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Comparative analysis of flexural strength of four commercially available dental restorative materials

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***Abstract*---**Background: The objective of this *in vitro* study was to investigate the flexural strengths of four commercially available restorative materials. The restorative materials used in this study were - Posterior Glass ionomer cement (GC Fuji), Resin modified Glass ionomer cement (GC), Ketac molar (3M ESPE), Miracle mix (XP). Materials and Methods :- Four restorative material under study were divided into 4 groups with each group containing five specimens of 2 mm × 2 mm × 25 mm of restorative material prepared according to ISO 9917-2 standard using a customized metal mould. After light polymerization, the specimens were stored in distilled water at 37°C for 24 hours. The specimens were subsequently blotted dry, measured and subjected to flexural testing using an Instron universal testing

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machine (Tinius Olsen) at a crosshead speed of 1mm/min until the specimen fractured. Results: - Data collected was statistically analysed using Kruskal Walli's Test and Chi Square test. The result showed that the mean flexural strength of Ketac Molar> Miracle Mix > RMGIC > Posterior GIC. Conclusion: -The knowledge of mechanical properties of the various materials is important for the long-term clinical success of material. Mechanical properties also help the clinician to select the appropriate material based on the clinical condition of the patient. In our study under experimental conditions, it was found that the mean flexural strength of Ketac Molar is greater than Miracle Mix followed by RMGIC which was found to be greater than Posterior GIC. However, the relative flexural strength of dental materials in clinical situation may differ. Thus, accordingly the materials should be used in stress bearing areas.

***Keywords*---**flexural strength, glass ionomer cement.

Introduction

Restorative dentistry is the most widely practiced branch amongst the various dental disciplines. History has already beheld a host of restorative materials, but all have fallen short of that classic formulation for which the dental researchers and clinicians were looking for: A material that would be - adhesive, esthetic, anticariogenic biocompatible and cost effective[1]. A change in approach in the 1950s and 1960s was brought about by understanding the importance of adhesion and biocompatibility which led to a revolution in dental material science. A closer association between the clinician and the research scientist lead to development of a material called as the "Glass-Ionomer Cement".

Glass Ionomer Cement was invented in 1969, and reported by Wilson and Kent in the early 1970's. Glass-Ionomer Cements (GICs) were clinically charismatic dental material, that have certain unique properties which make them useful as both luting and restorative materials. The effective properties of GIC include good marginal integrity, chemical adhesion to enamel and dentin in the presence of moisture, dimensional stability at high humidity, resistance to microleakage, biocompatibility, coefficient of thermal expansion similar to tooth structure, re-chargeability with fluoride, fluoride release and less shrinkage than resins upon setting, with no free monomer being released.[2]

Because of disadvantages of GIC like low strength, moisture sensitivity and inferior mechanical properties lead to the development of several modifications in the field of conventional GICs. In order to improve mechanical properties, some of the modifications and addition were added like to Increase viscosity by reducing filler size (e.g., Ketac Molar, 3M ESPE), By incorporating resin Hydroxyl Ethyl Methacrylate (HEMA) to GIC eg- Resin- modified glass ionomer cement, By incorporating silver eg- Metal modified GIC (Miracle mix).[3]

Test methods to investigate some of the physical properties of dental materials are described in ISO 4049.Strength values such as tensile, compressive, flexural and

shear strength are usually used as indicators of structural performances for restorative materials. This *invitro* study considers the flexural strength which is one of the parameters used to characterize resistance of a restorative material against occlusal loading. Flexural Strength is a clinically important and relevant parameter.[4]

In this study we have evaluated and compared the flexural strength of four clinically used and commercially available materials i.e. Ketac Molar, RMGIC, Miracle Mix and Posterior GIC.

Material and Methods

This *invitro* study was conducted in People's College of Dental Sciences and Research Centre, Bhopal, Madhya Pradesh the year 2021-22. Four commercially available restorative materials used in this study were:-Posterior Glass Ionomer cement (GC Fuji), Resin Modified Glass Ionomer cement (GC), Ketac Molar (3M ESPE) and Miracle Mix (XP).

All the materials were manipulated according to manufacturer's instruction. The preparation of the specimens was done according to ISO 9917-2 standards. From each material, five bars measuring 2 mm × 2 mm × 25 mm were prepared at room temperature using a customized split stainless steel mould.

The base of the mould was first coated with Vaseline to ease the removal of the specimens and then they were covered with cellulose strip for isolation. The test materials were carefully packed into the mould without voids and were enclosed again with cellulose strip on its top surface. A glass slide was placed on top of the mould and gentle pressure was applied to extrude excess material **[Fig.1].** Glass slider was removed as the material set. In RMGIC, the top surface of the specimens were light polymerized using Coltulux 3 by Coltene (Dentsply) **[Fig.2].** All the test specimens were then polished. The dimensions of the specimens were then measured with an electronic digital caliper (Mitutoyo, Japan) to an accuracy of ±0.01 mm. The specimens were stored in distilled water in a sealed container at 37°C for 24 hours.[Fig. 3]

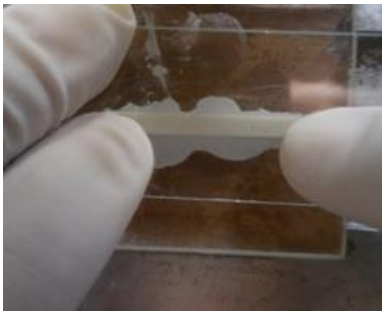

Fig. 1 - In Posterior GIC, Miracle Mix and Ketac Molar

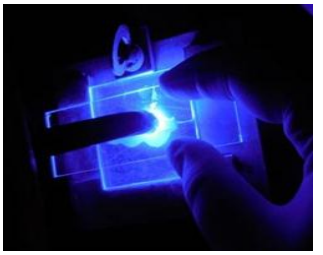

Fig. 2- Resin-Modified GIC

POSTERIOR GIC

KETAC MOLAR

Miracle Mix **RMGIC**

Fig. 3: Stored Specimens of 4 Different Restorative Materials.

Testing Procedure

The specimen was removed from the storage container, wiped dried and then mounted in a specially designed jig and subjected to a 3-point-bending test using an Instron Universal testing machine (Tinius Olsen) at a crosshead speed of 1mm/min until the specimen fractured [Fig: 4 and 5].

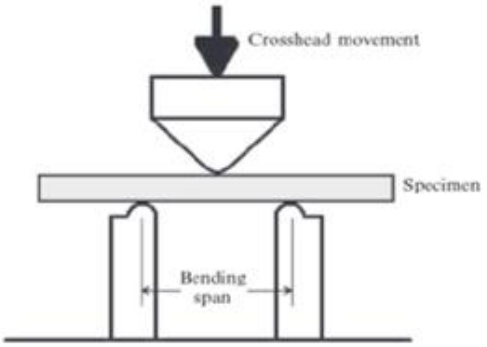

Fig. 4& 5: Instron Universal Testing Machine

The maximum load exerted on each specimen was recorded and the flexural strength "σ" was calculated in Mpa from the following equation:

$$\sigma = \frac{3FL}{3FL}$$

F= Maximum load in Newtons, exerted on specimen, L = Distance in milimeters between the supports, B = width in mm of the specimen measured immediately prior to testing, H = Height of the specimen in mm measured prior to testing. [5]

Statistical Analysis

The data obtained was subjected to statistical analysis with the consultation of a statistician. The data so obtained was compiled systematically using Microsoft Excel Spread Sheet. A master table was prepared and the total data was subdivided and distributed meaningfully and presented as individual tables.

Statistical procedures were carried out in 2 steps:
1. Data compilation
2. Statistical analysis
3. Presentation

Statistical analysis was done using Epi Info Version 7.2 (Developed by CDC, Atlanta, Georgia, USA). Data comparison was done by applying specific statistical tests to find out the statistical significance of the comparisons. Level of significance was fixed at $p<0.05$. Highly significant level was fixed at $p< 0.01$. Data collected was statistically analysed using Kruskal Walli's Test and Chi Square test.

Results

Flexural Load and Flexural Strength of 4 different commercially available restorative material in Group 1 to Group 4 was calculated as depicted in Table.1. Comparative and Statistically analysed results in Table 2 and Figure 6 illustrates that the mean flexural strength of Ketac Molar> Miracle Mix > RMGIC > Posterior GIC.

Table 1:- Flexural Load and Flexural Strength of 4 Diffrent Restorative Material Groups.

Group 1: Posterior GIC				Group 2 : Ketac Molar			
Sr. No.	Sample No.	Flexural Load (N)	Flexural Strength (MPa)	Sr. No.	Sample No.	Flexural Load (N)	Flexural Strength (MPa)
1	No.1	4.05	4.50	1	No.1	12.70	14.11
2	No.2	4.80	5.33	2	No.2	23.40	26.00
3	No.3	3.25	3.61	3	No.3	30.70	34.11
4	No.4	3.15	3.50	4	No.4	9.30	10.33
5	No.5	18.45	20.50	5	No.5	19.10	21.22
		Average	7.49			Average	21.15

Group 3 : RMGIC				Group 4 : Miracle Mix			
Sr. No.	Sample No.	Flexural Load (N)	Flexural Strength (MPa)	Sr. No.	Sample No.	Flexural Load (N)	Flexural Strength (MPa)
1	No.1	5.85	6.50	1	No.1	29.40	32.66
2	No.2	13.90	15.44	2	No.2	5.05	5.61
3	No.3	14.10	15.66	3	No.3	24.35	27.05
4	No.4	14.35	15.94	4	No.4	8.90	9.88
5	No.5	10.80	12.00	5	No.5	7.30	8.11
		Average	13.11			Average	16.66

Table 2: Comparative Analysis of Mean Flexure Strength of four Different Restorative Materials Groups.

Restorative Materials	**Flexural Strength**			
	MEAN	SD	Median	RANGE
Group 1: Posterior GIC	7.488	6.893	4.50	3.50-20.50
Group 2 : Ketac Molar	21.154	8.920	21.22	10.33-34.11
Group 3 : RMGIC	13.108	3.796	15.44	6.50-15.94
Group 4 : Miracle Mix	16.662	11.596	9.88	5.61-32.66
Total	14.603	9.451	13.05	3.50-34.11
Kruskal Wallis Test Chi Square Value	14.110			

P Value	0.003(HS)

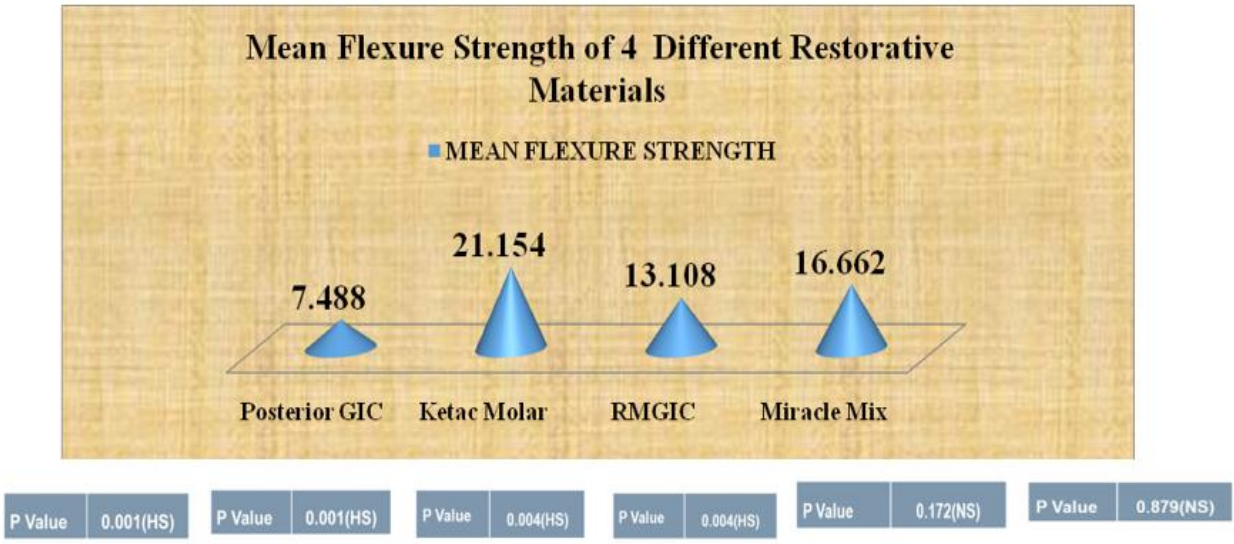

Figure 6: Graphical Representation of 4 Different Restorative Material Groups depicting the Mean Flexural Strength along with their P values.

Discussion

The flexural strength is defined as failure to stress of a material measured while lengthening. It is a mechanical property selected from the International Standard Organization for the control of restorative dental materials. Its relatively simple and accurate procedure for preparing the specimens that reduces the operator induced variability and improves the standard for assessing mechanical properties of GIC.This study was conducted to measure the flexural strength of 4 groups of commercially available restorative materials since this is one of the parameter used to characterize resistance of a restorative material against occlusal loading and thus measuring and comparing this parameter is clinically relevant[6].

Many factors like chemical composition, microstructure, powder liquid ratio, mixing method, degree of conversion and the interaction of various factors can affect the mechanical properties of Posterior GIC, Miracle mix, RMGIC and Ketac Molar. [7].

According to results as illustrated in Table 1 and 2 it has been found that under experimental conditions, the mean flexural strength of Ketac Molar > Miracle Mix > RMGIC > Posterior GIC.

RMGIC>GIC

Resin Modified GIC: Antonucci and Sumithra Mitra introduced resin modified GIC (RMGIC) in 1988. Conventional GIC formulations were susceptible to the moisture sensitivity and exhibited low early mechanical strength due to their slow acid-base setting reaction. Hence, polymerizable monomer such as (HEMA) was added to impart additional curing processes to allow bulk of the material to mature at a rapid rate. They have superior mechanical strength, extended working time and are easy to handle [8]. Yap and his Co-Workers have showed that an increase in powder weight significantly improved flexural strength. The higher powder-liquid ratio results in a higher amount of un-reacted glass per unit volume of cement. The latter acts as fillers that can retard crack growth and propagation during flexural strength testing, resulting in higher flexural strength [9]. Dijken et al. In 1999 additionally found RMGICs were, unlike conventional GICs, suitable for large 'open sandwich' restorations. This could be due to the better mechanical properties of the RMGIC[10]. According to Garoushi et al inclusion of glass fibres results in increased flexural strength significantly [11]. Further, according to Moberg et al the flexural strength at 24 h ranged from 18 to 34 MPa for the conventional glass-ionomers compared with 49–76 MPa for the RMGICs. In our study it was found to be 13.108 [12]. According to Yuan Lit et al the flexural strength of dual cure RMGIC was higher than the chemically cured GIC. The mean flexural strength of RMGIC was 18 MPa and chemically cured was 14 MPa[13]. These differences may be attributable to the presence of polymerized resin component, which toughens the cement and improves its ability to withstand loading in flexure.

Miracle Mix>RMGIC

Miracle Mix was introduced by Simmons in 1983. Silver-tin alloy of the type typically used in amalgams incorporated into a GIC was marketed as a material known as "Miracle Mix" by the GC company from 1983 [14]. It is still on the market as of the start of 2020, and is a useful material for certain niche applications [15]. In it the glass ionomer powder reinforced with silver alloy particles improves the flexural strength of this material. According to Li et al. the low flexural strength of RMGIC Fuji Il LC can be attributed to water absorption by its resin component. Since RMGIC's use mainly HEMA or modified HEMA monomers, the organic structure formed after the setting reactions contains a higher proportion of hydrophilic functional groups [16]. The earliest report of metal powders for reinforcement of glass-ionomer cements was patented by Wilson and Sced 1980. They described the addition of powders of aluminum, chromium, nickel-aluminum alloy, and silver-tin alloy, all of which were of relatively large particle size, i.e., not nanoparticles. All were claimed to improve the flexural strength [17]. Of these, the silver-tin alloy gave the greatest increase, raising the reported value to 40 MPa from a value of 10 MPa for the parent cement according to John W. Nicholson [18].

Ketac Molar > Miracle Mix

Ketac Molar (3M ESPE) is a glass ionomer restorative material used in restorative dentistry. They provide excellent results with little effort for many indications. The

excellent mechanical properties make it a suitable restorative material for posterior teeth. They can be used as bulk fill restoratives. These glass ionomer restoratives exhibit excellent wear resistance, minimal abrasion and excellent surface hardness. They can be used for treating patients in all age groups. Its quick and easy use, makes it suitable for paediatric restorative therapy. Ketac Molar demonstrated lower acid erosion than other glass ionomer products, resulting in a more durable and long lasting restoration [19].

The high powder to liquid ratio in Ketac Molar gives it excellent strength yet allows fluoride release and recharge to take place and enabling remineralization of the adjacent tooth substrate. Ketac Molar is high-viscous conventional GIC with a reduced number of steps required during placement and improved handling characteristics. Ketac Molar is highly viscous GIC [20]. Higher viscosity is the result of addition of high molecular weight polyacrylic acid to the large amount of fine grain powder which increases its flexural strength. R Peez and S Frank evaluated the time dependent physical-mechanical properties of Ketac Molar in comparison to four hand mix glass ionomer restoratives, and the result revealed that Ketac Molar exhibits the highest flexural strength 1h after start of setting and even after 24h, it remains at this high level [21].This was also found in our study.

Conclusion

Within the limits of the present *in vitro* study, we can conclude that the flexural strength of Ketac Molar is highest followed in decreasing order by Miracle Mix, RMGIC and Posterior GIC.

The knowledge of mechanical properties of the various materials is important for the long-term clinical success of material. Mechanical properties also help the clinician to select the appropriate material based on the clinical condition of the patient.

The results of this study must be interpreted with caution in predicting the clinical performance of the materials tested. This is because the relative flexural strength of dental materials in clinical situation may differ significantly from that predicted from mechanical properties evaluated in vitro .Thus, accordingly the materials should be used in stress bearing areas.

References

1.- Malik M, Sharma K. A Review Chemistry, Composition And Biocompatibility Of GIC's With Future Horizons: An Insight. Journal of Dental Herald 2015.
2.- Saito S, Tosake S, Hirota K. Characteristics of glass-ionomer cements. in Advances in Glass-Ionomer Cements. Eds. Davidson CL, Mjor I. Quintessence 1999; 15-50.
3.-Sidhu SK, Nicholson JW. A Review of Glass-Ionomer Cements for Clinical Dentistry. *J FunctBiomater*. 2016;7(3):16.
4.- McLean JW, Gasser O. Glass-cermet cements. Quintessence Int 1985;16(5):333-343.

5.- Zoergiebel J, Ilie N. Evaluation of a conventional glass ionomer cement with new zinc formulation: effect of coating, aging and storage agents. Clin Oral Investig. 2013 Mar;17(2):619-26.
6.- E. Sulaiman, Y.M. Yeo, Y.T.Chong. The flexural strength of five commercially available tooth- coloured restorative material.Annal Dent Univ Malaya 2007;14:39-45.
7.-Krämer N &Frankenberger R. Clinical performance of a condensable metal reinforced glass ionomer cement in primary molars. British Dental Journal 2001 ;190 :317- 21.
8.-Berzins DW, Abey S, Costache MC, Wilkie CA, Roberts HW. Resin-modified glass-ionomer setting reaction competition. J Dent Res. 2010;89(1):82-86.
9.- Yap AUJ and Teoh SH. Comparison of flexural properties of composite restoratives using the ISO and mini- flexural tests. Journal of Oral Rehabilitation 2003;30:171-7.
10.- A.M. YOUNG, Antibacterial releasing dental restorative materials, Woodhead Publishing,2010, Pages 246-279
11.- Garoushi, S.; Vallittu, P.; Lassila, L. Hollow glass fibres in reinforcing glass ionomer cements. Dent. Mater. 2017;33:86-93.
12.- Moberg, M.; Brewster, J.; Nicholson, J.W.; Roberts, H. Physical property investigation of contemporary glass ionomer and resin modified glass ionomer restorative materials. Clin. Oral Investig. 2019;23:1295-1308
13.- Yuan Li, Hong Li, Gang Zheng, Xuehui Zhang, Yongxiang Xu. A comparison study on the flexural strength and compressive strength of four resin-modified luting glass ionomer cements.Bio-Medical Materials and Engineering 2015; S9-S17
14.- Baig, M.S.; Fleming, G.J.P. Conventional glass-ionomer materials: A review of the developments in glass powder, polyacid liquid and the strategies for reinforcement. J. Dent. 2015;43:897–912.
15.- Moshaverinia, A.; Roopour, N.; Chee, W.W.L.; Schricker, S. A review of powder modifications in conventional glass-ionomer dental cements. J. Mater. Chem. 2011;21:1319–1328.
16.-.Pereira LCG, Nunes MCP, Palma Dibb RG, Powers JM, Roulet J-F, Navarro MF. Mechanical properties and bond strength of glass ionomer cements. J Adhes Dent 2002; 4: 73-80
17.- Peutzfeldt A, Garcia-Godoy F, Asmussen E. Surface hardness and wear of glass ionomers and compomers. Am J Dent 1997; 10: 15-17.
18.--Nicholson JW, Sidhu SK, Czarnecka B. Enhancing the Mechanical Properties of Glass-Ionomer Dental Cements: A Review. *Materials (Basel)*. 2020;13(11):2510
19.-Smales RJ, Gao W. In vitro caries inhibition at the enamel margins of glass ionomer restoratives developed for the ART approach. J Dent 2000; 28: 249-256.
20.-Jang K-T, Garcia-Godoy F, Donly KJ, Segura A. Remineralizing effects of glass ionomer restorations on adjacent interproximal caries. J Dent Child 2001; 68: 125-128.
21.- R Peez, S Frank. The physical-mechanical performance of the new Ketac Molar Easymix compared to commercially available glass ionomer restoratives. J Dent. 2006 Sep;34(8):582-7.