

Influence of Gingival Contour on Marginal Fit of CAD-CAM Zirconia Copings on Implant Stock Abutments

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ABSTRACT

Intraoral scanning subgingival finish lines has been described as challenging. The purpose of this study was to assess the impact of gingival contour around margins of implant stock abutments on marginal fit of Computer-aided Design - Computer-aided Manufacturing (CAD-CAM) zirconia copings. This in-vitro study was conducted on 40 analogues of implant stock abutments that were embedded into individual phantoms composed by a resin block. All 40 phantoms underwent two intraoral scans - one with (test group) and one without artificial gingiva (control group) - using a closed system intraoral scanner. Zirconia copings were then digitally designed and milled, followed by high-speed sintering, before being analyzed for marginal adaptation and internal surface roughness with scanning electron microscopy. Statistically significant differences between groups were assessed with the Mann-Whitney test. Median marginal gap values were 149.78 μm (95% CI: 112.39-216.66) for the test group and 94.90 μm (95% CI: 83.89-107.74) for the control group. A statistically significant difference was found between groups ($p=0.0001$). However, there were no subjective differences between groups for internal surface roughness. Within the limitations of this study, the present findings suggest that a gingival contour one millimeter higher than the finishing line affects marginal adaptation of CAD-CAM zirconia copings.

INTRODUCTION

With the increasing number of studies on digital workflow in implant dentistry, several computer-aided design and computer-aided manufacturing (CAD-CAM) methodologies have been described to create a three-dimensional (3D) virtual patient for planning implant surgeries and prosthodontics noninvasively.^{1,2} In this context, a digital design of the desired prosthesis can be developed from intraoral scans, either to three-dimensionally print temporary crowns or also to mill definitive CAD-CAM copings or crowns.³

One of the main factors that may affect marginal adaptation of CAD-CAM crowns is the intraoral scanning (IOS) procedure and device. In this context, different results have been reported for different IOS devices.^{4,5} Previous studies have reported that intraoral scanning finish lines and margins of a tooth preparation is challenging.^{6,7} Despite the scanning procedure being similar for implants, an implant scan body can be intraorally scanned to digitally transfer the implant position to the CAD software. This can be performed in addition to the direct scan of the implant abutment, which is required for acquiring images of the soft tissue profiles.^{8,9}

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One of the biomaterials that have showed satisfactory results in the literature on CAD-CAM crowns is zirconia.^{10,11} However, reproducibility of milled zirconia copings may vary among different clinical situations.¹² Furthermore, marginal fit of monolithic zirconia crowns may be affected by different milling units and CAD-CAM systems.¹³ On other hand, none of the above mentioned studies performed marginal gap measurements of monolithic zirconia copings or crowns using scanning electron microscopy (SEM).

Marginal adaptation alterations due to intraoral scanning challenges have also been described for implant stock abutments without scanbodies.⁵ However, little is known on the impact of gingival contour around tooth preparation and abutment finish lines on quantitative measurements of marginal fit of zirconia copings. Addressing such impact would be clinically relevant for implant cases with solid abutments, one-piece implant abutments, and could have implications even for cases of single tooth crowns, since tooth preparations must also be directly scanned with IOS, which could be challenging in cases of subgingival finishing lines.

Thus, the aim of this study is to assess the impact of gingival contour around margins of implant stock abutments on marginal fit of CAD/CAM zirconia copings.

MATERIAL AND METHODS

This *in-vitro* study was conducted on 40 analogues of implant stock abutments (Solid abutment, 4.8mm in diameter with 4mm in height, Institut Straumann AG) that were individually embedded in epoxy resin. The resulting 40 epoxy resin blocks were considered as phantoms of this study. In addition, artificial gingiva (Gingifast Rigid, Zhermarck) with margin located one millimeter higher than the abutment finish line was applied around all abutments of the study by using the positioning cylinder of the transfer coping of the same implant system. The rationale of applying artificial gingiva around all phantoms was to simulate slightly different clinical situations in regards to gingival margin levels.

All 40 phantoms were scanned twice – one with (test group) and one without artificial gingiva (control group) – directly (i.e. with no scan bodies), and using the same intraoral scanner (CEREC Omnicam System, Dentsply-Sirona, which does not require use of powder), totaling 80 intraoral scans. All resulting images were imported to a dedicated software (Sirona Connect 4.5; Dentsply Sirona) and saved as Standard Tessellation Language (STL) files. Such files were then checked in the software to confirm that the whole area had been scanned cleanly, that the scan had not been distorted due to irregular light reflection related to metal exposure, and that the margin area had been continuously scanned. In the virtual models, we depicted the finishing line of the abutments to digitally design the respective zirconia copings by using a software program (inLab 16; Dentsply Sirona) that was also used to save the resulting digital designs as STL files (Figure 1).

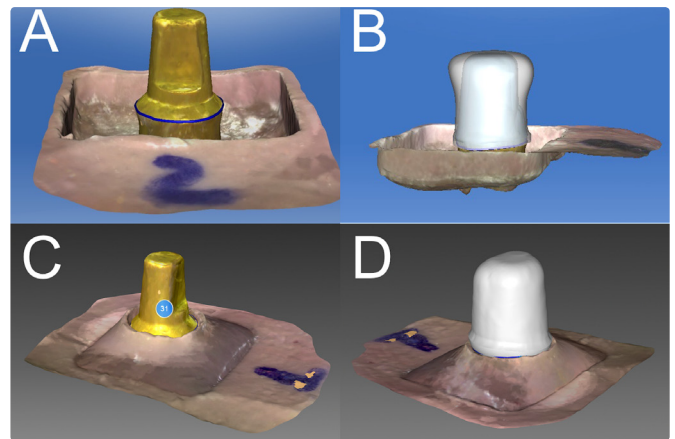


Figure 1: Computer-aided design procedures. A) Intraoral scan of an implant stock abutment of the control group (i.e. without gingival contour). B) Virtual wax-up of the implant-supported zirconia coping (control group). C) Intraoral scan of an implant stock abutment of the test group (i.e. with gingival contour). D) Virtual wax-up of the implant-supported zirconia coping (test group).

The STL files of each digitally designed zirconia copings were then milled from translucent zirconia blocks (In Coris TZI, Dentsply-Sirona) using an integrated milling unit (CEREC MC XL, Dentsply-Sirona). All copings were then dried before sintering for 30 min at 80°C and 10 min at 150°C, followed by high-speed sintering (Speedfire, Dentsply-Sirona) at 1510°C for 120 min. Copings were then cooled to room temperature and checked for fit with the corresponding phantoms (Figure 2). All aforementioned procedures were performed by a single experienced dental technician to reduce operative bias.

Scanning electron microscopy (SEM; Quanta FEG 250, FEI) was performed on all copings after being coated with gold-palladium alloy under high vacuum. Initially, internal surface morphology was assessed under x30 magnification, following previously described methodology.¹⁴ Quantitative

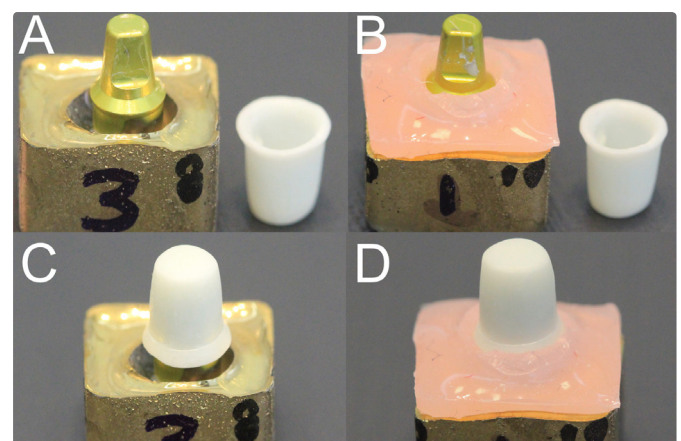


Figure 2: Computer-aided manufacturing procedures. A) Phantom and milled zirconia coping of the control group. B) Phantom and milled zirconia coping of the test group. C) Implant-supported zirconia coping in position (control group). D) Implant-supported zirconia coping in position (control group).

measurements of marginal adaptation (i.e. marginal gap measurement) were then carried out at $\times 4,000$ magnification. All measurements were digitally performed in microns with the software of SEM device in random order by two trained observers. Both observers performed their measurements twice, at intervals of two weeks in order to eliminate the memory bias.

For statistical analyses, sample size was calculated to give the study a power of 80% at a significance level of 5% with the uncorrected chi-square test. Normality of measurements was assessed using the Shapiro-Wilk test. Intra- and Interobserver agreements were calculated with the intraclass correlation coefficient (ICC). In addition, statistically significant differences between test and control groups were assessed with the Mann-Whitney test. All statistical analyses were performed at a level of significance of 5%, using the IBM SPSS Statistics 17 software (SPSS, Inc, Chicago, IL).

RESULTS

A total of 80 STL files (40 tests and 40 controls) were analyzed. Qualitative assessments of internal surface roughness of tests and controls were similar (Figure 3). Normality was rejected for the measurements, according to the Shapiro Wilk test ($p=0.031$). Strong intra and Interobserver agreements were confirmed according to ICC analysis (ICC ranging from 0.81 to 0.91, $p<0.001$). Median marginal gap values were $149.78 \mu\text{m}$ (95% CI: 112.39-216.66) for the test group and $94.90 \mu\text{m}$ (95% CI: 83.89-107.74) for the control group (Figure 4). A statistically significant difference was found between groups ($p=0.0001$).

DISCUSSION

This study aimed to assess the impact of gingival contour around stock abutments on marginal fit of zirconia copings. As shown by the present findings, gingival contour may affect intraoral scanning of finishing lines of stock abutments, leading to larger marginal gaps between such abutments and zirconia copings. This is in agreement with a previous study on gingival contours using the same IOS system of this study,¹⁵ and with previous studies indicating that intraoral scanning finishing lines and margins with IOS is challenging.^{6,7} On the other hand, all present marginal gap results can still be considered clinically comparable to previous results described in the literature.^{16,17} Furthermore, the findings presented herein are also comparable to other results of zirconia CAD-CAM crowns from a study concluding that CAD-CAM methodologies might offer advantages as compared with conventional procedures, such as less patient visits, better results of marginal fit and reproducibility of the prosthesis.⁶

As supported by the present study, different clinical situations such as gingival margin levels around subgingival finish lines of tooth preparations have been suggested to have a

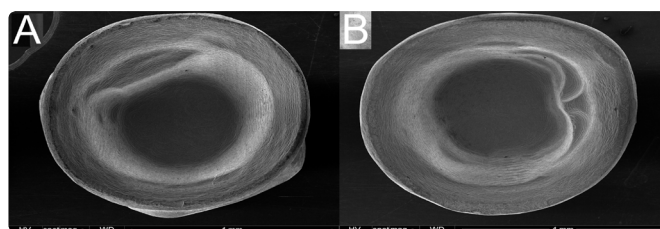


Figure 3: Scanning electron microscopy qualitative findings. A) Internal surface roughness analysis of the control group (4mm scale). B) Internal surface roughness analysis of the test group (4mm scale).

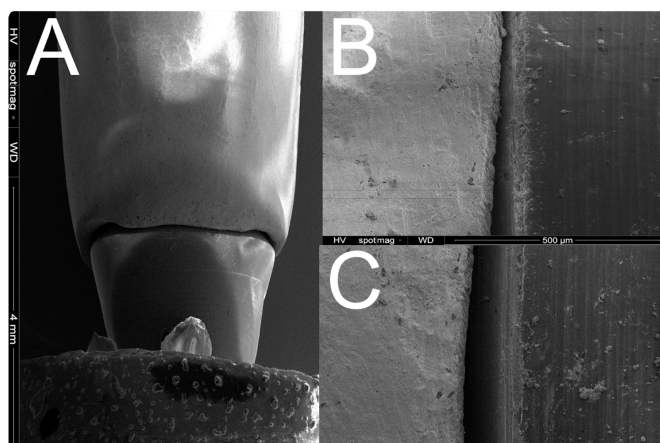


Figure 4: Scanning electron microscopy quantitative findings. A) Set-up view of the coping in position (4mm scale). B) Marginal gap assessment of the control group (500µm scale). C) Marginal gap assessment of the test group (500µm scale)

significant impact on marginal adaptation of CAD-CAM dental prostheses.^{6,7} Different marginal gap results using different CAD-CAM methods have been reported for both temporary resin and definitive ceramic CAD-CAM crowns.⁴ In addition, the present findings are also in accordance with a previous study validating direct intraoral scans of stock abutments.⁵ According to the aforementioned authors, despite results may vary among different IOS devices, satisfactory trueness and precision results can be obtained by directly scanning stock abutments. On the other hand, the aforementioned study used scanning powder to prevent diffuse reflections, whereas no powder had to be used in the present study.

One of the limitations of this *in-vitro* study performed on phantoms is that the impact of clinical factors such as saliva or proximity to adjacent teeth could not be addressed. Furthermore, this study used a 3-axis milling unit, while better marginal adaptation results for monolithic zirconia crowns have been reported with 5-axis milling devices.¹³ Future prospective clinical studies would be recommended to address the impact of different CAD-CAM systems on marginal fit of implant-supported zirconia crowns designed from intraoral scans of implant stock abutments.

In conclusion, within the limitations of this study, the present findings suggest that present of gingival contour 1 mm higher than the finishing line affects significantly marginal adaptation of CAD-CAM zirconia copings designed from intraoral scans of implant stock abutments.

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