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The comparative evaluation of temperature changes on the external root surface during the application of different obturation techniques

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Purpose: The present research aimed to examine the possibility of damage to tooth support tissues induced by temperature changes on the external root surface while applying different obturation techniques.

Methods: One hundred fifty mandibular premolar teeth were prepared using a ProTaper Next nickel-titanium rotary file system. After the preparation, the distance between the inner dentin and the external cementum was measured at nine points with cone-beam computed tomography. Then, 100 teeth with the closest dentin thickness were included in the study. The teeth were randomly divided into five groups: cold lateral condensation, warm vertical condensation, continuous-wave obturation, thermoplastic injection, and carrier-based obturation techniques. Temperature changes were measured from the external root surface with the degree of intraoral temperature while applying obturation techniques.

Results: The warm vertical condensation technique caused the highest temperature increases statistically, and the lowest temperature increases were detected while applying the cold lateral condensation and carrier-based obturation techniques.

Conclusion: Consequently, obturation techniques may be safely preferred in terms of temperature increases that may cause damage to supporting tissues.

Keywords: Cone-beam computed tomography; dentin thickness; obturation techniques; temperature increases; warm gutta-percha.

Introduction

Endodontic treatment first aims to completely disinfect the root canal system from infected and necrotic tissue remnants and obturate it hermetically with a stable and biocompatible filling material that prevents microorganism migration (1,2).

The root canal system has a complex structure characterized by irregular dentin canals, accessory canals, transverse anastomoses, and apical deltas. Such a complex structure makes it difficult to obtain an impermeable root canal filling by chemomechanical preparation and subsequent root canal filling techniques (1,3). In this regard, it has been reported that approximately 58% of failures in endodontic

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treatment are caused by the inability to fill the root canal system in an ideally homogeneous way (4).

Various techniques have been tried to achieve a three-dimensional hermetic root canal filling. Nowadays, the cold lateral condensation technique is preferred the most among conventional root canal filling techniques (5,6). Controlled obturation of gutta-percha while maintaining shape integrity is an important advantage of the aforesaid technique. However, it has been stated that the gutta-percha used in this technique has disadvantages, such as insufficient adaptation to root canal irregularities, the inability to adequately fill accessory canals, and the formation of gaps that may cause leakage during root canal filling (3,7-10). Therefore, new techniques that ensure hermetic filling of root canals with thermoplastic gutta-percha have been developed (11,12).

However, it should be remembered that these techniques, which provide numerous advantages in the success of root canal treatment, may also have some undesirable negative consequences during application. Possible temperature changes along the root canal walls during obturation are among the most important points regarding the safe application of obturation techniques with warm gutta-percha filling techniques.

It has been reported that warm gutta-percha root canal filling techniques may cause tissue damage due to the transfer to the periodontal tissues and alveolar bone (13). It is accepted that a 10 ˚C temperature increase above normal body temperature may cause irreversible damage to the tooth support tissues (14). A study revealed that a temperature of 56 ˚C causes the denaturation of alkaline phosphatases and leads to the onset of bone damage (15).

In light of this information, it is known that the temperature changes revealed while applying the warm gutta-percha technique are critical for the long-term success of endodontic treatment. The present research aimed to investigate the temperature changes measured while applying obturation techniques with thermocouples fixed to the external root surface. The hypothesis is that temperature changes on the external surface of the root during the application of different obturation techniques would not have a damaging effect on periodontal tissues.

Materials and Methods

Sivas Cumhuriyet University Non-Interventional Research Ethics Committee approved this study with the decision numbered 2019-09/07 at the meeting held on 11.09.2019. In the current research, mandibular premolar human teeth with a single root and a single canal were used. Tooth extraction was performed due to periodontal disease, orthodontic, or prosthetic treatment planning. Periapical radiographs of 150 extracted teeth in the mesiodistal and buccolingual directions were taken. Roots with resorption, cracks, or open apices were excluded from the study.

Tooth crowns were removed with a diamond fissure bur (Diatech Dental AG, Heerbrugg, Switzerland) under water cooling with a root length of approximately 14-16 mm to ensure working length standardization. The working length was determined by retracting 1 mm from the distance at which the #10 K-file was seen from the apical foramen. The teeth were prepared with a ProTaper Next nickel-titanium (PTN, Dentsply Maillefer, Ballaigues, Switzerland) rotary file system. 2 ml of 5.25% NaOCl (Imicryl Dental, Konya, Turkey) was utilized at every file change during root canal preparation, whereas 10 ml of 17% EDTA (Imicryl Dental, Konya, Turkey) was utilized when the preparation was complete and followed by 10 ml of 2.5% NaOCl. As final irrigation, the root canals were irrigated with 10 ml of distilled water and dried with paper points.

After the chemomechanical preparation, a standard silicon mold was prepared for evaluating dental cone-beam computer tomography (CBCT) (Rayscan Alpha, 12F, 221, Pangyoyeok-ro, Bunag-gu, Seongnam-si, Gyeonggi-do, Korea 13494). The teeth were embedded in the mold with the crowns up.

The tomography device with high resolution and image quality had a 10x10 cm FOV. Therefore, the diameter of our standard silicon mold was determined as 8 cm to remain within these values. The exposure dose was set at 10 mA-90 kVp.

The anatomic apex of each tooth was used as a reference point to determine the points where temperature measurements would be performed. Images were taken by CBCT and exported to the Carestream CS 3D Imaging Software (Atlanta, GA). This software was used for measuring distances between the inner dentin and the external cementum at 9 points in the horizontal section. These sections were obtained from the root's buccal, mesiolingual, and distolingual regions at 2, 7, and 12 mm levels toward the coronal section from the apex. One hundred teeth with the closest dentin thickness out of one hundred and fifty measured teeth were included in the study to standardize the measurements of temperature changes on the external root surface (Fig. 1) (Table 1).

The teeth were randomly divided into five groups with different root canal filling techniques, with 20 teeth in each group. The tooth root canals were filled using AH Plus (Dentsply, DeTrey, Konstanz, Germany). The experimental groups were as follows;

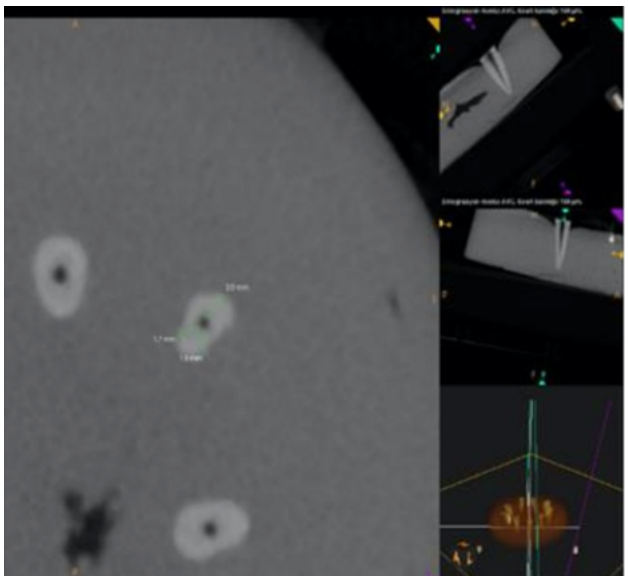

Fig. 1. Measuring the distances between inner dentin and outer cementum from a total of 9 points with CBCT.

Group 1: Cold Lateral Condensation Technique,

Group 2: Warm Vertical Condensation Technique,

Group 3: Continuous-Wave Obturation Technique,

Group 4: Thermoplastic Injection Technique,

Group 5: Carrier-Based Obturation Technique.

Group 1 (Cold Lateral Condensation Technique): The root canals were obturated by cold lateral condensation with #30/0.02 (Pearl-Endo, Pearl Dent Co. Ltd., Ho Chi Minh City, Vietnam) master cones and #15/0.02 (Pearl-Endo, Pearl Dent Co. Ltd., Ho Chi Minh City, Vietnam) auxiliary gutta-percha cones placed in the space opened with #20/0.02 (Golden Star Medical, Shenzhen, China) spreaders. Afterward, gutta-percha was condensed vertically in the coronal third region of the root canal with a suitable plugger type.

Group 2 (Warm Vertical Condensation Technique): A ProTaper Next X3 master cone (Dentsply Maillefer, Tulsa, OK, USA) was placed 1-2 mm from the apical foramen by feeling tug-back to prevent gutta-percha extrusion during condensation with the suitable pluggers. After this stage, the gutta-percha in the coronal 3-4 mm of the root canal was removed from the canal using a heat-carrying device, and vertical condensation was carried out using the pluggers sequentially. The root canal's remaining part was filled with heat application by transporting the gutta-percha pieces cut into 2-3 mm lengths into the root canal.

Group 3 (Continuous-Wave Obturation Technique): The root canals were obturated with the continuous-wave obturation technique using the Elements Free Obturation System (SybronEndo/Kerr Endodontics, Orange, CA, USA). A Buchanan heat plugger (SybronEndo/Kerr Endodontics, Orange, CA, USA), adjusted to be 5-7 mm behind the apical foramen, was selected and attached to the device's down-pack unit. A ProTaper Next X3 master cone (Dentsply Maillefer, Tulsa, OK, USA) was placed 1-2 mm from the apical foramen by feeling tug-back to prevent gutta-percha extrusion during condensation with the pluggers. The apical third was obturated by vertically condensing gutta-percha with the aid of the selected plugger at a constant temperature of 200 °C. Then, vertical condensation was carried out with a suitable cold hand plugger. The disposable gutta-percha cartridge attached to the device's backfill unit was activated with 200 °C heat, and the remaining space inside the root canal was filled with a thermoplastic injection of the warm gutta-percha.

Group 4 (Thermoplastic Injection Technique): The root canals were obturated with the thermoplastic injection technique using the backfill unit of the Elements Free Obturation System device. The tip of the disposable gutta-percha cartridge attached to the device's backfill unit was adjusted to be 3-5 mm shorter than the working length to prevent the uncontrolled extrusion of the molten gutta-percha from apical to periodontal tissues. After the device was operated and activated with a temperature of 200 °C, the cartridge's tip was placed at the predetermined working length, and root canal filling was completed with thermoplastic gutta-percha.

Group 5 (Carrier-Based Obturation Techniques): The root canals were obturated with the carrier-based obturation technique using the ThermaPrep 2 Oven (Dentsply Maillefer, Ballaigues, Switzerland) and ProTaper Next X3 guttacore (Dentsply Maillefer, Ballaigues, Switzerland). The ThermaPrep 2 Oven was brought to a temperature compatible with the ProTaper Next X3 guttacore. Following the light of the ThermaPrep 2 Oven warned that

Table 1. Dentin thickness of one hundred teeth imaged with CBCT according to regions mean and standard deviation values of measurements

n = 150	Buccal Mean ± SD	Mesiolingual Mean ± SD	Distolingual Mean ± SD
Dentin thickness	1.98 ± 0.60 mm	1.64 ± 0.60 mm	1.59 ± 0.54 mm

SD; standard deviation.

the heating process was completed, and the guttacore was placed in the root canal up to the reference point. Excess gutta-percha maintained above the root canal orifice was removed after 2-4 minutes by cutting with a diamond fissure bur.

Measuring Procedure to Detect Temperature Changes

In a Teflon model, 9 holes 1 mm in diameter were drilled at the points corresponding to the 9 points where the CBCT measurements of the teeth were made. K-type thermocouples with a diameter of 1 mm were placed through these holes, and their contact was provided on the tooth's root surface. All root canal filling techniques were performed in a temperature-adjustable water bath (Nüve BM402, Belgium) that can keep the water constant between 5 ˚C and 95 ˚C to imitate the intra-oral temperature. The reservoir of the water bath was filled with distilled water and kept constant at 37 ˚C (Fig. 2). In the present study, thermocouples were first connected to the E-680 series universal input-advanced scanner (Elimko, Emek, Ankara), a temperature-measuring device. Then, the thermocouples were used for temperature measurements during the root canal filling procedure. The temperature measurements obtained during the obturation procedures were recorded with the thermocouples fixed on the tooth's root surface at one-second intervals. One hundred teeth included in 5 groups were filled with different obturation techniques. The temperature increases at 9 different points of each tooth were measured during the procedure. Points T1, T4, and T7, located 2 mm coronal of the apical narrowing, were evaluated as the apical third; points T2, T5, and T8, located 7 mm coronal, were evaluated as the middle third; points T3, T6, and T9, located 12 mm coronal, were evaluated as the coronal third zone. A single value was obtained for each region by taking the average of the highest temperature increase measured by the three thermocouples in each region.

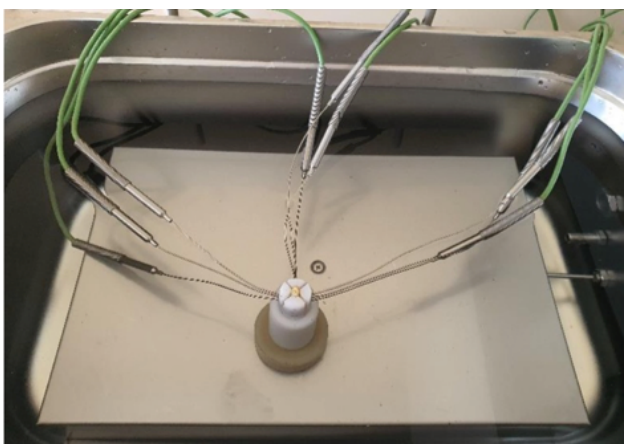

Fig. 2. 9 K-type thermocouple placement on the Teflon model in a 37 ˚C distilled water bath.

Statistical Analysis

The data acquired from the present research were evaluated with the SPSS 22.0 (SPSS Inc., Chicago, Illinois, ABD) package program. The normal distribution analysis of the variables was performed by the Kolmogorov-Smirnov and Shapiro-Wilk tests. Mean, standard deviation, and median values were utilized when presenting descriptive analysis. According to both tests performed to determine whether it had a normal distribution, it was observed that the variables in the apical, middle, and coronal third did not come from the normal distribution. Therefore, the analysis was continued with non-parametric tests. The Kruskal-Wallis H test was conducted to analyze the difference in the group means, and the Mann-Whitney U test was performed to determine which group differed when the difference in the means was statistically significant.

Results

The current study comparatively evaluated the temperature increases detected while applying the 5 obturation techniques. None of the experimental groups reached the critical value of 10 ˚C, the mean temperature increase.

The temperature increase values determined on the external root surface while applying obturation techniques are listed from the highest to the lowest as warm vertical condensation technique, continuous-wave obturation technique, thermoplastic injection technique, carrier-based obturation technique, and cold lateral condensation technique.

As a result, pairwise comparisons performed between the continuous-wave obturation and thermoplastic injection filling techniques, as well as the cold lateral condensation and carrier-based obturation techniques, showed no statistically significant difference ($p > 0.05$). While the warm vertical condensation technique caused the highest temperature increase, the lowest temperature increase values were determined in the cold lateral condensation and carrier-based obturation techniques among all study groups ($p < 0.05$) (Table 2).

Within the scope of the evaluation results performed in terms of root canal regions, the highest temperature increase in all groups was detected in the coronal third regions (Table 3).

Table 2. Temperature (˚C) increases were observed in all groups

Groups (n = 20)	Temperature ˚C	
	Mean ± SD	Median (min-max)
Cold Lateral Condensation Technique	0.27 ± 0.08[a]	0.24 (0.17-0.40)
Warm Vertical Condensation Technique	2.40 ± 0.29[b]	2.37 (1.76-3.21)
Continuous-Wave Obturation Technique	0.89 ± 0.39[c]	0.89 (0.28-1.83)
Thermoplastic Injection Technique	0.39 ± 0.16[c]	0.35 (0.16-0.78)
Carrier-Based Obturation Technique	0.27 ± 0.09[a]	0.26 (0.15-0.48)
p	< 0.001*	

SD; standard deviation. *Kruskal-Wallis. The different letters in each column indicate significant differences between the groups.

Table 3. Difference analysis of temperature (˚C) increases in apical, middle, and coronal third regions according to all groups

Groups (n = 20)	Apical third		Middle third		Coronal third	
	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)
Cold Lateral Condensation Technique	0.22 ± 0.10[a]	0.20 (0.10-0.47)	0.29 ± 0.12[a]	0.30 (0.10-0.60)	0.30 ± 0.13[a]	0.26 (0.13-0.60)
Warm Vertical Condensation Technique	1.57 ± 0.32[b]	1.58 (0.93-2.63)	2.41 ± 0.24[b]	2.35 (2.05-3.75)	3.23 ± 0.53[b]	3.16 (2.23-4.27)
Continuous-Wave Obturation	0.61 ± 0.25[c]	0.60 (0.20-1.20)	0.78 ± 0.45[c]	0.70 (0.20-1.40)	1.29 ± 0.63[a,c]	1.26 (0.33-3.0)
Thermoplastic Injection Technique	0.36 ± 0.16[c]	0.36 (0.13-0.63)	0.32 ± 0.10[a,c]	0.25 (0.15-0.45)	0.49 ± 0.37[a,c]	0.43 (0.13-1.67)
Carrier-Based Obturation Technique	0.24 ± 0.06[a]	0.23 (0.10-0.37)	0.23 ± 0.09[a]	0.20 (0.15-0.50)	0.34 ± 0.17[a]	0.31 (0.13-0.73)
p	<0.001*	<0.001*	<0.001*			

SD; standard deviation. *Kruskal-Wallis. The different letters in each column and row indicate significant differences between the groups. Vertical comparisons are symbolized by lower letters.

Discussion

It is essential to obturate the root canal system more hermetically to keep teeth functioning healthily for a longer time. Therefore, recent obturation techniques have become popular and widely used by clinicians. Filling root canals with warm gutta-percha techniques has led researchers to examine the possible temperature increase during root canal filling (16-19). Certain temperature increases that may occur during the mentioned obturation procedure can be absorbed and distributed by the dentin tissue surrounding the root canal system. This uncontrolled increase that can lead to undesirable complications may subsequently harm the cementum, periodontal ligament, and alveolar bone (19). The current research aimed to compare and evaluate the possibility of damage to support tissues by possible temperature increases on the external root surface while applying the current root canal filling techniques. The findings support the hypothesis that temperature changes occurring on the external surface of the root during the application of traditional and current obturation techniques do not damage periodontal tissues.

Since in vivo conditions were difficult to provide in the present and similar studies (20-22) and it was impossible to perform temperature measurements on the external root surface of the teeth, it was decided to conduct the present study using human teeth extracted in vitro. A study (23) where temperature measurements were performed while applying root canal filling techniques with the warm gutta-percha did not clarify that teeth should be placed in working blocks to imitate intraoral periodontal tissues. Few studies (24,25) were conducted under conditions suitable for the humidity and temperature of the oral environment. The above-mentioned studies evaluated temperature increases during the application of obturation techniques. Furthermore, the temperature of the environment was evaluated at 37 ˚C, which is the heat of the human body, for those studies (24,25). In the current study, temperature measurements were made in a water bath fixed at 37 ˚C, similar to the aforesaid studies, (24,25) by ensuring the full contact of the root surfaces with water to imitate the degree of the intraoral temperature. The teeth included in the current research were placed in a locked model made of Teflon, an insulating material, and were not embedded in any material, considering the research by Venturi et al. (25). In the present study, the thermocouples were fixed on the root surfaces of the teeth by passing them through the holes drilled according to their diameters in the Teflon model. The reason for exposing the root surfaces of the teeth without embedding them in

any material can be indicated as the desire to ensure the complete contact of the root's external surface and the thermocouple with the warm water adjusted at 37 ˚C.

White et al. (26) and Paghdiwala et al. (27) suggested that dentin thickness must be considered in temperature measurements and roots with a low dentin thickness were more prone to temperature increases. In the research by Lee et al. (20), root canal fillings were performed by softening gutta-percha with a System-B heat source, Touch'n Heat device (Analytic Technology, Redmond, WA, USA), and a flame-heated carrier. Temperature changes were measured 2 mm below the cementoenamel junction with K-type thermocouples. According to the results of that study, the highest temperature increase was observed in the mandibular incisors with the lowest dentin thickness. The lowest temperature increase was determined in the maxillary incisors with the highest dentin thickness. The highest temperature increase was detected in the group where the flame-heated carrier was used, whereas the lowest temperature increase was revealed in the group where the System-B heat source was used. Similar to the results of the above-mentioned study, (20) in the present study, dentin thickness plays an essential role in the effect of temperature increases in root canals on periodontal tissues. Therefore, in the current research, CBCT images were taken, and distances between the inner dentin and the external cementum were measured from 9 points of each tooth, and 100 teeth closest to each other formed the experimental groups to standardize the dentin thickness. Thus, more specific measurements can be performed by standardizing the effect of dentin thickness on the temperature increase effects of obturation systems. Similar to Lee et al. (20)'s study results, the current research found the highest temperature increase in the warm vertical condensation group, the technique in which gutta-percha is softened with the device heated in the flame. A lower temperature increase was determined in the continuous-wave obturation technique using the down pack unit of the Elements Free Obturation System, developed based on the System-B heat device. The reason for this temperature difference between the two groups can be explained by the inability to control the heat transmitted to the root canals with the instrument heated in the flame that is used in the warm vertical condensation technique. However, the heat source in the continuous-wave obturation technique constantly gives the same heat at 200 ˚C.

In the research by Hadis et al. (28), the temperatures of heat carriers were set as follows: the temperature of the E&Q Master (Meta Biomed Co., Chungcheongbuk-do, Korea) was set at 180 ˚C, the temperature of the E&Q Master was set at 230 ˚C, and the temperature of System B was set at 200 ˚C. The temperature changes created by these devices on the external root surface during root canal filling were measured with thermocouples placed 2, 8, and 12 mm coronally from the apical foramen. In all calculated temperatures, the highest temperature increase was observed in the coronal third, while the lowest increase was found in the middle third. In the present study, the down-pack unit of the Elements Free Obturation System set at 200 ˚C was used as the heat carrier. The thermocouples were placed at a distance of 2, 7, and 12 mm from the apical foramen, almost similar to the aforesaid study (28). Similar to the research by Hadis et al. (28), the reason for the highest temperature increase in the coronal third obtained from all experimental groups in our study can be interpreted as the fact that the highest amount of warm gutta-percha mass was found in this region due to the larger radius created by the flaring form.

A study by Donnermeyer et al. (29) evaluated the continuous-wave obturation, thermoplastic injection, carrier-based obturation using thermafil, and single-cone obturation techniques in terms of the temperature increase obtained from the root canals. Temperature measurements were performed with thermocouples placed in contact with the root canals at a distance of 3, 6, and 9 mm from the apex, and obturation procedures were carried out at 37 ˚C. In the above-mentioned study, the highest temperature increase among the 4 different techniques was observed in the continuous-wave obturation technique, followed by the thermoplastic injection, carrier-based obturation technique, and single-cone techniques (29). The findings of the aforesaid study are similar to the present study (29). The single-cone technique applied in the study mentioned above and the cold lateral condensation technique applied in our study can be reconciled since heat is not used in both during the application phase. The present study detected no significant difference in the temperature increase between the carrier-based obturation and cold lateral condensation techniques. The reason for this can be indicated as the fact that the heating of gutta-percha is not carried out in the root canals but in an external environment in a special oven and it cools down during transport to the root canal. Furthermore, the rate of gutta-percha covering the core of plastic carriers may be less than the rate applied in other thermoplastic gutta-percha techniques. Therefore, less warm gutta-percha can be found in the root canal in mass. This can be indicated as the reason why less temperature increase occurs in the root canal. Additionally, it was considered that the temperature difference between the groups might be due to differences in the stage of transfer of gutta-percha to the root canal in the root canal filling techniques applied. Al-

though there are studies in the literature evaluating the effect of carrier-based gutta percha obturation techniques using thermafil obturator on the temperature increase in root canals, there is no study using the guttacore obturator. The temperature increase values in this study, in which the Thermafil obturator was used, were found to be similar to our study. The reason for this can be interpreted as the presence of standard gutta percha on the outside of cuttacore and thermafil obturators and the application procedures of the method are the same. It is seen that gutta percha carriers in different materials do not affect the temperature increase.

Conclusion

Compared to the studies on temperature changes during root canal filling procedures in the literature, the current research provides more original clinical conditions reflection and reliable results. We believe that the findings acquired from this research will contribute significantly to dentists' preferences regarding clinical applications and the literature. Moreover, it is thought that current obturation systems, which are increasingly used in endodontic applications, can be used safely without damaging periodontal tissues.

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