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Comparative Efficacy of Diode, Nd:YAG and Er:YAG Lasers Accompanied by Fluoride in Dentinal Tubule Obstruction

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Abstract

Introduction: Recently, the management of dentin hypersensitivity by lasers has gained special attention. This study aimed to assess and compare the efficacy of the 980 nm diode, Nd:YAG and Er:YAG lasers accompanied by fluoride in dentinal tubule obstruction.

Methods: Twenty sound single-rooted human teeth were used for this invitro study. Forty dentinal discs were prepared of the roots and etched with 6% citric acid. One layer of fluoride varnish was applied over their surface. The sections were randomly allocated into 4 groups. The control group received no laser irradiation. Group 2 underwent 980 nm diode laser irradiation with 0.5 W power. Group 3 underwent Nd:YAG laser irradiation with 0.5 W power and group 4 underwent Er:YAG laser irradiation with 0.5 W power. All samples were then inspected under a scanning electron microscope, and the number of obstructed dentinal tubules and the diameter of open dentinal tubules in the field were determined. One-way ANOVA and Tukey's test were used for data analysis at a significance level of 0.05.

Results: All three laser types decreased the number of open dentinal tubules significantly compared to the control group ($P<0.05$). No significant difference was noted in dentinal tubule obstruction between the three laser groups ($P>0.05$). The diameter of open tubules in the three laser groups did not show a significant difference from that in the control group.

Conclusion: All three types of lasers evaluated in this study can effectively obstruct the dentinal tubules.

Keywords: 980 nm Diode laser, Er:YAG laser, Nd:YAG laser, Dentin hypersensitivity, Fluoride

Introduction

Dentin hypersensitivity (DH) is a common clinical problem affecting all age groups.[1] It is more commonly seen in canine and premolar teeth of both jaws.[2] DH is determined with a short, sharp pain due to the reaction of exposed dentin to different stimuli such as heat, touch, osmotic pressure or chemical stimuli. This pain cannot be attributed to any dental problem or pathology.[2]

Numerous theories have been suggested for explaining the mechanisms of DH. Due to the hydrodynamic theory, which has the highest rate of acceptance, DH occurs when the stimulus causes the movement of intratubular fluid inward or outward and leads to the activation of pain receptors. According to this theory, an ideal treatment for DH should involve a reduction of intratubular fluid or blocking the pulpal nerve response.[3]

Many desensitizing agents such as potassium nitrate, formaldehyde, composite resins, and varnishes have been suggested to resolve DH.[4] Recently, high-level and low-level laser systems were proposed to resolve DH. However, low-level lasers are more commonly used for this purpose due to their lower cost.[5] A number of studies have evaluated DH and its efficient management[6-8] and a few of them have evaluated the efficacy of different laser types for the resolution of DH, reporting contradictory results.[6,7] Thus, comprehensive information is not available on the efficacy of different laser types for the obstruction of dentinal tubules and the resolution of DH. Lasers can be applied in both low-level power and medium-level power modes by their effect on the nervous level and the occlusion of dentinal tubules respectively.[9]

Considering the significance and relatively high prevalence of DH and the gap of information regarding the efficacy of different laser types for the resolution of DH, this study aimed to compare the efficacy of 980 nm diode, Nd:YAG and Er:YAG lasers in the obstruction of dentinal tubules of extracted human teeth.

Materials and Methods

This experimental study was in vitro. The single-rooted

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human teeth were examined under a stereo microscope, and the teeth with no internal/external root resorption, cracks or root caries were selected. The minimum sample size was considered to be 10 samples in each of the four groups (a total of 40) according to a study by Patil et al,[10] using one-way ANOVA Power Analysis feature of PASS 11 software assuming alpha = 0.05, beta = 0.2, standard deviation of 3.71 and effect size of 0.55. The study was approved by the ethics committee of Azad university of Medical Sciences.

Twenty sound extracted single-rooted human teeth with no caries or restorations were collected. Soft tissue residues and debris were detached using a dental scaler. The coronal third and apical third of the teeth were cut by a diamond disc and low-speed handpiece under copious irrigation with sterile water. Two sections were made at the mesial and distal tooth surfaces measuring 2×2 mm with 2 mm thickness. All samples were then etched with 6% citric acid and rinsed with distilled water for 1 minute.

The sections were randomly allocated into 4 groups (n = 10). Group 1 served as the control group and did not receive any laser irradiation. The samples in group 2 underwent 980nm diode laser (wiser II, Doctor Smile, Italy) irradiation with the flat top handpiece. The samples in group 3 underwent Nd:YAG laser (Lightwalker, Fotona, Slovenia) irradiation with the Genova handpiece, and the samples in group 4 were subjected to Er:YAG laser (Lightwalker, Fotona, Slovenia) irradiation with the bleaching handpiece. Table 1 shows the laser irradiation parameters in the three experimental groups.

The cross-sectional area of all laser hand-pieces was 1 cm^2 and the distance from the tip of the laser hand-piece to the surface of the samples was 1 mm. The total irradiation time was 60 seconds, and irradiation was performed in three cycles, 20 seconds each, with 1-minute intervals.

Fluoride varnish (5% sodium fluoride, TCP and xylitol, Vericom CO LTD., Korea) was applied on the surface of all samples, and the samples in groups 2, 3 and 4 immediately underwent laser irradiation after the application of varnish. After the completion of irradiation, the varnish remained on the surface of the samples for 5 minutes. Excess varnish was then removed and the samples were immersed in artificial saliva. They were then dried using an air dry system, gold-plated and inspected under an electron microscope at ×2000 magnification (Vega/ Tescan – XMU, Tescan s.r.o, Czech Republic) to determine the number of obstructed dentinal tubules and the diameter of open dentinal tubules. The study was performed blindly in such a way that the technician who measured the number and diameter of dentinal tubules was blinded to the group allocation of the samples.

The percentage of open dentinal tubules and their diameter were compared between different groups using one-way ANOVA. Tukey's HSD test was used for pairwise comparisons. The level of significance was considered as $P < 0.05$.

Results

Table 2 shows the mean percentage of obstructed dentinal tubules. The percentage of obstructed dentinal tubules indicated a significant difference between the groups ($P < 0.05$). The results of pairwise comparisons showed that the mean percentage of obstructed dentinal tubules in all three laser groups was significantly higher than that in the control (fluoride varnish) group ($P = 0.000$). The mean percentage of obstructed dentinal tubules in the diode laser group was 4.00000 ($P = 0.236$) lower than that in the Er:YAG laser group and 2.30000 ($P = 0.688$) lower than that in the Nd:YAG laser group. The mean difference between the diode laser group and the control group was 49.00000 ($P = 000$). The difference in the mean percentage of obstructed tubules in the Er:YAG and Nd:YAG groups was 1.70000 ($P = 0.846$). The difference between the Er:YAG group and the control group in this regard was 53.00000 ($P = 000$). The difference in the mean percentage of obstructed tubules in the Nd:YAG and control groups was 51.30000. None of the differences were statistically significant ($P > 0.05$).

Table 3 shows the diameter of open dentinal tubules in the groups. As shown, regarding the minimum diameter of open dentinal tubules, the smallest value was noted in the Er:YAG laser group while the largest value was noted in the control (fluoride) group. Regarding the maximum diameter of open dentinal tubules, the highest value was noted in the control group while the smallest value was noted in the Nd:YAG laser group; however, these differences were not statistically significant ($P = 0.367$).

Discussion

A significant correlation exists between DH and the presence of open dentinal tubules because exposure of open dentinal tubules to different stimuli would stimulate the pain receptors and lead to DH.[2] DH can be effectively resolved by obstruction of dentinal tubules.[11] This study assessed and compared the effects of a 980 nm diode laser, an Nd:YAG laser and an Er:YAG laser on dentinal

Table 1. Laser Irradiation Parameters in the Three Experimental Groups

Laser Type	Exposure Settings
Diode	Flat-top hand-piece, 980 nm wavelength, continuous mode, 0.5 W power, 30 J/cm^2 energy density
Nd:YAG	Genova hand-piece 1064 nm wavelength, 0.5 W power, 10 Hz frequency, 30 J/cm^2 energy density, 100 ms pulse duration
Er:YAG	Bleaching Hand-piece 2940 nm wavelength, 0.5 W power, 10 Hz frequency, 30 J/cm^2 energy density, 100 ms pulse duration

Table 2. Mean Percentage of Obstructed Dentinal Tubules in the Study Groups (n = 10)

Group	Minimum	Maximum	Mean	Standard Deviation
Diode	74.00	93.00	87.2	4.96
Er:YAG	78.00	100.00	91.2	6.28
Fluoride (control)	33.00	45.00	38.2	4.13
Nd:YAG	86.00	93.00	89.5	2.27

Table 3. Diameter of open dentinal tubules (μm) in the study groups (n = 10)

Group	Minimum	Maximum	Mean	Standard Deviation
Diode	1.37	3.68	2.4180	0.84
Er:YAG	0.00	3.11	1.7980	0.98
Fluoride (control)	1.55	5.73	2.5120	1.36
Nd:YAG	1.49	2.90	2.1350	0.50

tubule obstruction. The results showed that all three laser types decreased the number of open dentinal tubules in a significant manner, but no significant difference was noted in dentinal tubule obstruction between them ($P > 0.05$). However, the diameter of open tubules in the three laser groups did not show any significant difference from that in the control group.

The Nd:YAG laser is a high-level infra-red laser that easily affects the tooth structure, melts the peritubular dentin and results in its entry into the dentinal tubules and their relative obstruction. As a result, the diameter of open tubules decreases. It confers a dull appearance to dentin.[12,13]

The Er:YAG laser is highly interacted with the structures bonded to water in dentin and thus causes sudden expansion of crystalline tooth structure. It destructs the dentinal tubules in an irregular pattern by the destruction of peritubular dentin.[9] The 980 nm diode laser has near infrared wavelength. Thus, part of its energy is absorbed by the mineral content of dentin such as phosphate and carbonate causing disarrangement of the crystalline regular structure of dentin by thermomechanical destruction and melting of dentin.[14,15]

Chiga et al[16] assessed the effect of Nd:YAG and Er:YAG lasers with 1 W power with and without fluoride varnish on the obstruction of dentinal tubules and concluded that both laser types can effectively obstruct the dentinal tubules. The laser wavelengths in our study were similar to those in the study by Chiga et al[16]; however, the laser power was 0.5 W. Nonetheless, both laser types efficiently obstructed the dentinal tubules. The mechanism of both Nd:YAG and Er:YAG lasers is the same and is through melting and re-solidification of dentin.[17-20] This can explain the similarity of our results to those of Chiga et al.[16] They evaluated the effect of the presence and absence of fluoride varnish and found that it had no effect on the obstruction of dentinal tubules. This finding has also been reported by some other studies[21,22] and justifies the use of fluoride varnish as the control in our study. Kurt et al[23] compared the effect of Nd:YAG and Er:YAG lasers and two desensitizing agents, namely NovaMin and PreviDent, on dentinal tubules. They showed that both Nd:YAG and Er:YAG lasers alone effectively decreased the permeability of dentinal tubules. However, statistically, none of the laser groups had any superiority over each other. Similarly, in our study, Nd:YAG and Er:YAG laser irradiation in combination with the application of fluoride varnish showed superior obstruction of dentinal tubules compared to the application of fluoride varnish alone (control group). However, the two laser groups were not significantly different in this respect. Similar results obtained in our study and those in the study by Kurt et al[23] may be due to the equal wavelength of lasers and the medium short pulse. However, Kurt et al[23] did not assess the effect of the laser in combination with a desensitizing agent.

Saluja et al[24] assessed the effect of Nd:YAG, 810 nm diode and CO_2 lasers on exposed dentinal tubules of human teeth. They reported that all laser types effectively obstructed the dentinal tubules. However, the Nd:YAG laser was more effective than the other two. The difference between their results and ours may be attributed to higher laser power (1 W in their study compared to 0.5 W in ours) and distance from the tip of the laser hand-piece to the tooth surface (1 cm versus 2 mm) in their study compared to ours. In our study, all three laser types showed equal efficacy. However, it should be noted that the diode laser used in our study had a 980 nm wavelength, which was different from the wavelength of the diode laser used by Saluja et al.[24] Öncü et al[25] evaluated the efficacy of different desensitizing agents and lasers for the obstruction of dentinal tubules. They concluded that the Er:YAG laser combined with Gluma had the highest efficacy for tubular obstruction, which was different from our results. The difference in desensitizing agents used in the two studies may explain the difference in the results. Studies on the efficacy of Gluma and fluoride for resolution of DH have shown that Gluma has a higher desensitizing effect than fluoride [22,26]. Moreover, the higher frequency and power of lasers in the study by Öncü et al[25] can explain the difference in the results.

Gholami et al[8] compared the effect of Er,Cr:YSGG, Nd:YAG, CO_2 and diode lasers on dentinal tubules. They showed that although the mean reduction in diameter of dentinal tubules in the Nd:YAG laser group was higher than that in other groups, the reduction in tubular diameter in all groups was significant. In the current study, no significant difference was noted in the reduction of dentinal tubule diameter between the laser groups. This controversy in the results may be related to the higher power, energy density and frequency of lasers used by Gholami et al[8] compared to our study. Nandakumar and

Iyer[27] compared the efficacy of Er,Cr:YSGG and diode lasers and some desensitizing agents using an electron microscope. They observed a minimum percentage of open dentinal tubules in the Er,Cr:YSGG laser group with no desensitizing toothpaste, which was different from our result. This controversy can be due to shorter irradiation time and distance of the laser beam from the surface of samples as well as higher diode laser power and frequency of the Er,Cr:YSGG laser in their study compared to ours.

As the flat-top beam profile can create a homogeneous and constant power on the beam spot-area compared to the conventional Gaussian beam profile, it seems that irradiation with a flat-top handpiece can be more effective without producing a remarkable thermal increase.[28] To our knowledge, this is the first study that evaluates the effect of the flat-top beam profile on dentinal obstruction. Further studies are needed to compare the flat top with the Gaussian beam profile on dentinal obstruction.

As this study was performed in vitro, the generalization of results to the clinical condition should be done with considerations. Further clinical studies are required to confirm the findings of this study.

Conclusion

980 nm diode, Nd:YAG and Er:YAG lasers accompanied by fluoride can effectively obstruct the dentinal tubules.

Conflict of Interests

The authors declare no conflict of interest.

Ethical Considerations

This study was in vitro.

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None.

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