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In-vitro fatigue and fracture testing of CAD/CAM-materials in implant-supported molar crowns

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ABSTRACT

Objective. To investigate the fatigue and fracture resistance of different CAD/CAM-materials as implant- or tooth-supported molar crowns with respect to the clinical procedure (screwed/bonded restoration).

Methods. 168 crowns were fabricated from different CAD/CAM-materials ($n = 8/\text{material}$): ZLS (zirconia-reinforced lithium silicate ceramic; Suprinity, Vita-Zahnfabrik), COB (composite; Brilliant Crios, Coltene), COL (composite; Lava Ultimate, 3M Espe), PMV/PPV (polyether ether ketone (PEEK) + milled composite veneer/composite paste veneer; BioHPP + HIPC veneer/Crealign veneer, Bredent), COH (composite; Block HC, Shofu), and ZIR (zirconia; IPS e.max ZirCAD, Ivoclar-Vivadent) as reference. Three groups were designed simulating the following clinical procedures: (a) chairside procedure ([CHAIR] implant crown bonded to abutment), (b) labside procedure ([LAB] abutment and implant crown bonded in laboratory, screwed chairside), and (c) reference ([TOOTH] crowns bonded on human teeth). Combined thermal cycling and mechanical loading (TCML) were performed simulating a 5-year clinical situation. Fracture force was determined and failures were documented. Data were statistically analyzed (Kolmogorov-Smirnov-test, one-way-ANOVA; post-hoc-Bonferroni, $\alpha = 0.05$). **Results.** All crowns of group LAB-PPV showed cracks after TCML. The other groups survived fatigue testing without failures. Fracture forces varied between 921.3 N (PPV) and 4817.8 N (ZIR) [CHAIR], 978.0 N (COH) and 5081.4 N (ZIR) [LAB], 746.7 N (PPV) and 3313.5 N (ZIR) [TOOTH]. Significantly ($p < 0.05$) different fracture values were found between materials in all three groups. Only ZLS crowns provided no significant ($p > 0.05$) differences between the individual groups.

Significance. Different ceramic and resin-based materials partly performed differently in implant or tooth situations. Individual resin-based materials (PPV, COB, COH) were weakened by inserting a screw channel. Most CAD/CAM-materials may be clinically applied in implant-supported crowns without restrictions.

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1. Introduction

Advanced digital techniques and an increasing number of CAD/CAM (computer-aided design/computer-aided-manufacturing) machinable materials enable continuous innovations in implant prosthetics. The benefits of a digital workflow including intra-oral scanning and CAD/CAM in combination with choosing an appropriate dental material may contribute to the success of implant-supported crowns.

While implants with preformed or custom abutments are state of the art in implant dentistry, the success of chairside cemented or bonded abutments and crowns might be limited by gingival and per-implant inflammation caused by residual cement remaining in areas difficult to access [1]. To resolve this problem screwed titanium bases with bonded abutments and crowns are available that enable bonding areas distant from the sulcus. Synchronization of the titanium base and the implant platform guarantees perfect fit and force-fit connections, avoiding fitting inaccuracies like observed for custom CAD/CAM fabricated ceramic abutments [2,3].

Bonding implant crowns to the titanium base in the laboratory in advance and leaving a screw channel may have further advantages: a screw-retained chairside fixation of the abutment–crown combination allows easy and reversible access to the screw for retightening as well as an uncomplicated maintenance of the implant restoration if necessary. Superior bonding quality (dry conditions, surface activation, optimized polymerization) may be achieved under laboratory conditions, improving bonding durability and reducing inflammatory reactions. Nevertheless, the strength of the crown might be affected by the presence of the screw channel [4–8].

Besides an optimized fabrication process and chairside/labside procedure, the selection of the appropriate crown material may essentially contribute to enduring success. A broad range of CAM machinable blocks is available for resin-based materials (composites, PEEK, PMMA), ceramics (feldspar, zirconia, lithium disilicate, zirconia-reinforced lithium silicate), and resin-infiltrated ceramics, which may be applied as monolithic restorations or with subsequent veneering. As implant crowns are more prone to occlusal overloading than tooth-supported crowns due to the missing of the physiological semi-elastic connection (periodontal ligament) and the tactile sensitivity, the application of brittle materials may cause numerous in vivo complications like fracture or chipping [9,10]. To overcome or minimize the risk of fracture, resin-based materials with improved shock absorbing capacity or monolithic ceramics of high strength might be preferred. However, despite of promising results of resin-based materials in implant-supported restorations [11,12], their mechanical resistance may be inferior to ceramics [13].

Up to date only limited scientific information and even less clinical data are available that show the performance of different currently available CAD/CAM materials used in implant-supported crowns with respect to the labside and chairside procedure. To give a first predication of their clinical survival, in vitro fatigue and fracture testing of CAD/CAM-fabricated crowns may be helpful.

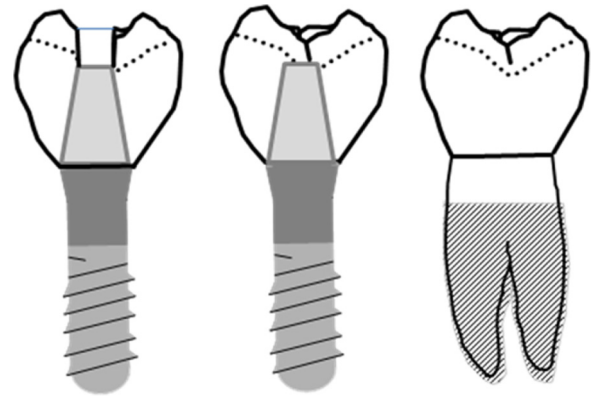


Fig. 1 – Designs of groups: LAB, CHAIR, and TOOTH (shaded area: artificial periodontium).

The hypothesis tested in this in vitro study was that molar crowns show different in vitro performance and fracture resistance when

- bonded to abutments chairside, bonded in the laboratory and screwed on implants chairside, or bonded to human teeth, or
- different CAD/CAM materials were used.

2. Materials and methods

A total of 168 identically shaped molar crowns (tooth 46) were fabricated from different CAD/CAM materials ($n=8$ per material and group), representing three resin-based composites, one polyether ether ketone (PEEK) combined with two different types of composite veneers, one zirconia-reinforced lithium silicate ceramic, and one zirconia ceramic (reference material). Details on the materials and their manufacturers are given in Table 1. For each material, three groups were designed to simulate the following clinical procedures (Fig. 1):

- Group ‘CHAIR’ (chairside procedure): the crown was directly bonded onto the implant-abutment analog and the excess luting material was removed.
- Group ‘LAB’ (labside procedure): a screw channel was manually drilled into the central fossa of the crown with a diamond bur (red/fine, diameter: 1.5 mm, water cooling). The crown was bonded onto the implant-abutment analog, the excess luting material was removed, and the screw channel was restored with composite (Filtek Supreme; Elipar Trilight 40 s, 3M Espe, D).
- Group ‘TOOTH’ (reference group): crowns were luted on prepared human molar teeth.

In the groups ‘CHAIR’ and ‘LAB’, the implant-abutment analogs ($n=112$; Straumann, D, titanium grade IV, implant diameter 4.1 mm, implant length 12 mm, abutment length 6 mm, 6°) were vertically positioned in resin blocks (Palapress Vario, Heraeus-Kulzer, D) in order to simulate the posterior implant situation replacing tooth 46. For the group ‘TOOTH’ extracted caries-free human molars ($n=56$) were collected at

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