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# THE EFFECTS OF HIGH TEMPERATURE HEATING ON COLOUR AND WEIGHT CHANGES IN GIC AND RMGIC (A STUDY TO SUPPORT IDENTIFICATION OF FIRE VICTIMS)

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***ABSTRACT***
***Background:*** *The temperature reached by fire disaster was varies. The disaster can cause fatalities and thus human identification is required. Dental restorative materials have properties that are resistant to high temperatures and play a role in identification process of fire victims. The identification process can be observed from the change in colour and weight of the restorative material. GIC and RMGIC are some of the most commonly used restorative material because they have good aesthetics properties, biocompatible, economical, and can release fluoride.* ***Purpose:*** *To determine the effect of high temperature heating on colour and weight changes in GIC and RMGIC as a support for forensic identification.* ***Method:*** *A total of 30 GIC and RMGIC samples used in this study were made in the form of cylinder with a size 3x2 mm. Each material was heated at four temperature groups of 30°C-200°C, 30°C-400°C, 30°C-800°C dan 30°C-1100°C using a furnace. The study was continued with the examination of colour using the Vitapan Classical Shade Guide and weight changes using a digital scale.* ***Results:*** *GIC and RMGIC experienced changes in colour and weight changes due to hight temperatures of 30°C-200°C, 30°C-400°C, 30°C-800°C dan 30°C-1100°C. High temperature heating shows the difference of each material. This is indicated by the p value <0,001 in the Two Way Anova Test and Post Hoc LSD which means that there is a significant difference in weight difference between GIC and RMGIC at each temperature interval.* ***Conclusion:*** *High temperature heating affects the colour and weight changes of GIC and RMGIC.*

***Keywords:*** *Forensic identification, GIC, High temperature heating, RMGIC*

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## INTRODUCTION

Fire disaster is one of the disasters that often occur in Indonesia, and the temperature achieved by this disaster varies. The temperature of 200°C is the temperature of the ejection of volcanic material, 400°C is the temperature of the bonfire, 800°C is the temperature of house fires, 900°C-1100°C is the temperature of the cremation process and firestorm can reach 2000°C.[1] This disaster can cause many unwanted losses and fatalities.

Identification of fire victims is important because they have the right to be returned to their families and adequately buried according to their beliefs. Victim identification can be conducted in two ways, namely visually and objectively. Visually, it was conducted by matching *ante-mortem* data with *post-mortem* data. Objective examinations are identification using DNA (*Deoxyribonucleic Acid*), fingerprints, and teeth.[2] The difficulty of objective forensic identification through fingerprints was found because the majority of the victim's body condition was no longer intact and difficult to identify.[3] DNA testing also has the disadvantage that would take longer time, effort, special personnel and more expensive than other identification methods. Teeth are the hardest parts of the human body that can withstand prolonged immersion, decomposition, drying and high temperatures up to 1600°C. Dental records are a top priority that must be carried out before a secondary examination in a fire disaster because the integrity of the teeth in fire victims is still good.[4]

Dental restorative materials can be used as evidence in revealing the identity of fire victims because they have different characteristics for each individual and properties that resistant to mechanical trauma, chemical trauma, high temperatures, and can change their colour when burned.[3] High-temperature changes in restorative materials can also cause physical and mechanical changes, such as changes in colour and material weight. These parameters can be used as the basis for comparing *antemortem* and *postmortem* data during the identification process. This change also allows for estimation of fire temperature, which is useful for medico-legal documentation.[5]

Dental restorative materials often used in dentistry include amalgam, composite resin, *glass ionomer cement* (GIC), *resin-modified glass ionomer cement* (RMGIC). GIC and RMGIC are the dental restorative materials that are often used in dentistry.[6] People generally choose to uses GIC as a restoration material because the price is relatively low.[7] Compared to GIC, RMGIC has better aesthetic properties, is more resistant to compression loads, is able to survive better in the oral cavity, and is equally capable of releasing fluoride ions.[7-8]

Based on this background, the authors want to conduct a study to determine the colour and weight changes in the two restoration materials GIC and RMGIC, due to high-temperature heating, which is later expected to be used as a support in forensic identification.

## MATERIALS AND METHODS

This study was conducted at the Preclinical Laboratory of Dentistry, Diponegoro University, Basic Biomedical Wet Laboratory, Faculty of Medicine, Diponegoro University, UPT Integrated Laboratory, Diponegoro University, Semarang (Ethics No. 64/EC/H/FK-UNDIP/VI/2021). This study used as experimental laboratory with a Pretest and Post-Test Control Group design. This study used 60 samples of restorative materials consisting of 30 GIC (GC Fuji IX, *Gold Label*, *Universal Restorative*, *shade* A2, *Tokyo, Japan)* samples and 30 RMGIC (GC Fuji II LC, *Gold Label*, *Universal Restorative*, *shade* A2, *Tokyo*, *Japan*) samples, where each material consisted of 4 treatment groups and 1 control group.


**Fig 1.** GC FUJI IX, Gold Label, Universal Restorative


**Fig 2.** GC FUJI II LC, Gold Label, Universal Restorative

The GIC and RMGIC samples were molded using a metal mold with a diameter of 3 mm and a thickness of 2 mm and compressed with a load of 500 grams for 30 seconds. And the excess filling was removed The sample was light cured for 20 seconds as close as possible to the sample surface and continued with finishing and polishing using an enhanced bur. The sample is removed from the metal mold. The sample was divided into 10 groups by a simple random sampling technique.

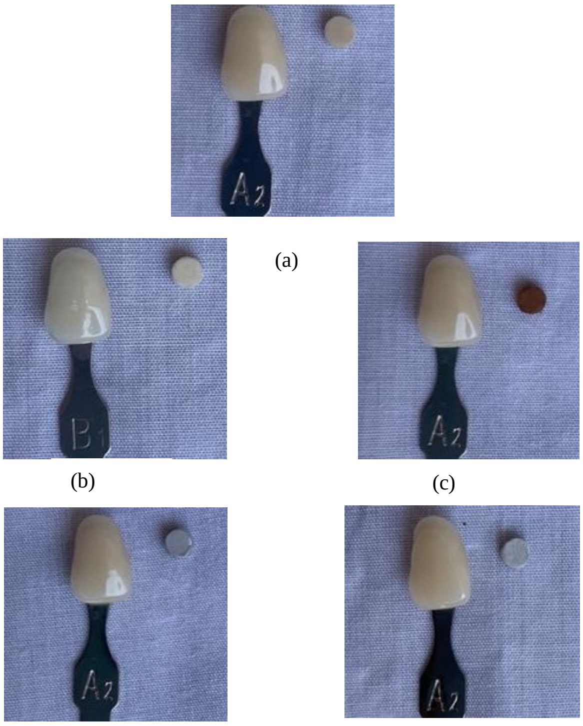
All samples that have been polished were measured by a digital micro scale (Ohaus, China) before being heated and each sample weight was limited to 43-46 mg. The samples were grouped into P1, P2, P3, P4, and P5 for GIC and P6, P7, P8, P9, and P10 for RMGIC. After that, at room temperature 30°C the furnace (Thermo Scientific, USA) was set.

Sample groups P1 and P5 were put into the furnace at a temperature of 30°C, then the temperature was raised to 200°C for 15 minutes, the temperature was lowered back to 30°C, cooled for 15 minutes and the sample was removed. The furnace was set again at 30°C, and groups P2 and P7 were added and given the same treatment up to 400°C. Likewise, with groups P3 and P8 at a temperature of 800°C and P4 and P9 at a temperature of 1100°C. Groups P5 and P10 were control groups that were not given any heat treatment.

Observations of colour changes and weighing of all samples were carried out after all samples had cooled. Weight measurement was done by calculating the difference between the weight before and after being heated using a micro digital scale. In contrast, the observation of colour changes was conducted by matching the colour between the control and treatment groups using the Shade Guide (Vitapan Classical, Germany). Colour matching was conducted outdoors by using sunlight and a plain white background. Three observers also carried out colour-matching with criteria including dental students, not colour blind, physically and mentally healthy, and able to distinguish colours well.

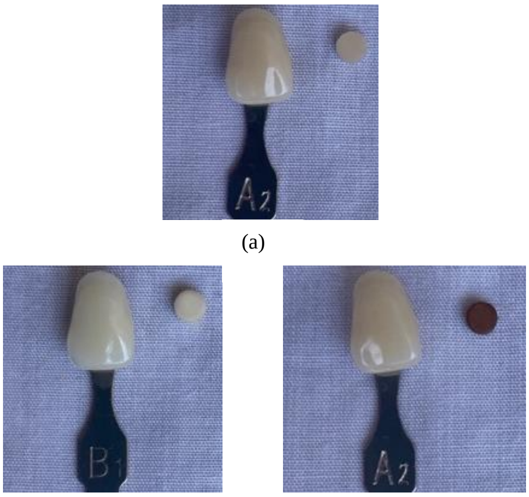
## RESULTS

The results of the colour changes observed by three observers are as follows:

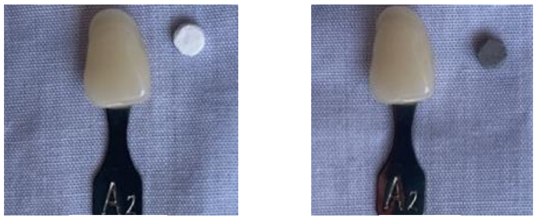


(a) (b) (c) (d) (e)

**Fig 3**. Changes in GIC after heating a) Group P5 which was not heated (Shade Guide number A2 brand Vitapan Classical) (b) Group P1 after heating at 200°C (c) Group P2 after heating at 400°C (d) Group P3 after heating at 800 °C (e) Group P4 after heating at 1100°C.



(a) (b)



(d) (e)

**Fig 4**. Change of RMGIC after heating a) Group P10 which was not heated (Shade Guide number A2 brand Vitapan Classical) (b) Group P6 after heating at 200°C (c) Group P7 after heating at 400°C (d) Group P8 after heating at 800 °C (e) Group P9 after heating at 1100°C.

The research data on weight changes were analyzed using a statistical program (IBM SPSS, v. 25, USA).

**Table 1**. The results of the Shapiro-Wilk normality test and the Levene Test homogeneity test on GIC

| Group by temperature interval | N | Significance | |
|---|---|---|---|
| | | **Normality** | **Homogeneity** |
| 30ºC-200ºC | 6 | 0,065 | 0,069 |
| 30ºC-400ºC | 6 | 0,232 | |
| 30ºC-800ºC | 6 | 0,298 | |
| 30ºC-1100ºC | 6 | 0,141 | |

Based on table 1, the result of the Saphiro-Wilk normality test in all GIC groups based on temperature intervals showed that the data were normally distributed with p>0.05 and the Levene's test homogeneity test on GIC obtained a value of 0.069 where p>0.05, which means that the research data is homogeneous.

**Table 2.** The results of the Shapiro-Wilk normality test and the Levene Test homogeneity test on RMGIC

| Group by temperature interval | N | Significance | |
|---|---|---|---|
| | | **Normality** | **Homogeneity** |
| 30ºC-200ºC | 6 | 0,078 | 0,124 |
| 30ºC-400ºC | 6 | 0,426 | |
| 30ºC-800ºC | 6 | 0,785 | |
| 30ºC-1100ºC | 6 | 0,699 | |

Based on table 2 the result of the Saphiro-Wilk normality test in all RMGIC groups based on temperature intervals showed that the data were norm[illegible]uted with p>0.05 and the Levene's test homo[illegible] test on GIC obtained a value of 0.124 where p>0.05, which means that the research data is homogeneous.

(c)

**Table 3.** The average percentage difference in weight and the results of the Two Way Anova test in the sample group and temperature

| Group | GIC | RMGIC | P *Value* |
|---|---|---|---|
| 30-200ºC | 7,32% | 2,03% | <0,001 |
| 30-400ºC | 11,47% | 8,32% | |
| 30-800ºC | 30,72% | 27,82% | |
| 30-1100ºC | 32,84% | 30,86% | |
| Control Group | 0,00% | 0,00% | |

Based on table 3 the result of the of the Two Way Anova test showed a significance value of <0.001 (p>0,05) as already known that there was a difference in weight difference at each temperature interval for both GIC and RMGIC and between GIC and RMGIC materials.

**Table 4.** Post Hoc LSD Test between GIC and RMGIC

| | Group | Group | Significance |
|---|---|---|---|
| LSD | GIC 30ºC- 200ºC | RMGIC temperature 30ºC-200ºC | <0,001 |
| | | RMGIC temperature 30ºC-400ºC | <0,001 |
| | | RMGIC temperature 30ºC-800ºC | <0,001 |
| | | RMGIC temperature 30ºC-1100ºC | <0,001 |
| | | RMGIC control | <0,001 |
| | GIC 30ºC- 400ºC | RMGIC temperature 30ºC-200ºC | <0,001 |
| | | RMGIC temperature 30ºC-400ºC | <0,001 |
| | | RMGIC temperature 30ºC-800ºC | <0,001 |
| | | RMGIC temperature 30ºC-1100ºC | <0,001 |
| | | RMGIC control | <0,001 |
| | GIC 30ºC- 800ºC | RMGIC temperature 30ºC-200ºC | <0,001 |
| | | RMGIC temperature 30ºC-400ºC | <0,001 |
| | | RMGIC temperature 30ºC-800ºC | <0,001 |
| | | RMGIC temperature 30ºC-1100ºC | 0,001 |
| | | RMGIC control | <0,001 |
| | GIC 30ºC- 1100ºC | RMGIC temperature 30ºC-200ºC | <0,001 |
| | | RMGIC temperature 30ºC-400ºC | <0,001 |
| | | RMGIC temperature 30ºC-800ºC | <0,001 |
| | | RMGIC temperature 30ºC-1100ºC | <0,001 |
| | | RMGIC control | <0,001 |
| | GIC control | RMGIC temperature 30ºC-200ºC | 0,001 |
| | | RMGIC temperature 30ºC-400ºC | <0,001 |
| | | RMGIC temperature 30ºC-800ºC | <0,001 |
| | | RMGIC temperature 30ºC-1100ºC | <0,001 |
| | | RMGIC control | - |

Table 4 shows that the result of the Post Hoc LSD test between GIC and RMGIC is 0.001 and <0.001. The results of the significant value of p<0.05 indicate a significant difference between changes in the weight of GIC and RMGIC materials between each temperature interval.

## DISCUSSION

Changes that occur in dental restorative materials due to high-temperature heating can complete post mortem data to be used as references in identifying fire victims. High temperatures can cause intrinsic changes in restorative materials, including GIC and RMGIC.[5] This study uses a heating device, namely a furnace with an exposure time of 15 minutes. The use of the furnace can be analogous to the oral cavity, which in case of fire, the first part that burns is the outer part of the body and oral cavities, such as the skin of the face, cheeks, and lips so that the teeth and restorative materials are only exposed to the heat of the fire.[9]

The results showed a colour change in GIC and RMGIC. Heating at a temperature of 30ºC-200ºC causes a similar colour change in both materials, which is lighter than the initial colour from shade A2 to shade B1. This colour change is influenced by the loss of water content in the material due to evaporation caused by intense high temperatures. In addition, the dryness of the two materials results in a whiter and more opaque colour stain.[10] In RMGIC, the colour change to become more opaque also occurs due to surface heating related to the persistence of free radicals of the inhibitory layer resulting from the polymerization process.[11]

Heating at a temperature of 30ºC-400ºC causes a colour change in GIC and RMGIC to blackish brown. The increase in opacity or darkness in both materials increases with the thermal increase. This occurs due to further oxidation of the organic matrix compounds of GIC and RMGIC. In addition, this is also caused by the carbonization process. The colour change to blackish brown also occurs due to the carbonization process. The further increase in oxygen atoms will cause a chain breakdown between carbon and hydrogen atoms. The hydrogen atoms will combine with oxygen atoms to become hydro oxygen or water molecules lost due to heating for a long time. In contrast, carbon atoms are covalently bonded to neighbouring carbon atoms.[12] Increasing the heating temperature of these two materials, removes impurity components, including water and mineral content, increasing the carbon composition level in the material.[10]

The colour changes due to heating temperatures of 800ºC and 1100ºC are very different compared to 400ºC. This difference can be attributed to the exposure of the two materials to long-term exposure to high temperatures. The colour change to opaque white is also caused by the melting of certain GIC and RMGIC, such as polyacrylic acid, polycarboxylic acid, water molecules, and matrix materials. The remaining components in these two materials are silica and alumina, which have very high melting points, causing grey and white colours in GIC and RMGIC.[11] This colour difference in GIC and RMGIC can also be attributed to the difference in the content of fluoroaluminosilicate glass powder in RMGIC which is higher than GIC. GIC and RMGIC contain glass particles and aluminosilicic acid where the influence of heat will make the acid more active and degrade the glass particles.[11]

Changes in the weight of the whole sample were also observed in this study. At a temperature of 30ºC-200ºC low weight loss occurs from GIC and RMGIC. GIC experienced an average weight loss of 7.32%, while RMGIC experienced an average weight loss of 2.03%. At a heating temperature of 30ºC-400ºC moderate weight loss occurs, with GIC experiencing an average reduction of 11.47% and RMGIC experiencing an average reduction of 8.32%. At high temperatures of 800oC and 1100ºC, GIC and RMGIC experienced high weight loss. At a temperature of 30ºC-800ºC, GIC experienced an average weight loss of 30.72% and RMGIC by 27.82%. At a temperature of 30ºC-1100ºC, GIC experienced a weight reduction of 32.84% and RMGIC by 30.86%.

All samples decreased in weight due to surface fragmentation loss of material continuity associated with reduced matrix content.[13] Changes in temperature will affect the water absorption in GIC and RMGIC both in size, distribution and speed. The temperature will increase the mobility of the water molecules and the polymer network will stretch.[14]

GIC and RMGIC, which are treated with high temperatures, will also experience changes in the matrix structure. The GIC and RMGIC matrix contains water called “loosely bound water” and “tightly bound water.” “Loosely bound water” can be easily lost through evaporation. This heat-treated water loss results in weight loss. The contraction caused by the loss of loosely bound water can compensate for the thermal expansion caused by temperature fluctuations. Much of the mass loss of GIC and RMGIC occurs after heating in a dry environment. At the same time, there is also absorption of heat energy, which increases the vibration of molecules, leading to the expansion of the material. The sum of these two phenomena can control the final dimensions of the GIC and RMGIC. If one of the factors dominates, there will be a volumetric expansion or shrinkage. However, in this study, the given temperature can make GIC and RMGIC lose mass greater than the occurrence of molecular vibrations so that both materials experience volumetric shrinkage.[15]

RMGIC has a similar experience to GIC, RMGIC has lower weight loss due to greater affinity for water. RMGIC has a resin matrix that is HEMA which is responsible for the water absorption of the material. The weight reduction in RMGIC is also associated with the degradation of the resin matrix, such as HEMA 25-50% and UDMA 1-5%, which can be degraded and affect changes in the weight of the material.[10]

In addition to colour changes and weight changes, changes observed in this study change the structure of the material.[13] RMGIC has a texture that is still hard when pressed, while GIC is more easily damaged when pressed but can still be said to be rigid. This is attributed to differences in the composition of the material. RMGIC contains the resin matrix such as HEMA and UDMA, which causes RMGIC to have superior mechanical properties when compared to GIC.[10]

The limitations of this study were use of sample molds and not the use of teeth. Later in this study, after the specified temperature was reached, the sample was removed from the furnace and allowed to cool at room temperature. Many factors can complicate the heating effect on tissues and restorative materials, such as exposure time and rate of temperature rise. In addition, the analysis of colour change observations in this study uses a subjective method that depends on the individual criteria of each observer, so that it can produce different interpretations of the colour changes. High temperature heating affects the weight changes in GIC and RMGIC. There were have differences in colour changes, GIC and RMGIC after being heated at 30ºC-200ºC, 30-400ºC, 30ºC-800ºC, and 30ºC-1100ºC. There were statistically significant differences in weight changes ($p<0.001$) in GIC and RMGIC after heating at 30ºC-200ºC, 30-400ºC, 30ºC-800ºC, and 30ºC-1100ºC.

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