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Structural changes in ceramic veneered three-unit implant-supported restorations as a consequence of static and dynamic loading

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ABSTRACT

Objectives. Static implant loading caused by non-passive restorations may cause technical complications. As metal–ceramic restorations are most common in implant prosthodontics, the objective of the study was to investigate the effect of static and dynamic loading upon the stability of the ceramic veneer of implant-supported fixed partial dentures (FPDs).

Methods. A total of 10 groups of three-unit implant FPDs with five samples each were investigated in the conditions after fabrication, static loading and dynamic loading (chewing simulator, 20,000 cycles, 100 N). The fluorescent penetrant method (FPM) was applied to detect microcracks at the cervical and occlusal aspects of the FPD abutments. Statistical analysis was performed based on the number of microcracks (t-test) and the presence of chipping fractures (Exact Fisher test) with the level of significance set at $\alpha = 0.05$.

Results. Static and dynamic loading led to an increase both in number of microcracks and frequency of chipping fractures. After static loading, the screw-retained FPDs cast in one piece revealed significantly lower numbers of cervical microcracks than did the cementable restorations fabricated from repositioning technique impressions ($p = 0.003$). The screw-retained FPDs which were fabricated using premachined gold cylinders showed the highest numbers of cracks and chipping fractures both after static and dynamic loading.

Significance. Static loading may damage the ceramic layer of implant-supported restorations. The use of prefabricated components may cause increased numbers of microcracks due to the lack of bonding oxides.

1. Introduction

Ceramic materials are used in dentistry not only because of their biocompatibility and little plaque accumulation but also because of esthetic advantages [1]. The major disadvantage, however, of ceramic-fused-to-metal restorations is their sensitivity to microscopic cracks and chipping fractures due to the brittle nature of ceramic materials [2–4].

Several investigators reported that fracture of the ceramic veneer is not an uncommon problem in clinical practice [5–9]

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and may cause premature failure of fixed partial prosthodontics [10]. Brägger et al. even reported significantly more porcelain fractures in fixed partial dentures (FPDs) on implants when compared to restorations supported by natural abutments [11]. Whereas fractures in the anterior region pose an esthetic problem, in the posterior area also functional aspects may be affected [5]. Although ceramic fractures do not necessarily mean the failure of the restoration, the renewal or repair process is both costly and time consuming and therefore remains a clinical problem [4,5,10,12,13].

In general two modes of loading act on implant-supported restorations, i.e. dynamic loads imposed by masticatory forces and static loads caused by inaccuracies in the fabrication process of the superstructure. It was shown in basic research studies, that current techniques of superstructure fabrication fail to produce passively fitting FPDs [14,15]. Additionally, ceramic veneering has to be considered as an additional factor contributing to the total strain development of a restoration [16].

Therefore, the aim of the study presented was to investigate the influence of static and dynamic loading upon the stability of the veneer ceramic of three-unit FPDs of different designs.

2. Materials and methods

2.1. *FPD fabrication*

An epoxy model (Araldit®; Ciba Geigy, Wehr, Germany) with two implants (ITI solid screw implants, 4.1 mm diameter, 12 mm bone sink depth, Straumann AG, Waldenburg, Switzerland) with an inter-implant distance of 7 mm served as a basis for the investigation. In order to precisely simulate the clinical procedure of superstructure fabrication, impressions and master casts (Fujirock®, GC Corporation, Tokyo, Japan) were made for each FPD (except for the control groups 0-c, 0-s). Custom made trays (Palatray XL®; Heraeus Kulzer, Hanau, Germany) and a polyether impression material (Impregum®, ESPE, Seefeld, Germany) were used for repositioning and pick-up technique impressions. Standardized FPD frames were waxed (Plastodent®, DeguDent, Hanau, Germany) and cast in Degudent U®, a high precious metal–ceramic alloy (DeguDent). Prefabricated plastic copings were utilized in all sample groups except for the type of screw-retained FPDs which were cast to premachined gold cylinders (s-cas).

The metal frameworks were ceramic veneered with Duceram Plus® (Ducera, Rossbach, Germany). In order to reduce deviations in ceramic thickness, one frame was veneered freehand and a silicone index (Silaplast®, Detax, Ettlingen, Germany) was obtained and used for the remaining samples. All manufacturing steps were carried out by the same certified dental technician and the recommended protocol for clinical practice was strictly adhered to. All restorations (except the control groups 0-c, 0-s) were examined on the epoxy model by an experienced practitioner using common visual and tactile methods to ensure they had an acceptable fit with no visual gaps between implant and superstructure. In Table 1, the abbreviations for the different FPD groups and the study protocol are introduced.

2.2. *Static loading procedure and strain gauge measurements*

The implants (left implant A, right implant B) of the epoxy model were equipped with 5.5 mm solid abutments for cementable FPDs and with synOcta abutments for screw-retained FPDs, respectively. Both, synOcta abutments and solid abutments were tightened to 35 N cm using the implant manufacturer's ratchet.

2.3. *Measurement equipment and protocol*

The measurement model was equipped with four strain gauges (SGs) placed on the model material mesially and distally adjacent to the implants (SG-Am, SG-Ad, SG-Bm, SG-Bd; LY11-0.6/120; Hottinger Baldwin Messtechnik GmbH, Darmstadt, Germany). A measurement amplifier (DMC 9012A; Hottinger Baldwin) was used together with BEAM® software (AMS Gesellschaft für angewandte Mess-und Systemtechnik GmbH, Flöha, Germany) to analyze the strains occurring. The readings of the SGs at the end of the cementation and screwing process were taken for evaluation.

2.4. *Cemented FPDs*

After temporary cement (ImProv®; Nobel Biocare, Cologne, Germany) had been applied, all SGs were set to zero, and then the FPD was placed on the abutments. An initial force of 200 N was applied to the pontics by a universal testing machine (Zwick, Ulm, Germany) for 30 s. The force was then reduced to 100 N and held for 3 min. After that, the bridges were relieved

Table 1 – Restoration types ($n = 5$) and investigation procedure

Cement-FPD; no impression, plastic coping	Screw-FPD; no impression, plastic coping	Cement-FPD; repositioning impression, plastic coping	Cement-FPD; pick-up impression, plastic coping	Screw-FPD; pick-up impression, plastic coping	Screw-FPD; pick-up impression, gold cylinder
Control groups, no loading		Fit evaluation on epoxy model			
		Static loading through fixation on epoxy model and simultaneous strain gauge measurements			
FPM 0-c	FPM 0-s	FPM I-c-rep	FPM I-c-pic	FPM I-s-pla	FPM I-s-cas
		Dynamic loading (20.000 cycles, 100 N, 2 s loading – 1 s unloading)			
		FPM II-c-rep	FPM II-c-pic	FPM II-s-pla	FPM II-s-cas