

COMBINED EFFECT OF FLUORIDE GEL AND DIODE LASER 980 NM ON ROOT CARIES INHIBITION

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ABSTRACT

Aim: To study the evaluation of the combined effect of Diode laser and fluoride gel on root dentin demineralization and compare between the use of laser only & laser with fluoride in root caries.

Methods: Tooth preparation & grouping, fluoride treatment, laser treatment, fluoride & laser treatment, tooth-sectioning and artificial caries application & environmental scanning electron microscope analysis.

Results: The effect of artificial caries on the fluoride and diode laser specimens showed an augmentation of the caries prevention mechanism.

Conclusion: Our results strongly dictate a synergistic rather than an additive effect of the combined diode laser and fluoride gel treatments in root caries inhibition.

INTRODUCTION

Despite the decline of dental caries in developed countries, a continuous increase in root caries prevalence has been reported and is regarded as a serious threat to oral health for adults in all age groups^(1,2). Moreover, a further increase in the prevalence of root caries in the 21st century has been predicted, highlighting the importance of the search for effective methods of root caries prevention^(3,4).

Dental caries is still considered the most prevalent disease during childhood and adolescence^(5,6) and its manifestation is found to be high in some

individuals⁽⁷⁾ even though a noteworthy decline in dental caries incidence has been documented worldwide in the last decades. Histopathologically, In dentin from the deepest layer to the enamel, the distinct areas affected by caries are the advancing front, the zone of bacterial penetration, and the zone of destruction⁽⁸⁾. The advancing front represents a zone of demineralized dentin due to acid and has no bacteria present. The zones of bacterial penetration and destruction are the locations of invading bacteria and ultimately the decomposition of dentin. The zone of destruction has a more mixed

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bacterial population where proteolytic enzymes have destroyed the organic matrix. The innermost dentin caries has been reversibly attacked because the collagen matrix is not severely damaged, giving it potential for repair. The outer more superficial zone is highly infected with proteolytic degradation of the collagen matrix and as a result the dentin is irreversibly demineralized. Although fluoride is the most powerful treatment to prevent tooth decay, the development of new methods to control this disease completely is still necessary⁽⁹⁾.

As an alternative to fluoride, lasers have been tested to improve dental enamel properties in order to enhance its resistance to demineralization⁽¹⁰⁾. Since the 1960s, it has been consistently confirmed that lasers can significantly increase the acid resistance of enamel, and, when associated with fluoride, a significant synergism between them has been shown in the reduction of enamel solubility⁽¹¹⁾. Several laser wavelengths were used for this purpose, and laser treatment was demonstrated to be an efficient tool in prevention of tooth demineralization. Effects of the combined fluoride and laser treatment in the inhibition of caries have been reported for both enamel and root⁽¹²⁻¹⁶⁾.

Recently, other methods used in cavity disinfection are laser and ozone gas technology^(17,18). Stimulated emission means that the light of laser radiation is strengthened. Stimulation with an external factor of the medium laser environment, which is known to be a solid, liquid or gas-filled orb, results in the formation of a laser beam. Diode lasers are ideal for use in dental surgeries as they are portable and of small design. Other advantages are that they do not occupy much space, can be easily moved and are relatively cheap⁽¹⁸⁾. The absorption rates of diode lasers into the tissues are enamel 5%, dentine 30%, decay tissue 35%, soft tissue and blood 60%, and the response rates are enamel 15%, dentine 20%, decay tissue 3% and soft tissue/blood 20%⁽¹⁹⁾.

The main purpose of the present study was to evaluate the combined effect of Diode laser and fluoride gel on root dentin demineralization and compare between the use of laser only & laser with fluoride in root caries.

MATERIALS & METHODS

Tooth Preparation & Grouping

Sample preparation

Forty extracted caries-free single rooted permanent premolars were used in the current study (Tab 1). Extraction had been done for orthodontic treatment. After extraction, the teeth were stored at 4°C in 0.1% thymol solution. All teeth were cleaned by being gently brushed and carefully scaled, for the removal of debris, attached soft tissues, and calculus. The root surfaces were not polished or sonicated. Twenty teeth were selected and viewed under a stereomicroscope (Olympus® SZ40, Olympus Optical Co. LTD, Tokyo, Japan). By using a very small round bur, we created 4 3 mm x 1 mm windows (2 on the distal surface and 2 on the mesial surface) of each tooth, 1 mm below the cemento-enamel junction, with a 2-mm distance between the 2 windows on the same root surface. The 4 windows on the same tooth were assigned to 2 groups: (C) Control, (L) Laser treatment alone (non fluoride group).

Another 20 teeth were selected, with the same procedures were repeated to make 4 windows that were assigned to groups (F) Fluoride treatment alone, and (FL) Fluoride followed by laser treatment. (fluoride group).

Fluoride Treatment

A fluoride gel, Cavity Shield™ 5% Sodium Fluoride Varnish (3M ESPE), was applied for 4 min to each of the windows in Groups (3)-(8), and wiped off with tissue papers.

TABLE (1) groups assessment.

Non fluoridated 20 teeth	C control 10 specimens	Artificial Caries	CA control +Artificial caries 10 specimens
	L Laser 10 specimens		LA Laser + Artificial caries 10 specimens
Fluoridated 20 teeth	F Fluoride only 10 specimens		FA Fluoride+ Artificial caries 10 specimens
	FL Fluoride+ laser 10 specimens		FLA Fluoride+ laser+ Artificial caries 10 specimens

Laser Treatment

Diode laser was applied to the groups L (laser only) and FL (fluoride followed by laser). The samples were irradiated using diode laser irradiation of 980 nm wave length, 2 W power for 20 sec, in contact mode (Quanta system, Italy) and optic fiber transmission system. The fiber tip diameter with 320 micrometer was positioned perpendicularly to the windows on the root surface areas. Laser irradiation was performed by hand, screening the dentin surface in a uniform back and forth motion. During laser application; all the standard safety concerns were followed during the experiment⁽²⁰⁾.

Tooth-sectioning and artificial caries application

All teeth were sectioned longitudinally into mesial and distal halves. On random bases, half the specimens of each group (10 specimens) were individually submitted to the process of the artificial caries by the following sequence. To prevent cross-contamination between fluoride and nonfluoride groups, we immersed 10 root sections (each with 2 windows of 3mm x 1 mm window) from each group separately, in the process of caries induction using artificial caries media (6 % hydroxyethyl cellulose to a 50 m mole lactic acid solution) of 4.5 pH for seven days. The specimens were then washed and

kept in distilled water⁽²⁰⁾.

Environmental scanning electron microscope analysis

The windows in each root specimens were examined using an ESEM (Inspect S ESEM, FEI). The ESEM was very useful in examining the specimens before and after laser, fluoride and artificial caries in order to confirm the results.

RESULTS

The normal architecture of the root dentin structure was detected clearly as the control group showing the closed dentinal tubules in *fig. 1*

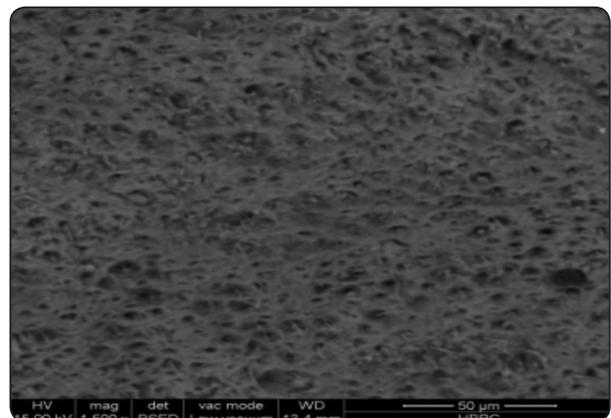


Fig. (1) SEM micrograph of control specimen before treatment X1500.

In *fig. 2 (a)* Areas of open dentinal tubules due to artificial caries and discrete areas of thick fluoride coating the dentin and occluding the dentinal tubules X400. While in *fig. 2 (b)* the SEM micrograph shows the areas of open dentinal tubules due to artificial caries through the removal of the dentin smear layer in high magnification X1500.

In the diode laser treated specimens showed some areas of crack and destruction of the dentin surface pattern X500 in *fig 3 (a)*, while on high magnification in *fig 3 (b)* showed areas of spot melting and loss of dentin pattern and open dentinal tubules also X2000.

In *fig. 4*; the micrograph showed a line of demarcation between the laser additional effect of the (laser+ fluoride+ artificial caries) versus the non laser treated (thick layer of fluoride+ artificial caries). That area of the (laser+ fluoride+ artificial caries) denoted by the (red arrow) appeared as multiple thick islands of fluoride aggregations with slight melting tendency X1000.

The effect of fluoride and diode laser with artificial caries is more clearly seen in *fig. 5* that showed the micrograph of the (laser +fluoride +artificial caries) group with the fluoride islands (white arrows), voids in dentin might be due to laser effect (blue arrow) and the coalesce of the fluoride

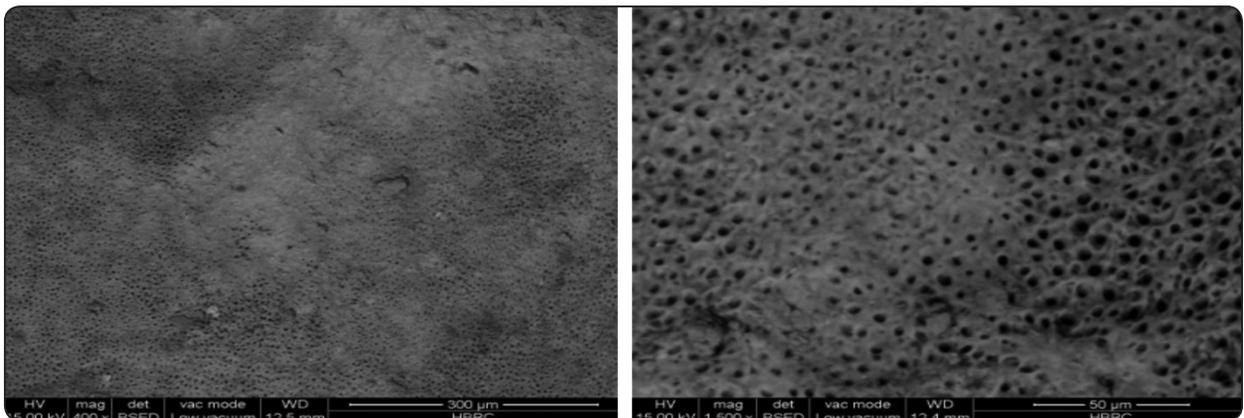


Fig. (2a) SEM micrograph of (*fluoride and artificial caries group*) shows areas of open dentinal tubules due to artificial caries and areas of fluoride coating the dentin X400. (Fig. 2b) SEM micrograph of showed variable sizes of open dentinal tubules due to artificial caries in high magnification X1500.

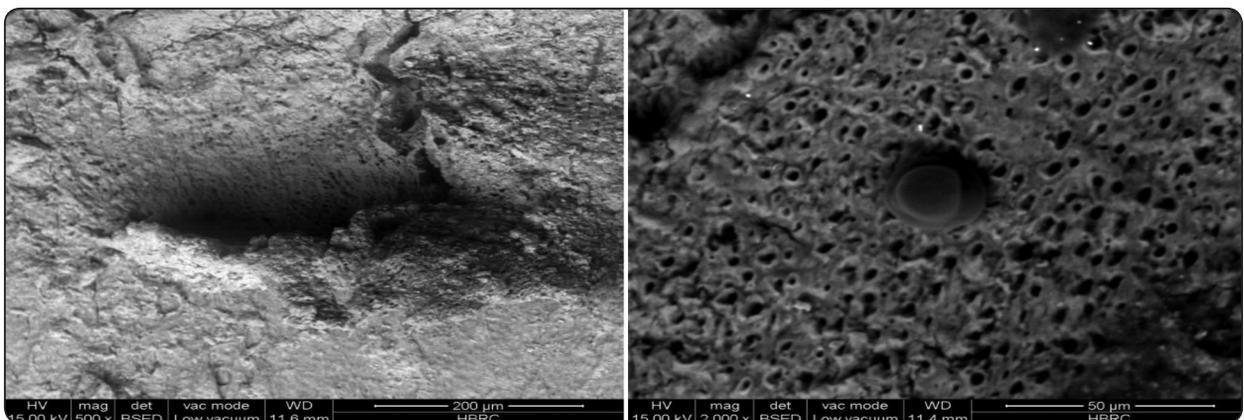


Fig. (3) (a & b) SEM micrograph of (*Laser on control group*) shows areas of crack and destruction of the surface pattern X500, while on high magnification shows areas of spot melting and loss of dentin pattern X2000.

islands (red arrows) giving a full homogenous fluoridated dentin thick layer.X2003, also it is clear that the number of opened dentinal tubules is scarcely found. In *fig. 6* the islands of fluoride coating melted by the laser can clearly noticed (blue arrows), with areas of narrow dentinal tubule lumen denoting intact organic and inorganic content with fluoride coating with reduction in tubule porosity

(arrow head), which denotes that dentin didn't lose its reparative capacity. Also, areas of destruction of the inorganic dentin part (peritubular dentin) leaving the odontoblastic process (organic part) intact (thin white arrow), while a few number of the widened hollow opened dentinal tubules due to the destruction by the artificial caries (dotted white arrow), with loss of the dentin reparative capacity.

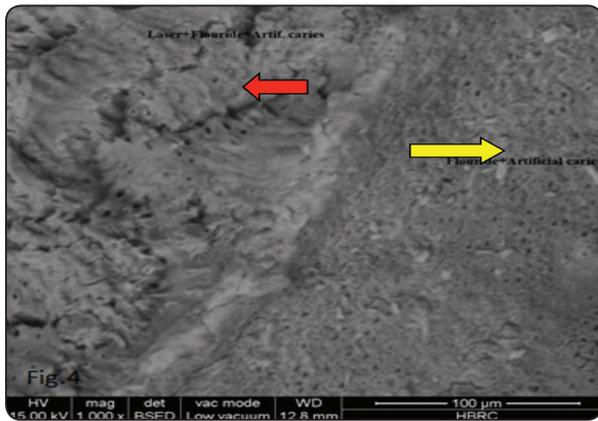


Fig. (4) SEM micrograph shows line of demarcation with a thick layer between {fluoride + artificial caries (yellow arrow)} and {laser+ fluoride+ artificial caries (red arrow)}, LFA also appear as thick islands of fluoride with slight melting tendency X1000.

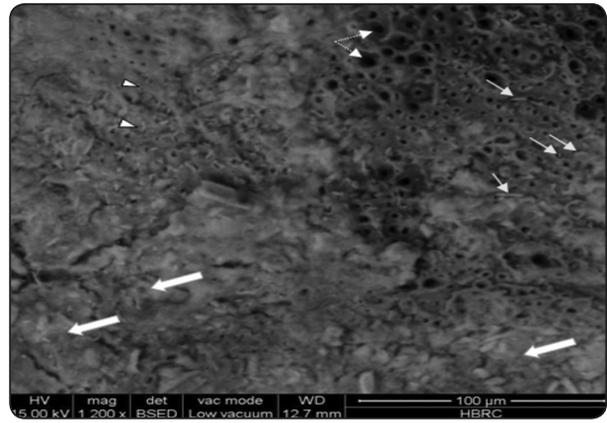


Fig. (6) SEM micrograph showed, few number of the widened hollow opened dentinal tubules due to the destruction of the artificial caries (dotted white arrow). Destruction of the inorganic dentin part (peritubular dentin) leaving the odontoblastic process (organic part) intact (yellow arrow). Narrow dentinal tubule denoting intact organic and inorganic content with fluoride coating with reduction in tubule porosity (arrow heads). Melting of the fluoride coating by laser preserving the dentin surface.(Bold arrows).X1200.

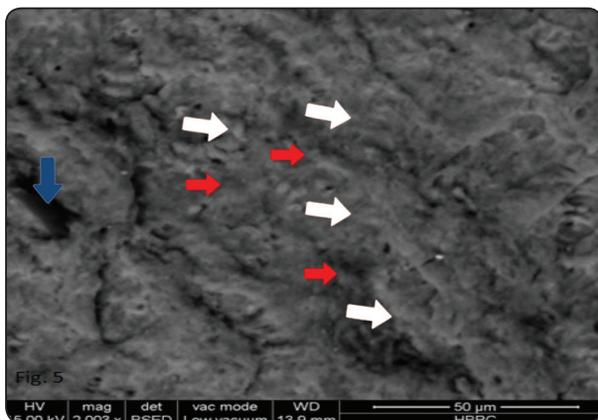


Fig. (5) SEM micrograph of the laser +fluoride +artificial caries shows the fluoride islands (white arrows), voids in dentin might be due to laser effect (blue arrow) and the coalesce of the fluoride islands (red arrows) giving a full homogenous fluoridated dentin thick layer.X2003.

DISCUSSION

The dental caries is considered a pathologic process of external origin involving softening of the hard tissue and proceeding to the formation of a cavity. Localized destruction of the tooth surface is initiated by decalcification of the enamel followed by enzymatic lysis of organic structures leading to cavity formation!. The bacteria in the biofilm are always metabolically active causing fluctuations in pH. These fluctuations may cause a loss or gain of mineral content from the tooth when the pH is dropping or increasing respectively⁽²¹⁾.

The cumulative result from this demineralization process may be a net loss of mineral, leading to dissolution of the dental hard tissue and formation of a caries lesion⁽²²⁾.

In a study made by (Featherstone *et al.*, 2003)⁽²³⁾ showed that CO₂ laser treatment did not achieve significant caries inhibition in dentin. That study differed in the selection of experimental/control sites on different teeth without a “combined fluoride-laser treatment” group, a stronger acid challenge in the pH-cycling scheme, and different laser parameters.

A comparison between the laser and the non laser treated enamel specimens showed an increase in acid resistance with increasing the laser energy, also the demineralization of enamel was reduced dramatically in the presence of 0.2ppm fluoride for the laser and non laser treated specimens.

In agreement with our study, the caries prevention study using CO₂ laser with and without sodium fluoride on enamel and dentin showed that the synergistic effect of CO₂ laser and sodium fluoride has a greater caries preventive effect than the laser only, at the enamel and dentin surfaces⁽²⁴⁾. (Similar previous SEM studies showed that enamel and dentin surfaces subjected to heat treatment by cw CO₂ laser (1,2,3W) were sufficiently melted and the smear layer was solidified⁽²⁵⁾).

Laser wavelengths in the near infrared and red region of the visible spectrum are poorly absorbed by the calcium and phosphorous dental mineral content, but they are optimally transmitted and scattered through the sound enamel. This holds true for diode laser 980 nm and Nd:YAG laser 1064 nm. Laser and fluoride varnish showed 43% inhibition of pits and fissure lesions and 80 % inhibition of smooth surface lesions compared to the untreated groups⁽²⁶⁾.

ESEM micrographs revealed difference between fluoridated and non fluoridated, laser and unlaser specimens. So far, scarce data are available

concerning the effect of a 980nm high-power diode laser on root dentin surface. The ESEM micrograph showed the clear difference between the effect of artificial caries and fluoride, showing how much the fluoride coated a large root area preventing the caries effect appearing as widening and opening of the dentinal tubules, as if acid etched, *fig.2(a&b)*. when the diode laser was used some few areas of crack and destruction of the dentin surface pattern *fig 3 (a)*, while on the high magnification in *fig 3 (b)* showed areas of spot melting and loss of dentin pattern and open dentinal tubules also X1500, this might be clarified by the technique the diode laser was used in a contact mode fiber tip and in a back and forth movement, which can cause twice application of the same spot, without any signs of carbonization due to poor absorption of 980 nm wavelength.

The low absorption coefficient of diode laser wavelength in enamel and dentin⁽²⁷⁾ showed a great benefit as it caused rapid elevation of the surface energy during exposure and rapid decay of temperature once stopped. As a result, the action needed is carried out, but in the same time it did not penetrate deeply and affect the pulp or the underlying structures²⁰. Although a synergistic effect of laser and chemical inhibitors on the dissolution of enamel has been demonstrated by (Fox *et al.*, 1992)⁽²⁸⁾, it was not clear whether the intensified cariostatic effect on the root is synergistic or just an additive effect of laser and fluoride (Hicks *et al.*, 1995b, 1997)^(29,30).

(Westerman GH *et al.*)⁽³¹⁾ used a combined effect of argon laser and APF treatment either before or after the laser irradiation, the lesion depth was 54-57% less than that of the control group. The argon laser only group, compared to the control group, indicated a 24% reduction in lesion depth. They found an increase of the root-surface area due to the roughening caused by laser irradiation. (Gao *et al.*, 2006)⁽³²⁾ When used the CO₂ laser in combination

with fluoride treatment, a synergistic inhibition (about 85%) was achieved on root demineralization, this lead to the formation of a more acid resistant root structure that might be the cause of reduction of lesion depth

In this study the effect of the artificial caries on the fluoride and diode laser specimens showed an augmentation of the caries prevention mechanism. The fluoride islands and the coalesce of these islands giving a full homogenous fluoridated dentin thick layer (fig.5), and it was clear the reduction of open dentinal tubules. In addition, different stages of caries appear in the same group denoted in (fig.6) Few number of the widened hollow opened dentinal tubules due to the destruction of the artificial caries (dotted white arrow), which is the destruction zone where the dentin lose its reparative ability. Also, projection of odontoblastic processes (organic part) appeared to be intact with destruction of the inorganic dentin part (peritubular dentin), which is a lesser degree of destruction, leaving the dentin reparative ability (intact odontoblastic processes). Same was clear in areas with narrow dentinal tubule denoting intact organic and inorganic content with fluoride coating with reduction in tubule lumen size (arrow heads). and finally the most preventive area appear with melting of the fluoride coating by laser preserving the dentin surface. (Blue arrow). Our results strongly dictate a synergistic rather than an additive effect of the combined diode laser and fluoride gel treatments in root caries inhibition.

CONCLUSION

Based on the result of the present study, it can be concluded that; best results appeared preserving the root dentin surface from the artificial caries, and maintaining its reparative ability was when a combined effect of fluoride gel and diode laser synergistically used.

REFERENCES

- 1- Katz RV. The clinical diagnosis of root caries: issues for the clinician and the researcher. *Am J Dent* (1995); 8:335-41.
- 2- NIH (National Institutes of Health), US Department of Health and Human Services, Craniofacial Research. Oral health in America: a report of the Surgeon General. *J CA Dent Assoc* (2000); 28:685-95.
- 3- Blinkhorn AS, Davies RM. Caries prevention. A continued need worldwide. *Int Dent J* (1996); 46:119-25.
- 4- Griffin SO, Griffin PM, Swann JL, Zlobin N. Estimating rates of new root caries in older adults. *J Dent Res* (2004); 83:634-38.
- 5- U.S. Department of Health and Human Services, National Institute of Dental and Craniofacial Research, and National Institutes of Health, J. Calif. Dent. Assoc. (2000); 28: 685.
- 6- Y. B. O. Lima , J. A. Cury, *Caries Res.* (2003) 37, 335.
- 7- J. D. B. Featherstone, *Community Dent. Oral Epidemiol.* (1999); 27: 31.
- 8- Kidd EA, Fejerskov O. "What constitutes dental caries? Histopathology of carious enamel and dentin related to the action of cariogenic biofilms". *Journal of Dental Research.* (2004); 83 Spec No C: C35-38
- 9- Rodrigues L.K.A. Santos M.N. Pereira D. Assaf A.V. Pardi V. Carbon dioxide laser in dental caries prevention. *J. Dent.*(2004);32:531-40.
- 10- Attin T, Hartmann O, Hilgers RD, Hellwig E. Fluoride retention of incipient enamel lesions after treatment with a calcium fluoride varnish in vivo. *Arch Oral Biol.* (1995);40:169-74.
- 11- R. H. Stern, R. F. Sognnaes, F. Goodman, J. Am. Dent. Assoc. (1966); 73: 838.
- 12- Featherstone JDB, Zhang SH, Shariati M, McCormack SM. Carbon dioxide laser effects on caries-like lesions of dental enamel. *Proc SPIE* (1991); 1424:145-49.
- 13- Flaitz CM, Hicks MJ, Westerman GH, Berg JH, Blankenau RJ, Powell GL. Argon laser irradiation and acidulated phosphate fluoride treatment in caries-like lesion formation in enamel: an in vitro study. *Pediatr Dent* (1995); 17:31-35.
- 14- Hicks MJ, Flaitz CM, Westerman GH, Blankenau RJ, Powell GL, Berg JH. Enamel caries initiation and progression following low fluence (energy) argon laser and fluoride treatment. *J Clin Pediatr Dent* (1995); 20:9-13.

- 15- Hsu CY, Jordan TH, Dederich DN, Wefel JS. Laser-matrix fluoride effects on enamel demineralization. *J Dent Res* (2001) ;80:1797-801.
- 16- Nogales, C.G., P.H. Ferrari, Kantorovich EO, Lage - Marques JL. "Ozone Therapy in Medicine and Dentistry." *J. Contemp. Dent. Pract.* (2008); 9(4): 75–84.
- 17- Saini, R.. "Ozone Therapy in Dentistry: A Strategic Review." *J. Nat. Sci. Biol. Med.* (2011) ; 2(2): 151–53.
- 18- Coleton, S.. "The Use of Lasers in Periodontal Therapy." *Gen. Dent.* (2008); 56(7): 612–16.
- 19- Yukna, R.A.. "Lasers in Periodontal Therapy." *Today's FDA* (2011) ;23(3): 40–41.
- 20- Nermin M Yussif ,Ali M Saafan and Samah S Mehani: Post-cure irradiation of pit and fissure sealant by diode laser. (part II). *Laser Int Mag Las Dent.*(2013);2: 16-21.
- 21- Manji F, Fejerskov O, Nagelkerke NJ, Baelum V. A random effects model for some epidemiological features of dental caries. *Community Dent Oral Epidemiol* (1991); 19: 324-28.
- 22- Roberson MT, Heymann HO, Swift EJ. *Sturtevant's Art and Science of Operative Dentistry*. 4th ed: Mosby-Yearbook, Incorporated; (2002); 82-104.
- 23- Featherstone JD, Fried D, Le CQ. New carbon dioxide laser treatment on artificial caries progression in dentin. *Proc SPIE* (2003); 4950:236-40.
- 24- Hossain MM, Hossain M, Kimura Y, Kinoshita J, Yamada Y, Matsumoto K. Acquired acid resistance of enamel and dentin by CO₂ laser irradiation with sodium fluoride solution. *J Clin Laser Med Surg* (2002) ;20:77–82.
- 25- Mozammel H, Yukio N, Yuichi K, Mitsuhiro I, Yoshishige Y, Koukichi M: Acquired acid resistance of dental hard tissues by Co₂ radiation. *J Clin Laser Med Surg* (1999); 17(5): 223-26.
- 26- Huang Guay-Fen, Wan-Hong Lan, Ming-Kuang Guo, Chun-Pin Chiang: Synergistic effect of Nd:YAG laser combined with fluoride varnish on inhibition of caries formation in dental pits and fissures in vitro. *J Formos Med Assoc* (2001); 100(3): 181-185.
- 27- Featherstone J D B: Caries detection and prevention with laser energy. *Dent Clin North Am* (2000); 44: 955-69.
- 28- Gao XL, Pan JS, Hsu CY. Laser-fluoride effect on root demineralization. *J Dent Res* (2006); 85:919–23.
- 29- Hicks MJ, Westerman GH, Flaitz CM, Blankenau RJ, Powell GL, Berg JH. Effects of argon laser irradiation and acidulated phosphate fluoride on root caries. *Am J Dent* (1995b); 8:10-14.
- 30- Hicks MJ, Flaitz CM, Westerman GH, Blankenau RJ, Powell GL. Root caries in vitro after low fluence argon laser and fluoride treatment. *Compend Contin Educ Dent* (1997); 18:543-52.
- 31- Westerman GH, Hicks MJ, Flaitz CM, Blankenau RJ, Powell GL. Argon laser irradiation effects on sound root surfaces: in vitro scanning electron microscopic observations. *J Clin Laser Med Surg* (1998); 16:111-15.
- 32- Fox JL, Yu D, Otsuka M, Higuchi WI, Wong J, Powell G. Combined effects of laser irradiation and chemical inhibitors on the dissolution of dental enamel. *Caries Res* (1992); 26:333-39.