THE EFFECT OF GALLIUM-ARSENIDE LASER IRRADIATION ON ODONTOGENESIS

Eman Adnan Mustafa[1], Sausan Al Kawas[2]*

1. BDS, MSc, lecturer, Department of Oral & Craniofacial Health Sciences, College of Dentistry, University of Sharjah, United Arab Emirate, P.O. Box: 27272 Sharjah, UAE.
2. DDS, PhD, Associate Professor, Head of Oral & Craniofacial Health Sciences Department, College of Dentistry, University of Sharjah, United Arab Emirates, P.O. Box: 27272 Sharjah, UAE.

Abstract

The applications of lasers in dentistry show that dental structures react differently to various types of laser. This study explores the effect of gallium-arsenate (GaAs) laser radiation on rats' incisor teeth.

A total number of 20 rats, aged 1-21 days, are divided into five groups; one control group (4 rats) and four laser groups (a total of 16 rats). Laser groups were exposed to 60 seconds of laser radiation on alternate days from day 1 till day 19. The groups were sacrificed at different ages (15, 17, 19 and 21 days old). The specimens were prepared for processing and staining with hematoxylin and eosin and examined by light microscope.

The results showed that the developing teeth of laser groups exhibit uneven thickness of dentin and multiple areas of interglobular dentin whereas pulp tissue appeared to be more cellular and vascular. However, no effect of laser can be noticed on the enamel, cementum, periodontal ligament and eruption process. It is concluded that GaAs laser irradiation has a positive effect on dentin formation. Consequently, GaAs laser can be used within pulp-capping procedures.

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Introduction

In the past 50 years, the use of laser in dentistry went through many dramatic changes. It is evidenced that the efficiency of the laser can be determined by the ability of the tissue to absorb and transmit laser to the surrounding tissues [1, 2].

The first applications of laser to the dental tissues were reported by Goldman (1965) then followed by Stern and Sogannaes (1972). In their studies, they used ruby laser on enamel and dentin. In 1977, Adrian found that Nd:YAG laser caused no pulp necrosis, this information allowed other investigators to consider the use of Nd:YAG laser for caries removal [3-5].

Corresponding author:

Dr. Eman Adnan Mustafa,
Department of Oral & Craniofacial Health Sciences, College of Dentistry, University of Sharjah, United Arab Emirate,
P.O. Box: 27272 Sharjah, UAE.

E-mail: emustafa@sharjah.ac.ae

Another group of lasers termed as low level lasers (LLL) or low power lasers were applied in 1980s. Those lasers showed to be less traumatic and have more stimulating effect than other groups of lasers [2]. LLL raise tissue temperature much less than high energy lasers as Nd-YAG and CO2 which can increase tissue temperature to a level high enough to vaporize the tissue [6]. LLL stimulate a set of structural and functional changes in the living tissues. They have an immediate effect on cell vitality as mitochondrial production of ATP increases. Their biostimulation effect depends mainly on the wave length, power energy values, exposure time and optical features of the tissues [7, 8].

The most effective irradiation is that within the red and infra-red wavelength, such as helium-neon laser (He-Ne 632.8 nm), helium-neon-arsenate laser (He-Ne-As 780-870 nm) and gallium arsenate laser (GaAs 904 nm). They can penetrate deep into living tissues because the hemoglobin does not absorb such wavelengths [1, 2, 9, 10].

A series of biological effects promote the use of LLL in the treatment of pain, wound healing, inflammation and edema, as they can stimulate fibroblasts proliferation, collagen production, enzyme activity, leukocytes activity, and angiogenesis [11-15].

Different authors described the effect of LLL on erupted teeth. Their conclusions suggest that laser can alter composition and morphology of enamel [16], and can stimulate dentin formation and pulp cells [17, 18]. In addition, the effect of laser was demonstrated in the induction of new periodontal ligament, cementum, and bone [19]. Silvestri (2004) indicated that diode lasers can selectively result in tooth agenesis [20].

There has been relatively few studies evaluation the effects of laser radiation on the developing teeth. Accordingly, the present study attempts to highlight the effect of LLL on the odontogenesis of the rat incisors teeth.

Materials and Methods

Experimental animal groups: Twenty Sprague-Dawley rats aged from 1-21 days post partum were arranged into two main groups. During the time of the study, all the rats were housed in similar quarters and the environmental conditions were kept constant.

The first group of rats is the control group which is consisted of four animals. They were sacrificed at different ages at 15, 17, 19 and 21 days old. For comparison purposes with the laser groups both left and right sides of the heads were used.

The second group is the laser group which consisted of sixteen rats that were divided into four groups according to different doses of laser irradiation:

Laser group A (4 rats): this group was utilized until 15 days old. It was exposed to multiple doses of laser irradiation for 60 sec/dose, on alternated days from day 1 to day 13 of their age. The group was sacrificed at 15 days old.

Laser group B (4 rats): this group was exposed to multiple doses of laser radiation as with group A except that irradiation was continued until day 15 of their age. The group was sacrificed at 17 days old.

Laser group C (4 rats): this group exposed to laser radiation as with groups A and B except that irradiation was proceeded until day 17. The group was sacrificed at 19 days old.

Laser group D (4 rats): this group is similar to the other groups except that irradiation was extended until day 19. The group was sacrificed at 21 days old.

Laser device \ Optodent: Optodent is a patented dental unit for infra-red and laser therapy invented by Mario Scalvini in 1989. Specifications of Optodent are 220 Voltage supply, 50HZ power frequency, maximum power 40 Watt, dimensions 340x120x210 mm. The Optodent system is made up of two different emitting sections; infra-red emitting hand piece and optic fiber giving off Gallium-arsenate (GaAs) laser. Laser section was used to carry out this study. GaAs laser is an infra-red diode laser with 20 Watt peak power, average power of 5mw, the wave-length is 904 nm, impulse width 200 nsec, impulse frequency 3000 HZ, and the emission is continuous.

Application of laser: all the groups of rats were subjected to the same lab conditions. During laser application, the optic fiber was applied to the right lower jaw below the lower border of the eye in close contact with the skin. Laser was applied according to the correct exposure time.

Preparation of the specimens: The animals were killed with chloroform vapor. The samples were immediately immersed in 10% formalin, then decalcified with 10% formic acid. After that the samples were dehydrated in ethanol, cleared with xylene, and subsequently embedded in paraffin wax. Serial sagittal sections were prepared for Harris hematoxylin and eosin staining procedures. Sections were examined by Olympus & Leitz light microscopes at different powers starting with low power 4x then high powers 10x and 40 x.

Results

Observation of serial sagittal sections reveals the effect of laser in the development and eruption of rats' incisor teeth as explained below:

1. Histological appearance of the rats' incisors in the control group from 15th -21st day old: From 15th to 17th day old, the erupted incisor rat tooth appeared as an arc-shaped which is consisted of a powerful crown with no root. The labial portion is covered with enamel while the lingual and lateral portions are covered with cementum. The bulk of the tooth is formed by dentin core. At the proximal end of the tooth there was an odontogenic epithelium which is contained a mass of undifferentiated mesenchymal cells (Figures. 1 & 2).

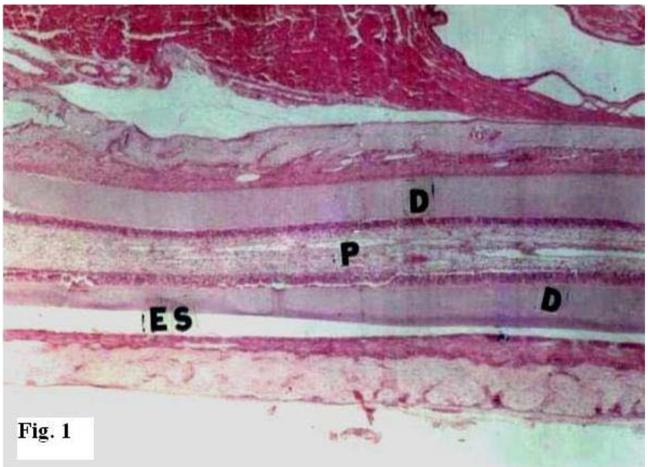

Figure 1. Histological appearance of early developing rat incisor in the control group: Low power observation of developing incisor tooth in control group, show normal histological appearance. ES=enamel space, D=labial and lingual dentin, P= pulp. (H&E , original magnification 4x).

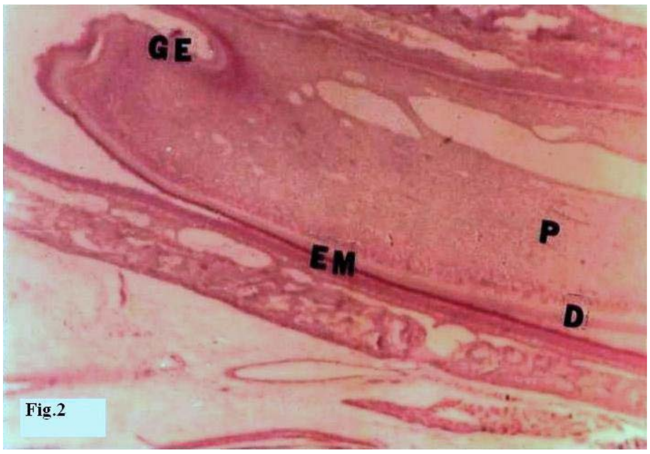

Figure 2. Histological appearance of the growing end of rat incisor in the control group: The histological observation of developing incisor tooth in different region, showing the incisor tooth growing end (GE), EM=enamel matrix, D=labial dentin, P=pulp. (H&E , original magnification 4x).

The developing incisor tooth from 15 -21 days old shows three main stages from proximal to distal ends beginning respectively with growth, then calcification ended with eruption process at the distal end (Figure. 3).

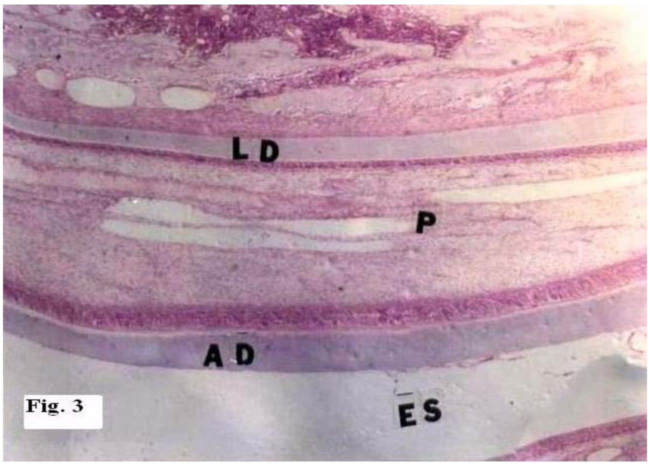

Figure 3. Histological appearance of late developing rat incisor in the control group: The histological observation showing normal histology of enamel space =ES, labial dentin =AD, lingual dentin= LD, and the pulp = P. (H&E , original magnification 4x).

2. Histological appearance of the rats' incisors in the laser groups from 15th -21st day old: In all laser groups, the morphology of the incisor teeth appears similar to control groups. The developing enamel at the labial side shows no disturbances in formation. Interestingly, the dentin in laser groups is thicker than the dentin of control groups especially at the middle third of the tooth (Figure. 4).

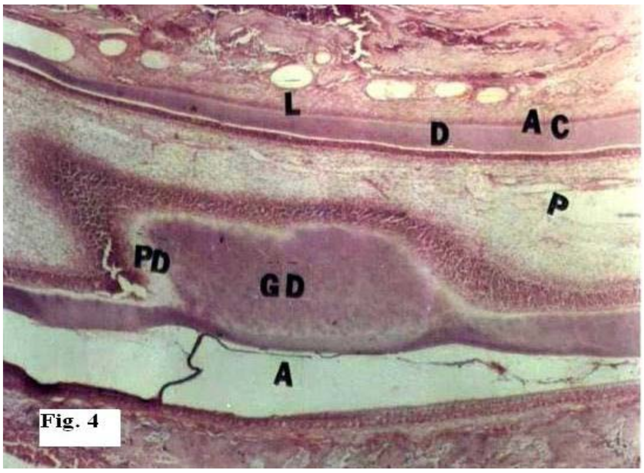

Figure 4. Histological appearance of late developing rat incisor in laser group: Low power observation of a developing incisor tooth, shows interglobular dentin (GD) with thick layer of predentin (PD) at the labial side (A). At the lingual side (L), dentin (D), pulp (P) and acellular cementum (AC) show normal histological appearance. (H&E , original magnification 4x).

The affected dentin represents a marked degree of interglobular dentin formation which is accompanied by increased thickness of predentin (Fig. 5). The pulp in turn shows prominent changes by increase in its blood vessels and cells mainly at the areas of increased dentin formation (Fig. 6). In all laser groups, the portion that covered with cementum showed no developmental disturbances in cells or structures. The eruption process of the incisor teeth in all groups seems normal compared to control group.

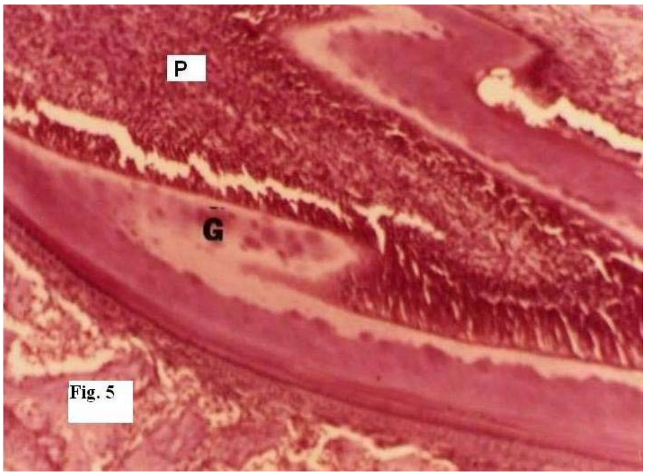

Figure 5. Histological section of early developing rat incisor in laser group: A histological changes in early developing rat incisor, showing increase thickness of predentin with interglobular (G) dentin surround by dense pulp cells (P). (H&E, original magnification 10x).

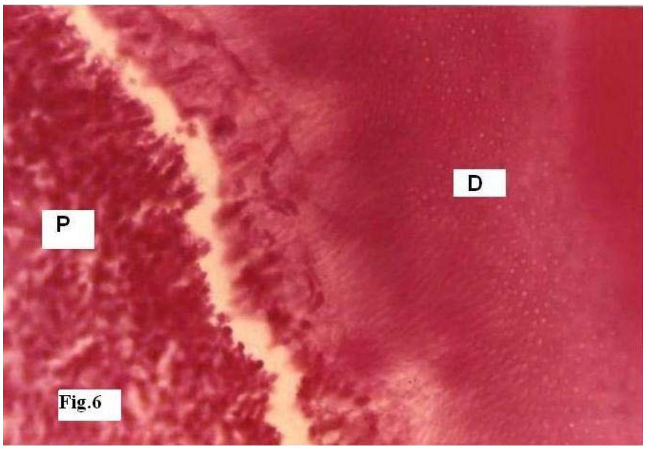

Figure 6. Histological section in the pulp region of rat incisor in laser group: A high power observation of rat incisor demonstrates increasing thickness of predentin adjacent to newly formed dentin (D). Pulp (P) shows increase cellularity near the predentin. (H&E, original magnification 40x).

Discussion

Studies report that single doses of low-power laser irradiation can stimulate dentin and pulp tissues in fully erupted human teeth [17, 21, 22]. Conversely, other report that low power laser has no positive effects on hard tissues like bone or teeth [23, 24].

Accordingly and due to the lack of sufficient research in the field of fractional laser irradiation, the present study investigates the effects of laser irradiation on the rats' teeth.

Rat incisors included in this present study are selected on the basis of the presence of successive developmental stages along their structure, which exhibits many similarities to human tooth formation. Furthermore rat incisors continue to grow and erupt; which in turn give a clear view of the effectiveness of lasers on the eruption pattern [25].

The laser groups showed a remarkably irregularity in the distribution of dentin thickness, this can be attributed to the disturbance in the histodifferentiation of the odontoblasts. These results go in line with Godoy's study as well as & Olivi's 2007 which are undertaken on pulp-exposed teeth [17, 21]. The findings are also consistent with the results of studies carried on human teeth presented by Tate 2006 and Matsui 2007, who concluded that use of laser may induce formation of dentin, but higher energies of laser may cause irreversible changes to the pulp [26, 27].

The changes in the pulp are due to the influence of laser on the cell proliferation in addition to the formation of newly formed blood vessels that are also confirmed by other studies [17, 21, 27].

It is interesting to note that laser has a selective effect on the odontoblasts among all dental tissue cells. It is possible that odontoblast cells are stimulated in the same manner as the fibroblast cells that also affected by laser. Many studies stressed that there is an increase in collagen synthesis by fibroblasts after laser irradiation of wounded tissues [19, 24, 28].

It can be noted that the main effect of laser is mostly on the growth and calcification stages rather than eruption stage; this is in agreement with studies carried out by Murakami 2005 and Masuda 2006 on rats' teeth. They prove that different types of laser can provoke changes in the pulp and dentin without disturbing the eruption process [18, 29].

The primary effects of laser in this study are at the middle third of the teeth, which was related to the area that was subjected first to the laser irradiation on day one of the experiment. This area manifested the effects of laser at these specific locations by changes in the developing tooth structures. This finding is agreed on by other investigators how could localize the influence of laser in specific areas of the pulp in the fully erupted teeth [17, 26, 29].

GaAs laser directly influences the dentin and pulp rather than enamel and cementum; this can be attributed to the translucency of the latter structures which enhances laser transmission to deeper structures [24, 30, 31]. It can also be attributed to their structural diversity from dentin and pulp [24, 29].

Conclusion

In conclusion, it can be said that GaAs laser irradiation have positive effects upon dentin formation. Consequently, GaAs lasers can be used during pulp-capping procedures.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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