ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

FRACTURE RESISTANCE OF CLASS II (MOD) RESTORATIONS: INFLUENCE OF RESTORATIVE TECHNIQUE AND BEVEL PREPARATION" – AN IN-VITRO STUDY

Roma. M[1], Saurav Miglani[1] , Sureshchandra B[2] .

1. Post graduate student, Department of Conservative Dentistry and Endodontics, A. J Institute of Dental Sciences, Mangalore, Karnataka, India.
2. Principal and HOD, Department of Conservative Dentistry and Endodontics, A. J Institute of Dental Sciences, Mangalore, Karnataka, India.

Manuscript Info

Manuscript History:

Received: 14 December 2015
Final Accepted: 22 January 2016
Published Online: February 2016

Key words:
Indirect Inlay Restorations; Compressive Strength; Bevel Preparation

Corresponding Author

Roma. M

Abstract

Background and Objectives: Composite resins have heralded a new era in restorative dentistry. Although clinicians have been using resin based composites successfully to restore posterior teeth in class II situations for several years, creating a functional, anatomical proximal contact remains a clinical challenge. Therefore, this in-vitro study evaluates the effects of restorative technique, bevel and thermal cycling on the fracture resistance of newer generation composite resin MOD restorations.

Materials and Method: The selected specimen teeth (forty four premolars) were randomly sampled into eight teeth in four experimental groups and six teeth in two control groups with one group of intact teeth and other group with prepared cavity but no restoration. The experimental groups included two groups of direct composite restoration and another two groups of indirect composite restoration, with and without bevel preparations. These specimens were subjected to fracture strength study under compression and statistically analyzed using Kruskal Wallis Test and Mann–Whitney "U" Test.

Results: The mean compressive load required to fracture the specimens was maximum in Group I (389.2 N) and minimum in Group III (163.7 N). Group comparison showed that there was no significant difference among the groups for the load values whereas there was significant difference among the groups for the deformation values. Inter-comparison among the groups was done. For the load values, Group I showed high significance when compared to Group III, and Group II showed significant difference when compared to Group VI. For the deformation values, Group I showed significant difference when compared to Group III, Group II showed significant difference when compared to Group III, Group II showed significant difference when compared to Group VI and Group III showed significant difference when compared to Group VI.

Interpretation and Conclusion: Within the limitations of this in-vitro study, inlay cavity preparations resulted in higher removal of tooth structure compared to direct composite probably due to the proximal flare required to remove the undercut in indirect restorations. Fracture strength was inversely proportional to the amount of the tooth structure removed. Direct composite preparations had higher resistance to occlusal load fracture than indirect restorations.

Introduction:-
Composite restorative resins have been made available to the dental profession for over two decades. Initially, these materials were thought to be suitable for use in both anterior and posterior teeth. However, it was soon realized that certain characteristics of the resin systems available at that time were not satisfactory for load bearing situations and in particular for Class II restorations. More recently, composites have been developed specifically for use in posterior teeth and worldwide clinical trials have demonstrated satisfactory performance of these materials for over five years.

Although posterior composite restorations have increased in popularity and have been well accepted by patients esthetically, these materials have their limitations. However, improved materials, accessory products and techniques have helped to maximize their potential. The typical intracoronal cavity preparation especially in maxillary premolars, exaggerates the heights of the cusps. Weakened or unsupported cusps are subjected to stresses which tend to deflect or fracture them at bucco-pulpal or linguo-pulpal line angles.

Posterior composite resin restorations have recently been introduced as inlay/onlay systems. The recent developments of visible light curing systems have significantly improved the wear resistance and compressive strength of these materials. The aim of additional extraoral cure of inlay/onlay is:
1. To improve the mechanical properties through a decrease in the remaining double bonds.
2. To decrease the gap formation.

The composite inlay/onlay is a versatile restorative technique for esthetic restoration of posterior teeth, especially the maxillary first premolars. Among many advantages, related to the technique are the improved contour, better marginal adaptation, and absence of the restoration contraction. Apart from questions related to shrinkage of luted inlay, contraction of certain inlay types is essentially complete when the post-cure cycle is completed, in contrast to direct placement types where contraction may continue for some time after light curing.

Although there is an established need for non-metallic restorations it would appear that composite restorations or other systems which overcome certain limitations would be of value in certain clinical situations. One such system is the composite inlay, which has been defined as follows.

“A composite inlay is a restoration which is cemented into a cavity as a solid mass that has been fabricated from composite resin with a form established either by an indirect or direct procedure”.

The introduction of glass ionomer cement as universal luting agent with the composite systems has added a new dimension to the utilization of inlay and onlay systems in routine conservative clinical practice.

The purpose of the present study is to compare the fracture resistance of Class II MOD restorations with the influence of restorative technique and bevel preparations restored with composite inlays and onlays under compression load in the Instron machine.

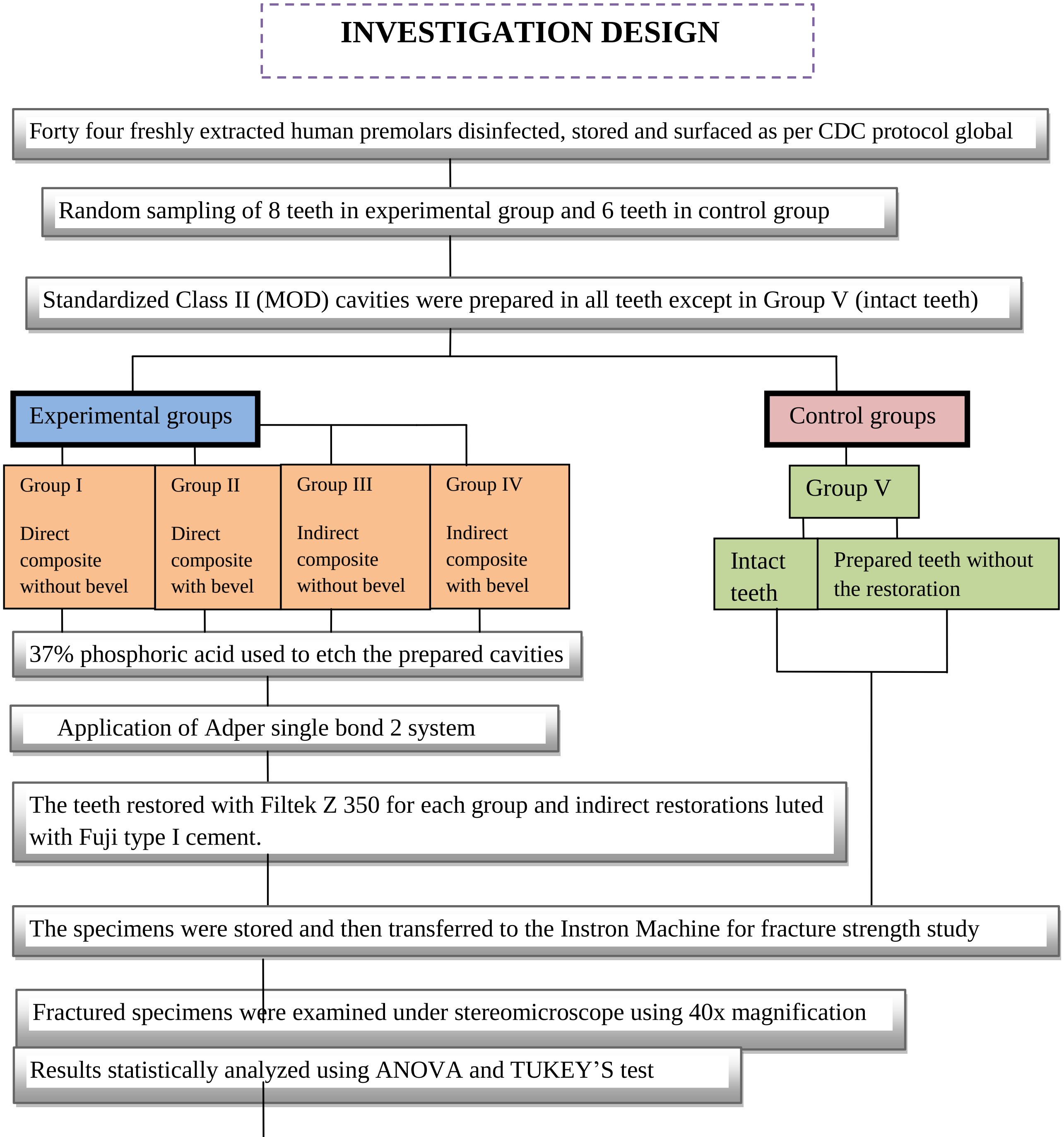
Materials and method:-
This study was conducted at the Department of Conservative Dentistry and Endodontics, A.J Institute of Dental Sciences, Mangalore and Department of Metallurgy, Composite Technology Park, Bangalore.

Forty-four freshly extracted non-carious human premolars extracted for the orthodontic purposes in the age group of seventeen to twenty-five years were collected from the Department of Oral and Maxillofacial Surgery, A.J Institute of Dental Sciences, and other private clinics in and around Mangalore following the protocol meant for infection control. Those meant for bond strength studies were stored in normal saline solution for a minimum period of seventy-two hours at room temperature before being evaluated for use in this study. After cleaning the teeth of all calculus and surface debris the teeth were examined by trans-illumination to rule out any cracks or defects in them. The selected specimens were used within a month of extraction and storage.

TABLE I
Study materials:-

PRODUCT	TYPE	MANUFACTURER
Etchant	37% Phosphoric acid	
Adper Single Bond	Fifth generation bonding system	**3M ESPE**
Filtek Z 350	Nanocomposites	**3M ESPE**
Ketac Cem	Type I luting cement	
Curing light LED	Light curing Unit	
Metal Mould		
Instron machine	Universal testing machine	**--**
Acrylic jig	Used to hold the teeth	**-**

TABLE II

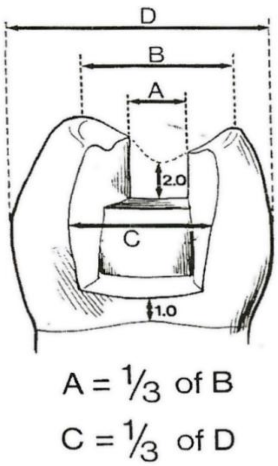


Preparation and grouping of the specimens:-

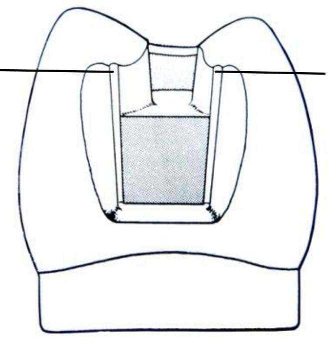
The specimens were embedded up to the cemento-enamel junction, 3mm above the surface of the acrylic resin cylinder made using a hollow cylindrical metallic rod of height 1 inch and diameter 1.5 inch. Each tooth was positioned in the block so that the lingual and buccal cusp tips were in horizontal plane parallel to the base of the mount.

Standardized Class II cavity preparations (MOD) were prepared using No.271 carbide bur with a high speed aerotor handpiece under air/water spray in all teeth, except the teeth in Group V (intact teeth) which is a positive control group. Standard preparatory widths were done according to the following specification.

For this study, a cavity width of approximately one-third of the intercuspal distance was chosen for the occlusal portion of the preparation and one-third of the total faciolingual dimension was used to determine the width of the proximal boxes. All line angles and point angles were rounded. The occlusal portions of all specimens were prepared to a depth of 2mm. The axial wall in the proximal box was prepared to a depth of 2mm at the contact area.
The specimens were randomly divided into 6 groups, with eight specimens in each experimental group and six specimens each in the control groups labelled with coloured adhesive tapes for identification.



TOOTH PREPARATION FOR DIRECT COMPOSITE



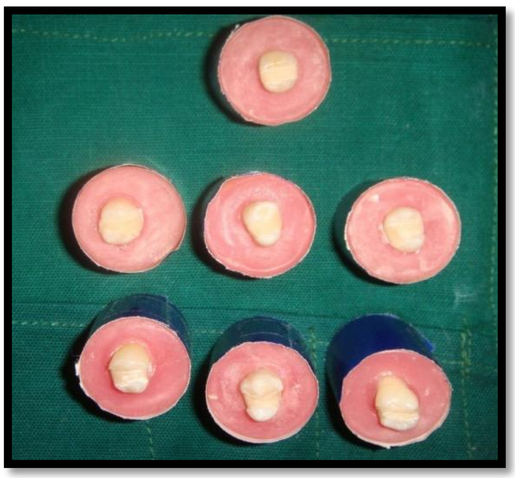
TOOTH PREPARATION FOR INDIRECT COMPOSITE

Group I	Direct composite restoration without bevel with the application of Adper single bond and Filtek Z 350
Group II	Direct composite restoration with bevel with the application of Adper single bond and Filtek Z 350
Group III	Indirect composite restoration without bevel with the application of Adper single bond and Filtek Z 350
Group IV	Indirect composite restoration with bevel with the application of Adper single bond and Filtek Z 350
Group V	INTACT TEETH
Group VI	Prepared teeth without restoration

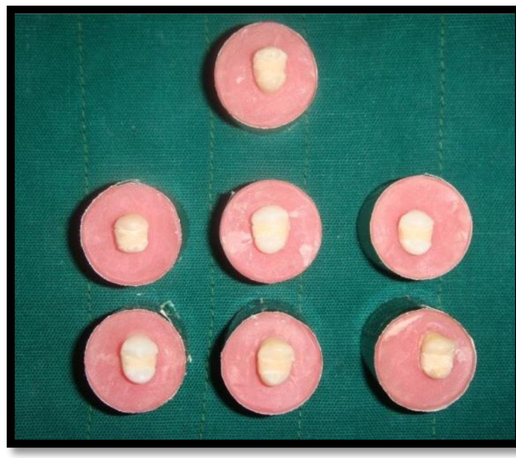
Group i	**Experimental group**
Group ii	**Experimental group**
Group iii	**Experimental group**
Group iv	**Experimental group**
Group v	**Positive control group**
Group vi	**Negative control group**

GROUP I -Direct Composite Restoration without bevel

GROUP II -Direct Composite Restoration with bevel

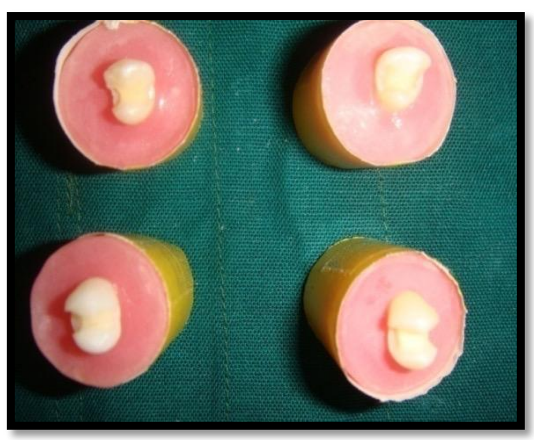


GROUP III -Indirect Composite Restoration without bevel



GROUP IV -Indirect Composite Restoration with bevel

GROUP V – Intact teeth



GROUP VI –Prepared teeth without restoration

Results :-

1. The mean compressive load required to fracture the specimens was maximum in Group I (389.2 N) and minimum in Group III (163.7 N).
2. Group comparison was done using Kruskal Wallis Test for the load and deformation. Results showed that there was no significant difference among the groups for the load values whereas there was significant difference among the groups for the deformation values.
3. Inter-comparison among the groups was done using Mann–Whitney ‘U’ Test. For the load values, Group I showed high significance when compared to Group III, and Group II showed significance when compared to Group VI. For the deformation values, Group I showed significance when compared to Group III, Group II showed significance when compared to Group III, Group II showed significance when compared to Group VI and Group III showed significance when compared to Group VI.

TABLE I – Represents the compressive load in MegaPascal required to fracture all the forty four specimens.
- Represents the deformation at the maximum load in mm.

TABLE II – Indicates the mean and standard deviation of the compressive load and deformation at the maximum load using Kruskal Wallis Test.

TABLE III – Indicates the Inter-comparison among all the groups using Mann-Whitney ‘U’ Test.

TABLE- I (Represents the compressive load in MegaPascal required to fracture all the forty four specimens and represents the deformation at the maximum load in mm.)

COMPRESSIVE LOAD REQUIRED TO FRACTURE THE SPECIMENS IN MEGAPASCAL AND DEFORMATION AT THE MAXIMUM LOAD IN mm					
GROUP I Direct composite without bevel			**GROUP III** **Indirect composite without bevel**		
	LOAD (MPa)	DEFORMATION(mm)		LOAD(MPa)	DEFORMATION(mm)
1	4166	1.187	**1**	1895	1.498
2	4239	1.314	**2**	892.7	0.357
3	4441	2.653	**3**	1386	0.270
4	4892	3.065	**4**	1408	0.637
5	2307	1.115	**5**	1535	0.491
6	1976	1.029	**6**	1959	0.836
7	2120	0.994	**7**	673.6	0.499
8	768	0.281	**8**	729.3	0.287
GROUP II Direct composite with bevel			**GROUP IV** **Indirect composite with bevel**		
	LOAD (MPa)	DEFORMATION(mm)		LOAD (MPa)	DEFORMATION(mm)
1	3078	1.431	**1**	1332	0.639
2	3831	1.087	**2**	2447	0.927
3	5000	1.548	**3**	1456	0.935
4	2784	1.450	**4**	7070	3.453
5	3076	1.061	**5**	970.9	0.530
6	1204	0.632	**6**	1784	0.312
7	1513	0.670	**7**	1505	1.006
8	2211	1.147	**8**	1276	1.254
GROUP V- Positive control			**GROUP VI- Negative control**		
	LOAD(MPa)	DEFORMATION(mm)		LOAD (MPa)	DEFORMATION(mm)
1	998.5	0.6232	**1**	1189	0.4946
2	1647	0.4648	**2**	1498	0.5169
3	1773	1.1210	3	1417	0.5884

TABLE- II
DEFORMATION AT THE MAXIUMUM LOAD

GROUPS	N	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
1.00	8	1.4547	0.92637	0.28	3.07
2.00	8	1.1283	0.34515	0.63	1.55
3.00	8	0.6097	0.40526	0.27	1.50
4.00	8	1.1321	0.98389	0.31	3.45
5.00	3	0.7363	0.34242	0.46	1.12
6.00	3	0.5333	0.04900	0.49	0.59

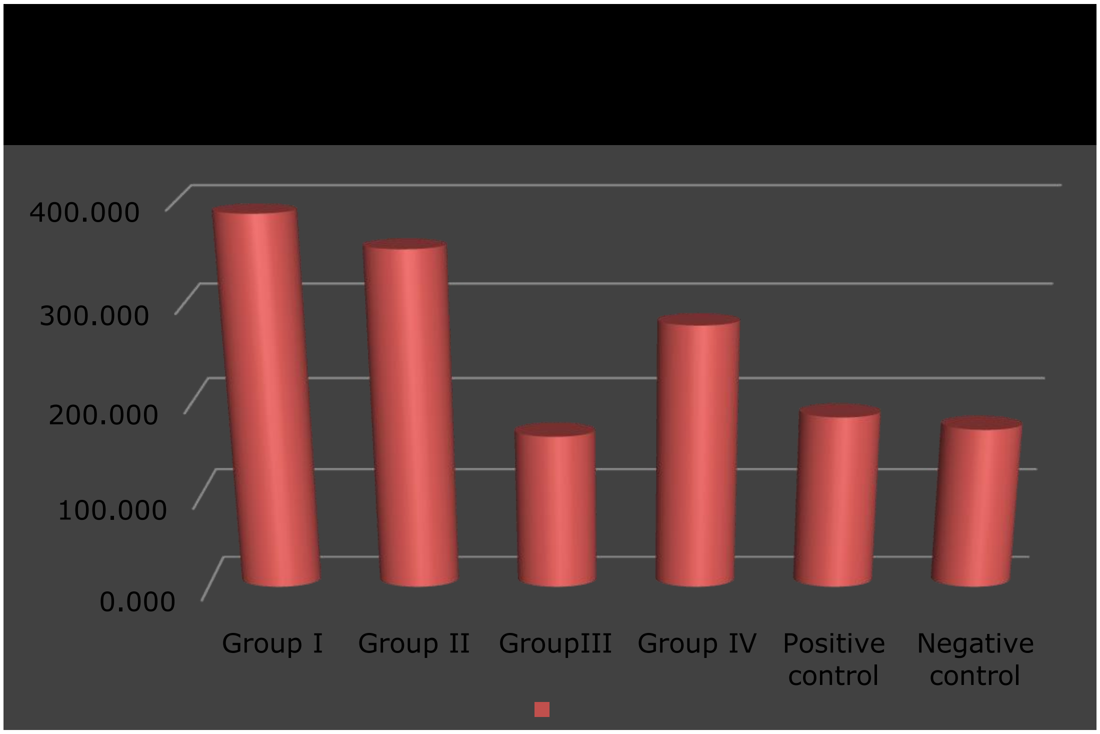
H= 11.943, p = 0.036 Significant H = Kruskal Wallis test P = Probability

TABLE - III(Inter-comparison among all the groups using Mann-Whitney 'U' Test).
RESULTS COMPARISON

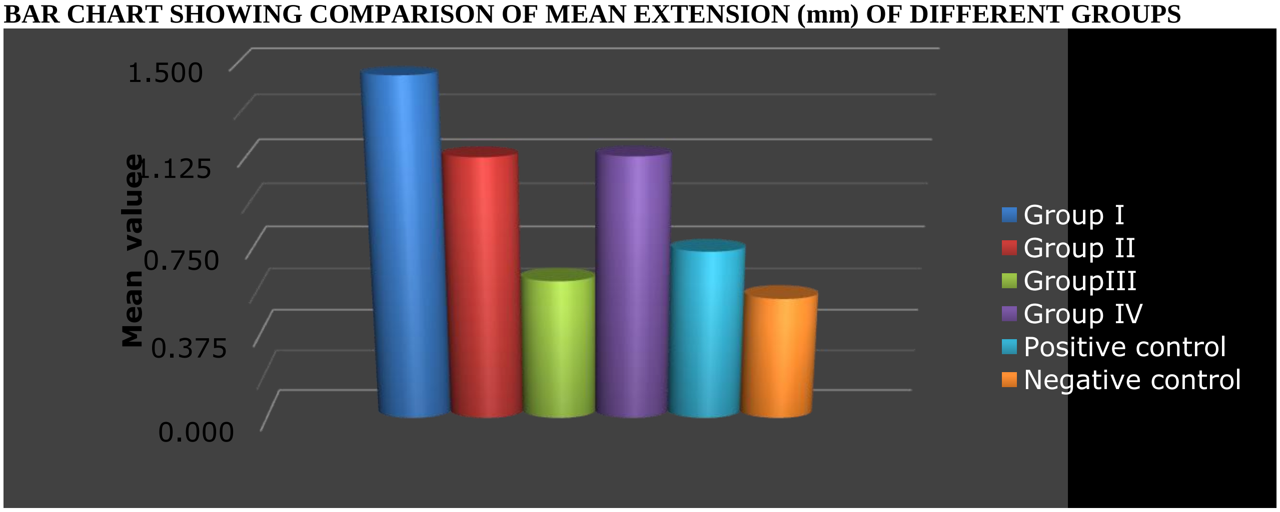
	Load		Deformation	
Comparison	**Z**	**P**	**Z**	**P**
G1 Vs G2	**0.315**	**0.753**	**0.12**	**0.834**
G1 Vs G3	**0.2731**	**0.006 (Hs)**	**0.216**	**0.036 (s)**
G1 Vs G4	**0.147**	**0.141**	**0.126**	**0.208**
G1 Vs G5	**0.1837**	**0.066**	**0.1225**	**0.221**
G1 Vs G6	**0.1837**	**0.066**	**0.1837**	**0.066**
G2 Vs G3	**0.2521**	**0.012 (s)**	**0.2310**	**0.021 (s)**
G2 Vs G4	**0.1575**	**0.115**	**0.1260**	**0.208**
G2 Vs G5	**0.1633**	**0.102**	**0.1633**	**0.102**
G2 Vs G6	**0.2041**	**0.041 (s)**	**0.2449**	**0.014 (s)**
G3 Vs G4	**0.945**	**0.345**	**0.1785**	**0.074**
G3 Vs G5	**0.612**	**0.540**	**0.612**	**0.540**
G3 Vs G6	**0.204**	**0.838**	**0.408**	**0.683**
G4 Vs G5	**0.204**	**0.838**	**0.612**	**0.540**
G4 Vs G6	**0.816**	**0.414**	**0.1633**	**0.102**

Z = Mann Whitney U test
P = Probabiltiy
NS = P > 0.05 = Not Significant
S =P < 0.05 = Significant
HS = P < 0.01 = Highly Significant
VHS = P < 0.001 = Very Highly Significant

BAR CHART SHOWING COMPARISON OF MEAN COMPRESSIVE LOAD (MPa) OF DIFFERENT GROUPS



BAR CHART SHOWING COMPARISON OF MEAN EXTENSION (mm) OF DIFFERENT GROUPS



1.455 1.455

Discussion:-

Over the last few decades, the development of new adhesive materials and advances in restorative techniques and adhesive dentistry have made possible reinforcement of weakened remaining tooth structure. From Buonocore's acid etch technique in 1950s, to the present self-etching primers, the development in adhesive dentistry have come a long way in not only creating superior posterior esthetic composite restorations but also with minimum chairside clinical time.

The need for an alternative to amalgam due to the growing demand not only for the more esthetic restorations but, also to protect the existing tooth structure are responsible for the fast and continuous development of new composites and adhesive systems. Until the last decade, the American Dental Association had not recognized posterior composite restoration as a standard treatment modality. However, with the development of newer generation of bonding systems and improved composites and the clinical procedures the general dentists as well as academicians today consider posterior composite restorations as a standard procedure.

Composites are basically technique sensitive materials and require a certain and definitive protocol not only during preparation of tooth to receive the composite restoration but also follow the total isolation technique with proper instruments and instrumentation technique for an ultimate well finished gap-free posterior composite restoration.

All clinicians who do direct posterior composite restorations are commonly encountered with the problem of polymerization shrinkage that can result in marginal defect or cuspal flexion producing postoperative sensitivity. All of the composites shrink due to its own polymerization shrinkage. Clinicians over the years have attempted many techniques to reduce the contraction stress in the interface using layer/multiple increment technique or ceramic–insert technique. None of these methods have completely solved the problem, and all are technique sensitive.

An alternative for the polymerization shrinkage that occurs during the setting of composites, is the use of indirect method on a removable die. By this indirect technique, to a certain extent polymerization shrinkage that occurs will be on the removable die. Hence, the clinicians thought of an alternative ‘indirect-inlay technique’ by cementing the restoration which is fabricated on the removable die on to the prepared tooth which is cemented with a luting cement like glass ionomer cement.

An indirect technique with composites in the posterior teeth has several advantages including the reproduction of the lost original tooth tissue. One has enough time to sculpture MOD inlay on the removable die, proximal contact and contours including gingival finish line that can be reproduced in a much better way. In the indirect technique, a lot of chairside time is saved and the composite can be cured in a better manner on a removable die than directly in the patient’s mouth.

Murillo Baena Lopes et al. (2006)[11] evaluated the bond strength of indirect and direct composite restoration and concluded that the indirect technique with a combination of factors may be improved during polymerization. In the present study, apart from the evaluation of composite system and composite bonding system on the fracture resistance the investigators went into an additional factor with both direct and indirect restorations with and without bevel only on the cavosurface. The effect of adhesive restorations on large MOD cavities in increasing fracture resistance has been extensively studied. However in the study, the investigators went in for standardized class II MOD cavities with a conservative outlook.

Coelho-de-Souza F H et al (2008)[3] studied the fracture resistance of MOD restorations and influence of bevel on the ultimate fracture resistance. They demonstrated that a bevel placed around the cavosurface margin of a direct and indirect restoration had higher fracture resistance when compared to the same restorations without bevel placement.

The results of the present study did not agree with the study of Coelho FH (2008)[3] and others[11,15] who demonstrated that bevelled restorations generally provide better fracture resistance. The results of the present study indicated that the Group I (direct composite without bevel) fractured to the highest load level and amongst the experimental groups, Group III (indirect composite was placed without bevel) had the least fracture resistance. In the present study, lower fracture resistance was observed for all indirect cavity preparations.

Mondelli J et al (2007)[9] compared the load-to-fracture resistance of sound human maxillary premolars with different cavity widths proving that the removal of tooth tissue significantly affects the load fracture resistance of the teeth. Additional removal of tooth structure is expected in proximal cavities while eliminating undercuts to allow the correct path of insertion of the indirect restoration. This will simultaneously result in a change in the cavity design.

The results of the previous study by FH Coelho (2008)[3] and others[11,15] are somewhat contradicting to those of the present study. The findings of the present study are consistent with the observations made by Jose Mondelli et al (2007)[9] and Mondelli J.et al (1980)[40]. Jose Mondelli et al (2007)[9] observed in their study the lower fracture strength for all indirect restorations.

Mondelli J (1980)[40] compared the load to fracture of sound human maxillary premolars with different cavity widths proving that the removal of tooth tissue significantly affects the load to fracture resistance of tooth. Later studies by Miller B J et al (1992)[33] have also demonstrated this.

Methodological differences may impair reliable comparison of inlay cavity preparations that would result in higher removal of tooth structure. Compared to direct composite cavities, fracture resistance is inversely proportional to the amount of the tooth structure removed and hence, direct composite restorations in the present study without bevel had a higher fracture resistance to the occlusal load level than indirect restoration without bevel.

Maria Jacinta et al (2005)[15] studied the fracture resistance of maxillary premolars restored with direct and indirect resin techniques and concluded that cavity preparation significantly weakens the remaining tooth structure, while the direct and indirect intracoronal adhesive restorations can partly restore the fracture resistance of teeth weakened by cavity preparation.

In the present study, the fracture resistance of Group VI (the teeth were prepared and not restored) was comparatively lower than that of Group V (intact teeth). These findings are consistent with the several other basic researches including those of Mondelli J[40], Blaser PK[39] and others. Several researchers have demonstrated in literature that decreased fracture resistance occurs when the cavity preparations are prepared and this is in agreement with the results of the present study as well.

Routinely, for all posterior restorations a bevel is placed only when the restoration is stronger than the tooth structure. However, in case of posterior composites, clinicians applied bevel on the cavosurface in order to produce long lasting adhesive interface, and based on the observations of the work of Coelho FH (2008)[3] and others[11,15] bevelled restorations generally established better fracture resistance and less gap formation initially.

Regarding the type of fracture observed in all groups, palatal cusps fractures were more frequent than the buccal cusps fracture. However, other researchers have observed that the most of the fractures occurred in the non-functional cusp of maxillary premolars. The fractured specimens were examined under magnification (40x) using stereomicroscope to evaluate the failure pattern as follows: cohesive fracture of the tooth, adhesive fracture at the interface, cohesive fracture of the restorative material, and complete fracture of the specimens involving the two cusps and the restorative material.

The results of the present study did not agree with the observations made by Coelho FH (2008)[3] and others[11,15]. The present study demonstrated that direct composite placed without bevel fractured to a higher load level than the bevel which was placed in Group II. However, there was no statistically significant difference in the intergroup comparison. In Group III, where the indirect composite was placed without bevel, the mean composite load required to fracture was minimum, and inter-comparison among the groups was done with Mann-Whitney ‘U’ Test. For the load values, Group I showed high significance to Group III, and Group II, showed significance compared to Group VI.

In Group IV, where indirect composite was placed with bevel fractured to a higher load level than in Group III, and as compared to the values obtained in Group II, where direct composite was placed without bevel.

In conclusion, inlay cavity preparations resulted in higher removal of tooth structure compared to direct composite probably due to the proximal flare required to remove the undercut in indirect restorations. Fracture strength was inversely proportional to the amount of the tooth structure removed. Direct composite preparations had higher resistance to occlusal load fracture than indirect restorations.
Within the limitations of this study,

a) Use of bevel resulted in improved fracture resistance and marginal adaptation, reducing the impact of the long-term storage on restoration quality,
b) Long-term storage had a significant effect on restoration quality in almost all of the conditions tested,
c) In most of the conditions tested, indirect restoration presented similar results when compared to direct restorations, except for fracture resistance after six months.

Summary:-

An in-vitro experimental study was formulated to compare the fracture resistance of class II MOD restorations with the influence of restorative technique and bevel preparation.

Forty-four freshly extracted premolar teeth following orthodontic extractions were randomly assigned into four experimental groups (eight teeth) and two control groups (six teeth). Groups I, II, III and IV formed the experimental groups, and Group V and VI formed the positive and negative control groups for this in-vitro study, respectively. All the selected teeth were mounted in an autoploymerizing resin in a metal ring. Standardized class II MOD cavities were prepared on all the specimens, except the specimens in Group V (intact teeth). In Group I, the specimens included direct composite restoration without bevel preparation; Group II, the specimens included direct composite restoration with bevel preparation; Group III specimens included indirect composite restorations without bevel preparation and Group IV specimens included indirect composite restorations with bevel preparations; specimens in Group VI were not restored with any restorative material and served as the negative control for the present investigation. Common bonding system Adper Single Bond 2 and common composite material Filtek Z350 was used for all the specimens of the experimental groups. Indirect restorations were luted with Fuji Type I cement.

The forty-four specimens were stored under moist conditions for 24 to 48 hours. The teeth were then given a thermal cycling treatment which comprised of 25 cycles between 5°C and 57 °C, with a dwell time of 30 seconds. The teeth were then subjected to a compressive load in an Instron machine which is a bench model for universal testing machine.

Conclusion:-

The present in-vitro investigation evaluated the effects of restorative technique, bevel and thermal cycling on the fracture resistance of newer generation composite resin MOD restorations.

1. Group I (direct composite without bevel) fractured at the highest mean compressive load, while Group III (indirect composite with bevel) recorded the lowest value.
2. The ranking of resistance to fracture among experimental groups showed that Group I recorded higher mean compressive load value than that of Group II, followed by Group IV and Group III.
3. Statistical analysis using Kruskal Wallis Test was done for the group comparison for the load and deformation. Results showed that there was no significant difference among the groups for the load values whereas there was significant difference among the groups for the deformation values.
4. Inter-comparison among the groups was done using Mann–Whitney 'U' Test. For the load values, Group I showed high significance when compared to Group III and Group II showed significance when compared to Group VI. For the deformation values, Group I showed significance when compared to Group III, Group II showed significance when compared to Group III, Group II showed significance when compared to Group VI, and Group III showed significance when compared to Group VI.

References:-

1. **Karl – Johan Soderholm.** Review of the fracture toughness approach. **Dent Mater.2010;26:e63-e77.**
2. **Aggarwal V, Longani A, Jain V, Shah N.** Effect of cyclic loading on marginal adaptation and bond strength in direct Vs indirect class II MO Composite Restorations. **Oper Dent. 2008;33(5):587-592.**
3. **Coelho-de-Souza FH, Camacho GB, Demarco FF, Powers JM.** Fracture resistance and gap formation of MOD preparation: Influence of restorative technique, bevel preparation and water storage. **Oper Dent. 2008;33(1):37-43.**
4. **Cavalcanti SCSXB, Oliveria MT, Arais CAG, Giannini M.** The effect of the presence and presentation mode of co-initators on the microtensile bond strength of dual-cured adhesive systems used in indirect restorations. **Oper Dent. 2008; 33(6):682-689.**
5. **Watanabe T, Tsubota K, Takamizawa T, Kurokawa H, Rikuta A, Ando S, Miyazaki M.** Effect of prior acid etching on bonding durability of single-step adhesives. **Oper Dent. 2008;33(4):426-433.**
6. **Arrais CAG, Giannini M, Rueggeberg FA, Pashley DH.** Effect of curing mode on microtensile bond strength to dentin of two dual-cured adhesive systems in combination with resin luting cements for indirect restorations. **Oper Dent. 2007;32(1):37-44.**
7. **Asaka Y, Amano S, Rikuta A, Kurokawa H, Miyazaki M, Platt JA, Moore BK.** Influence of thermal cycling on dentin bond strengths of single-step self-etch adhesive systems. **Oper Dent. 2007;32(1):73-78.**

8. **Rodrigo Borges Fonseca, Alfredo Julio Fernandes-Neto, Lourenco Correr- Sobrinho, Carlos Jose Soares**. The influence of cavity preparation design on fracture strength and mode of fracture of laboratory-processed composite resin restorations. **J Prosthet Dent. 2007;98(4):277-284**
9. **José MONDELLI, Fábio SENE, Renata Pereira RAMOS, Ana Raquel BENETTI.** Tooth Structure and Fracture Strength of Cavities. **Braz Dent J. 2007;18(2):134-138.**
10. **Priscilla Solomon, Gopi Krishna, Parameswaran A, Gali Pradeep, Deivanayagam Kandaswamy.** Fracture resistance of premolar teeth with class II preparations restored with light cured composite with beta quartz inserts, light cured composite and silver amalgam in comparison with intact unrestored teeth - An in-vitro study. **J Conserv Dent. 2007;10(4):122-128.**
11. **Murilo Baena Lopes, Simonides Consani, Mario Alexandre Coelho Sinhoreti, Luciana Andreia Salvio, Lourenco Correr Sobrinho.** Bond strength evaluation of direct and indirect composite restorations. **Arquivos em Odontol. 2006; 42(4):257-336.**
12. **Santiago González López, Maria Victoria Sanz Chinesta, Laura Ceballos García, Francisco de Haro Gasquet, Maria Paloma González Rodríguez.** Influence of cavity type and size of composite restorations on cuspal flexure. **Med Oral Patol Oral Cir Bucal. 2006;11(6):E536-540.**
13. **De Munck J, Van Landuyt K**, **Peumans M, Poitevin A, Lambrechts P, Braem M, Van Meerbeek B**. A Critical Review of the Durability of Adhesion to Tooth Tissue: Methods and Results. **J Dent Res. 2005;84(2):118-132.**
14. **Fabiana Mantovani Gomes Franca, Worschech CC, Paulillo LA, Martins LR, Lovadino JR**. Fracture resistance of premolar teeth restored with different filling techniques. **J Contemp Dent Pract. 2005;6(3):62-69**.
15. **Maria Jacinta M. Coelho Santos, Rebeca Basrroso Bezerra.** Fracture resistance of maxillary premolars with direct and indirect adhesive techniques. **J Can Dent Assoc. 2005;71(8):585a-d.**
16. **Manhart J, Chen HY, Hanum G, Hickel R.** Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. **Oper Dent. 2004;29(5):481-508.**
17. **Annie J St-Georges, John R Sturdevant, Edward J Swift Jr, Jeffrey Y Thompson**. Fracture resistance of prepared teeth restored with bonded inlay restorations. **J Prosthet Dent. 2003;89(6):551-557.**
18. **Jakob Leirskar, Hakon Nordbo, Nina Rygh Thoresen, Turid Henaug, Frithjof Ramm von der Fehr.** A four to six years follow-up of indirect resin composite inlays/onlays. **Acta Odontol Scand. 2003;61(4):247–251.**
19. **Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, Van Landuyt K, Lambrechts P, Vanherle G.** Adhesion to enamel and dentin: current status and future challenges. **Oper Dent. 2003;28(3):215-235.**
20. **Buainain de Freitas Claudia Reginal, Serra Miranda Maria Isabel**, **Ferrarezi DE Andrade Marcelo**, **Orbegoso Flores Nictor Humberto**, **Vaz Luis Geraldo**, **Catanzaro Guimaraes Norberto**.
21. Resistance to maxillary premolar fractures after restoration of Class II preparations with resin composite or ceromer. **Quintessence Int. 2002;33(8):589-594.**
22. **Dalpino PH, Francischone CE, Ishikiriama A, Franco EB**. Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly restored with ceramic materials. **Am J Dent. 2002;15(6):389-394.**
23. **Bremer BD, Geursten W**. Molar fracture resistance after adhesive restoration with ceramic inlays or resin-based composites. **Am J Dent. 200;14(4):216-220.**
24. **Bouillaguet S, Ciucchi B, Jacoby T, Wataha JC, Pashley D.** Bonding characteristics to dentin walls of class II cavities, in-vitro. **Dent Mater. 2001; 17(4):316-321.**
25. **D Dietschi, I Krejci.** Adhesive restorations in posterior teeth: rationale for application of direct technique. **Oper Dent. 2001; supplement 6: 191-197.**
26. **Shortall AC, Uctasli S, Marquis PM.** Fracture resistance of anterior, posterior and universal light activated composite restoratives. **Oper Dent. 2001;26(1): 87-96.**
27. **Kyoung KyuChoi, Jack L Ferracane, Thomas J Hilton, David Charlton.** Properties of Packable Dental Composites. **J Esthet and Rest Dent. 2000; 12(4):216–226.**
28. **Tantbirojn D, Cheng YS, Vesalius A, Hodges JS, Douglas WH.** Nominal shear or fracture mechanics in the assessment of composite-dentin adhesion. **J Dent Res. 2000;79(1):41-48.**
29. **Gale M.S, Darvell B.W.** Thermal cycling procedures for laboratory testing of dental restorations. **J Dent. 1999;27(2):89-99.**

30. **Moscovich H, Creugers NH, De Kanter RJ, Roeters FJ.** Loss of sound tooth structure when replacing amalgam restorations by adhesive inlays. **Oper Dent. 1998;23(6):327-331.**
31. **Karl F Leinfelder.** Posterior composite resins: the materials and their clinical performance. **J Am Dent Assoc. 1995; 126(5):663-676.**
32. **Hunter AR, Treasure ET, Hunter AJ.** Increases in cavity volume associated with the removal of class II amalgam and composite restorations. **Oper Dent. 1995; 2091):2-6.**
33. **Watts DC**, **Wilson NH, Burke FJ.** Indirect composite preparation width and depth and tooth fracture resistance. **Am J Dent. 1995; 8(1):15-19.**
34. **Miller BJ, Robinson PB, Davies BR.** Effects of the removal of composite resin restorations on class II cavities. **Br. Dent J. 1992;173(6):210-212.**
35. **Bruno Fissore, Jack I Nicholls, Ralph A Youdelis.** Load fatigue of teeth restored by a dentin bonding agent and a posterior composite restoration. **J Prosthet Dent. 1991;65(1):80-85.**
36. **Reel D.C, Mitchell R.J.** Fracture resistance of teeth restored with class II composite restorations. **J Prosthet Dent. 1989;61(2):177-180.**
37. **Joynt RB, Wieczkowski G, Klockowski R, Davis EL.** Effects of composite restorations on resistance to cuspal fracture in posterior teeth. **J Prosthet Dent. 1987;57(4):431-435.**
38. **Sergio G. Salis, James A. A. Hood, Alastair N. S. Stokes, Ewen E J Kirk.** Patterns of indirect fracture in intact and restored human premolar teeth. **Endo Dent Traumatol 1987;3(1):10-14.**
39. **Eakle W.S.** Fracture resistance of teeth restored with class II bonded composite resin. **J Dent Res. 1986;65(2):149-153.**
40. **Paul K Blaser, Melvin R Lund, Michael A Cochran, Rosario H Potter.** Effects of designs of class II preparations on resistance of teeth to fracture. **Oper Dent. 1983;8(1):6-10.**
41. **Jose Modelli, Lincoln Steagall, Aquira Ishikiriama, Maria Fidela de Lima Navarro, Francisco Bruno Soares.** Fracture strength of human teeth with cavity preparations. **J Prosthet Dent. 1980;43(4):419-422.**