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Addition of gourami (*Osphronemus goramy*) fish scale powder on porosity of glass ionomer cement

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ABSTRACT

Background: Porosity is one of the disadvantages of glass ionomer cement (GIC) restorative materials, as it causes a reduction in strength and durability; the greater the porosity, the lower the strength of the restorative material and vice versa. As gourami fish scales contain calcium and phosphate, they have the potential to reduce the porosity of GIC. **Purpose:** This study aimed to analyse the effect of adding gourami fish scale powder (GFSP) on the pore size and porosity level of the GIC. **Methods:** This experimental research included a post-test-only control. The GFSP was fabricated using the freeze-drying method. Sixteen Fuji IX Extra sample cylinders with a diameter of 5 mm and a height of 3 mm were divided into four groups: K0, which comprised GIC without the addition of GFSP; K1, which contained GIC powder + 2.5% GFSP (by weight); K2, which comprised GIC powder + 5% GFSP (by weight), and K3, which contained GIC powder + 10% GFSP (by weight). The samples were observed using scanning electron microscopy and measured using ImageJ software. Data were analysed using a one-way analysis of variance (ANOVA) test. **Results:** The addition of 2.5% GFSP (by weight) produced the smallest pore size and lowest porosity, while the one-way ANOVA test results were significant among all groups at $p = 0.000$. There was no significant difference in pore sizes between K0 and K1 ($p = 0.359$), but a significant difference was found in the level of porosity ($p = 0.024$). **Conclusion:** The addition of GFSP affected the porosity of the GIC; the pore size and porosity level of the GIC were reduced by the addition of 2.5% GFSP.

Keywords: glass ionomer cement; gourami fish scale powder; porosity

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INTRODUCTION

Glass ionomer cement (GIC) is a restorative material with several advantages, including anti-cariogenic properties (due to fluoride release), biocompatibility, has a natural tooth colour and low toxicity. However, it also has disadvantages, namely, low fracture and wear resistance, brittleness and porosity, which lead to poor polishing results.¹ Porosity refers to the presence of an open cavity,² and pores act as a source of stress concentration, increasing the brittleness of specimens.³ The greater the porosity, the lower the strength and resistance of a material; this affects its compressive strength and allows it to change colour easily.^{4,5} The appearance of pores in GIC may also facilitate the increased adhesion of microorganisms on the surface of restorations due to increased roughness.⁶

A previous study found the porosity of a conventional self-cured GIC to be 7.27%–7.81%; the value for resin-modified glass ionomer cement was 5.42%–5.96%, while it was 1.01%–1.41% for composite resin.⁷ This shows that the porosity of conventional GIC is greater than resin-modified or composite resin. Furthermore, a study examined several types of GIC and found the total number of pores in light-cured Fuji IX GIC to be 13, while there were 295 in conventional Fuji IX material.⁸ Based on these studies, the porosity of conventional Fuji IX GIC is high. Pore sizes and porosity levels can be reduced or increased using materials containing calcium and phosphate,⁹ and the physical and mechanical properties of GICs can be improved by modification with hydroxyapatite.^{10,11}

One substance that contains calcium, phosphate and hydroxyapatite is gourami (*Osphronemus goramy*) fish

scales.¹² Gourami fish scales contain 5%–7.5% calcium and 5% phosphate, while other freshwater fish scales contain only 2%. In addition, the hydroxyapatite content is similar to that found in bone and dentin. The addition of 2.5%, 5%, and 10% powdered gourami scales to GIC materials tends to reduce Toll-Like Receptors 2 (TLR2) and TLR4 in rats.¹² The addition of 2.5% gourami fish scale powder (GFSP) can decrease the width of the marginal gap (a gap at the tooth-material junction) and increase the compressive strength and inhibition zone of *Streptococcus mutans* and *Lactobacillus acidophilus*.¹³

Gourami fish scales are reported to contain phosphate and calcium, which are the main materials used in teeth restoration. However, the use of these scales in dentistry has not been optimised, and their application to reduce the porosity of GIC is limited. As a restoration material, it is suspected that gourami fish scales have the potential to reduce the pore size and porosity and improve the mechanical properties of GICs. Therefore, this study aimed to analyse the effect of GFSP addition on the pore size and porosity level of conventional GIC.

MATERIALS AND METHODS

This experimental research study included a post-test-only control group design and was conducted using a random sampling technique. First, fish body scales were cleaned of fat and dirt using a cleaning brush under running water. Then, they were placed on a tray and allowed to dry at room temperature (28–33°C) for 48 hours. Next, the samples were placed in a freeze dryer for 24 hours (Zirbus Technology VaCo 5-II-D Serial No. 11/3184, Bad Grund, Germany).¹⁴ The dried fish scales were ground using a blender (Miyako, Jakarta, Indonesia) and refined with a Test Sieve Analys Mesh 200 to produce GFSP (74 µm) (ABM Jakarta, Indonesia), which was stored in a dry, airtight glass bottle.¹⁵

This study used 16 GIC sample cylinders with a diameter of 5 mm and a height of 2 mm,¹⁶ which were

divided into four groups. Sixteen GIC samples (Fuji IX Extra GC Gold Label HS Posterior, GC Corporation, Tokyo, Japan) were prepared at a 1:1 ratio of one spoonful of solid powder to one drop of liquid, respectively, based on the manufacturer's instructions. One spoonful of powder weighed 0.23 grams. The samples were divided into four groups, as follows: The K0 (control) group consisted of GIC without added GFSP. The K1 group contained GIC powder and 2.5% GFSP (by weight), where the weights of the GIC powder and GFSP were 0.224 and 0.006 g, respectively. The K2 group contained GIC powder and 5% GFSP (by weight), where the weights of the GIC powder and GFSP were 0.218 and 0.012 g, respectively. Group K3 contained GIC powder and 10% GFSP (by weight), where the weights of the GIC powder and GFSP were 0.207 and 0.023 g, respectively.

The samples were prepared by mixing GIC powder with GFSP on a paper pad. Then, the GIC liquid was added according to the manufacturer's instructions. It was stirred with an agate spatula until homogeneous and placed into a cylindrical mould with a plastic filling instrument (OneMed, Jakarta, Indonesia). Subsequently, the GIC was compacted with stopper cement (Schwert SS, Cologne, Germany), and the surface was covered with a celluloid strip. The top of the mould is loaded with 0.5 kg to obtain a similar density

After setting, the GIC was removed from the mould and stored in a closed container. The porosity (which appeared as dark round or irregular shapes) was observed using scanning electron microscopy (SEM) (Hitachi TM3030 Plus, Tokyo, Japan) under 500-x magnification. The pore size and porosity levels on the surface of the samples were calculated for all five fields of view using ImageJ software (Maryland, US). The research data were tested for normality using Shapiro–Wilk and Levene homogeneity tests. A statistical test was performed using a one-way analysis of variance (ANOVA) and continued with a least-significant difference (LSD) test using SPSS version 22 software (IBM, US).

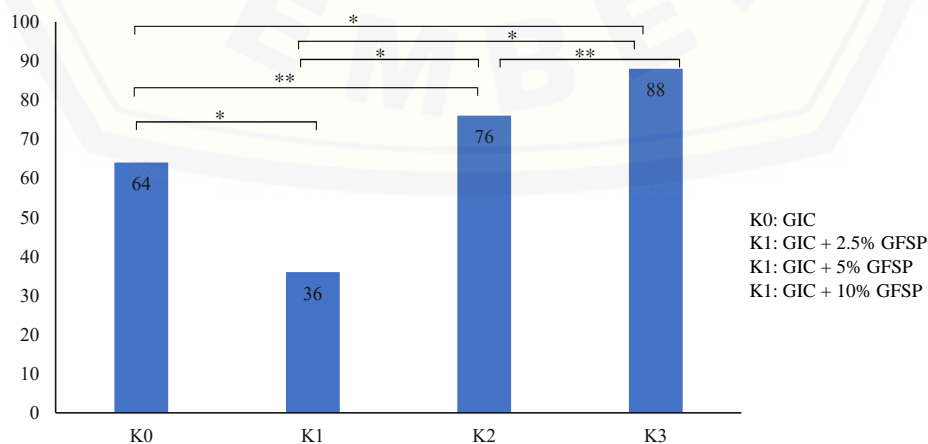


Figure 1. Average total porosity level and least-significant difference test results between groups. * $p < 0.05$, ** $p > 0.05$.

RESULTS

The smallest pore size and the lowest level of porosity were found in the K1 group, as shown in Figures 1 and 2. The pore size in the K2 and K3 groups was larger than in the K0 and K1 groups. The average value from the lowest to highest was K1, K0, K2 and K3, which indicates that the result was directly proportional to the degree of porosity.

The one-way ANOVA test results on the level of porosity showed a significant difference between all groups ($p = 0.003$). Additionally, the LSD test results indicated

significant differences between K0 and K1, K0 and K3, K1 and K2, and K1 and K3, as shown in Figure 1. The one-way ANOVA test for pore size revealed a significant difference between all groups ($p = 0.000$), while the LSD test between groups showed significant differences between K0 and K3, K1 and K2, K1 and K3, and K2 and K3 (Figure 2).

The SEM image results revealed that the smallest pore size and lowest level of porosity were found in K1. Moreover, visible crack lines in the form of porosity-related fractures were observed in all groups. Based on the results, the largest cracks were found in the K3 group (Figure 3).

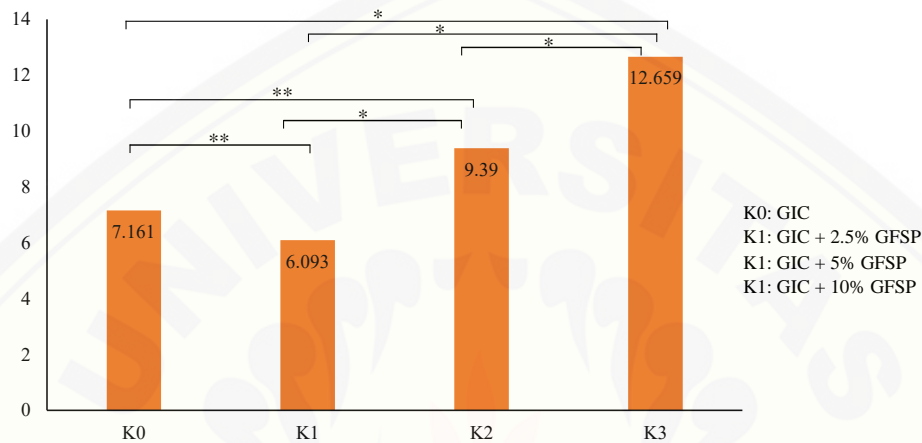


Figure 2. Average pore size (µm) and least-significant difference test results between groups. * $p < 0.05$, ** $p > 0.05$.

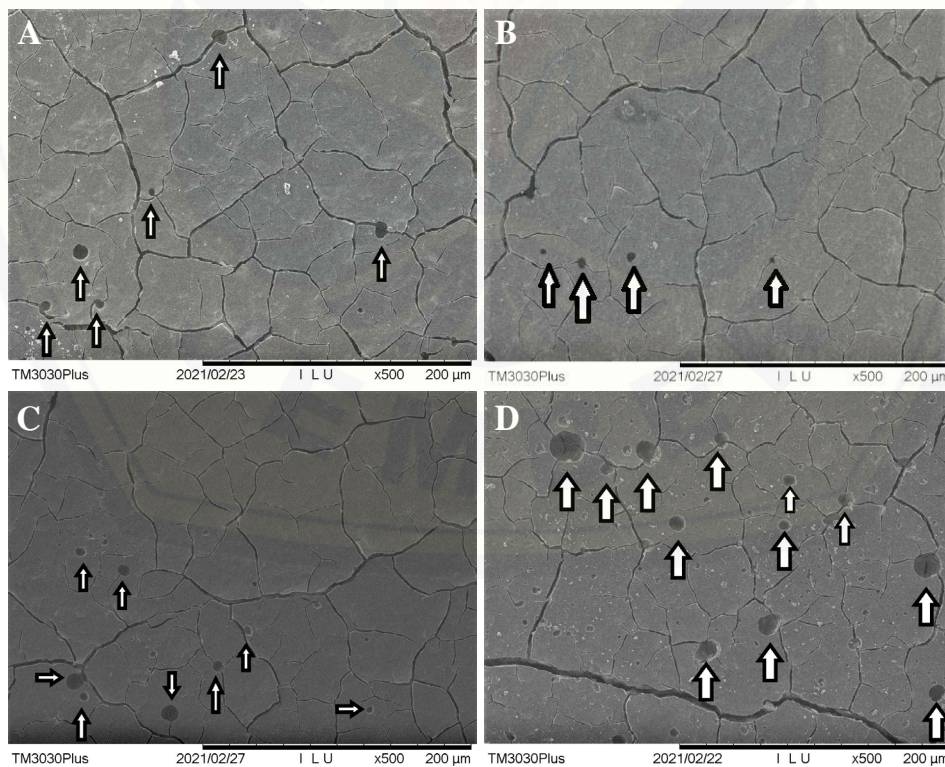


Figure 3. Microscopic characterization of the pore size and level of porosity under a 500-x scanning electron microscope. (A) K0 (glass ionomer cement [GIC] without the addition of gourami fish scale powder [GFSP]). (B) K1 (GIC + 2.5% GFSP). (C) K2 (GIC + 5% GFSP). (D) K3 (GIC + 10% GFSP). Porosity is indicated by the white arrows.

DISCUSSION

The results showed that the pore size and level of porosity in the GIC with 2.5% added GFSP were smaller and lower, respectively, than the control. It is suspected that the hydroxyapatite in GFSP binds strongly to GIC and plays a role in the chemical changes that occur during the initial setting reaction of the cement. Moreover, hydroxyapatite dissolves rapidly below pH 2.05 when mixed with GIC liquid with a pH of 1.23.¹⁷ After the reaction, hydroxyapatite from the GFSP adsorbs in the GIC matrix and fills the vacancies (distances) between the glass particles, thereby increasing the density of the cement and reducing its porosity.¹⁷ When GIC powder and GFSP containing hydroxyapatite are mixed with liquid, calcium ions are released; they initiate an acid–base reaction against metal ions, such as Al^{3+} and Sr^{2+} , on the surface of the GIC powder, forming more salt bridges and crosslinking structures.^{18,19}

The pore size and porosity level increased with higher concentrations of GFSP (5% and 10%), which is probably due to the absence of a bond between the GIC and GFSP. An increase in the amount of added GFSP did not lead to the formation of optimal crosslinking bridges. The addition of an extremely large amount of GFSP presumably caused an ineffective reaction in the GIC with no formation of bonds between the particles, thereby increasing the porosity.²⁰ The supplementation of other materials to a GIC powder affects its mechanical properties. Previous studies have confirmed that a smaller amount of GIC powder caused inadequate crosslinking, thereby reducing the matrix formed.²¹

It is assumed that the higher porosity at concentrations of 5% and 10% was caused by differences in the size of the powder particles. The largest particle size in the GIC was 50 μm , while the particle size of the GFSP reached 74 μm . Groups K2 and K3 revealed a larger pore size and a higher level of porosity due to the addition of more GFSP than in K1. The addition of larger-sized particles with smaller surface areas in the GIC/GFSP mixtures reduced the adhesion force between the powder mixtures.²²

In this study, higher viscosity was obtained at concentrations of 5% and 10% due to the difference in particle size and the extremely large amount of added GFSP. A high viscosity causes the inhomogeneous mixing of samples and increases air trapping, thereby causing the pore size and level of porosity to increase.²³ Air trapped during mixing reduced the polymer conversion rate by inhibiting the setting reaction and causing an inadequate acid–base reaction, thereby reducing polymer crosslinking.^{24,25} Porosities were observed in the K0 group (GIC without the addition of GFSP). This involves an acid–base reaction between polyacrylic acid as a proton donor and aluminosilicate glass as a proton acceptor. The polyacrylic acid further destroys the bonds in the aluminosilicate glass, while H^+ ions from polyacids and tartaric acid cause the release of Al^{3+} , Ca^{2+} , Na^+ and fluorine cations from the surface of the GIC powder, leading to the formation of porosity.¹⁷ Furthermore, porosity occurs

during the hardening process, where Na^+ and fluorine ions are unable to bond completely, leading to the release of fluorine ions and the development of empty cavities (or porosity) in the particle structure of the GIC. The release of cations from the GIC's surface causes the release of glass particles, leading to porosity.^{26,27} Moreover, the technique of placing the material in a dental cavity or impression also causes air to enter the material.⁷

In conclusion, the addition of GFSP affected the porosity of the GIC; the addition of 2.5% GFSP reduced both the pore size and the level of porosity. Further research is needed regarding the appropriate mass weight gain of GFSP for improving the mechanical and physical properties of GIC. In addition, it is necessary to investigate obtaining a GFSP particle size identical to that of GIC powder.

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