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Impact of digital impression techniques on the adaption of ceramic partial crowns in vitro

Oliver Schaefer [a,*], *Mike Decker* [a], *Frank Wittstock* [a], *Harald Kuepper* [a], *Arndt Guentsch* [a,b]

[a] *Policlinic of Prosthetic Dentistry and Material Science, Centre for Dental Medicine, Jena University Hospital, Jena, Germany*

[b] *School of Dentistry, Marquette University, Milwaukee, WI, USA*

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ABSTRACT

Objectives: To investigate the effects, digital impression procedures can have on the three-dimensional fit of ceramic partial crowns in vitro.

Methods: An acrylic model of a mandibular first molar was prepared to receive a partial coverage all-ceramic crown (mesio-occlusal-distal inlay preparation with reduction of all cusps and rounded shoulder finish line of buccal wall). Digital impressions were taken using iTero (ITE), cara TRIOS (TRI), CEREC AC with Bluecam (CBC), and Lava COS (COS) systems, before restorations were designed and machined from lithium disilicate blanks. Both the preparation and the restorations were digitised using an optical reference-scanner. Data were entered into quality inspection software, which superimposed the records (best-fit-algorithm), calculated fit-discrepancies for every pixel, and colour-coded the results to aid visualisation. Furthermore, mean quadratic deviations (RMS) were computed and analysed statistically with a one-way ANOVA. Scheffé's procedure was applied for multiple comparisons ($n = 5$, $\alpha = 0.05$).

Results: Mean marginal (internal) discrepancies were: ITE 90 (92) μm, TRI 128 (106) μm, CBC 146 (84) μm, and COS 109 (93) μm. Differences among impression systems were statistically significant at $p < 0.001$ ($p = 0.039$). Qualitatively, partial crowns were undersized especially around cusp tips or the occluso-approximal isthmus. By contrast, potential high-spots could be detected along the preparation finishline and at central occlusal boxes.

Conclusions: Marginal and internal fit of milled lithium disilicate partial crowns depended on the employed digital impression technique.

Clinical significance: The investigated digital impression procedures demonstrated significant fit discrepancies. However, all fabricated restorations showed acceptable marginal and internal gap sizes, when considering clinically relevant thresholds reported in the literature.

1. Introduction

Currently two separate genres of digital impression systems exist. The first one uses scans of the oral cavity to instantly generate virtual working casts that allow clinicians to design their restorations at the chair-side. This design is subsequently sent to an in-house milling-unit that manufactures customised restorations from prefabricated material blanks. Thereby, defective teeth may be restored within a single appointment.

* *Corresponding author at*: An der Alten Post 4, 07740 Jena, Germany. Tel.: +49 3641 934481; fax: +49 3641 934482.
E-mail address: oliver.schaefer@med.uni-jena.de (O. Schaefer).

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Systems that belong to the second genre rather concentrate on image acquisition and recognition to build virtual copies of the natural dentition. Data are transferred to specialised dental laboratories or dedicated production centres, where restorations are designed (computer-aided design, CAD), further processed, and finally manufactured (computer-aided manufacturing, CAM) most commonly by subtractive technologies like computer-numeric-controlled milling (CNC-milling).[1]

Some digital impression systems allow the practitioner to occasionally choose from one of the aforementioned treatment approaches. However, both genres offer considerable benefits over conventional impressions, such as an increased patient comfort, time- and therefore cost-efficient treatment procedures, or the opportunity to easily review and adjust preparations in real-time.[2] Another advantage is the access to industrially prefabricated materials with refined composition and microstructure.[3]

Succeeding leucite-reinforced ceramics, lithium disilicate materials offer improved physical characteristics, while also remaining suitable for CAM in a pre-sintered state. Mechanical properties include a modulus of elasticity of 91.0 GPa, a hardness of 5.5 GPa, and a biaxial-flexure-strength of 375 MPa.[4] Moreover, these glass ceramics were able to withstand mouth-motion cyclic loading and showed no failures up to load levels of 1100–1200 N, which exceeded physiologic chewing forces.[5] Due to a favourable translucency and shade-variability, monolithic restorations can be fabricated and subsequently characterised both chair- and lab-side. Based on these properties, lithium disilicate ceramics may be used to replace missing anterior and posterior teeth up to a second premolar as a pontic in fixed dental prostheses.[3]

Adequate marginal and internal adaption is considered a decisive factor for the clinical longevity of these restorations.[6] Although threshold values can vary, gap sizes larger than 150 μm were reported to promote discoloration, exposure of luting resin, dissolution of cement, microleakage, plaque retention, secondary decay, and gingival inflammation.[7,8] Optical- or scanning electron microscopy is usually used to evaluate marginal and internal discrepancies in vitro. Common sample sizes range from 5 to 10 specimens per group, with 2–150 different measuring locations, selected in a systematic or random manner. In this context, Groten et al. suggested that a minimum of 50 measurement locations along the margin of a crown yielded clinically relevant information and a consistent estimate for gap size.[9]

Furthermore, dental ceramics cannot withstand elastic deformation to the same extent as tooth structures or resinous materials. Stress concentrations depend on the geometry of the specimen material, loading conditions, the presence of intrinsic or extrinsic flaws, and marginal and internal fit. However, resin-based luting agents have been shown to reduce, yet not completely absorb, the resulting shear-forces.[10]

Although digital impressions possess clear advantages compared to their conventional analogues, the fitting-accuracy of resulting restorations remains questionable.[11] Therefore, the objective of this in vitro study was to estimate the marginal and internal fit of lithium disilicate partial crowns fabricated using different digital impression techniques. The tested null hypothesis was that different intraoral scanning principles would not affect the marginal or internal fit of partial coverage crowns fabricated from lithium disilicate glass ceramics.

2. Materials and methods

2.1. *Tooth preparation*

An acrylic model of a mandibular left first molar (AG-3 ZE 36, Frasaco GmbH, Tettnang, Germany) was prepared to receive a partial crown restoration using a standard set of diamond burs (Set 4562, Brasseler GmbH, Lemgo, Germany). The preparation featured a 1.5 mm occlusal height reduction, a 1 mm rounded shoulder finish line of the buccal wall, and a 1 mm deep occlusal box. The 3 mm deep proximal grooves were finished with oscillating diamond tips (SONICflex prep ceram, KaVo Dental GmbH, Biberach, Germany) to achieve 90° margins as well as rounded and soft internal line angles. Prior to preparation, an initial impression was taken with a sectional tray system (Multi Tray, Kettenbach GmbH, Eschenburg, Germany) and a vinyl polysiloxane material (Panasil Putty, Kettenbach GmbH). To ensure standardised reductions, the impression was removed from the tray, sectioned vertically, and regularly set back in place to verify the progress made towards a predetermined preparation depth. Finally, the prepared cavity was evaluated digitally by a preparation assistant system (PREPassistant, KaVo Dental GmbH), originally developed for preclinical dental training.

2.2. *Impression taking and virtual cast fabrication*

The prepared tooth was mounted in a typodont (AG-3, Frasaco GmbH) and scanned 5 times with 4 different digital impression systems (Table 1). The iTero (ITE) scanner uses a parallel confocal imaging technology in combination with a red laser beam to capture teeth and surrounding soft tissues. Reflected light is split and led through a focal filter allowing only the image within the focal point of the lens to project onto the sensor. In this case, the distance between the lens and the

Table 1 – Selected characteristics of the digital impression systems used in the present study, as provided by the respective manufacturer.

Token	System	Manufacturer	Measurement principle	Measurement type	Measurement prerequisites
ITE	iTero	Cadent	Confocal imaging	Still images	–
TRI	cara TRIOS	Heraeus Kulzer	Ultrafast optical sectioning	Video	–
CBC	CEREC AC with Bluecam	Sirona Dental Systems	Stripe-light projection	Still images	Powdering
COS	Lava Chairside Oral Scanner	3M ESPE	Active wavefront sampling	Video	Powdering