Temperature Changes in the Deciduous Pulp Chamber During Cavity Preparation With the Er:YAG Laser

Mariana Silvério Castilho, DDS, MS   Aline Evangelista de Souza-Gabriel, DDS, MS
Melissa Andrea Marchesan, DDS, MS   Luis José Floriam, DDS, MS, PhD
Manoel Damião Sousa-Neto, DDS, MS, PhD   Yara Teresinha Correa Silva-Sousa DDS, MS, PhD

ABSTRACT

Purpose: The purpose of this in vitro study was to evaluate the temperature changes in the pulp chambers of deciduous molars during cavity preparation with an Er:YAG (erbium substituted: yttrium aluminium garnet) laser.
Methods: Two cavities were prepared in 14 maxillary deciduous molars: one with the Er:YAG laser and other with a diamond bur using a high-speed handpiece (control), providing 4 groups with 7 cavities each. The laser treatment was applied for 30 seconds (group 1) and 60 seconds (group 3). The internal pulp temperature was recorded during preparation procedures with a thermocouple, and temperature changes were calculated by the difference between the maximum and initial temperature.
Results: There were significant differences ($P<.01$) between Er:YAG laser irradiation for 60 seconds and 30 seconds and the 2 high-speed drilling groups, which were similar. The Er:YAG laser used for 60 seconds provided the highest temperature alteration (4.01°C).
Conclusion: Er:YAG laser irradiation increased the temperature of the deciduous teeth compared to the high-speed drilling treatment. The temperature increments, however, remained below the critical value (5.5°C). (J Dent Child 2007;74:21-5)

KEYWORDS: CAVITY PREPARATION, DECIDUOUS TEETH, ER:YAG LASER, TEMPERATURE

The word laser is an acronym for "light amplification by stimulated emission of radiation." A laser device is a nonionizing light that transforms one type of energy, usually electrical, into optical energy.[1,2] This energy presents some particular characteristics (monochromatic, collimate, and coherent) that, in contact with the irradiated tissue, results in different effects depending on the:

1. laser light's physical properties, such as:
    a. wavelength;
    b. power;
    c. pulse duration;
    d. spot size; and
    e. irradiation time.[1-4]
2. optical properties of the irradiated tissue, such as:
    a. optical density;
    b. structure; and
    c. absorption maximum peak.[1,5,6]

This innovative technology has benefited from decades of continuous investigation.[1,7-11]

Among the laser systems currently available, the erbium substituted: yttrium aluminium garnet (Er:YAG) laser has been advocated as a viable approach for caries removal and cavity preparation for composite restorations with minimal extension into sound tooth structure, as long as it is utilized under water-cooling.[2,9,10,12-17]

The ability of the Er:YAG laser to effectively ablate dental hard tissues is ascribed to its 2.94 μm wavelength emission, which is coincident to the main absorption peak of water and is also well absorbed by hydroxyapatite crystals.[1,8,18,19] During irradiation, the water is vaporized almost instantaneously and the stream pressure causes an increase in the irradiated volume.[1,2,19] This expansion surpasses the crystal

Dr. Castilho is postgraduate student, Dr. Souza-Gabriel is research fellow, Dr. Marchesan is professor of Endodontics, Drs. Floriam and Silva-Sousa are professors of Pediatric Dentistry, and Dr. Sousa-Neto is professor of Endodontics and chairman, all in the Department of Dentistry, University of Ribeirão Preto, Ribeirão Preto, São Paulo, Brazil.
Correspond with Dr. Sousa-Neto at sousanet@unaerp.br

Table 1. Studied Groups

Group	Cavity preparation	Time (s)	Cavity depth (mm)	Cavity diameter (mm)
1	Er:YAG laser	30	0.5	1.0
2	High-speed turbine	10	0.5	1.0
3	Er:YAG laser	60	0.8	1.5
4	High-speed turbine	20	0.8	1.5

strength of dental structures and produces an explosive ejection of both organic and inorganic tissue microparticles, thus determining the microcrater-like appearance typical of lased surfaces.[14,18-22] Histological investigations have indicated that the pulpal response to Er:YAG laser irradiation is reversible and similar to that of a high-speed turbine.[4,23] Clinical studies demonstrated that the Er:YAG laser causes less pain, vibration, pressure and noise than high-speed drilling.[3,9,13] Its use often reduces the need for local anesthesia and increases patient's comfort and acceptance,[3,9] particularly in pediatric dentistry.[16]

Previous researchers using the Er:YAG laser in primary teeth, however, report only surface morphology,[19,21,22,24] bond strength,[19,21] or microleakage.[11,25,26] No available published data exists that evaluate the thermal effect of this laser on the deciduous dentin-pulp complex. The pulpal outline of primary teeth follows the dentin-enamel junction more closely than the pulpal outline of permanent teeth, and the dentin is not so thick, leading to thinner dentine-enamel layer on the occlusal surface of the primary teeth.[11,24]

The purpose of this in vitro study was to evaluate temperature changes in the pulp chamber of deciduous human molars during cavity preparation with the Er:YAG laser.

METHODS

Fourteen noncarious maxillary deciduous molars stored in 0.1% thymol solution at 4°C were used in this experiment. All the selected teeth had completed the natural exfoliation process. Teeth were cleaned with a scaler to remove the remaining pulp tissue and were washed in running water for 24 hours to completely remove the thymol solution. They were also examined under a X10 stereomicroscope (Nikon Inc Instrument Group, Melville, NY) to exclude those with structural defects.

The occlusal enamel of each specimen was removed with carborundum discs (Broadbean, São Paulo, Brazil) using a low-speed handpiece (Dabi Atlante, Ribeirao Preto, São Paulo, Brazil) under continuous water-cooling, producing a plain dentin surface. To determine the positions of the cavity preparations, 3 points were marked in the exposed surface: one in the central portion and the other two equidistant 2 mm from the first point in a mesiodistal direction.

A standardized 4-mm deep cavity was prepared in the center of the vestibular face of the tooth's cervical portion using a no. 1011 diamond bur (KG Sorensen, São Paulo, Brazil) using a high-speed handpiece (Dabi Atlante, Ribeirão Preto, São Paulo, Brazil). This was necessary to introduce the type K thermocouple inside the pulp chamber. An adjustable acrylic apparatus was developed at the Dental Research Laboratory of the University of Ribeirão Preto, Ribeirão Preto, São Paulo, Brazil, to keep the specimens in a standardized position and allow an appropriate fixation of the thermocouple during cavity preparation. A wax ring was attached to the specimen to facilitate the fixation in the acrylic device and to avoid the water used for refrigeration reaching the thermocouple and leading to inaccurate temperature measurements.

Samples were randomly assigned to 4 groups, each with 7 cavities, and were submitted to the following treatments:

1. group 1—cavity prepared with the Er:YAG laser for 30 seconds;
2. group 2—cavity prepared with a diamond spherical bur in a high-speed rotation to the same depth of the group 1 cavity;
3. group 3—cavity prepared with the Er:YAG laser for 60 seconds;
4. group 4—cavity prepared with a diamond spherical bur in a high-speed rotation to the same depth of the group 3 cavity.

Details about the studied groups are described in Table 1.

Laser irradiation was performed with an Er:YAG laser device (Opus 20; Opus Dent, Tel Aviv, Israel) at an output energy of 14 Hz and 420 mJ. This laser employs a solid crystal of yttrium-aluminum-garnet (YAG) doped with erbium ions. The laser beam was delivered on noncontact mode by means of a sapphire point (17-mm length, 1.3-mm diameter) and an angled handpiece attached to the optic fiber system.

The temperature was measured during the cavity preparation with Er:YAG laser irradiation. Subsequently, the cavity depth was measured with a no. 80 Hedströen file (Dentsply Maillefer, Ballaigues, Switzerland) and a rubber stop.

The obtained values were transferred to a spherical bur with a ruler and a pen. Cavity preparations with high-speed drilling were performed similar to the laser cavity depth. Burs were discarded after every two prepared samples, and all the procedures were accomplished under water-cooling. Laser preparation times were standardized at 30 or 60 seconds and were measured by digital chronometer.

Temperature variation during cavities preparations were measured by a digital multimeter (Et-2070; Mimipa, São Paulo, Brazil) with a thermocouple positioned inside the pulp chamber. The study was performed in a temperature-controlled room, with the initial temperature of each sample standardized at 22ºC. All procedures were accomplished at the Laser Center of the University of Ribeirão Preto, Ribeirão Preto, São Paulo, Brazil, following the security precautions for use of the laser device. Temperature alteration was obtained by the difference between the highest recorded value during cavity preparation and the initial value (22ºC).

Temperature averages and standard deviations were calculated and data were analyzed by analysis of variance (ANOVA). Multiple comparisons were done using Tukey's statistical test at a 0.01 significance level.

RESULTS

Temperature means and standard deviations for each group are shown in Table 2.

The ANOVA showed a statistically significant difference ($P<.01$) among groups 1 through 4.

Tukey's test indicated that group 3 (prepared with the Er:YAG laser for 60 seconds) provided the highest increase in temperature, followed by group 1 (prepared with the Er:YAG laser for 30 seconds) and group 2 (prepared with high-speed drilling with the same dimensions of group 1).

Group 4 (prepared with high-speed drilling with the same dimensions of group 3) was statistically different from group 3, presenting intermediate values between groups 1 and 2.

DISCUSSION

In pediatric dentistry, fear and anxiety during the restorative procedures are mainly associated with the:

1. noise and vibration produced by high- and low-speed handpieces; and
2. need for local anesthesia.[16,19,22]

Caries removal and cavity preparation with laser technology has become a subject of major interest due to the possibility of accomplishing noninvasive dental preparations with minimum patient discomfort.[3,9,13,16]

This study showed that the Er:YAG laser device for cavity preparation increased deciduous teeth temperature when compared to high-speed drilling. These results differ from those performed in permanent teeth that observed a similar temperature increase with Er:YAG laser irradiation and conventional bur preparation[15,27] or those that verified a lesser increase in intrapulpal temperature during laser preparation compared to bur treatment.[28]

The greater temperature increase was obtained with Er:YAG laser irradiation for 60 seconds (4.01ºC), followed by the application for 30 seconds (2.29ºC). A suitable explanation for such a performance would be that increasing the laser irradiation time promotes a reduction in dentin thickness[1,2] and that the laser focal point is approached to the thermocouple. Consequently, the pulp chamber thermal alterations are intensified.[6,28,29] The stimulus generated in the dentin-pulp complex can accelerate the deciduous teeth exfoliation process.[24]

Nevertheless, in all groups, the temperature increments remained below the critical threshold described of 5.5ºC.[7] This is partially explained by the fact that, when the equipment is working in noncontact mode, during laser irradiation a slight energy dispersion occurs due to the amplification of the spot size (the beam's diameter).[3,14,28] Besides, in healthy dental pulp, blood circulation and periodontal structures ensure a certain level of heat dispersion.[4,23] For this reason, in vitro models for temperature measurements are probably only an approximation of the real conditions of the buccal cavity .

Table 2. Mean and Standard Deviation (°C) of Temperature Alteration* for Each Experimental Group†

Group	Cavity preparation	Time (s)	Mean±(SD)
1	Er:YAG laser	30	2.29±0.70b‡
2	High-speed turbine	10	1.14±0.39c
3	Er:YAG laser	60	4.01±0.77a
4	High-speed turbine	20	1.33±0.50bc

*Temperature alteration was obtained by the difference between the highest recorded value during cavity preparation and the initial value (standardized in 22ºC).
†Critical value (α=0.001): 1.13.
‡Same letters indicate statistical similarity.*

Several studies using the Er:YAG laser in permanent teeth[7,15,17,18,25,28,29] have shown that pulp temperature is not increased to a level than can cause irreversible damages to pulp tissue. Indeed, it was speculated that the Er:YAG laser leads to initiation and completion of pulp repair earlier than the high-speed drill.[23] On the irradiated surface, the Er:YAG laser:

1. modifies the calcium-to-phosphorus ratio;
2. reduces the carbon-to-phosphorus ratio; and
3. leads to the formation of more stable and less acid-soluble compounds.

This results in reduced dental susceptibility to a caries attack.[5] It is also important to highlight that previous investigations emphasize that the laser device should be used with continuous water mist to avoid pulp necrosis[9,12,16-18] or dentin carbonization[12,15,19,20] and to provide effective dental ablation.[1,4,8]

In the dental literature, different results can be observed related to the temperature changes during Er:YAG laser dental treatment. Hoke et al[8] observed an increase of 2.2ºC, Burkes et al obtained values around 4ºC, Zanin et al[6] verified a maximum increase of 3.1ºC, Oelgiesser et al[30] reported a maximum temperature peak of 5.5ºC, and Attrill et al[17] observed a maximum increase of 4.0ºC. These results cannot be directly compared to those found in the present study, however, since they presented differences in scope and experimental design.

Another feature to be considered is that the time spent in the cavity preparation with the Er:YAG laser was almost three times greater than the diamond bur in a high-speed handpiece. Previous research[2,3,14] also observed that a longer time was required during Er:YAG laser treatment. In fact, it has been discussed that cavity preparation is only a small part of the complete treatment time.[3] Thus, since the restoration time is supposed to be the same in laser and bur treatment and the need for local anesthesia is significantly lower in laser practice,[3,7,13] the entire clinical time with the laser device or mechanical drill would be similar.

This study's results offer perspectives on new research that evaluate the temperature alteration during preparation with the Er:YAG laser in deciduous teeth varying in the: (1) type of cavity; (2) laser parameters; (3) teeth group; and (4) histological changes in pulp tissue. Further in vitro and in vivo research is required to support optimal and safe applicability of this promising pediatric dentistry alternative technology.

CONCLUSION

Within the limitations of this in vitro study, it may be concluded that Er:YAG laser irradiation increased the temperature of the deciduous teeth compared to the preparations performed with high-speed drilling. The temperature increments, however, remained below the described critical value of 5.5ºC.

ACKNOWLEDGMENT

The authors wish to acknowledge the Coordination Professional Improvement of Faculty of Higher Education, CAPES, for providing postgraduate student fellowships (grant no. 33032017004MO).

REFERENCES

1. Hibst R, Keller U. Experimental studies of the application of the Er:YAG laser on dental hard substances: I. measurement of the ablation rate. Lasers Surg Med 1989;9:338-344.
2. Coluzzi DJ. Fundamentals of dental lasers: Science and instruments. Dent Clin North Am 2004;48:751-770.
3. Keller U, Hibst R, Geurtsen W, Schilke R, Heidemann D, Klaiber B. Er:YAG laser application in caries therapy: Evaluation of patient perception and acceptance. J Dent 1998;26:649-656.
4. Mehl A, Kremers L, Salzmann K, Hickel R. 3D volume-ablation rate and thermal side effects with the Er:YAG and Nd:YAG laser. Dent Mater 1997;13:246-251.
5. Apel C, Meister N, Schmitt H, Graber G, Gutknecht N. Calcium Solubility of dental enamel following subablasive Er:YAG and Er:YSGG laser irradiation in vitro. Lasers Surg Med 2002;30:337-341.
6. Zanin F, Brugnera-Júnior, A, Pécora JD, Pinheiro ALB, Spanó JCE, Barbin EL, Marchesan MA. Heat generated by Er:YAG laser in the pulp chamber of teeth submitted to removal of dental tissue and composite resin. Proc SPIE 2004;5313:109-113.
7. Zach I, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965;19:515-528.
8. Hoke J, Burkes E, Gomes E, Wolbarsht ML. Er:YAG (2,94μm) lasers effects on dental tissues. J Laser Appl 1990;6:61-65.
9. Pelagalli J, Gimbel C, Hansen, R, Sweett A, Winn D. Investigation study of the use of Er:YAG laser versus dental drill for caries removal and cavity preparation—phase I. J Clin Laser Med Surg 1997;15:109-115.
10. Sousa-Neto MD, Marchesan MA, Pecora JD, Junior AB, Silva-Sousa YT, Saquy PC Effect of Er:YAG laser on adhesion of root canal sealers. J Endod 2002;28:185-187.
11. Borsatto MC, Corona SAM, Chinelatti MA, Ramos RP, Rocha RASS, Pecora JD, Palma-Dibb RG. Comparison of marginal microleakage of flowable composite restorations in primary molar prepared by high-speed carbide bur, Er:YAG laser, and air abrasion. J Dent Child 2005;72:3.
12. Burkes EJJ, Hoke J, Wolbasht M. Wet versus dry enamel ablation by Er:YAG laser. J Prosthet Dent 1992;67:847-851.
13. Matsumoto K, Nakamura Y, Mazeki K, Kimura Y. Clinical dental application of Er:YAG laser for class V cavity preparation. J Clin Laser Med Surg 1996;14:123-127.
14. Aoki A, Ishikawa I, Yamada T, Otsuki M, Watanabe H, Tagami J, Ando Y, Yamamoto H. Comparison between Er:YAG laser and conventional technique for root caries treatment in vitro. J Dent Res 1977,6:1404-1414.
15. Armengol V, Jean A, Marion D. Temperature rise during Er:YAG and Nd:YAG laser ablation of dentin. J Endod 2000;26:138-141.
16. Kato J, Moriya K, Jayawardena JA, Wijeyeweera RL. Clinical application of Er:YAG laser for cavity preparation in children. J Clin Laser Med Surg 2003;21:151-155.
17. Attrill CC, Davies RM, King TA, Dickinson MR, Blinkhorn SA. Thermal effects of the Er:YAG laser on a simulated dental pulp: A quantitative evaluation of the effects of a water spray. J Dent 2004;32:35-40.
18. Paghdiwala AF, Vaidyanathan TK, Paghdiwala MF. Evaluation of Er:YAG laser radiation of hard tissues: Analysis of temperature changes, depth of cuts, and structural effects. Scanning Microsc 1993;7:989-997.
19. Monghini EM, Wanderley RL, Pecora JD, Palma Dibb RG, Corona SA, Borsatto MC. Bond strength to dentin of primary teeth irradiated with varying Er:YAG laser energies and SEM examination of the surface morphology. Lasers Surg Med. 2004;34:254-259.
20. Sekine Y, Ebihara A, Takeda A, Suda H. Erbium:YAG laser application to cavity preparation: Light microscopy investigation of tooth pulp. Proc 4th Int Congr Laser Dent 1994;167-171.
21. Giusti J, Santos-Pinto L, Lizarelli R, Bagnato V. Ablation rates and morphological patterns of deciduous tooth enamel after Er:YAG laser irradiation: An in vitro study. J Oral Laser Appl 2002;2:1-6.
22. Wanderley RL, Monghini EM, Pecora JD, Palma-Dibb RG, Borsatto MC. Shear bond strength to enamel of primary teeth irradiated with varying Er:YAG laser energies and SEM examination of the surface morphology: An in vitro study. Photomed Laser Surg 2005;23:260-267.
23. Takamori K. A histopathological and immunohistochemical study of dental pulp and pulpal nerve fibers in rats after the cavity preparation using Er:YAG laser. J Endod 2000;26:95-99.

24. Kohara EK, Hossain M, Kimura Y, Matsumoto K, Inoue M, Sasa R. Morphological and microleakage studies of the cavities prepared by Er:YAG laser irradiation in primary teeth. J Clin Laser Med Surg 2002;20:141-147.
25. Stiesch-Scholz M, Hannig M. In vitro study of enamel and dentin marginal integrity of composite and composer restorations placed in primary teeth after diamond or Er:YAG laser cavity preparation. J Adhes Dent 2000;2:213-222.
26. Yamada Y, Hossain M, Nakamura Y, Murakami Y, Matsumoto K. Microleakage of composite resin restoration in cavities prepared by Er:YAG laser irradiation in primary teeth. Eur J Paediatr Dent 2002;3:39-45.
27. Cavalcanti BN, Lage-Marques JL, Rode SM. Pulpal temperature increases with Er:YAG laser and high seed handpieces. J Prosthet Dent 2003;90:447-451.
28. Glockner K, Rumpler J, Ebelesender K, Stadtler P. Intrapulpal temperature during preparation with the Er:YAG laser compared to the conventional burr: An in vitro study. J Clin Laser Med Surg 1998;16:153-157.
29. Geraldo-Martins VR, Tanji EY, Wetter NU, Nogueira RD, Eduardo CP. Intrapulpal temperature during preparation with the Er:YAG laser: An in vitro study. Photomed Laser Surg 2005;23:182-186.
30. Oelgiesser D, Blasbalg J, Ben-Amar A. Cavity preparation by Er:YAG laser on pulpal temperature rise. Am J Dent 2003;16:96-98.