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Evaluation of Irradiation Capabilities of Modified Laser Fiber Optic for Endodontic Applications

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Abstract : The usage of laser in endodontic application has a great potential because of laser energy efficiency in disinfection but the limitations of the possibility of directing of laser beam to any direction rather than forward direction led to many attempts of modifications of the fiber optic tips to direct the laser beam toward the walls of the root canal. In this study we proposed a modification protocols of the fiber optic tips to remove the cladding from the core of fiber optic in specific window design to allow for the laser beam to skip in lateral emission to be used in endodontic applications. This modification led to increase the width of spread in lateral emissions of laser beam by range (207% - 368%) and the total area around the fiber optic by range (96% - 164%) in in comparison to unmodified one.

Keywords – *Endodontic, Fiber optics, Laser, Lateral emission, Side firing.*

I. Introduction

Endodontic treatment has been defined as the removal of necrotic tissues and microorganisms from the root canal system. Even if this root canal system was prepared mechanically and chemically irrigated, it wouldn't completely eradicate the presence of remnants of tissues and microorganisms in areas of the system that could not be reached by mechanical preparation. (1)

Lasers are utilized in dentistry for a broad range of applications, such as disinfection to enhance conventional cleansing of the root canals. The use of lasers for endodontic procedures (root canal therapy) has attracted researchers as a result of findings that infrared lasers can also generate shockwaves that eradicate smear layer and microorganism from the confines of root canal system higher than the debridement executed by rotary files and medicaments. (2)

The root canal system of a permanent tooth is up to 20mm in period and tapers from 1mm in width at its orifice down to 0.2mm at its apical construction in a funnel-shaped manner. Onto this conical form, we face the features of curvatures, branches, deltas, and other natural anatomical complexities. (3) To cope with such complexities in shape, most hand operated and powered endodontic instruments must have safe tipped designs. so that the files cut the lateral walls of the root canal but restrict their gliding in a forward direction to reduce the opportunity of perforating or ledging the canal walls or transporting the root. (4)

The main issues associated with the usage of laser in endodontics resulted mainly from the employment of the most of the current fibers to plain forward emitting ends , Such fiber when it comes closer to the apical area of the root canal may leads to high risk of deleterious thermal damage to the periapical tissue.(5)

For these reasons, fiber tip designs that would evenly distribute energy along the root canal and prevent shock waves driving fluids out of the apex, would be ideal for root canal procedures. Several modifications of fiber tips have been considered to laterally direct laser energy as that one we proposed in this study.

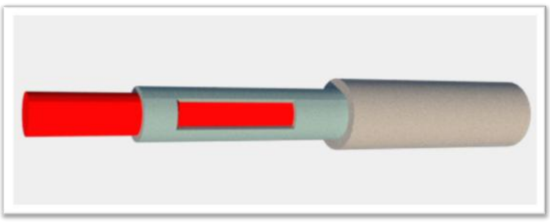
II. MATERIALS AND METHODS:

a- Fiber Optic Modification Sequence:

In this study we made a modification on diode laser tip (BIOLASE® E4-9 EZ, BIOLASE, Inc. USA) by creating on side window with (5mm x 0.4mm) dimensions to allow the lateral emission of laser beam, this modifications were designed on 3D software and executed in successive steps aiming to create a window or windows on the side of the fiber optic to allow for the skipping of the laser light beam from the side of the fiber optic, this modification was made by creating a window in the jacket cover followed by the cladding removal form the area underneath the window.

The creation of this windows in the jacket covering, started with marking the points of guidance in cutting through jacket covering around the fiber optic, this marking points was made by fixing the fiber optic on an endometer and created small groves on each mm of jacket covering using surgical blade (No.11) under 600x magnification using digital microscope (Mustool© G600, China), and the creation of windows was made by connecting the groves into the design dimensions that mentioned before.

The cladding removal was made by the combination of three cladding removal techniques started by surface etching using 37% Phosphoric Acid Etchant Gel (Meta Etchant©, META BIOMED CO. LTD. Korea). applied over the area of windows creation as shown in for 1 minute. The second step was submersion of the fiber in a solution mix 40/60 acetone/methanol inside a plastic syringe help in upright position for 7.2 minutes. The third step was Fiber window surface roughness with finishing bure (Mani TR-13EF D.S iso 198/ 018) on high-speed contra handpiece.



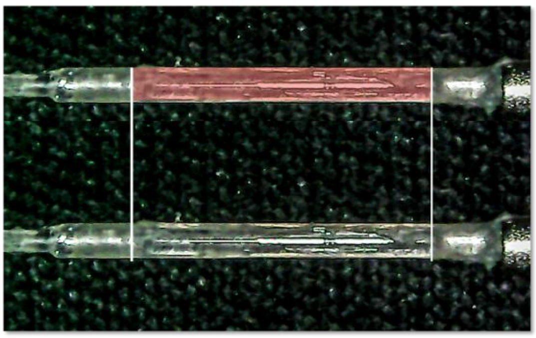


Figure (1) Photograph showing the 1 window design in 3D and the fiber optic after jacket openning according to the calculated design dimensions.

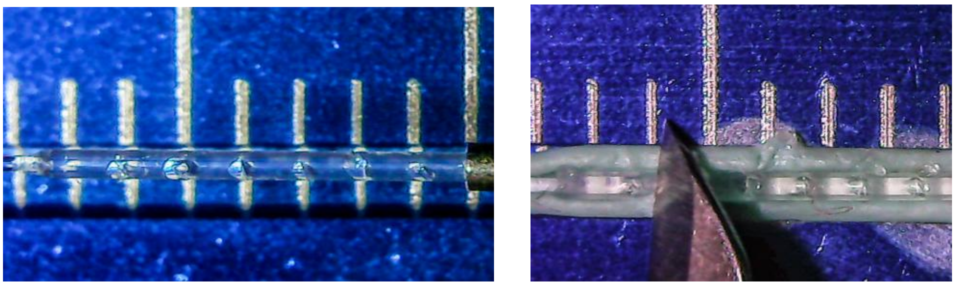


Figure (2) Photograph showing the jacket covering removal

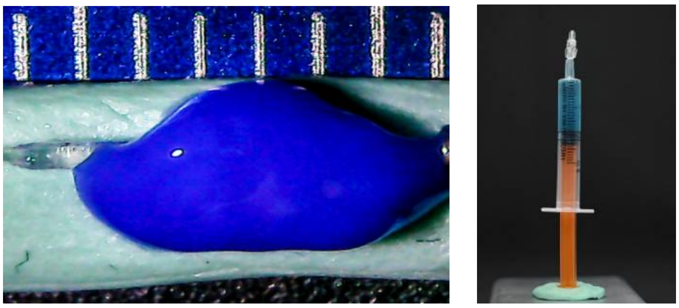


Figure (3) A) Photograph showing the 1st step of the the chemical modification of the cladding by the application of the acid each on the opennings of the laser fiber jacket B) Photograph showing the second step of the chemical cladding modification using the acetone/methanol mix.

b- The distribution Display of visible red light emitted through the fibers:

The aim of this experiment is to produce a real visualization of the effect of the modifications that made to the fiber optics on the spread and distribution of the emitting laser beam in comparison to the spread and distribution that comes out of the unmodified tip.

This experiment consists of successive several steps to display the distribution of visible red light emitted through the different fiber optics, The distribution of visible red light was photographed against a grid under consistent lighting conditions and fixed shooting sittings using DSLR camera (Canon EOS 750D DSLR camera with 105mm Sigma macro lens) , the fiber was held in direct contact to the grid to visualize the spread of the light out of the modified area, and also held inside vertically sectioned tooth to visualize the light concentration areas inside the root canal.

The produced photographs are saved in (.CR2 and .JPEG) format and used for representation on 3D interactive mapping for visualization of the light intensity representation, and in 2bits format for measurement of the width of spread of light in numerical values.

c- Photographs processing for 3D visualization and measurements:

All photographs are processed in the same technique to allow for changing it into representable numerical values, this photographs were taken in RAW (.CR2) format and modified in (Adobe Photoshop 2021) to simplify the red light into white area on black background to be measurable and comparable area across all photographs as the following: RAW photos opened in Camera RAW inside Photoshop, then all black values changed into -100 to eliminate all mixed black values in the photograph followed by setting the saturation value into 0 to change the photograph into black and white and finally hide all color channels rather than the red color channel (hide blue and green) and the photographs saved in .PNG format for analysis in (ImageJ software)for image processing and analysis.

In ImageJ software all photographs converted into 3D interactive surface plat for values of light strength representation and the photos converted into 2bit photos for the measurement of the area of spread. The measurements of the spread performed after celebration of the2 bits photographs into 1:1 and the results collected and tabulated into excel sheet for statistical analysis (using SPSS v.26 software by IBM Inc. USA).

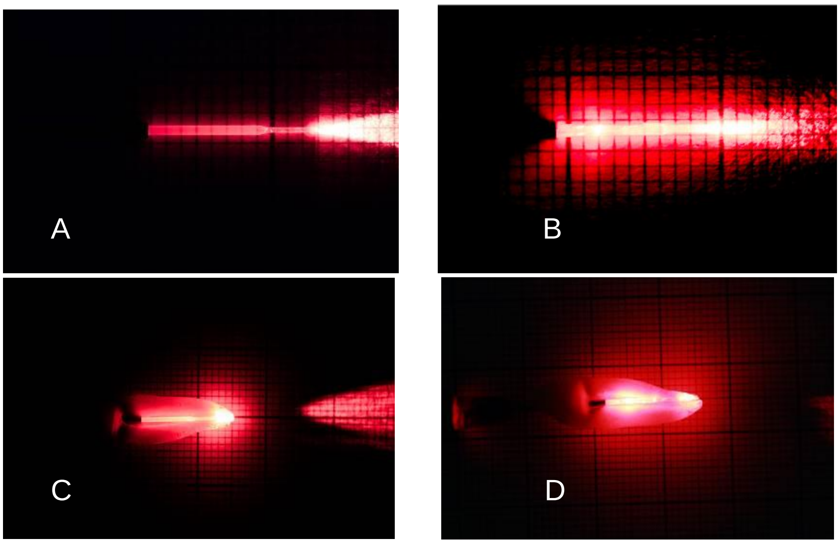
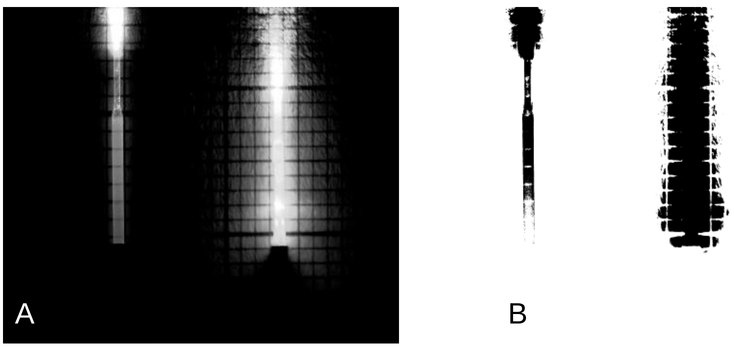


Figure (4) Photograph showing the spread of light out of A) the unmodified fiber optic and B) modified fiber optic on a grid and C) the unmodified fiber optic inside the canal space D) the modified fiber optic inside the canal space

III. Results

The hypothesis of this experiment is to find if the modification of the fiber optic by the proposed designs will leads to significant changes in the distribution pattern and width of the emitted visible red light from the fiber optic visually any numerically in comparison with the unmodified fiber optics.

Visually the captured photographs showed that, there was a significant changes in the distribution pattern and width of the emitted visible red light from the modified fiber optic in comparison to the unmodified fiber optics as shown in figures (),as the calculation of numbers obtained from the analysis of the 2bits photos obtained from the captured photographs of the light spread showed that, there was a significant increase of the width of spread increased by range(207% - 368%) on the width and by range (96% - 164%) in the total area around the fiber optic in comparison to unmodified one , and the changes in the distribution and intensity of the emitted visible red light from the modified fiber optic in comparison with the unmodified fiber optics after 3D mapping analysis showed also high values of light intensity on the modified area by 47% over the same area on the unmodified fiber .



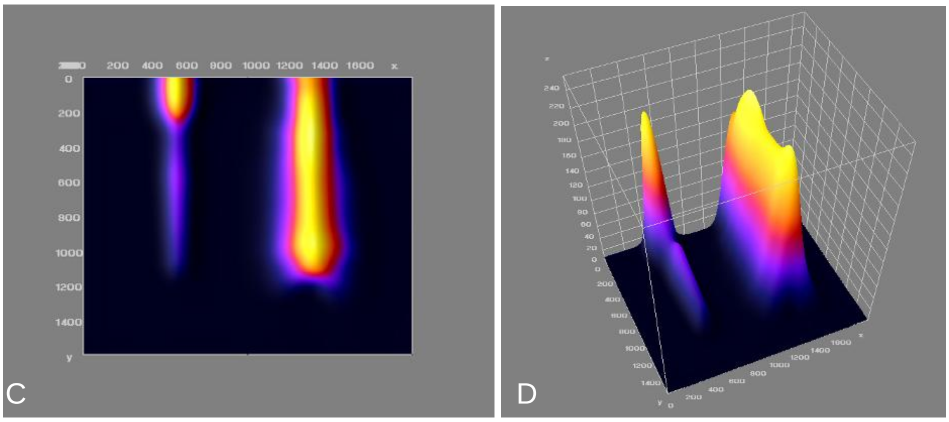


Figure (5) Photograph showing A) spread of light out of the unmodified and the modified fiber optic and B) 2Bits converted photographs for the measurements of the width and the total are of spread of light C&D) the 3D interactive representation of the light intensity around the modified and the unmodified fiber optic.

IV. Discussions

The potential of the laser power advantages in many fields was and still the main motive for all researchers to attempt new approaches to find new usage of the laser power in all dental fields, as we tried to do in this study. In this study we attempt to make a modification on the fiber optic design to allow the fiber optic to emit the laser beam in the lateral direction to target the walls of the root canal aiming to achieve higher levels of root canal disinfection and better sealing of the dentinal tubules. So, we designed this study in an successive steps of modification of the fiber optic to investigate the effect of this modifications on the efficacy of the laser functionality in the endodontic treatment.

The concept of fiber optic selection for this study:

Introduction and evaluation of a new fiber designs to accommodate the complexity of the root canal system to decreases the risk of deleterious thermal changes in the adjacent periapical tissues in comparison with traditional laser fibers used today was one of main aims of the fiber optic selection for this study. So, we worked hard on the selection of the fiber optic type that will produce the real change when we modify it to meet the needs for better performance in irradiation of the root canal space and overcome the backdrop of the existing systems available in the market.

Regarding most of the available types of fiber optics in the market we were searching for a fiber optic with specific properties that support the concept of high effective thermal energy delivery throughout the length of the fiber optic core, to allow for reaching the gool of lateral emissions of the laser beam from the side of the fiber optic when we remove the cladding from the sides of the fiber optic. For this reason, we selected the BIOLASE fiber optic tips that contain high amount of Carbon and Titanium Dioxide (CTi) that was reported that when the Carbon and Titanium Dioxide particles are embedded into the core of a laser tip and fused to the core this CTi fused core-initiation consistently converts over 90% of laser light to thermal power. (6, 7)

The manufacturer of the selected type of fiber optics used in this study also provide an endodontic fiber optic with 200µ diameter, with recommended protocol as using the irradiation in continuous mood in 0.1W in withdrawal motion from epics upward in speed of 1mm/second, but we founded that this fiber optic is so fragile to withstand the modification technique we used in this study, so we decided to work on the 400µ diameter, 9mm length fiber optic.

Design concept of fiber modification:

Modification of fiber optic by removal of side cladding to allow for skipping path for the laser beam from the side of the fiber optic is not a new concept originated by us, but we followed the previous attempts, and we add our designs of modifications to this concept to provide more effective and controllable models, that we hope to be as good as what is the endodontist needs to achieve by optimum cleaning and sealing of the root canal without ledging, perforation or endangering the apical periodontium by the forward emission of laser beam like what is usually happening with the traditional forward emitting laser fiber optics available to date.(8)

Previous attempts to produce side firing tips with a safe tip, have used optical fiber, with the terminus polished at an angle of 45 degrees,(9) also, it was described that the surface modification to optical fibers increases the lateral energy emissions along the length of the fiber tip, to facilitate endodontic laser applications.(10)While these fibers are suitable for directly delivering laser energy on the walls of the canal, they also have forward emissions. Thus, some of the shockwaves produced are directed in a forward direction. Tips with side firing capabilities and with a “safe tip” design also reported to be useful for a number of dental applications as in endodontics, such tips could preferentially ablate the walls of the root canal, with little or no energy apically directed, without risk of laser energy or shock waves passing toward the apical constriction at the end of the root. (4)

We built upon this previous attempt to make the modification of the of the fiber optic to be more controlled by specific dimensions rather than the complete removal of the cladding from the entire sides of the fiber optic, and we made just windows to let the light to skip through small area directly to the targeted zoon. The window we created on the side of the fiber optic was designed in on large window with the dimensions of 0.4 x 5 mm to get will defined exposure areas with specific dimensions to help in further upcoming research in modifications of the fiber optics for the usage in endodontics.

The concept of chemical removal of the cladding:

The most of the previous attempts to make chemical etching of the fiber optic was mainly depends on the use of solution of Hydrofluoric acid (HF) in different concentrations,(11, 12) but we founded that the effect of HF on the selected type of the fiber optic for this study was very aggressive so we decided to use the phosphoric acid gel instead, and followed by chemical etching by a mixture of acetone/methanol,(13) and the final step was mechanical roughness using finishing bure to ensure the proper removal of the cladding from the windows areas on the fiber optic.

The concept of the assessment of the distribution display of visible red light emitted through the modified fibers:

The aim of this experiment was to produce a real visualization of the effect of the modifications that made to the fiber optics on the spread and distribution of the emitting laser beam in comparison to the spread and distribution that comes out of the unmodified tip. The visual representation of the light spread out of the modified fiber optics was an indicator for the efficacy of the modification process as shown in the results section, as the removal of the cladding from the areas of windows allowed for the skip of light from the lateral wall of the fiber optic. Also, when we compared the total area of spread of light from the modified fiber optics it was obvious that the window design helped in increasing the area of irradiation of the root canal by the laser beam.

The spread of light out of the modified fibers was photographed and the collected photos was transformed into two sets of data to evaluate the spread of light in 3D visual manner and in numerical values, the 3D analysis of the photos was built upon using a software that let us to convert the photographs into a 3D map represents the degrees of illumination in a 3D interactive graph that we could analyses and get valuable information about the light spread patterns, this information we couldn’t get it as clear from the 2D photographs. The numerical values we got also from transforming the photographs into a 2bit photos and the measurement of the widest area of the light spread, this values demonstrated that the difference between the modified and the unmodified tips. This numerical values were in alignment with the visual 3D mapping values that showed that improvement of the lateral spread of the light out of the modified fiber optic.

V. Conclusion:

It was concluded that the proposed modification protocol of the fiber optic presented in tis study may improve the lateral emission of the laser beam from the fiber optic tip and this may have a potential on the effectiveness of the endodontic applications.

References:

[1.] Sin JHM, Walsh LJ, Figueredo CM, George RJTB. Evaluation of effectiveness of photosensitizers used in laser endodontics disinfection: A systematic review. 2021;3(1):e202000007.

[2.] Bordea IR, Hanna R, Chiniforush N, Grădinaru E, Campian RS, Sîrbu A, et al. Evaluation of the outcome of various laser therapy applications in root canal disinfection: A systematic review. 2020;29:101611.

[3.] Luca DDN, Pagavino G. Innovations in Shaping and Cleaning the Root Canal System.

[4.] George R, Walsh LJJJobo. Performance assessment of novel side firing safe tips for endodontic applications. 2011;16(4):048004.

[5.] George R, Walsh LJ. Laser-assisted endodontics. Lasers in Dentistry—Current Concepts: Springer; 2017. p. 191-210.

[6.] Yuan L, Wei X, Martinez JP, Yu C, Panahi N, Gan JB, et al. Reaction spinning titanium dioxide particle-coated carbon fiber for photoelectric energy conversion. 2019;7(5):49.

[7.] Ahmed N, Kamarulzaman N, Zulkipli N, Jusoh Z, Rahman H, Harun S, editors. Generation of Q-switched Erbium-Doped Fiber Laser Using Titanium Dioxide Film Based Saturable Absorber. IOP Conference Series: Materials Science and Engineering; 2020: IOP Publishing.

[8.] Jahan KR, Hossain M, Nakamura Y, Yoshishige Y, Kinoshita J-I, Matsumoto KJLims. An assessment following root canal preparation by Er, Cr: YSGG laser irradiation in straight and curved roots, in vitro. 2006;21(4):229-34.

[9.] Ngo AK, Fried NMJJoe. Side-firing germanium oxide optical fibers for use with erbium: YAG laser. 2006;20(7):475-8.

[10.] George R, Walsh LJJLiS, Medicine MTOJotASfL, Surgery. Performance assessment of novel side firing flexible optical fibers for dental applications. 2009;41(3):214-21.

[11.] Lazarev A, Fang N, Luo Q, Zhang XJRosi. Formation of fine near-field scanning optical microscopy tips. Part I. By static and dynamic chemical etching. 2003;74(8):3679-83.

[12.] Lazarev A, Fang N, Luo Q, Zhang XJRosi. Formation of fine near-field scanning optical microscopy tips. Part II. By laser-heated pulling and bending. 2003;74(8):3684-8.

[13.] Samavati Z, Samavati A, Ismail AF, Yahya N, Rahman MA, Othman MHDJO, et al. Effect of acetone/methanol ratio as a hybrid solvent on fabrication of polymethylmethacrylate optical fiber sensor. 2020;123:105896.