박수진 석사학위논문

금 수복물과 자연치아의

구강 내 실시간 온도 변화 연구

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치의학과

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In vivo real-time temperature analysis

of natural tooth and gold inlay restoration

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이 논문을 박수진 석사학위논문으로 제출함

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1. 국문요약(국문초록)

요약(국문초록)

1. 목 적

치의학에서는 손상된 치아 경조직을 수복하기 위해서 다양한 종류의 수복재료를 사용하고 있다. 이러한 수복재료는 치아 경조직을 대체할 만큼 우수한 물성과 기계적 특성을 가져야 한다. 특히, 수복재료의 선택에 있어서 수복재료의 열적 특성은 중요한 고려사항이라고 할 수 있는데, 이는 인간이 생활하는 동안 인간의 구강 내로는 다양한 온도의 음식들이 유입되며 구강 내 온도가 시시각각 변화함에 따라서 구강 내 경조직은 그의 열팽창계수에 따라서 팽창 혹은 수축하게 된다. 따라서 구강 내에 사용되는 수복재료는 치아와 유사한 열팽창계수를 갖는 재료로 선택되어야 할 것이다.

현재 사용되고 있는 많은 종류의 수복 재료 중에서 금 합금은 뛰어난 수복재료로써 평가받고 있으며 많은 경우에 성공적으로 사용되고 있다. 그러나 여러 연구에서 금으로 수복된 치아에서 cracked tooth가 많이 나타난다는 보고가 있었으며 이는 금 합금의 열팽창계수가 치아의 그것과 다르기 때문이라는 제안이 있었다. 금 합금의 열적 특성에 대한 연구는 in-vitro 조건에서 많이 진행되어 왔으나 실제로 금 합금이 구강 내에서 어떠한 열적 행동을 보이는지에 대한 연구는 없는 실정이다. 따라서 본 연구에서는 구강을 통해서 뜨거운 액체 또는 차가운 액체를 섭취함에 따라서 구강 내 금 수복물이 겪는 표면 온도 변화를 실시간으로 측정, 분석하고자 한다.

2. 방 법

5명의 남자, 5명의 여자로 구성된 총 10명의 피험자 집단에서 각각 8개의 수복되지 않은 자연치아와(Group NT) 8개의 금 인레이(Group GR)로 수복된 대구치와 소구치를 선택하여 각각의 치아 표면에 thermocouple sensor를 부착한 뒤 flowable resin을 이용하여 약 3mm두께로 고정시킨다. 처음 부착 이후 2분 동안 피험자의 resting temperature를 측정하며, 이후 섭씨of 58.6도의 뜨거운 물 10ml를 마신다. 2분 후 같은 온도의 뜨거운 물을, 다시 2분 후에는 섭씨 4.42도의 찬 물을 마신다. 2분 후에 같은 온도의 한번 더 마신 2분 동안 온도의 변화를 기록한 뒤 측정을 종료한다.

3. 결 과

수복되지 않은 자연치아와 금 인레이로 수복물의 표면 온도 변화 양상을 측정한 결과, 뜨거운 물을 마심으로 인한 최대 온도는 자연치아는 평균 40.5°C, 금 인레이는 평균 44.7°C로 금 인레이가 더 많은 온도상승을 보였으며 ($p<0.05$), 차가운 물을 마신 후 나타난 최소 온도는 자연치아는 평균 31.5°C, 금 인레이는 평균 25.0°C로 금 인레이의 온도가 더 많이 감소했다 ($p<0.05$).

또한 시간에 따른 온도변화 양상을 분석한 결과, 뜨거운 물을 마신 이후 최고 온도에 도달하기까지 소요된 시간은 자연치아의 경우 평균 15.5초 소요된 반면 금 인레이의 경우 평균 9.5초 소요되었다. 차가운 물을 마신 이후 최소 온도에 도달하기까지 소요된 시간은 자연치아에서 평균 13.0초로 나타났으며, 금 인레이에서 평균 7.4초로 나타났다. 즉, 금 인레이가 자연치아보다 온도 변화가 더 빠르게 일어났다 ($p<0.05$).

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주요어 : 구강 내 온도변화, 실시간 온도변화, 생체 내, 자연치아, 금 인레이

학 번 : 2011-22445

2. 외국어초록(Abstract)

Abstract

In vivo real-time temperature analysis of natural tooth and gold inlay restoration

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Objectives: Teeth restored with metallic restoration materials have an increase incidence of crack tooth syndrome. One proposed mechanism is that the thermal expansion of dental restoration material exerts harmful effect to the remaining tooth structure. Therefore, the present study analyzed the in-vivo thermal behavior of gold restoration material compared to the natural teeth.

Methods: Study sample included eight gold inlay and eight natural teeth from ten volunteers. Customized multi-channel electronic temperature recording device attached to each sample teeth using 3mm thick flowable resin. During the recording period, each volunteer was given 10ml of 58.6°C hot water and 4.42°C cold water for intake.

Results: There was no significant difference in resting temperature of natural teeth and gold restored teeth ($p>0.05$). The maximum temperature after intake of the hot water was higher in gold restored teeth ($p<0.05$). The intake of the cold water made the temperature of gold restored teeth lower than natural teeth ($p<0.05$). Analysis of time required reaching the maximum and minimum temperature after each intake showed that the gold restored teeth took less time for maximum heating/cooling than the natural teeth ($p<0.05$). Overall, the rate of temperature change was higher in gold restored teeth than natural teeth ($p<0.05$)

Conclusions: The modality of temperature change in gold restored teeth and natural teeth was different.

Clinical significance: The higher temperature change of intraoral gold inlay compared with natural teeth implies that the gold restoration could be expands more than non-treated natural tooth in the same condition. Therefore, in case of intracoronal gold restoration, careful application of gold is required.

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keywords : intraoral temperature change, in vivo, real time, natural tooth, gold inlay

***Student Number* : 2011-22445**

I Introduction

Various materials are now employed in the area of dental rehabilitation. To select proper materials for substitution of enamel, materials are judged based on its physical and mechanical properties such as toughness, coefficient of thermal expansion (CTE).

Above all, the thermal properties of restoration materials are of great importance because the intraoral tissues are exposed to daily intake of substances with various temperatures, consequently make the temperature of restoration materials and tooth structure fluctuate. Lin et al. refers to these phenomenon as 'thermophysical properties' [1]. Intraoral environment complicates their thermophysical properties due to the several factors such as the layers of tooth structure, the flow of dentinal fluid, pulpal blood flow etc. [1]. Therefore, simple application of restoration material's CTE value may not be suitable for the comprehensive evaluation of the thermophysical properties [2].

While thermal properties of tooth and dental restoration materials ex-vivo are well known, for example, CTE and thermal conductivity, thermophysical properties of dental restoration materials at intraoral environment have not been studied thoroughly.

Gold alloy is one of the most widely used restoration materials in dental rehabilitation [3] due to its physical and chemical properties such as strength and hardness, corrosion resistance and biocompatibility. It is widely used successfully in the case of full veneer crown and bridge, class II cavity restoration, etc. However, sometimes cast gold inlays fail due to secondary caries, retention loss etc. occurs [4]. And there is some studies of which cast gold inlays are associated with cracked tooth syndrome [5].

In disregards of the aforementioned properties of gold alloy, it is not exactly same as enamel. In particular, thermal characteristics of gold alloy are different from that of enamel. Nevertheless, in vivo is far different from ex-vivo. In the current study, we analyze the real-time thermal behavior -surface temperature change during intake of hot and cold water- of gold and non-treated natural teeth in vivo.

II Materials and methods

The study included ten adults; five male and five female. Age of the volunteers was ranged between 25 and 31 years. Ethical approval was obtained (IRB No. D20140013). Informed consent form was provided to each volunteer and they signified on the form of agreement.

Selected 16 first molars were divided into two groups: Group NT; untreated natural teeth (8 first molars), Group GR; gold restored teeth (8 first molars).

In Group NT, the thermocouple sensor was located at the buccal side of the natural teeth. In Group GR, the sensor placed at the most buccal aspect of the restoration material (if the design of the gold inlay has buccal extension, sensor was located at that point. If not, sensor was located at the buccal margin of occlusal table.)

Finally, flowable resin (charisma, shade A2, Lot 010130, Heraeus Kulzer, Germany) was applied over the sensor with 3mm thick and cured with light emitting diode (LED, hi-light, Dent all, Lot HLL 0075, Korea).

After attachment of the sensor, the subject was instructed not to open the mouth for the first 2miniutes in order to acquire resting temperature, which is the value of the intraoral temperature at a plateau. After the intraoral temperature has stabilized, the subject was given 10ml of 58.6°C hot water and the water were held in the mouth for 3 seconds and than swallowed. After 2 minutes, the subject was given hot water again for the intake. Another 2mins was waited, the subject was instructed to drink 10ml of 4.42°C cold water, to hold, and to swallow in the same manner, which is repeated once again.

During the recording period, the thermocouple sensor was connected to the main device to send the data acquired from the sensor to the computer.

Statistical analysis was performed using independent student's t-test by SPSS, Version 21.0 with a level of significance of $\alpha = 0.05$.

III Result

Figure 1 shows an example of the temperature change from the sample teeth selected from one subject during the intake of hot and cold water. After the hot water ingestion, the intraoral temperature rises from resting temperature (Group NT: 36.86°C, Group GR: 36.95°C) to maximum temperature (Group NT: 38.41°C, Group GR: 42.36°C) for the certain period of time (Group NT: 17.48, Group GR: 8.50s). The intraoral temperature was recovered slowly to 97% of the resting temperature for the 2mins interval. For the second intake of hot water, the surface temperature of Group NT and Group GR was rise again from 37.71°C and 37.91°C to 38.81°C and 42.31°C for 19.01s and 8.02s respectively. Temperature was recovered 99%.

After the intake of the 4.42°C cold water, the intraoral temperature was decreased. Group NT showed a temperature decrease of 3.13°C from 38.19°C to 35.05°C. A temperature decrease from 38.32°C to 28.39°C was observed in Group GR. And temperature recovery occurred to 94% of the staring temperature during 2mins interval. For the second intake of cold water, the decrease of temperature of Group NT and Group GR started from 36.19°C and 36.03°C to 31.13°C and 27.29°C for 11.01s and 7.50s respectively. Until the completion of recording, intraoral temperature was recovered to 94% of the starting temperature.

The means of resting temperatures (Group NT: 37.36°C, Group GR: 36.98°C), maximum temperatures (Group NT: 40.50°C, Group GR: 44.70°C), and minimum temperatures (Group NT: 31.52°C, Group GR: 24.99°C) in the respective groups are presented in Fig.2. The resting temperature of each group showed no significant difference. The mean value of the maximum temperatures in Group GR was higher ($p<0.05$) than that of the Group NT. The mean value of the minimum temperatures in Group GR was lower ($p<0.05$) than that of Group NT.

Time measured from the fluid intake to when intraoral temperature reaches the peak (Fig. 3). Group GR reached the peak temperature more promptly ($p<0.05$) for the hot and cold water consumption. For the intake of the hot fluid, Group NT required 15.47 seconds to reach the maximum temperature. Group GR required 9.50seconds for maximum heating. In case of the intake of the cold water, Group NT and Group GR took 13.03 seconds and 7.44 seconds to reach the minimum temperature respectively.

The slope of the temperature change in function of time was calculated (Fig.4). The slope was defined as the value of dividing the difference between peak temperature and temperature value at fluid intake in time consumed. The rate of temperature rising of Group NT and Group GR was 0.30°C/sec and 0.67°C/sec respectively. The cooling velocity appeared when cold water consumption was 0.48°C/sec and 1.48°C/sec in Group NT and Group GR respectively. The rate of temperature change was approximately three times higher in group GR ($p<0.05$) for both hot and cold water intakes.

The aforementioned characteristics of the temperature change in the two groups are summarized in table 1.

IV Discussion

The aim of this study falls into the two categories. The first is to evaluate the thermal range of intraoral temperature at molar area during hot and cold water intake. The second is to evaluate the thermal behavior of the dental gold alloy with a goal to elucidate mechanism of how the gold inlay restoration affects the remaining tooth structure and pulp tissue.

Intraoral temperature is affected by body temperature, temperature of the food we intake, and surrounding soft tissue. In particular, human race consume diverse food with broad range of temperature that cause the intraoral temperature more extreme. In the current study, we used thermocouple to measure small area in real time. The diameter of thermocouple sensor was 0.005mm. Thus it is appropriate method to evaluate the temperature change of intraoral gold inlay.

The intraoral temperature was similar to the result shown by Longman et. al. [6]. Previous studies shown that the intraoral temperature varies depending on the location of teeth within the oral cavity [6, 7], not only on the anterior-posterior location of teeth but also on the buccal-lingual and upper–lower arch because of the effect of the tongue[8]. Therefore, in the present study, first molars were selected as the sample tooth under consideration of aforementioned factors. The sensor was attached on the buccal side of the first molar in order to control the location effect of temperature. To reduce the protective effect of the tongue on the sample tooth, volunteers instructed to hold the given water in his or her mouth for 3 seconds and swallow.

Previous studies using thermocouple employed prefabricated individual mold to attach the sensor to the tooth surface to record intraoral temperature, so the air gap between tooth and the sensor disrupted the accuracy of recorded value [1]. In this study, sensor was attached to the tooth surface using flowable resin, therefore there was no gap between the sensor and the tooth to interfere recording of accurate tooth surface temperature. To prevent direct recording of the temperature of ingested fluid (to provide insulation effect) not the temperature of tooth, sufficient amount of flowable resin (3mm) was covered over the sensor.

The subjects hold the given fluid in his of her mouth for 3 seconds before swallow to provide sufficient time to contact teeth to simulate the clinical situation. Second intake of the fluid at the same temperature was performed 2minuites after the first intake to reflect the clinical situation.

10 ml of volume at each intake was decided by average volume of swallow in adult female population [9].

The result shows that intraoral gold inlay changes its temperature more than natural tooth structure. It is considered as the result of the thermal conductivity of the gold 297$Wm^{-1}K^{-1}$, is higher than that of the dentin 0.57 $Wm^{-1}K^{-1}$ [10].

Human adults are more tolerable to cold fluid than hot fluid [8]. Therefore, in order to reflect the clinical situation, the mean temperature of given fluid was 58.6°C hot water 4.42°C cold water, which means disparity of given fluid's temperature compared to the human resting temperature. This lead to the result of the difference between resting temperature and the minimum temperature is greater than the difference between resting temperature and the maximum temperature, as shown in fig.1.

Higher thermal conductivity of gold alloy also contributes to the more prompt change of temperature in Group GR. In both group, the average time required to reach the peak temperature was longer than 3 seconds, which implies the temperature change of teeth was partially contributed by indirect heat transfer from adjacent tissues.

The rate of temperature change was calculated based on the linear slope of temperature change in the function of time. Differentiation method was not available because of the systemic error in the present data.

Systemic error of the thermocouple sensor (±0.4%), and the response time (0.003s) confines the accuracy of this study. Individual polymorphism of oral anatomy and swallowing pattern may also increase deviation of the data.

There are several studies that report the incidence of crack tooth syndrome is associated with intracoronal restoration [5, 11, 12]. Seo et. al. showed that the 72% of cracks among sample was found on restored teeth [5]. Ratcliff et. al. pointed out class I and class II restoration increase risk of crack 29 times than non-restored teeth[12].

Proposed etiology of the intracoronal restoration affecting crack tooth syndrome [1, 5, 11, 13] includes two categories; thermal cycling mechanism and mechanical concern [14, 15].

Brown et. al. said magnitude of stress is proportional to temperature change [13]. Along with the mismatch of CTE between gold and natural tooth, the magnitude of temperature change of gold alloy, which was founds to be greater than that of natural tooth, may attribute to the development of crack in metallic restored teeth.

Lopes et. al. reported that thermal stress affected the restored tooth to develop interfacial debonding and microcracking [16]. Yan et. al. proposed this is responsible for the mismatch of change of dimension upon intraoral temperature fluctuation. The expansion and contraction of restoration materials make mechanical stress to produced at the interface [2].

From the present study, the greater magnitude and rapid change of temperature of gold alloy in-vivo could allow this material expands and contracts more than remaining tooth hard tissues which may eventually lead to microleakage.

The known thermal properties could give us some clues for the intraoral thermophysical properties of the restored tooth, but it is difficult to describe the intraoral thermophysical properties solely based on the known thermal properties because the restoration materials lies within the tooth structure with varying depth and volume, and the surrounding intraoral environment is complicated with various tissues and body fluids. From the study presented in this paper, we now obtained the in-vivo data that shows not only the magnitude but also the rate of intraoral temperature change are greater in the case of gold restoration than in the case of the natural tooth.

V Conclusions

The modality of temperature change in gold restored teeth and natural teeth was different. The temperature change of gold alloy was greater in the magnitude and the rate.

This thermophysical properties of intraoral gold inlay compared with that of natural teeth implies that the gold restoration could be expands more than non-treated natural tooth in the same condition and it could eventually lead to the restoration failure. Therefore, in case of intracoronal gold restoration, careful application is required.

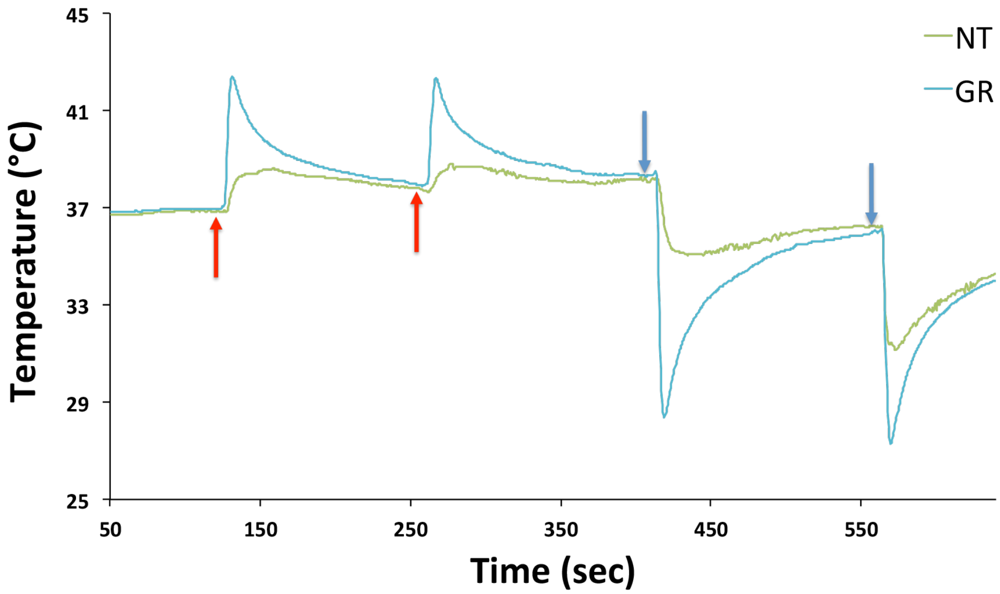

Fig1. Graph showing the change of intraoral temperature in the function of time during hot and cold water consumption. Timing of hot and cold water consumption denoted as red arrows and blue arrows respectively. NT; Natural Tooth, GR: Gold Restored tooth.

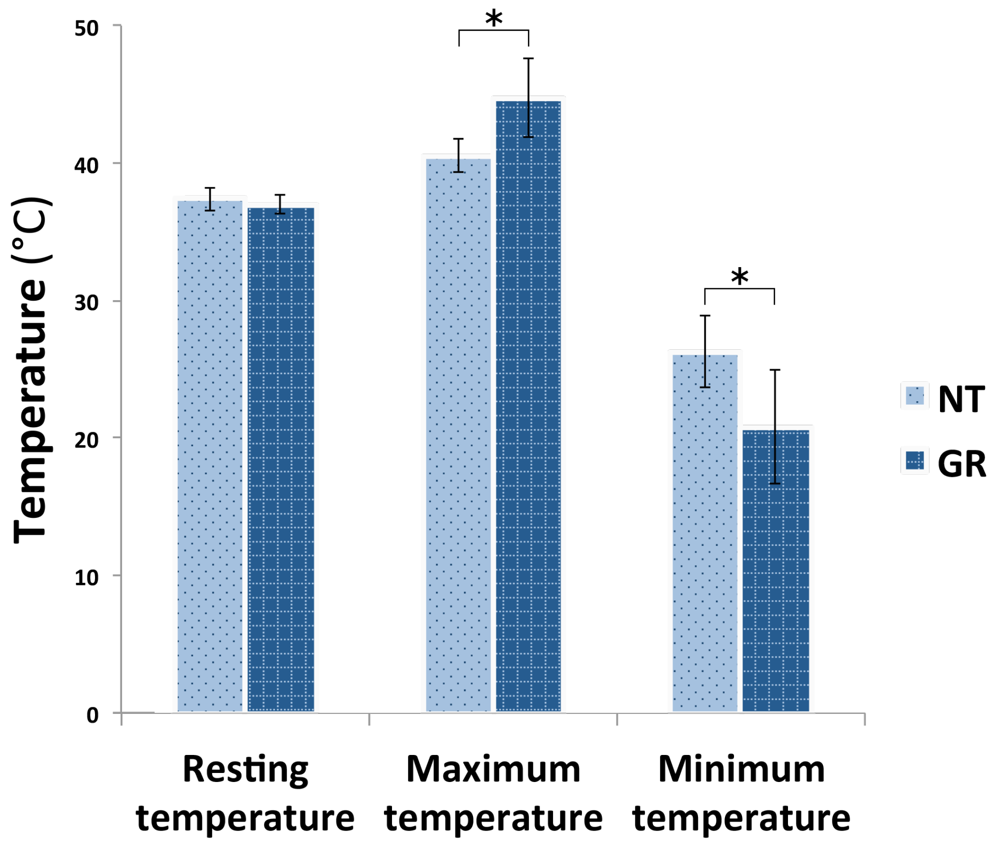

Fig2. The means of resting temperature[a], maximum temperature, and minimum temperature recorded. NT; Natural Tooth, GR: Gold Restored tooth.

([a]resting temperature was determined as the mean temperature during 10 seconds after the intraoral temperature reached a plateau)

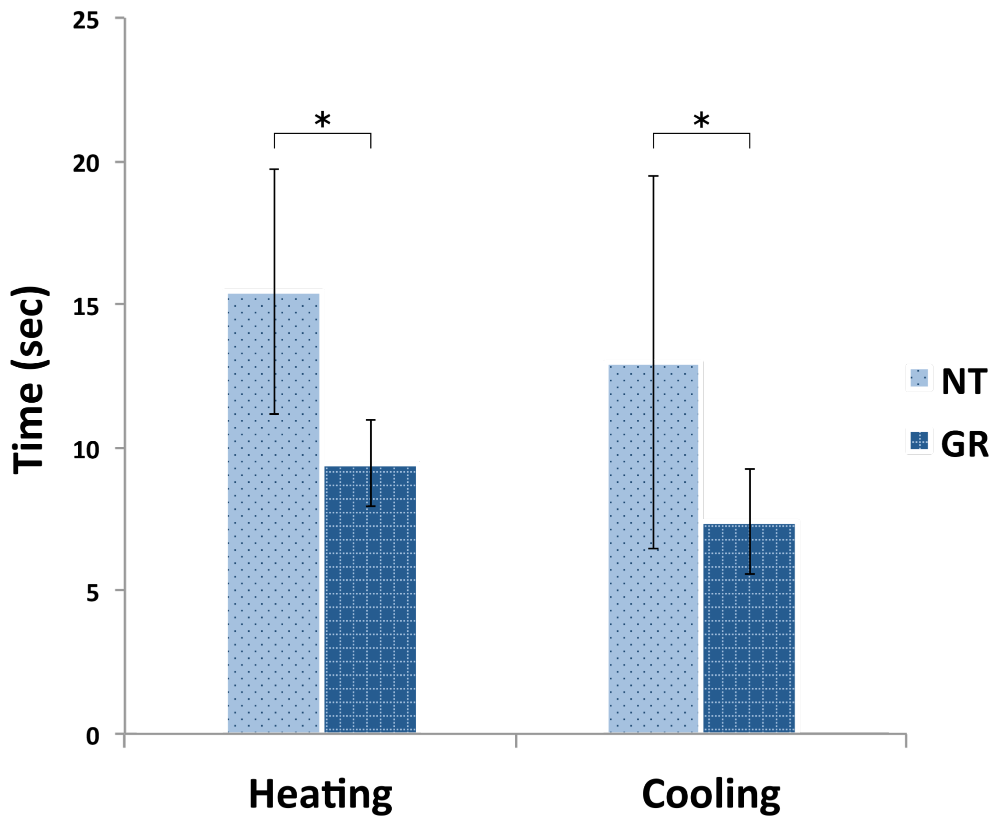

Fig3. Time required reaching the maximum/minimum temperature. NT; Natural Tooth, GR: Gold Restored tooth.

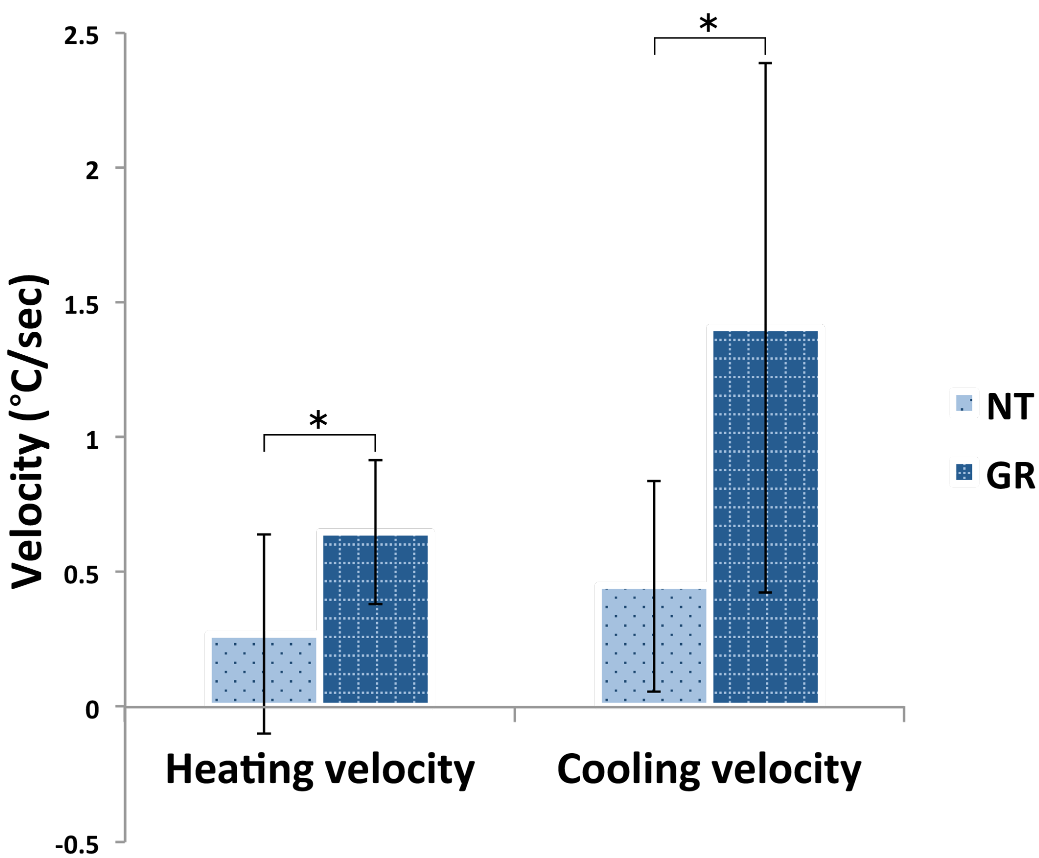

Fig4. The heating/cooling velocities between the two groups. NT; Natural Tooth, GR: Gold Restored tooth.

	Group1			Group2		
	Mean		SD	Mean		SD
Resting(mean)	37.36	±	0.828571838	36.97704132	±	0.655895273
MAX	40.51	±	1.206988516	44.69691675	±	2.87139173
MIN	31.5193655	±	3.127437049	24.99417888	±	4.934099322
Heating time	15.46857225	±	4.261848905	9.497043438	±	1.509502726
Cooling time	13.02593256	±	6.509568697	7.441238188	±	1.828342814
Heating velocity	0.295869966	±	0.383544584	0.665735182	±	0.279329032
Cooling velocity	0.477929358	±	0.402494634	1.47744583	±	1.013680179

Table1. Intraoral temperatures in the respective groups

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