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Retention behavior of double-crown attachments with zirconia primary and secondary crowns

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ABSTRACT

Objective. To investigate whether adequate retention of zirconia conical crown (CC) attachments can be achieved, and to investigate their long-term retention.

Methods. Sixteen individual zirconia primary crowns were produced with convergence angles of 1° or 2° (eight of each). After determination of the convergence angles of the primary crowns, monolithic zirconia secondary crowns were manufactured. To evaluate the retention behavior of all-zirconia CC, the crowns were fitted with forces from $F = 12.5$–100 N. Force magnitudes during the loosening process (L) were then measured. L/F ratios were recorded and the coefficient of friction (μ_0) was calculated. Long-term retention was tested with up to 50,000 cycles of denture integration at a speed of 30 mm s^{-1} and a fitting force magnitude of 53 N.

Results. Even when primary crowns were manufactured with the utmost care, the real convergence angles were greater than the nominal angles of the standardized burs (1° and 2°) by 0.28° (SD 0.11°). Without mechanical aging, mean L/F was 0.632 (SD 0.038) for 1° samples and 0.526 (SD 0.022) for 2° samples, indicative of high retentive forces of up to 63.2% of the fitting forces. When all the test results were used, best-fitting curves gave $\mu_0 = 0.117$ for new samples and $\mu_0 = 0.126$ for samples after 50,000 integration cycles.

Significance. When the correct milling and sintering parameters are chosen, the retention behavior of zirconia CCs is adequate and stable. This innovative type of attachment is appealing because of the beneficial properties of zirconia and the efficient CAD/CAM-based manufacture.

1. Introduction

Rehabilitation of partial tooth loss is a common task in dentistry [1]. Because up to 29% of adults in Western society are provided with removable dental prostheses (RDP) [2], improving RDP treatment is an important task in restorative dentistry. Conical crowns (CC) have been used as attachments for decades [3], and are a reliable type of treatment with favorable survival [4–6]. These attachments are characterized by inner copings (primary crowns) permanently cemented to the abutment teeth and secondary crowns integrated within the

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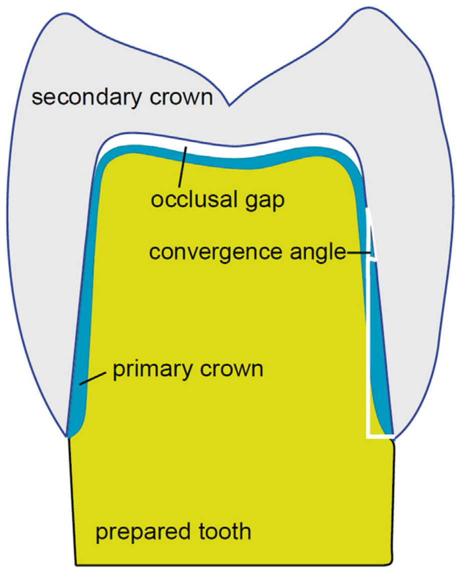

Fig. 1 – Conical crown attachment consisting of a primary and a secondary crown. In the fitted state, there is an occlusal gap between the two crowns.

removable prosthesis (Fig. 1). Yet, use of CC attachments is restricted: they have been established in countries such as Germany [6], Sweden [7] or Japan [8].

The force needed to remove an integrated conical crown RDP (here: the "loosening force", L) depends on the force that was applied during incorporation of the denture (here: the "fitting force", F) and on the coefficient of static friction (μ_0). This means, for CC, there is no absolute value of the loosening force, as there is, for example, for clasp attachments. As long as there is an occlusal gap between the inner and outer crowns, the magnitude of the fitting force will determine the penetration of the primary crown into this gap. The deeper the penetration into the occlusal gap, the greater the elastic deformation of the secondary crown and the higher the pressure along the contact surface. The higher this pressure, the greater the loosening force. Penetration of the inner crown into the occlusal gap can be limited, however [9]; this results in the maximum loosening forces and protects both the material and periodontal health.

When focusing on constant fitting forces, loosening forces for a given material combination (μ_0 constant and known) can be modified by adjustment of one factor, the convergence angle (α) of the primary crowns. Fingerhut et al. [9] proposed the following equation for this correlation:

$$\frac{L}{F} = \frac{\mu_0 - \tan\alpha}{\mu_0 + \tan\alpha} \qquad (1)$$

Lower loosening forces (i.e. poorer retention) will result if primary crowns are made more conical. Use of new combinations of materials for primary and secondary crowns (with unknown μ_0) does, however, require experimental investigation, as in this work.

Recent developments in CAD/CAM techniques have the potential to enable substantial progress in CC fabrication. CAD/CAM has enabled use of ceramics as materials for primary crowns [10], introducing their beneficial material properties to the field of removable prosthodontics. Use of zirconia for the primary crowns is esthetically advantageous and results in smoother surfaces and long-term wear resistance [11]. Zirconia primary crowns are, however, combined with electroplated secondary crowns, which are bonded intra-orally to tertiary frameworks made of metal [10]. This elaborate method makes manufacture difficult, time-consuming, and expensive. Invasive preparation is, moreover, needed to create space for the restoration. In addition, one well-known shortcoming of CC, the composite veneering, is still necessary. The composite compromises esthetics, and results in increased wear and frequent chipping [12,13].

The idea of combining zirconia primary crowns with monolithic zirconia secondary crowns without any electroplated structures is therefore appealing. Use of CAD/CAM techniques for both primary and monolithic secondary crowns should facilitate manufacture and reduce manufacturing time. Monolithic secondary crowns make composite veneering redundant, reducing chipping complications. Less tooth substance has to be prepared, because there is no need for a tertiary framework. Zirconia is a biocompatible, wear-resistant material [14], used as the standard of care in many types of modern dentistry, which meets the demand of allergic or hypersensitive patients for metal-free restorations.

The literature contains little information on the use of all-zirconia for CC [15]. This study was designed to investigate whether the precision of dental laboratory devices is sufficient for manufacture of all-zirconia CC. Moreover, the purpose of the study was to investigate whether adequate retention can be achieved with the new attachments. It was hypothesized that neither long-term aging nor wet testing conditions significantly influence retentive properties.

2. Materials and methods

2.1. *Manufacture of all-zirconia double crowns*

A resin canine (Frasaco, Tettnang, Germany) was prepared and digitized by use of a dental laboratory scanner (D800; 3shape, Copenhagen, Denmark). The prepared tooth was reproduced sixteen fold out of zirconia (Cercon base; Degudent, Hanau, Germany). The zirconia teeth were divided into two groups of eight teeth each. Eight primary crowns with a convergence angle of 1° and eight primary crowns with a convergence angle of 2° were digitally designed (Dental Designer, 3shape) with a minimum thickness of 0.6 mm (Brain Xpert Pro Cam, Degudent). The convergence angle was defined as the angle between the tooth axis and the primary crown (Fig. 1). The primary crowns were then milled from zirconia blanks (Cercon ht; Cercon Brain Xpert; Degudent) and sintered (Cercon heat plus; Degudent). Subsequently, the primary crowns were bonded to the zirconia teeth (Panavia F 2.0; Kuraray, Hattersheim, Germany).

To enable testing of loosening forces, the samples were embedded vertically in cylindrical steel molds by use of acrylic resin (Technovit 4071; Heraeus Kulzer, Hanau, Germany). To achieve a standardized and uniform convergence angle, the