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Color stability of dental restorative materials submitted to cold temperatures for forensic purposes

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ABSTRACT

In the *post-mortem* examination of the dental arches of accident victims in cold locations, dental restorative materials can be found. Cold temperatures can be capable of causing color changes of aesthetic materials, such as composite resin (CR) and glass ionomer cement (GIC). The aim of this study was to evaluate the effect of the cold action on the color stability of CR and GIC restorations, in order to discriminate them and enable the adequate comparison between *antemortem* and *post-mortem* data. Sixty bovine teeth (30 CR and 30 GIC) were prepared ($6 \times 6 \times 2$ mm) and separated into groups ($n = 10$). The color readouts were taken by a portable spectrophotometer, before and after of cold action (2.5 °C, −20 °C, −80 °C) inside of freezers. There were color alterations in the coordinates (ΔE, ΔL^*, Δa^* e Δb^*) for both materials. The authors concluded that cold was capable of producing changes in color in the two esthetic materials, with similar intensities between the two, at all the temperatures studied, when analyzed at 7 days. After being submitted to cold for 30 days, the changes were more significant for CR, allowing it to be differentiated from GIC after 30 days, at all the temperatures tested. Therefore, the test proposed in the study was shown to be practical, feasible and capable of helping Forensic Odontology with the identification of victims.

Innumerable accidents occur in snowy locations as a result of collisions, aircraft crashes, severe blizzards, cold waves, earthquakes, avalanches, or accidents in cold chambers and other situations in which the victim's death results from low temperatures or harmful factors in environments where exposure to cold continues to act on the body even after the victim's death.[1] In Iceland, researches about natural disasters have demonstrated that 193 persons had suffered fatal accidents resulting from avalanches.[2] The Galtuer avalanche in February 1999, which killed 31 people, was the worst in Austria since 1953.[3] A database analysis of accidents in the Swiss Alps pointed out that avalanches with fatal victims are more numerous than the same type of incidents with survivors.[4]

In these cases, discovery and rescue of victims may require prolonged periods of time due to the climatic and geographic conditions of the location itself.[1] The bodies may not be found whole, either because of the action of time, mechanical shocks or for other reasons. Canadian researchers showed that over the course of two decades, 204 persons died in accidents due to avalanches. The predominant causes of death were a combination of asphyxia and severe traumas. In 87 victims it was possible to perform an external exam of the cadaver, in the majority, however, this was not possible because pf their multiple traumatic injuries.[5]

Every time it is necessary to identify bodies in an advanced state of decomposition, skeletal, mutilated, dismembered, fragmented, among other conditions, in which dactyloscopy (fingerprinting) would possibly be discarded by the impossibility of obtaining records on the body,[6] Forensic Odontology becomes the most feasible, practical and fast method of choice when seeking a positive identity, or exclusion of a suspected victim.[7]

Some softwares like CAV-ID (Computer Aided Victim Identification), WinID, IDIS (Intelligent Dental Identification System), ADIS (Automated Dental Identification System), Plass Data system and Toothpics can accelerate the human identification process,[8] mainly

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in remote or hard-to-reach regions, sending the *post-mortem's* data immediately after accidents happen.

However, the teeth are the most resistant structures of the human body, even more so than bone tissue, after exposure to extreme temperatures[9] and frequently, they are the only findings capable of being analyzed, because both the teeth and restorative materials used in performing dental treatments have high resistance to the action of injurious agents.[10] Thus, cold temperatures are not capable of destroying them, but may cause changes in the dental restorative materials when these are present in the victim's oral cavity.

But there is no database of *ante-mortem* records of dental color, similar fingerprints. So, the software may, often, be not well indicated for this kind of analysis and comparisons. Color change in esthetic materials may contribute to investigations for confirming submission to cold temperatures, offer information about the approximate temperature to which they were submitted, and about the period in which they were exposed to these conditions.

This is why it is important to study the possible color changes that have occurred in esthetic materials widely used in Dentistry, such as composite resin (CR) and glass ionomer cement (GIC),[11] with the purpose of distinguishing between them, thus seeking support for adequate comparison of *post-mortem* and *antemortem* data, and consequently make a greater contribution to elucidating the identification of a victim.

Thus, the aim of this study was to evaluate the effect of cold temperatures on the color stability of these restorative materials, in an endeavor to simulate their behavior when present in the teeth of victims' who died by freezing or other reasons in extremely cold environments.

1. Materials and methods

Sixty sound bovine incisive teeth were prepared (6 × 6 × 2mm) in the central region of the buccal surface. After this, the teeth were randomly separated into two groups, according to the restorative material used (Table 1).

After restoring the teeth, initial color readouts were taken using a portable spectrophotometer (VITA Easyshade®, Bad Säckingen, Germany), that consisted of a digital tip 6 mm in diameter, with 19 optical fibers and spectrophotometric sensors that emit bands of light. The color readouts were taken by measuring the reflected light from the restoration, according to the CIE $L^*a^*b^*$[12] scale.

The CIE $L^*a^*b^*$ scale (Commission Internationale de L'Éclairage) consists of three Cartesian coordinate axes in which L^* (gray scale) indicates color luminosity (ranging from 0 − black to 100 − white); a^* indicates the amount of red (positive values) and green (negative values) and b^* indicates the amount of yellow (positive values) and blue (negative values) of color.[12]

For the color readout, the restored teeth were placed on a standard white background (White Standard Sphere for 45°, 0° Reflectance and Color Gardner Laboratory Inc. Bethesda, Geretsried, Germany). The tip of the equipment was kept perpendicular and in contact with the surface of the restoration. Three measurements were taken in each tooth, and the average obtained was considered the initial color readout.

The teeth restored with each material were randomly separated into groups (n = 10) according to the temperature to which they were submitted: 2.5 °C (frost free refrigerator, RFGE 700 GE®, Campinas, SP, Brazil), −20 °C (vertical freezer, CVU18 Consul®, Joinville, SC, Brazil) or −80 °C (Ultra Freezer, AL 374 - 80 V, American Lab®, Charqueada, SP, Brazil).

The internal temperatures to which the samples were submitted were measured using an infrared thermometer (MT-360, Minipa®, Sao Paulo, SP, Brazil), portable digital, that performs non-contact temperature measurements with the assistance of a laser sight, to identify the location of measurement. After 7 and 30 days of exposure to cold, the samples were removed from the freezer immediately after new color readouts were taken according to the methodology described. The color changes (ΔE) of the materials were calculated by the formula[13]:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Where $\Delta L^* = L^*_f - L^*_i$; $\Delta a^* = a^*_f - a^*_i$ and $\Delta b^* = b^*_f - b^*_i$, being L^*_i, a^*_i and b^*_i referred to as the initial readouts; and L^*_f, a^*_f and b^*_f as final readouts for color coordinates. The color values (ΔE) and the changes in coordinates (ΔL^*, Δa^* and Δb^*) were analyzed according to Two-way ANOVA, repeated measures, Bonferroni, $p < 0.05$, to compare all the materials and the temperatures tested since the materials could present similar alterations at different temperatures. The variation factors considered for comparison were temperature and time.

2. Results

The comparisons of ΔE readout mean values may be visualized in Fig. 1. There was no statistically significant difference ($p > 0.05$) in color change when the materials were submitted to low temperatures for 7 days.

After 30 days, the authors observed that the temperature to which the material was submitted was not significant for its color change because there was no difference ($p > 0.05$), irrespective of the temperature to which the two materials were subjected. However, there was a greater color change in CR at the three temperatures tested, a significant result ($p < 0.05$) in comparison with GIC.

Comparative analysis between 7 days and 30 days for each material showed there was greater color change ($p < 0.05$) in CR after 30 days, at all temperatures tested. For GIC, there was no statistically significant difference ($p > 0.05$) at any of the temperatures analyzed (Fig. 1).

The comparisons of ΔL^* readout mean values may be visualized in Fig. 2. After 7 days, there was no statistically significant change

Table 1
List of materials used, commercial brands, manufacturers, colors and restorative methods.

Category	Commercial Name	Manufacturer	Color	Restorative Method (clinical steps)
Composite Resin	Filtek[MR] Z250 XT	3M ESPE®, Sumare, SP, Brazil	A3	1. Acid etching (37% phosphoric acid, Alpha Etch DFL®, Rio de Janeiro, RJ, Brazil) for 15 s, washing, and drying; 2. Bonding system application (Adper Single Bond 2, 3M ESPE®, Sumare, SP, Brazil) and photo-activation (Ultralux EL Dabi Atlante®, Ribeirao Preto, SP, Brazil) for 10 s; 3. Material was inserted in increments and photo-activated for 20 s; 4. Finishing and polishing (File Discs Sof LexTM Pop On, 3M ESPE®).
Glass Ionomer Cement	Ketac™ Fil Plus	3M ESPE®, Sumare, SP, Brazil	A3	1. Powder/liquid (1:1) agglutination up to 1 min; 2. The material was applied in increments while it still had a humid shine until the cavity was filled.