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MACROSTRUCTURE OF TEETH RESTORED WITH DIFFERENT DENTAL MATERIALS ANALYZED AFTER THERMAL INVERSION.

Macroestrutura de dentes restaurados com diferentes materiais dentários analisados após inversão térmica.

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ASTRACT

Objective: This study aimed to investigate the macrostructure of teeth restored with different dental materials after thermal inversion. Material and methods: The sample consisted of 16 bovine mandibular incisors. Half of the teeth underwent class V restorations with amalgam (Amalgam GS 80, SDI Dental Ltd., Dublin, Ireland), while the other half was restored with composite (Charisma, Kulzer GmbH, Hanau, Germany). During 30 minutes the teeth were exposed to heating at 100^{o}C, 200^{o}C, 300^{o}C and 400^{o}C. Next, cooling was performed in half of the sample using a fan (slowly) and in the other half using water (quickly). Qualitative analysis was performed to detect eventual macroscopic alterations in the teeth, especially considering: I) the color of the restoration; II) the structure of the restoration; III) fitting of the restoration in the cavity; IV) main alteration of the restoration from the original form; V) main alteration of the tooth from the original form. Results: Different macroscopic alterations were observed after slow and quick cooling of the amalgam after heating at 200^{o}C, 300^{o}C and 400^{o}C, while for the composite the alterations were detected only after heating at 400^{o}C. Conclusion: Optimal human identification performances and forensic reports must consider the eventual macroscopic alterations in dental restorations and teeth detected in charred bodies retrieved from the water.

KEYWORDS

Dental materials; Forensic dentistry; Forensic sciences; Human identification.

INTRODUCTION

According to the guidelines of the International Criminal Police Organization (INTERPOL), fingerprint analysis, forensic dentistry and genetics figure as the three primary methods reliable for human identification[1]. The contribution of forensic dentistry to the identification of charred bodies, in specific, is well-known in practice and broadly documented in the scientific literature[2-6]. Previous studies showed that the general macroscopic morphology of the human teeth is recognizable even under exposure to 1100°C[7]. In the other hand, dental restorations are more easily affected and may be destroyed earlier in fire[7].

With the current high rates in urban violence, the most diverse criminal strategies are used to vanishing forensic evidences and hamper police investigations. In especial scenarios, the bodies are not only charred, but also disposed in the water. The thermal inversion between fire and water may promote structural changes in the teeth and dental restoration materials that may have a negative impact in the human identification process. Based on the comparison of antemortem (AM) and postmortem (PM) data, dental human identification requires a detailed registration of cadaveric findings[8]. Knowing the dental alterations from thermal inversion potentially detectable during the autopsy is relevant to support optimal forensic reports and is justified to indicate whether or not cadaver occultation was attempted.

In this context, the present study aimed to investigate the macroscopic alterations in the structure of teeth and dental restoration materials after exposure to thermal inversion.

MATERIAL AND METHODS

This experimental study was designed and conducted with the approval of the local committee of ethics in animal research (protocol: 00.0474.2017).

The sample consisted of sixteen bovine mandibular incisors donated from the local slaughterhouse. Before donation, the teeth were cleaned with saline solution and immersion in 1% sodium hypochlorite (ASFER Industries Ltd., Sao Paulo, Brazil) for 30 minutes.

After cleaning, trained dentists performed Class V[9] cavities in each tooth. Later, half of the sample was restored with amalgam (GS 80, SDI, Victoria, Australia) and composite (Charisma, Kulzer GmbH, Hanau, Germany) following proper technical standards[10]. Polishing of the amalgam (Microdont, Sao Paulo, Brazil) and composite (TDV, Pomerode, Brazil) restorations was performed and the teeth were prepared to undergo heating. In this phase, two refractory plates made of phosphate agglutinate (Heat Shock Polidental, Cotia, Brazil) were used for positioning the teeth pair-wise (one restored with amalgam and the other with composite) in furnace (Ney Vulcan 3-550, Dentsply Ceranco, York, USA). Each pair of teeth was kept in furnace in room temperature, which increased 10°C per minute up to 100, 200, 300 and 400°C. After reaching maximum temperature, the teeth remained in furnace for 30 minutes. The estimated time from room to maximum temperature was nearly 8, 18, 28 and 38 minutes to reach 100, 200, 300 and 400°C, respectively.

The cooling process was performed with two different approaches – slowly and quickly. The first was performed using a fan (NV15 Mondial, Conceicao do Jacuipe, Brazil), while the second was performed with immersion in a container (Xalingo, Santa Cruz do Sul, Brazil) with water in room temperature. The teeth and their restorations were macroscopically analyzed (Figure 1). For a more detailed analysis, a magnifier

(Veho Discovery VMS 004 de luxe, VEHO Inc., Hampshire, United Kingdom) was implemented.

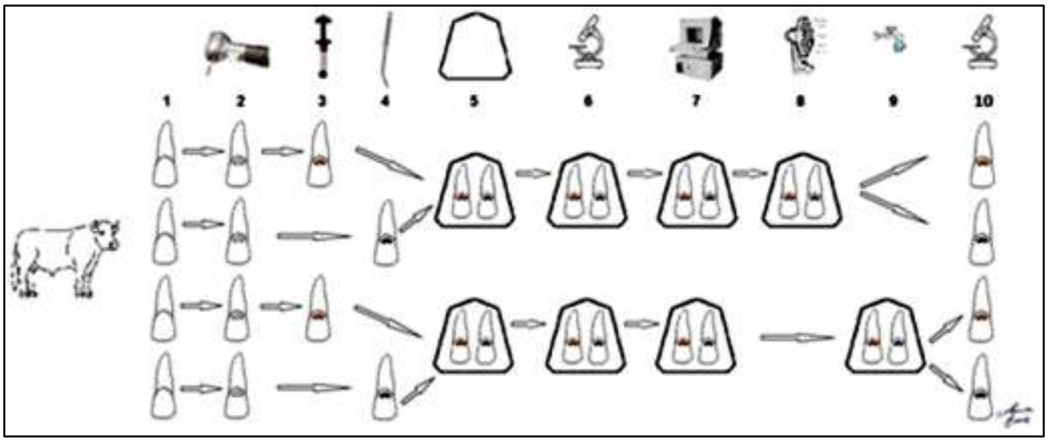

Figure 1 – Schematic flow of sample preparation.

Caption – 1: bovine teeth; 2: preparation of Class V cavities; 3: cavities restored with composite; 4: cavities restored with amalgam; 5: restored teeth positioned in refractory plates; 6: initial observation with magnifier; 7: teeth ongoing heating in furnace; 8: cooling performed with a fan; 9: cooling performed with immersion in water; 10: final observation and analysis.

In each tooth, five characteristics were considered for a qualitative analysis: I) the color of the restoration; II) the structure of the restoration; III) fitting of the restoration in the cavity; IV) main alteration of the restoration from the original form; V) main alteration of the tooth from the original form.

RESULTS

Tables 1 and 2 summarize the main outcomes of the macroscopic analysis of the structure of bovine teeth and Class V dental restorations with amalgam and composite after exposure to thermal inversion.

Figures 2 and 3 illustrate part of the macroscopic alterations detected during the study. At 100˚C, the composite restorations were maintained in the cavity with certain macroscopic adaptation both after slow and quick cooling. The first sign of alteration in the macrostructure of the composite restoration became more evident at 200˚C when brightness decreased and a more opaque aspect was observed. At 300˚C, color alterations were observed followed by macroscopic cracks and carbonization at 400˚C (Table 1).

In the amalgam dental restorations, macroscopic alterations began earlier. At 100˚C, change in brightness and the presence of oxidation were detected. At 200˚C, the amalgam was not adapted in the margins of the dental cavity. The increase of heating to 300˚C made evident macroscopic cracks in the restoration, while at 400˚C the underlying tooth was fractured (Table 2).

The macroscopic alterations observed in composite and amalgam dental restorations were similar after slow and quick cooling throughout the increase in heating. The single difference was observed in teeth with amalgam restorations, which fractured only after quick cooling (Table 1).

Table 1 - Macroscopic alterations in the structure of bovine teeth and composite dental restorations after slow and quick thermal inversion.

Alteration	100°C		200°C		300°C		400°C	
	Slow	Quick	Slow	Quick	Slow	Quick	Slow	Quick
Dark margins	X	X	X	X	√	√	√	√
Color change	X	X	X	X	√	√	√	√
Brightness change	X	X	√	√	√	√	√	√
Porosity	X	X	X	X	X	X	X	X
Cracks	X	X	X	X	X	X	√	√
Carbonization	X	X	X	X	X	X	√	√
Calcination	X	X	X	X	X	X	X	X
Restoration dislodged	X	X	X	X	X	X	X	X
Cavity shape change	X	X	X	X	X	X	X	√
Adaptation in the margin	√	√	√	√	X	X	X	X
Fracture of restoration	X	X	X	X	X	X	X	√

X: not detected; √: detected.

Table 2 - Macroscopic alterations in the structure of bovine teeth and amalgam dental restorations after slow and quick thermal inversion.

Alteration	100°C		200°C		300°C		400°C	
	Slow	Quick	Slow	Quick	Slow	Quick	Slow	Quick
Oxidation	√	√	√	√	√	√	X	X
Loss of superficial parts	√	√	√	√	√	√	X	X
Color change	X	X	√	√	√	√	√	√
Brightness change	√	√	√	√	√	√	√	√
Porosity	√	√	√	√	√	√	√	√
Cracks	X	X	X	X	√	√	X	√
Carbonization	X	X	X	X	X	X	X	X
Calcination	X	X	X	X	X	X	X	X
Restoration dislodged	X	X	X	X	X	X	X	X
Cavity shape change	X	X	X	X	X	X	X	X
Adaptation in the margin	√	√	X	X	X	X	X	X
Fracture of restoration	X	X	X	X	X	X	X	X

X: not detected; √: detected.

DISCUSSION

Knowing the macroscopic alterations potentially detectable in teeth restored with amalgam and composite is an important part of the forensic dental investigations of charred bodies retrieved from water. However, experimental studies with human cadavers are hampered by logistics and (bio)ethical aspects mainly related to sampling, storing and management of the deceased. In this context, this study was conducted by simulating the process of thermal inversion from heating to cooling. Due to their anatomic similarities with human teeth and previous application in the scientific literature[11], bovine incisors were used in this research.

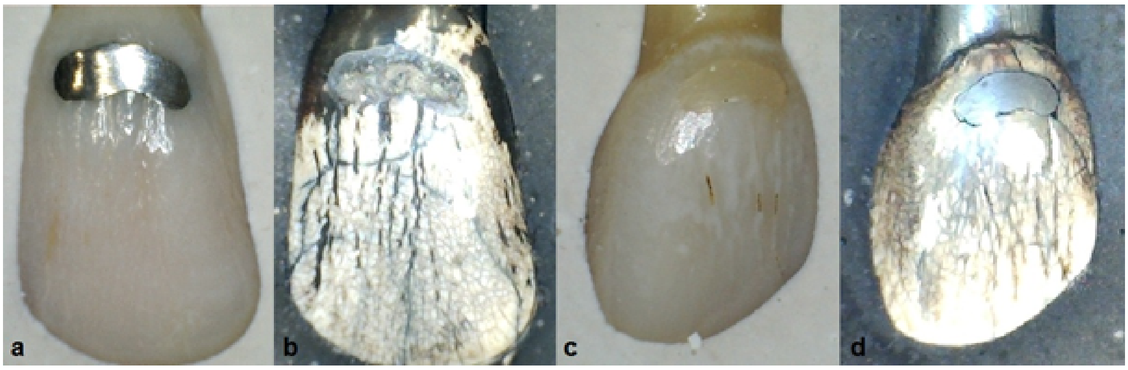

Figure 2 – Amalgam (a, b) and composite (c, d) restorations before (a, c) and after (b, d) heating at 400^{o}C and slow cooling.

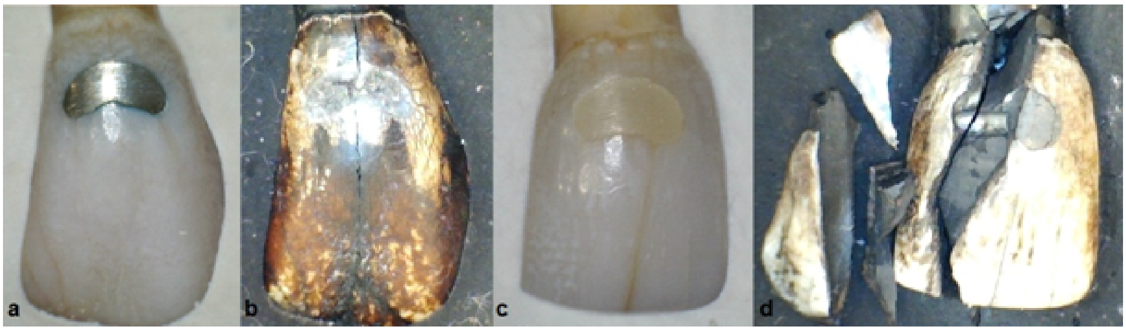

Figure 3 – Amalgam (a, b) and composite (c, d) restorations before (a, c) and after (b, d) heating at 400^{o}C and quick cooling.

The methodological set up and macroscopic variables investigated in this study were based on previous studies[12]. Specifically in relation to the progressive heating, the scientific literature shows studies that worked in a range from 100^{o}C to nearly 1000^{o}C[12,13]. In the present study, the heating scale included observations at 100^{o}C, 200^{o}C, 300^{o}C and 400^{o}C. Higher temperature intervals (>500^{o}C) were not addressed because at this level the fragmentation process starts hampering further observations of the interaction and interface of the dental restorations and the tooth cavity.

Regarding the outcomes obtained in the present study, no visual alteration was observed in composite restorations at 100^{o}C, while change in brightness, color and the presence of cracks were observed at 200^{o}C, 300^{o}C and 400^{o}C. Similar findings at 100^{o}C were observed in the available scientific studies that used the same composite[14]. On the other hand, at 200^{o}C slightly different outcomes were observed between the present study and the scientific literature. According to Pol et al.[12] (2015) and Brandão et al.[15] (2007), no alterations and grayish coloration surrounding the dental restoration were observed after heating, respectively. In the next heating levels (300^{o}C and 400^{o}C), the macroscopic alterations became more evident – such as the color change of composites to grayish and opaque. Color alterations were also observed by Pol et al.[12] (2015), and Brandão et al.[15] (2007). While the first corroborated the grayish opaque color, the second described the teeth with a whitish aspect. Additionally, it is important to note that cracks were also observed by Pol et al.[12], 2015, when the heating reached 400°C.

In opposite to the alterations observed within composites, amalgam restorations showed early evidences of oxidation when exposed to 100°C for 30 minutes. In the following heating set ups, these restorations presented change in color and brightness and porosities. Other authors showed no alteration of the amalgam restorations at 120°C and the increase in brightness at 150°C[16]. Differently, decrease of brightness was also reported in the scientific literature – specifically when heating reaches 200°C[12]. Additional alterations reported in the scientific literature include the formation of superficial bubbles on the restoration[13]. The potential explanation for the formation of bubbles and porosities is the evaporation of mercury[17] which takes place around 200°C. At 400°C most of the findings observed in the present study confirmed the previous literature, such as the lack of marginal adaptation of the restoration in the dental cavity[12] and irregularities in the superficial outline of the restoration[18].

Apart the qualitative analysis of dental restorations after heating, this study focused mainly in investigating the macroscopic effects of thermal inversion with slow (using a fan) and quick (by immersion in water) cooling. The main distinct finding was observed after cooling composite restorations previously exposed to 400°C. The slow cooling process did not induce fracture of the restoration, while the quick cooling resulted did. This phenomenon may be justified in the abrupt contraction of the dental material during thermal inversion. In teeth restored with amalgam, the main difference was observed at 200°C. After slow cooling, the oxidation zone was detected at the cavo-surface angle margin, while after quick cooling the oxidation was found below the angle. It may be justified based on the thermal properties of the amalgam. Heat and cold transmission is quicker through amalgam compared to dental tissue. More specifically, conductivity and diffusivity are higher in the first. Additionally, the coefficient of thermal expansion is nearly three times higher in amalgam. Consequently, after quick cooling the amalgam shrank and created a space in the interface between the tooth and the restoration. Corrosion products could penetrate this space and cause a deeper oxidation zone compared to the teeth that underwent slow cooling[19,20].

At 300°C, brightness is decreased in the amalgam restoration after slow cooling, while discrete brightness is maintained after quick cooling. The potential explanation for this finding is the cooling process in water, which washed the surface of the amalgam restoration from oxidation products of heating. In this context, brightness is referred to as discrete, because porosities and irregularities remain in the amalgam surface after the cooling (washing) process. Additional differences were observed at 400°C. After slow cooling, the amalgam restoration did not reveal cracks, which may be explained by the decreased concentration of Mercury in the amalgam gamma-2 phase[19,20] and the remaining tin that could melt within the cracking spaces. In other words, restoration cracks were eventually present but not macroscopically detected in this study.

The macroscopic assessment of teeth and restorations after thermal inversion figured as one of the limitations of the present study. In order to retrieve more detailed information of the teeth and restorations, future studies should be designed to include microscopic analyses as well. Other methodological set ups could consider different analyses in relation of different timing. Moreover, more realistic and palpable outcomes could be obtained by simulating the thermal inversion process in body farm environments.

CONCLUSION

Thermal inversion promoted structural alterations that could be macroscopically detected in teeth restored with composite and amalgam. These alterations could be expected in charred bodies disposed in the water. However, the outcomes of the present study were obtained in a controlled scenario. Studies remain necessary to investigate these alterations with methodological designs that approach more closely the real forensic practice.

RESUMO

Objetivo: Este estudo objetivou investigar a macroestrutura de dentes restaurados com diferentes materiais odontológicos e analisá-los após inversão térmica. Material e método: A amostra foi composta por 16 incisivos inferiores bovinos. Metade dos dentes foi preparada com restaurações Classe V em amálgama (Amálgama GS 80, SDI Dental Ltd., Dublin, Irlanda) e a outra metade em resina composta (Charisma, Kulzer GmbH, Hanau, Alemanha). Durante 30 minutos, os dentes foram expostos às temperaturas de 100°C, 200°C, 300°C e 400°C. Na sequência, o resfriamento se deu usando um ventilador (n=8, resfriamento lento) e imersão em água (n=8, resfriamento rápido). Análise qualitativa foi realizada pela detecção de eventuais alterações macroscópicas, mais especificamente relacionadas a: I) cor da restauração; II) estrutura da restauração; III) adaptação da restauração na cavidade; IV) principal alteração da restauração de sua forma original; e V) principal alteração do dente de sua forma original. Resultados: Diferentes alterações macroscópicas foram observadas após inversão térmica lenta e rápida para o amálgama quando inicialmente exposto à 200°C, 300°C e 400°C, enquanto para as restaurações em resina, observou-se alterações mais evidentes quando em resfriamento após 400°C. Conclusões: Processos de identificação mais aprimorados devem considerar as eventuais alterações macroscópicas de restaurações e dentes de vítimas carbonizadas recolhidas da água.

PALAVRAS-CHAVE

Materiais dentários; Odontologia legal; Ciências forenses; Identificação humana.

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