

Research Article

Nd:YAG Lasers Treating of Carious Lesion and Root Canal In Vitro

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Dental caries is a transmissible bacterial disease process, with cavities at the end, and caused by acids from bacterial metabolism. The essence of dental treatment is to clean and disinfect bacterial contamination from the tooth. In this work, we tried to demonstrate the cleaning and disinfecting effects of Nd:YAG laser irradiation on dental carious lesion and root canal in vitro. Acousto-optic Q-switched quasicontinuous and Cr³⁺:YAG crystal Q-switched pulse Nd:YAG lasers were employed to treat caries lesion and the root canal, respectively. Results showed that acousto-optic Q-switched quasicontinuous Nd:YAG laser irradiation and Cr³⁺:YAG crystal Q-switched pulse Nd:YAG laser irradiation could rapidly clean decayed material and bacterial contamination from dental carious lesion and the narrow tail end of root canal with minimally invasive in vitro, respectively. It was concluded that acousto-optic Q-switched quasicontinuous laser irradiation may be a rapid and effective alternative caries treatment, and Cr³⁺:YAG crystal Q-switched pulse Nd:YAG laser irradiation may be an effective method for canal cleaning and disinfecting during root canal therapy.

1. Introduction

Dental caries is the most prevalent disease among preschool children (early child caries) [1], although it has been reported to be a declining incidence worldwide in the last decades [2]. Almost 76% of children aged 5 in China [3] and about 30% aged 2 to 5 in America [4] were affected by dental caries, and the percent is in rise. Dental caries is a transmissible bacterial disease process and caused by acids from bacterial metabolism. Cariogenic bacterial, feeding on the carbohydrates in food, can be easily transferred to babies from mothers or caregivers before the teeth erupts [5–7] and colonize teeth as dental plaque when teeth erupts. Acids produced by bacteria in dental plaque rapidly diffuse in all directions through the pores of enamel or dentine and into the underlying tissue to dissolve acid soluble mineral, and finally cavity was formed in the tooth after many months or years. Usually, dental caries can be inhibited and even reversed in its early stages of process by removing cariogenic bacteria from teeth. Unfortunately, it is often not

self-limiting and progresses without proper care until the tooth is destroyed with cavities. Then, it is more difficult to remove bacteria from rough, cavitated surfaces, which quicken the dental caries progress. In addition, bacterial contamination in root canal is also considered the principle etiologic factor for the development of pulpal and periapical lesions [7, 8].

Dental treatment can prevent and inhibit the dental caries by cleaning and disinfecting the bacterial contamination in tooth or enhancing the caries resistance of tooth at the very beginning of dental caries process [9]. For those small lesions, enhancing the caries resistance to prevent caries normally by topical fluoride is the focal point of treatment [10]. Mentionable, laser has been widely used in dentistry for decades, which is well known to increase enamel resistance to acids dissolving, and Nd:YAG laser irradiation combined with topical fluoride treatment can induce an even greater increase in caries resistance [11]. However, there is no doubt that removal of plaque is the most effective way to help prevent periodontal disease and caries processing due to the

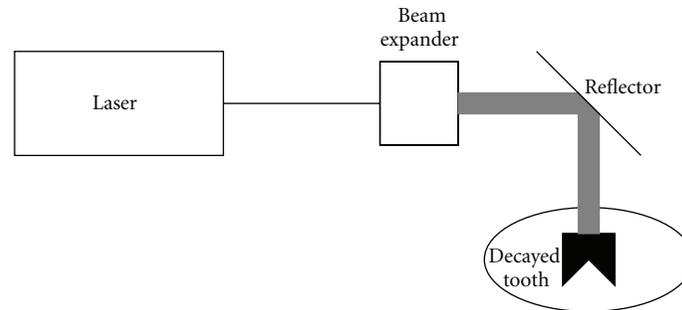


FIGURE 1: The sketch of quasicontinuous laser system.

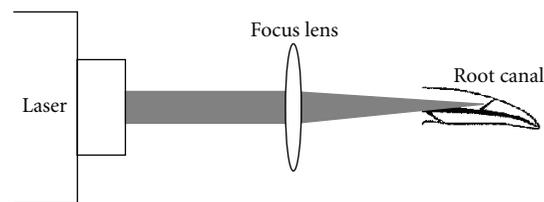


FIGURE 2: The sketch of Q-switched laser system.

well-known harm of fluoride [12, 13]. Many types of lasers have been used for dental caries prevention, and Nd:YAG laser is the most studied one [11, 14–16]. For larger lesions, cleaning and disinfecting the bacterial contamination in tooth to inhibit the caries is the essence of treatment. Aiming to preserve tooth structures and prevent further destruction of the tooth, large portions of decayed material is removed from the tooth by a dental drill and cleaned carefully by a spoon during traditional caries treatment [17], which is with great invasive and painful even terrifying for patient especially preschool children. Moreover, it is impossible to completely remove pulp tissue, debris, and bacteria which cause secondary caries and pain.

Thus, it is necessary to develop an alternative caries treatment, which can remove the bacterial containment painless with minimally invasive. Present work is to demonstrate the ability of acousto-optic Q-switched quasicontinuous Nd:YAG lasers and Cr³⁺:YAG crystal Q-switched pulse Nd:YAG lasers in cleaning of decayed material (pulp and others) speedily and disinfecting of bacteria completely of human tooth in vitro. Laser irradiation treatment may be an ideal alternative dental caries treatment especially preschool children aged 2 to 5 years.

2. Materials and Methods

2.1. Laser System. Quasicontinuous laser beam with wavelength of 1064 nm provided by an acousto-optic Q-switched Nd:YAG laser system (Figure 1) was vertically delivered to the carious lesion on tooth surface. Comparing to continuous-wave laser, acousto-optic Q-switched quasicontinuous laser has a relative higher peak power, which is better for bacterial disinfecting, and a shorter half-height pulse width, which will be beneficial to avoid overheating. This laser system was normally set with 30 W peak average output power

and 600 Hz frequency. The peak power density of the laser irradiation was about 152.86 W/cm² with a diameter of about 0.5 cm and beam area of approximate 0.196 cm².

The Q-switched laser beam, provided by a Cr³⁺:YAG crystal Q-switched laser system (Figure 2), was vertically focused on the canal directly. The focused Q-switched pulse laser irradiation has a smaller diameter, a higher peak power, and energy density, which is better for cleaning and disinfecting of narrow canal gap. This laser system was normally set with 100 mJ single-pulse energy, 1/3/5 Hz frequency, and about 100 ns half-height pulse width.

2.2. Materials. Human teeth with carious lesion on crown surface (one was shown at Figure 3(a)) were collected from the affiliated hospital to reveal the cleaning and disinfecting effect of quasicontinuous acousto-optic Q-switched Nd:YAG laser irradiation for decayed material from caries lesion. The tail end of root canal (one is shown at Figure 3(b)), which is the most narrow part and the difficult point of cleaning and disinfecting in root canal system, was prepared in the affiliated hospital to reveal the cleaning and disinfecting effect of Cr³⁺:YAG crystal Q-switched laser irradiation for tissue and bacterial contamination in tooth canal.

2.3. Experiment. To demonstrate the cleaning effect of laser treatment, carious lesion tooth samples were exposed to acousto-optic Q-switched quasicontinuous laser irradiation, and tooth canal samples were exposed to Cr³⁺:YAG crystal Q-switched pulse Nd:YAG laser irradiation, respectively. The cleaning efficiency is evaluated from the difference between pictures of lesion surface before and after laser treated. The disinfecting effect and efficiency of laser treatment is evaluated from the colony counts loss of samples. The experiment samples were scrubbed by swabs with sterile physiological saline before and after laser treatment, respectively. Then, the

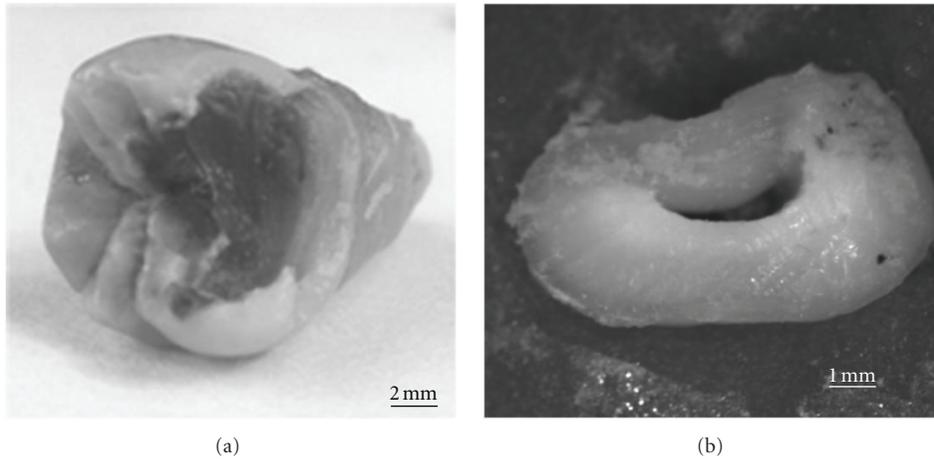


FIGURE 3: Stereomicroscope images of (a) tooth with carious lesion and (b) tail end of root canal.

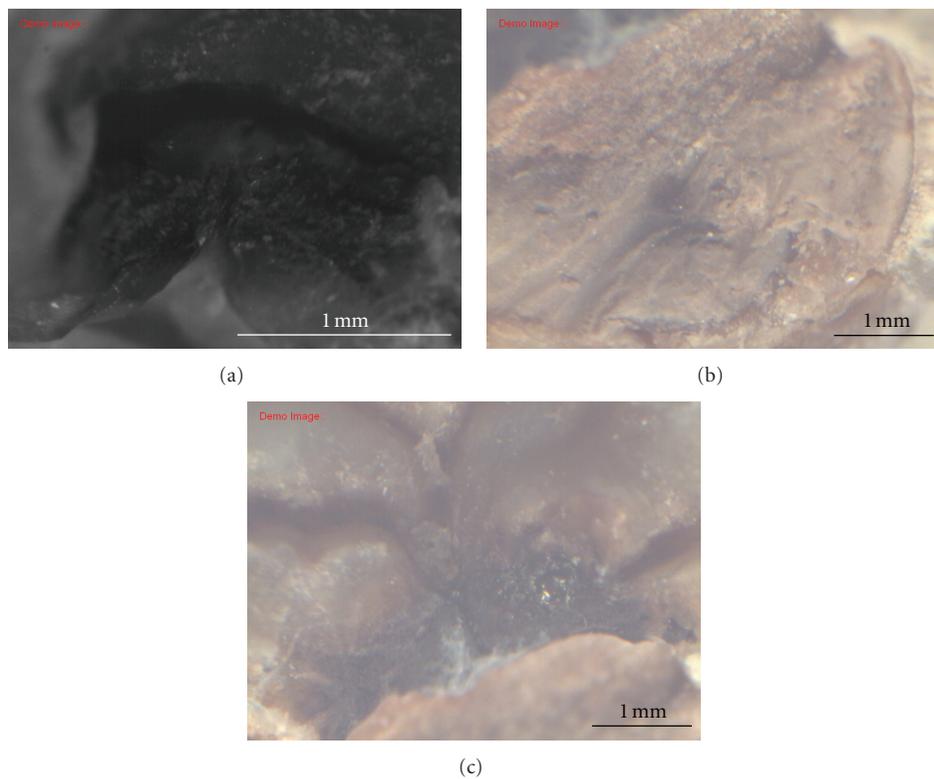


FIGURE 4: Stereomicroscope images of decayed tooth surface (a) before and (b, c) after acousto-optic Q-switched Nd:YAG quasicontinuous laser treatment.

infected physiological saline of each sample was inoculate to 3 parallel agar dishes and cultivated at 37°C for 24 hours. In order to prevent the bacterial contamination from hands, the medical rubber gloves were necessary during the whole experiment.

3. Results and Discussion

3.1. Cleaning and Disinfecting Effects. Figure 4 showed the stereomicroscope images of carious lesion on the surface of

tooth before (Figure 4(a)) and after laser treatment (Figures 4(b) and 4(c)). It was clear that decayed material in caries lesion was cleared away by laser irradiation without any visible damages to surrounding normal tooth tissues after no more than 2-second quasicontinuous laser irradiation. However, there was little carbonization in the treated area, carbonization indicated that laser treatment with less power density or shorter irradiation time would be better for caries material cleaning. The obvious change of caries in tooth before and after laser treatment indicated that the

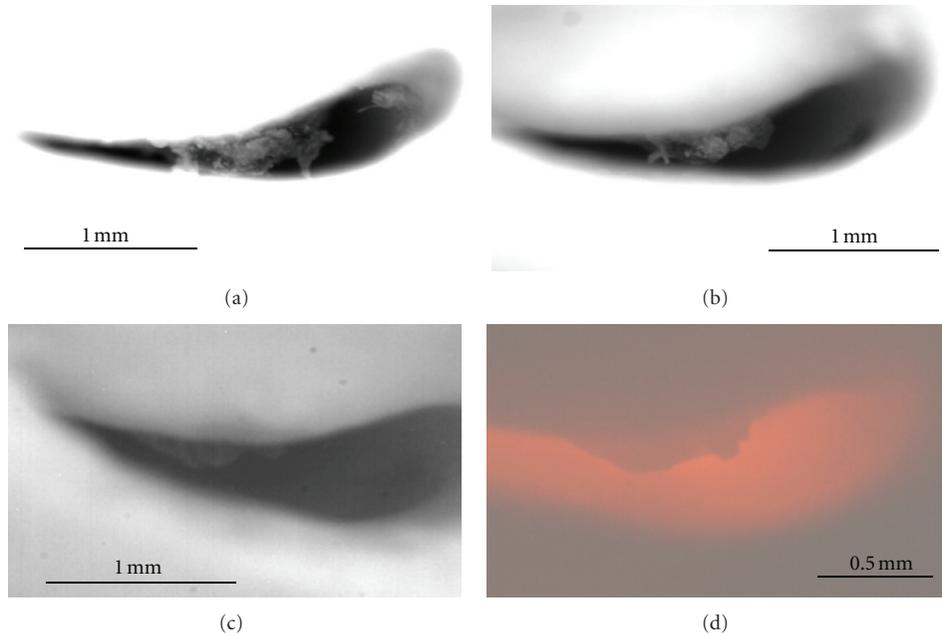


FIGURE 5: Stereomicroscope images of organisms in untreated (a), 20 pulses (b), and 40 pulses (c, d) laser irradiation-treated root canal gap.

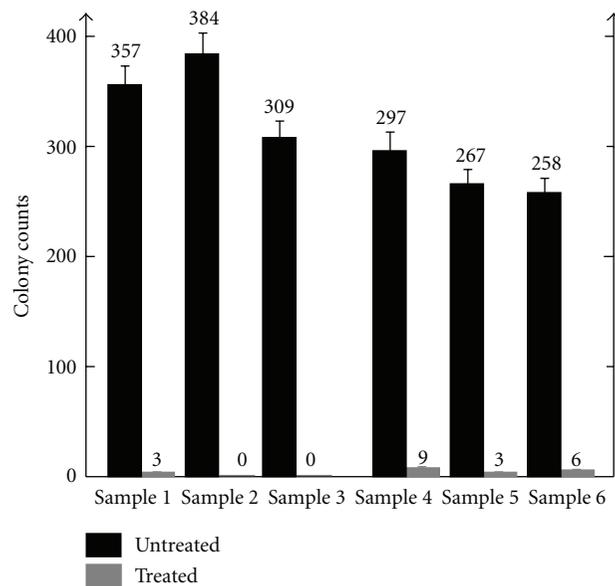


FIGURE 6: The colony counts of carious lesions (samples 1–3) and root canals (samples 4–6).

acousto-optic Q-switched Nd:YAG quasicontinuous laser irradiation was a speedy and efficient cleaning method and treatment for carious lesion.

Figure 5 shows the images of root canal sample before (Figure 5(a)) and after 20 pulses (Figure 5(b)), 40 pulses laser-treated by Cr³⁺:YAG crystal Q-switched laser. (Figures 5(c) and 5(d)) comparing Figure 5(a) to Figure 5(b), it was clear that much portion of the tissue in canal was removed and almost cleared away after 40-pulse laser treatment. Particularly, there was almost no byproduct in tooth canal after laser treatment according to Figures 5(c) and 5(d).

These results indicated that Cr³⁺:YAG Q-Switched laser irradiation might clean up the root canal after more than 40 pulses, and Cr³⁺:YAG Q-switched laser treatment may be an ideal method for tooth canal cleaning.

The colony counts of experiment tooth samples before and after laser treatment were shown in Figure 6 ($P < 0.05$). Samples 1–3 refer to the tooth samples with carious lesion, and samples 4–6 refer to root canal samples. According to decrement colony counts of untreated and treated samples, the disinfecting effect was obvious and the disinfecting efficiency was high, approximately 100% and 98.5% for

caries and root canal disinfecting, respectively. The results indicated that Q-switched laser irradiation treatment was a very effective disinfecting method for caries treatment, even root canal.

4. Discussions

It is an advantage to choose laser beam with less power density, or less repeated frequency for tooth treatment, because the carbonization showed in Figure 4(b) was due to overheat of acousto-optic Q-switched quasicontinuous laser irradiation. In addition, those experimental samples used in this work were only with carious lesion on the crown surface, but majority of patients in clinics have caries lesion deeply inside the tooth. Thus our further work will aim at laser holing for cleaning material in deep carious lesion.

Acousto-optic Q-switched quasicontinuous laser irradiation with big beam size, high average energy density, and repeated frequency was effective for caries lesion treatment, and Cr³⁺:YAG crystal Q-switched laser irradiation with smaller beam size, shorter pulse width, and higher peak energy density is effective for root canal treatment without any obvious byproducts as carbonization appeared in caries lesion laser treatment. Both acousto-optic Q-switched quasicontinuous laser irradiation and Cr³⁺:YAG crystal Q-switched laser irradiation had advantages over each other in dental caries treatment and had common advantages such as no pain, no vibrating, overtraditional treatment with drill and spoon. Laser irradiation treatment was very friendly for patient especially for the preschool children patients. It will be a good alternative for early child caries inhibition and readiness to be accepted by child patients.

5. Conclusions

In conclusion, acousto-optic Q-switched quasicontinuous laser irradiation may be a rapid and effective alternative caries treatment, and Cr³⁺:YAG crystal Q-switched pulse Nd:YAG laser irradiation may be an effective method for canal cleaning and disinfecting during root canal therapy.

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