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Original article

Accuracy and mechanical performance of passivated and conventional fabricated 3-unit fixed dental prosthesis on multi-unit abutments

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ABSTRACT

Purpose: The aim of this study was to evaluate the fit and mechanical stability of conventional versus passive fitting 3-unit fixed dental prosthesis (FDP) screw-retained on implants.
Methods: Twenty acrylic models, each with two embedded implants, were fabricated and functioned as patient-models. Impressions were taken and 20 all-ceramic FDPs were prefabricated on the plaster casts. Respectively 10 FDPs were fixed on the plaster casts (group 1) and on the patient-models for passive fitting (group 2). The fit of each FDP was checked on the patient-model by means of visual control (grades 1–10) and microscopic examination. Furthermore, specimens were artificially aged for possible prosthodontic failures, followed by a fracture strength test.
Results: Group 2 [1.4 (±0.3)] showed significantly ($p<0.001$) better results in the visual examination of the marginal fit compared to group 1 [6.3 (±2.4)]. The microscopic marginal misfit was 160 μm (±80 μm) at the abutment margin and 150 μm (±80 μm) at the axial wall of the abutment for group 1, respectively, 0 μm and 0 μm up to 17 μm for group 2 ($p<0.001$). No failure of the FDPs could be observed during artificial aging in both groups. The fracture load showed no significant difference ($p=0.60$) between group 1 [2583 N (±664 N)] and group 2 [2465 N (±238 N)].
Conclusions: Visual and microscopic examination detected huge differences in marginal fit between groups 1 and 2. However, no statistically verifiable differences could be detected in long-term stability of implant-supported FDPs irrespective of the fit.

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1. Introduction

Dental literature suggests that an implant-supported prosthesis must exhibit a passive fit to prevent implant fracture, component failure and screw loosening [1]. Due to their lack of flexibility in the bone-implant interface, osseointegrated implants show less mobility (approximately 10 µm) than natural teeth (approximately 100 µm), resulting in an increased risk of porcelain chipping, screw loosening/fracture or even loss of osseointegration [2]. In current practice, clinical and laboratory procedures fail to achieve a passive fit.

There are different approaches to overcome the problem of strain development in implant-supported FDPs during the manufacturing process. Basic research on this topic shows that inaccuracies from impression-making and master cast fabrication cause approximately 50% of the stresses evoked by superstructure fixation [3]. One approach is to compensate inaccuracies in fit by cementing implant-supported FDPs, as known from conventional prosthodontics [4–6]. Another approach is to directly bond the secondary crowns into the tertiary framework of the removable dental prosthesis (RDPs) to compensate the inaccuracies resulting from impression-making and laboratory procedures [2]. On the contrary, Jemt et al. [7] stated that stress levels of clinical magnitude do not lead to bone loss but seem to significantly promote bone remodeling because bone tolerates a certain level of misfit. A study by Karl et al. [8] showed that a vertical load of 200 N does not cause bone damage. Furthermore, it showed low stress levels in the cervical portion of cement-retained samples in contrast to high ones for the corresponding area of screw retained FDPs. In the apical area of the implants, only low stresses were found for both groups. Nevertheless, the closest possible approximation to passive fit is important for the long-term stability of implant-supported FDPs and a low complication rate.

Ceramic materials have become popular in dentistry due to the little plaque accumulation and high biocompatibility as well as esthetic advantages [9]. Nevertheless, ceramics are very sensitive to microscopic cracks and veneering porcelain fractures (chipping) especially when porcelain is fused to metal restorations [10–12]. Although chippings do not always lead to a total failure of the restoration, the repair process is time consuming and, therefore, remains a clinical issue [12,13]. Today, with the increase in implant insertions, it is important to know that there are significantly more ceramic fractures in FDPs on implants compared to FDPs on natural abutment teeth [14]. This study was performed to investigate the difference between conventionally and passive fitting fabricated screw-retained bridges on multi-base abutments concerning marginal fit, failures during artificial loading and fatigue strength test. It was hypothesized that FDPs with passive fit lead to less stress in the FDPs and, therefore, show better marginal fit and fewer complications during and after artificial aging. The fracture strength is assumed to be higher.

2. Material and methods

2.1. Specimen fabrication

Two implants made of titanium grade IV (BL RC Ø4.1 mm/12 mm, Straumann AG, Basel, Switzerland) were embedded perpendicularly, approximately in the region of the second premolar and the second molar in a self-curing resin block (DPC-Laminierharz LT 2, Duroplast-Chemie Vertriebs GmbH, Neustadt/Wied, Germany) with an edge length of 3.0 cm × 1.5 cm × 1.5 cm regarding to the ISO-standardisation 14801:2007. Young's modulus of the resin material was 3450 MPa, corresponding to Type III cancellous bone [15]. The implant shoulders were 3 mm above the resin to mimic oral conditions with minimal bone loss. Twenty specimens with two implants each were fabricated nearly identically with a transferring guide, and numbered from 1 to 20 (Fig. 1). Impression posts (BL RC open tray, Straumann AG) were screwed on each implant and impressions with regular-body polyether (Impregum Penta, 3M ESPE, Seefeld, Germany) were taken using the open-tray technique. After 24 h, the impressions were poured in a class IV plaster (Fujirock, GC Europe, Leuven, Belgium) (Fig. 2). Forty-eight hours after cast fabrication on each master cast, two abutments (BL RC Multibase 4.5/2.5 mm, Straumann AG) were screwed in place (Fig. 3) and titanium caps (BL RC Bar Titanium Cap 4.6/5.5 mm, Straumann AG) as titanium bases were mounted. (At that time titanium bases were not available and this was the only possibility on Straumann implants to screw retain all-ceramic FDPs with a titanium base on the abutment or implant) (Fig. 4).

A wax-up of the FDP-framework was performed by a dental laboratory technician (Fig. 5) and subsequently, each of the 20 specimens was digitized twice using an optical scanning device (Etkon CS2, Straumann AG), by means of a double scan technique. The first scan was conducted with abutments and bar titanium caps in place of each specimen, the second scan with the wax-up of the FDP-framework fixed on the bar titanium caps of each specimen. All scans for specimens 1–20 were performed with the same wax-up to get identical and comparable all-ceramic frameworks for comparable results of the fracture strength test. The data of the 40 scans were sent to the company (Straumann AG), where the 3-unit FDP frameworks were fabricated from zirconia (Zerion HSC Zirconium, Straumann AG) with the computer-aided design (CAD)/computer-aided manufacturing (CAM) technique.

All 3-unit frameworks were returned to the corresponding master cast and adapted according to the literature [16,17]. Next, the frameworks were veneered with feldspathic veneering porcelain (IPS e.max ceram, Vivadent-Ivoclar; Schaan Lichtenstein). During the veneering process the outer shape of the restoration was checked by silicone molds to receive identical FDPs.

To finalize the FDP fabrication, the veneered all-ceramic FDPs were bonded to the bar titanium caps. Samples 1–10 (group 1) were fixed on the particular master casts, whereas samples 11–20 (group 2) were directly fixed on the appropriate