British Journal of Healthcare and Medical Research - Vol. 10, No. 5
Publication Date: October 25, 2023
DOI:10.14738/bjhmr.105.15714.
Altinawi, A. (2023). Image Visualization and Mechanical Measurements on Biocompatible Glass Ionomer Restorative Cement. British Journal of Healthcare and Medical Research, Vol - 10(5). 250-258.

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Image Visualization and Mechanical Measurements on Biocompatible Glass Ionomer Restorative Cement

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ABSTRACT

The present study aimed to corroborate image visualization techniques with mechanical measurements on biocompatible glass ionomer restorative cement of different compositions. Commercially available biocompatible glass ionomer restorative cement (BGIRC) was mixed with Arabic Gum (AG) powder with different weight percentages (0, 0.5, 2, 4, & 8). Mean and variance values were measured for image visualization. Additionally, diametral tensile strength and compressive strength tests were used to measure the mechanical properties. T-test and Tukey's post hoc tests were used to find any statistical significance among the data. The findings revealed that mean values for the image visualization technique displayed the same pattern as diametral and compressive strength tests and their values. The mean values also displayed a significant difference between the groups with different wt.% of AG powder when mixed with BGIRC. Image visualization parameter i.e., mean values and mechanical testing i.e., diametral tensile strength surfaced a method in emphasizing the properties of the BGIRC with AG. Although the diametral tensile strength test is a more reliable method for identifying the mechanical properties of BGIRC with AG, image visualization displays a factual evaluation of the material.

Keywords: Image visualization, Mechanical measurement, Restorative cement, Arabic gum.

INTRODUCTION

Biocompatible glass ionomer restorative cement (BGIRC) plays a vital role in dentistry due to its composition and multipurpose application within the field [1]. It is formed using powdered glass, and polyacrylic acid which yields a paste-like solution. The most significant property of BGIRC is their adhesive ability which enables them to form bonds with dental-compatible materials and specifically to tooth structures [2]. The common use of BGIRC is the restoration of cavities, cementation of dental bridges and crowns, and attaching of orthodontic brackets and bands [2]. Additionally, BGIRC tends to free fluoride ions at regular intervals, a quality that paves the way to the re-mineralization and protection of other dental tissues and also stops decay around dental restorations [3]. Besides having adhesive properties and discharging fluoride ions, they are also unshrinkable, quickly fixed, and less sensitive to post-operative treatment [4]. Recently BGIRC has been used for aesthetic purposes the most, as they can emulate natural tooth color when combined with other biomaterials [5]. The Arabic Gum (AG), commonly known as Acacia gum as it is extracted from Acacia trees is a natural

polymer that is used in numerous industries as it has various applications [6]. The AG is widely used in cosmetic and personal care, edible, and pharmaceutical industries due to its chemical composition, and solubility properties [7]. Moreover, the usage of AG is not harmful to the environment as it is biodegradable [8]. The Arabic gum also exhibits adhesive and biocompatible characteristics just like BGIRC, thus making it safe to use for oral purposes [9]. Additionally, AG is widely used as a binding substance for drug products and texture improvement in the food industry [10]. Other than conventional testing such as mechanical and chemical tests, the Image Visualization (IV) technique is becoming common and preferred in various industries [11, 12]. Using the IV technique, materials or surface qualities can be objectively assessed. Properties extracted through IV serve as crucial tools across the food industry and materials science studies. The main aim of using IV is to simplify the evaluation by analyzing the textures present on the surface of the substance or material. It can be carried out by using tests in the laboratory using machines, or using image processing software. The most common image visualization scale is the mean and the variance [13], they are the statistical term used to measure the features of the texture. By using IV, we can identify porosity, roughness, graininess, and tractability [14]. Besides using IV, conventional testing methods such as diametral tensile strength and compressive strength tests primarily serve as a way to predict the properties of biomaterials. The accuracy and reliability of diametral tensile strength and compressive strength tests have been in practice in the field of dentistry for a long [4]. Using diametral tensile strength and compressive strength tests is time-consuming and wastage is produced. However, diametral tensile strength and compressive strength tests are prerequisites for many commercially available dental biomaterials to fulfil safety, quality, and regulatory compliance for dental practitioners [15]. Earlier studies are available on the mechanical properties of different biocompatible materials using AG [6, 16, 17]. However, to date, no study is available to support BGIRC with AG using an image visualization approach as well as mechanical properties. In the present study, the findings of the image visualization and mechanical properties are carried out using BGIRC with AG.

MATERIALS AND METHODS

Study Design

The current study was designed to corroborate a relationship between the mechanical values and image visualization measurements on biocompatible glass ionomer restorative cement with oxidized AG powder.

Gum Arabia Oxidization Process

Gum Arabic Powder of 1 gram was added to 20 ml distilled water gradually with a constant stirring using a wooden stirrer for 30 minutes and was heated at 70 degrees centigrade. Later 30 ml of 30% H_2O_2 was added to supplement a catalytic amount of $FeSO_4$ of 2 gms. The solution was heated at 100 degrees centigrade for almost 120 minutes with additions of distilled water at regular intervals to maintain the quantity of the solution. Finally, the peroxide strip test was used to check the reaction, and using a vacuum water was evaporated.

Preparation of Samples

In the present study, disk-shaped samples were prepared using commercially available biocompatible glass ionomer restorative cement i.e., GC Fuji II (GC Corporation, Tokyo Japan). Different weight percentages (0.5, 2.0, 4.0, and 8.0) of the GC Fuji II BGIRC were added to the AG oxidized powder (size 50 to 120 microns). Initially, the GC Fuji II and AG oxidized powder

URL: http://dx.doi.org/10.14738/bjhmr.105.15714.

was mixed manually, and later to optimize the mixture a vibrator was used for 5 minutes. One GC Fuji II BGIRC was prepared without using AG oxidized powder for the control group. The liquid and powder ratio used for mixing the GC Fuji II BGIRC and AG oxidized powder was 1:1 (i.e., powder: liquid ratio) according to the standard, see Table 1. All the samples were prepared by mixing the GC Fuji II BGIRC and AG oxidized powder till a uniform appearance was visible and later poured into a custom-made silicon mould. Thus, each study group sample was disk-shaped having dimensions of 3 mm height and 5 mm diameter. After 40 minutes each sample was removed from the mould and placed in an incubator for 24 hours at 37 degrees centigrade and later stored in labelled containers for the study.

Table 1: Details of the preparation of each sample group to understand the powder: liquid ratio used in the study.

No of samples	Group with wt.% of A. G	Powder Formulation (gm)
6	G1; Control: 0.0 wt.% A. G	4.00
6	G2; Control: 0.5 wt.% A. G	4.02
6	G3; Control: 2.0 wt.% A. G	4.08
6	G4; Control: 4.0 wt.% A. G	4.16
6	G5; Control: 8.0 wt.% A. G	4.32

Image Acquisition

After preparation of all the samples, image acquisition was carried out using a Stereomicroscope (SMZ1000, Nikon, Tokyo, Japan), see Figure 1. To increase accuracy and achieve optimal reading 3 different samples for each group were examined. Thus, a total of 15 images (3 from each group) were acquired and saved for image analysis in default format i.e., jpg. Later all the jpg format images obtained were converted to bmp format files.

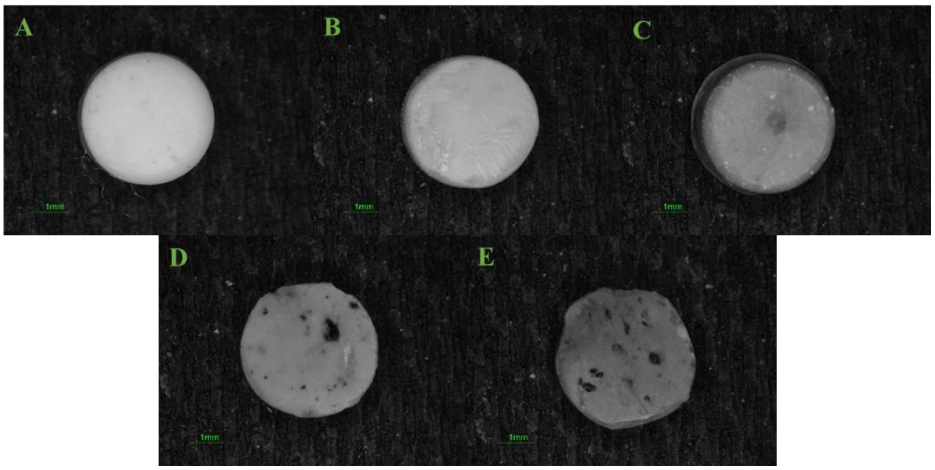


Figure 1: Image acquisition using stereomicroscope one sample from each group; (A) G1; control group, (B) G2; AG powder 0.5 wt.%, (C) G3; AG powder 2 wt.%, (D) G4; AG powder 4 wt.%, (E) G5; AG powder 8 wt.

Image Visualization Analysis

Software MAZDA version 4.6 (Institute of Electronics, Technical University of Lodz, Poland) was used to extract image parameters before mechanical measurements. Sample (n=3) from every group were selected with an ROI of 600 pixels. A total of 15 images from 5 different

groups (3 each) with 2450 ROI were examined for mean and variance. Other signal intensity of each ROI was normalized considering the limitation of the dynamics to μ±3σ (μ, grey-level mean; and σ, grey-level standard deviation).

Diametral Tensile Strength Test

For diametral tensile strength 15 samples from 5 different groups (3 each) were placed so that their circular shape was sitting in between the fixed base and movable side of the Universal Testing Machine (Model no. 3369, Instron, Canton, MI, USA) to put pressure on the diameter of each sample see figure 2. A crosshead speed of 1.5 mm/min with a 5kN compressive force was applied to each sample till it cracked the sample. Using software Bluehill diametral tensile strength values were calculated in mega Pascal.

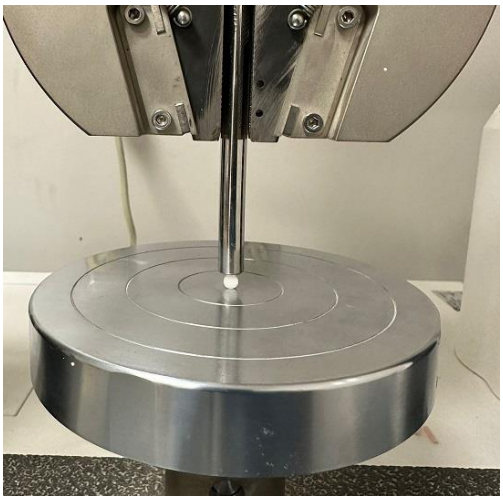


Figure 2: Diametral tensile strength test for a control group sample (G1).

Compressive Strength Test

To measure compressive strength, every sample (n=3) from each group was placed with a flat surface between the fixed base and movable side of the same Universal Testing Machine as used for the diametral tensile strength Test, which can be seen in Figure 3. A crosshead speed of 1 mm/min with a 5kN compressive force was applied to each sample till it cracked the sample. Using software Bluehill compressive strength values were calculated in mega Pascal.

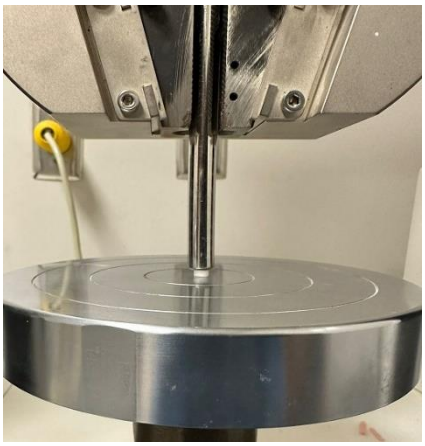


Figure 3: Compressive strength test for a control group sample (G1).

URL: http://dx.doi.org/10.14738/bjhmr.105.15714.

Statistical Analysis

The data acquired from the image visualization, diametral tensile strength, and compressive strength were analyzed with SPSS version 28 software (IBM Corporation, Armonk, NK). The T-test and Tukey's post hoc tests were used to compare groups at a 95% confidence level where $p < 0.05$.

RESULTS

The image visualization analysis for the values of the mean for each group depicts that by adding AG powder to GC Fuji II BGIRC decreases with the increase in the quantity of AG powder, as seen in Figure 4. The highest value of mean was recorded for G1 i.e., control group, whereas the lowest variance was recorded for the G5 group where AG powder was 8 wt%. A firm and almost constant decrease was noted with the presence of a significant decrease among the groups.

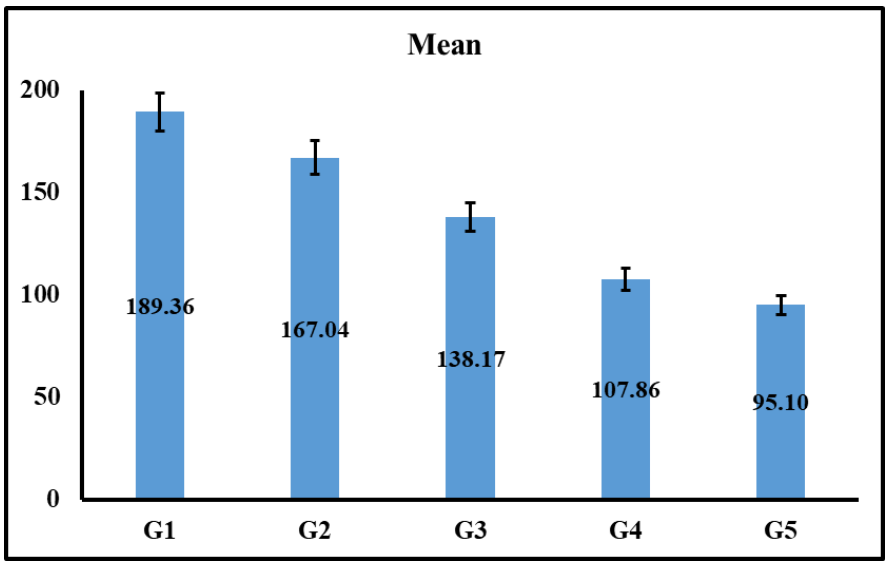


Figure 4: Mean values of each group (G1 to G5). Statistically significant differences were present between the groups G1:G2, G1:G3, G1:G4, G1:G5, G2:G3, G2:G4, G2:G5, G3:G4, G3:G5.

Figure 5 illustrates the variance values for each group, by adding AG powder to GC Fuji II BGIRC does not display a regular pattern with an increase in AG powder. The highest variance value was recorded for G4 where AG powder was 4 wt%, whereas the lowest variance was recorded for the control group. However, the presence of a significant difference between the groups was not found.

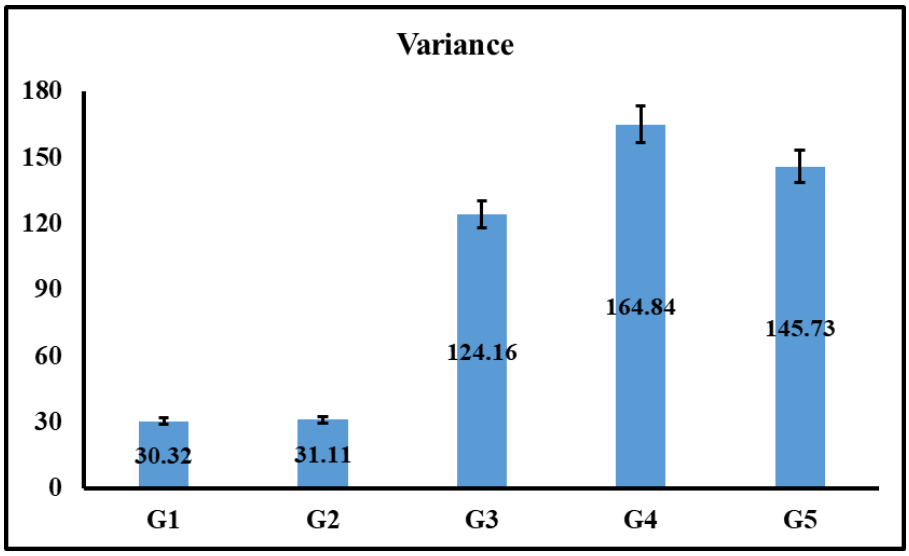


Figure 5: Variance values of each group (G1 to G5).

In Figure 6, the diametral tensile strength test of all the groups (G1 to G5) is displayed. The highest diametral tensile strength test value was recorded for G2 where AG powder was 0.5 wt%, whereas the lowest diametral tensile strength test value was recorded for G5 where AG powder was 8 wt %. Increased quantity of AG powder to GC Fuji II BGIRC displayed lower diametral tensile strength values. However, the presence of significant differences was recorded between a few groups.

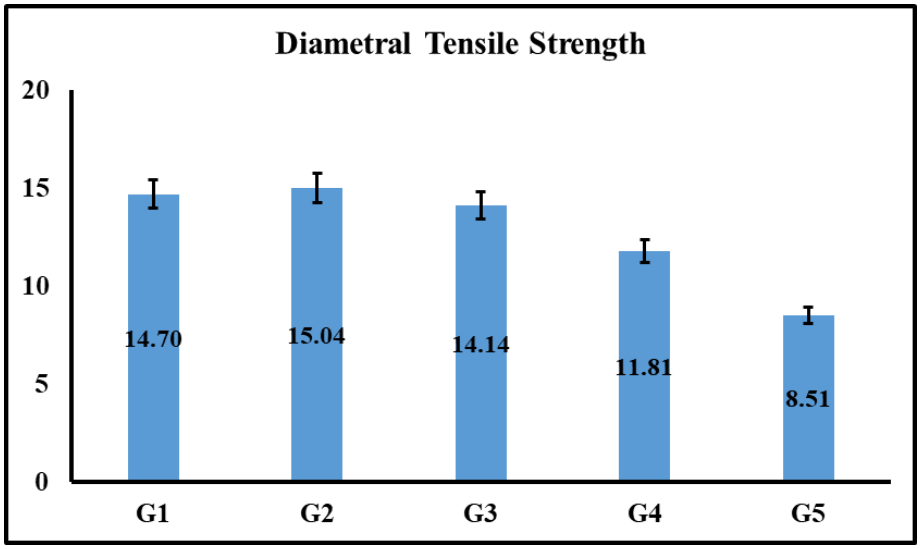


Figure 6: Diametral tensile strength values for each group (G1 to G5). The statistically significant difference was present between the groups: G1:G5, G2:G5, G3:G5.

Figure 7, the compressive strength test values of all the groups (G1 to G5) showed the same pattern as diametral tensile strength test values. The highest diametral tensile strength test value was recorded for G2 where AG powder was 0.5 wt%, whereas the lowest diametral tensile strength test value was recorded for G5 where AG powder was 8 wt %. Increased quantity of AG powder to GC Fuji II BGIRC displayed lower compressive strength values. However, the presence of significant differences was recorded between a few groups.

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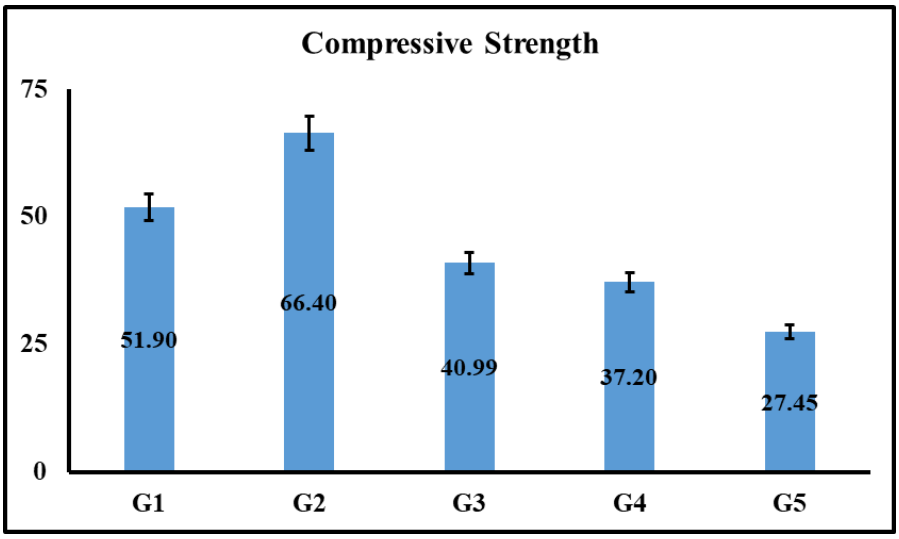


Figure 7: Compressive strength test values of each group (G1 to G5). Statistically significant differences were present between the groups G1:G2, G1:G3, G1:G4, G1:G5, G2:G3, G2:G4, G2:G5, G3:G5, G4:G5.

DISCUSSION

Image visualization on restorative cement is an apparent approach for estimation reasons where the tooth is exposed to different environmental factors such as extreme force, constant saliva, hot or cold substances, and different types of dietary items either liquid or solid [18, 19]. Similarly, diametral tensile strength and compressive strength tests are the most widely used methods for detecting the mechanical properties of the restorative material along with AG [20]. Before using and applying BGIRC, dental practitioners have to be assured that the substance properties are fulfilling the standard [21] and will stand with the oral conditions. The findings of the image visualization such as mean and variance, and mechanical tests tend to deliver higher dependability and correctness. Numerous studies have been performed on testing BGIRC [4, 21, 22]. Image visualization technique is still new on BGIRC along with AG in comparison to mechanical testing. However, using image visualization techniques is easier in terms of time, cost, and effort [23]. In Figure 4 and Figure 6 two different tests (i.e., mean and diametral tensile strength) approaches were used but both of them displayed the same findings and patterns in terms of the results. However, figure 5 i.e., the variance values were independent and did not depict any coherent findings by the mean, diametral tensile strength, and compressive strength test values. The compressive strength from G2 to G5 control group was also consistent in line with the mean and diametral tensile strength test values, whereas G1 didn't match the findings of the mean and diametral tensile strength tests. Image visualization laboratory-based studies have been performed on several [24-26]. However, image visualization laboratory-based studies on biocompatible restorative dental material with AG are not present. In the present study, the image visualization approach was used by examining the values of the mean and the variance, where mean values showed accurate findings in line with diametral tensile strength test values. Additionally, the presence of statistically significant differences was also witnessed in different groups for the mean values of BGIRC with AG. The findings of the present study recommended the image visualization mean value is a dependable approach to identifying the mechanical properties of biocompatible dental restorative materials using AG.

CONCLUSION

Image visualization parameters i.e., mean values and mechanical testing i.e., diametral tensile strength surfaced a method in emphasizing the properties of the BGIRC with AG. Although the diametral tensile strength test is a more dependable method in identifying the mechanical properties of BGIRC with AG, image visualization displays a factual evaluation of the material. The present study was carried out in a BGIRC with an oxidized AG powder in disk-shaped samples. It is recommended that future studies should be carried out on different shapes and materials to calculate the image visualization value of the mean and compare it with mechanical property (diametral tensile strength test).

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