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APPLICATION OF ER: YAG LASER IN THE TREATMENT OF ENDODONTICS

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ABSTRACT

With the gradual maturity of laser technology, it has become widely considered a new method for disease treatment. Er: YAG laser are two representative solid-state lasers. This laser is easy to use, comfortable and safe, and thus, it has recently become a research hotspot in dental treatment. Er: YAG laser has been used for the treatment of dentin hypersensitivity and dental caries, root canal therapy, pulp preservation and apical surgery. It is effective adjuvant methods for the treatment of dental pulp diseases and provide new avenues for clinical treatment. In this paper, the application of Er: YAG laser in the treatment of endodontics is described to provide a reference for clinical treatment options.

KEYWORDS: Er: AG laser; Dentin hypersensitivity; Dental decay; Root canal treatment; Vital pulp therapy; Apical surgery.

As a new treatment method, laser treatment is widely used in various fields of medicine. In the 1970s, Weichman first tried to seal the apical foramen with a high-energy infrared laser in vitro. This research has created a new direction for laser treatment of dental pulp surgery.[1] Since then, Scholars from all over the world have conducted a lot of research on laser treatment of dental pulp diseases[2], and laser treatment technology has continued to mature. Er:YAG laser, as representative solid-state laser, is currently hot spot in laser treatment and research.

Working principle

Light amplification by stimulated emission of radiation (Laser) has the advantages of monochromaticity, coherence and directivity. Lasers are classified according to working medium and can be divided into solid lasers, liquid lasers and gas lasers. Solid-state lasers are lasers doped with crystals or glass doped with a small amount of activated ions as the working medium. Er:YAG laser belongs to this category.

Erbium-doped yttrium aluminum garnet laser (Er: YAG) is erbium-doped yttrium aluminum garnet as the working medium, and the wavelength is 2940 mm. Its wavelength is just at the peak of water absorption, and is specifically absorbed by hydroxyapatite, so it has a good cutting effect on dental hard tissues, and is often used in the treatment of oral hard tissue diseases.

2 Clinical application

2.1 Treatment of dentin sensitivity

The occurrence of dentin hypersensitivity is closely related to the exposure of the dentin tubules to the oral environment, and the external stimuli cause the fluid flow in the dentin tubules. Reducing or sealing dentin tubules, thereby reducing the hydrodynamic factors of dentin tubules, is an effective way to treat dentin hypersensitivity. Er: YAG laser has good curative effect on dentin hypersensitivity. The principle is that Er: YAG laser causes the hard tissue of the tooth body to melt and recrystallize through the thermal effect.[3] Tosun et al.[4] used 1.5 W, 10 Hz Er:YAG laser-assisted Clinpro fluoride protective paint to treat human molar dentin. Scanning electron microscope observation confirmed that Er:YAG laser could enhance the ability of sodium fluoride coating to seal dentin tubules and reduce teeth permeability of essential tubules. Ozlem et al.[5] used lasers or desensitizers to treat 100 teeth of 17 adult patients, which were detected by electronic pressure sensitive probes at 30 min, 7d, 90d and 180d after treatment. Desensitization effect, the results showed that $1W/cm^2$, 10 Hz Er: YAG laser desensitization effect was similar to Gluma desensitizer, no pulp irritations and allergies and other adverse reactions. The above research showed that Er:YAG laser could be used as a safe and effective treatment for dentin sensitivity.

2.2 Treatment of caries

Er: The YAG laser can be specifically absorbed by water and hydroxyapatite. It can remove hard tissues of teeth through micro-blasting, thereby painlessly removing carious tissues, and avoiding micro-cracks of teeth caused by traditional turbine handpieces. The 250 mJ, 4 Hz

Er:YAG laser can remove caries, change the physical structure of the dentin surface, and increase the surface microhardness of the remaining dentin.[6] Compared with the traditional turbine handpieces, using Er:YAG laser to remove caries has no adverse effect on the subsequent dental restoration, and can also enhance the composite resin-filled dentin adhesion.[7] Baraba et al.[8] applied 4 modes of Er:YAG laser to remove caries, including SSP, SP, MSP and FFC. The temperature of the tooth tissue during irradiation was measured in the study. The results showed that Er:YAG laser could effectively remove carious tissues and cariogenic bacteria without generating excessively high temperature to avoid dental pulp damage. Among them, the increase of tooth temperature in FFC mode was the smallest, (4.5 ± 2.4) ℃, which indicatesd that laser caries removal had good safety and comfort.

Despite the specific advantages of Er:YAG laser caries removal, its clinical application is still controversial. Some scholars pointed out that when using Er:YAG laser to remove caries, the haptic feedback obtained by the operator would result in longer operation time than using a turbine handpieces. In addition, Er:YAG laser propagates along a straight line, so it is difficult to remove the carious tissue on the inner wall of the caries.[9] In summary, Er:YAG laser has a good development prospect as a minimally invasive method for the treatment of caries, but it still cannot completely replace turbine handpieces.

2.3 Living pulp preservation treatment

2.3.1 Direct pulp capping

Pulp capping is a commonly used method of preserving live pulp. The purpose is to avoid micro-leakage of bacteria and stimulate the formation of the dentin barrier to preserve pulp vitality. Some studies have found that using Er:YAG laser for direct pulp capping has the advantage of promoting the penetration of pulp capping agent and tissue healing after pulp capping. Hasheminia et al.[10] used Er:YAG laser at 200 mJ and 3 Hz combined with MTA to directly cover the pulp of cat mechanically exposed teeth under sterile conditions. Histological examination showed that the thickness of the formed dentin bridge was greater than that of the MTA alone group, and no case of pulp necrosis occurred. Stefanova et al.[11] used Er:YAG laser to remove carious tissue from human occlusal surface to dental pulp exposure in vitro. When the exposed hole was less than 1 mm, calcium hydroxide, tricalcium silicate cement and MTA were used to directly cover the pulp . Scanning electron microscope observation showed that Er:YAG laser-treated dentin surface had better edge contact with the pulp capping agent interface. Er: The dentin tubules were open after YAG laser caries removal, which was conducive to the penetration of the pulp capping agent. So far, there have been few studies on the use of laser for pulp capping, and most of them are in vitro experiments and animal experiments, and a large number of clinical studies are urgently needed for verification.

2.3.2 Vitrectomy

In view of the good coagulation and sterilization ability, and the removal of soft tissue without direct contact, laser has a good application prospect in vitrectomy. Huth et al.[12] used different methods to perform pulp mutilation on 200 deciduous molars of 107 healthy children. 36 months postoperative follow-up revealed that there was no statistically significant difference between the 180 mJ, 2 Hz Er:YAG laser group and the formaldehyde cresol group. Odabas et al.[13] used Er:YAG laser at 2 W, 100 mJ, 20 Hz to perform pulp marrow excision on deciduous molars. The 12-month follow-up data showed that there was no statistical difference between the two groups in the laser treatment and formaldehyde cresol groups. Different studies have some differences in the selection of Er:YAG laser parameters. Therefore, when clinically applying the two lasers to vitrectomy, how to choose the most suitable parameters still needs more clinical evidence.

2.4 Root canal treatment

The anatomy of the root canal is very complex, which makes mechanical preparation combined with chemical drug washing can not effectively remove dental pulp, microorganisms and toxins in irregular areas such as apical bifurcations and lateral root canals. Studies have shown that after conventional mechanical preparation, about 35% of the inner wall of the root canal was not in contact with the instrument.[14] The root canal preparation process produced a lot of dentin debris, which leaded to the formation of the smear layer. The smear layer is a layer of irregular, amorphous granular material covering the inner wall of dentin[15], which can enter the dentin tubules to a depth of 40 μm, block the dentin tubules, and reduce the permeability of the root canal inner dentin. As a protective layer of bacteria in the dentin tubules, the smear layer affects the disinfection drugs and root canal sealants entering the dentin tubules, which will reduce the efficiency of root canal disinfection and affect the sealing of root canal filling.[16] Er: YAG laser can effectively improve the root canal cleaning effect by changing the structure of dentin, removing the smear layer, killing bacteria, etc.[17,18] At present, Er:YAG laser is mainly used for root canal washing and root canal disinfection.

2.4.1 Root canal washing

Laser-activated irrigation (LAI) is a new method of root canal washing.[19,20] The wavelength of Er: YAG can be specifically absorbed by water, and the root canal can be effectively cleaned by activating the irrigation fluid in the root canal.

Photon-induced photoacousticstreaming (PIPS) is a new method of root canal washing. The working principle is that when the pulp cavity and the root canal are filled with liquid, the Er:YAG laser is used for irradiation, and the laser energy propagates into the solution to produce a cavity effect, which is complicated The root canal system is effectively washed.

In vitro studies showed that PIPS was an effective means to remove the contaminated layer of the root canal wall[21-22], and the effect of the upper middle segment of the root canal was better than that of the apical segment.[23] Its ability to remove debris was similar to ultrasonic washing.[24] PIPS could also effectively remove microorganisms in the root canal.[25,26] The 0.3 W, 20 mJ, 15 Hz Er:YAG laser could activate 5.25% sodium hypochlorite solution, effectively removing enterococcus faecalis in the dentin tubules.[27] Kasic et al[28] established an in vitro infection model of Enterococcus faecalis and Candida albicans, and found that PIPS had a significant killing effect on both microorganisms, and it was better than the 1.5 W, 15 Hz Er:YAG laser. The bactericidal effect of PIPS was affected by the concentration of sodium hypochlorite washing solution. Golob et al.[29] used PIPS to activate three different concentrations of sodium hypochlorite (1%, 3% and 5%) for washing. It was found that PIPS activated 5% sodium hypochlorite solution was used to remove stain Layers and Enterococcus faecalis biofilms work best.

Calcium hydroxide is a widely used root canal disinfection drug, and it is still controversial how to completely remove it before root canal filling. PIPS can effectively remove calcium hydroxide in the root canal.[30] Lloyd et al[31] compared the ability of PIPS or passive ultrasonic irrigation to remove calcium hydroxide in Weine Class II root canals of mandibular molars, and confirmed that the removal effect of PIPS was superior to passive ultrasonic irrigation.

PIPS can also produce good results in the disinfection of root canal retreatment cases, without weakening the resistance of the tooth.[32] Suk et al.[33] found that PIPS could effectively remove root canal sealers such as MTA, AHPlus, and EndoSequence BC by using micro-CT scanning in vitro, which further supported its application in root canal retreatment.

The laser energy required by PIPS is low, and the optical fiber only needs to be placed in the liquid in the medullary cavity, and does not directly contact the dental tissue, avoiding damage to the dental body and surrounding tissues. PIPS as a laser-mediated root canal irrigating method can activate the irrigating agent, effectively remove the smear layer and debris, kill microorganisms, remove drugs and sealing agents in the root canal, and has good clinical application value.

2.4.2 Root canal disinfection

The bacterial biofilm in the root canal is an important pathogenic factor leading to periapical periodontal disease. It can be closely attached to the dentin wall, which is difficult to be completely removed by conventional mechanical preparation and drug disinfection.[34] In the treated root canals of persistent periapical periodontitis, Enterococcus faecalis is the dominant bacteria causing secondary infections. It has a strong resistance to the physical and chemical effects of the outside world, and can penetrate into the dentin tubules to a depth of 1 000 μm and attach to the dentin collagen.[35] However, the penetration depth of the commonly used root canal irrigation fluid does not exceed 160μm, and it is difficult to remove the infected bacteria hidden in the deep layer of the root canal. Studies showed that Er:YAG could kill Enterococcus faecalis settled deep in the dentin more than 1000μm.[36] Er: The YAG laser produced a photothermal effect, the substrate attached to the bacteria absorbs the laser to generate heat, the local temperature rised rapidly, the microenvironment of the bacteria was changed, and eventually the deep bacteria were killed.[37] In addition, Er:YAG laser may also have a bactericidal effect that is not related to temperature increase. For example, light-absorbing molecules in the area of the chromophore in bacteria will specifically absorb the laser, causing cell damage and bacterial death. Melanin can specifically absorb Er:YAG laser, so Er:YAG laser has better bactericidal effect on P. melanogenes.[38]

Er: YAG laser directly irradiates the dried root canal, which can effectively remove the debris and smear layer in the root canal and reduce the bacteria in the root canal. Some studies used scanning electron microscope to observe the root canal dentin surface after Er: YAG laser irradiation, and found teeth Essential tubules were open. This feature promotes the increased permeability of dentin, which was conducive to the penetration of disinfectant drugs into dentin, thereby improving the cleaning and bactericidal effects of drugs and increasing the success rate of treatment. Therefore, it was recommended to be applied before root canal disinfection.[39]

2.5 Apical surgery

Root apex surgery promotes the healing of periapical tissues by removing the periapical lesion tissue and removing the root apex of the affected tooth and back filling. Inadequate apical resection and incomplete filling are the main reasons for the failure of apical surgery. In recent years, Er:YAG laser has been used for the excision of infected root tips due to its excellent hard tissue cutting ability, and has achieved good results. Lietzau et al.[40] applied Er:YAG for apical resection and returned visits on 1d, 7d, and 180d after surgery. It was found that laser resection of the apex can effectively reduce postoperative inflammation and improve prognosis compared with traditional apical surgery. Bodrumlu et al.[41] used Er:YAG lasers with different pulse widths for apical resection, and found that the temperature rise caused by the pulse width at 50μm was the smallest, and emphasized that Er:YAG lasers with any pulse width should be matched with water cooling. Angiero et al.[42] used Er:YAG laser and Er, Cr:YAG laser to fill 65 patients with periapical periodont after apical resection. The success rate was as high as 86.15%. Pozza et al.[41] compared different lasers for apical resection, and used staining to test their permeability. It was found that the 400 mJ, 10 Hz Er:YAG laser for apical resection combined with the 150 mJ, 10 Hz Nd:YAG laser for apical surface treatment followed by MTA closure resulted in lower microleakage than the Er:YAG laser alone.

The above research suggested that the combined application of the Er:YAG and Nd:YAG laser could effectively remove the smear layer at the apical resection site, reduce bacterial penetration, relieve inflammation, and improve the efficacy of apical surgery.

Summary

Because heat will be generated during laser irradiation, if the heat is too high, it will damage the teeth and the surrounding soft and hard tissues, causing a thermal damage effect.[42] Therefore, the safety of laser treatment is worthy of attention. Animal experiments show that a temperature rise of 10℃ is the critical temperature for bone tissue damage.[43] Temperature rise within 7℃ can avoid damage to human periodontal ligament cells.[44] Er: YAG laser cutting fresh pig alveolar crest bone plate in vitro at 22℃ caused a higher temperature rise than traditional surgical bone saws, but within 10℃, it would not cause surface carbonization.[45,46] Some scholars reported that the application of 100 mJ, 50 Hz Er:YAG laser treatment of the tooth root surface for 40 s under water cooling would not cause the temperature of the medullary cavity to rise.[47,48] Choosing appropriate parameters of laser and auxiliary water cooling is an effective way to avoid thermal damage. Kimura et al.[49] used Er:YAG laser at 2 Hz, 34, 68 and 102 mJ to irradiate the root canals of rats under water cooling. Histological examination of root surface periodontal tissues was performed immediately, 1, 2, 4, and 8 weeks after treatment, and found that 68 mJ and 102 mJ laser groups showed moderate to severe inflammation and absorption on part of the root surface, There was no inflammation or absorption on the root surface of 34 mJ laser group and control group. However, the histological changes in the apical area of the laser treatment group with different parameters were not statistically different from the control group without laser treatment. Er:YAG laser-assisted root canal preparation with appropriate parameters will not cause thermal damage to periodontal tissues, and has certain safety.

In summary, the Er:YAG laser, as an effective method for the treatment of endodontics, has shown broad application prospects in the treatment of dental hard tissue diseases, viable pulp preservation therapy, root canal therapy and apical surgery. So far, there are few relevant research reports, and more clinical research is still needed to provide a scientific basis for the application of Er:YAG laser in endodontics.

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