Evaluation of temperature rise and efficacy of cavity disinfection with diode laser: An in vivo study

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Abstract

Background: Management of caries using minimally invasive dentistry is prevalent in dentistry today. A newer technology is to disinfect/sterilize caries in depth of the dental tissue with diode laser. However, to have a bactericidal effect, increased energy density of light amplification by stimulated emission of radiation (LASER) may be required which in turn may lead to higher thermal load causing harmful effects on vital pulpal tissue.

Aims: The aim was to evaluate temperature rise and efficacy of cavity disinfection with diode laser.

Materials and Methods: Twenty permanent molar teeth with dentinal caries were randomly assigned into two groups on the basis of LASER irradiation: Group 1 – at 1 W, Group 2 – at 2 W. The elevation of subsurface temperature during irradiation was measured using thermocouples positioned in the center of a prepared cavity. Dentinal samples were collected before and after disinfection of the cavity. These samples were subjected to microbiological evaluation for Streptococcus mutans on Mutans-Sanguis agar and Lactobacilli on Rogosa agar.

Statistical Analysis: Log transformed “t”-test and paired “t”-test were used for the statistical analysis.

Results: Although the reduction in microbial count revealed insignificant difference at two different wattages, the rise in temperature with 1 W was less than that with 2 W.

Conclusion: Efficacy of 1 W and 2 W is similar, but 1 W causes less thermal changes, thus, 1 W is recommended over 2 W.

Keywords: Cavity disinfection; diode laser; temperature rise

INTRODUCTION

Dentinal caries is the most common disease with which a dentist deals with in a day-to-day practice. In deep carious lesions, complete elimination of carious tissue by only mechanical procedure leads to weakening of the tooth structure and may also affect the vitality of the pulp.[1]

In recent years, minimally invasive dentistry has become a prevailing concept in operative dentistry, according to which the amount of enamel and dentin should be maximally conserved by inactivation/disinfection of carious dental tissue and the stimulation of remineralization.[2,3] Therefore, disinfection of the cavity preparation after caries excavation can aid in the elimination of bacterial remnants that can be responsible for recurrent caries, postoperative sensitivity, and failure of the restoration.[1] Various adjuncts have been used over the past years for cavity disinfection. Few of these are antimicrobial photodynamic therapy, propolis, calcium hydroxide, Acidulated phosphate fluoride (APF) gel, 2% chlorhexidine, etc., which can be valuable clinically before definitive restoration.

Light amplification by stimulated emission of radiation (LASER) is gaining popularity in recent years.

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Laser radiation in the near-infrared range causes permanent destruction of the bacterial cell membrane and thus has a bactericidal effect. The application of diode lasers to disinfect/sterilize cavies in the depth of the dental tissue without precedent cavity preparation is based on the property of infrared light to deeply penetrate into dental tissue.

Increased energy density of the laser automatically leads to higher thermal load, which might be harmful to the vital tissue, in particular, to the dental pulp. Very few studies have been conducted which have used diode laser for cavity disinfection, but the power to be used which causes a maximum reduction in bacterial load, and minimum thermal changes remains a question.

Thus, the goal of the study was to evaluate temperature rise and efficacy of cavity disinfection using 940 nm diode laser at two different powers, that is, 1 W and 2 W in continuous mode for 30 s.

**MATERIALS AND METHODS**

This study was a randomized, single-blinded study conducted in the department of pedodontics and preventive dentistry. Prior ethical approval was obtained by Internal Ethical Committee. A 9–16-year-old healthy children who had dentinal caries in at least two permanent molars and presented themselves to the department clinic for treatment were screened, and those fulfilling the following inclusion criteria were considered for participation in the study. A letter providing all the information of the study was given to the parent/guardian, and they were considered after receiving the written consent.

Permanent molars with cavitated occlusal dentinal caries with no medical history, no clinical and radiographic signs of pulp involvement were included in the study. Carious lesions involving pulp and patients having pain in the tooth were excluded from the study. Twenty permanent molars in ten patients were randomly assigned into two groups, and each group received one of the following laser irradiation with 940 nm diode laser for cavity disinfection.

- Group 1: Irradiation at 1 W, continuous mode, and fiber diameter 400 μm
- Group 2: Irradiation at 2 W, continuous mode, and fiber diameter 400 μm.

After isolating the tooth with a rubber dam, cavity preparation was done, and infected dentin was removed, leaving affected dentin. The prepared cavity was allowed to cool down. After cooling, temperature was recorded at the base of the cavity using thermocoupling device, and dentinal samples were collected from the base of the cavity using a sterile spoon excavator and transferred into Eppendorf tubes containing 0.5 ml of phosphate buffer solution for microbiological evaluation for S. mutans and Lactobacilli. After the dentinal sample was collected, the cavity of Group 1 was irradiated with 1 W and Group 2 with 2 W diode laser.

Immediately after cavity disinfection with laser, temperature of the cavity was again recorded using thermocoupling device, and the dentinal sample was again collected from the base of the cavity using a sterile spoon excavator, and samples were transferred into Eppendorf tubes containing 0.5 ml of phosphate buffer solution for microbiological evaluation for S. mutans and Lactobacilli.

To evaluate the rise in temperature, difference between the temperature of the cavity before and after cavity disinfection with laser was recorded. Further, for microbiological evaluation, 2 μl of the samples collected before and after disinfection were inoculated on the Mutans-Sanguis agar (M977; HiMedia, India) a selective medium for S. mutans and Rogosa agar medium (M130; HiMedia, India) for Lactobacilli, respectively. The plates were incubated for 72 h in an atmosphere containing 5% carbon dioxide (CO₂) and 95% N₂ at 37°C. Colony-forming units on the plates were counted using colony counter by a blinded assessor [Figure 1a-h].

**RESULTS**

Statistical analysis was done by the Statistical Package for the Social Sciences (SPSS) software package (SPSS 16 Inc., Chicago, IL, USA). The recorded data did not show normal distribution for the microbiological count, therefore, nonparametric test (log transformed “t” test) was used. The recorded data for temperature rise show normal distribution, therefore, parametric test (paired “t” test) was used. The levels of significance and confidence interval were 5% and 95%, respectively, that is, P < 0.05.

The mean temperature rise with 1 W was 1°C, whereas with 2 W was 2.6°C [Figure 2a]. In intragroup comparison, there was a significant decrease in the microbiological count of S. mutans and Lactobacilli before and after cavity disinfection with both 1 W and 2 W. In intergroup comparison, although the decrease in the microbial count with 2 W was slightly more than that with 1 W, but the results for S. mutans (P = 0.6) and Lactobacilli (P = 0.8) were statistically insignificant [Figure 2b and c].

**DISCUSSION**

Dental caries is defined as a multifactorial, transmissible, infectious oral disease caused primarily by the complex interaction of cariogenic oral flora (biofilm) with fermentable dietary carbohydrates on the tooth surface.
over time. Affected dentin is the inner carious dentin that shows loss of mineral but the collagen cross-linking remains intact, which serves as a template for remineralization and is capable of self-repair. Thus, affected dentin should not be removed.\textsuperscript{[9]}

However, the affected dentin has bacterial remnants which may lead to recurrent caries, postoperative sensitivity, and ultimately leading to failure of restorative treatment.\textsuperscript{[1]} During cavity preparation, the complete eradication of bacteria can cause weakening of tooth structure and also removal of extensive caries can affect the vitality of the pulp. Therefore, disinfection of the prepared cavity aids in the elimination of bacterial remnants from the affected dentin leading to the successful restorative treatment. It has been demonstrated that bacteria are capable of invading the dentinal tubules up to a depth of 1 mm, and unfortunately, the chemical disinfectants penetrate up to 130 µm inside the dentine. This difference in depth of penetration between the invading bacteria and the disinfectant solution is often responsible for recurrent caries.\textsuperscript{[2]} Various chemical cavity disinfectants used are

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\caption{(a) \textit{Streptococcus mutans} count before cavity disinfection in Group 1. (b) \textit{Streptococcus mutans} count after cavity disinfection in Group 1. (c) \textit{Lactobacilli} count before cavity disinfection in Group 1. (d) \textit{Lactobacilli} count after cavity disinfection in Group 1. (e) \textit{Streptococcus mutans} count before cavity disinfection in Group 2. (f) \textit{Streptococcus mutans} count after cavity disinfection in Group 2. (g) \textit{Lactobacilli} count before cavity disinfection in Group 2. (h) \textit{Lactobacilli} count after cavity disinfection in Group 2.}
\end{figure}

\begin{figure}[h]
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\caption{(a) Change in temperature of the floor of the cavity before and after irradiation with laser. (b) Decrease in \textit{Streptococcus mutans} count of both the groups. (c) Decrease in \textit{Lactobacilli} count of both the groups.}
\end{figure}
sodium hypochlorite, chlorhexidine, benzalkonium chloride, iodine-based disinfectants, and ozone. Natural-based disinfectants are also being used, such as propolis, Salvadora persica, and Morinda citrifolia (noni).

LASER was introduced in 1960 by Maiman, and since its introduction, it is gaining popularity in dentistry. Various types of LASER used in dental practice are neodymium-doped yttrium aluminum garnet (Nd:YAG); erbium (Er):YAG; Nd:yttrium–aluminum–perovskite; diode; argon; Er; chromium-doped: yttrium, scandium, gallium, and garnet; CO2; and potassium titanyl phosphate. Of the above, the use of diode laser is increasing in dentistry due to its wide applicability, compact size, low weight, easy application, and reasonable price as compared to other lasers, thus allowing the dental professionals to perform current procedures faster and more efficiently.

Diode laser is a semiconductor laser with a solid material active media, which is available in various combinations such as gallium aluminum arsenide and indium gallium arsenide phosphate. They range from 810 to 1064 nm, which is under infrared spectrum of light.

There are many theories which explain the antibacterial effect of the laser. Thermal and photodisruptive effects of the laser are principally considered the reasons for eliminating the bacteria. It causes lethal damage by destroying the cell wall integrity and possibly denaturation of the protein. This damage to the cell wall results in cessation of the growth of cells and successively causing their lysis. The cellular protein is also highly sensitive to the thermal changes.

Various studies have been conducted showing the disinfective efficacy of laser in dental procedures. Kaiwar et al. (2013) conducted a study to verify the disinfection of diode laser and concluded that 980 nm diode laser can eliminate bacteria that have immigrated into dentin, thus being able to increase the success rate of endodontic therapy. Mohan et al. compared the cavity disinfection efficacy of APF gel, propolis, diode laser, and 2% chlorhexidine for S. mutans and Lactobacilli and concluded that diode laser is most effective against microorganisms because of the greater depth of penetration of laser radiation of about 1 mm into the dentin, surpassing the effect range of chemical disinfectants. Thus, the diode laser was used in the present study.

The efficacy of diode laser at two different power settings: 1 W continuous watts (CW) and 2 W CW for cavity disinfection were tested for the elimination of S. mutans and Lactobacilli in the present study, as they are the principal colonizers of dental caries and their elimination is necessary for the longevity of the restoration. The results of the present study showed that laser irradiation at 1 W CW and 2 W CW significantly reduced S. mutans and Lactobacilli count, and both powers had comparable efficacy in cavity disinfection. Similar results were seen in the study conducted by Kivanc et al., who evaluated the antimicrobial effects against Enterococcus fecalis with diode laser on the root surface using three different powers (1.2 W, 2 W, and 3 W) and concluded that diode laser irradiation with 1.2 W demonstrated comparable performance with 2 W and 3 W for the elimination of E. fecalis from the root canal. Contrasting results were seen in a study conducted by Al-Habeeb et al. on antibacterial effects of diode laser in the coronal cavity at 1 W and 1.3 W, which showed a significant difference in the antibacterial efficacy between the output powers. As the power of laser increased, the effect against S. mutans also increased.

Although diode laser has antimicrobial activity but its application on the outer surface of the tooth could result in pulp damage, as the laser energy absorbed by the dentin generates heat within the dentin, which might, if it is excessive, result in structural changes and damage to the dental hard tissue as well. Thus, the present study also evaluated possible pulpal damage caused by the use of diode laser at 1 W CW and 2 W CW due to temperature rise during cavity disinfection. The study showed that there was a significant difference in temperature rise, as 1 W CW showed an average rise of 1°C, and 2 W CW showed an average rise of 2.6°C but none of them caused pulpal damage.

Zach and Cohen showed that 15% of teeth undergoing an intrapulpal temperature rise of 5°C were irreversibly damaged, as there was destruction of majority of odontoblasts. Krmek et al. suggested an increase in temperature of 3.5°C is deemed to be the maximum ceiling to not produce irreversible pulpal damage. Kivanc et al. also evaluated temperature rise along with antimicrobial efficacy and concluded that 1.2 W has less temperature rise but 2 W and 3 W can also be used. Sari et al. (2013) studied temperature rise in the pulp during light-activated bleaching and concluded that 810 nm diode laser at 4W causes rise in temperature within the safe range for the health of the vital pulp which is <5.6°C. Kouja et al. evaluated the pulpal and subsurface temperatures during proximal tooth surface irradiation with 808 nm diode laser and concluded that 1 W at continuous mode and 5 W at pulsed mode are safe for the pulpal health.

**CONCLUSION**

As the antibacterial efficacy of diode LASER has been established in various dental procedures, it gave us the opportunity to evaluate its effect on the disinfection of prepared cavities. Thus, the present study showed a significant reduction in S. mutans and Lactobacilli count.
with comparable efficacy at 1 W CW and 2 W CW. Rise in temperature was more in 2 W CW when compared to 1 W CW but did not damage the pulp. Hence, we recommend the use of diode laser at 1 W CW over 2 W CW, as it causes less temperature rise and comparable antibacterial efficacy when used in cavity disinfection.

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Conflicts of interest
There are no conflicts of interest.

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