DENTAL MATERIALS 23 (2007) 288–295

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Influence of cavity dimension and restoration methods on the cusp deflection of premolars in composite restoration

Mi-Ra Lee, Byeong-Hoon Cho, Ho-Hyun Son, Chung-Moon Um, In-Bog Lee*

Department of Conservative Dentistry and Dental Research Institute, College of Dentistry, Seoul National University, 28-2 Yeongeon-Dong, Jongro-Gu, Seoul 110-749, South Korea

ARTICLE INFO

Article history:
Received 19 April 2005
Received in revised form
12 December 2005
Accepted 10 January 2006

Keywords:
Cusp deflection
Polymerization shrinkage
Composites
C-factor
Bulk filling
Incremental filling
Indirect composite inlay

ABSTRACT

Objectives. The aim of this study was to measure the cusp deflection by polymerization shrinkage during composite restoration for mesio-occluso-distal (MOD) cavities in premolars, and to examine the influence of cavity dimension, C-factor and restoration method on the cusp deflection.

Methods. Thirty extracted maxillary premolars of similar size were prepared with four different sizes of MOD cavity, and divided into six groups. The width and depth of the pulpal wall of the cavity were as follows: group 1: 1.5 × 1 mm, group 2: 1.5 × 2 mm, group 3: 3 × 1 mm, and groups 4–6: 3 × 2 mm. Groups 1–4 were restored using a bulk filling with a composite. Group 5 was restored incrementally, and group 6 was restored with an indirect composite inlay. Cusp deflections were measured using LVDT transducers. The cusp deflections were compared between groups using ANOVA and Scheffe tests, and a correlation analysis was done.

Results. The cusp deflections of groups 1–4 were 12.1 (2.2), 17.2 (1.9), 16.2 (0.8) and 26.4 (4.2) μm, respectively. There was a strong positive correlation between the length cubed divided by the thickness cubed of the remaining cusp (L^3/T^3) and cusp deflection. The C-factor was related to the % flexure (100 × cusp deflection/cavity width). The cusp deflections of groups 5 and 6 were 17.4 (2.0) and 17.9 (1.4) μm, respectively, which were much lower values than those of group 4.

Significance. : The cusp deflection increased with increasing cavity dimension and C-factor. Use of an incremental filling technique or an indirect composite inlay restoration could reduce the cuspal strain.

1. Introduction

Recently, posterior composite restoration has become more common because of patients' increased demand for esthetic restoration, improvement of adhesive dentistry due to the dentin bonding system, and concern about amalgam toxicity.

However, the major drawback of composite restoration is the high polymerization shrinkage of the composite material. It has been reported that linear shrinkage ranges from 0.2 to 2% [1–3] and that volumetric shrinkage ranges from 0.9 to 5.7% [3–7], using in vitro measurements.

Polymerization shrinkage can lead to detachment of the restoration from the tooth surface, or may induce enamel microcracks. As a consequence, secondary caries and post-operative hypersensitivity due to bacterial infiltration via microleakage may occur [8,9]. In addition, when the bond

* *Corresponding author*. Tel.: +82 2 2072 3953; fax: +82 2 2072 3859.
E-mail address: inboglee@snu.ac.kr (I.B. Lee).
0109-5641/$ – see front matter
doi:10.1016/j.dental.2006.01.025

strength between the adhesive and the tooth is strong enough, the tooth structure may experience shrinkage stress, resulting in a cusp deflection [10–17].

Cusp deflection is the result of interactions between the polymerization shrinkage stress of the composite and the compliance of the cavity wall, and is a common biomechanical phenomenon observed in teeth restored with composites.

In order to measure cusp deflection, many methods have been developed, involving photography [10], microscopy [11,12], strain gauge [13,14], interferometery [15] and linear variable differential transformer (LVDT) [13,16,17]. Cusp deflection during composite restoration has been reported to be about 10–45 μm, varying according to the measurement method, tooth type and cavity size.

There are two important categories of biomechanical factors that influence cusp deflection. The first category is composed of geometric and material factors, such as cavity width, cavity depth [10,13,16], the thickness of remaining tooth material [15,18], the polymerization shrinkage of the composite [15], flow [19] and the compliance of cured composite and tooth [11,15]. The second category is comprised of clinical factors, such as use of liner [11,20], filling technique (bulk cure versus incremental cure) [10,14,21–23], restoration methods (direct versus indirect) [24] and use of a light curing method, which influences the polymerization rate [25,26].

Hood [18] reported that the remaining cusp after cavity preparation acts as cantilever beams under occlusal load. The prepared cavity floor serves as a fulcrum for cusp bending; the cantilever length is increased with cavity depth. According to mechanical principles, the cusp deflection is proportional to the cantilever length cubed, and to the inverse of the thickness of the cantilever cusp cubed.

Feilzer et al. [27,28] and Davidson and Feilzer [29] reported that the extent of polymerization shrinkage stress can be influenced by the cavity configuration (C-factor, bonded surface/unbonded free surface). As the C-factor increases, the compensation for polymerization shrinkage by the flow of composite decreases, and thus, the polymerization stress at the bonded surface increases.

Many researchers have suggested an incremental filling technique for composite restoration to reduce polymerization shrinkage stress and cusp deflection [10,14,29]. However, controversy remains over whether incremental filling can reduce cusp flexure as compared to bulk filling. Segura and Donly [10] and McCullock and Smith [14] reported that the cusp deflection of incrementally filled teeth was significantly lower than that of bulk filled teeth. However, Versluis et al. [21] and Abbas et al. [22] reported that an incremental filling technique generated more shrinkage stress. In addition, Rees et al. [23] reported that there was no significant difference in cusp flexure between the bulk and incremental placement.

The use of indirect composite inlay restoration has recently begun to increase. Indirect restoration was expected to improve the physical properties of restoration and to result in less shrinkage stress, because bulk polymerization occurs extraorally and the space for resin cement is very thin [24]. However, polymerization shrinkage stress is affected by the cavity configuration as well as the extent of polymerization shrinkage of the composite itself [28]. When the composite inlay is bonded, the high C-factor with few free surfaces cannot compensate for the polymerization shrinkage stress. As a consequence, the remaining stress causes cusp deflection and microcracks in the tooth [30]. Rees and Jacobsen [24] reported a cusp tip movement of 0.2–7.4 μm using composite inlay restoration. However, most studies mentioned above have only reported the measurement values of cusp deflection, with few biomechanical analyses of the factors affecting the cusp deflection.

The purpose of this study was to measure the cusp deflections of premolars restored with composite by bulk filling for four different dimensions of MOD cavities, and to compare the cusp flexure resulting from the bulk filling with that of the incremental filling and indirect composite inlay. This biomechanical analysis of the results provides a guideline for successful composite restoration in clinic.

2. Materials and methods

2.1. Instrumentation for a measurement device

The device used for measuring cuspal deflection consists of two XYZ tables (Micro Motion Technology, Bucheon, Korea) with three attached micrometers (Mitutoyo, Kawasaki, Japan) and two LVDT probes (AX-1, Solartron Metrology, West Sussex, UK) (Fig. 1). The LVDT probes are capable of detecting linear changes in a range of ±1 mm with a resolution less than 0.1 μm. The calibration of the probe was adjusted to 10 V/mm (10 mV/μm) of the output voltage using the micrometer.

Cuspal deflection was detected by the LVDT, and the measured value (as a function of time) was stored on a computer through a data acquisition board, PCI-6024 (National instrument, Mopac Expwy, Austin, TX, USA), using a data acquisition and analysis software, Labview (National instrument, Mopac Expwy, Austin, TX, USA).

2.2. Preparation of teeth

Thirty maxillary premolars extracted for orthodontic treatment were stored in chloramine-T solution. The teeth were divided into six groups of similar average bucco-lingual width. The dimensions of the teeth for each group are shown in Table 1. Each tooth was buried 3 mm below the cemento-enamel junction in an acrylic mold with dimensions of 15 mm

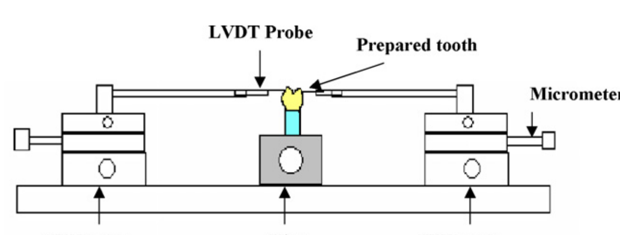

Fig. 1 – Configuration of the instrument for measuring cusp deflection.