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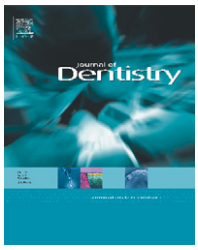

Quantification of residual dentine thickness following crown preparation

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ABSTRACT

Objectives: Pulpal response to tooth preparation is a major concern in fixed prosthodontics. Research has suggested that 2 mm or more of remaining dentine is critical in protecting the pulp following tooth preparation. However, clinicians have no means of knowing dentine thickness either before or after preparation and therefore lack feedback about this important aspect of preparation quality. The aim of this project was to develop a method for measuring local dentine thickness following tooth preparation for metal ceramic crowns, in vitro, which could be used as a tool to evaluate preparation technique and instrumentation.

Methods: Microtomography (XMT or micro-CT) scans were taken of extracted teeth before and after crown preparation. Local dentine thickness was defined for every voxel within the 3D tooth image as the sum of distances from that voxel to the pulp and to the anatomical surface. The method also allows the thickness of material removed to be quantified. Three-dimensional colour-coded maps of dentine thickness were generated, and the distributions of dentine thickness throughout the teeth were analysed. This was tested by a single operator on sixteen extracted upper central incisors.

Results: This method enabled clear visualisation and analysis of residual dentine thickness. In the trial, it revealed consistent over-prepared regions along the labial proximal line angles which, in a clinical case, could affect subsequent tooth and restoration longevity. All but one of the prepared teeth had regions with a residual dentine thickness of less than 1.5 mm, in 6 it was less than 1.0 mm and in 3 of these it was less than 0.5 mm.

Conclusion: Although ex vivo, this method can be used as a research tool to look for patterns of over- or under-preparation, leading to possible modification of technique, instrumentation and, or crown design.

Clinical significance: It is not currently possible for clinicians to know the thickness of residual dentine following crown preparation, a key factor in long term outcome. The described method of quantifying and visualising this thickness allows preparation techniques and instrumentation to be evaluated in vitro, leading to prospective improvements in clinical procedures.

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1. Introduction

Clinicians face the task of preparing teeth for restorations without knowing the proximity of the pulp to the prepared surface. This is particularly problematic when preparing teeth for complete crowns such as metal ceramic or all ceramic crowns. Only an estimate of the size and proximity of the pulp can be made, even with good quality bite wing radiographs.[1] Although the size of pulp chamber is indicated better on bitewing radiographs,[2] this must be interpreted with caution as pulp size was found to be underestimated in the region of the clinical crown (above the cemento–enamel junction) by 23% on buccal views compared to 0.5% on mesial views.[3] Such underestimation risks iatrogenic pulpal exposure in the worst case scenario. Additionally, intraoral radiographs give no indication of dentine thickness along the X-ray line of sight. A novel instrument called Prepometer™ (Hager and Werken, Duisburg, Germany) was purported to indicate the thickness of dentine overlying vital pulp during tooth preparation for restorative procedures. However a clinical trial of the instrument showed no correlation between the Prepometer™ value and residual dentine thickness.[4]

Pulp tissue reaction to tooth preparation for direct or indirect restorations is a major concern in fixed prosthodontics.[5] The residual dentine thickness following tooth preparation has a critical influence on subsequent pulp degeneration.[6] Previous studies suggested that 2 mm or more is critical in preventing pulpal damage.[7,8] Later it was reported that 1 mm of dentine might protect the pulp from the cytotoxic effects of luting cements such as zinc phosphate and glass ionomer.[9] However, a histomorphometric study following Class 5 cavity preparation in young teeth reported that residual dentine thickness of even 0.5 mm had little effect on the numbers of odontoblasts per pulpal unit area.[10] It was proposed that the repair capacity of the pulp–dentine complex was age dependent.[10] Nevertheless, young age and extent of coronal tooth destruction were reported as predictors for root canal therapy subsequent to extensive dentine preparation, potentially important predictors that are missed during treatment planning.[11] Cheung et al.[12] showed that over a mean observation period of 169 months, the pulp survival rate was 84.4% following restoration with metal-ceramic crowns.

Although there is no consensus regarding the minimal thickness of dentine required to protect pulp vitality, 2.7–19% of initially vital teeth have been reported to develop periapical pathology following preparation for complete crowns after an observation period of 1–25 years.[13–17] Labial reduction of between 1.3 and 1.5 mm, as recommended for metal ceramic crown preparation,[18,19] may leave as little as 0.5 mm of residual dentine protecting the pulp.[20] Such minimal residual dentine thickness may lead to pulp degeneration requiring endodontic treatment.[21] In a study of coronal tooth structure, preparation for complete crowns removed more tooth structure than for partial coverage or direct restorations and the Tooth Restorability Index[22] fell from 10.7 to 7.5 units.[23] Perceived simplicity and aesthetics seem to influence the clinicians' decision in opting for metal ceramic crowns, particularly with anterior teeth. However, when the clinician was informed of the extent of tooth structure lost with complete crown restorations, more than 50% of dentists altered their initial choice of complete to partial coverage restorations.[23]

In a study of the ten year outcome of crowns provided in general dental practice,[24] complete porcelain crowns had the highest failure rate (52%), followed by bonded crowns (38%), with all metal crowns having the lowest failure rate (32%). Although many factors could contribute to these failure rates, it should be noted that this is also the ranking order for the amount of tooth tissue removed during preparation.

X-ray microtomography (XMT or micro-CT), was described by Elliott and Dover in 1982.[25] It is a miniaturised version of computed tomography (CT) that has a resolution within the micron range.[26] Modern XMT systems produce a full 3D X-ray attenuation map of the scanned object and have been used in a wide variety of dental applications.[27] Being non-destructive, it can be used to compare images of teeth before and after preparation.

The aim of the current study was to use XMT to develop a method for precise 3D mapping of the thickness of residual dentine protecting the pulp following metal ceramic crown preparation. Information gained from this ex vivo method can be used to evaluate technique, instrumentation and crown design, thus contributing to improved clinical outcome.

2. Materials and methods

The analysis was performed on archived XMT data obtained prior to the Human Tissue Act, using anonymised teeth collected from the oral surgery department of the Royal London Hospital, following verbal consent of the patient as was the practice at the time. Explicit ethical approval for the use of such material for laboratory studies was not then required. Data from sixteen extracted human upper central incisor teeth that had been stored in formal saline were used in this study. These teeth were intact without any signs of trauma, caries or restorative fillings. Each tooth was mounted in dental gypsum (British Gypsum, Leicestershire, UK) in an arch form to simulate the dental arch. Teeth were prepared by a single operator (GPC) to receive metal ceramic crowns according to contemporary tooth preparation guidelines[28]; the aim being to produce a uniform reduction of 2 mm incisally, 1.2 mm labially with a shoulder finish line, and 0.5 mm chamfer finish line palatally and proximally. Putty indices (depth indicating bur) were used to guide the operator with the depth of the preparation achieved. The sixteen teeth were scanned before and after preparation using XMT.

2.1. *X-ray microtomography (XMT)*

The XMT system was designed and built in-house, being optimised for dental research.[29] The specimen stage was positioned to give a 30 μm voxel (3D pixel) size, which was considered sufficient for clinically relevant results.

Previously, this data had only been analysed using simple 2D techniques and the results were not published. For this study, in order to assess crown preparation quantitatively, it was necessary to provide a means of measuring the distance from the prepared surface to the pulp chamber and to measure