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Research progress of laser caries prevention

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Abstract: *Overview Caries is an infectious disease of chronic progressive destruction, mainly affected by a variety of factors of bacteria, if it cannot be treated timely, it gradually develops into a series of complications, such as endodontic disease and periapical disease, which affects the whole body health and reduces the quality of life of patients. The report of the fourth national oral health epidemiological survey shows that the caries rate of 12-year-old children's permanent teeth is 34.5% and the caries rate of 5-year-old children's milk teeth is 70.9%, which are 7.8 and 5.8 percentage points higher than the caries rate of the third national oral abortion respectively, and the caries rate is on the rise and the pattern is still serious. It is important to strengthen the oral health education, improve the caries prevention awareness of the public, and improve the caries prevention ability of dental hard tissues through certain measures to reduce the incidence of caries. In the past 30 years, the topical application of fluoride containing drugs and fluoride toothpaste has greatly reduced the prevalence of dental caries. However, the widespread application of fluoride has also increased the incidence of dental fluorosis and fluorosis bone disease. Laser caries prevention has good safety and convenient operation compared with other methods, and this paper will review the research on laser in caries prevention in recent years.*

Keywords: *Caries; laser caries prevention; Er: YAG laser; CO_2 laser*

1. Laser caries prevenyion mechanism

Since Stern et al. first applied ruby laser (Rubylaser) to enamel caries prevention (Rubylaser) in 1965 [1] and found that ruby laser could enhance the acid resistance of enamel, scholars at home and abroad have conducted a lot of research on laser caries prevention (Rubylaser) [2]. Although there are many types of lasers, the core anti-caries mechanism is basically similar. Domestic and foreign scholars have concluded that laser can improve the acid resistance of dental hard tissues and promote remineralization of demineralized enamel roughly as follows [3] [4]: (1) the thermal effect generated by laser irradiation can close the enamel micropores and inhibit the entry of foreign acidic substances or ions into the enamel, thus enhancing the caries resistance of the enamel [5] [6]; (2) the reduction of enamel solubility may be due to the laser irradiation After hard tissue irradiation, carbonate and water on the tooth surface decreased, resulting in higher solubility of hydroxyapatite, reduced proteolysis, and increased phosphate content, thus reducing the solubility of dental hard tissues [7]; (3) after laser irradiation, the melting effect on the surface of dental hard tissues, which makes the newly generated crystalline material more difficult to dissolve, thus enhancing the resistance of enamel to acidity; (4) the appropriate thermal effect of laser irradiation, which exposes more enamel columns on the enamel surface and calcium ions, phosphate ions and fluoride ions precipitated from saliva can deposit more on the enamel surface, forming crystals that act as a catalyst for the repair of the damaged apatite structure; (5) water and mineralized material in the tooth structure can highly absorb laser radiation energy, and the absorbed energy has been shown to cause thermal decomposition and carbonation crystallization of hydroxyapatite, resulting in the conversion to hydroxyapatite crystals that higher acid resistance [8].

2. Advances in laser caries prevention research

At present, the drug that can enhance the anti-caries ability of dental hard tissues is mainly fluoride, which is also a more widely used anti-caries method in clinical practice today. If laser can replace or enhance the anti-caries effect of fluoride, it will greatly improve the use of laser [9]. There are many kinds of lasers and the anti-caries ability varies among different lasers.

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2.1 Er: YAG Laser

After Er:YAGLaser was licensed for use by the U.S. Food and Drug Administration (FDA) in 1998, it was quickly and widely recognized and used in a large number of clinical treatments, and scholars at home and abroad have conducted a lot of research on the anti-caries ability of this Laser. Xiaoya Xu and Dongxue Xu [10] explored the suitable energy density of early demineralized enamel to prevent caries by studying and comparing different parameters of early demineralized enamel and microzone components affected by Er:YAG laser irradiation. It was found that each experimental group produced changes in enamel morphology, compared to the control group. The results of energy spectrum analysis showed that the mass fraction of element C in the enamel decreased after laser irradiation in each experimental group, where the mass fraction ratio of both Ca and P elements (CA/P ratio) increased. It was concluded that early demineralized enamel surfaces irradiated by Er:YAG laser at 50 mJ did not cause substantial enamel defects, and the chemical structure of enamel tissue changed, resulting in increased acid resistance of early demineralized enamel surfaces.Sun [11] used a micro dental diode laser at a wavelength of 980 nm in combination with a chelating agent on the enamel surface in the designated area, and it was possible to see 15 μm crystals attached to the enamel surface under electron microscopy in less than 20 min. Reza used 60 isolated premolar teeth, bonded in vitro to brackets and immersed in acid-etching solution to simulate enamel demineralization around brackets common in orthodontic treatment, and used Er, Cr:YSGGLaser The results showed that the calcium content of the Laser group was lower than that of the blank control group, and the calcium ion content of the Laser combined with fluoride group was the lowest, and it was concluded that Er, Cr: YSG-Laser can prevent demineralization around orthodontic brackets, strengthen the enamel acid resistance, and enhance the effect of fluoride when combined with fluoride and can reduce the amount of fluoride used in clinical operations, thus reducing the risk of excessive fluoride concentrations [12]. puneet obtained similar results after testing 120 isolated teeth treated with Er, Cr:YSGG Laser and fluoride, respectively, using a microhardness tester: both Er, Cr:YSGG Laser alone and in combination with fluoride significantly increased the hardness of enamel, suggesting that the Er, Cr:YSGG laser enhances the acid resistance of enamel and promotes remineralization of demineralized enamel [13].Grzech and JMatys [14], among others, found in their study of the effect of the Er:YAG laser on dental aerosol formation that, compared to the initial aerosol volume measured in dental clinics, the Er:YAG laser was significantly more effective in orthodontic bracket Fewer aerosols were produced during debonding and root canal irrigation. By comparing the combination of ion-release restorative materials and caries dentin disinfected with photodynamic therapy, Er, Cr:YSGG laser and chemical disinfectant, GülKeskin et al. found that caries-treated teeth treated with Er, Cr:YSGG laser and photodynamic therapy had a lower aerosol volume. The microtensile bonding strength of caries-affected carious dentin (CAD) treated with photodynamic therapy was higher than that of chemical disinfectant [15]. Photodynamic therapy with Er, Cr:YSGG laser irradiation may result in enhanced bond strength to CAD.Merve [16] found changes in both thermal morphology and spectra of irradiated caries by irradiating carious deciduous teeth with Er, Cr:YSGG laser at low energy density.The anti-caries mechanism of Er:YAG laser is to cause changes in enamel structure and decrease solubility; enhance its anti-demineralization The anti-carious mechanism of Er:YAG laser is to change the structure of enamel surface, reduce the solubility, enhance its anti-demineralization ability, melt the enamel surface and close the micro-pores.

2.2 CO_2 Laser

Zhao, Xue [17] et al. investigated the use of a novel 9.3-μm CO_2 laser and silver diamine fluoride to prevent enamel demineralization and inhibit cariogenic bacteria, and found that irradiation with the 9.3-μm CO_2 laser alone prevented enamel demineralization and reduced the adhesion of cariogenic bacteria. Moreover, the addition of silver diamine fluoride (SDF) significantly improved the preventive effect and antimicrobial capacity. Saberi, Rouzsaz [18] et al. compared the effect on enamel microhardness through an in vitro study using 445 nm and 915 nm diode lasers to irradiate enamel block models, respectively. The results of the study showed that the 445 nm diode laser did not reduce the enamel microhardness, making it suitable for bleaching treatment. However, more studies are needed to consider the effects of other factors, such as color change and pulp temperature.Badreddine, Stephen et al. used a 9.3 m CO_2 single laser pulse to scan enamel block models at high speed and found an inhibitory effect on enamel demineralization.The results of the study showed that the 9.3 m CO_2 laser at energy densities of 0.6, 0.8, and 1.0 J/ cm^2 , and no damage to enamel after laser irradiation was found after measuring depth and surface mineral loss [19].Tavares [20] investigated the in situ effect of CO_2 laser (9.3 μm) irradiation in combination with AmF/NaF/$SnCl_2$ solution for the prevention and control of erosive tooth wear of human enamel. It was found that CO_2 9.3 μm laser application prevented and controlled the progression of caries

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in human enamel, with higher efficiency when combined with AmF/NaF/$SnCl_2$ solution application.Peter [21] found in a randomized, single-blind controlled 1-year clinical trial of CO_2 9.3-μm short-pulse laser inhibition of fissure caries that, compared with fluoride varnish alone, microsecond short-pulse 9.3-μm CO_2 laser irradiation significantly inhibited caries progression in pits and fissures.Elahe, Tehrani [22] et al. in a paper on the effect of CO_2 laser (10.6 μm) and Remin Pro paste on the microhardness of enamel white spot lesions found that CO_2 laser (10.6 μm) could be used for rehardening of softened enamel in the deeper layers of the enamel. Rechmann, Le [23] et al. in a paper on the anti-caries effect of a newly developed laser irradiation pattern of in vitro CO_2 9.3 μm short pulse laser found that enhanced anti-caries were achieved for all applied fluences. As seen by scanning electron microscopy, the use of the spreading beam resulted in increased resistance without enamel melting. Short-pulse 9.3-μm laser irradiation using two laser beam configurations resulted in a significant reduction in enamel mineral loss. Modifying the beam to a more uniform profile resisted enamel caries even without significant enamel melting.Chang et al. treated the tooth surfaces using CO_2 laser, Er:Yaglaser, and UV laser, respectively, and compared the differences in acid resistance and permeability of the enamel surfaces treated with these lasers and found that CO_2 laser had more advantageous enamel resistance compared to the other two lasers, with a difference of statistically significant; and the CO_2 laser has a better anti-caries effect in combination with fluoride because of its higher enamel permeability compared to other lasers [24-25]. It was also found that the anticariogenic ability of ammonium fluoride was significantly improved by using amine fluoride solution immediately after 15s continuous irradiation of the dentinal surface with CO_2 laser, and it was speculated that more enamel columns might be exposed after laser irradiation of the dentinal surface, thus allowing better penetration of ammonium fluoride solution into the dentinal tissues. rechmann also confirmed through a 12-month clinical control experiment that: treatment of the dentinal surface with CO_2 laser can effectively inhibit the occlusal The CO_2 laser is also effective in suppressing the occlusal surface and sulcus caries. The different output power and frequency of laser will also affect the treatment results, and the tissues to be affected will have different responses to laser depending on their hardness, density, elasticity, specific heat capacity and water content, so the clinical workers should be familiar with different types of laser and use the relative appropriate laser power for different treatment targets to achieve the best treatment effect. Foreign scholars conducted in vitro experiments using CO_2 laser and selected a power setting lower than the melting threshold of enamel to irradiate isolated bovine teeth, and concluded that a wavelength lower than the melting threshold of enamel could improve the resistance of enamel to acidity and minimize the damage of the laser to the tooth surface according to the laser intensity distribution by polarized microscopic tomography. may not be so accurate, and excessive power can cause unnecessary damage to the tooth surface, so care should be taken when selecting parameters, and care should be taken when selecting to observe whether the intensity is too high [26].

2.3 Other Lasers

Marcia, Castro et al. found by using optical coherence tomography and FTIR spectroscopy that early enamel caries can be prevented by the combination of Nd:YagLaser and fluoride [26].Cristina, Corona [27] et al. evaluated the effectiveness of caries prevention by studying an 18-month randomized clinical trial using CO laser irradiation of partially erupted Mohammed, Frentzen [28] observed the caries resistance of enamel after topical fluoride treatment and 445 nm laser irradiation, and scanning electron microscopy showed that the laser The scanning electron microscopy showed that the enamel surface was intact after laser irradiation and there was no thermal damage. Thus, it was concluded that 445 nm laser irradiation might help to prevent dental caries, but its effectiveness was lower than that previously achieved by using argon ion laser. After irradiating enamel samples with 2.5W, 3.5W, 5.5WEr, Cr:YSGG laser and dentin samples with 2W, 3W and 4W laser, the specimens were demineralized in lactic acid solution for 24 h. The solubility of calcium ions precipitated was detected by energy spectrometer, and it was found that the solubility of calcium ions in the solution of all groups was significantly smaller than that of the blank control group, except for the enamel group with 2.5W irradiation power. The differences were statistically significant, and the author concluded that irradiation of the tooth surface with Er, Cr:YSGG laser at co-power resulted in increased acid resistance of the hard tissues, but low power may not have an effect on enamel caries resistance, but for dentin, there is no difference in the laser size antacid nature [28-29].

3. Shortage and prospect of laser caries prevention

Lombardo [30] wrote in the systematic evaluation of laser caries prevention that laser (subablative parameters) irradiation can reduce the incidence of caries and the laser treatment is safe and well tolerated by patients. However, because the laser energy will cut the soft and hard tissues of the dentition, the laser

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irradiation will more or less damage the dentition, which is the side effect of laser, and the damage other than the treatment purpose should be avoided as much as possible in the clinic. Some scholars used carbon dioxide laser to irradiate the tooth surface in order to investigate the anti-acid ability of laser on dental tissues and the degree of damage to the enamel surface, and after the experiment the authors concluded that the carbon dioxide laser could indeed improve the caries resistance of the enamel, but the laser was found to cause the enamel surface to crack under electron microscopy, so the scholars did not recommend the use of laser alone as a caries prevention measure [31]. It has also been found that the power of Er,Cr:YSGG laser is greater than 4.5 W when the melt appears on the dentin surface, indicating the destruction of dentin morphology, and this scholar suggested that the laser power should be less than 4.5 W when the Er,Cr:YSGG laser treats dentin.Although after decades of development, the investigation of the mechanism and clinical application of laser in caries prevention The use of laser has been questioned to some extent due to the possibility of thermal and cutting injuries while enhancing the caries resistance of enamel. In order to minimize the trauma of laser to dental hard tissues while preventing caries, the proper power and wavelength selection of various types of lasers in treating dental surfaces need further research, and in addition, most of the current research is basic research or in vitro experiments, although the experimental conditions are becoming more and more perfect, it still cannot be the same as human oral environment, so the clinical experimental research of laser in anti-caries is also worthy of our expectation [32]. Therefore, the clinical experimental research of laser in anti-caries is very worthy of our expectation [33].

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