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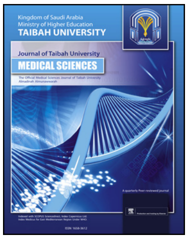

Original Article

Effects of deformation rate variation on biaxial flexural properties of dental resin composites

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الملخص

أهداف البحث: تهدف هذه الدراسة إلى تحديد قوة الثني ثنائي المحور لمواد الراتنج المركبة في معدلات تشوه محددة.

طرق البحث: تم اختيار اثنين من الهجائن الدقيقة من مواد الراتنج المركبة [فلتك زي ١٠٠ ريستوراتف تي ام (زي ١٠٠) وفلتك زي تي ام ٢٥٠ (زي ٢٥٠)]، واثنين من مواد الراتنج المركبة المعبأة عن طريق النانو (فلتك سبريم اكس تي بودي وفلتك عالي الشفافية). كما تم تصنيع عينات على شكل أقراص (١٢×١ مم) باستخدام قوالب نايلون مقسمة، من أجل تحديد معامل الثني. وتم تصنيع عينات على شكل قضبان (٢٥×٢×٢مم) من كل مادة. وتم اختبار العينات لاحتساب قوة الثني ثنائي المحور ومُعامله في الظروف الجافة والظروف الرطبة بعد أسبوع و١٣ أسبوعا و٥٢ أسبوعا.

النتائج: سُجّلت أعلى قوة ثني ثنائي المحور لـ "زي ٢٥٠" (١٦٢+/- ١٩ ام بي أي) ويتبعها فلتك عالي الشفافية (١٥٤+/- ١٦ ام بي أي) و "زي ١٠٠" (١٥٠ +/- ١٨ ام بي أي) وفلتك سبريم اكس تي بودي (١٣٦+/- ١٨ ام بي أي). وأظهرت الزيادة في معدل التشوه وجود نمط واضح بزيادة قوة الثني ثنائي المحور في المواد. بعد أسبوع واحد من الغمر، كانت قوة ثني ثنائي المحور ١٢٦ +/- ١٨ لـ "زي ١٠٠" و١٢٤ +/-١٧ لـ "زي ٢٥٠"، التي كانت أعلى من فلتك سبريم اكس تي بودي ٩٩+/- ١٦ ام بي أي وفلتك عالي الشفافية ١١٥+/- ١٩ ام بي أي في ظروف مماثلة. انخفض المُعامل الانثنائي للعينات المغمورة لمدة أسبوع واحد بشكل واضح مقارنة بالعينات الجافة؛ "زي ١٠٠" من ١٨.٣± ١.٢جي بي أي إلى ١٥.٧± ٠.٨ جي بي أي، و"زي ٢٥٠" من ١٦.٧± ٠.٨ جي بي أي إلى ١٣.٣± ١.٤جي بي أي، وفلتك سبريم اكس تي بودي من ١٣.٧± ٠.٦ جي بي أي إلى ١١.٠± ٢.١ جي بي أي وفلتك عالي الشفافية من ١٢.٧± ٢.٣ جي بي أي إلى ١٠.٤± ١.٠جي بي أي.

الاستنتاجات: تنخفض قوة ومعدلات انحناء مواد ترميم الأسنان المصنوعة من الراتنج عند غمرها في وسط مائي لحين تشبعها بالماء. وبعد الوصول إلى التوازن فإن الوسط المستخدم للغمر لا يؤثر على المواد التركيبية. إن تأثيرات معدل التشوه على قوة الثني ثنائي المحور في مواد ترميم الأسنان المصنوعة من الراتنج ليست ذات قيمة.

الكلمات المفتاحية: مواد طب الأسنان؛ الخواص الميكانيكية؛ مُعامل؛ طب الأسنان الترميمي

Abstract

Objectives: This study aimed to determine the biaxial flexural strength (BFS) of resin composite materials at distinct deformation rates.

Methods: Two micro-hybrid [Filtek Z100™ Restorative (Z100), Filtek™ Z250 (Z250)] and two nano-filled [Filtek™ Supreme XT Body (FSB), Filtek™ Supreme Translucent (FST)] composite resins were selected. Disc-shaped (12 × 1 mm) specimens were fabricated using nylon split moulds. Bar-shaped specimens (25 × 2 × 2 mm) were fabricated from each material to determine the flexural modulus. The specimens were tested for BFS and flexural modulus under dry and wet conditions after 1, 13, and 52 weeks.

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Results: The highest BFS was recorded for Z250 (162 ± 19 MPa), followed by FST (154 ± 16 MPa), Z100 (150 ± 18 MPa), and FSB (136 ± 18 MPa). The materials exhibited a clear trend of increase in BFS with deformation rate. Following immersion for 1 week, the BFS was 126 ± 18 MPa for Z100, and 124 ± 17 MPa for Z250, which were higher than those of FSB (99 ± 16 MPa) and FST (115 ± 19 MPa) under comparable conditions. There was a remarkable reduction in the flexural moduli of the specimens immersed for 1 week compared to those of the dry specimens: Z100 (from 18.3 ± 1.2 GPa for dry specimen to 15.7 ± 0.8 GPa after immersion for 1 week), Z250 (from 16.7 ± 0.8 GPa to 13.3 ± 1.4 GPa), FSB (from 13.7 ± 0.6 GPa to 11.0 ± 2.1 GPa) and FST (from 12.7 ± 2.3 GPa to 10.4 ± 1.0 GPa).

Conclusion: This study concludes that the BFS and flexural moduli of resin-based dental restoratives decline when they are immersed in an aqueous medium until saturation with water. However, after equilibrium is established, the immersion medium does not affect the restorative materials further. Variations in deformation rate did not have a significant effect on the BFS of resin-based dental restoratives.

Keywords: Dental materials; Mechanical properties; Modulus; Restorative dentistry

Introduction

Restorative dental materials form the basis for replacement of tooth structure lost due to disease or injury. Given this significance, a variety of direct aesthetic restorative dental materials has been developed; however, no restorative material possesses ideal properties. For example, silicate cement, the first tooth-coloured restorative material, was introduced in the 1870s; it did not gain much acceptance due to its brittleness, quick erosion, and marginal discoloration.[1] The first polymeric, tooth-coloured polymethyl methacrylate (PMMA)-based composite was introduced in the 1940s. Although, it was relatively better in terms of aesthetics, it exhibited inferior properties such as high polymerisation shrinkage, poor bonding, and mismatch of thermal expansion coefficients.[2] Subsequently, Rafael L. Bowen used high-molecular weight epoxy and methacrylate derivatives to overcome the deficiencies associated with PMMA-containing composites.[3] The advancement by Bowen significantly helped industries develop novel resin-based composites (RBCs) as restorative materials comprising resin and inorganic fillers.

Resin-based composites have been widely accepted in dental practice due to key benefits such as minimal need of tooth preparation[4] and aesthetic properties.[5] However, they exhibit a number of drawbacks including polymerisation shrinkage,[6] bond strength,[7,8] and inferior fracture toughness.[9] Since the development of RBCs, extensive research has been carried out to improve their clinical life with focus being mainly on the development of new monomers[10] and fillers based on particle size, content, and silanisation.[11] One of the most important developments in this field during the past decade has been the incorporation of nanotechnology in RBCs.[12–14] Nanotechnology is the manufacturing and handling of materials and structures in the size range 0.1–100 nm using a number of physical or chemical techniques.[15] It is believed that lower filler particle size and broader particle size distribution enable enhanced filler loading, thereby reducing polymerisation shrinkage and improving mechanical properties such as flexural and tensile strength.[16,17]

Biaxial flexural strength (BFS) has been employed by researchers to evaluate the mechanical properties of restorative materials.[18,19] The key benefit of using BFS as a parameter is that tensile stress is mostly applied on the central loading area, eliminating edge failures. The disc-shaped specimens (12 × 1 mm) used to test the BFS simulate the average width of molars. Additionally, BFS testing is not influenced by specimen geometry and flaw directions.[20]

Clinically, restorative materials undergo variable stresses in a cyclic pattern due to functional masticatory forces. The stresses encountered vary in several aspects including anatomical features, physiological chewing patterns, diet, and individual variations.[21] For instance, patients with parafunctional habits such as bruxism may exert higher stress on restorations than would physiological forces of mastication alone.[22] Nevertheless, the strength of RBCs is determined under a constant deformation rate. The international standard for testing polymer-based restorative and luting materials (ISO 4049) recommends a narrow range of deformation rates (0.5–1.0 mm/min) to test flexural strength.[16] However, a constant deformation rate may reflect the precise behaviour. Moreover, according to ISO 4049, 2000, it is recommended that the specimen be stored in distilled water for 1 week prior to being tested for flexural strength. However, long-term water storage at body temperature is essential in order to simulate real clinical environment and reveal any water-induced degradation effects. This study was based on the hypothesis that the RBCs would exhibit no difference in BFS at varying deformation rates under storage conditions. Thus, this study aimed to determine the BFS of RBCs at distinct deformation rates (0.01, 0.1, 1.0, and 10.0 mm/min) and up to 1 year of water storage regime. In addition, the effect of nanoclusters and micro-hybrid fillers on the BFS of RBCs has been comparatively analysed.

Materials and Methods

Materials

The current study used four resin-based dental restorative composite materials (A3 shade): two micro-hybrid materials [Filtek Z100™ Restorative (Z100) and Filtek™ Z250 (Z250)] and two nano-filled materials [Filtek™ Supreme XT Body (FSB) and Filtek™ Supreme Translucent (FST)]. In terms of

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