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AINSHAMS DENTAL JOURNAL

AIN SHAMS DENTAL JOURNAL
Official Publication of Ain Shams Dental School
June 2020 - Vol. XXIII

A comparative evaluation of marginal integrity and compressive strength of different recent reinforced glass ionomer restorations at different storage times.

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Abstract:

Aim: This research was designed to evaluate the Marginal integrity and Compressive strength of different recent reinforced glass ionomer restorations at different storage times. **Materials and method**: For the evaluation of marginal adaptation, Class V cavities were prepared on forty-five human premolar teeth and divided into three study groups (n = 15): Group I (Ketac Molar), Group II (riva self-cure), and Group III (Zirconomer). The samples were thermocycled and subjected to dye penetration test. The sections were made and evaluated under stereomicroscope at × 40 magnification. For the compressive strength evaluation, forty-five cylindrical specimens were fabricated measuring 3 mm × 6 mm and grouped into three study groups (n = 15): Group I (Ketac Molar), Group II (riva self-cure), and Group III (Zirconomer). All were then subjected to the Universal Testing Machine at crosshead speed of 1 mm/s.

Results: The marginal adaptation was found significant ($P < 0.05$) for all study groups, with ketac molar showing maximum followed by riva self-cure, and Zirconomer. The compressive strength was found to be highly significant ($P < 0.01$) with the maximum score for Zirconomer followed by riva self-cure, and Ketac Molar. **Conclusion**: The sealing ability was maximum in Ketac Molar, riva self-cure, and Zirconomer whereas the compressive strength was maximum for Zirconomer followed by riva self-cure, and Ketac Molar.

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Introduction:

The basic purpose of the restorative materials is to substitute the biological, functional, and esthetic properties of natural tooth structure [(1)].

One of the most important requirements for the success of restoration is to prevent the micro leakage, which is achieved with the proper adherence of restorative material to the cavity walls. The inadequacy of the restorative materials to attain the complete marginal seal leads to occurrence of gaps, in which the seepage of ions, fluids, and bacteria occurs, which causes secondary decay, sensitivity, and pulpal affections [(2)]. Thus, the newer materials were introduced with better biomechanical properties such as better marginal seal , good esthetics , easy polishability , biocompatibility , and high compressive strength [(3)].

The compressive strength of a material is defined as 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 [(4)]. The necessity of good compressive strength, with minimum micro leakage, has led to the development of various posterior esthetic restorative materials with promising results such a glass ionomer restorative material, composites, compomers, Giomers and Zirconomer. Since glass ionomer restorative materials fail to achieve sufficient hardness, resistance to fracture and have a low abrasion resistance, a newer conventional glass ionomer restorative material, high viscous glass ionomer, was evolved with improved mechanical properties [(5)].

A new hybrid esthetic restorative material, resin modified glass ionomer, was introduced with physical and mechanical properties of composite resin and added benefits of high radiopacity, fluoride release, and antiplaque effect of glass ionomer restorative material. Resin modified glass ionomer, is based on prereacted filler technology, where prereacted glass particles are incorporated in the resin matrix to enhance its strength [(6,7)].

A new class of restorative glass ionomer that comprises the strength and durability of amalgam is evolved as a recent posterior restorative material called Zirconomer. The inclusion of Zirconia fillers in glass component of Zirconomer reinforces the structural integrity of restoration and imparts superior mechanical properties in posterior load-bearing areas [(8)].

Thus, the present in vitro study will be undertaken to compare the marginal integrity and compressive strength of high viscous glass ionomer, resin modified glass ionomer, and Zirconomer to evaluate the best restorative material in marginal adaptation and compressive strength.

All the materials compositions were listed according to the manufacturer's profile.

Table (1) Materials used in this study:

Material category	Brand name	Composition	Manufacture and Batch number
(1) High viscous glass ionomer	Ketac molar	**Powder**: aluminum-calcium-lanthanum-fluorosilicate –glass. **Liquid**: aqueous solution of polycarbonic acid and tartaric acid.	3-M ESPE, Deutschland GmbH Germany, 41453
(2) Resin modified glass ionomer.	Riva	**Powder:** calcium-fluoro-aluminosilicate glass particles of a conventional GIC plus free radical initiator systems. **Liquid**: aqueous solution of polyacrylic acid, HEMA and chemical activator.	Riva, SDI Ltd. Australia 1602231
(3) zirconia reinforced glass ionomer	Zirconomer	**Powder**: Fluor aluminosilicate glass, zirconium oxide, pigments and others. **Liquid:** polyacrylic acid solution and tartaric acid.	Shofu Inc., Tokyo, Japan 03150682

I. Marginal adaptation

1. Selection and preparation of teeth:

A total number of forty-five freshly human extracted non carious premolars due to orthodontic treatment plane, patient range from (25_35) age, teeth free of cracks and any developmental defects were used in this study. The teeth were washed under running water to remove blood, scaled with periodontal scaler to remove calculus and remnants of periodontal tissue and polished with fine pumice free from eugenol and soft rubber cups rotating at low speed (15000 rpm) under coolant. Teeth were stored in distilled water at room temperature until use. The distilled water was changed daily.

2. Grouping of specimens:

The teeth were randomly divided into three main equal groups (A) (n=15), according to the type of restorative material, ketac molar (A1), Resin modified glass ionomer (A2) and Zirconomer (A3). Each main group were further subdivided into three subgroups(B) (n=5) according to the storage time, one day (B1), one month (B2) and three months (B3).

3. Preparation of the specimen:

A standardized class V cavity was prepared on the gingival third of the buccal surface of each tooth. The dimensions of the cavity were 2mm occlusocervically in which the occlusal margin is located in enamel and gingival margin is located in cementum and 2mm axial depth and 2mm mesiodistally. Standardized of the depth was done by marking the shaft of the bur with permanent marker and checked by a periodontal probe. Standardization of the external cavity dimension was done by using a cut matrix band, which was cut according to the previous dimensions, then placed in the matrix holder and applied to each tooth prior to cavity preparation and by using a pencil, the cavity outline was drawn on the specific location. For cavity preparation a round bur was used to gain access through the enamel, then the cavity preparation was completed by using a inverted cone carbide bur No.2 for lateral extension followed by fissure carbide bur in a high speed hand piece (450000 rpm) with water coolant, then the cavity was finished by using low speed fissure burs No. 2 with water coolant. The gingival and occlusal walls were kept parallel to each other. The gingival margin was placed 1mm gingival to the cementoenamel junction.

4. Application of the restorative material:

The restorative materials were applied into the cavities according to the manufacturer instructions. The teeth were stored in artificial saliva to stimulate the clinical situation at 37°C in an incubator with 100% humidity at different storage times (24 hours, one month and three months) until time of testing.

At the end of the storage period of each group, the teeth were removed from the water and dried with oil free compressed air. Then a soft brush was used to coat the crown and the root of each tooth with clear nail varnish except for the restoration and away one millimeter all around the margins of the cavity, the nail varnish was left to dry completely for 5 minutes.

After sealing of the restored teeth, they were immersed in 2% methylene blue dye solution for 12 hours at room temperature. Then the teeth were removed and washed under running water to removed excess dye before teeth sectioning and dried using oil free compressor air.

Teeth were sectioned longitudinally in buccolingually parallel to long axis of tooth direction through the middle of the restoration using a fine diamond disc at low speed with coolant.

5-Microscopic examination and assessment of Marginal adaptation:

The dye penetration along the cavity wall (including both axial and gingival margins) was assessed with a measuring Stereomicroscope at 35× magnification in which the image of the restoration was captured and transferred to a computer equipped with the image analysis software program, where the leakage was scored as follows:

Score of 0: no leakage

Score of 1: leakage depth up to one third of the internal surface

Score of 2: leakage depth up to two thirds of the internal surface

Score of 3: leakage through the entire lateral surface to the bottom of the filling

Then the data were analyzed and tabulated.

II.Compressive strength

1. Mould construction:

forty-five cylindrical specimens were be prepared in a special designed Teflon mold with dimensions of 3 mm in diameter and 6 mm in height was used to form cylindrical samples. These dimensions were determined according to International Standards Organization (ISO) No. 9917. A total number of forty-five samples were be prepared according to three experimental groups (n= 15) according to restorative materials. Each group will be subdivided into 3 sub-groups (n=5) according to storage times (one day, one month, three months).

2. Sample preparation:

A celluloid strip was placed on a glass slab and under the Teflon mold. Each restorative material was mixed as described before according to manufacture instructions, and then packed inside Teflon mold using plastic hand instrument. After complete filling of Teflon mold another celluloid strip was placed over the restoration and covered by a glass slab. A 250-gm constant load was placed on the top of glass slab to ensure maximum adaptation and complete filling of restoration inside to Teflon mold. The samples were removed from the mold after setting and stored in distilled water at different storage time (one day, one month and three months) prior to testing. Universal mechanical testing machine was used to measure the compressive strength of all samples.

3.Compressive strength testing:

The samples were loaded on the Lloyd mechanical testing machine at cross head speed of 1 mm/min. The samples were placed with flat end vertically between the two metal Plates. The load was applied until the sample was crushed and the peak force required to fracture each sample was recorded in Newton from stress strain curve. The compressive strength was calculated in (MPa) using the following equation: $CS = 4P/\pi d^2$ Where (CS) is the compressive strength (MPa), (P) is the load at the fracture point (N), (d) is the diameter (mm) of the sample and (π) is a constant = 3.14.

Then the data were analyzed and tabulate.

Results:

1-Marginal adaptation

Specimens filled with Zirconomer and after three months storage time revealed significantly ($P \leq 0.05$) the highest mean dye penetration values while those specimens filled with ketac molar after one day storage time revealed significantly ($P \leq 0.05$) the lowest mean dye penetration value.

Regardless of the storage time whether one day, one month, or three months, Zirconomer revealed statistically significantly highest mean dye penetration. This was followed by RMGI. Moreover, ketac molar showed significantly lowest mean dye penetration.

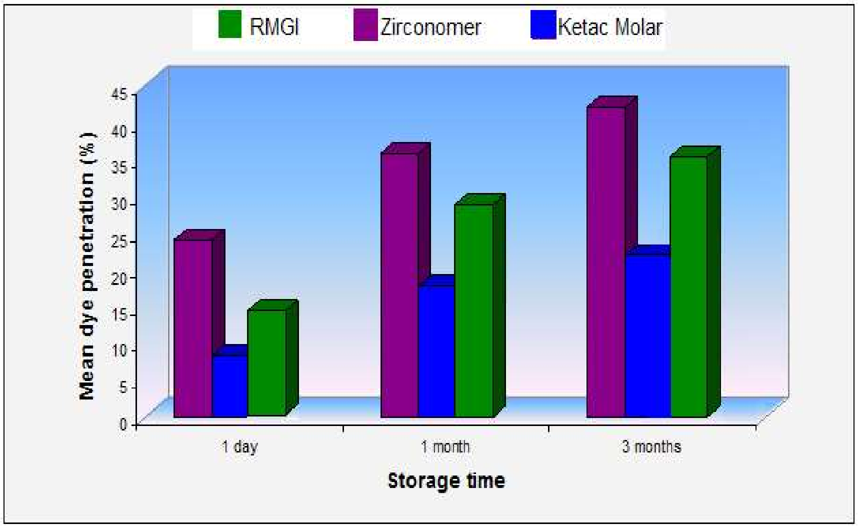

Fig1. ***Bar chart showing the percentage of mean dye penetration values of different restorative materials.***

2- compessive strength

Specimens filled with zirconia reinforced glass ionomer (Zirconomer) and after one day storage time revealed significantly ($P \leq 0.05$) the highest mean values while those specimens filled with high viscous glass ionomer (ketac molar) after one-month storage time revealed significantly ($P \leq 0.05$) the lowest mean values.

Regardless of the storage time whether one day, one month, or three months, zirconia reinforced glass ionomer (Zirconomer) revealed statistically significantly highest mean value. This was followed by RMGI (riva self-cure). Moreover, high viscous glass ionomer (ketac molar) showed significantly lowest mean compressive strength.

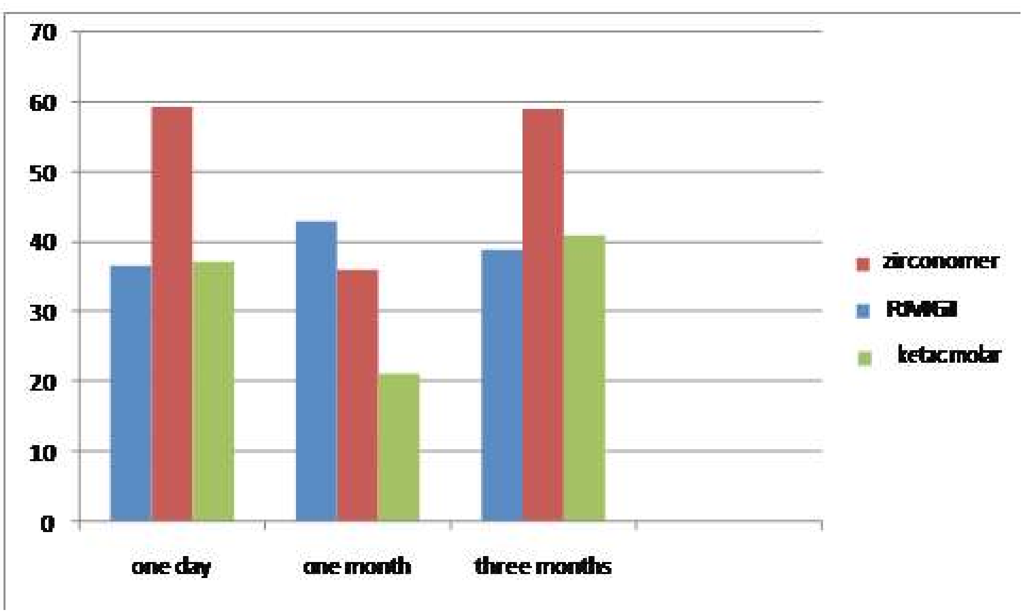

Fig2. ***Bar chart showing the percentage of mean compressive strength values of different restorative materials.***

Discussion:

1-Marginal adaptation

A- Effect of the restorative materials on marginal adaptation:

The study samples were stored in natural saliva to stimulate the clinical situation before cavity preparation. After retrieving from artificial saliva, Class V cavities were prepared in each tooth. In the present study, Class V cavities were selected because of its configuration or "C" factor. The "C" factor of Class V restoration is 5 which corresponds to the ratio between the number of bonded to unbonded surfaces which is responsible for Glass ionomer filling is indicated for cervical lesion especially when aesthetic is not a prime concern. The properties of GICs over composite restorative material are its ability to bond chemically to the tooth structure, release fluoride, biocompatible, lower shrinkage and reduced microleakage the internal bond disruption as well as marginal gaps around the restorations [9].

The study samples were divided into three equal groups according to restorative materials and were filled according to the manufacturer's instructions as described before.

After completing the restorations, all the study samples were subjected to thermocycling. The process of thermocycling was done to mimic the intraoral temperature variations [10]. The green stick compound has been used to coat the root and the crown. Two coats of nail varnish were applied, leaving 1 mm wide margin around the restoration to avoid any dye penetration from invisible cracks, areas devoid of enamel or cementum, etc. [11]

The longevity of the restoration is largely determined by marginal sealing of the cavity [12]. Thus, the ability of restoration to minimize the extension of microleakage at the tooth/restoration interface is important in predicting its clinical success. A variety of methods was used to evaluate the extent of microleakage and the marginal integrity of restorations. The use of dye diffusion is one of the most commonly used methods. Studies on marginal sealing by measurement of microleakage may be carried out using different techniques. These are namely use of different types of dyes, chemical markers, radioactive isotopes, air pressure, bacteria, and electrochemical method. The most commonly methods were those with stained solutions-methylene blue, aniline blue, fluorescein, eosin, erythrosine, and Indian ink. Advantages of using stained solutions include precision in assessment of marginal sealing, possibility of direct reading of the diffused marker under the microscope, and simplicity of application. In this study, methylene blue was used for dye penetration due to its adequate visualization after clearing of the specimens. Particle sizes of the dye suspension are suitable for detecting microleakage occurrence since they can easily penetrate through the cracks. Low molecular weight of the dye, which can easily facilitate its diffusion because of its small particle size as suggested by Pasricha [13].

The results of this study presented in Fig (1), In this present study, none of the materials evaluated completely eliminated microleakage at the occlusal or gingival margins of the restoration.

The study concluded that occlusal and gingival marginal adaptation score was found maximum in high viscous glass ionomer (ketac molar) followed by resin modified glass ionomer (Riva self-cure) and the least marginal adaptation was in zirconia reinforced glass ionomer (Zirconomer).

The mean marginal adaptation in occlusal and gingival margin for (Ketac Molar) was highest that proves that it is more effective in preventing microleakage. The study was in accordance with a study conducted by Fracasso et al [14]. The probable reason for decreased microleakage in this group is due to the formation of strong chelation reaction with calcium on the tooth surface. There are chemical interactions of polyalkenoic acids and hydroxyapatite which produce adequate marginal sealing as studied by Eronat et al [15].

Resin modified glass ionomer showed high marginal adaptation as compared to Zirconomer, which was in accordance with the studies conducted by Asafarlal S [16]. The probable reason for decrease microleakage in Zirconomer that large size of filler particle in Zirconomer prevent proper adaptation of this material to the tooth surface.

Study disagreement with some investigators determined marginal adaptation at occlusal and gingival margin of resin modified glass ionomer and reported that resin-modified glass ionomer restorations did not show less microleakage than high viscosity glass ionomer material tested in class V cavities. This is due to difference in materials use, size of cavity, method of curing and type of dye.

Another disagreement with Albeshti et al [17], who determined marginal adaptation at zirconia reinforced glass ionomer and high viscous glass ionomer and showed that high viscous glass ionomer restorations had less marginal adaptation than zirconia reinforced glass ionomer. This was due to difference in type of material whereas they were used ketac silver another type of high viscous glass ionomer.

B-Effect of storage time on the marginal adaptation:

The results of this study presented in Fig (1) showed that highest marginal adaptation value recorded after one day storage time this is may be due to the short time of water storage [18] followed by 3 months storage time while the lowest mean value recorded after 1-month storage time. Which might be related to the hydrolytic degradation of restoration by time [19].

The hydrolytic degradation of the restoration and chemical bond in the submicron spaces of the hybrid layer of carboxylic group and hydroxyapatite increases with increased exposure to water [20]. The increase storage time allow increase water uptake, that lead to increase permeability and increase the hydrolytic degradation of the material [21]. The water sorption and degradation process cause rapid drop in the physical properties, loss of chemical bond from the hybrid layer and consequently, drop in the marginal adaptation at the restoration tooth interface [22].

2-Compressive strength:

The compressive strength is an important mechanical property in evaluating restorative materials, particularly in the process of mastication, it is often used as a measure of the ability of a material to withstand masticatory forces. This test is more suitable to compare brittle materials, which show relatively low result when subject to tension. Compressive strength of a material could be tested by two axial sets of force are applied toward each other, in order to approximate the molecular structure of the material. In this test, a compressive force is applied to a cylindrical specimen across its long axis by compression plates. [23]

A- Effect of the restorative materials on compressive strength:

The data in figure (2) revealed that zirconia reinforced glass ionomer (Zirconomer) recorded statistically significant higher compressive strength due to 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[24].

followed by resin modified glass ionomer (Riva self-cure) and the lowest value of test was high viscous glass ionomer (ketac molar).

Ketac Molar had the lowest value for compressive strength as compared to the other study groups. This is may be attributed to the poor mechanical properties, such as low fracture strength, toughness, and higher occlusal wear rate as mentioned by Lohbauer [5].

Our Study in disagreement with Eronat N et al [7] who determined that compressive strength of high viscous glass ionomer (ketac molar) more than resin modified glass ionomer (Riva self-cure). This is may be due to difference in specimens' dimensions and tested after one day storage time.

B-Effect of storage time on the compressive strength:

The data in (2) revealed that highest mean value recorded after One day storage followed by 3 months storage while the lowest mean value recorded after 1 month storage.

Water storage can result in a decrease in compressive strength over time, since water absorption cause plasticity in the material. [25]

The data of the present study do not suggest a significant influence of storage on the compressive strength of Zirconomer. This is may be due to homogenous incorporation of micro sized zirconia particles in glass component, which further reinforce the material with high strength, lasting durability and high tolerance to occlusal load.

Also, Bhatia et al reported that the property of transformational toughening, which has the ability to stop the growth of cracks, and gives zirconia its unique mechanical properties [23].

The compressive strength value for RMGI did not show significantly difference at different storage times. This is may be due to the acid base reaction producing a stronger polysalt matrix [26].

Regarding the results of our study Zirconomer showed high compressive strength of the whole tested materials at different storage times, while ketac molar revealed improving the marginal adaptation comparing all other tested materials at different storage times.

Conclusions:

With respect to the material used and the methodology of this study, the following could be concluded: -

1- Different restorative materials affect the marginal integrity and compressive strength of restoration.

2- The use of high viscous glass ionomer (ketac molar) would be a favorable choice with regard to microleakage reduction.

3- The use of zirconia reinforced glass ionomer (Zirconomer) would be a favorable choice with regard to high compressive strength.

4- The storage time is inversely proportional to the sealing ability and compressive strength of esthetic restorative materials.

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