# Influence of Laser and Ultraviolet Surface Modification Strategies on Zirconia Implants Osseointegration in Rabbits: In vitro – Histological study

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**Abstract: Introduction:** Zirconia is a promising alternative to titanium regarding to dental implant field. Additional surfaces modifications to enhance osseointegration is essential for hard and dense zirconia implants. **Objectives:** This study aimed to evaluate the influence of laser and Ultraviolet surface modification strategies to enhance osseointegration of zirconia implants. **Materials and Methods:** CAD/ CAM zirconia discs (8mm x 3mm) (N=30) and implant cylinders (3mm x 6mm) (N=36) were milled and sintered according to manufacturer instructions. Specimens were divided into three groups; (Unmodified control surfaces), (Nd: YAG laser modified surfaces) and (UV light modified surfaces). Zirconia surfaces were modified by Nd: YAG laser and UV light. Surface roughness topography (Ra) values and wettability of all discs were characterized using confocal laser scanning microscopy and contact angle records. In vivo phase was performed by insertion of zirconia implants into the femur's heads of rabbits for histological evaluation of osseointegration. **Results:** No significant difference was detected between (Ra) mean values of unmodified and UV light modified surfaces. While, Nd: YAG laser modified surfaces recorded the significantly highest (Ra) mean value ($P<0.001$). Regarding to the contact angle records, the significantly lowest records were for the UV modified surfaces, then Nd: YAG laser modified surfaces, and the unmodified surfaces recorded the highest values ($P<0.001$). Histological finding revealed superior osseointegration for the Nd: YAG laser modified implants, satisfied osseointegration for the UV modified implants, and the poorest osseointegration features were observed around the unmodified implants. **Conclusions:** Nd: YAG laser and UV light enhanced osseointegration of zirconia implants through alteration of zirconia surface topography and wettability.
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**Keywords:** Zirconia implants, Nd: YAG laser, UV light, wettability, osseointegration.

## 1. Introduction

Dental implants have been considered a well-accepted and predictable alternative to the rehabilitation of completely and partially edentulous patients. The clinical success of this treatment modality is strictly related to osseointegration which defined as a direct attachment of osseous tissue to an implant without intervening fibrous tissue(1). Implant surface characteristics are considered as factors that affect the rate and extent of the implant bone response as well as the mechanical quality of the bone/implant interface(2). Distinctive alterations of implant surfaces may lead to different and unique chemical as well as physical surface properties; and even might potentially lead to changes in the bone-to-implant reaction. Moreover, the biological activity of dental implants is evidently affected by the surface topography and surface physicochemical properties. Surface topography has an obvious effect on cell behavior. Likewise, protein adsorption and subsequent cell behavior will depend on surface physiochemistry, especially surface energy (wettability)(3, 4). The surface topography of dental implants is important for adhesion and differentiation of osteoblasts during the initial phase of osseointegration as well as in long-term bone remodeling(5). It was reported that, both the early fixation and long-term mechanical stability of the prosthesis can be improved by a high roughness profile compared to smooth surfaces(6). The surface wettability or hydrophilicity of implants is another aspect of osseointegration that considered as one of the key factors for the initial proteins' interaction on the implant surfaces. This physiochemical property is expressed by the water contact angle that ranges from [0 degree] on very hydrophilic surfaces to greater than [90 degree] on hydrophobic surfaces. Hydrophilic surface was demanded to be valuable for the early phases of wound healing and osseointegration, moreover, the influence of these hydrophilic surfaces to enhance osseointegration can be supported by progresses in the bone implant contact and bone anchorage during bone healing in the early stages(7,8). Theoretical relationship between roughness and wettability was defined in 1936 by Wenzel as increasing roughness is directly related to wettability enhancement. Practically, it was stated that roughness could be recognized to produce an apparent contact angle, hence roughness has a strong influence on wettability of engineering surfaces(9). Currently, zirconia is considered to be an alternative ceramic material to overcome titanium problems, especially in the dental field. Yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP) is the most frequently studied ceramic candidate for fabrication of dental implants. Y-TZP presents various interesting characteristics that appropriate for biomedical applications, such as low porosity, high density, high flexural and compression strength in addition to its superior fracture toughness(10,11). It has been established that modifying surface characteristics, such as topographical configuration and physicochemical properties, can influence the zirconia implants osteoconductivity consequently improving the initial stability and osseointegration. zirconia implants have been treated with different chemical, physical and pharmacological surface strategies including: CaP coating, sand-blasting or impregnation with collagen type I(12). Sand-blasting or sand-blasting in combination with acid etching (13-19). Selective infiltration etching with bioactive-hybrid zirconia surfaces(20). Recently femtosecond laser microstructuring have been proposed to modify the biological activity of zirconia dental implants surfaces by the following benefits: increases surface roughness without increase the monoclinic phase (21), increases the bone to implant contact and improves the bone density when immediate loading is applied(22,23). Other added advantages of Laser are simplicity, clean, better control of configuration enables implant surface and lack of direct contact (24). It has been reported that surface treatment with Nd:YAG laser creates a uniform roughness on the zirconia surface(25).Ultraviolet (UV) irradiation has the ability to increase the hydrophilicity of zirconia surface, this is attributed to increasing the oxygen (O) and decreasing in carbon (C) elements on the surfaces resulting in reducing of zirconia surface hydrocarbon degree as well as increases surface energy and wettability(26 – 30). UV photofunctionalization of titanium implants prospered to enhance bioactivity and osseointegration by promoting interactions of proteins and cells to the superior hydrophilic modified implant surface hence UV light is believed to enhance osteoconductivity(31). UV light has been suggested to raise the level of protein absorption and cellular attachment to implant surfaces(32,33). Several studies have revealed that bone implant contact of implants treated with UV light was highly enhanced due to the effect of superhydrophilicity(34-36). This current study aimed to evaluate the influence of laser and UV surface modification strategies on surface topography and wettability of zirconia implants to enhance osseointegration in a rabbit model.

## 2. Materials and Methods

### 2.1. Zirconia Specimens Fabrication (Discs and Implants)

CAD/ CAM zirconia blank was used for the preparation of zirconia specimens (ZIRCONIA PRETTAU ® Zirkonzahn Worldwide – Gais/South Tyrol /Italy). Auto-CAD software system was used to design zirconia discs (8mm x 3mm) and implant cylinders (3mm x 6mm). Specimens were milled and sintered according to manufacturer instructions (1600ºC for 8 hours).

### 2.2. Grouping and Surface Modification Strategies

Thirty zirconia discs, and thirty-six zirconia implants were randomly divided into three groups: (Unmodified control surfaces), (Nd: YAG laser modified surfaces) and (UV light modified surfaces). Zirconia specimens modified with laser strategy were exposed to Nd:YAG laser at wavelength 1064 nm, power 2w, 240 pulses per minute with pulse width 7 ns, repetition rate 10 hz and the distance between laser source and disc is 30 cm for 2 minutes (Continuum corporate 140 Baytech Drive San Jose, CA 95134 USA). While zirconia specimens modified with UV strategy were exposed to UV lamp at wavelength 365 nm for 48 hours (Philips Lighting Company. A division of Philips Electronics North America Corporation 200 Franklin Square Drive - Somerset N.J. 08875 6800).

### 2.3. In vitro Characterizations

Control and modified zirconia discs were laboratory analyzed, (n=10/each group) using confocal laser scanning microscopy (Zeiss 710 Carl Zeiss MicroImaging GmbH, 07740 Jena, Germany) at X100 magnification to assess surface roughness topography by measuring the surface roughness parameter (Ra) in micrometer (um) and all values were automatically displayed and represented by colored 3D images. Surface wettability was evaluated by recording surfaces contact angles (θ); The contact angles were measured using Rame hart, Instrument Company. A drop of distilled water (2 μL) was placed on the surface, using a micro syringe (Hamilton Company, Reno, NV). The contact angle was the average of the measurement at 5 different positions within 20 sec after the water drop was placed on the surface.

### 2.4. In vivo Study Design in Rabbit Model

Eighteen male line V Spain white rabbits (six months old and 3 kg) were obtained in a good systemic health from the Poultry Research Center, Faculty of Agriculture, Alexandria University. Rabbits were randomly divided into three groups (n=6): (rabbits receiving unmodified control implants), (rabbits receiving Nd: YAG laser modified implants) and (rabbits receiving UV light modified implants). Then, each group of rabbits was divided into two subgroups (n=3); the first subgroup allowed for four weeks healing period and the other subgroup allowed for eight weeks healing period. This study design was guided through the ethical committee of the faculty of Dentistry - Alexandria University (IRB NO: 00010556 – IORG 0008839).

**2.4.1. Surgical Protocol**

All surgical procedures were performed under general anesthesia and aseptic conditions. Each rabbit received two implants; each one inserted into the distal head of its right and left femurs. Rabbits were anesthetized with intramuscular injection of ketamine with xylazine at a dose of 35 mg/kg and 5 mg/kg of body weight respectively. Surgical flap was reflected and the femur distal head was exposed, then sequential drilling of implant socket was performed under sufficient cooling at room-temperature with an absolute minimum amount of trauma, each implant was inserted followed by repositioning and suturing of the surgical flap. Postoperative intramuscular injection of broad-spectrum antibiotic and analgesic were administrated every 72 hours for 10 days. Rabbits were monitored daily for weight gain and cage behavior. The implants of the first subgroups were allowed to heal for four weeks, while those of the second subgroups were allowed to heal for eight weeks before rabbits' sacrifice.

**2.4.2. Histological Examination**

Rabbits were sacrificed at the end of each experimental period, and then femur heads containing the implants were fixed in 10% neutral buffered formalin for one week followed by demineralization in 8% trichloroacetic acid. The decalcified bone segments containing the implants were processed following the routine procedures(37). Each implant was separated from its bone segment which then sectioned into two longitudinal halves. Each half of bone was embedded in a box of molten wax to obtain 5 um longitudinal sections of the parallel edges of bone facing the implant space. The sections were stained with Hematoxylin & Eosin stain (H&E) for histological examination with light microscope.

**2.5. Statistical analysis**

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Kolmogorov-Smirnov test was used to verify the normality of distribution of variables, ANOVA was used for normally distributed quantitative variables for comparing between more than two groups and followed by Post Hoc test (Tukey) for pairwise comparison. Significance of the obtained results was judged at the 5% level.

## 3. Results

### 3.1. In vitro characterization results

Comparison among studied groups regarding the surface roughness (Ra) and contact angle (θ) mean values are shown in table 1. Confocal laser microscope displayed the surface roughness (Ra) values in micrometer. No significant difference was detected between unmodified and UV light modified surfaces, while Nd: YAG laser modified surfaces logged the significantly highest (Ra) mean values (F=1646.279) with (P<0.001). Surface roughness topography for all specimens were automatically displayed and represented by colored 3D images at X100 magnification, (Figure 1: A-C). Regarding to the surface wettability as measured with contact angle (θ). There was a significant decrease in the contact angle mean values from the control group to the other two modified groups, where the highest values were recorded for the control group reflecting the lowest surface wettability, followed by laser treated group and the UV one revealed the lowest values indicating the highest surface wettability. Also, difference between laser and UV modified surfaces was significant (F=232.771) with (P<0.001). The contact angle values of the studied groups were displayed and represented by images in figure 2: A-C.

**Table (1): Comparison among the studied groups according to surface roughness (Ra) values and contact angle (θ).**

| | Unmodified (n = 10) | Laser modified (n = 10) | UV modified (n = 10) | F | p |
|---|---|---|---|---|---|
| **Surface roughness (Ra)** | | | | | |
| Mean ± SD. | $0.13^{b}\pm0.01$ | $0.76^{a}\pm0.05$ | $0.14^{b}\pm0.01$ | $1646.279^{*}$ | $<0.001^{*}$ |
| Median (Min. – Max.) | 0.13(0.12–0.14) | 0.77(0.68–0.82) | 0.14(0.12–0.16) | | |
| **Contact angle (θ)** | | | | | |
| Mean ± SD. | $130.7^{a}\pm5.7$ | $84.4^{b}\pm9.6$ | $70.6^{c}\pm1.9$ | $232.771^{*}$ | $<0.001^{*}$ |
| Median (Min. – Max.) | 131.4(119.8–137.5) | 85.8(71.7–99.8) | 71.4(68–72.6) | | |

Means with **Common letters** are not significant (i.e. Means with **Different letters** are significant)

*: Statistically significant at $p \le 0.05$

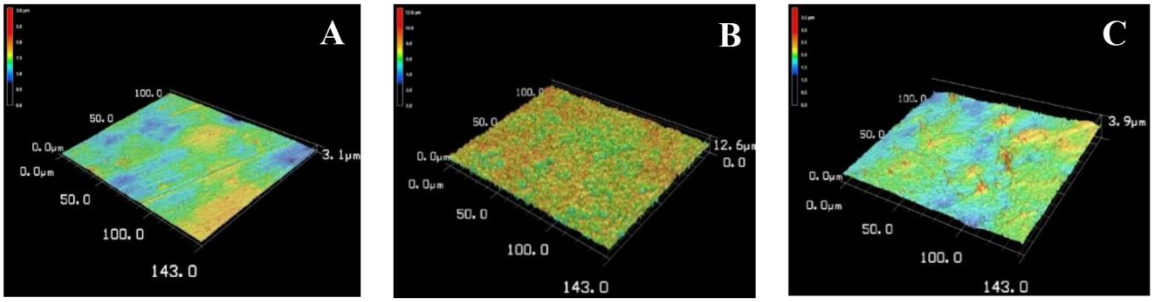


Figure 1 (A-C): CLSM 3D images; Comparable, low homogenous surface roughness profiles are displayed by the unmodified (A) and UV modified surfaces (C), while the highest profile is observed for laser treated surfaces reflecting profile homogeneity (B). X100. These observations equivalent with the recorded surface roughness parameter (Ra) means values for the studied groups.

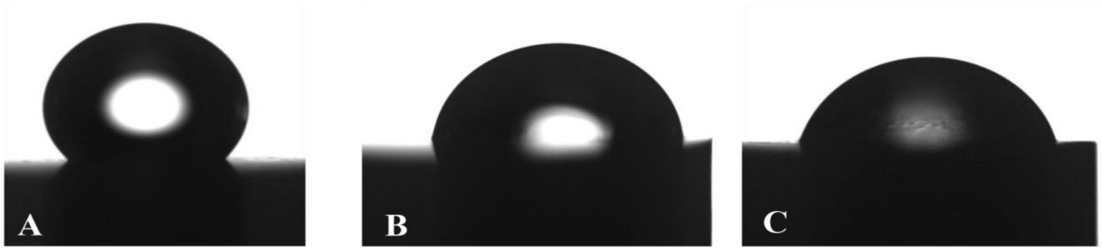


Figure 2 (A-C): Contact angle images; (A) Unmodified control surfaces recording the highest contact angle. An observed decrease is recorded for the laser treated surfaces (B), and the lowest contact angle is registered for the UV modified surfaces (C).

**3.2. Histological Findings**

In the current display of the histological results, the expression used; Implant Bone Interface (IBI) is the assumed or virtual interface after withdrawing the implant from the surrounding bone prior to cutting of the sections. Hematoxylin and Eosin stain results for collagen, muscle fibers and cytoplasm appear bright pink. While, nuclei appear deep blue. Histological observations of the unmodified zirconia implants revealed poorer osseointegration features represented by fibrous tissue formation along the implant bone interface (IBI). After four weeks healing period, IBI was consisted of longitudinally oriented layer of fibrous tissue which exhibited rich cellular content between its layers, and seemed to contact the adjacent bone all over its extension with some segments of interruption. In the eight weeks period, some segments of IBI consisted of fibrous tissue were observed but looked thinner comparing to the first observation period and did not extend all over implant boundary but direct contact between the bone and assumed implant surface was a noticeable observation on short segments of that interface. Osteoblast like cells could be traced at the deepest surface of the fibrous tissue adjacent to both of the bone and the implant surface. A noticeable observation in this group was the cancellous type of bone configuration either adjacent to the implant surface or even deeper to it, (Figure 3: A-D). Nd: YAG laser modified implants showed superior peri-implant bone healing and osseointegration features. The four weeks findings resulted in that, the bone facing the implant space consisted of a continuous line of trabeculae resting on a deeper layer of compact bone. That bony interface was only interrupted at very limited spots all over the full circumference of the implants. The bone trabeculae exhibited specific directivity towards the implant surface. A prevailing appearance was the occurrence of cells at the IBI either embedded in a thin straight homogenous cement line like structure that appeared adjacent to the implant assumed surface or even directly facing this surface. The different trabeculae were outlined by osteoblast like cells and were surrounded by delicate cells rich connective tissue. The histological picture of Nd: YAG laser modified implants after eight weeks was characterized by two important features; The first was a generalized increase in the peri-implant bone density with prevalence of the compact configuration of lamellar bone which appeared in association with most of the implants included in this group, and the second feature was the outstanding remodeling figures in the bone slightly deeper to the implant interface, (Figure 4: A-D). Gratified osseointegration features were observed around UV modified implants. Along the space representing implant boundary after four weeks, a cement line like structure was seen connecting thin widely apart bone segments. The implant bone boundary included more segments of bone contact with the implant and less interruption zones was observed after eight weeks. Persistence of the cement line was an evident observation in association with most of the implants included in this group, also both bone facing the implant and deeper bone appeared more mature than its appearance in the previous observation period of the same group. However, bone remodeling figures could also be traced in the bone deeper to the implant interface, Higher magnification of this interface revealed the homogenous and continues structure of that cement line which was accompanied with noticeable cellular activity, (Figure 5: A-D).

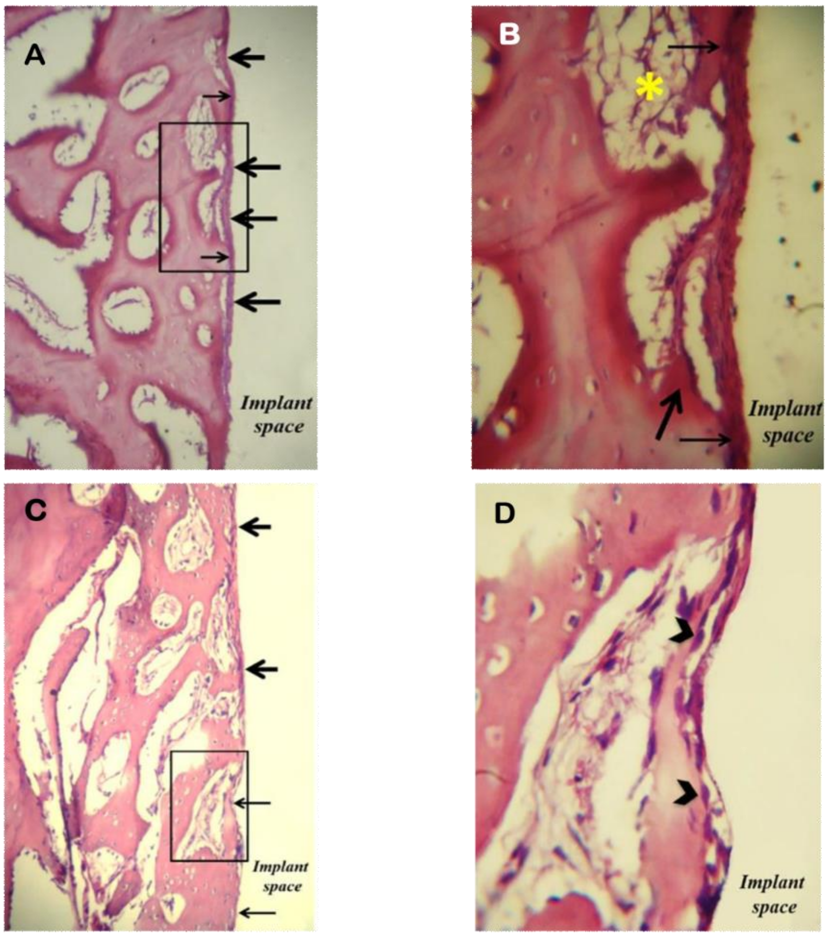


Figure 3 (A-D): [A]: Light micrograph (LM), (unmodified zirconia implants/4 weeks) showing the fibrous tissue continuous layer contacting between the implant surface (right side of the image) and adjacent bone. On its deep surface the fibrous tissue is forming an actual contact with the bone at specific zones (thin arrows) or exhibiting areas of contact interruption (thick arrows). H&E - Original magnification X100. [B]:Higher magnification for the marked area on [A] shows the structure of the fibrous tissue forming the IBI. At its deep surface note its actual contact with the deeper bone (thin arrows) and gaps of interruption with it. At these gaps, note the evident insertion of the deepest layer of the fibrous tissue into the bone (thick arrows) and its merging with the loose fibrous tissue filling the gaps (asterisks) H&E, X400. [C]:Light micrograph (LM), (unmodified zirconia implants/8 weeks) showing IBI consisting of thin fibrous layer at some segments of the implant interface (thick arrows) and other areas of actual contact between the bone and implant without fibrous intervention (thin arrows) .H&E- X100. [D]:Higher magnification for the marked area on [C] shows large osteoblast like cells on the bone surface adjacent to the implant (arrow heads). H&E, X400.

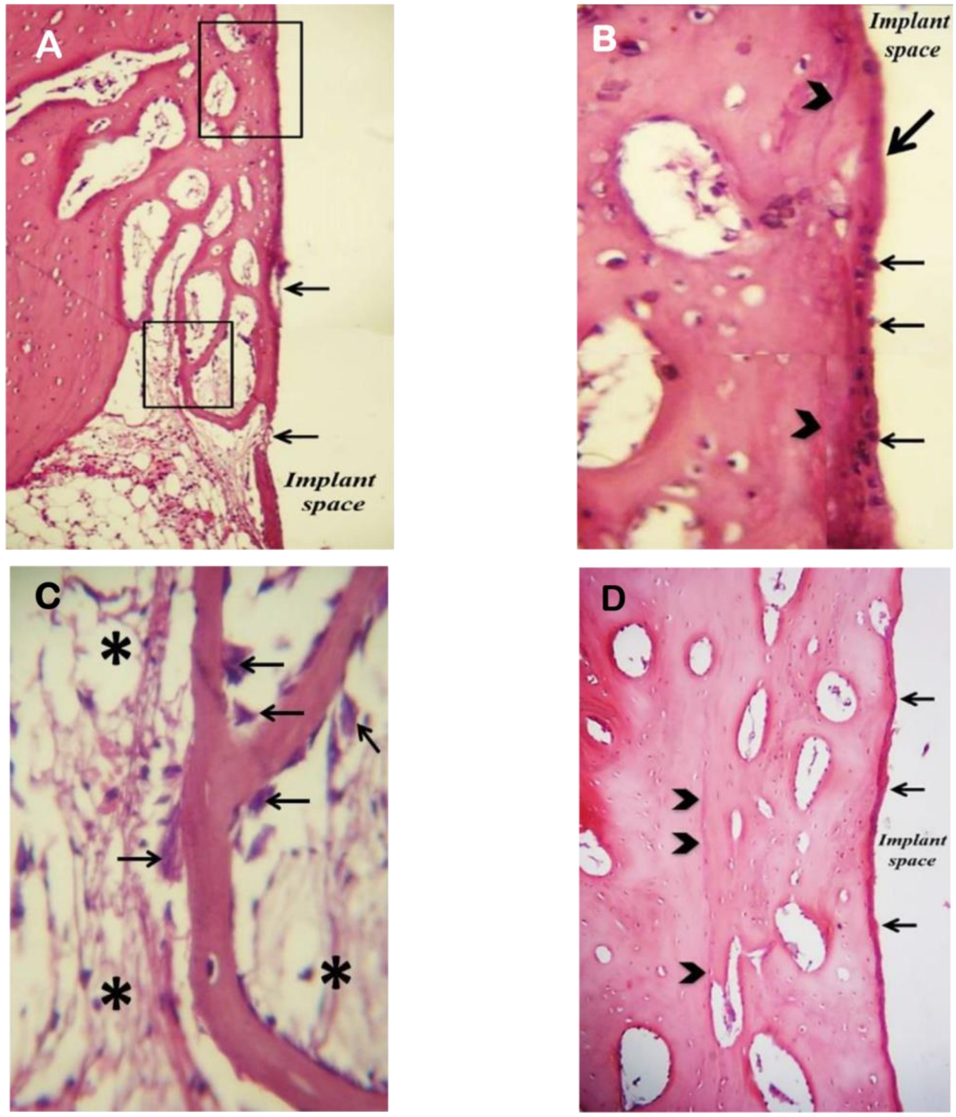


Figure 4 (A-D): [A]:LM, (Nd: YAG laser modified zirconia implants/4 weeks) showing implant bone interface (IBI) formed of a continuous border of trabecular bone confluent and merging with deeper mass of compact bone. The bone trabeculae exhibit the same orientation in a specific direction towards the implant surface with noticeable interconnectivity. Note the restricted zones of interruption of the interface with the adjacent bone (arrows). H&E - Original magnification X100. [B]:Higher magnification for the upper marked area on [A] illustrating the cement line like structure at the IBI (thick arrow), and the cells bordering this interface (thin arrows). Note the faint remodeling lines in the bone layer just interior to the implant face (arrow heads). H&E-X400. [C]:Higher magnification of the down marked area on [A] showing prominent voluminous cells bordering the bone trabeculae (arrows) and cell rich delicate connective tissue surrounding them (asterisks). H&E- X400. [D]:LM, (Nd: YAG laser modified zirconia implants/8 weeks) showing thick trabecular cancellous adjacent to the IBI. Note the evident line separating this bone from the deeper bone of the insertion site, (arrow heads). Note the persistence of the cement line on the IBI (arrows), H&E, X100.

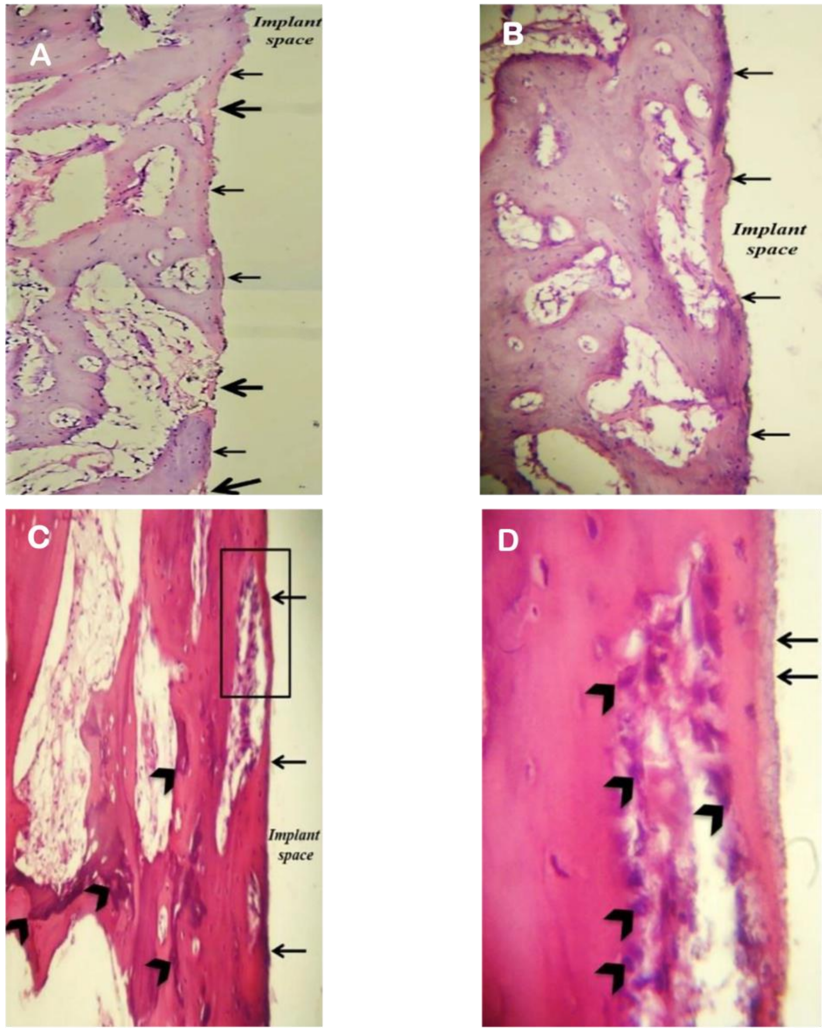


Figure 5 (A-D): [A]:LM, (UV light modified zirconia implants/4 weeks) showing the cement line formation adjacent to the implant interface at segments of bone formation (thin arrows) and at discontinuity zones (thick arrows). H&E - Original magnification X100. [B&C]:LM, (UV light modified zirconia implants/8 weeks) showing broader segments of bone contact with the implant and more maturity and density of the formed bone as well as the persistence of the cement line (arrows). H&E - Original magnification X100. Note on [C] the remodeling features in the deeper bone as revealed by its different stages of staining (arrow heads). [D]:Higher magnification for the marked area on [C] illustrating the prominent cementing line at the IBI (thin arrows) and the cellular activity in the bone close to the implant (arrow heads), H&E: X400.

## 4. Discussion

Zirconia implants could be considered as a promising alternative to titanium with a superior soft-tissue response, biocompatibility, and aesthetics with no significant differences in bone-to-implant contact value compared to titanium implants. This is agreed with comparable studies(38-41). Osseointegration is the privilege success goal of implants that depends on topographical and physicochemical properties. Numerous animal studies found that osseointegration of zirconia implants was similar to that of titanium implants(42-45). Moreover, zirconia implants with roughened surfaces exhibit enhanced bioactivity with improved osseointegration and tougher biomechanical fixation compared to smooth surfaces(46-48). However, surface modification of zirconia is considered to be technically more challenging than for titanium. This is attributed to the fact that conventional surface modification techniques performed for titanium either have no effect on zirconia or do not profit adequate surface roughness(10). Laser modification strategy focuses on improving the implant osseointegration through generating a pattern of micro- and nano-scale microchannels. These microchannels have been proposed to act as a micromechanical and biologic seal by connecting the attachment of connective tissue and bone. On the other hand, surface roughness at micro – nano level produced by laser enhancing the surface wettability that plays a key role in determining proteins adsorption and cell adhesion on the implant surfaces resulting in improved peri-implant osseointegration(49-51). UV light application on zirconia has been shown to induce decreasing in the atomic percentage of carbon, with a uniform increase of the other elements in connotation to the reduction of superficial hydrocarbons(34,52,53). Hence, UV treatment of zirconia has been proposed to induce electron excitation from the valence band to the conduction band, provided sufficient photon energy to transform the hydrophobic surface property of zirconia to be hydrophilic(54). In the current study Nd:YAG laser irradiation strategy was nominated to modify zirconia surface topography to the micro-roughness scale that was investigated by measuring the surface roughness parameter (Ra) using the confocal scanning laser microscope. These laser modified surfaces recorded the significantly highest (Ra) values ($P<0.001$) proving mechanical alteration of zirconia surface topography to a high roughness profile. These results were in agreement with other studies that reported an increased zirconia surface roughness by modifying its external surface yielded a smooth surface with irregular small micro scratches using Nd:YAG laser(55-61). On the other hand, there was no significant difference in the (Ra) mean values recorded for unmodified and UV light modified zirconia surfaces indicating that UV irradiation influence on zirconia surface topography is completely negative lacking any surface topographical alteration. Similar results were recorded by other studies of the same interest(54,62). In light of these findings, UV irradiation strategy was applied in the present study for alteration of zirconia surface physicochemical properties through modification of zirconia surface energy to enhance its wettability hence substantial improvement of bioactivity associated with superior biological and cellular responses. Surface wettability was evaluated by recording surfaces contact angles that revealed significant differences between unmodified and both modified surfaces. Additionally, the significantly lowest contact angle mean was recorded to the UV modified surfaces ($P<0.001$). These results proved the highest wettability for the UV treated zirconia surfaces followed by Nd:YAG laser modified surfaces and the unmodified surfaces recorded the least wettability. Similar results were found in other studies(29-31,63). Based on the In vitro results, it was revealed that, the Nd:YAG laser modification strategy succeeded to alter zirconia surface topography producing the significantly highest roughness and subsequently improved surface wettability. While, UV irradiation vain to modify zirconia surface topographical properties, but at the same time it significantly enhanced surface wettability. As a second phase of this study, the in vivo experiment was essential to evaluate the influence of these modified zirconia surfaces on osseointegration in rabbits. The current histological method of examining the implant bone interface in demineralized sections by withdrawing the implant from the surrounding bone prior to the step of embedding has proved to be a convenient method. However, this method allowed observation and examination of serial sections of the interface and provided a reliable method for evaluating the contact all over the interface. Also, it had provided an insight into the bone configuration deeper to the level of the IBI in serial sections. Regarding to the first observation period in the unmodified zirconia implants, insertion of the deepest fibers of the fibrous contact between IBI into bone at the insertion site is thought to have provided a histological evidence for an indirect contact between bone and implant. The histological appearance of this fibrous tissue is closely similar to the periosteum which usually attaches the bone and adjacent structures(64). However, this appearance is thought to have rejected the possibility of osseointegration failure although it can be described as an indirect one. Also, this assumption can be supported by the biological fact that the fibrous tissue when formed at any location, it become spontaneously coated by a layer of secreted proteoglycans. The latter mainly provides for tissue adherence and cell attachment as well as attachment of growth factors and is thought to have agglutinated both of the fibrous tissue and cells to the implant surface(65). Moreover, the histological appearance of IBI of the same unmodified surfaces after eight weeks is thought to support the aforementioned assumption due to the appearance of an establishment of actual contact between the implant and bone of the insertion site at certain locations and the appearance of cells suspended directly at the bone surface adjacent to the implant. These cells are apparently responsible for bone formation at the implant surface and are thought to be involved in establishment of more expanded contact if left and investigated after longer periods of time. In both the Nd:YAG laser and UV modified zirconia implants, the histological appearance of the woven bone adjacent to the implant during the first observation period and its transformation into lamellar bone as seen at the second observation period, is in accordance with the description of the gradual steps of osseointegration and tissue healing progression adjacent to the implant. However, in the second observation period, although the lamellar bone configuration in UV modified implants was dense cancellous type, yet the prevailing type was the compact configuration with frank formation of Haversian systems in the Nd:YAG laser modified implants. This is thought to reveal a difference in bone maturity and remodeling between UV and laser modified implants being better in the latter. This is could be attributed to the mechanical modification of zirconia surface topography by the Nd:YAG laser irradiation recording the significantly highest roughness that also enhanced surface wettability thus improving proteins adsorption and cell adhesion resulting in improved osseointegration features compared to UV altered zirconia surfaces that reflected the significantly highest wettability in association with non-significant surfaces topographical modification. Other studies interested in laser zirconia surface modifications agreed with the present observations(66-69). The histological outcomes of the UV treated zirconia implants were in accordance with other similar studies suggested that, biological activity of zirconia implants could be enhanced by UV irradiation that improving surface wettability(11,54,70,71). The bone cementing line formation and orientation all over the implant surfaces considered as a real histological mirror for the osseointegration potential that depends upon implant surface properties(72). The formation of cementing lines and the associated cells at the assumed implant interface for both laser and UV modified implants are thought to provide an evidence for the achievement of osseointegration and in accordance with. This is thought to occur through the wettability of the implant and the resultant protein adsorption with subsequent cell adhesion. The histological findings of Nd:YAG laser modified implants at both observation periods clearly provides an evidence that the highest roughness topography created by laser irradiation on zirconia surface improved the early phase of peri-implant healing through the associated enhanced wettability which motivated proteins adsorption as exhibited by the formation of cementing lines all over the implant surfaces. Correspondingly, this highest roughness provided an enhanced microroughened media for cellular attachment and activity as revealed by bone formation on the surfaces of the implants included in this group indicating the greatest osseointegration. It is sturdily stated that, increasing surface roughness profile in combination with perfection of the surface wettability of zirconia implants are powerful modification modalities to enhance bioactivity, peri-implant bone healing and osseointegration.

**Conclusions**

Within the limitations of this study, Nd:YAG laser modification strategy could be recognize to modify zirconia surfaces topography to the micro-roughness scale. Additionally, this micro-roughness topography has a prevailing effect on zirconia surface wettability. UV irradiation could enhance zirconia surface wettability without any topographical modification.The histological outcomes demonstrated enhanced osseointegration features for both Nd:YAG laser and UV light modified zirconia implants in conjunction with greater bone-to-implant segments after four and eight weeks for the laser modified implants.

**Ethics approval and consent to participate**

This study was approved by the ethics committee of the Faculty of Dentistry - Alexandria University regarding using animals in research studies (IRB NO: 00010556 – IORG 0008839).

**Availability of data and materials**

All data presented in the manuscript are available for publication.

**Competing interests**

Yousreya Shalaby, Samia Soliman Omar, Dawlat Mostafa and Hassan Mohammed Fahmy declare that they have no competing interests.

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No funding conflicts are related to the study.

**Authors' contributions**

Author YS prepared the specimens, Author DM conducted the laboratory Characterizations, and performed the animal surgeries. Author SS prepared the histological sections, applied the histological examination and displayed the histological outcomes. Author HF shared all authors during research conduction. All authors shared in the preparation of the manuscript. All authors read and approved the final manuscript.

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