dental materials 33 (2017) e101–e114

Available online at www.sciencedirect.com

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Laboratory mechanical parameters of composite resins and their relation to fractures and wear in clinical trials—A systematic review

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ARTICLE INFO

Article history:
Received 23 September 2016
Accepted 29 November 2016

Keywords:
Composite resin
Material fracture
Chipping
Clinical
Flexural strength
Fracture toughness
Flexural modulus
Compressive strength
Diametric tensile strength
Artificial aging

ABSTRACT

Objective. To evaluate a range of mechanical parameters of composite resins and compare the data to the frequency of fractures and wear in clinical studies.
Methods. Based on a search of PubMed and SCOPUS, clinical studies on posterior composite restorations were investigated with regard to bias by two independent reviewers using Cochrane Collaboration's tool for assessing risk of bias in randomized trials. The target variables were chipping and/or fracture, loss of anatomical form (wear) and a combination of both (summary clinical index). These outcomes were modelled by time and material in a linear mixed effect model including random study and experiment effects. The laboratory data from one test institute were used: flexural strength, flexural modulus, compressive strength, and fracture toughness (all after 24-h storage in distilled water). For some materials flexural strength data after aging in water/saliva/ethanol were available. Besides calculating correlations between clinical and laboratory outcomes, we explored whether a model including a laboratory predictor dichotomized at a cut-off value better predicted a clinical outcome than a linear model.
Results. A total of 74 clinical experiments from 45 studies were included involving 31 materials for which laboratory data were also available. A weak positive correlation between fracture toughness and clinical fractures was found (Spearman rho = 0.34, p = 0.11) in addition to a moderate and statistically significant correlation between flexural strength and clinical wear (Spearman rho = 0.46, p = 0.01). When excluding those studies with "high" risk of bias (n = 18), the correlations were generally weaker with no statistically significant correlation. For aging in ethanol, a very strong correlation was found between flexural strength decrease and clinical index, but this finding was based on only 7 materials (Spearman rho = 0.96, p = 0.0001). Prediction was not consistently improved with cutoff values.
Significance. Correlations between clinical and laboratory outcomes were moderately positive with few significant results, fracture toughness being correlated with clinical fractures and

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http://dx.doi.org/10.1016/j.dental.2016.11.013

flexural strength with clinical wear. Whether artificial aging enhances the prognostic value needs further investigations.

Contents

1. Introduction

The mechanical stability of direct dental materials is one of the prerequisites for the long-term clinical success of restorations made of these materials [1,2]. Other important parameters are e.g., biocompatibility and colour stability [2]. Due to mastication during food consumption, unconscious bruxism at night or during the day or gnashing, restored and unrestored teeth are submitted to a multitude of mechanical and chemical interaction in the oral cavity [3]. If the mechanical loading surpasses the material-inherent ability to withstand occlusal forces during mastication and bruxism, cracks and fractures of the material may ensue. Especially multi-surface restorations in both the posterior and anterior region are at risk of material fractures, particularly Class II restorations which restore the proximal–part of the tooth and/or even cusps and Class IV restorations which include the restoration of the incisal edge [4–7]. Recent published systematic reviews showed that fracture is one of the most frequent reasons of failure of composite resin in posterior teeth [4,6,8].

More fractures occur in patients with high chewing forces; especially bruxist patients are at risk of fractures [9]. Another consequence of the mechanical loading of the material is the two- and three body wear of especially the occlusal surface, which is clinically expressed as loss of anatomical shape [4,10]. If we take into consideration the quantity of resin material sold [11], around 800 million composite resin restorations were placed worldwide in 2015 alone; about 80% were placed in the posterior region and 20% in the anterior region. A meta-analysis on posterior resin restorations has shown that at least 5% of them will fail due to fracture of the material and about 12% will show noticeable wear within an observation period of 10 years [4]. In other words, at least about 32 million of posterior resin restorations placed in 2015 will be replaced or will need repair work due to fracturing by 2025.

One way to diminished the economical impactis to better evaluate resin composites in vitro. Ferracane evaluated different tests that may be appropriate for the prediction of the clinical performance [1]. The author notes that there is low evidence that clinical wear is related to flexural strength, fracture toughness and degree of conversion of the polymer matrix. He concluded though that the overall clinical success of dental composites is multi-factorial and therefore it is unlikely that even a battery of in vitro test methods accurately predicts the clinical performance.

The laboratory tests used to characterize the mechanical stability of artificial materials are numerous and include flexural strength tests of different kinds (e.g., three-point/four-point bending test, biaxial flexural strength), tensile strength test, compressive strength test, fracture toughness, various surface hardness tests and tests to determine the modulus of elasticity. Furthermore, specimens can be tested after 24 h of immersion in water or after artificial aging. Other concepts to determine the mechanical behavior of composite resin propose dynamic loading tests to determine the fatigue resistance of specific materials [12,13].

The ISO standard 4049 on polymer based restorative materials describes only the three-point flexural strength test after 24 h storage in water [14]. This test is also the most commonly used test [15]. For load-bearing restorations in the posterior region (Class I/Class II) the test demands a mean minimal flexural strength value of 80 MPa. No other mechanical test is included in any ISO standard related to dental polymer materials.

To assess the wear behavior, different laboratory wear tests have been developed. In 2001, the International Organization for Standardization ISO published a Technical Specification on “Guidance on testing of wear”, describing 8 different test methods of two- and/or three-body contact [16]. These test methods vary with regard to load, number of cycles and their frequency, abrasive medium, type of force actuator, sliding