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The influence of different thickness of flowable composite base materials on compressive strength of composite restorations (An *In vitro* study)

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Abstract

The mechanical properties(compressive strength) of restorative materials play a crucial role during mastication for clinical performance of materials in particular stress bearing areas at posterior regions. High viscosity, sticky consistency and difficult condensation characteristics of the restorative material in the proximal box of posterior restorations have been indicated to result in non -optimal cervical adaptation, there for a flowable resin composite placed at the cervical margin of the proximal box as an intermediate layer to improve placing characteristics and cervical marginal adaptation. One hundred (100) specimens were prepared divided into ten groups (each group contain ten (10) specimens. Specimens were produced in cylindrical form of tefelon mold with hole cavity dimensions(4 mm diameter and 6 mm depth) for testing compressive strength. specimens divided into four groups [A (control group), B, C and D (each of 10 specimens)] according to the type of composite materials (Z250-XT,SDR,VF,FDF) used in this study , and six experimental groups [B1, B2, C1, C2, D1 and D2 (each of 10 specimens)] according to combination of flowable composites with different thickness (2mm and 4mm) as a base and nanohybrid composite (Z250-XT) with different thickness (2mm and 4mm) as a capping materials. compressive strength of the specimens was measured by using universal testing machine (an axial compression test). Data were analyzed statistically by one way ANOVA test and least significant difference test. The result showed that the group (C2) composed from 4mm thickness of veritizs flow and 2mm thickness of Z250-XT had the highest compressive strength and the group (B1) composed from 4mm of Z250-XT and 2mm of SDR^{TM} had the lowest compressive strength. The difference between these two groups was statistically significant ($p<0.05$).

Keyword: Mechanical properties, Compressive strength, Flowable resin, Tefelon mold.

Introduction

Resin composites were introduced in to dental practice as esthetic restorative material for anterior teeth when they were first developed. However, the growing demand for more esthetic restoration and minimal loss of tooth substance in cavity preparation has made posterior composites an attractive alternative to amalgams and the use of esthetic material for the restoration of posterior teeth has increased over the past year. This was achieved due to the development of several bonding systems and improved mechanical and physical properties (Fusayama, 1990). The mechanical and surface properties of a resin composite are influenced by many variables, for example, monomer contents, filler type, and amount and degree of polymerization. During the last years, hybrid resin composites have been used which are filled with 0.5-1µm sized filler particles of glass or zirconium completed with smaller amounts of microfiller particle clusters (Mitra *et al.,* 2003). Mechanical properties of restorative materials have important role in efficacy and longevity of the tooth and restoration. A badly broken down tooth in anterior or posterior region of oral cavity which has happened because of caries or root canal therapy, needs to be restored with a suitable restorative material which can resist complicated forces of mastication (Saygili and Mahmali, 2002; Summitt *et al.,* 2006). Since the majority of mastication forces in posterior region are particularly compressive, the restored endodontically treated tooth or the complex and extensive restoration should bear these kinds of forces (Summitt *et al.,* 2006; Powers and Sakaguci, 2006). The compressive strength is the most important mechanical property of core build up materials. A restorative material with lower compressive strength than tooth, tends to fail, fracture and it ends with periodontal problems or extraction of the broken tooth (Powers and Sakaguci, 2006; Van Noort, 2007). High viscosity, sticky consistency and difficult condensation characteristics of the material in the proximal box of posterior restorations have been indicated to result in non-optimal cervical adaptation (Da Cunha Mello *et al.,* 1997; Jain and Belcher, 2000). Sandwich methods suggested did not improve the clinical durability of the proximal resin composite restoration (Lindberg *et al.,* 2003; Andersson-Wenckert *et al.,* 2004). To improve placing characteristics and cervical marginal adaptation, a flowable resin composite placed at the cervical margin of the proximal box has been recommended as an intermediate layer. Their easy handling, low viscosity, increased elasticity and wettability may result in stress-relieving properties (Unterbrink and Liebenberg, 1990; Kubo *et al.,* 2003; Dresch *et al.,* 2003).

Materials and Methods

Four dental composites material have been examined in the present work, summarized in Table (1).

Table (1): List of the materials that were used

Material	Z250-XT	Surfil SDR flow	Vertise Flow	Filtek bulkfil flow
Manufacturer	3M ESPE Dental products, USA	DENTSPLY, Caulk,USA	Kerr, Italian	3M ESPE Dental prouduct,USA

Sampling grouping: The total composite specimens was 100; divided into four groups [A(control group), B, C and D (each of 10 specimens)] according to the type of composite materials used in this study and six experimental groups [B1, B2, C1, C2, D1 and D2 (each of 10 specimens)] according to combination of flowable composites with different thickness (2mm and 4mm) as a base and nanohybrid composite (Z250-XT) with different thickness (2mm and 4mm)as a capping materials as following:

Group: (A) composed of Z250-XT composite only as a control group.

Group: (B) composed of SDR™ flowable composite only .

Group: (B1) composed of 4mm Z250-XT and 2mm SDR flowable composite

Group: (B2) composed of 2mm Z250-XT and 4mm SDR flowable composite

Group: (C) composed of Vertise flow composite material only .

Group: (C1) composed of 4mm Z250-XT and 2mm Vertise flow

Group: (C2) composed of 2mm Z250-XT and 4mm Vertise flow .

Group: (D) composed of filtek bulkfill flowable only.

Group: (D1) composed of 4mm Z250-XT and 2mm filtek bulkfill flowable

Group: (D2) composed of 2mm Z250-XT and 4mm filtek bulkfill flowable

preparation of composite resin specimens: To perform the static compression tests, 100 cylindrical specimens (4mm diameter and 6mm height) composed from different materials according to groups of this study , in the translucent tefelon mold to stimulate the condition of deep seated cavity (Figure 1). The materials were applied according to the manufacturers' recommendations.

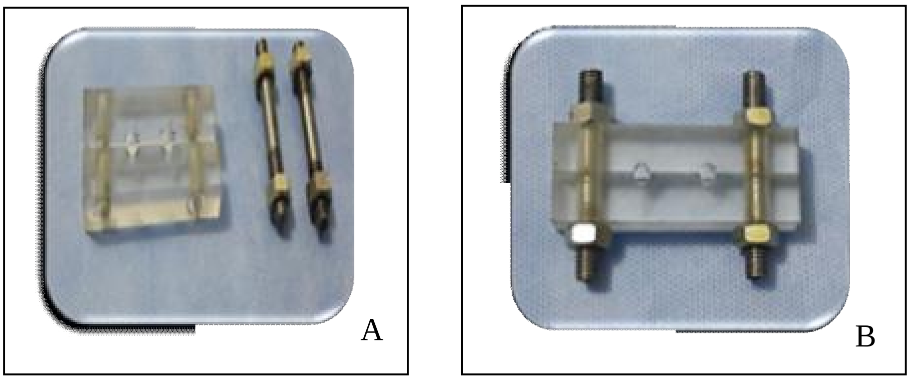

Figure (1): Teflon mold used in this study; A tefelon mold with two holes and two screws, B the mold hold with screws.

The flowable composite resin in the combination groups (SDR flow, vertise flow, feltik bulkfill flow) that were placed in the bottom of the cylinder,consider as a base and been of two thickness(2mm and 4mm). The nanohybrid composite resin (Z250-XT) that were placed above the flowable composite of the cylinder of tefelon mold, consider as a capping materials, to complete the full thickness of the mold at different thickness (4mm and 2mm) respectively. All the composite materials were filled in the mold according to manufacture instructions as follow: By means of a two-part teflon mold, both composite materials were packed into the mold (Rafiee and Rafiee, 2009). The internal surface of the mold may be evenly coated, prior to filling, with a 3% solution of paraffin wax in petroleum jelly, to facilitate the removal of hardened specimens (IS/ISO 9917-1:2003). The flowable composite material was loaded in to holes of the mold by injecting the materials directly. The thickness of flowable composite was examined by using scaled periodontal prop to ensure exact thickness of the materials and the transparency of the mold material also allows for patterning a ring indicated the thickness of flowable composite materials as a standardization mean (Figure 2).

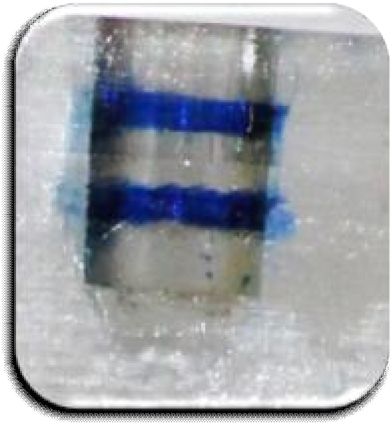

Figure (2): patterned rings in the holes of the mold.

The conventional composite(Z250-XT) was condensed into the holes of the mold until the cavity was overfilled by using stainless steel condenser to get (4mm and 2mm) thickness according to the groups of this study. Thereafter the surface of the material was covered with dental transparent strip and microscopic glass slide in order to produce a flat smooth surface and to prevent the formation of oxygen-inhibited layer on the surface of the samples. A total of 200gm load has been applied for 1 minute to expel excess material from the mold and to reduce voids, as shown in (Cristina *et al.,* 2007). The load of 200mg and the glass slide was removed to exam the absence of porosity in specimens and then the composite resin was irradiated from the top through the celluloid strip in a way that the distal end of the light curing device tip was held without pressure in contact to the celluloid strip and the center of the top and coincident with the specimen's long axis (Lombardini *et al.,* 2012). All specimens will be cured by using a source of blue light from light source device (wave length 440-480 mW/cm2, radii plus-LED, SDI, Swizerland), which was verified before polymerization by using a radiometer.

The base (flowable composite) and nanohybrid capping composite (Z250-XT) were cured for 20 sec for each 2mm thickness according to manufacture instruction and to ensure adequate polymerization of the composite materials (Figure 3). Afterward; the specimens were additionally subjected to another 40sec of light exposure laterally from two sides (Rafiee and Rafiee, 2009) (Figure 4).

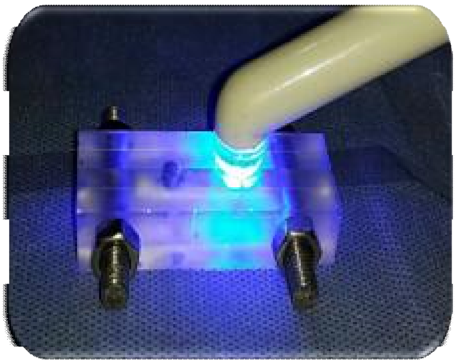

Figure (3): The specimen cured for 20sec (each 2mm) from the top surface of the specimen.

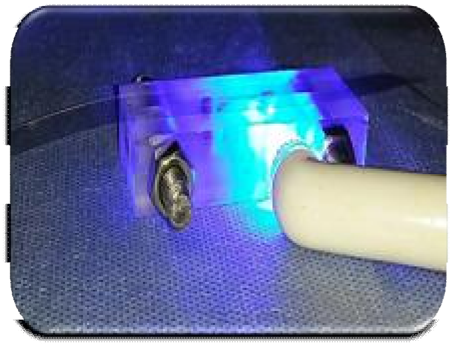

Figure (4): The specimens cured laterally for additional 40sec.

Sample storage: Immediately after curing of composite resin specimen, the specimens stored for 24hrs in a thermostat water bath (HH-1) with distilled water at 37°C to complete polymerization and inhibit any further polymerization from

transient light (Lombardini *et al.*, 2012).
Testing procedure: After one day of storage, the compressive strength of each specimen was tested in newton using Digital compressive tester (INSTRON 1122, England) (Figure 5). The specimens positioned with its long axis coincided with the indenter of the compression tester (Figure 6). The compression tests were carried out on an Instron mechanical testing machine with a constant cross-head speed of 0.5mm/min. Early sign of fracture was calculated immediately through the digital device

Figure (5):Compressive strength tester

Figure (6): The indenter on the sample. (INSTRON1122, England).

Results and Discussion

Compressive strength of Z250-XT composite and three different types of flowable composite: The descriptive statistics which represent the mean, standard deviation (±SD) with the maximum (Max) and minimum (Min) values of the compressive strength in (Mpa) for Z250-XT and three types of flowable composites used in this study are shown in (Table 2).

Table (2): Descriptive statistic of compressive strength of Z-250XT and flowable composites used in this study.

	G.A	G.B	G.C	G.D
Mean	211	177	201	189
S.D.	17.450	1.642	2.353	1.646
Min.	191	175	198	187
Max.	237	180	205	192

The result showed that the group A has the highest mean value of compressive strength (211Mpa), while the group B has the lowest mean value(177Mpa) as shown in (Table 2). One way ANOVA test showed a highly significant difference between the Z250-XT and three flowable composite materials as shown in (Table 3).

Table (3): One way ANOVA test of compressive strength of Z-250XT and flowable composites used in this study.

ANOVA	Sum of Squares	D.F.	Mean Square	F-test	p-value
Between Groups	6417.204	3	2139.068	27.123	0.000 (HS)
Within Groups	2839.155	36	78.865		
Total	9256.359	39			

The result of LSD test showed that (group A) has highly statistical significant difference than (group B) and (group D), while the (group A) has significant difference as compared with (group C). Also, the result show that (group B) has highly statistical significant difference than (group C) and (group D) , and (group C) has highly statistical significant difference than (group D).As shown in (Table 4).

Table (4): LSD test between Z250-XT and three flowable composites materials.

Groups		Mean Difference	P-value
	B	33.775	0.000 (HS)
A	C	10.118	0.015 (S)
	D	22.007	0.000 (HS)
B	C	-23.657	0.000 (HS)
	D	-11.768	0.000 (HS)
C	D	11.889	0.000 (HS)

Compressive strength of control group and experimental groups: The descriptive statistics for control group and experimental groups shown in (

Table 5).

Table (5): Descriptive statistic of compressive strength of control and experimental groups in Mpa.

	G.A	G.B1	G.B2	G.C1	G.C2	G.D1	G.D2
Mean	211	120	183	164	277	129	217
S.D.	17.4	22.0	10.0	17.4	14.8	13.9	20.6
Min	191	88	163	144	249	106	192
Max	237	148	197	190	291	149	238

The result showed that the (group C2) has the higher mean value of compressive strength (277 Mpa), while the (group B1) has the lower mean value. As shown in (Table 5). One way ANOVA test between the control group and experimental groups showed a highly significant difference among all the groups of this study. As shown in (Table 6).

Table (6): One-Way ANOVA test of compressive strength between control and experimental groups.

ANOVA test	Sum of Squares	D.F.	Mean Square	F-test	p-value
Between Groups	266063.214	6	29562.579	121.225	0.000 (HS)
Within Groups	21947.813	63	243.865		
Total	288011.027	69			

Clinical application of composite resins for restoration of posterior teeth requires some mechanical properties to avoid marginal degradation and fracture of restorations. Posterior Composite resin restorations are influenced by mechanical properties, such as fracture toughness, compressive strength, flexural strength, wear resistance and diametral tensile strength. Composite resins have better mechanical properties, such as compressive strength, than other tooth colored restorations such as conventional or resin-modified glass ionomers, suggesting a longer clinical life in regions submitted to occlusal loads (Della Bona *et al.,* 2008). Compressive strength is one of the most important mechanical properties of a core buildup material which restore the structure of a tooth in posterior region, a core buildup material should have the same mechanical properties as tooth structure (Da Cunha Mello *et al.,* 1997; Saygili and Mahmali, 2002; Albers, 2002; Summitt *et al.,* 2006; Powers and Sakaguci, 2006). The results of this study show high compressive strength of nanohybrid Z250-XT, group A, (211 Mpa±17.45), this may be due to higher filler loading (81.8% by Wt., 67.8% by Vol.), result in higher mechanical properties of the composite (Salerno *et al.,* 2011). The result show that the lower compressive strength of SDR™, group B, (177 Mpa ± 11.45), this may be due to lower filler loading (68% by Wt., 44% by Vol.), result in lower mechanical properties of the composite (Salerno *et al.,* 2011). The high compressive strength of Vertise flowable, group C, (201 Mpa ± 2.35), this may be due to higher filler loading (70 % by Wt., 60% by Vol.) (Salerno *et al.,* 2011). The high compressive strength of filtek bulkfil flowable,group D, (189 Mpa ± 1.64) may be due to high filler loading (64.5 % by Wt.,42.5% by Vol.) (Salerno *et al.,* 2011) and adding zirconia–silica (0.01-3.5) to the flowable, will increase the fracture toughness and compressive strength (Khaled *et al.,* 2010). The results of this study revealed that the compressive strength of all groups with flowable composites base increased with increase the thickness of flowable composite base thickness from 2mm to 4mm. This result may be because of application of a thin layer of a flowable composite at the cervical margin as a liner underneath capping composites enhances the marginal adaptation of the restoration (Fabianelli *et al.,* 2003) and the use of a flowable composite as a liner under resin-based composite restoratives lead to increase in flexural strength (Gomec *et al.,* 2005) and creation of a stress-absorbing layer that improves the integrity of the bonded interface area (Montes *et al.,* 2001) and the flowable composites have lower elastic moduli than more densely-filled materials (Labella *et al.,* 1999; Price *et al.,* 2000; Sabbagh *et al.,* 2002). This explanation come in agreement with the studies of Behle (1997), Unterbrink and Liebenberg (1999), Jackson and Morgan (2000), who stated that the low-viscosity flowable composites can be used as stress-absorbing layer material. Also, this finding come in agreement with study of Gomec *et al.* (2005) who stated that the placement of flowable composite as a liner under the capping resin-based composite restoratives increase the compressive strength and flexural strength.

Conclusion

Increase the thickness of flowable composite placed as a liner or a base under the resin-based composite restoratives increase the compressive strength.

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