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FLEXURE STRENGTH, FLEXURE MODULUS AND COLOR STABILITY OF DIFFERENT DENTAL RESIN COMPOSITES

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ABSTRACT:
Evaluation of some physicomechanical properties; color stability, flexural strength and flexure modulus of different dental resin composites. Materials and Methods: Three types of dental resin composite were used in this study; (1) Conventional nanohybrid (Grandio So, Voco, Cuxhaven, Germany), (2) Fiber reinforced bulk fill (Posterior Ever X, GC, Tokyo, Japan), (3) Conventional nanofill (Z350, 3M ESPE, St Paul, MN, USA). Color stability, flexural strength and flexural modulus were tested according to ISO 4049. Highest color stability was Z350 (nanofill composite) while highst flexural strength was Ever X Posterior (fibers reinforced composite) and highest flexural modulus was GrandioSo (nanohybrid). Conclusion: Physicomechanical properties of dental resin composite are mainly influence by internal structure of composite (resin type and percentage, filler load and size, type of photoinitiator, type of saline coupling agent).

KEYWORDS: TEGDA,UDEMA,toughness,iso404

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INTRODUCTION

Dental resin-based composites (RBCs) have been developed and marketed over the last few decades and are being increasingly used in restorative dentistry as an alternative to dental amalgam due to their good characteristics and applicable techniques [1-3]. One of the most critical advantages of dental resin-composites is their color matching to the dental tissues (enamel and dentin). This, to a great extent, satisfies most of the dental patients' desires to have a good restoration [4,5]. In addition, unlike to amalgam restorations, resin-composite restorations are more conservative because they bond micromechanically to the tooth structures. This prevents unnecessary removal of sound tooth structure [6,7]. Resin-composite materials can be used to repair chipped, broken and worn teeth as well. In case of minor damage to a dental resin-based composite restoration, it can be easily repaired by adding an additional resin composite material without removing the entire restoration. From the standpoint of biocompatibility, resin-composite materials are safer than amalgam due to the lack of mercury toxicity [8,9]. The organic part represents 10–30% by weight of new composite. The basic matrix resin consists of a mixture of various polymerizable monomers such as Bisphenol A-glycidyl dimethacrylate (Bis-GMA) and/or urethane dimethacrylate (UDMA).They combined with triethyleneglycol dimethacrylate (TEGDMA) to adjust viscosity and photoinitiators, coinitiators, inhibitors of polymerization and UV-stabilizers [10,11]. Filler size is only one of several parameters affecting the overall properties of a resin-composite.

Within each type of composite, the materials are distinguished by the size of their reinforcing fillers [12]. Conventional dental composites had average particle sizes that far exceeded 1μm. These “macrofill” materials have a higher compressive strength, but difficult to polish and impossible to retain surface smoothness so, the surfaces often became rougher with wear and attracted plaque. For the importance of long-term esthetics, manufacturers began to formulate “microfill” composites allowing for a much more aesthetic finish [13,14]. The filler level in the microfilled materials was low, but could be increased by incorporating highly filled, pre-polymerized resin fillers (PPRF) within the matrix to which additional “microfill” particles were added. The “microfill composites were polishable but generally weak due to their relatively low filler content, and a compromise was needed to produce adequate strength for application in regions of high occlusal forces with enhanced polishability and esthetics. Therefore, the particle size of the conventional composites was reduced through further grinding to produce what was ultimately called “small particle hybrid” composites. These were further distinguished as “midifills,” with average particle sizes slightly greater than1μm but also containing a portion of the 40 nm-sized fumed silica “microfillers.” [15,16]. Further refinements in the particle size through enhanced milling and grinding techniques resulted in composites with particles that were submicron, typically averaging about 0.4–1.0 μm, which initially were called “minifills” and ultimately came to be referred to as “microhybrids.”. These formulations of smaller particle hybrid composite resins enhance their physical, mechanical, and optical characteristics similar to the natural tooth structure. These restorative materials have high fracture strength, good color stability, and durability of polish [17]. The “nanofill” composites, containing only nanoscale particles ranging from 1 to 100 nm was developed. These materials have high initial polishing ability with superior polish and gloss retention. The incorporation and use of these nanoparticles into dental composites and bonding agents has improved the physical properties including; compressive strength and hardness, coefficient of thermal expansion, wear resistance, esthetics (by improving the light scattering), and bond strengths [18, 19]. Main cause of using dental composites resin as a filling material is its tooth color matching. A crucial property of esthetic restorative materials is their long-term color stability. An unacceptable color match is a primary reason for the replacement of composite resin restoration [20]. Three types of discolorations are generally described: (i) external discoloration due to the accumulation of plaque and surface stains (extrinsic stain), (ii) surface or subsurface color alteration and (iii) intrinsic discoloration. Extrinsic discoloration is mainly caused by colorants contained in beverages and foods. It has been proven that common drinks and food ingredients could cause significant change in surface color. Surface or subsurface color alteration implying superficial degradation or slight penetration and reaction of staining agents within the superficial layer of composite resins (absorption) and body. Intrinsic discolorations are due to physicochemical reactions in the deeper portion of the restoration [21,22]. In 1979, a specific commission (Commission International de L’Eclairage), proposed the CIE L*a*b* system, consisting of three coordinates, in which L* refers to the luminosity of the object to be evaluated, ranging from black to white; a* is a measure of chroma in the red-green axis; and b* is a measure of chroma in the yellow-blue axis. In this way, the CIE L* value varies from 0 (black) to 100 (white), the CIE a* value can be positive (red) or negative (green), and the CIE b* value characterizes yellowness or blueness if positive or negative, respectively [23]. According to individual ability of human eye to appreciate differences in colors, three different intervals were used to distinguish changes in color values:

ΔE (where $\Delta E= (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$), (i)

when $1.0 < \Delta E < 3.3$, color change is imperceptible by the human eye, but appreciate only for skilled dentist, (ii)

when $\Delta E > 3.3$ – it easily observed, so

, color change value is not clinically acceptable. (iii) In this way, the restorations might be considered clinically acceptable when ΔE is less than 1.5 [23,24]. Flexural strength is an important mechanical property, particularly for brittle materials. FS testing includes compressive, tensile and shear stresses testing that the restoration will be mostly subjected to in the oral cavity [25, 26]. Flexural modulus is an intrinsic material property which is directly linked to its composition and the bonding between atoms. It is considered as a function of many factors such as filler content, monomer chemistry, monomer structure and filler/matrix interactions. Together with adhesive properties, flexural modulus is a critical factor in microleakage, secondary caries and filling dislodgement [27, 28].

Aim of Study

Evaluation of color stability, flexural strength, flexure modulus and fracture toughness) of different dental resin composites (Grandio So, Z350 and Posterior Ever X).

MATERIAL AND METHODS

Table 1 represents the restorative materials that were evaluated. The restorative materials were handled according to the manufacturer guidelines, and all specimen's preparation procedures were accomplished by one operator.

Table 1: Specifications of tested resin composite materials

Commercial Name	Composite Type	Manufacturing	Chemical composition	Filler loading (wt %)
GrandioSo	Conventional Nanohybrid	Voco, Cuxhaven, Germany	Matrix: Bis-GMA, Bis EMA, TEGDMA Filler: glass ceramic fiber, functionalized silicon dioxide nano particles	89%
Ever-X Posterior	fiber reinforced bulk fill	GC, Tokyo, Japan	Matrix: Bis-GMA, PMMA, TEGDMA Filler: Short E-glass fiber filler barium glass	74.2%
Filtek™ Z350 XT	Conventional Nanofill	3M ESPE, St Paul, MN, USA	Matrix: Bis-GMA, UDMA, Bis-EMA, TEGDMA Filler: silica nanofiller (5–75 nm), zirconia/silica nanocluster (0.6–1.4 μm)	72.5%

Color stability testing:

Eleven specimens of each composite were prepared in a half-split stainless-steel round mold of 4 mm diameter and 2 mm thickness. Mold was put on the glass slide covered with Mylar strip and separating medium was applied to mold wall with a brush, then the composite material was applied to the mold cavity with a plastic instrument. After that, glass slide covered with Mylar strip was applied on the top of the mold. Curing was carried out on the top then on the bottom of the specimens before removal from the mold. Curing was achieved by light-emitting-diode LED curing unit (EliparTM Deep Cure, 3M, ESPE, USA) for 20 sec that radiated the light in 430-485 nm spectral wavelength range with irradiance of 1200 mW/cm2 output intensity. According to ISO 4049:2009a [29]: a first specimen was stored dry for 7 days at 37 °C in vacuum oven chambers (Vacuum drying chambers, Binder, Bohemia, North American), and served as the color reference. Another ten specimens were divided to 2 groups (n=5): first group; specimens were stored in distilled water for 7 days at 37 °C to demonstrate which color changes arise as a result of water storage. Second group; each specimen was initially dried at 37 °C for 24 hrs. Then, one half of each specimen was covered with tin foil, and the whole specimen was stored in water at 37 °C in a xenon light box (SIEMENS Procmat Manual Dental Xenon Box, Germany). After 24 hrs, the foil was removed, and the specimen was dried for another 5 days at 37 °C.

Method of color measuring:

The specimen's colors was measured using a Portable Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany). A white background was selected, and measurements were made according to the Commission International de L'Eclairage (CIE) L*a*b* color space relative to the CIE standard illuminant D65. The color changes (ΔE) (%) of the specimens was evaluated using the following formula [29]:

$$\Delta ECIELAB = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})\ ½.$$

Where: L* = lightness (0-100) (black/white), a* = change the color of the axis red/green and b* = color variation axis yellow/blue.

Flexural strength testing:

The Flexural strength (E*f*) testing was performed according to ISO 4049:2009 by three-point bending test [29]. Ten bar-shaped specimens of each composite with dimensions

of 2.0 (depth) × 2.0 (width) × 25.0 (length) mm were prepared in a half-split stainless-steel mold. Mold was put on the glass slide covered by Mylar strip and separating medium was applied to mold wall with a brush, then the composite material was applied to the mold cavity by a plastic instrument. After that, glass slide covered with Mylar strip was applied on the top of the mold. Curing was done on the top then on the bottom of the specimens before removal from the mold. The composite was photo-polymerized by LED curing unit for 20 sec with three overlapping light exposures to cure the entire length of specimen. After polymerization, all the specimens were stored in distilled water at 37˚C for 24 hrs. The flexural strength test was performed in a universal testing machine (INSTRON, 3600 series, USA). The test assembly consists of two supporting wedges placed 20 mm apart and a loading wedge that applies load at crosshead speed of 0.75 mm/min. The applied force and strain during the bending was measured as a function of deflection. The flexural strength was calculated according to the following formula (MPa) [29]:

$$TS = 3F\ d/2wh2$$

Where F = maximum force, d = distance between the two anchors, w = width of the specimen, h = height of the specimen.

Flexural modulus calculating:

Elastic modulus was calculated after recording flexural strength by the following equation (GPa) [29]:

$$E= FL3/4BH3d$$

Where F is the maximum load; L is the distance between the supports; B is the width of the specimen, H is the height of the specimen, and d is the deflection (in millimeters).

II.6. Statistical Analysis:

The data were collected and tabulated and statistically analyzed by an IBM compatible personal computer with SPSS Statistical Package of Social Science version 20 (SPSS Inc. Realesed 2011. IBM SPSS statistics for windows, version 23.0, Armnok, NY: IBM Corp.).

Two types of statistical analysis were done:

a. Descriptive statistics was expressed in mean ($\bar{x}$) and standard deviation (SD) values.

b. Analytic statistics:

For each of the physical/mechanical properties, One-way ANOVA was used to determine statistical significance between groups and post hock test.

Results:

Color Stability:

Color stability% of all tested composites means ± standard deviations values are listed in Table 2. The lowest color stability was Ever-X Posterior (0.79 ± 0.031) followed by GrandioSo (0.64 ± 0.036). The highest color stability appeared in Z350 (0.5319 ± 0.03641). One-way ANOVA revealed that, there was significant difference between color stability % all tested composite (P = 0.0356).

Table (2): Color stability% means ± SDs, values of all tested composites.

Composites	Color Stability Mean ± SD (%)
Ever-X Posterior	0.79 ± 0.031a
GrandioSo	0.64 ± 0.036b
Filtek™ Z350 XT	0.54 ± 0.04c

Means with the different small superscripted letters demonstrated statistically significant differences (p ≤ 0.05).

As can be illustrated from the Table 2 of post hock (Tukey's) multiple comparison test; there was significant difference in color stability % between Ever-X Posterior and GrandioSo. GrandioSo and Ever-X Posterior were significantly higher than Z350.

Flexural strength (MPa):

Flexural strength (MPa) of all tested composites means ± standard deviations values are listed in Table 3. The highest Flexural strength (MPa) mean value was in Ever-X Posterior (153 ± 10 MPa) followed by GrandioSo (151 ± 6 MPa). The lowest value appeared in Z350 (118 ± 7 MPa). One-way ANOVA revealed that, there was significant difference in Flexural strength (MPa) of all tested composite (P = 0.0056). As can be illustrated from the Table 3 of post hock (Tukey's) multiple comparison test; there was no significant difference in flexural strength (MPa) between Ever-X Posterior and GrandioSo, while Ever-X Posterior and GrandioSo were significantly higher than Z350.

Table (3): Flexural strength (MPa) means ± SDs, values of all tested composite.

Composites	Flexural strength (MPa) Mean ± SD
Ever-X Posterior	153 ± 10a
GrandioSo	151 ± 6a
Filtek™ Z350 XT	118 ± 7b

Means with the different small superscripted letters demonstrated statistically significant differences ($p \leq 0.05$).

III.3. Flexural modulus (GPa):

Flexural modulus (GPa) of all tested composites means ± standard deviations values are listed in Table 4. The highest Flexural modulus (GPa) mean value was in GrandioSo (18.3 ± 0.16 GPa) followed by Ever-X Posterior (15.6 ± 0.09 GPa). The lowest value appeared in Z350. (13.9 ± 0.12 GPa). One-way ANOVA revealed that, there was significant difference in Flexural strength (MPa) of all tested composite (P = 0.006).As can be illustrated from the Table 4 of post hock (Tukey's) multiple comparison test of flexural modulus (GPa); GrandioSo was highly significant than Ever-X Posterior. GrandioSo and Ever-X Posterior were significantly higher than Z350.

Table (4): Flexural modulus (GPa) means ± SDs, values of all tested composite.

Composites	Flexural strength (MPa) Mean ± SD
Ever-X Posterior	153 ± 10a
GrandioSo	151 ± 6a
Filtek™ Z350 XT	118 ± 7b

Means with the different small superscripted letters demonstrated statistically significant differences ($p \leq 0.05$).

Discussion:

Importance of dental restoration color stability is crucial for both dental professionals and patients. A crucial property of esthetic restorative materials is their long-term color stability and an acceptable color match [30]. Color was measured in current study by spectrophotometer. Thus, when compared with observations by the human eye, or conventional techniques, it was found that spectrophotometers offered a 33% increase in accuracy and a more objective match in 93.3% of cases [31]. In current study, significance difference in color stability is due to: different in fillers size appear to affect how well a composite finishes. During polishing, fillers may dislodge from the matrix leaving voids on the restorative surface. In general, larger filler particles leave bigger defects, thus producing a rougher surface. The rougher the surface, the more susceptible the material is to stain [32]. Also, it has been shown that the hydrophobic urethane dimethacrylate (UDMA) exhibits less staining compared to Bisphenol glycidyl methacrylate (Bis-GMA), which is the common resin monomers used. Conversely, composite resins with hydrophilic monomers e.g. tri-ethylene glycol dimethacrylate (TEDGMA) exhibit higher water absorption, and therefore permits penetration of any hydrophilic colorant into the resin matrix [33]. Traditionally, it has been believed that changes in amine compound (N, Ndimethyl-p-toluidine) in the initiator system of cured resin produce intrinsic color change in composite resins. This is thought to be related to the tendency of isomeric dimethacrylate to form yellow-tinted charge transfer complexes with the tertiary aromatic amines. Studies have also found that the photoinitiator (camphoroquinone) in light polymerized based composite may oxidize into a yellowish-brownish colored compound thus leading to the discoloration of the composite resins [34,35]. So that highest color stability is recorded to Z350 because it is nanofilled composite and has non amine photoinitiator. Lowest color stability related to Ever X Posterior due to it has large glass microfibers and amine based photoinitiator and amount of TEDGMA resin. Difference in flexural strength, and modulus was explained by Asmussen, and Peutzfeldt [36] observed that the variation of the BisGMA/TEGDMA/UEDMA ratio affected significantly the mechanical properties of the composite, suggesting that specific combinations should be developed according to the specific applications of the material. The long-term durability, evaluated by means of water sorption and solubility of the composites, it has also been depended on their organic content. Filler type and percentage are considered as the most critical factor influencing the improvement of the mechanical properties of resin-based composites. In fact, the morphological aspect of the filler determines its percentage, the saline content and the microstructural characteristics of the composite.

The introducing nanofilled composites and incorporation of nanofiller in hybrid composites have been considered the most recent advances in filler technology. Characteristically, these filler particles, due to their considerably small size and rounded shape, expose a high surface area and require, as a consequence, a higher amount of saline [37-39]. Kim et al. [40] observed a significant influence of the filler rate and morphology on the flexural strength and modulus of the composites evaluated. Also, Yap and Teoh [41] comparing different categories of composites, observed that the microfine composite, with the lowest filler content (40% in volume), presented the lowest flexural properties (strength and modulus). Adabo et al., [42] found that the incorporation of silanized nanofiller particles significantly increased flexural strength, abrasion and attrition wear resistance of an experimental hybrid composite. Other factors besides the filler content, such as degree of conversion and type of monomer, could also influence the mechanical behavior of composites [41]. So that, highest flexural strength was Ever-X Posterior because microfiber filler that increase surface area of filler and increase bonding with resin also GrandioSo has high flexure strength and highest flexure modulus due to highest filler loading (89%).

Conclusion:

Physicomechanical properties of dental resin composite are mainly influence by internal structure of composite (resin type and percentage, filler load and size, type of photoinitiator, type of saline coupling agent). So that, selection of proper composite type is major factor for restorative treatment durability.

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