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The Er.Cr.YSGG laser's impact in the occlusion of dentinal tubules: in vitro study

Impacto do laser de Er.Cr.YSGG na oclusão dos túbulos dentinários: estudo in vitro

Mohammed Ziad TARIK[1], **Mohamed K. DHAHIR**[1], **Salah A. ALKURTAS**[2]

1 - University of Baghdad, Institute of Laser for Postgraduate Studies. Baghdad, Iraq.
2 - Al-Turath University. Baghdad, Iraq.

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ABSTRACT

Background: Severe discomfort due to exposed dentin that is brought on by thermal, tactile, evaporative, electrical, osmotic, or chemical stimulation is known as dentinal hypersensitivity. It typically includes the teeth's facial surfaces close to the cervical boundary and, typically, in premolars and canines. It might be caused by either cemental or enamel loss. **Objective:** To assess how well the Er.Cr.YSGG laser seals dentinal tubules when it's used on exposed dentine. **Material and Methods:** Twenty-nine natural posterior teeth were prepared, sectioned, cleaned, and made ready for treatment. Samples were split into groups: Group A, the group under negative control (N = 10), and Group B: Er.Cr.YSGG (Waterlase, I plus, Biolase Technology, Irvine, CA) was administered (N = 10) along with a pilot research group (N = 9). Wavelength of 2780 nm, irradiation mode is free-running pulse, power of 0.25 W, frequency of 20 Hz, pulse width of 60 μs, time of 2 seconds, Fiber tip size: 600 μm, non-contact mode, power density of 83.33 W/cm^2 with 0% water and 0% air, fiber tip fixed on a distance of 1 mm perpendicular to the dentin surface with a clamp holder. Scanning electron microscopy (SEM) was used to analyze dentin-obstructed surfaces. A qualitative evaluation of the micrographs was conducted to analyze the shift in surface features. Data analysis was performed using (spss) software (version 26, IBM,USA) to investigate the data's normal distribution. The Kolmogorov-Smirnov and Shapiro-Wilk tests revealed that the data had an abnormal distribution. Mann-Whitney U test was carried out to show a comparison between groups (control, laser group). **Results:** The data obtained from the laser group showed a large reduction in tubular diameter (0.737 μm) as compared to the control group (3.095 μm). The selected parameters (0.25W/2s, 83.33 W/cm^2) were best to reduce and plug any exposed dentinal tubules without any indication of fissures or cracks. **Conclusion:** The study conclusively demonstrates that Er:Cr:YSGG laser irradiation offers a viable solution for dentin hypersensitivity by partially or completely occluding dentin tubules. Future clinical trials are warranted to further explore its efficacy.

KEYWORDS

Dentinal tubules; Er.Cr.YSGG; Hypersensitivity; Laser; Teeth sensitivity.

RESUMO

Contexto: O desconforto severo devido à dentina exposta que é causado por estimulação térmica, tátil, evaporativa, elétrica, osmótica ou química é conhecido como hipersensibilidade dentinária. Normalmente acomete as superfícies vestibulares dos dentes próximas ao limite cervical e, tipicamente, em pré-molares e caninos. Pode ser causado por perda de cemento ou esmalte. **Objetivo:** Avaliar o nível de eficácia do laser de Er.Cr.YSGG ao selar os túbulos dentinários quando aplicado em dentina exposta. **Material e Métodos:** Vinte e nove dentes posteriores naturais foram preparados, seccionados, limpos e preparados para tratamento. As amostras foram divididas em grupos: Grupo A: grupo sob controle negativo (N = 10); e Grupo B: Er.Cr.YSGG (Waterlase, I plus, Biolase Technology, Irvine, CA), que foi administrado (N = 10) juntamente com um grupo de pesquisa piloto (N = 9). As características do laser aplicado foram: comprimento de onda de 2780 nm, modo de irradiação é pulso de corrida livre, potência de 0,25 W, frequência de 20 Hz, largura de pulso de 60 μs, tempo de 2 segundos, tamanho da ponta da fibra: 600 μm, modo sem contato, densidade de potência de 83,33 W/cm^2 com 0% de água e 0% de ar, ponta da fibra fixada a uma distância de 1 mm perpendicular à superfície da dentina com um suporte de grampo. Microscopia eletrônica de varredura (MEV) foi usada para analisar superfícies obstruídas pela dentina. Uma avaliação qualitativa das micrografias foi conduzida para analisar a mudança nas características da superfície. A análise de dados foi realizada usando o software (SPSS) para investigar a distribuição normal dos dados. Os testes de Kolmogorov-Smirnov e Shapiro-Wilk revelaram que os dados tinham uma distribuição anormal. O teste U de Mann-Whitney foi realizado para mostrar uma comparação entre os grupos (controle, grupo laser). **Resultados:** Os dados obtidos do grupo laser mostraram uma grande redução no diâmetro tubular (0,737 μm) em comparação ao grupo controle (3,095 μm). Os parâmetros selecionados (0,25 W/2s, 83,33 W/cm^2) foram os melhores para reduzir e tampar quaisquer túbulos dentinários expostos sem qualquer indicação de fissuras ou rachaduras. **Conclusão:** O estudo demonstra conclusivamente que a irradiação a laser Er:Cr:YSGG oferece uma solução viável para a hipersensibilidade dentinária ao ocluir parcial ou completamente os túbulos dentinários. Futuros ensaios clínicos são necessários para explorar melhor sua eficácia.

Palavras-chave:

Dessensibilizantes dentinários; Terapia a Laser; Hipersensibilidade; Laser; Sensibilidade dentária.

INTRODUCTION

Dentin hypersensitivity (DH) is marked by localized, acute pain in exposed dentin triggered by external thermal, mechanical, chemical, or osmotic stimuli, not attributable to other dental defects or pathologies. Factors like erosion, abrasion, and attrition, as well as periodontal treatments or surgery, may link it to the condition [1-4]. Several theories have been proposed regarding the cause of tooth hypersensitivity. One of the most well-articulated is Brännström's Hydrodynamic theory [5]. It suggests that fluid flow inside dentinal tubules may cause a painful sensation. When dentinal tubules are exposed to cold, the flow increases quickly, which the patient may interpret as pain [6]. The literature mentions a variety of dentin hypersensitivity treatment techniques, but for them to be successful, they must fulfill specific requirements. These treatments need to be easy to use, provide a long-lasting effect, operate swiftly, avoid causing irritation or discoloration to the tooth pulp, and be cost-effective. Obstructing the teeth's exposed tubules by blocking pulpal sensory neurons can accomplish desensitization [2]. Desensitizing products that contain potassium nitrate have the ability to function by obstructing the synapses between nerve cells, which in turn reduces nerve activation and associated discomfort. Moreover, a variety of substances, including calcium phosphate, potassium oxalate, and sodium fluoride, have been reported to obstruct dentinal tubules. Additionally, there have been reports that adhesive materials, cements, varnishes, and lasers can occlude dentinal tubules [2].

Recently the clinical application of lasers had increased. Dentists use a variety of these lasers, classifying them as either hard or soft. Hard lasers consist of CO_2 (carbon dioxide), Nd:YAG (neodymium yttrium aluminum garnet), and Er:YAG. These lasers can treat both hard and soft tissue, although they may cause harm to the pulp. Conversely, low-level laser treatment (LLLT), also known as biostimulation, involves the use of soft or cool lasers that utilize semiconductor diode technology to produce laser energy in a non-thermal manner [7].

In general, lasers have a wide range of applications in dentistry, including photodynamic therapy for cancer, orthodontic treatments that expose partially and unerupted teeth, removal of hypertrophic, inflamed tissue, periodontal treatments that lengthen crowns, and oral medicine procedures that remove various types of tissue. Not only did they treat dentinal hypersensitivity, but they also made big steps forward in hard tissue treatments like removing cavities, preparing cavities, or taking out restorative material [7]. Erbium Chromium: The class 4 laser employed in this investigation is the Yttrium-Scandium-Gallium-Garnet laser (Waterlase®, ©BIOLASE, Inc., USA). It has a wavelength of 2780 nm. The patient will benefit from having this kind of laser at the dentist's office in many ways. This study set out to assess how the Er.Cr.YSGG laser influenced the occlusion of exposed dentinal tubules.

MATERIAL AND METHODS

Teeth collection and preparation

We utilized twenty-nine adult human wisdom teeth extracted for various purposes. We discarded crowns that had caries, restorations, cracks, or any other apparent abnormality. We used an ultrasonic scaler (Castellani- Italy) to clean the teeth in an apical-coronal direction, removing any remnant cementum and attached periodontal ligament. Next, we polished the teeth for 20 seconds with a non-fluoride paste to remove any debris. Finally, we rinsed, dried, and stored the teeth for 48 hours in distilled water containing 0.1% thymol((2-Isoprpoyl-5-methylphenol), expired date 06-2026, Uk) to prevent any microbial growth. The teeth were mounted on one hand of the surveyor and the engine held on another arm for precision and uniform sectioning of the tooth surface at a zero plane with a double-faced diamond disk 0.2 mm (Star dent, China) one disk for every 3 teeth, and the cutting was done under water irrigation. The teeth were sectioned transversely to expose the dentine and put in an ultrasonic cleaner(HH-S2china) for 3 min to remove the debris of cutting, then dried with gauze. Following this, to stimulate the surface of hypersensitive dentine, teeth received 17% EDTA(Dia prep pro, Korea) for 2 min. and 35% phosphoric acid for 10 sec for smear layer removal; the prepared teeth were then occupied in numbered containers.

Irradiation and temperature assessment for the research groups

This study was done on 10 teeth for the Study Group (G2); the teeth were fixed with stainless- steel, and the handpiece of Er,Cr: YSGG Laser was fixed with a clamp 1mm from the irradiated dentine surface.

A pilot study was conducted on nine teeth to determine the optimal parameters (power and exposure time) for the research group. Different power parameters (0.25W, 0.5W, 0.75W) for different exposure times (2 sec, 4 sec, 8 sec) were taken.

For power 0.25W, we tested three different times: 2 seconds, 4 seconds, and 8 seconds to determine the optimal result. The results were recorded and analyzed to identify the differences in the effect of each parameter on the sample. The pilot study followed the same procedure for the other two power parameters.

According to the earlier, the chosen parameters for pilot trials were (0.25W and 2sec).

Samples have been divided into groups, each consisting of ten samples

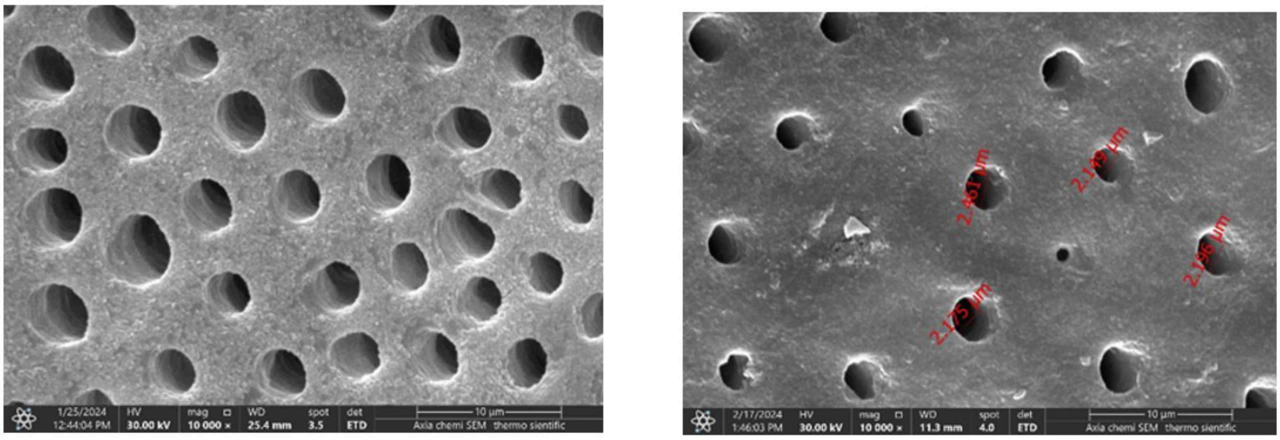
Group 1(G1) control group did not receive any treatment.

Group (G2) study group: Er, Cr:YSGG laser treatment (Waterlase, 1 plus, Biolase Technology, Irvine, CA) as depicted in Figure 1. Wavelength of 2780 nm, irradiation mode is free-running pulse, power of 0.25 W, frequency of 20 Hz, pulse width of 60 μs, time of 2 seconds, Fiber tip size: 600 μm, non-contact mode, power density of 83.33 W/cm^2 with 0% water and 0% air, fiber tip fixed on a distance of 1 mm perpendicular to the dentin surface with a clamp holder.

Temperature and irradiance measurement for the study group

To assess temperature, one root canal prepared with the SX-file (protaper files) and treated with deionized water and then dried with a paper point is now ready for insertion of the head of the thermocouple probe (prośket MT-1232, 1st Edition, 2013, Taiwan) to the opposite side of the irradiated surface. The study was carried out on ten teeth for the study group (G2). The teeth were secured with a stainless-steel rack, the thermocouple probe was positioned at the root of the teeth and set in place, and the Er, Cr:YSGG laser handpiece was clamped 1 mm from the irradiated dentine surface. Then, after 50 seconds, as soon as the pulp's temperature reached a stable state in the water path, the teeth were irradiated using the 2780 nm Er, Cr:YSGG laser, and temperature was recorded every second

Figure 1 - Settings for laser exposure group.



A B

Figure 2 - SEM views of two samples (control group). Magnification 10000x. A) open dentinal tubules sample 1; B)open dentinal tubules sample 2.

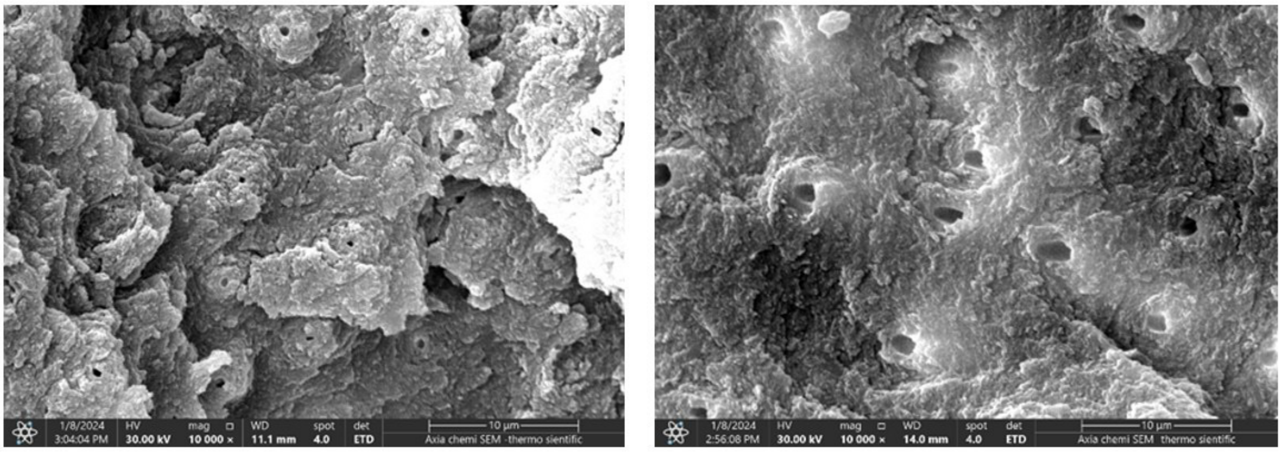


Figure 3 - SEM for two samples views of treated dentin (0.25w, 2sec). Magnification: 10000x.

for 60 seconds, which was a 2-second exposure time and a 58-second observation time for documenting any increase in temperature during the exposure period and the irradiated tooth's recuperation time during the observation period.

SEM results

Surfaces of dentin revealed different levels of dental tubule occlusion with various samples. SEM micrographs showing the control group after they were treated with 17% EDTA for two minutes and 35% phosphoric acid for ten seconds to remove the smear layer. The smear layer does not cover the dentin; the tubules were fully opened, as shown in Figure 2. The diameters of control samples were measured by SEM analysis and showed a mean (3.095 um).The protocol we followed in measuring the samples involved randomly selecting ten dentinal tubules from each sample at a constant magnification of 10000x for all samples. The mean for each sample was calculated, and the result was considered as the outcome for each individual sample.

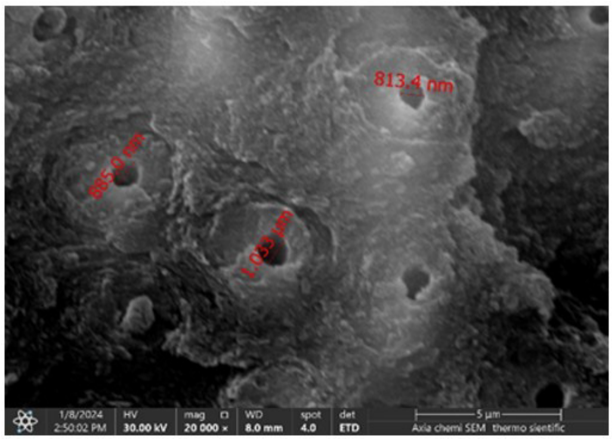


Figure 4 - Illustrated diameters of study group with Magnification 20000x.

All dentin samples treated by Er,Cr:YSGG Laser at a wavelength of 2780 nm, narrowing with some of the occluded tubules, were observed at power 0.25 W for an application time of 2 sec. Figure 3 showed minimal surface precipitate and total obliteration of most of the dentinal tubules. The remaining tubules underwent some changes, including a narrowing of their diameter.

The diameters of treated samples were measured by SEM analysis and showed a mean reduction equal to 0.737 um, as shown in Figure 4.

Temperature measurement

For temperature measurement, no changes in samples temperature were recorded during exposure or after that during observation time.

Statistical results

Data analysis was performed using SPSS software (version 26, IBM, USA) to investigate the data's normal distribution. Both the Kolmogorov-Smirnov and the Shapiro-Wilk tests were used, they revealed that the data had an abnormal distribution ($p>0.00$). So they were described by (median, mean, standard deviation) and non-parametric assessment. Mann-Whitney U test was carried out to show a comparison between groups (control, laser group). The data obtained from the laser group showed a large reduction in tubular diameter (mean, median) as compared to the control group (median, mean) as shown in Table I. Figure 5 illustrates the comparison between the control and laser groups. The laser and control groups exhibited a statistically significant difference (p-value 0.000) as shown in Table II.

DISCUSSION

Dentinal hypersensitivity can be mitigated by reducing the fluid circulation within the dentinal tubules, so obstructing signals from reaching the odontoblastic process [8]. In hypersensitive teeth, the tubule diameter is considerably broader than those of teeth that are not sensitive. Different techniques can be used to block dentinal tubules, initially by closing the dentin surface, occluding in their orifices, or occluding in the subsurface dentin in their tubules [3,9]. For effective desensitization, the treatment in our study centered on reducing and obstructing the radius of dentinal tubules by using Er.Cr.YSGG laser with specifications (0.25W/2s, 83.33 W/cm^2).

This investigation involved exams completed immediately post-exposure utilizing Scanning Electron Microscopy (SEM). The samples underwent multiple preparatory procedures: Cleaning: samples were subjected to ultrasonic

Table I - Shows the mean tubular diameter for (A) control group (B) laser group

Samples A	Mean	Samples B	Mean
1	3.448	1	0.477
2	3.306	2	0.7
3	2.747	3	1.03
4	2.126	4	0.404
5	2.508	5	0.507
6	2.309	6	0.98
7	3.437	7	1.078
8	3.492	8	0.966
9	4.34	9	0.633
10	3.234	10	0.451

Table II - Shows the impact of Er,Cr: YSGG laser used for this study on the diameter of dentinal tubules

Group	Median	Mean	Std. Deviation	p-value*
Control	2.954	3.095	0.957	>0.000
Laser	0.640	0.737	0.315	

*Mann-Whitney test.

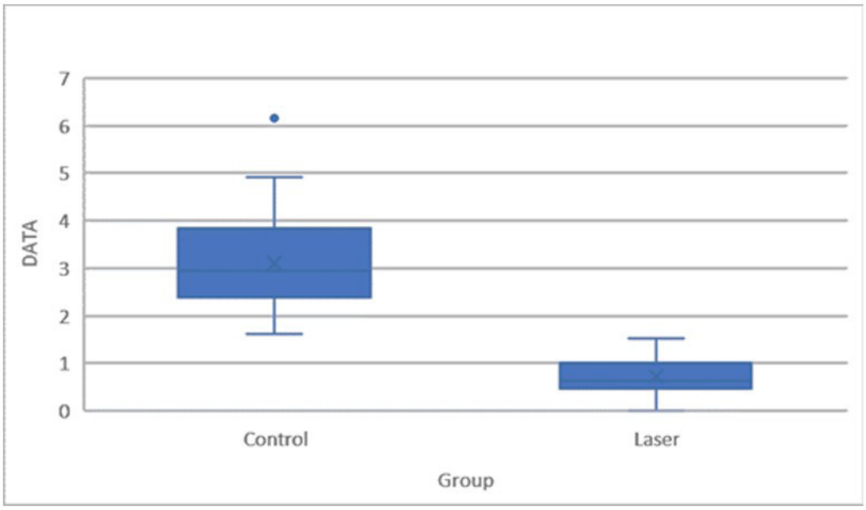


Figure 5 - Illustrates the comparison between the control and laser group.

scaling in an apico-coronal direction to eliminate residual cementum and periodontal ligament. Polishing: Samples were polished with non-fluoride paste for 20 seconds to eliminate debris, then rinsed and dried. Storage: The purified samples were maintained for 48 hours in distilled water with 0.1% thymol to inhibit microbial proliferation.

The dentinal tubules were deliberately expanded to replicate dentine hypersensitivity. Two chemical agents, 17% EDTA gel and 35% phosphoric acid, were employed to replicate the condition of sensitive dentine. This essential measure was implemented to guarantee that the prepared dentin surface was devoid of leftover substances, including the smear layer and plugs.

The FDA had allowed the use of erbium lasers on hard tissues; therefore, it is decided to employ the Er.Cr.YSGG laser of 2780 nm (Waterlase®) group for this therapy. This is consistent with other research [10-17]. 0.25 W of power is used for 2 sec from Er.Cr:YSGG laser. According to Aranha et al. [18], the Er.Cr.YSGG laser, which belongs to the family of erbium lasers, has significant absorption in the bound water of a tooth's crystalline structure, which results in the expansion and detonation of dental hard tissues.

As reported by Hu et al. [19], the desensitization with Erbium laser is accomplished by water molecule absorption to produce a microblasting action and deposition of insoluble salts that narrow or block down dentinal tubules. This results in a reduction of the tubular surface diameter by up to 50%.

The clinical uses of high- and low-intensity dental lasers have been the subject of a great deal of research. Low-level laser therapy induces photophysical, photobiological, and photochemical effects on the cells of irradiated tissues, while high-intensity lasers act by increasing temperature to ablate, vaporize, cut, and coagulate dental tissue [20].

Dentin exhibits low thermal conductivity, which may lead to a notable increase in local temperature. In the case of laser applications in this study, the fundamental consequences are photothermal and photomechanical effects. Dentine primarily consists of hydroxyapatite crystals and water, making infrared-emitted lasers the most effective for its treatment [21]. Furthermore, Erbium lasers perform thermal ablation on enamel and dentine, a process that is mediated by water and characterized by explosive effects. Because of the surrounding hard tissue, this application causes the water in the subsurface layers to heat up to a temperature of over 100 °C. This pressure overcomes the strength of the tissue, generating an "explosion" with the extirpation of hard tissues. In order to accommodate this occurrence, it's crucial to stay below the melting point of dentine or enamel, which varies according on the kind of laser (for example, the ablation threshold of Er, Cr: YSGG lasers can reach up to 800 °C, and CO_2 lasers can reach 1000 °C) [22].

Brännström's hydrodynamic theory suggested that dentine hypersensitivity is due to the movement of fluid within the dentinal tubules. Obstruction of the tubules diminishes fluid mobility that activates nerve endings in the dentin, resulting in reduced pain and discomfort from stimuli like as temperature fluctuations, pressure, and osmotic changes. This underscores the significance of the research in diminishing sensitivity by decreasing the diameter of the tubules with minimal power and time.

Finally, the main purpose of our study conducted in vitro was to examine the laser's occlusion of dentinal tubules; The laser's impact on nerves wasn't taken into consideration.

As a limitation of the study we consider that aging protocols to investigate the long term effects of tubule occluding agents should be performed in future studies.

CONCLUSION

The findings of this study indicate that Er:Cr:YSGG laser irradiation can partially or completely occlude dentin tubules, thus recommending its consideration for the management of dentin hypersensitivity in future clinical trials.

Author's Contributions

MZT: Investigation, Writing – Original Draft Preparation. MKD: Supervision. SAA: Supervision.

Conflict of Interest

The authors have no conflicts of interest to declare.

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Regulatory Statement

Not applicable, as in vitro studies do not require approval from an ethics committee, according to the Department of Biomedical Applications, Institute of Laser for Postgraduate Studies, University of Baghdad.

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Mohammed Ziad Tarik
(Corresponding address)
University of Baghdad, Institute of Laser for Postgraduate Studies, Baghdad, Iraq.
E-mail: mohammed.zeyed2202m@ilps.uobaghdad.edu.iq

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