Comparative Evaluation of Compressive, Flexural Strength and Micro Hardness of Different Dental Materials

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Abstract— The aim of this study was to measure and compare the mechanical properties of five commercially available dental materials. And also to ascertain proper materials for clinical treatment. Methods. Specimens for the study were prepared by the used of customized cylindrical teflon mould dimensioning 5mmx5mm for compressive strength, 5mm x 3mm for hardness and 25mm x 5mm for flexural strength were grouped with 4 specimens in each GroupI: Filtek Z350XT (Composite); Group Beutifill-II (Giomer); Group III: Ketak molar (RMGIC), Group IV: Zirconomer (Zirconia Reinforced Restorative). Using LED light curing was done. Compressive strength and flexural strength was evaluated using Universal testing machine, and Microhardness was measured on Vicker's Microhardness Tester, Reichert Austria Make. Results. The obtained results revealed that the Composite Z-had the highest flexural strength followed by the Beutifill-II. Zirconomer had the least flexural strength than Compoglass and ketak molar respectively. Compoglass had highest compressive strength whereas Zirconomer had least compressive strength. Again Compoglass showed highest Microhardness followed by Z350. Significance. On the mechanical characterization of some dental materials, the collected data from one-way ANOVA followed by Tukey's Kramer poc hoc test suggested that the mechanical properties of composite Z-350 showed statistically significant difference in Flexural property as compared to the others specimens. Meanwhile, Compoglass was found to be more prominent in micro-hardnessnalysis.

Key words: Dental materials; Mechanical properties; Flexural strength; Compressive strength; Micro-hardness

I. INTRODUCTION

The human tooth structure mainly destroyed by trauma and caries is always replaced with suitable core materials to bring the success and longevity of the subsequent cast restoration. Large varieties of dental materials such as silver, amalgam, composite resin glass ionomer cement, resin modified glass ionomer cement and compomers have been used for core build-up procedures. Compressive Strength of core materials is thought to be important because core build-ups usually replace a large amount of tooth structure and it must resist multidirectional masticatory forces. Compressive strength may be considered to be a critical indicator of success because higher the compressive strength, maximum resistance to resist masticatory and parafunctional forces. Flexural strength tests are considered to be sensitive to surface imperfections such as voids, cracks and related flaws, which can influence the fracture strength of brittle materials. High flexural strength values reflect a limited tendency for crazing and high resistance to surface defects and erosion. Therefore, flexural and tensile strength are considered to be the most important mechanical properties. The clinician must know which material to select for core build up and which techniques to apply to reach optimum results. Therefore, the purpose of this study was to compare the compressive, diametral tensile and flexural strengths of five common used core materials. [1]

Hence the objectives of this study was to determine the mechanical properties as compressive strength, flexural strength and Microhardness of different dental materials.

II. LITERATURE SURVEY

In the recent decay very large research is done to enhance the physical and mechanical properties of dental materials. Narasimha Jayanthi V. Vinod in their study showed Comparative Evaluation of Compressive Strength and Flexural Strength of Conventional Core Materials with Nanohybrid Composite Resin Core Material, he concluded that Fluorocore had the highest compressive strength and flexural strength of the four materials tested in this study. And the strength of Filtek Z350 was less than Fluorocore but higher than other conventional core build up materials like amalgam and Vitremer GIC. [2]. M.N. Hegde et al. have fabricated the 48 specimens of composite using customized biparpite brass split mould measuring 5mm x5mm and demonstrated that nanocomposites have better compressive strength than micro hybrid ($P < 0.001$) [3]. K.V. Kiran et al. evaluate and compared the compressive strength of microhybrid and nanocomposites and showed that the compressive strength of nanocomposites is higher than microhybrid. Also, they found that the Charm Fill Plus showed highest compressive strength and Tetric Ceram showed the least compressive strength, among the tested materials [4]. Ting Wang et al. in his literature suggested that the "crack bridging" mechanism which is associated to the micro-cracks inside the composite material may affect the fracture toughness. Keyoung Jin Chun and Jong Yeop Lee done the comparative study of mechanical properties of dental restorative materials and dental hard tissues in compressive loads and result showed that gold alloy one of the material has a hardness lower than enamel and higher maximum stress strain and elastic modulus than dentin . [5]

D.Xie, W.A.Brantley , B.M.Culbertson, G. Wang had studied Mechanical properties and microstructure of glass ionomer cements to determine the flexural strength (FS), compressive strength (CS), diametral tensile strength (DTS) and knoop hardness. The result showed that RMGICs exhibited much higher FS and DTS, lower knoop hardness compared to the conventional GICs [6]. Antara Agrawal and Kundabala Mala in their study objective was to find out the best core build up material with respect to their physical properties among resinbased composites, after statistical analysis result showed that Both dual cure composite materials with nanofillers were found superior to amalgam core. [7]

III. MATERIALS AND METHOD

A. Materials

Following materials are tested in this study

Sr.No	Materials	Manufacturer
1	Composite Z350	3M ESPE
2	Giomer (Beautiful II	Shofu Inc. Kyoto,japan
3	Glass ionomer –ketak molar	3M Deutschland
4	Zirconomer	Shofu Inc. Kyoto,japan
5	Compoglass F	Ivaclarvivadent

Table No 1

B. Sample Preparation

Cylindrical Teflon mold was used to make total 25 samples for the different dental class of materials were fabricated to test the flexural strength, compressive strength and Micro hardness. The samples were tested for compressive strength and flexural strength as per ASTM D 695-02 Standard and ASTM D 790-03 Standard respectively using Universal Testing Machine computerized, software based) (Fig2) Company: Star Testing Systems, India. Model No. STS 248, at a cross head speed of 3 mm/min with accuracy of machine: ±1% till the samples fracture. And samples for Micro hardness as per ASTM E 384- 06 Standard using Vicker's Micro hardness Tester, Reichert Austria Make, and Sr.No.363798 with a Load: 100 g

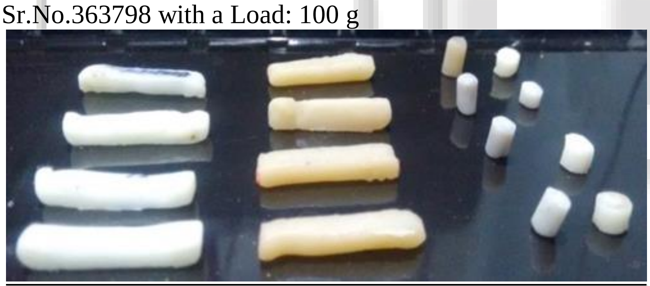

Fig. 1: Samples prepared for testing

Fig. 2: Universal Testing Machine for compressive and flexural strength

Fig. 3: Vicker's Micro hardness Tester

C. Strength Measurements

Flexural Strength (FS) test was performed in three point bending, with a span of 20 mm between supports. The sizes of samples choosed n = 4 for FS and CS. The compressive strength was calculated by the equation;

$$CS=4P/(\pi d^2), \quad (i)$$

Where p is the load at fracture and "d" is the diameter of the sample cylinder. Flexural strength (FS) was calculated by the equation;

$$\sigma = \frac{3P_{max}L}{2bh^2} \quad (ii)$$

Where L is the distance between the two supports, b the breadth and h the depth of the specimen.

D. Micro Hardness Measurements

The micro hardness of the specimens was determined using Vicker's Micro hardness Tester, Reichert Austria Make, and Sr.No.363798 with load of 100 g and 30 s dwell time.

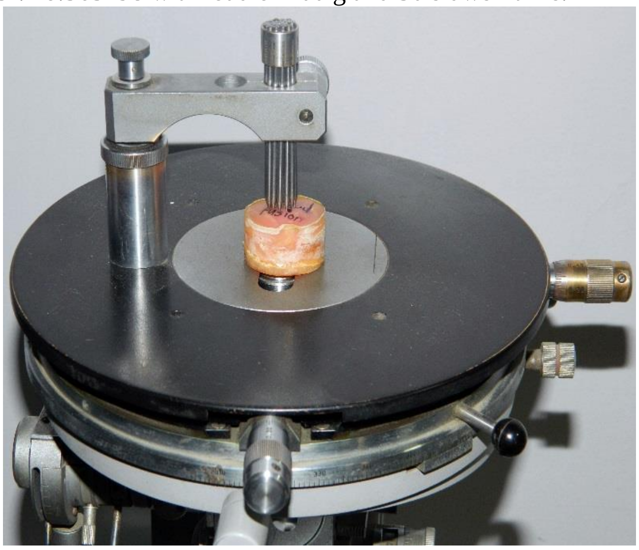

Fig. 4: Vicker's Microhardness Tester

IV. RESULT AND ANALYSIS

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	83039.1596	4	20759.7899	34.07626046	2.30E-07	3.055568
Within Groups	9138.234194	15	609.2156129			
Total	92177.39379	19				

Table 2: ANOVA compressive strength

	Mean Diff	SEM	q Value	Prob	Alpha	Sig	LCL	UCL
BEAUTIFIL-II Z350	-27.8925	17.453	2.26012	0.52041	0.05	0	-81.7856	26.00062
KETAK MOLAR Z350	-64.79	17.453	5.24992	0.01521	0.05	1	-118.683	-10.8969
KETAK MOLAR BEAUTIFIL-II	-36.8975	17.453	2.9898	0.26437	0.05	0	-90.7906	16.99562
ZIRCONOMER Z350	-89.49375	17.453	7.25166	0.001	0.05	1	-143.387	-35.6006
ZIRCONOMER BEAUTIFIL-II	-61.60125	17.453	4.99153	0.02164	0.05	1	-115.494	-7.70813
ZIRCONOMER KETAK MOLAR	-24.70375	17.453	2.00174	0.62775	0.05	0	-78.5969	29.18937
COMPOGLASS Z350	96.195	17.453	7.79466	4.91E-04	0.05	1	42.30188	150.0881
COMPOGLASS BEAUTIFIL-II	124.0875	17.453	10.05478	3.04E-05	0.05	1	70.19438	177.9806
COMPOGLASS KETAK MOLAR	160.985	17.453	13.04457	1.17E-06	0.05	1	107.0919	214.8781
COMPOGLASS ZIRCONOMER	185.68875	17.453	15.04631	1.54E-07	0.05	1	131.7956	239.5819

Table 2: Tukey Kramer Test for comparison: - Compressive strength

Source of Variation	SS	Df	MS	F	P-value	F crit	
Between Groups	11206.838	4	2801.7096	10.945741	0.0005658	3.25917	
Within Groups	3071.5614	12	255.96345				
Total	14278.4	16					

Table 4: ANOVA- Flexural Strength

	Mean Diff	Sem	Q Value	Prob	Alpha	Sig	Lcl	Ucl
Beautifil-II Z350	-17.145	11.313	2.14328	0.5723	0.05	0	-53.204	18.914
Ketakmolar Z350	-64.70583	12.219	7.48878	0.00145	0.05	1	-103.65	-25.758
Ketakmolar Beautifil-II	-47.56083	12.219	5.50449	0.01494	0.05	1	-86.509	-8.6126
Zirconomer Z350	-67.8375	13.855	6.92413	0.00276	0.05	1	-112	-23.674
Zirconomer Beautifil-II	-50.6925	13.855	5.17415	0.02231	0.05	1	-94.856	-6.5294
Zirconomer Ketakmolar	-3.13167	14.605	0.30324	0.99946	0.05	0	-49.684	43.4203
Compoglass Z350	-43.0975	11.313	5.38757	0.01721	0.05	1	-79.157	-7.0385
Compoglass Beautifil-II	-25.9525	11.313	3.24429	0.21212	0.05	0	-62.012	10.1065
Compoglass Ketakmolar	21.60833	12.219	2.50086	0.43283	0.05	0	-17.34	60.5565
Compoglass Zirconomer	24.74	13.855	2.5252	0.42395	0.05	0	-19.423	68.9031

Table 5: Turkey Kramer test for Comparison-Flexural Strength

Source of Variation	SS	df	MS	F	P-value	F crit	F crit
Between Groups	6295.534227	4	1573.883557	66.83910417	3.55E-07	3.47805	4.066181
Within Groups	235.4734667	10	23.54734667				
Total	6531.007693	14					

Table 7: ANOVA- Microhardness

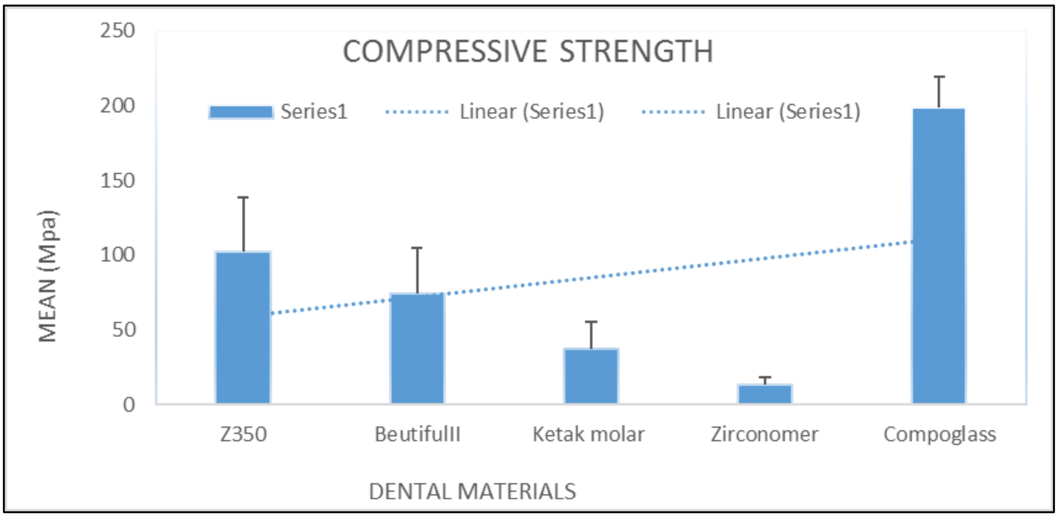

Fig. 5: Error bar chart illustrates the mean compressive strength and standard deviation

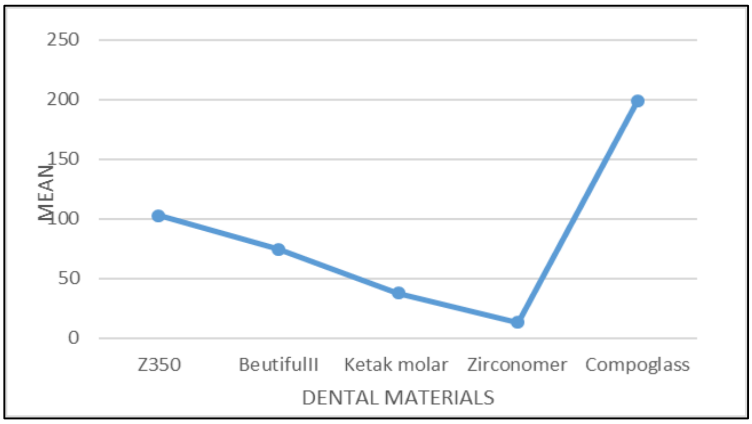

Fig. 6: Mean Compressive strength [MPa]

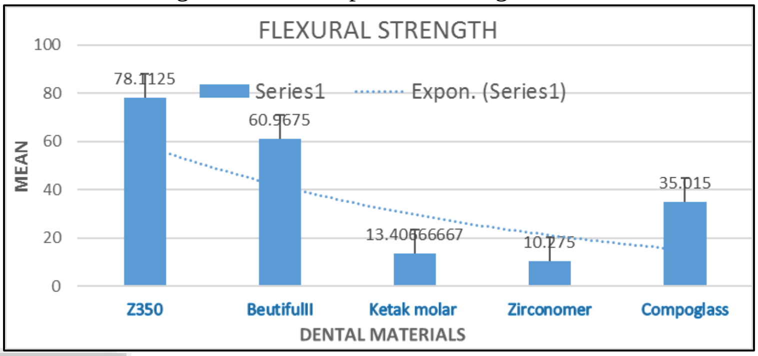

Fig. 7: Error bar chart illustrates the mean Compressive strength and standard deviation

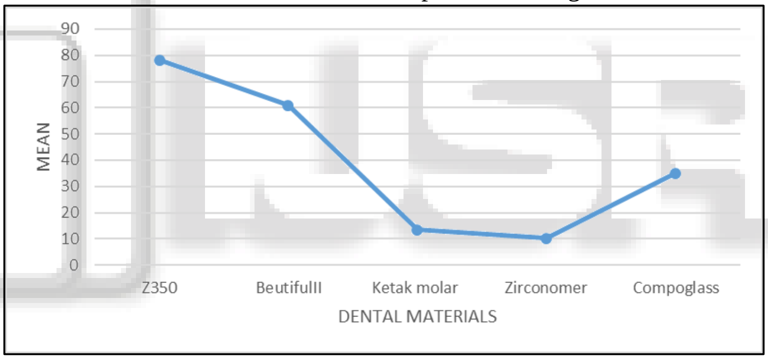

Fig. 8: Mean Flexural strength [MPa]

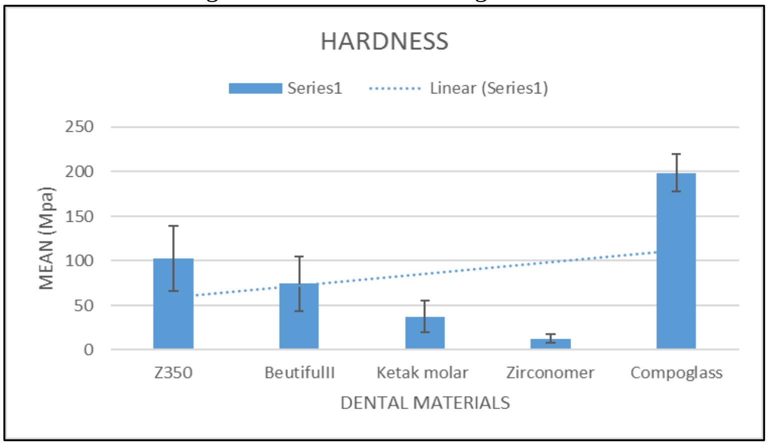

Fig. 9: Error bar chart illustrates the mean Compressive strength and standard deviation

Onaway analysis of variance (ANOVA) with the post hoc Turkey –Kramer multiple range test was used to determined significant difference among the different dental materials in each test .A level of α =0.05 was used for statistical significance.

The results were recorded for compressive strength [MPa], flexural strength [MPa] and Microhardness [HV] in the five groups as Z350, B-II, KM, ZIR, and COMP-F.The recorded observations were subjected to statistical analysis. Comparison of Compressive Strength, Flexural Strength [MPa] and Microhardness [HV] between five materials was done. The null Hypothesis 1 was that there is no significant difference in the mean flexural strength, compressive strength and Microhardness of the five dental materials.i.e.

$\mu 1=\mu 2=\mu 3=\mu 4=\mu 5$.Alternative Hypothesis was that there is a significance difference in the mean flexural strength, compressive strength and Microhardness of the five dental materials.i.e. $\mu 1\neq\mu 2\neq\mu 3\neq\mu 4\neq\mu 5$. ANOVA analysis was used. The P value was compared with the level of significance. And if $P < 0.05$, the alternative hypothesis was accepted, concluded that there is a significant difference in the mean value of flexural strength, compressive strength and Microhardness. Otherwise the null hypothesis is accepted. If significance difference is found between the mean values then multiple comparisons using Tukey's –Kramer test is carried out. The result showed that the CompositeZ350 had the highest flexural strength followed by the Beutifill-II. Zirconomer had the least flexural strength than Compoglass and ketak molar respectively. Compoglass had highest compressive strength whereas Zirconomer had least compressive strength. Again Compoglass showed highest Microhardness followed by Z350. The results are shown in the table 2. The difference in flexural strength between Z350 and Beutifill-II , ketak molar and Zirconomer materials was found not statistically significance otherwise all other materials were significantly different. ($P< 0.001$). Similarly the difference in mean compressive strength among the group Z350- KM, Z350- ZIR, Z350- COMP-F, BF-II – ZIR, BF-II – COMP-F, KM- COMP-F, and ZIR-COMP-F was found statistically significant. Whereas the material Z350 is significantly different in hardness among the other materials

V. Conclusions

In this investigation we introduced a straightforward approach for applying the quantitative mechanical methods for monitoring the biaxial flexural strength, compressive strength and Microhardness of the clinically applicable dental composite Z-350, Beautifil II, Ketak-Molar (GIC) and Zirconomer. Within the limitation of this study we report the highest flexural strength ~78.11 ±0.5 (MPa) for Z-350 which decreases linearly through all the other composite samples and found to be minimum ~10.27 ±0.5 (MPa) for Zirconomer. Highest compressive strength ~198.5625±0.5 (MPa) for Compoglass-F was found. Predominantly, the highest Microhardness in Hv (100g) was reported to be ~80.94 ±0.5 for Beautifill II and minimum among all ~26.29 ±0.5 for Z-350. The reasons are as follows

1) Composition of composite (filler in the matrix)
2) Shape, size and volume of that filler material contribute to it.

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