Research, Society and Development, v. 12, n. 8, e3912842834, 2023
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v12i8.42834

Analysis of intrapulpary temperature variation during the operative and restorative phase in human molars

Análise da variação de temperatura intrapulpar durante a fase operatória e restauradora em molares humanos

Análisis de la variación de la temperatura intrapulpar durante la fase operatoria y restauradora en molares humanos

Received: 07/26/2023 | Revised: 08/08/2023 | Accepted: 08/09/2023 | Published: 08/12/2023

Ítalo Cardoso de Carvalho
ORCID: https://orcid.org/0000-0001-7404-9825
São Paulo State University, Brazil
E-mail: italo.carvalho@unesp.br
Flávia Guimarães de Oliveira
ORCID: https://orcid.org/0009-0002-7003-0929
University Center of Volta Redonda, Brazil
E-mail: fguimaraes.o@hotmail.com
Ana Paula de Almeida Gomes
ORCID: https://orcid.org/0000-0001-8581-3358
São Paulo State University, Brazil
E-mail: ana.p.gomes@unesp.br
Camila Gobbi de Carvalho Barbosa
ORCID: https://orcid.org/0000-0001-9825-2449
São Paulo State University, Brazil
E-mail: camila.gobbi@unesp.br
Luis Felipe Abbado de Souza
ORCID: https://orcid.org/0000-0002-9872-9566
São Paulo State University, Brazil
E-mail: felipe.abbado@unesp.br
Tereza Cristina Favieri de Melo-Silva
ORCID: https://orcid.org/0000-0001-5309-7190
University Center of Volta Redonda, Brazil
E-mail: terezafavieri@gmail.com
Cláudio Luis de Melo-Silva
ORCID: https://orcid.org/0000-0001-5093-2189
University Center of Volta Redonda, Brazil
E-mail: claudiolmelo@hotmail.com

Abstract
The aim of this study was to analyze the intrapulpal temperature variation during the operative and restorative phase in human molars. This study was approved by the Research Ethics Committee, registration CAAE 43677521.6.0000.5237 and 24 samples were made from human molars divided into 2 groups, group 1 (n = 12) restored with Bulk Fill composite resin in a single increment and group 2 (n = 12) restored with conventional composite resin in two increments. The temperature was monitored and recorded with a Lutron Tm-902C digital thermostat device during preparation, adhesive system application and restoration. The mean temperature variation in ºC for cavity preparation was -2.07 ± 0.89, application of the adhesive system was 1.12 ± 0.65, restoration with Bulk Fill resin was 2.73 ± 0.72 and restoration with conventional resin was 1.94 ± 0.35. Thus, in the operative phase there was a decrease in temperature in both groups and in the restorative phase the Bulk Fill resin presented a higher temperature compared to conventional resin.
Keywords: Composite Resins; Polymerization; Temperature.

Resumo
Neste estudo, foi analisado a variação de temperatura intrapulpar durante a fase operatória e restauradora em molares humanos. Este estudo foi aprovado pelo Comitê de Ética em Pesquisa, registro CAAE 43677521.6.0000.5237. Foram confeccionadas 24 amostras a partir de molares humanos divididos em 2 grupos, o grupo 1 (n = 12) restaurados com resina Bulk Fill em incremento único e o grupo 2 (n = 12) restaurados com resina convencional em dois incrementos. A temperatura foi monitorada e registrada com aparelho termostato digital Lutron Tm-902C durante o preparo,

aplicação do sistema adesivo e restauração. A variação média de temperatura em ºC para o preparo cavitário foi de -2,07 ± 0,89, aplicação do sistema adesivo de 1,12 ± 0,65, restauração com resina Bulk Fill foi 2,73 ± 0,72 e restauração com resina convencional apresentando 1,94 ± 0,35. Neste estudo, concluiu-se que na fase operatória ocorreu uma diminuição da temperatura em ambos os grupos e na fase restauradora a resina Bulk Fill apresentou maior temperatura comparada à resina convencional.
Palavras-chave: Resinas Compostas; Polimerização; Temperatura.

Resumen
En este estudio se analizó la variación de la temperatura intrapulpar durante la fase operatoria y restauradora en molares humanos. Este estudio fue aprobado por el Comité de Ética en Investigación, registro CAAE 43677521.6.0000.5237. Se realizaron 24 muestras de molares humanos divididos en 2 grupos, grupo 1 (n = 12) restaurados con resina Bulk Fill en un solo incremento y grupo 2 (n = 12) restaurados con resina convencional en dos incrementos. La temperatura fue monitoreada y registrada con un termostato digital Lutron Tm-902C durante la preparación, aplicación del sistema adhesivo y restauración. La variación de temperatura promedio en oC para la preparación cavitaria fue -2,07 ± 0,89, aplicación del sistema adhesivo 1,12 ± 0,65, restauración con resina Bulk Fill fue 2,73 ± 0,72 y restauración con resina convencional presentando 1,94 ± 0,35. En este estudio se concluyó que en la fase operatoria hubo disminución de la temperatura en ambos grupos y en la fase restauradora la resina Bulk Fill presentó una temperatura superior a la resina convencional.
Palabras clave: Resinas Compuestas; Polimerización; Temperatura.

1. Introduction

Current dentistry aims to preserve pulpal health. During the restorative stage, biological, physical and chemical factors affect the pulp. In deep cavities, the thickness of the remaining dentin is smaller, making it easier for external factors to alter the pulp tissue (Savas et al, 2014).

Different dental procedures can lead to warming of the pulp tissue. This occurs in the exothermic reaction of the photopolymerization of the composite resin, the adhesive system and in the making of the cavitary preparation through the rotating instruments and drills (Braga, 2017; Brito et al., 2017).

The pulp is formed by highly innervated and vascularized connective tissue. The increase in temperature from the operative and restorative phases can be quite aggressive causing damage to the pulp organ, since it has low recovery capacity because it is surrounded by dentin and its vascular supply is only through the orifice of the apex of the dental root (Oliveira et al., 2009; Ramagem, 2018).

Currently, the concern of dentists to maintain biological structures and their functions has been widely used. This gave rise to minimally invasive dentistry. This technique preserves a greater amount of dentin tissue, invading only what is necessary during the removal of carious tissue and in the preparation of cavitary, preserving a greater structure of dental support (Raucci Neto, 2009; Magalhães et al., 2017; Silva Neto et al., 2021).

The drills are effective during preparation, however if they are used incorrectly can harm the pulp irreversibly because, in addition to vibration, it generates a large amount of heat that results in postoperative sensitivity and even pulp death (Oliveira et al., 2009).

Composite resins have undergone major improvements in recent years, along with photopolymerizers and their techniques for activating composites (Awliya, 2007). Chosen in most of cases for tooth restoration, composite resins have the disadvantage of releasing heat during polymerization (Hernandez & Bonilla, 2016). The act of polymerizing a composite resin is a thermophysical method well known among dentists for being present in numerous procedures of their clinical routine. Polymerization is a reaction that occurs through the covalent bond of resinous monomers where they will be converted into polymers. It is essential that the wavelength in blue color (465 to 470 nm) of the device is reaching the photoinitiator present in the resin composed, in its majority, the camphoroquinone (Martins, 2016).

In the market there are photopolymerizers with different powers and some release a lot of heat, which can cause damage to the pulp of vital teeth (Baratieri, 2010; Brandão & Machado, 2019). The intensity of the light increases the characteristic stresses of the polymerization contraction of the composite resin and produces thermal energy that will dissipate in the dental element, raising the intrapulp temperature (Ramagem, 2018; Martins, 2016; Andreatta, 2015).

2. Methodology

2.1 Ethical aspects

Considering that human teeth were used throughout the study, a research project was previously submitted to the ethics committee before the execution of the experiment. Being approved on March 18, 2021, with CAAE number 43677521.6.0000.5237.

2.2 Experimental design

The project was designed and written considering the recommendations proposed by the CRIS guide (Checklist for Reporting In-vitro Studies) (Krithikadatta et al., 2014). The in vitro study followed a prospective and parallel model with the experimental factors (2 x 3): restorative material [in 2 levels: composite resin Bulk Fill (Filtek One Bulk Fill – FBF) and conventional composite resin (Filtek Z350XT – FXT); and operative phase [in 3 levels: cavity preparation, application of adhesive system and restoration]. The experimental unit was the pulp temperature and response variables was evaluated: temperature variations during the operative and restorative phases.

The primary outcome was the temperature variation during the cavity preparation and as secondary outcomes, the temperature variation during the application of adhesive system and restoration was evaluated. Table 1 describes the composition of materials, according to the manufacturers.

Table 1 – Materials used in the present study according to the “safety data sheet” of each material.

Trade name	Classification	Composition	Maker
Filtek One	Direct Composite Bulk Fill	Silane Treated 60 – 70 %; Aromatic Urethane Dimethacrylate 10 – 20 %; Diurethane Dimethacrylate (UDMA) 1 – 10 %; Silane Treated Silica 1 – 10 %; Ytterbium Fluoride (YbF3) 1-10 %	3M ESPE, Sumaré, São Paulo, Brazil
Filtek Z350XT	Conventional nanoparticulate composite resin	60-80% silane treated ceramics; 1-10% Bis-GMA; 1-10% UDMA; 1-10% BISEMA-6; <5% PEGDMA; <1% Triethylene glycol dimethacrylate.	3M ESPE, Sumaré, São Paulo, Brazil
Ambar Universal APS	Universal adhesive system	Bis-GMA; HEMA; TEGDMA and Water	FGM Dental Group, Joinville, Brazil

Source: Manufacturer.

2.3 Sample calculation

The sample calculation was based on the primary outcome of the study (temperature variation during the cavity preparation) and performed at G*Power software (Faul, 2007). The ANOVA test of repeated measures within-between interactions was selected, family F. With an effect size of 0.359, power of 80%, significance level of 5%, and considering the number of experimental groups (total of 2 groups), as well as the times of measurements that would be performed (3 moments), resulted in a minimum total sample size of 16.

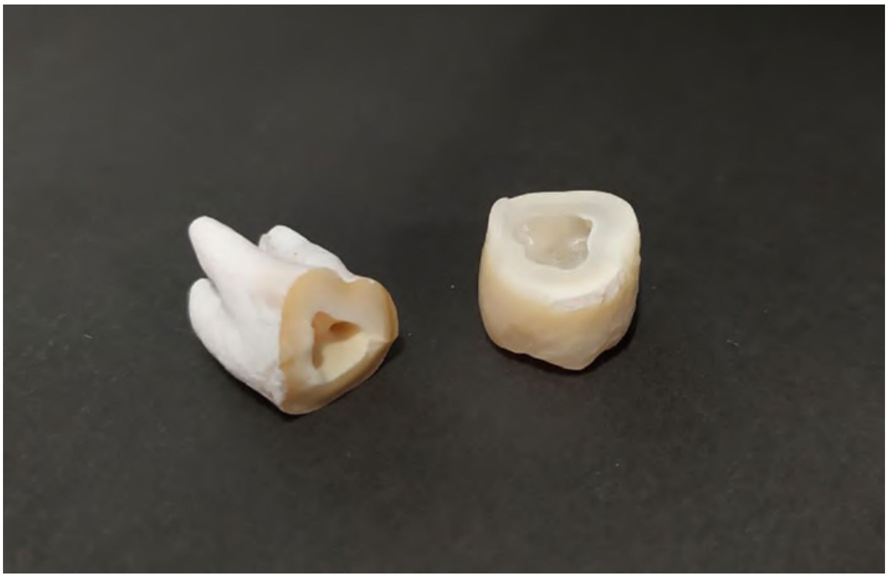
2.4 Sample preparation

Initially, 24 healthy permanent human molars were sectioned in the cervical third of the root with IsoMet 1000 – Buehler (Figure 1), removing the furca region and exposing the pulp tree as shown in Figure 2.

Figure 1 – IsoMet 1000.

Source: Authors.

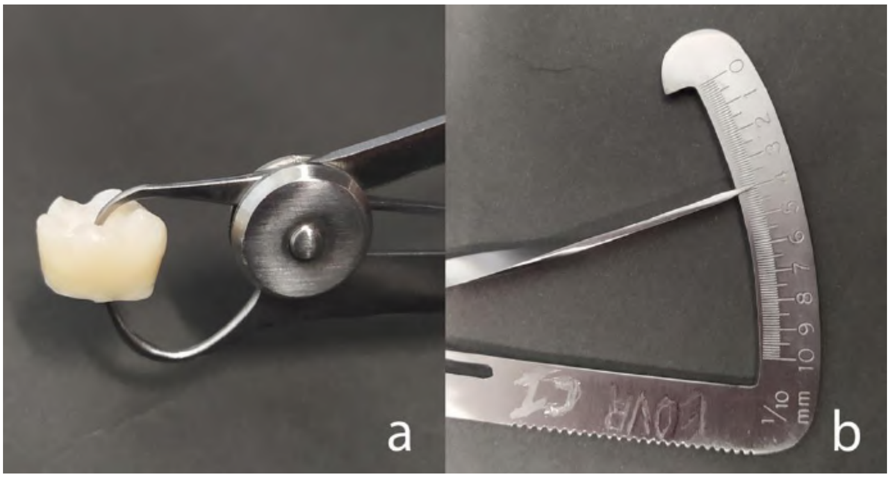
Figure 2 – Tooth sectioned.



Source: Authors.

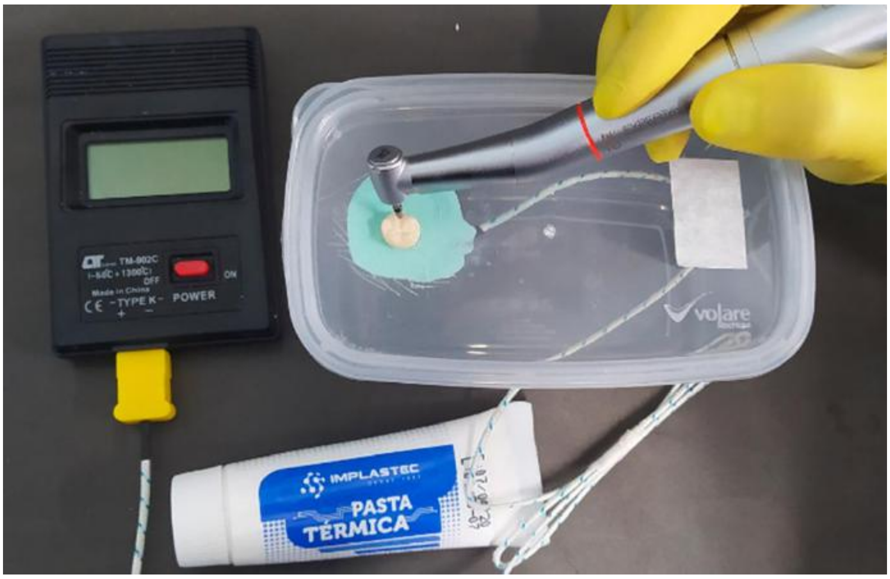
With the specimeter, the coronary portion (enamel and dentin) was measured at the deepest point of the main sulcus to the roof of the pulp chamber of the samples (Figure 3) and as inclusion criteria those that presented values of 4.0 ± 0.5 mm was selected. Then, the groups were divided into two groups (n=12). Therefore, Figure 4 shows the apparatus assembled to perform the temperature test, with the specimens fixed in a plastic container whose lid has been previously perforated. To make it possible to monitor the temperature constantly, the sensor of the digital thermometer (Tm-902C – Lutron, Pennsylvania, USA) was inserted into the pulp chamber surrounded by a material that allows heat dissipation throughout the pulp chamber (Thermal Paste – Implastec, São Paulo, Brazil). For the assembly to be sealed, the silicone by condensation reaction (Profile - Coltene, Altstätten, Switzerland) was used.

Figure 3 – Selection of teeth included in the study.



a) anddental thickness, b) 4mm specimeter. Source: Author.

Figure 4 – Apparatus for performing the temperature test.

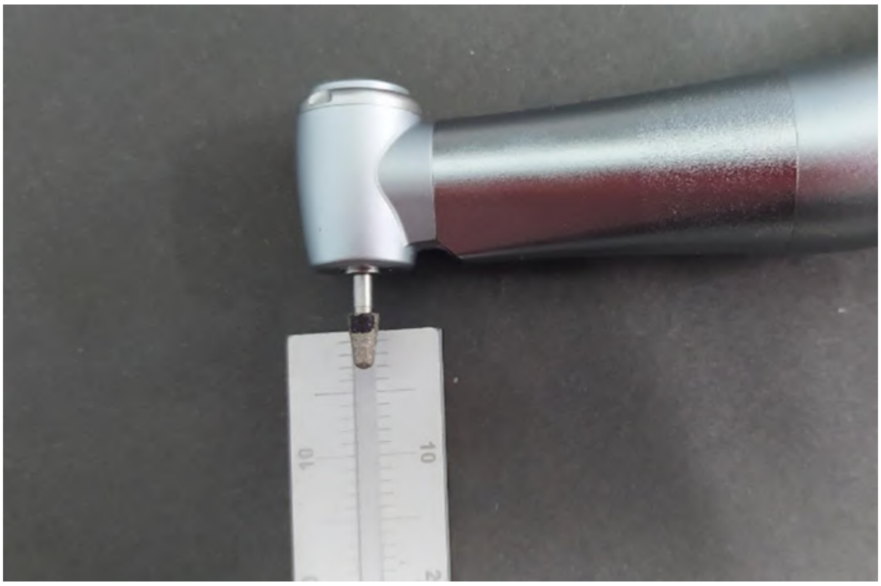


Source: Authors.

2.5 Cavity preparation

For the cavity preparation, an electric motor (ELECTROmatic – Kavo, Biberach an der Riß, Germany) configured at 40.000 rpm was used in conjunction with a diamond drill (#3131 – KG Sorensen, Serra, Brazil) marked with the aid of a 3.0 mm (Figure 5), respecting the measurement of 1 mm of dentin remaining for the samples. Black Class I preparations were performed under constant refrigeration until reaching the desired depth and the temperature was recorded before starting the preparation (P_0) and after its completion (P_1).

Figure 5 – Apparatus for performing the temperature test.



Source: Authors.

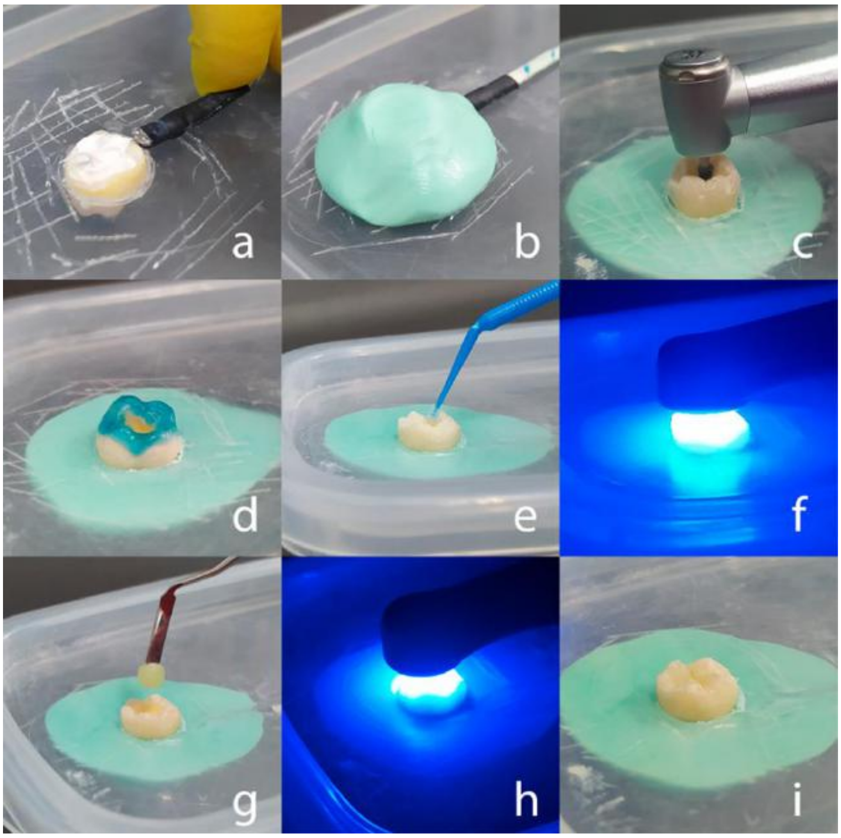
2.6 Application of adhesive system

After the cavitary preparation, the steps of the adhesive system were started making the selective conditioning of the enamel with phosphoric acid at 37% and recording the initial temperature (A0) after the tooth enamel drying stage. Then, the universal adhesive (Ambar – FGM, Joinville, Brazil) was applied in 2 layers with microbrush in an active way in the preparation. In the first and second layers, an air jet was applied at 30 cm from the tooth to volatilize the adhesive solvent, and only the second layer was photoactivated with a curing light (Valo Cordless – Ultradent, Indaiatuba, Brazil) for 20 seconds (1000 mW/cm^2) and recorded the temperature peak reached (A_1).

2.7 Restoration

For restoration, the composites presented in Table 1 were used. FBF group was restored by the single increment technique and the initial temperature of the restoration (R_0) was recorded, the composite inserted into the cavity by means of a suprafill spatula followed by photopolymerization with a curing light (1000 mW/cm^2) for 40 seconds and recorded at the final temperature peak (R_1). The conventional resin, by the incremental technique, was used for restoration of FXT group. The temperature at R_0 was recorded before inserting the first increment into the cavity. Soon after, the first layer of the resin was inserted to the middle of the cavity (1.5 mm), and it was polymerized for 20 seconds recording the value of R1. Next, the second increment of the conventional resin was inserted and polymerized for another 20 seconds and thus the maximum of the final temperature reached (R_2) was recorded. Figure 6 shows the stages of the operative and restorative phases. Where the difference between FBF FXT groups lies in the technique selected to insert the resin into the cavity and in the number of consecutive photoactivations.

Figure 6 – Study sequence of temperature test.



a) Thermostat insertion, b) pulp chamber sealing, c) preparation, d) selective conditioning, e) adhesive system, f) photopolymerization, g) resin insertion and, h) photopolymerization (only FXT group), i) finished restoration. Source: Authors.

2.8 Statistical analysis

Data for each response variable was submitted to the Shapiro-Wilk and Levane tests, indicating homogeneity and normality ($p>0,05$). Thus, submitted to analysis of variance ANOVA for repeated measures and Tukey's post hoc test of multiple comparisons (α= 5%) for detect any significant differences among the groups.

3. Results

In the course of the study, through statistical analysis, it was found that the mean temperature of the final preparation (P_1 = 20.64 ºC) decreased in relation to the initial preparation (P_0 = 22.72 ºC), as shown in the Table 2, therefore A>B.

Table 2 – Mean, standard deviation, statistical analysis (equal letters, equal values) of the temperature variation of the preparation ($p<0.001$).

Time	Mean ºC	Standart deviation (SD)
P_0	22.72 A	0.69
P_1	20.64 B	0.89
Δ_p	-2.07	0.89
n	24	24

Source: Authors.

It is important to note that there was a decrease in pulp temperature during the operative phase of the cavity preparation, since the cooling of the high-speed engine was present. This cooling effect is consistent with the general understanding that such instruments dissipate heat and prevent substantial temperature elevations within the pulp chamber (Farah, 2018).

Table 3 shows the results regarding the mean temperature recorded during the application of the adhesive system. In this research, the mean initial temperature of the application of the adhesive system was A_0 = 20.64 ºC and A_1 = 21.77 ºC, with a variation of 1.12 ± 0.65 ºC at the time of application and photoactivation of the adhesive system.

Table 3 – Mean, standard deviation, statistical analysis (equal letters, equal values) of the temperature variation of the application and photoactivation of the adhesive ($p<0.001$).

Time	Mean ºC	Standart deviation (SD)
A_0	20.64 A	0.91
A_1	21.77 B	0.65
Δ_a	1.12	0.65
n	24	24

Source: Author.

In the case of application of the adhesive system, because it is a thin layer, despite the depth of application, there was a slight increase in temperature with a low variation between the initial and final time of this stage.

Table 4 presents the mean temperature values of the restoration with a bulk fill composite (FBF group) while Table 5, the values for the conventional resin (FXT group). Thus, it was verified in Table 4 that the mean temperature in R_0 was 21.74 ºC and in R_2 was 24.47 ºC. Therefore, there was an increase in temperature (2.73 ± 0.72 ºC) at the time of photoactivation of the composite. In Table 5, the variation in temperature was 1.94 ± 0.35 ºC, being R_0 = 21.84 ºC and R_2 = 23.78 ºC. In this sense, there was increasing warming in the polymerization steps of the two increments.

Table 4 – Mean, standard deviation, statistical analysis (equal letters, equal values) of the temperature variation of the restoration with FBF ($p<0.001$).

Time	Mean ºC	Standart deviation (SD)
R_0	21.74 A	1.12
R_1	24.47 B	1.59
Δ_r	2.73	0.72
n	12	12

Source: Authors.

Table 5 – Mean, standard deviation, statistical analysis (equal letters, equal values) of the temperature variation of the restoration with FXT (p<0.001).

Time	Mean ºC	Standart deviation (SD)
R_0	21.84 A	0.74
R_1	22.97 B	0.76
R_2	23.78 C	0.70
Δ_r	1.94	0.35
n	12	12

Source: Authors.

The difference between the two Tables 4 and 5 lies in the intermediate photopolymerization of the FXT group, since it is a conventional composite resin where it is known that increments of up to 2 mm do not negatively interfere with the longevity of the restoration considering the cavity configuration factor (Factor C) and inherent polymerization shrinkage.

The comparison between the mean values obtained in the restoration with the FBF group and the FXT group is shown in Table 6. Even going through two polymerization steps due to the incremental technique, the conventional resin (1.94 ± 0.35 ºC) showed a lower temperature variation compared to the Bulk Fill resin (2.73 ± 0.72 ºC) of single polymerization, presenting 0.79 ºC of difference between the composites.

Table 6 – Mean, standard deviation and comparative analysis (p<0.001) between FBF x FXT in ºC (equal letters, equal values).

Time	FBF Group	FXT Group
R_0	21.74±1.12 A	21.84±0.74 A
R_f	24.47±1.59 B	23.78±0.70 B
Δ_r	2.73±0.72 a	1.94±0.35 b
n	12	12

Source: Authors.

Table 6 presents a comparative analysis between the FBF and FXT groups regarding the means and standard deviations of temperatures in ºC. The results reveal significant differences with a significance level of p<0.001. Equal letters indicate statistically similar values. It can be observed that at the beginning of the experiment (R_0), there was no significant difference in the average temperatures between the FBF group (21.74±1.12 ºC) and the FXT group (21.84±0.74 ºC), both labeled as "A". The temperature variation (Δ_r) was distinct between the groups, with FBF ("a") showing a greater variation compared to FXT, labeled as "b". These findings suggest that the FBF and FXT groups may have differing responses to temperature changes throughout the experiment. The sample size was consistent in both groups, with n=12. These findings contribute to understanding the thermal responses of these groups in a specific context.

4. Discussion

The temperature difference in preparation (-2.07 ± 0.89 ºC) reaffirms the importance of using the cooling system of dental engines to avoid excessive temperature increase (Britto et al., 2018). Depending on the intensity of the aggression will result in different pulp responses, whether it is mild, moderate inflammation or necrosis (Oliveira et al., 2009). The pulp organ presents reversible response under a temperature variation of 2.77 ºC, while temperatures above 5.55 ºC occur loss of pulp vitality (Zach & Cohen, 1965).

In the context of thermal elevation within the pulp chamber, it was observed that the irradiance intensity from the light-curing unit emerged as a predominant factor compared to the exothermic reaction of bulk-fill resins. Even in the presence of an exothermic polymerization reaction, the bulk-fill resins demonstrated insulating properties when exposed to the irradiance from the light-curing unit. Concerning direct pulp capping procedures, a strategy involving a reduction in the number of light activations is recommended to alleviate the period during which the intrapulpal temperature exceeds the 10 degree Celsius threshold. This strategic approach holds the potential to contribute to pulp health promotion within clinical interventions (Nilsen et al., 2020; Oliveira et al., 2022).

The temperature variation found in this study did not have the potential to cause any serious aggression to the pulp (Aranha et al.,2011). Furthermore, a way to reduce the pulp temperature during the application of the adhesive system is through the simulated pulp pressure during photoactivation of the adhesive system (Da Silva et al., 2017).

In the present work it was established that the light emitted, and the thickness of the remaining dentin is directly related to the elevation of the temperature within the pulp organ (Savaris, 2008), where there is a direct relationship between temperature variation, type of light used, thickness of remaining dentin and amount of consecutive photoactivation.

In order to avoid failures in photopolymerizing devices, it is of paramount importance for Dentists to be up to date in relation to the maintenance of their photopolymerizing devices and choose the most appropriate technique for each case (Brandão & Machado, 2019).

5. Conclusion

Based on the results obtained in the present study, it is concluded that during the operative phase there is a decrease in temperature due to the cooling of the rotation instrument. However, the elements restored with Bulk Fill resin presented higher temperature values than the sample restored with conventional resin, although the temperature variations remained within safe limits, this difference suggests that Bulk Fill resin may have a potential to induce reversible pulp reactions. Drawing from the results, it is suggested to investigate the long-term effects of temperature variations in dental restorations, explore the mechanisms behind temperature differences among resins, assess the clinical impact of these variations, and develop enhanced cooling strategies.

References

Andreatta, L. M. L. (2015). *Variação da temperatura no interior da câmara pulpar em função de diferentes fontes de luz e camada de resina composta*. In Vitro. 2015. 127p. Dissertação (Mestrado) – Faculdade de Odontologia de Bauru, Universidade de São Paulo, Bauru.

Aranha, V. M. S., Silva-Concilio, L. R., Neves, A. C. C., Barcellos, D. C., & Rode, S. M. (2011). Comparação da variação da temperatura produzida por dois tipos de instrumentos cortantes rotatórios diamantados no preparo cavitário. *Braz Dent Sci*, 14 (3/4), 38-41. https://doi.org/10.14295/bds.2011.v14i3/4.753

Awliya, W. Y. (2007). The influence of temperature on the efficacy of polymerization of composite resin. *The Journal of Contemporany Dental Practice*, 8(6), 9 -16. https://thejcdp.com/doi/JCDP/pdf/10.5005/jcdp-8-6-9

Baratieri, L. N. et al. 2010. *Odontologia restauradora* - fundamentos & técnicas. Santos: Editora GEN.

Braga, S. S. L. (2017). *Efeito da microcirculação pulpar simulada e fontes fotoativadoras na geração de calor na câmara pulpar durante restaurações bulkfill*. 70p. Dissertação (Mestrado) – Faculdade de Odontologia, Universidade Federal da Uberlândia, Uberlândia

Brandão, J. M. S. F., & Machado, I. (2019). *Fotopolimerizadores uma ferramenta fundamental para os cirurgiões dentistas*. 6p. Trabalho de Conclusão de Curso (Graduação em Odontologia) – Centro Universitário do Planalto Central Apparecido dos Santos, Faculdade de Odontologia, Brasília.

Britto, B. A. L., Reis, J. A. B., Prado, J. P., Silva, I. S. N., & Soares, A. F. (2018). Avaliação da variação de temperatura com uso de fontes externa: revisão bibliográfica. *Id on Line. Revista Multidisciplinar e de Psicologia*, 12(42), 969- 83.doi: https://doi.org/10.14295/idonline.v12i42.1388

Da Silva, T.M., Gonçalves, L.L., Siqueira, E.P., Pereira, T.C., Pontes, S., O., Grecca, A.R., Lopes, S. R., & Gonçalves, S.E.P. (2017). Influence of simulated pulpal pressure on the variation of intrapulpal temperature during adhesive system light-curing. *Braz Dent Sci*, 20(2), 55–61. 10.14295/bds.2017.v20i2.1409.

Farah R. I. (2018). Effect of cooling water temperature on the temperature changes in pulp chamber and at handpiece head during high-speed tooth preparation. *Restorative dentistry & endodontics*, 44(1), 3. https://doi.org/10.5395/rde.2019.44.e3

Faul, F., Erdfelder, E., Lang, A-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*, 39(2), 175–91. 10.3758/BF03193146.

Hernandez, D. J., & Bonilla, S. (2016). Aumento de la temperatura en la superfificie dental durante la foto-polimerización. *Odontología Vital*, 2(25), 17-22. https://www.scielo.sa.cr/scielo.php?script=sci_arttext&pid=S1659-07752016000200017

Krithikadatta, J., Gopikrishna, V., & Datta, M. (2014). CRIS Guidelines (Checklist for Reporting In-vitro Studies): A concept note on the need for standardized guidelines for improving quality and transparency in reporting in-vitro studies in experimental dental research. *J Conserv Dent*, 17(4), 301-04. 10.4103/0972-0707.136338.

Savas, S., Botsali, M. S., Kucukyilmaz, E., & Sari, T. (2014). Evaluation of temperature changes in the pulp chamber during polymerization of light-cured pulp-capping materials by using a VALO LED light curing unit at different curing distances. *Dental materials journal*, 33(6), 764–769. https://doi.org/10.4012/dmj.2013-274

Magalhães, G. A. P., Araújo Neto, V. G., Costa, E. O., & Carneiro, S. V. (2017). Perspectiva de acadêmicos e cirurgiões-dentistas frente à conduta de lesões cariosas profundas em dentes decíduos. *Jornada Odontológica dos Acadêmicos da Católica*, 3(1). http://reservas.fcrs.edu.br/index.php/joac/article/view/1701

Martins, M. I. T. (2016). *Variação da temperatura durante a fotopolimerização de novas resinas bulk-fill*. 107p. Dissertação (Mestrado) – Instituto superior de ciências da saúde Egas Moniz, Almada.

Nilsen, B. W., Mouhat, M., Haukland, T., Örtengren, U. T., & Mercer, J. B. (2020). Heat Development in the Pulp Chamber During Curing Process of Resin-Based Composite Using Multi-Wave LED Light Curing Unit. *Clinical, cosmetic and investigational dentistry*, 12, 271–280. https://doi.org/10.2147/CCIDE.S257450

Oliveira, D., Rocha, M. G., Zoidis, P., Pereira, P., & Ribeiro, A. P. (2022). The effect of different pulp capping methods on the intrapulpal temperature when using light-cured procedures. *Journal of clinical and experimental dentistry*, 14(8), 633–638. https://doi.org/10.4317/jced.59779

Oliveira, M. A. V. C., Biffi, J. C. G., & Dechichi, P. (2009). CVD (Chemical Vapor Deposition) – solução para controle de temperatura durante preparo cavitário? *Revista de Odontologia da UNESP*, 38(6), 363-69. Disponível em: https://www.revodontolunesp.com.br/article/588018a77f8c9d0a098b4d5b

Ramagem, M. M. (2018). *Influência da fotopolimerização com aparelhos led na indução de estresse térmico sobre cultura de células*. 55p. Dissertação (Mestrado) – Faculdade de Ciências da Saúde, Universidade de Brasília, Brasília.

Raucci Neto, W. (2009). *Análise da alteração de temperatura no preparo cavitário e eficiência na remoção de tecido cariado com laser ER:YAG*. 82p. Dissertação (Mestrado) – Faculdade de Odontologia, Universidade de São Paulo, Ribeirão Preto.

Savaris, C. (2008). *Alteração de temperatura na dentina durante o procedimento restaurador com resina composta variando as fontes fotopolimerizadoras*. 64p. Dissertação (Mestrado) – Faculdade de Odontologia de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto.

Silva Neto, J. M. A., Agra, L. A. C., Luz, M. C. M., Souza, S. V. P., Santos, J. V., & Mendonça, I. C. G. (2021). Os avanços da odontologia minimamente invasiva nos dias atuais. *Revista Eletrônica Acervo Saúde*, 13(2), 1-7. https://doi.org/10.25248/reas.e6267.2021

Zach, L., & Cohen, G. (1965). Pulp response to externally applied heat. *Oral Surgery, Oral Medicine, Oral Pathology*,.19, 515–30. 10.1016/0030-4220(65)90015-0.