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Chipping fracture resistance of denture tooth materials

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ABSTRACT

Objective. The applicability of the edge chipping method to denture tooth materials was assessed. These are softer materials than those usually tested by edge chipping. The edge chipping fracture resistances of polymethylmethacrylate (PMMA) based and two filled resin composite denture tooth materials were compared.
Methods. An edge chipping machine was used to chip rectangular blocks and flattened anterior denture teeth. Force versus edge distance data were collected over a broad range of forces and distances. Between 20 and 65 chips were made per condition depending upon the material, the scatter, and the indenter type. Different indenter types were used including Rockwell C, sharp conical 120°, Knoop, and Vickers. The edge toughness, Te, was evaluated for different indenter types.
Results. The edge chipping data collected on the blocks matched the data collected from flattened teeth. High scatter, particularly at large distances and loads, meant that many tests (up to 64) were necessary to compare the denture tooth materials and to ascertain the appropriate data trends. A linear force–distance trend analysis was adequate for comparing these materials. A power law trend might be more appropriate, but the large scatter obscured the definitive determination of the precise trend. Different indenters produce different linear trends, with the ranking of: sharp conical 120°, Rockwell C, and Knoop, from lowest to highest edge toughness. Vickers indenter data were extremely scattered and a sensible trend could not be obtained. Edge toughness was inversely correlated to hardness.
Significance. Edge chipping data collected either from simple laboratory scale test blocks or from actual denture teeth may be used to evaluate denture materials. The edge chipping method's applicability has been extended to another class of restorative materials.

1. Introduction

The edge chipping test is used to evaluate the resistance of brittle materials to flaking near an edge as shown in Fig. 1. This method, originally developed in the late 1980s to study hard metal cutting tools at the National Physical Laboratory in London [1–4], has been applied to dental restoration materials [5–13] human dentin [14] and enamel [15]. A short review paper on edge chipping as applied to

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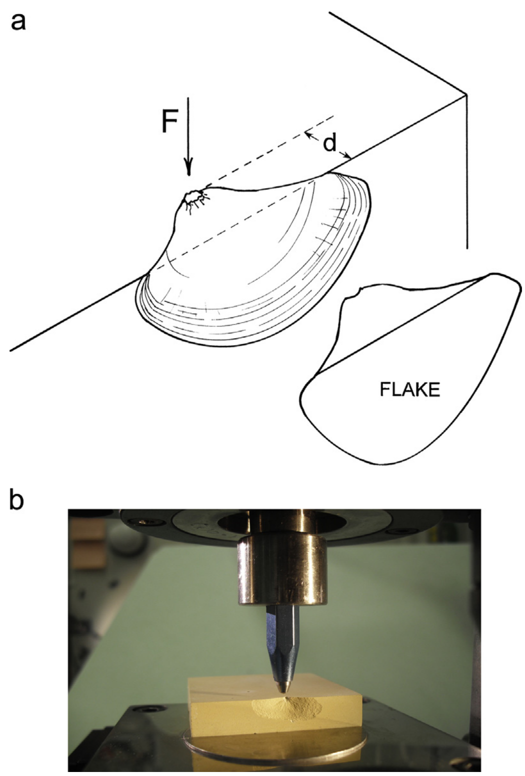

Fig. 1 – Edge chipping. The image on the right shows a sharp conical indenter that has made a large chip in a 4 cm wide slab of dental stone which is easy to photograph. Actual chips are much smaller.

dental materials was recently prepared [10]. A detailed evaluation of six computer aided design and machining) CAD/CAM restorative materials including porcelains glass ceramics, filled resin composites, and zirconia was recently reported [16].

Chips are formed by advancing an indenter or stylus into a material near an edge. The force required for chip formation is recorded as a function of the distance from the edge. The greater the load application point distance is from the edge, the greater is the force that is needed to create the chip. The shape of the chip is usually independent of the material tested.

In this work, the edge chipping test was applied to denture tooth materials. They are not as hard and are more compliant (lower elastic modulus) than some of the materials cited above and exhibit some ductility. Nevertheless, clinical chipping of denture teeth had been observed, and a simple quick test to evaluate candidate materials for dentures would be helpful. The goal of this work was to: ascertain whether the laboratory chipping tests could compare the edge chipping resistance of candidate denture materials and expand the applicability of the test method to softer materials.

Three hypotheses are set forth in this paper: edge chip indenter type does not affect test results, force versus distance data follow a linear trend; and the edge chip resistance of several denture tooth materials can be differentiated.

2. Materials and methods

Three resin based denture tooth materials were evaluated as shown in Table 1.[1] The first is a highly cross-linked polymethylmethacrylate (PMMA) with organic filler [17]. It was available in the form of monolithic wear test type rectangular blocks and also anterior teeth that were made of three layers. The upper two layers were incisal and dentin designated versions of the highly cross-linked PMMA, which had the similar composition and properties, but different pigmentation. A supporting cervical (neck) region was a less highly cross-linked PMMA.

The other two materials are hybrid silica-filled urethandimethacrylate (UDMA) composites [17]. They have small differences in composition and filler content. Composite I (SR Phonares NHC) was available in the form of wear blocks and four-layered anterior denture teeth. It is described by the manufacturer as a “nano hybrid composite” (NHC) [17]. The two uppermost (incisal and dentin) layers, into which the chips were made, were supported by cervical (neck) material that was a low cross-linked PMMA. Composite I had been developed to offer reduced shrinkage and improved wear resistance and durability in comparison to acrylic teeth [17], but there were some reports of in vivo chipping fractures. Composite II (SR Phonares II) was a newer refined composite, with slight changes in the composition as compared to Composite I, and was designed to mitigate or eliminate the reported in vivo chipping fractures. The dentin and incisal versions of Composites I and II differ only in the amount of pigments added.

Test pieces for all three materials were available in the form of six wear test type rectangular blocks, nominally 10 mm × 15 mm × 4.5 mm thick. The six surfaces were polished to make well-defined, reproducible edges. They were progressively hand ground wet with a rotary polishing wheel using 1200, 2400, and 4000 grit wet SiC papers.

Incisal denture teeth of all three materials were also prepared by polishing as shown in Fig. 2a. The gingival side was ground flat to support the tooth evenly on the edge chipping machine base as shown in Fig. 2b. The incisal surface was ground parallel to the base. Finally the palatal surface was ground flat to eliminate a small amount of material and to make the 90° edge. The incisal and palatal surfaces were polished to provide a single well defined 90° edge.

A commercial edge chipping machine (Engineering Systems Model CK 10, Nottingham, UK) was used to make the chips. All test pieces were waxed to a mounting plate. At the beginning of a test sequence, the indenter was positioned over a flat portion of the specimen well away from the edge, and a small indentation was made. The instrument crosshair was then precisely lined up with the center of the indentation. The X–Y stage then was moved to make indentations and chips at prescribed distances from the edge, ranging from 0.05 mm to 0.60 mm. Force was gradually applied in displacement control

[1] Commercial products and equipment are identified only to specify adequately experimental procedures and does not imply endorsement by the authors, institutions or organizations supporting this work, nor does it imply that they are necessarily the best for the purpose.