Influence of the Mechanical Properties of Composites for Indirect Dental Restorations on Pattern Failure

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Abstract

This study evaluated the fracture pattern of two composites for indirect dental restoration relating to compressive strength and microhardness (Tetric and Tetric-Ceram).Four specimens of each composite polymerized by light were tested in universal testing machine at(1mm/min) crosshead for compressive strength . Microhardness was determined by the Vickers indentation technique. Results obtained show that the compressive strength and microhardness for the (Tetric–Ceram) was more than Tetric and showed partial fracture of the matter.Therefore, indirect composite resin (Tetric-Ceram) materials that guarante both good esthetics and adequate mechanical properties may be considered as substitutes of natural teeth.

Key words:flexural strength, compressive strength, dental composites and indirect restoration.

دراسة تأثير الخواص الميكانيكية للمتراكبات البوليميريه المستخدمة في ترميم الأسنان على أنماط الفشل

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بغداد – العراق

ألخلاصه

في هذه الدراسة تم حساب نمط التكسر لنوعين من المتراكبات لمواد ترميم الأسنان تبعا لفحص الانضغاطية والصلادة ألمجهريه لمادتي (Tetric–Ceram,Tetric). حضرت أربعة نماذج من كل متراكب وتم بلمرتها باستخدام نظام التصلب الضوئي التقليدي و اجري عليها فحص الانضغاطيه باستخدام منظومة فحص الانضغاطيه بسرعة مقدارها(1ملم \ دقيقه). قيست الصلادة ألمجهرية للنماذج المحضرة أعلاه باستخدام منظومة الصلادة ألمجهريه (Vickers). من النتائج المستحصله تبين إن متانة الانضغاطيه والصلادة ألمجهريه للمادة (Tetric–Ceram) كانت أعلى مقارنة بمادة إل (Tetric) التي أظهرت فشل جزئي لجسم المادة لذالك فان المواد المتراكبة البوليميريه (Tetric–Ceram) المستخدمة في هذا البحث أعطيت نتائج جيدة وميكانيكيه مقبولة وتكون مناسبة لترميم وتعويض السن الطبيعي.

الكلمات المفتاحية :متانة الانحناء،متانة الانضغاط، ومتراكبات لترميم الأسنان.

Introduction

Photo-polymerized dental composites for indirect restorations have been used as an alternative esthetic material for ceramic single restorations, multi-unit fixed partial dentures, and implant-supported prostheses (Touati; B,*et al*. ,1997, Vallittu,2004).The first generation of composites for indirect restoration was introduced to the dental market in the 1980 decade but they showed poor in vitro and clinical performance. Deficient bonding between organic matrix and inorganic fillers was the main problem leading to unsatisfactory wear resistance, high incidence of bulk fracture, marginal gap, micro leakage, and adhesive failure in the first attempts to restore posterior teeth (Mc.Cabe,1991). Efforts to solve these problems included the increase of inorganic filler content, reduction of filler size, and modification of the polymerization system(Shellard, *etal*. ,1999, Miara, 1998).

The use of different polymerization methods may result in variation of mechanical properties, e.g., the application of heat for additional polymerization increases the conversion rate of monomers, reflecting in improvement of surface hardness, compressive and flexural strength (Ferracane, *etal.* ,1992). However, few cannot be directly compared because they often use different methodologies to evaluate mechanical properties.
Since there has been a rapid introduction of new dental restorative composite resins, the selection of the appropriate material becomes rather difficult. As mechanical properties are one of the most important characteristics when deciding for a suitable material, scientific validation on the efficacy of these new technologies is necessary.

Microhardness tests are considered an efficient method to investigate the physical strength of a material and therefore may be one an appropriate indicative method to guide indirect composite application. The hardness of a material is a relative measure of its resistance to indentation when a specific, constant load is applied. Thus, hardness may be described as a measure of the ability of a material to resist indentation or scratching (Cesar, *et al*.,2001). The aim of this study was to compare compressive strength ,Microhardness and fracture pattern of two indirect composites polymerized by light.

Material And Methods

Two indirect composites light cured selected for this study characteristics of the material used were given in table (1) displays the brand names, manufacturers, and filler content of the composites tested. Compressive strength test was performed according to previous studies (McCabe,*etal*.,1991, Kildal,*etal*. ,1997). Samples were made with 5mm thick increments of each composite resin using a cylindrical Teflon matrix with 10 mm diameter and 5 mm height. Polymerization method for each system using unit-light. After storage for 24 h, specimens were tested in a universal testing machine at a crosshead speed of 1mm/min. Data were obtained in kgf and transformed in MPa using the following formula:

$$RC = F * 9.807 / A$$

(RC)is the compressive strength (MPa).
(F) is the recorded force (kgf) multiplied by the constant 9.807 (gravity). (A) was the base area. After compressive strength testing, the specimens were classified according to the type of fracture: complete fracture if the specimen had rupture into multiple fragments, or partial fracture when the specimen rupture into two parts.

Table.(1) Specifications of the composite systems for indirect restoration evaluated in this Study.

Material and Manufacturer	Filler size	Filler content (% vol)
Tettric-Ceram, Heraeus-Kulzer, Hanau, Germany	1 µ m barium glass, colloidal silica 1 µ m silicon dioxide, aluminum oxide bis-GMA,UDMA TEGDMA	79.5-63.7%
Tetric, Ivoclar, Liechtenstein - Switzerland	1.5 µ m barium glass, silicon, dioxide ytterbiumtrifluride bis-GMA,UDMA TEGDMA	79.5-61%

After one day of dark storage the specimens were positioned with their molds centrally under the indenter of Vickers microhardness test (yap,2002) using (9.8N) load and adual time of 20 seconds .The results of pilot study suggested that this load provided well-scribed indentations for both Tetric composite and (Tetric-Ceram).Three hardness measurements were made at random positions around the center of the top surface and three were made at the bottom surface making sure that the area of indentation was free from air voids.

The lengths of the diagonals of the resulting indentation were measured using calibrated piece that read in microns and the Vickers Microhardness Number (VMN) was determined for the tabulated readings (manufacturers machine leaflets).Mean hardness values were then calculated for each surface. The mean hardness value of the bottom surface was divided by the mean hardness value of the top surface to obtain The mean hardness ratio using the following formula .

Mean hardness ratio= VHN of bottom surface VHN of top surface .

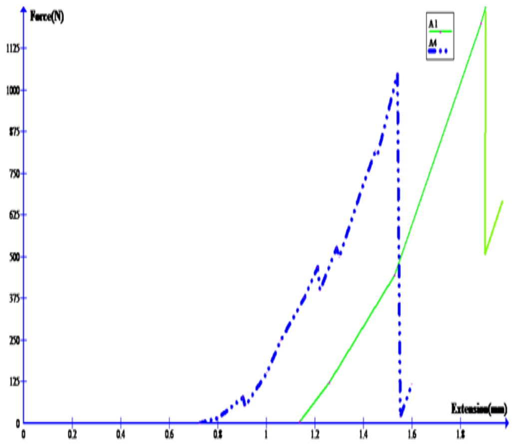
Results and Discussion

Mean values of compressive strength (MPa) are shown in Table (2). Tetric -ceram had highest compressive strength than Tetric as illus trated in Fig-1 which showed further more failure mode in load deflection curve (B2,A3) Tetric-Ceram and (A4,A1) Tetric. In general we can concluded that there was differences between Microhardness of Tetric composite verses Tetric-ceram using conventional light curing unit, as illustrated in table 2.

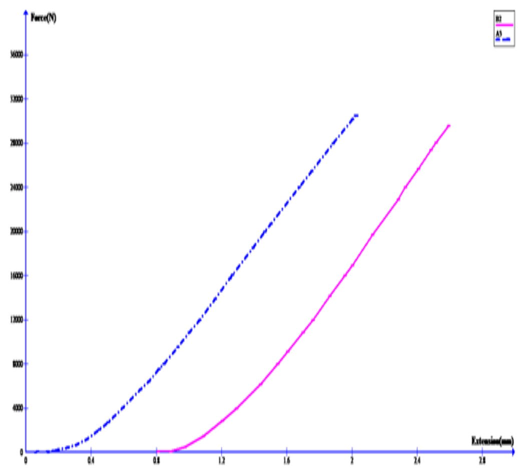
Table.(2)Compressive strength, Pattern of ractures(%),microhardness of the tested indirect composites.

Type	Compressive strength (MPa)	Patternoffractures (%)		microhardness
		Bulk	Partial	
Tetric-Ceram B2	261.4		100%	72,2-70.1
Tetric-Ceram A3	269.5		100%	40,4-40
Tetric A4	255	100 %		36,3-32,7
Tetric A1	118.84	100 %		69.67-67.66

Compressive and tension stresses that act in the material simultaneously (van Noort,R.2002), the evaluation of this property is important for us as flexural strength reflects resistance to materials used in posterior teeth, particularly in multi-unit fixed partial dentures. In our study, because of high monomer conversion rate(Ferracane,*et al.* ,1994).



A



B

Fig.(1) Show failure mode in load-deflection curves A (Tetric-Ceram) B (Tetric).

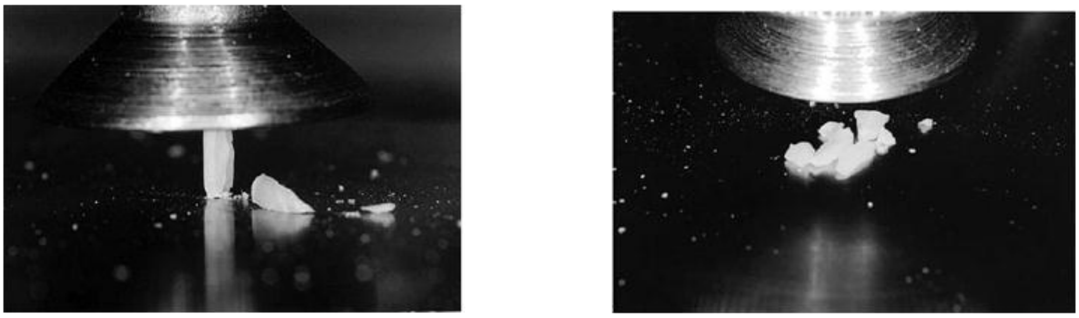
Both filler morphology and filler loading are shown to influence flexural strength, flexural modulus, hardness, and fracture toughness of dental composites Parallel conclusion was drawn by another study (Miranda ,*et al.* ,2003) with the same composites tested here, which reported that Tetric showed higher microhardness than Tetric-ceram. The presence of filler particles increases the compressive strength and hardness of the resin matrix. Initially, it was thought that increasing the level of filler content in composites could optimize properties such as wear resistance, compressive strength, hardness, water sorption, and elastic modulus. Later researches have reported that there is no correlation between filler content and mechanical properties (Ferracane,*et al.* ,1992).

This study verified that Tetric resulted into the highest microhardness mean values when compared to the other tested materials(Tetric-ceram,) although it did not present the highest filler content. Interestingly, the indirect composite with the lowest filler content presented the lowest mean microhardn - ess data. Although divergence exists when considering a possible correlation between filler particle content and composite mechanical properties, it must be pointed out that perhaps the manufacturers information about the filler particle size and filler content is not as closely monitored as they advertise (Cesar, *et al.* ,2001)

Therefore, further research is necessary to determine indirect composite behavior in order to assist clinicians in a better understanding of their clinical indications.

The opaque composites Tetric have more polymer of Bis-GMA in the organic matrix and higher elastic modulus. On one hand and on the other hand, Tetric-ceram have high content of multifunctional monomers in the organic matrix and was more resilient. Tetric-ceram manufacturer claims that the material was more resistant to fractures because it was more resilient than the resins with large amount of Bis-GMA (Miranda,*et al.* ,2003). Stated that compressive resistance cannot predict the capacity of the composite resin to support stress, and that this relationship was limited to frail materials. Composite resins would suffer a "barrel" effect when submitted to a compressive test and expand until plastic deformation occurs**(**Van,*et al.* ,2002). In relation to the fracture pattern, 100% Tetric specimens had partial fracture mode,while (Tetric-ceram) specimens showed 100% of complete fracture mode (Figures2). Observation of fracture pattern under compressive force was important for the understanding of material behavior. Failure pattern may be dependent on the volume and distribution of inorganic particles or the organic matrix components, but the interpretation of the failure mechanism was very complex as several forces were interacting and competing simultaneously. Tetric had 100% partial fractures and exhibited a pattern of homogeneous fracture propagation with longitudinal rupture of the specimen into two or three large fragments. Ferracane and Condon (Ferracane,*et al.*,1992) speculated that composites submitted to heat might present internal stress relief, specifically at the interface between organic matrix and inorganic particles. This would increase the adhesion between both phases and the cross-linking between the methacrylate groups. The occurrence of large fragments denotes this great adhesion between phases. However, during the compressive test, when the first longitudinal fracture occurred, the testing machine automatically stopped its movement preventing the total rupture of Tetric specimens. This did not happen for Tetric-ceram, which presented 100% of complete fracture and were reduced to minute fragments without the longitudinal fracture pattern observed for Tetric. Within the limitations of an in vitro study, clinicians must be aware that indirect composites are essentially direct composites in their composition. However the additional curing process seems to be the most relevant point in each system. The results of the indirect composites Tetric confirm this hypothesis , as their flexural behavior and elastic modulus were superior compared to the other tested composites.

Nevertheless, only clinical investigat - ions were able to confirm if post-polymerized composites have higher success rate than simple photo cured resins used for indirect restorations or if the adhesive cementation would sustain those difference.



A B

Fig.(2) (A) Partia fracture of Tetric (B) Complete fracture of (Tetric-ceram).

Conclusion

The composites polymerized by light (Tetric) failed under compression because it was more rigid and showed partial fracture in the material bulk which had different indirect composite resins presented distinct microhardness mean values through the indentation technique under constant load of 9.8 N. Such differences may be related to the intrinsic composition of each material as well as the variation of their polymerization methods.

As proper substitutes of natural teeth, indirect composite resins should gather both adequate mechanical properties and good esthetic in order to produce successful results.

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