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Effect of cavity design and different restorative materials application techniques on the fracture resistance of class II restorations.

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ABSTRACT

The aim of this study was to evaluate fracture resistance of different class II MOD cavity designs using direct technique (sonicFill composite), indirect inlay technique (Tescera composite), CAD/CAM system (Cerasmart composite blocks) and CAD/CAM system (IPS.emax ceramic). 110 non carious extracted maxillary premolars were divided into 11 groups with 10 in each group. The MOD class II cavity with two different designs were prepared in all teeth except positive control group. 20 prepared teeth ,10 for each cavity design, were left unfilled as negative control groups. Other groups were restored using sonicFill, Tescera, Cerasmart and IPS.emax. A fracture test was performed for all groups. The highest fracture resistance values were shown by intact teeth (+ve control group). The lowest values were found in sonicFill in both cavity designs. IPS emax exhibited highest fracture resistance among all tested materials with both cavity designs. The results of comparison between fracture resistance of the two cavity designs showed that highest values were observed in cavity design without proximal step. In all groups the unfilled cavities showed significantly lower values than intact and restored teeth. Indirect and CAD/CAM systems were applied successfully in case of extensive loss in premolar teeth.

Keywords: cavity design, fracture resistance, inlay, proximal step, ceramic.

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INTRODUCTION

Nowadays the use of light irradiated direct resin based composite materials in posterior restorations has become an important treatment modality in modern dental practice. The ability to bond such restorations either to enamel or dentine has offered the benefits of maintaining sound tooth structure with the potential for tooth reinforcement, while at the same providing a cosmetically acceptable restoration in comparison to conventional non-bonded amalgam restorations [1-3].

The Direct strategies of resin composite, which can be polymerized directly in the tooth cavity, brought inherent phenomena which may be fortuitous or not. Some of these phenomena are dimensional instability, post-operative hyper sensitivity and poor inter-proximal contact. Similarly, glass-ionomer cannot be considered an alternative due to its poor strength properties and high solubility which affect its long term durability [4-7].

Much effort is being focused on modification of composite resin techniques to enhance the flexural strength, wear resistance, hardness and other mechanical properties. This can be accomplished by indirect composites that are handled in the laboratory, utilizing various combinations of light, heat, pressure and vacuum to increase the degree of polymerization, density, mechanical properties and wear resistance [8-15].

Computer-aided design/computer-aided manufacturing (CAD/CAM) technologies have permitted the creation of dental restorations through numerically controlled machining, resulting in uniform material quality, more prominent reproducibility, and a cost diminishment. These advances have been utilized effectively with many ceramic materials. Further, composite blocks have recently been acquainted as alternatives to conventional indirect or direct resin composites [16-20]. Nevertheless, the long-term clinical performance, esthetic and mechanical properties of CAD/ CAM ceramics are superior to those of CAD/CAM composite materials [20-22].

One of the most important categories of biomechanical factors that impacts the fracture resistance of the restorative material is geometric factors, such as cavity design. As the cavity preparation becomes more profound, the strength of the prepared tooth is impressively diminished and the tooth becomes more flexible [23,24].

Therefore, the aim of this study is to evaluate the effect of different mesio-occluso-distal (MOD) cavity designs on fracture resistance of restorations prepared using direct composite, indirect composite, CAD/CAM composite and CAD/CAM ceramic.

MATERIAL AND METHODS

Materials:

Four types of restorative materials: a sonic-activated bulk fill direct composite, a micro hybrid indirect composite, a nanofilled CAD-CAM composite, a Lithium disilicate CAD/CAM glass-ceramic were used in this investigation (Table 1)

The variables interactions between different test groups are shown in (Table 2)

Where ;

D_1: Cavity Design MOD Without proximal step
D_2: Cavity Design MOD with proximal step
C_1: Unprepared Tooth
C_2: Prepared Design one without restoration.
C_3: Prepared Design Two without restoration.
M_1: SonicFill direct composite material.
M_2: Tescera indirect composite material.
M_3: Cerasmart indirect CAD/CAM Composite blocks.
M_4: IPS e.max CAD in-direct CAD/CAM Ceramic.

Methodology:

110 freshly extracted non carious human upper premolars were used in the study. They were scrubbed of soft tissues under running water. Surface deposits were carefully removed using a hand scaler. The teeth were selected as having standard premolar crown form and dimensions. Then any teeth having obvious enamel cracks were discarded. The teeth were stored in distilled water until use.

The buccopalatal and mesiodistal widths of each tooth were measured with a digital caliper (Mitutoyo, Kawasaki, Japan) so that the mean buccopalatal and mesiodistal width of teeth are 8± 0.5 mm and 6.5 ± .5 mm respectively.

Each tooth was mounted vertically in a cubic stainless steel mould using chemically cured acrylic resin (Denture Base material self-cure (Type Ⅱ) Jading, shanghai china). The resin was extended to within 2 mm of the amelocemental junction (approximately the level of the alveolar bone in the healthy tooth).

Ten intact, sound and un-prepared teeth were considered as positive control group C1. The mesio-occluso-distal (M.O.D) inlay cavity with two different designs were prepared in the remaining 100 teeth, 50 for each cavity design, using a diamond fissure bur mounted in high speed hand piece with a profuse water coolant.All preparations were done by the same operator eliminate the problem of operator differences. The first cavity design (D1) was class Ⅱ M.O.D Cavity with buccolingual width 3 mm and occlusal depth 3 mm below the enamel-dentine border (Figure 1.a)

All measurements were carried out with the digital caliper. Moreover, all the preparation depths were controlled with silicon keys and measured with periodontal probe (probe UNC#12 HDL#6, Hu friedy, Tuttilnger, Germany).

The second cavity design (D2) had the same criteria as (D1) however, a gingival wall (proximal step) was prepared 0.5 mm above the enamel-cement junction (Figure 1.b)

A total of 20 prepared teeth ,10 for each cavity design, were left unfilled prepared teeth as negative control groups C2 &C3.

The prepared teeth were impressed with polyvinyl siloxanes (Express VPS, 3MESPE) and impression was poured with die stone (Quick Die, Bisco).

IPS e.max CAD (GC, America, Alsip, IL, USA, A_2 Shade) is lithium disilicate glass ceramic for CAD/CAM Technology. The blocks were milled in CAD/CAM unit in its crystalline intermediate phase. The typical color was ranging from whitish to blue and bluish grey. The crystalline intermediate has a workable resistance of 130-150 MPa after processing. After milling, the restoration was crystallized in a ceramic furnace (Ivoclar Vivadent, programat, P300, P500, P700) for 20-30 minutes at 840 °C. when the lithium disilicate grew in controlled manner and changed its microstructure, the final physical properties increased to 360 MPa and the corresponding optical properties were also achieved. IPS e.max CAD/CAM ceramic blocks were used in each cavity design n=10.

Cerasmart CAD/CAM composite blocks (GC, America, Alsip, IL, USA, A_2 Shade) were milled using CAD/CAM device (CEREC Blue cam, Sirona dental system /Germany) with soft ware (COS Crown 2.1, Sirona dental system). The imaging liquid (CEREC liquid, Vita Zahnfabrik, Bad Sackingen, Germany) was applied to the prepared teeth and spread to a thin film with compressed air. Imaging powder (CEREC powder, Vita Zahnfabrik) was sprayed on the prepared tooth and scanned with CEREC Bluecam. 20 inlays were machined from post-heated, polymerized composite blocks (Cerasmart, GC America). Teeth were rinsed free of imaging powder and the inlays were placed in their respective preparations.

Tescera indirect composite (Bisco, Schaumburg, IL USA, A_2 Shade) was applied in each cavity design n=10.The inlays were post cured by heat cup and under pressure at 135 °C in a nitrogen atmosphere at 550 KPa. The inner surface of the inlays was sandblasted before cementation for 10 seconds with aluminum oxide particles (25-50 µm)

Cementation of inlays was carried out using dual-cure resin cement, panavia F 2.0 (Kurary Medical) according to manufacturer's instruction. The cement was polymerized using LED light unit (Elipar S10, 3M ESPE) Calibrated at 1.200 mw/cm² from facial, lingual and occlusal 40 seconds in each direction. The light intensity was checked by using radiometer (Hilux curing light Meter berlioglu, Dental Ankara Turkey).

The margins of the restoration were finished and polished with polishing discs (Sof-Lex ,3MESPE). All Specimens were stored in water at 37°C until testing.

SonicFill (kerr corp, orange CA, USA) was applied in bulk with its special hand piece. Total etch bonding system was used (optibond FL.) and cured with blue-violet LED according to manufacturer's instructions. SonicFill was applied in both cavity designs n=10.

The fracture resistance of the specimens was measured using universal testing machine (Instron 6022, Instron, MA, USA). The stainless steel bar with rounded ends of 3 mm diameter was used. The steel bar was adjusted to simultaneously contact the buccal and palatal cusps of all restored teeth during the fracture test. Pressure was performed with 0.5 mm/min of cross-head speed and the data obtained as a result of the fracture test were calculated in Newtons.

RESULTS

Table (1) The materials used in the study.

Material	**brand name**	**Composition**
Sonic-activated bulk fill composite	SonicFill	Resin: Ethoxylated bisphenol-A-dimethacrylate(EBDMA) , Bisphenol-A-glycerolate dimethacrylate (Bis-GMA) , Triethyleneglycoldimethacrylate (TEGDMA) Fillers: 83.5 wt% SiO_2, Glass oxides
Microhybrid indirect composite	Tescera	Resin:Bisphenol-A-glycerolate dimethacrylate(Bis-GMA), , Triethyleneglycoldimethacrylate (TEGDMA), Camphorquinone (CQ),tertiary amine Fillers:81 wt% amorphous Si,glass frit
Nano-Ceramic CAD-CAM composite	Cerasmart	Matrix: 2,2-bis(4-methacryloxypolyethoxyphenyl)propane Bis-MEPP , urethane dimethacrylate UDMA, DMA nanoFillers : 71 wt% silica (20 nm), burium glass (300 nm)
mm Lithium disilicate CAD-CAM glass-	IPS e.max CAD	SiO_2 80 wt% ,Li_2O, K_2O,P_2O_5,ZrO_2,ZnO and other oxides

Table (2): Factorial design and variables interaction.

	D1	D2	C1	C2	C3
M1	M1 D1 N = 10	M1 D2 N = 10	(N = 10)	(N = 10)	(N = 10)
M2	M2 D1 N = 10	M2 D2 N = 10			
M3	M3 D1 N = 10	M3 D2 N = 10			
M4	M4 D1 N = 10	M4 D2 N = 10			
			Total no = 110		

Table (3): Means and standard deviations of fracture resistance of different experimental or control groups.

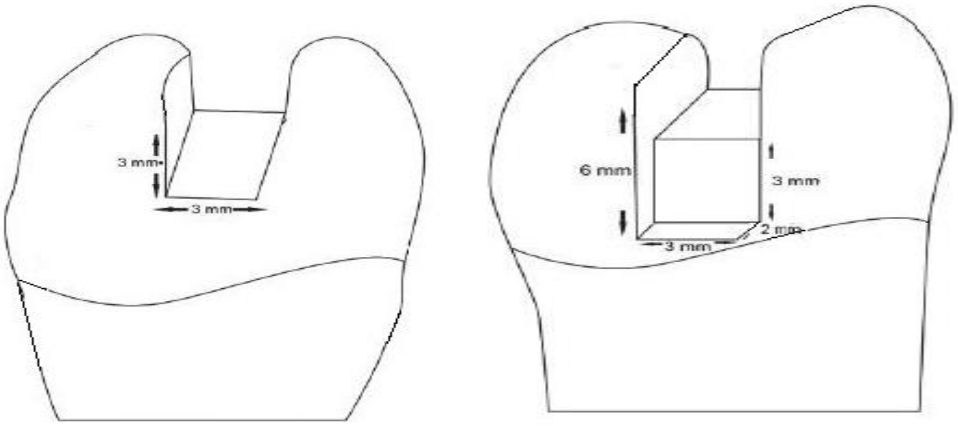
Material	**Cavity design D1**		**Cavity design D2**	
	Mean	**SD**	**Mean**	**SD**
SonicFill	2,163.9	430.1	1,511.3	106.6
Tescera	2,745.3	530.2	2,232.7	260.9
Cerasmart	2,588.7	500.2	2,166.4	450.3
IPS.emax	2,890.8	489.3	2,490.8	535.9
–ve Control unfilled cavities	973.8	130	820.6	142
+ve Control intact teeth	3,120.9	490		

The means and standard deviations of the fracture resistance of all tested materials with different cavity designs are shown in (table 3) and graphically illustrated in (figure 2)

From table (3); the highest fracture resistance values were shown by intact teeth (+ve control group). The lowest fracture resistance values were found in direct composite sonicFill in both cavity designs. IPS emax exhibited the highest fracture resistance among all tested materials with both cavity designs ($p>00.001$).

The results of comparison between fracture resistance values of the two cavity designs, regardless material type, showed that highest values were observed in the cavity design without proximal step (D1) ($p>0.001$).

In all groups the unfilled cavities showed significantly lower fracture strength values than intact and restored teeth with different restorative materials ($p>0.001$)



(a) (b)
(b)

Fig (1): The Schematic diagram of premolar tooth with class II MOD cavity preparation (a); premolar tooth with class II MOD cavity preparation with proximal step (b).

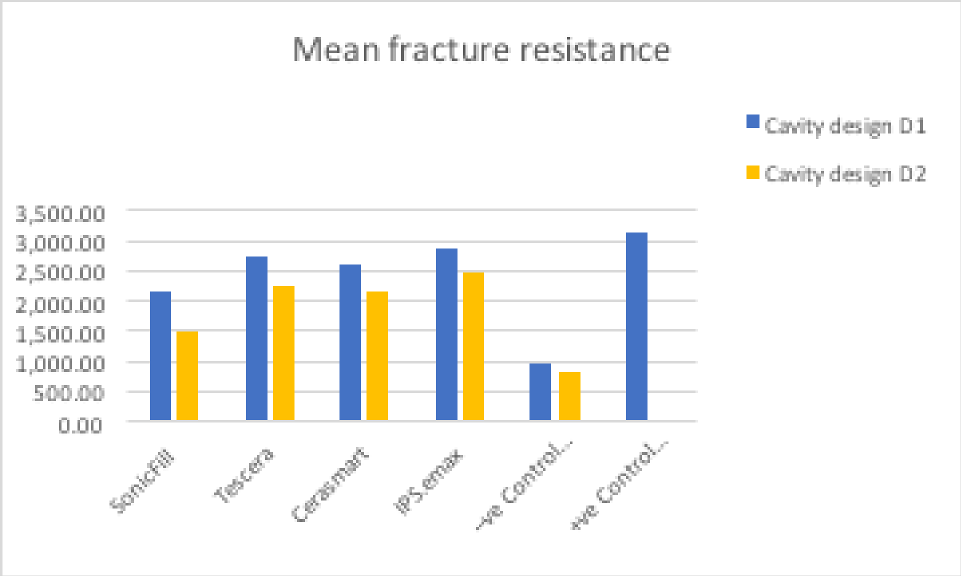


Figure (2) : Bar chart of of fracture resistance of test groups in this study.

DISCUSSION

Due to the increase of esthetic demands in dental field, the need for exceptional restoration techniques and the escalation of ceramic and composite materials made the ceramic and composite inlays superlative in this area. Recently, ideal contact points, smooth surface finishing, more longevity restorations and better marginal adaptation were getting distinctly common in indirect restorations. Inlay restorations, one of the indirect technique, preserve the tooth structure and may be an ideal alternative to the crown restorations. Whilst the indirect inlay techniques are contrasted with direct composite techniques, there is emplacement of the tooth with an anatomy similar to the natural one, better management of the occlusal and proximal contact points, better marginal seal particularly in the gingival wall, insignificant polymerization shrinkage resulting from adhesive agent, better polishing and finishing feasibility, shorter clinical work and less contamination prospect [25].

The stress might be formed within the material due to occlusal and functional forces. Henceforth the fracture resistance is an imperative criteria in assessing the long-term success of restorative materials. Even though fracture as a result of normal bite forces in teeth is hardly observed, fracture is observed more normally in the teeth with cavity preparation or caries. As a result of cavity preparation, the structure of the tooth is debilitated and its liability towards fracture is increasing. It was found in a review that the structure of the upper premolar teeth with a MOD cavity weakened by 59%. Accordingly, it was found that the intact teeth (positive control group) which did not undergo any preparation and restoration processes had the highest fracture values in our study [26].

In our study the cavity design and the gingival extension of the proximal box in the M.O.D cavity had exquisite impact on the fracture resistance regardless the type of restorative material used. This result was in agreement with Cobankara FK et al and Santos MJ et al [27,28] who stated that the more extension of the cavity gingivally, the more weakening effect on the remaining tooth structure.

Adhesive resin cement that was used in this study significantly improved fracture resistance of prepared teeth. This was supported by the results of the unfilled cavities [29,30] (negative control group) and further confirmed by st.Georges et al [31]. Adhesive systems allow new cavity designs to be used without adverse extension or additional means of retention [32].

The IPS e.max exhibited the highest fracture resistance value in both cavity designs while sonicFill composite exhibited the lowest value. This was in agreement with the study by Dalpino et al [33] who found that bonded indirect ceramic restoration has higher fracture resistance than the direct and indirect composite resin restoration. They also concluded that bonded indirect ceramic inlay is ideal option for reinforcing teeth weakened by wide cavity preparation.This was partially in agreement with Liu et al [34] who concluded that there was no significant difference in the fracture resistance of teeth restored with Z 100 resin and IPS Empress CAD.

Tescera exhibited higher fracture resistance value than direct composite and this might be due to polymerization of Tescera under heat, pressure and light in an oxygen free environment. The additional polymerization lead to an increase in degree of conversion, improved mechanical properties and reduction of wear. Such finding agreed with Drummond et al [35].

Despite the high filler loading of sonicFill, it showed to be less successful in terms of fracture resistance when compared to indirect strategies which is in line with the findings of our study. This could be explained via that the composites polymerized under high temperatures, have higher flexural strength and modulus of elasticity than composites polymerized by light [35,36].

Tescera also exhibited higher fracture resistance than cerasmart. This Could be attributed to its higher filler loading 83.5 wt% compared to only 71 wt% . This was in agreement with Hirata et al [36] who reported that filler loading plays an important role in the mechanical properties of composite. Such finding agreed also with the conventional wisdom regarding composite resins' performance in that increasing the filler percentage reduced the resin content which is accountable for inferior mechanical properties.

Cerasmart nanofilled composite blocks showed lower fracture resistance in both cavity design than IPS.emax. This could be explained by its lower flexural modulus which is mandatory for high-stress areas. This was in agreement with Awadu, Nuthanson and Lauvahutunon et al [37,38] who concluded that mechanical properties substantially depend on microstructure, morphology, site and amount of filler loading. Moreover, they concluded that Cerasmart exhibited lower strength properties than lithium disillicate ceramic material.

IPS e.max CAD showed the highest fracture resistance in both cavity designs amongst all tested groups. This might be due to high elastic modulus of lithium disillicate. This was in agreement with Yamanel et al [39] who concluded that low modulus of elasticity means more stress was transferred to the tooth structure.

Many clinical studies and other in vitro studies verified that indirect ceramic restorations exhibit better result and excellent clinical behavior compared to indirect composites and it is considered the best option for posterior teeth restoration due to it high strength properties [40,41].

CONCLUSIONS

Under the constraints of this in vitro study, an indirect ceramic may offer a good other option to direct and indirect composite restorations in case of more tremendous loss of dental structure in the premolar teeth.

REFERENCES

[1] Morimoto S, Vieira GF, Agra CM, Sesma N, Gil C, Fracture strength of teeth restored with ceramic inlays and overlays. Braz Dent J 2009; 20:143-8.

[2] Burke FJ, Wilson NH, WattsDC, The effect of cuspal coverage on the fracture resistance of teeth restored with indirect composite resin restorations. Quintesser1993; 24:875-80.

[3] Brunton PA, Cattell P, Burke FJ, Wilson NH. Fracture resistance of teeth restored with onlay of three contemporary tooth-colored resin-bonded restorative materials. J Pr Dent 1999; 82:167-71.

[4] Magne P, Belser UC. Porcelain versus composite inlays/onlays: Effect of mechanical loads on stress distribution, adhesion and crown flexure. Int J Periodontics Resto Dent 2003; 23:543-55.

[5] Soares CJ, Martins LR, Fonseca RB, Correr-Sorbrinho L, Fernandes Neto AJ. Influence of cavity preparation design on fracture resistance of posterior leucite-rein ceramic restorations. J Prosthet Dent 2006; 95:421-9.

[6] Habekost Lde V, Camacho GB, Pinto MB, Demarco FF. Fracture resistance of premolars restored with partial ceramic restoration and submitted to two different lc stresses. Oper Dent 2006; 31:204-11.

[7] Dejak B, Mlotkowski A. Three-dimensional finite element analysis of strength and adhesion of composite resin versus ceramic inlays in molars. J Prosthet Dent 2008; 9:40.

[8] Malament KA, Socransky SS. Survival of dicor glass-ceramic dental restorations over 14 years. Part ll: Effect of thickness of Dicore material and design of tooth prepare Prosthet Dent 1999;81:662-7.

[9] Santos MJ, Francischone CE, Santos junior GC, Bresciani E, Romanini JC, Saqueto R, et alClinical evaluation of two types of ceramic inlays and onlays after 6 month Appl Oral Sci2004;12:213-8.

[10] Boushell LW, Ritter AV. Ceramic inlays:A case presentation and lessons learned from the literature. J Esthet Restor Dent 2009;21:77-87.

[11] Krifka S, Anthofer T, Fritzsch M, Hiller KA, Schmalz G, Federlin M. Ceramic inlays and partial ceramic crowns; influence of remaining cusp wall thickness on the ma integrity and enamel crack formation in vitro. Oper Dent 2009;34:32-42.

[12] Cobankara FK, Unlu N, Cetin AR, Ozkan HB. The effect of different restoration technique on the fracture resistance of endodontically treated molars. Oper Dent 2008;3:33.

[13] Roberson TM, Heymann HQ, Swift EJ Jr. Sturdevant's art and science of operative dentistry. 4 th ed. St. Louis: Mosby Inc;2002. P.569-590.

[14] Jacobsen P. Restorative dentistry: an integrated approach, 2 nd ed. London: Wiley-Blackwell Publishing; 2008. P.85-98.

[15] Jackson RD. Indirect resin inlay and onlay restoration: a comprehensive clinical overview. Pract Periodont Aesthet Dent 1999;11:891-900.

[16] Miara P. Aesthetic guidelines for second-generation indirect anlay and onlay composite restorations. Pract Periodont Aesthet Dent 1998; 10: 423-431.

[17] Floyd CJE, Dickens SH. Network structure of bis-GMA. And UDMA. Based resin systems. Dent Mater 2006; 22: 1143-1149.

[18] Sideridou I. Tserki V, Papanastasiou G. Study of water sorption, solubility and modulus of elasticity of light-cured dimethacrylate-based dental resins. Biomaterials 2003; 24:655-665.

[19] Asmussen E. Peutzfeldt A. Influence of UEDMA BisGMA and TEGDMA on selected mechanical properties of experimental resin composite. Dent Mater 1998; 14: 51-56.

[20] Ruse ND, Sadoun MJ. Resin-composite blocks for dental CAD/CAM applications. J Dent Res 2014; 93: 1232-1234.

[21] Ozen J, Caglar A, Beydemir B, Aydin C, Dalkiz M. Three-dimensional finite element stress analysis of different core materials in maxillary implant-supported fixed partial dentures. Quintessence Int 2007; 38:355-363.

[22] Hopp CD, Land MF, Consideration for ceramic inlays in posterior teeth: a review. Clin Cosmet Investing Dent 2013; 5:21-32.

[23] Van Dijken JW, Hasselort L. A prospective 15-year evaluation of extensive dentin enamel-bonded pressed ceramic coverages. Dent Mater 2010; 26: 929-939.

[24] Manhart J, Chen H, Hamm G, Hickel R. Buonocore Memorial lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. Oper Dent 2004; 19: 481-508.

[25] Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designes for posterior teeth, Int J Periodontics Restorative Dent 2002; 22: 241-249.

[26] Yamanel K, Çaglar A, GÜlsahi K, Özden UA, Effects of different ceramic and composite materials on stress distribution in inlay and onlay cavities: 3-D finite element analysis. Dent Mater J2009; 28: 66-670.

[27] Cobankara FK, Unlu N, Ceetin AR, Ozkan HB. The effect of different restoration technique on the fracture resistance of endodontically treated molars.Oper Dent 2008; 33-33.

[28] Santos MJ, Bezerra RB, Fracture resistance of maxillary premolar restored with direct and indirect adhesive technique. J Can Dent Assoc 2005; 71:585.

[29] McDonald A, Setchell D, Developing a tooth restorability index. Dent Update 2005; 32: 343-344, 346-348.

[30] Ibrahim AM, Richards LC, Berekally TL, Effect of remaining tooth structure on the fracture resistance of endodontically-treated maxillary premolars: An in study. J Prosthet Dent 2016; 115: 290-295.

[31] St-Georges AJ, Sturdevant JR, Swift EJ Jr, Thompson JY. Fracture resistance of prepared teeth restored with bonded inlay restorations. J Prosthet Dent 2003; 89: 551-557.

[32] Roggendorf MJ, Krämer N, Dippold C, Vosen VE, Naumann M, Jablonski-Momeni A, Frankenberger R. Effect of proximal box elevation with resin composite on marginal quality of resin composite inlays in vitro. J Dent. 2012 Dec;40(12):1068-73.

[33] Dalpino PH, Francischone CE, Ishikiriama A, Franco EB, Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly with ce materials. Am J Dent 2002; 15:389-94.

[34] Liu X, Fok A, Li H, Influence of restorative material and proximal cavity design on the fracture resistance of MOD inlay restoration. Dent Mater 2014; 30: 327-333.

[35] Drummond JL, Lin L, Al-Turki LA, Hurley RK. Fatigue behaviour of dental composite materials. J Dent 2009; 37: 321-330.

[36] Hirata M, Koizumi H, Tanoue N, Ogino T, Murakami M, Matsumura H, Influence of laboratory light sources on the wear characteristics of indirect composite. Dent Mater J 2011; 30: 127-135.

[37] Awada A, Nathanson D, Mechanical properties of resin-ceramic CAD/CAM restorative materials. J Prosthet Dent 2015; 114: 587-593.

[38] Lauvahutanon S, Takahashi H, Shiozawa M, Iwasaki N, Asakawa Y, Oki M, Finger WJ, Arksornnukit M, Mechanical properties of composite resin blocks for CAD/CAM. Dent Mater J 2014; 33: 705-710.

[39] Yamanel K, Caglar A, Gülsahi K, Ozden UA, Effect of different ceramic and composite materials on stress distribution in inlay and onlay cavities; 3D finite element analysis Dent Mater J 2009; 28: 661-70.

[40] Manhart J, Scheibenbogen-Fuchsbrunner A, Chen HY, Hickel R, A2-year clinical study of composite and ceramic inlays. Clin Oral I nvesting 2000;4: 192-8.

[41] Lange RT, Pfelffer P, Clinical evaluation of ceramic inlays compared to composite restorations. Oper Dent 2009; 34:263-72.