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Cuspal deflection of teeth restored with bulk fill flowable composite resins, with and without fiber-reinforcement and evaluated by Micro-computed Tomography ☆

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A R T I C L E I N F O

Method name:
Cuspal deflection angle determination

Keywords:
Bulk-fill flowable composite resin
Ribbond fiber-reinforcement
Cuspal deflection
Polymerisation shrinkage
Digital image processing

A B S T R A C T

Polymerisation shrinkage of composite resins is a clinical challenge which has been well documented in the literature. Many studies investigating polymerisation shrinkage stress measure cuspal deflection, which is a manifestation of this stress. The introduction of flowable bulk-fill composite (BFRBC) materials has streamlined the restorative process, though the shrinkage and cuspal deflection from these BFRBCs has not been compared with regards to its use with polyethylene fibers (Ribbond fibers). The authors describe a method to measure the cuspal deflection of flowable BFRBCs placed in cavities of standardised dimensions at distinct steps of the restorative process, with and without fiber-reinforcement and using x-ray micro-computed tomography. Coordinate points are established on the buccal and lingual aspects of scanned specimens using the Volume Graphics VG Studio max 3.2.5 (Hiedelberg, Germany 2018) software. The system allows for these landmarks to be established across each scan (of the same tooth), ensuring standardization of each specimen. Further anatomical points are used to enable analysis. Comparison of angles generated across these points determines the extent of cuspal deflection.

- A method of measuring the cuspal deflection of composite resins is proposed.
- Experimental procedures are provided.
- Data analysis methods are outlined.

Specifications Table

Subject area	*Medicine and Dentistry*
More specific subject area	*Restorative dentistry.*
Name of your method	*Cuspal deflection angle determination*
Name and reference of original method	*Demirel, G.* et al. *(2020) "Volumetric cuspal deflection of premolars restored with different paste-like bulk-fill resin composites evaluated by microcomputed tomography," Operative Dentistry, 45(2), pp. 143–150. Available at:* https://doi.org/10.2341/19-019-l.
Resource availability	*X-ray micro-computed tomography scanner. Volume graphics VG Studio* max *3.2.5 (Hiedelberg, Germany 2018) software program for analysis.*

☆ Related research article: Demirel, G. et al. (2020) "Volumetric cuspal deflection of premolars restored with different paste-like bulk-fill resin composites evaluated by microcomputed tomography," Operative Dentistry, 45(2), pp. 143–150. Available at: https://doi.org/10.2341/19-019-l.

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Method details

X-ray micro-computed tomography (μ-CT) is a well-known method for assessment of various dental products and has been used in dental material research for void determination [1,2]. Cuspal deflection of bulk-fill composites has been measured using μ-CT scanning, though the various changes were assessed through superimposition of scans taken before and after restoration placement and composite material polymerization [3]. Here, in this methodology, the authors provide an easy workflow procedure to determine cuspal deflection across the restorative process by measuring the angles between fixed landmarks and the cusps. This method also allows for more accurate superimposition of various scans.

Required equipment and software

- Caries-free molars, extracted, prepared to standardized cavity dimensions, and embedded in singular resin molds with a polyvinyl acetate matrix (or equivalent) to secure the flowable composite between scans.
- Dental composite resin / dental restorative material with the appropriate bonding agent and etchant, Ribbond fibers or equivalent, if applicable.
- Curing light, if applicable.
- Williams Probe and dental tweezers.
- Foam to separate specimens, or equivalent.
- Plastic cylinder to secure mounted samples during scanning, or equivalent.
- X-ray μ-CT scanner.
- Processing Software to analyze scans eg. Volume graphics VG Studio max 3.2.5 (Hiedelberg, Germany 2018).

The described method is indicated for use with a Nikon Metrology XTH 225 ST X-ray μ-CT scanner (Yokohama, Japan) and Volume graphics VG Studio max 3.2.5, though any X-ray μ-CT scanner and software for analysis can be used for image acquisition and analysis.

Image acquisition

Image acquisition:

(1) Three flowable bulk-fill resins (BFRBC) were selected for use in this study. 27 samples were divided into 3 groups, with 9 teeth allocated to each material group.
(2) The specimens are scanned at various stages of the restorative process:
   a. Group A: specimens prepared with a wall width of 3.5 mm and depth of 5 mm. No Ribbond fibers (Ribbond) placed beneath BFRBC.
   b. Group B: specimens prepared with a wall width of 3.5 mm and depth of 5 mm. Ribbond fibers placed beneath BFRBC.
   c. Group C: specimens prepared with a wall width of 1.5 mm and depth of 5 mm. Ribbond fibers placed beneath BFRBC.
   Three BFRBC systems were used in groups A, B, and C respectively.
(3) Specimens are placed in the X-ray μ-CT scanner.
(4) The X-ray μ-CT scan is taken at 100 kV with a beam current of 200μA and an exposure of 0.5fps.
(5) The scanned data is transferred to the software analysis program (Volume graphics VG Studio max 3.2.5).
(6) Specimens are segmented and analysed individually in the software.

Scanning stages:

(1) For the control group A, three scans were taken of each specimen at the following stages:
   a. The prepared tooth after etching and application of the bonding agents according to manufacturer guidelines.
   b. The tooth after placement of the BFRBC, without light curing. A layer of glycerin was applied to the uncured material and the specimens were placed in a dark tube during scanning to shield from oxygen inhibition. No ambient light was present in the micro-CT scanner.
   c. The tooth after light curing of the BFRBC with a Bluephase-N (Ivoclar Vivadent) curing light.
(2) For the test groups B and C, four scans were taken of each specimen at the following stages:
   a. The prepared tooth after etching, application of the bonding agents according to manufacturer guidelines and placement of a layer of Ribbond fiber on the floor of the cavity, uncured. The specimens were placed in a dark tube during scanning to shield from oxygen inhibition. No ambient light was present in the micro-CT scanner.
   b. The tooth with Ribbond fibers as described, light cured.
   c. The tooth after placement of the BFRBC, without light curing. A layer of glycerin was applied to the uncured material and the specimens were placed in a dark tube during scanning to shield from oxygen inhibition. No ambient light was present in the micro-CT scanner.
   d. The tooth after light curing of the BFRBC with a Bluephase-N (Ivoclar Vivadent) curing light.
(3) Specimens are clearly labelled and vertically stacked in a tube, which is used as an organisational tool. Foam may be used to stabilize and separate the specimens within the tube, and the tube is then fixed to a rotating table within the μ-CT scanning apparatus.

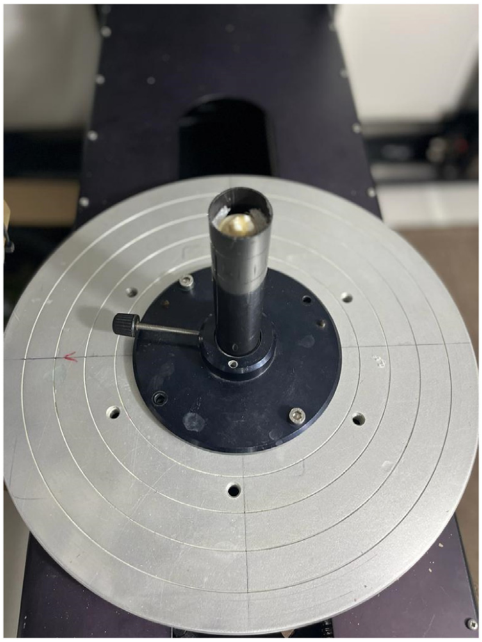

Fig. 1. Tooth specimens are stabilised with foam and placed into a tube which is secured to a table within the μ-CT scanner.

(4) Tooth specimens are positioned with the buccal surfaces facing the x-ray tube to ensure standardization.
(5) To ensure high and consistent image resolution, two specimens may be vertically mounted in a cylindrical sample carrier.
(6) X-ray μ-CT scans are taken at 100 kV with a beam current of 200μA and an exposure of 0.5fps.
(7) The scan data is transferred to the software analysis program (Volume graphics VG Studio max 3.2.5).
(8) Specimens are segmented and analysed individually in the software (See Fig. 1).

Measurement parameters

Step 1:

Specimens are extracted and segmented from the scans. This is repeated for each scan.

A best fit registration allows for alignment of scans 1, 2 and 3 (Group A), and scans 1, 2, 3 and 4 (Groups B and C).The VG Studio Max software enables this registration.

Scanned images for each specimen must be extracted and aligned to enable further analysis.

Step 2:

A software function termed ‘nominal actual comparison’ may be used to enable comparisons of surface deviation between scans.

Landmark points must be established on the first scan before importing these landmarks to the subsequent scans.

Images are orientated to enable the fitting of geometric elements (points, planes, lines) which are used to locate angles for measurement.

To locate planes with minimal deviation, the Gauss least squares method is used.

Fixed planes to import across all scans of a specimen:

PLANE 1

This plane is located along the floor of the cavity (See Fig. 2).

Points on the mesial and distal extent of the cavity floor are selected and a plane is expanded between these points.

All geometric elements generated further will now be relative to plane 1.

PLANES 2 & 3

Planes 2 and 3 are located on the buccal and lingual aspects of the tooth, orthogonal to plane 1. To generate these planes, the first point of contact is located on the buccal and lingual aspects of the tooth, respectively (See Figs. 3 and 4).

Planes might not be orthogonal on selection; therefore the following parameters may need to be set if using the VG Studio Max 3.2.5 software:

Toggle to the constraints tab and select ‘orthogonal to axis’, then select ‘Z axis’

Ensure that Plane 1 has been selected as the coordinate system.

PLANE 4

This plane marks the midpoint between planes 2 and 3.

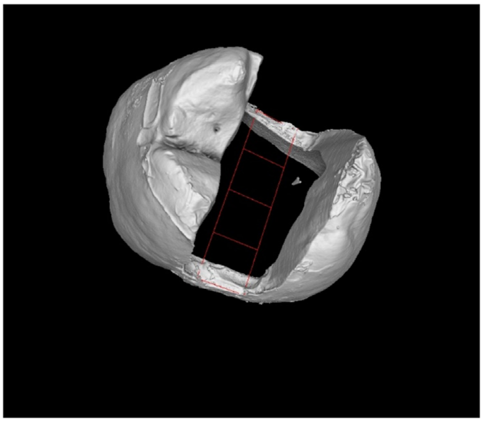

Fig. 2. Plane 1 generated along the floor of the cavity.

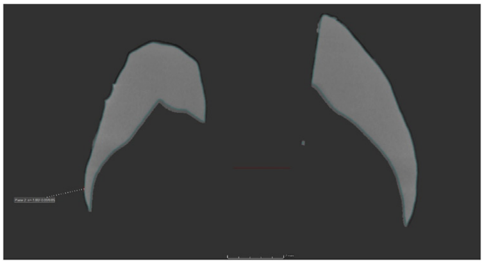

Fig. 3. Plane 2 is located at the buccal first point of touch and is perpendicular to Plane 1.

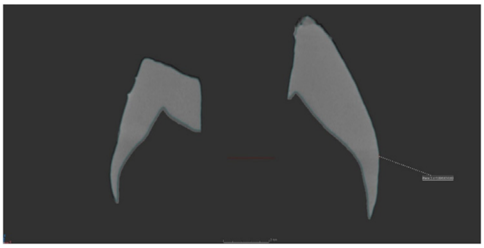

Fig. 4. Plane 3 is located at the lingual first point of touch and is perpendicular to Plane 1.

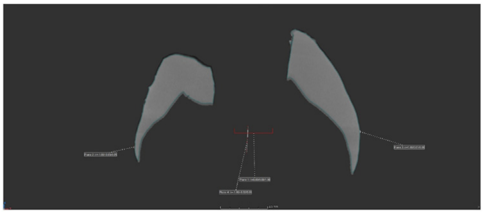

Fig. 5. Planes 1, 2, 3, and 4.

Using the VG Studio software, Planes 2 and 3 are highlighted in the scan tree. The intersect drop box (below 'tools' bar) is selected and the 'symmetry element' function is used to locate the midpoint.

These 4 planes must then be imported from scan 1 onto the subsequent scans, providing stable reference points for each specimen (See Fig. 5).

Step 3:

Locate the highest cusp points on buccal and lingual aspects on the tooth.

These will be referred to as Points 1 and 2, where Point 1 is the highest cusp point on the buccal aspect and Point 2 is the highest cusp point on the lingual aspect (See Fig. 6).

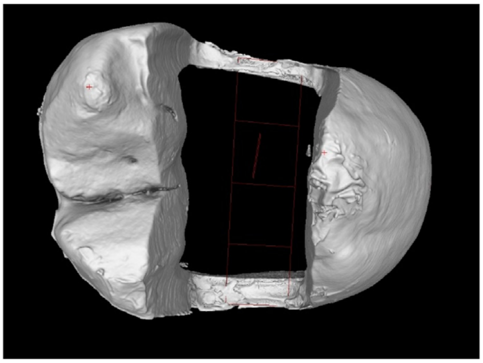

Fig. 6. Points 1 and 2.

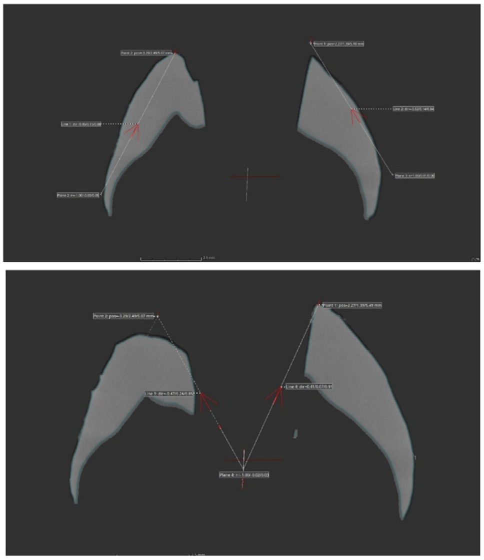

Fig. 7. Lines 1, 2, 3, and 4.

Ensure that all points are in relation to the designated coordinate system (Plane 1) and that the correct scan has been selected before locating the first point of contact from the occlusal view.

This is done for the buccal aspect, then for the lingual aspect.

Step 4:

Generate lines between planes and points to enable angular measurements.

LINES 1 & 2 (buccal)

Point 1 and Plane 2 are selected and the 'combine' function is used to generate Line 1. This is repeated for Point 1 and Plane 4 to generate Line 2 (See Fig. 7).

LINES 3 &4 (lingual)

Point 2 and Plane 3 are selected and the 'combine' function is used to generate Line 3. This is repeated for Point 2 and Plane 4 to generate Line 4 (See Fig. 7).

Step 5:

Measurements can now be obtained; the following parameters are selected to generate a total of four angles per scan (2 buccal and 2 lingual angles) (See Fig. 8):

Type: angle

Angle mode: angle to plane

Projection: *xyz*

Steps 3, 4, and 5 must be repeated for each scan using the fixed planes (1, 2, 3, and 4) which are imported to each scan.

These values are transferred to an Excel spreadsheet. Changes in these angles indicates movement of the cusp i.e. cuspal deflection. For analysis, these can be converted to percentages of the values obtained at the initial scanning stage.

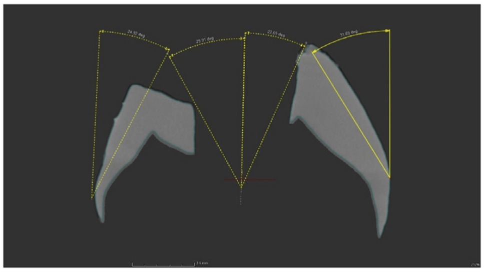

Fig. 8. Angle measurements to be recorded.

Ethics statements

This method describes in-vitro test research utilizing teeth extracted for reasons other than for the purpose of the experiment. Teeth used in the study were extracted at Tygerberg Oral Health centre for periodontal, orthodontic or maxillofacial reasons. Patients were informed of the nature and purpose of this study and given the opportunity to consent to or refrain from the use of their teeth for research purposes before treatment. Donors remain anonymous and samples were destroyed after testing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Raeesa Parker: Investigation, Formal analysis, Writing – original draft. **Riaan Mulder:** Supervision, Resources, Funding acquisition. **Colm Keanly:** Data curation.

Data availability

Data will be made available on request.

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