Original Article

A Comparative Evaluation of Compressive Strength of Various Tooth-Colored Restorative Materials: An *In Vitro* Study

Sumera Pervaiz Khan[1], S. Deep[1], Prabhav Chauhan[1], Abhishek Jain[1], Bhawana Chauhan[1], Shivani Agrawal[1]

[1]Department of Pediatric and Preventive Dentistry, Shree Bankey Bihari Dental College, Ghaziabad, Uttar Pradesh, India.

Abstract

Background: The basic purpose of the restorative materials is to substitute the biological, functional, and esthetic properties of healthy tooth structure. Therefore, compressive strength is one of the major factors used by clinicians to predict the performance of a restorative material. **Aim**: The aim of the study is to compare and evaluate the compressive strength of glass ionomer cement (Type II; restorative), Compomer, Giomer, and Zirconomer. **Methods**: A sample size of 48 was taken and divided into 4 groups of 12 each: Ketac Molar, Compomer, Giomer, and Zirconomer. These were prepared as cylinders, measuring 8 mm × 4 mm and then transferred to the Universal Testing Machine individually until evidence of failure was observed. Thus, the compressive strength of all the four groups was evaluated and the data tabulated was sent for statistical analysis for comparison. **Results**: Giomer had the highest value for compressive strength possibly because of the crosslinked polymer matrices followed by Zirconomer, Compomer, and Ketac Molar. **Conclusion**: The maximum mean value score of compressive strength was found for Giomer followed by Zirconomer and Compomer and the least mean value score was found for Ketac Molar.

Keywords: Compomer, Compressive strength, Giomer, Glass-ionomer cement, Zirconomer.

Introduction

Dental caries has been affecting mankind from time immemorial. Since ancient times to 18th century, dental caries have been replaced or restored with wide variety of materials including stone chips, ivory, human teeth, turpentine resin, cork, gums, and metal foils - tin and lead.

It is of paramount importance by the dental professionals to preserve and conserve what nature has given.[1] The basic purpose of the restorative materials is to substitute the biological, functional, and esthetic properties of healthy tooth structure.[2]

The philosophy of minimal intervention (MI) density and the CAMBRA approach is gaining popularity worldwide as both integrate the new understanding that caries is a biofilm-related, multifactorial, and lifestyle-associated bi-directional disease. In the oral cavity, restorations undergo stress from masticatory forces producing different reactions that lead to deformation, which can ultimately compromise their durability over time.[3] This is limited if the strength of restorative materials is close to the strength of the tooth structure.[4] Thus, the quest for an ideal restorative material with optimum physical properties and durability exists.

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Compressive strength may be considered to be a critical indicator of success because higher the compressive strength, more the resistance to masticatory forces.[5-7]

Properties of glass ionomer (GI) cements such as bonding to the dental substrate and fluoride release made them to be used for clinical conditions. However, the remarkable uses of GI cement (GIC) are limited by their mechanical strength. To improve their mechanical properties, several modified GICs have been developed, a fact that justifies the constant research effort that has been made to assess the alleged improvements.[8]

Resin-modified glass ionomers were introduced to the dental profession in 1991.[9] Compomers were developed in an attempt to acquire the physical strength of methacrylate-based

Address for correspondence: Dr. Abhishek Jain, Department of Pediatric and Preventive Dentistry, Shree Bankey Bihari Dental College, Ghaziabad, Uttar Pradesh, India.
Email: abhi1150592@gmail.com

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composites and to retain the clinically attractive properties of glass ionomers.[1,10,11]

The majority of the components are identical to methacrylate-based composites, which contain dimethacrylate monomers and inorganic filler particles.[10,11] However, Compomers contain additional "ion-leachable glass" powder as found in glass ionomer materials and special monomers with structures that are characterized by the presence of acidic functional groups and polymerizable methacrylate-based residues.[11,12]

Recently, zirconia reinforced GI, a novel material, was introduced that could overcome the drawbacks of previously used tooth-colored restorative materials; the main powder component of Zirconomer results from Baddeleyite (ZrO2) that contains high levels of zirconia.[5] The glass component of Zirconomer is subjected to controlled micronization and to acquire optimum particle size and characteristics. The grain size has an effect on an exclusive characteristic of zirconia called transformation toughening, which gives it higher strength, toughness, high hardness, and corrosion resistance; thus, when it is homogeneously incorporated in the glass component, it further reinforces the material for lasting durability and high tolerance to occlusal load.[5]

Hence, this biomaterial promises to show outstanding strength, durability, and sustained fluoride protection, therefore combining and retaining the benefits of both popularly used restorative materials amalgam and conventional GI.

To overcome these disadvantages, recently, a new category of hybrid esthetic restorative material which differs from both resin-modified GI and composites has been introduced known as GIOMERS.

Giomer is a specialized restorative material with the properties of both GIC and composites. The S-pre-reacted GI (PRG) technology not only provides the benefits of mechanical strength of a composite material but also provides release of multiple ions which in turn provide multiple biological functions such as fluoride release and recharge, anti-plaque effect, anti-biofilm effect and modulation of pH. Furthermore, the esthetics, light transmission, diffusion, and fluorescence properties are similar to natural teeth.[12-14]

Since the comparison of the physical and mechanical properties of GIC would help the clinician to choose the appropriate and best material available for the restoration of weakened tooth structure, the present study has been conducted to comparatively evaluate the compressive strength of four different types of GICs, namely Ketac Molar, Zirconomer, Giomer, and Compomer.

Although some studies have been carried out on similar materials, they are sparse and more research is needed to authenticate the results of these, thereby justifying the need for this study.

Aim and objective

The aim and objective of the study are to evaluate and compare the compressive strength of GIC (Type II; restorative), Compomer, Giomer, and Zirconomer.

Methods

A total number of 48 samples were prepared according to the manufacturer's instructions and were randomly divided into four equal groups, Groups I–IV, consisting of 12 samples each (n = 12): Ketac Molar, Giomer, (Zirconomer), and Compomer. After curing and setting of all materials, they were removed from the split cylindrical mold measuring 8 mm × 4 mm and stored.

In the present study, compressive strength was recorded by positioning the specimen vertically on the universal testing machine individually and subjected to load cell of 20 kN, at a crosshead speed of 1 mm/s at an angle of 90° to restoration until visible or audible evidence of failure was observed.

For all the study samples, the compressive strength was calculated in megapascals using the formula: [14]

$$CS = Load/\prod r2$$

Where CS = compressive strength; load is expressed in Newton (N); $\prod = 3.14$; r = half the diameter of mold.

Ethical clearance

Institutional ethical clearance was obtained for the research vide number SBBDC/2020/152118-A dated 22.12.2020.

Results

Graph 1 showed the mean compressive strength of the groups where Group I was seen to have the highest compressive strength (289.70 ± 16.58) and Group IV had the least compressive strength (152.10 ± 15.99).

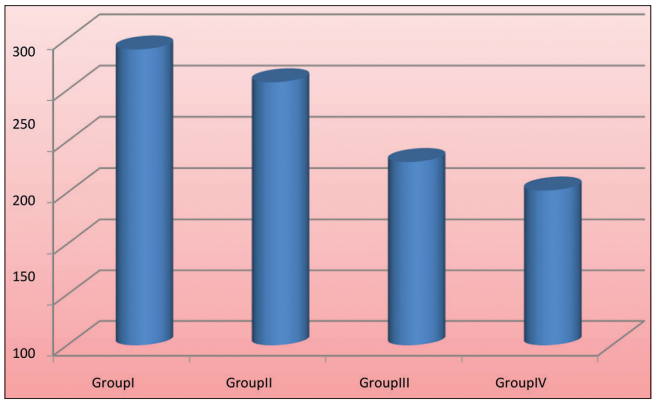
Graph 2 showed a statistically significant difference ($P < 0.0001$) among all the groups using Analysis of Variance (ANOVA test).

Compressive strength of Group I ranged from 269.60 to 319.26, Group II from 229.64 to 292.40, Group III from 158.93 to 212.16, and Group IV from 126.10 to 177.53. Giomer had the highest value for compressive strength possibly because of the crosslinked polymer matrices. Zirconomer showed better results than Compomer and Ketac Molar which may be attributed to zirconia as filler particle whereas Ketac Molar exhibited the lowest mechanical properties.

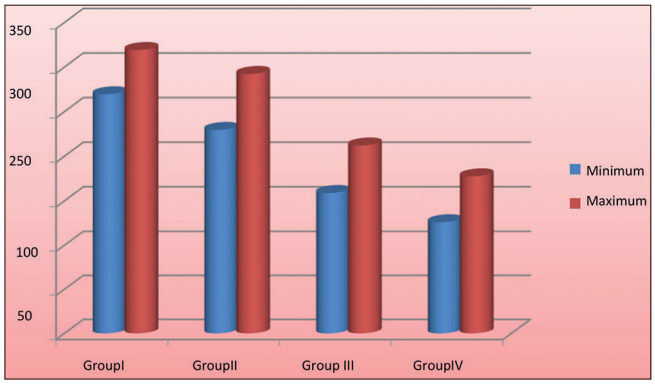
Discussion

GICs were introduced by Wilson and Kent in 1972.[15] The unique properties of GIC, such as adhesion to moist teeth, anti-carcinogenic character, lack of exothermic polymerization, excellent adhesion to dentin, close thermal expansion to tooth, and satisfactory biocompatibility, make it an important material in dental applications.[16]

One of the major drawbacks is its weak mechanical properties such as brittleness, low strength, and toughness.[17] Hence, GICs were mostly used for the restoration of teeth in areas with less masticatory load due to their poor mechanical strength.[18]



Graph 1: Graphic representation of compressive strength with respect to different groups



Graph 2: Graphic representation of compressive strength by analysis of variance (ANOVA test)

Despite the brilliant properties of GIC, its weak mechanical property poses an obstacle for its use as a posterior restorative material. Since then, several modifications have been introduced with the purpose of enhancing their mechanical properties.[15]

Resin-modified glass ionomers set by the twin processes of neutralization (acid–base reaction) and addition polymerization, and the resulting material has a complicated structure based on the combined products of these two reactions. They contain the same essential components as conventional glass ionomers (basic glass powder, water, and polyacid) but also include a monomer component and associated initiator system. The monomer is typically 2-hydroxyethyl methacrylate, HEMA, and the initiator is camphorquinone.

Moreover, competition between these two network-forming reactions means that there is a sensitive balance between them. This mixture of setting reactions may jeopardize the reliability of the set material, and as a consequence, close adherence to the manufacturer's recommendations on the duration of the irradiation step is essential to produce material optimal properties.[9] Compomer is an example of this type of modified GIC.

A newer product category called "giomer" has been proven in many research studies to overcome weaknesses such as technique sensitivity, limited fluoride release, and water sorption which decrease physical properties with time. Giomer is a tooth-colored restorative material that uses a resin base and PRG technology.

S-PRG technology delivers some properties of GI such as fluoride release and recharge which helps to prevent caries recurrence. It also provides properties of composite resin such as excellent esthetics, easy polishability, biocompatibility, and smooth surface finish.

Moreover, it has an antiplaque effect by forming a material film layer with saliva that is reported to minimize plaque adhesion and inhibit bacterial colonization.[19] Giomers report comparable microleakage scores to that of composite resins in permanent teeth.[20]

A giomer is a proprietary product exclusive to Shofu Dental Corporation (San Marcos, CA). Like a traditional methacrylate-based composite, the giomer chemical composition comprises inorganic filler particles and organic-resin matrix.[20,21]

Instead of applying purely glass or quartz as the typical fillers, the giomer incorporates inorganic fillers that are derived from the complete or partial reaction of ion-leachable glasses (e.g., fluoroboroaluminosilicate glasses) with polyalkenoic acids in water before being interfaced with the organic matrix.[20,21]

The addition of zirconia as filler particle in the glass component of Zirconomer improves the mechanical properties of the restoration by reinforcing structural integrity of the restoration and can be used in load bearing areas, such as posterior restorations. The combination of strength, durability, and sustained fluoride protection and chemical bonding makes it good permanent posterior restorations in patients with high caries incidence as well as in cases where strong structural cores and bases are required.[22]

In addition, Zirconia is highly rated in terms of esthetics and has several other advantages, including biocompatibility as it is metal free and has a low degree of bacterial adhesion, high flexural strength, and acceptable optical properties.[23]

To sum up, the introduction of modified GIs with superior mechanical strength is being used in posterior restorations.[8] This newer generation of GI has retained the most desirable qualities of conventional versions, namely fluoride release, ion exchange adhesion to conditioned enamel and dentin, and low interfacial shrinkage stress.[24]

The results of this particular study showed Giomer having the highest compressive strength followed by Zirconomer, Compomer, and Ketac molar, respectively. The difference between all the four groups was observed to be significant. These results are supported by a study carried out by Walia *et al*. The maximum mean value score of compressive strength was found to be the highest for the Giomer followed by Zirconomer and the least mean value score was found for the Ketac Molar.[2]

Giomer had the highest value for compressive strength which was in accordance with the study conducted by Quader *et al*.[25] which showed the resin-based PRG fillers and cross-linked polymer matrices that result in the higher compressive strength than the acid–base reaction in GIs.

Zirconomer showed lesser value of compressive strength as compared to Giomer but more than Ketac Molar. The addition of zirconia as filler particle in the glass component of Zirconomer improves the mechanical properties of the restoration by reinforcing structural integrity of the restoration in load-bearing areas.[25]

Ketac Molar had the lowest value for compressive strength as compared to the other study groups. The reason for the low score of compressive strength for Ketac Molar is due to the poor mechanical properties, such as low fracture strength, toughness, and higher occlusal wear rate as studied by Lohbauer.[26]

Shetty *et al*. evaluated the compressive strength of Zirconomer to be significantly better than Ketac Molar which is again supportive of the findings in this research work.[27]

Although contradictory to the findings of this study where Zirconomer was seen to have higher compressive strength compared to Compomer, Patil K.M and Hambire U.V found compoglass to have higher compressive strength compared to zirconomer.[28]

According to a study carried out by Dheeraj *et al*., GIC had less compressive strength when compared to Zirconomer which is again in accordance with the results of this study.[29]

Dental caries has been affecting mankind from time immemorial. Since ancient times to 18th century, dental caries has been replaced or restored with wide variety of materials including stone chips, ivory, human teeth, turpentine resin, cork, gums, and metal foils - tin and lead.

It is of paramount importance for the dental professionals to preserve and conserve what nature has given.[1] The basic purpose of the restorative materials is to substitute the biological, functional, and esthetic properties of healthy tooth structure.[2]

The longevity of a dental restoration is essentially dependent on various factors that include properties of the dental material used, age of the patient, and rate of progression of caries in the restored tooth.[30]

In the oral cavity, restorations undergo stress from masticatory forces producing different reactions that lead to deformation, which can ultimately compromise their durability over time.[3] This is limited if the strength of restorative materials is close to the strength of the tooth structure.[4] Thus, the quest for an ideal restorative material with optimum physical properties and durability exists.

The compressive strength of a material is an important factor to be considered in restorative materials. It is the amount of stress required to distort the material in an arbitrary amount. It is calculated by dividing the maximum load by the original cross-sectional area of a specimen.[5]

Despite the brilliant properties of GIC, its weak mechanical property poses an obstacle for its use as a posterior restorative material. Since then, several modifications have been introduced with the purpose of enhancing their mechanical properties.[15]

Conclusion

The results of this particular study showed Giomer having the highest compressive strength followed by Zirconomer, Compomer, and Ketac molar, respectively. The difference between all the four groups was observed to be significant.

Therefore, it will be apt to mention here that more studies are to be conducted to authenticate this result.

Limitations and future studies

With the development of new technologies and upcoming advancements in the field of dentistry, there should be a constant effort in the development of a restorative material with higher mechanical strength while preserving the adhesion and fluoride release properties of GIC. Further studies may be required to prove the result obtained in this study.

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