanium as dental endosseous implants' material[3]**.** However the radiolucency and the good wear resistance of PEEK are advantageous for many orthopedic applications also it can be imaged by X-ray, CT scan, or MRI without any distortion in comparison to the conventional titanium (Ti). In spite of these superior properties, PEEK is still classified as bioinert because of its much decreased reaction with the surrounding tissue, which restricts its potential applications **.** For overcoming this problem, many method have been suggested which can broadly be divided into two main categories: incorporation of bioactive materials and surface treatment techniques such as laser surface modification[1]. Laser treatments are used because of the resolution is high, speed of operating is high, and the bulk properties of implant will not be changed by the laser**.** That's why, lasers were introduced to improve implant. The CO2 laser of wavelength 10600 nm with an advanced technique referred to as a factional CO2 laser, it deliver the energy in parallel vertical columns of multiple microscopic thermal spots called microscopic treatment zones (MTZs), while the distance between spots remains intact and untreated[4]**.**

Aims of the Study: Modification of PEEK surface using Fractional CO2 laser in different range of parameters to change the surface topography regarding roughness and wettability to enhance osseointegration.

Materials and Method

Sample Preparation: PEEK block (Ceramill PEEK 98X20 N -JUVORA dental innovations, UK) was used to prepare substrate . By CAD- CAM system, PEEK was cut into discs (2 mm thickness and 10 mm diameter). To have a uniform smooth surface for standardization, the discs were smoothed by silicon carbide paper of 500 grit and a rotation motion, polishing machine at 200 rpm for one minute used to polish the discs, finally cleaned with ethanol alcohol using ultrasonic cleaner.

Laser Irradiation: Laser irradiation was done at Institute of Laser for post graduate studies/University of Baghdad considering all safety requirements. Different parameters were tested to study their effects on PEEK surface; therefore several trails were done using Fractional CO^2 laser device Figure (1).

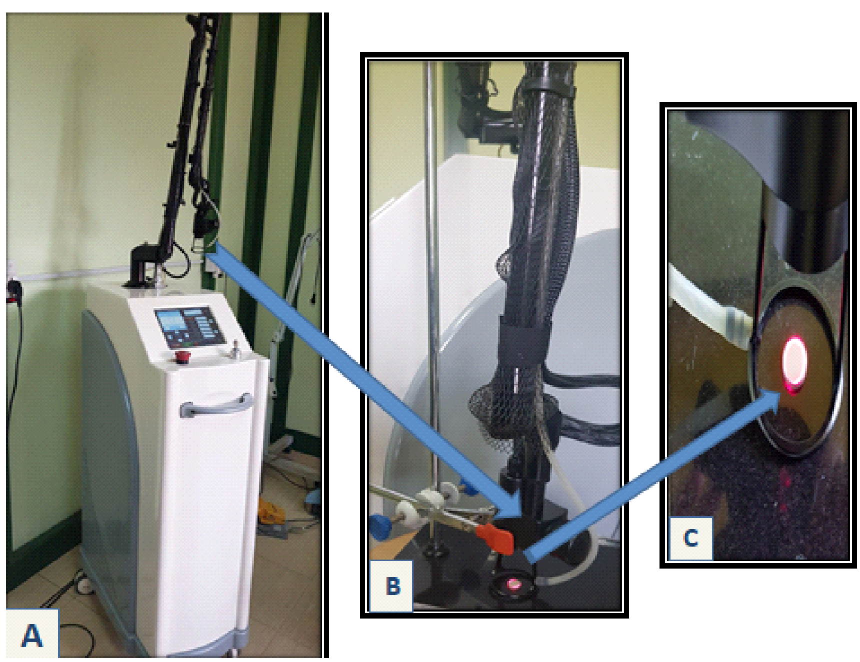

Figure (1): (A) fractional CO^2 device. (B) Articulating arm of laser device (C) PEEK disc ready for laser irradiation

During irradiation, the arm of the laser device was fixed using laboratory clamp and PEEK specimen was set on a stage at fixed distance between the beam source and the specimen surface in-----cm.

Light Microscope: Surfaces of the irradiated PEEK discs were examined microscopically at (4,10, 20 and 40X) magnification powers using light microscope (BX51/OLYMPUS).

Scanning electron microscope (SEM): Laser irradiated samples were scanned by SEM (Oxford instruments, UK) to see the difference on the surface topography.

Atomic force microscope (AFM): Surface roughness was assessed by atomic force microscope (AFM) for the irradiated and non-irradiated samples.

Energy-dispersive X-ray spectroscopy (EDS): PEEK samples were scanned by (EDS) (Oxford instruments, UK) for surface analysis and to calculate the percentage of elements formed on the surface of the irradiated and non-irradiated samples.

Contact Angle: Wettability test was conducted using contact angle measuring device (Creating Nano Technologies Inc., Taiwan). The specimen was placed on adjustable table and micropipette dropper was used to dispense a drop of normal saline in 6.89 micro liter volume. The distance between the dropper tip and specimen surface was 4 mm.

Results

1. Range of powers were used (2, 4, 6, 8, 10, 12) W The distance between spots was 0.2mm and 0.2 ms pulse duration to ensure maximum coverage of laser effect. The energy range was (4 - 25) which was n't enough to produce any effect.
2. To test the effect of pulse duration different values were also studied starting from 0.2ms then increase the pulse duration. 0.4,0.6,0.8 ms to increase the energy per pulse accordingly. Starting from short pulse duration up to 0.6ms there was no effect even when the power increased. At 0.8 ms pulse duration, the effect was recognized on the specimen surface.
3. Considering the result from previous trials an attempts were carried out regarding distance between spots,duration and scans. Then decision was made to increase the distance (0.2, 0.4, 0.6mm,….) to reduce heat accumulation, And as shown in figure (2) different powers were tested with 0.4mm distance and 1ms duration which produce deferent effects with sign of carbonization in most trails.

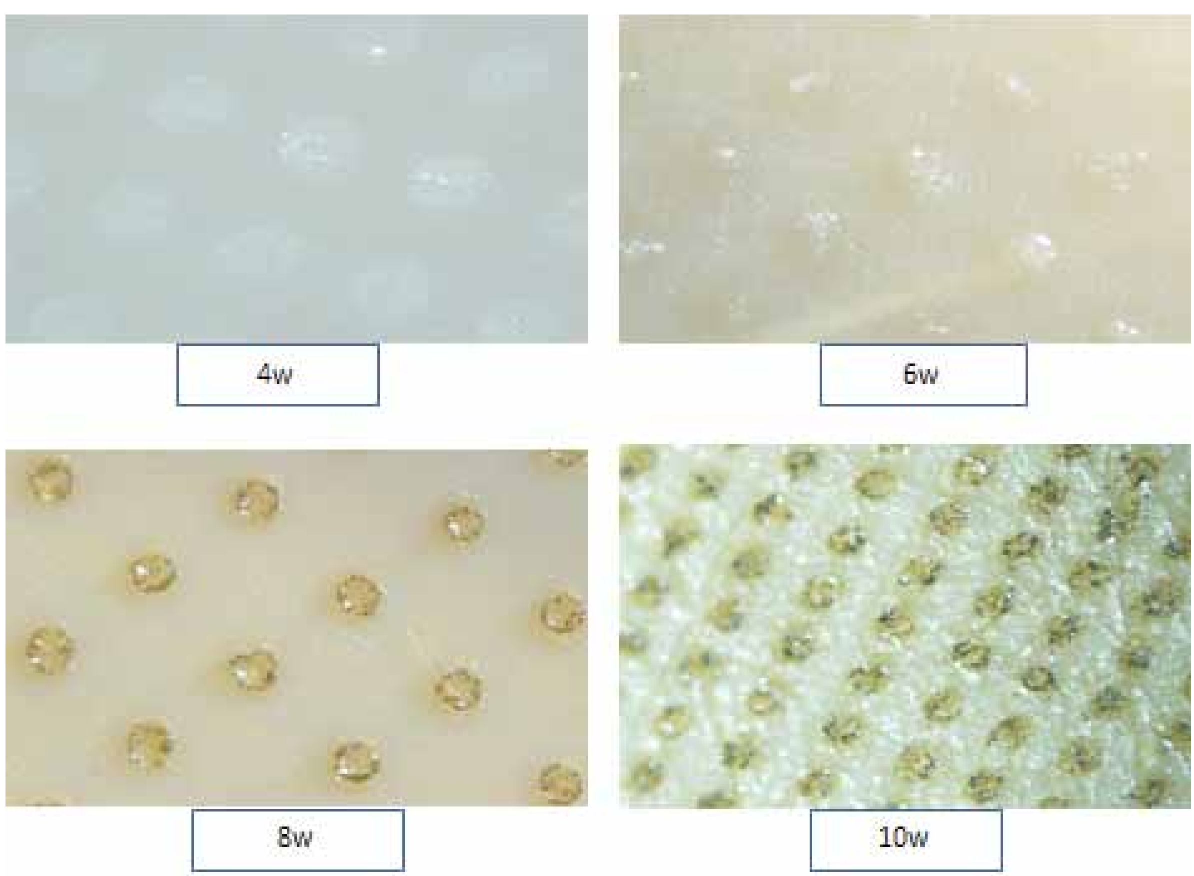

Figure (2): Light microscope image of PEEK specimen treated with 0.4mm distance, 1ms duration and 1 scan. (10 X).

4. The collected data of previous trials direct the operator to reduce pulse duration to have best criteria, including surface roughness, wettability, without carbonization or cracks. The effect for specimens irradiated under 6W power shows interaction without carbonization, this also confirmed with SEM. Increased power (W) does not improve the result, in fact carbonization was clearly appeared with SEM.

Discussion

Numerous method have been used to modify the surface wettability, such as Fractional CO2 laser treatment because laser treatment can be used to target specific areas with higher precision,restriction manual movement of the hand piece during operation and the pattern which can be achieved is homogenous[5].

Wettability results agreed with[6] who concluded that the contact angle analysis showed a reduction in water contact angle with increasing laser power intensity, and the derived surface free energy increased accordingly . Different method of surface modification enhance wettability this is agree with [7].

For surface physical properties of dental implant materials, the surface with a certain degree of roughness is essential for the formation of bone implant interface[8,9]. In many ways, laser has been considered a new tool to process material surfaces because of its high efficiency and accuracy.

First of all, the rough surface is beneficial for the adsorption of organism protein and mineral. Second, the adhesion, migration, proliferation, differentiation, protein synthesis, and mineralization of osteoblasts on the materials surface were also promoted because of the increase in surface roughness[10,11]. In addition, the increase in surface roughness can expand the contact area between implant materials and bone and make the formation of locking effect at the bone implant interface. Finally, the bonding strength of the bone implant interface can be improved by forming rough surfaces[12,13].

Conclusions:- Successful modification of PEEK surface can be done with fractional CO2 laser. Laser parameters as power, pulse duration, distance between spotes and number of scans are key factors induced different range of effect considering material's properties.

Ethical Clearance: The Research Ethical Committee at scientific research by ethical approval of both environmental and health and higher education and scientific research ministries in Iraq.

Conflict of Interest: The authors declare that they have no conflict of interest.

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