Implant adaptation of stock abutments versus CAD/CAM abutments: a radiographic and Scanning Electron Microscopy study

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Summary
Implant adaptation of stock abutments versus CAD/CAM abutments: a radiographic and Scanning Electron Microscopy study.

Introduction. ***The study evaluated a null-hypothesis of no differences of fit between stock abutments and CAD/CAM titanium, gold sputtered and zirconia abutments when examined for radiographic adaptation and Scanning Electron Microcopy (SEM) at their inner aspect. The agreement between microscopic and radiographic fit was also assessed.***
Methods. ***Implants (Osseospeed, Astra Tech, Mölndal, Sweden) were connected to titanium abutments (Ti-design, Astra Tech, Mölndal, Sweden) (control group n=12), to stock zirconia abutments (Zir-design, Astra Tech) (group 1 n=12) and to third party zirconia abutments (Aadva Zr abutment, GC, Tokyo, Japan) as observed under SEM (JEOL JSM-6060LV, Tokyo, Japan). Two independent operators blindly evaluated the images, according to a three-score scale: perfect adaptation, no complete adaptation, and clear evidence of no adaptation. A Kruskal-Wallis test was applied to assess significant differences in adaptation scores between the groups.***
Results. ***All specimens showed precise SEM adaptation at all tested interfaces and no radiographically apparent gaps. No significant differences were found and therefore the null-hypothesis tested was accepted. Radiographic and SEM scores were in agreement.***
Discussion. ***CAD/CAM titanium, gold sputtered and zirconia abutments and third-part CAD/CAM zirconia abutments show an adaptation to Astra Tech implants that is comparable to that of stock titanium and zirconia abutments. Clinicians might be able to verify such adaptation with an x-ray. In-vivo studies would be needed to evaluate the clinical outcome of CAD/CAM abutments.***

Key words: titanium, zirconia, interface, abutment.

Introduction

Because of the constant increase of patient's demands for dental aesthetics, and consequent attempts of prosthetic technology to catch-up with these exigencies, abutments for implant-supported restorations are among the components that undergo frequent updates (1). In particular, because titanium abutments might display a bluish halo through thin soft tissues (2), alternative abutment materials have been sought. Due to its biocompatibility and aesthetic properties zirconia is increasingly used for abutment manufacturing (3). In addition, zirconia abutments have a very high fracture resistance that is only little lower as compared to titanium (3). Besides zirconia, CAD/CAM processing is increasingly used for abutment manufacturing. The customization possible with CAD/CAM abutments would allow for more refined prosthetic design and for enhanced sustain of the soft tissue contour. Such components are available in different materials from implant companies and lately also from some third party manufacturers. Unfortunately, no or little data assessing the fit of many of these new components from either proprietary or third party companies are available. Nevertheless, the implant abutment interface is a critical area for long-term outcome of implant-supported prostheses (1). A reliable interfacial contact is desirable to maximize mechanical stability of abutments and prosthesis (4) and to avoid possibly associated biological complications (5). It has been demonstrated that gaps at the implant abutment interface might increase stresses at prosthetic components, implants and peri-implant bone (6). As a consequence of misfit-caused stresses, screw loosening or fracture might happen (7). These events have been described as the most common mechanical complication during -3 to -5 years clinical trials (5, 8). In addition, the implant abutment margin could favor bacterial accumulation and therefore it could be a source of peri-implant inflammation (9). It was even hypothesized that bacterial leakage at the implant abutment interface may play an etiologic role in peri-implantitis (10-11) however its low prevalence in the literature seems to contradict this theory (12). In any case because precision of the implant abutment interface might influence the rate of biological and mechanical complications it seem highly desirable to have a tight marginal fit at this interface.

Aim of this study is therefore to evaluate by radiographic and Scanning Electron Microscopy (SEM) examination at their inner aspect the fit of Astra Tech stock titanium and zirconia abutments, Aadva CAD/CAM zirconia abutments and Atlantis CAD/CAM titanium, gold sputtered and zirconia abutments. A correlation between microscopic and radiographic fit will also be assessed. A null-hypothesis of no differences between stock and CAD/CAM abutments will be tested.

Material and methods

Seventy-two implants (Osseospeed, Astra Tech, Mölndal, Sweden) were used in this study. They were randomly divided into six equally sized groups. Implants in group 1 were connected to titanium abutments (Ti-design 5,5 h1,5, Astra Tech, Mölndal, Sweden); implants in group 2 were connected to zirconia abutments (Zir-design 5,5 h1,5, Astra Tech, Mölndal, Sweden); implants in group 3 were connected to CAD/CAM zirconia abutments (Aadva Zr abutment, GC, Tokyo, Japan); implants in group 4 were connected to CAD/CAM titanium abutments (Atlantis, Astra Tech); implants in group 5 were connected to CAD/CAM gold coated titanium abutments (Gold Hue, Atlantis, Astra Tech); implant in group 6 were connected to CAD/CAM zirconia abutments (Atlantis, Astra Tech). Implants and stock abutments were all from the same lot number as provided by manufacturer. CAD/CAM abutments were provided by the manufacturers. In essence, both Atlantis and Aadva systems scanned the fixture interface and afterwards the abutment was designed through a CAM process aiming at matching the design of Astra Tech Ti- and Zir-Design abutments. At the end of the machining phase the CAD/CAM abutments had a similar shape to the stock abutments investigated.

X-ray evaluation

This part of the study was intended to simulate the evaluation of implant abutment adaptation that may be done in clinical practice (13, 14). Firstly specimens were subjected to radiographic analysis using conventional film (Ultra-Speed, Kodak, Rochester, NY, USA) and a dental tube (096 Belray, Takara Belmont, Osaka, Japan) placed perpendicular to the implant abutment interface with the aid of a film holder (XCP, Dentsply Rinn, Elgin, IL, USA). Films were developed using fresh developer and fixer solutions (GBX Chemicals, Kodak Rochester, NY, USA).

Proper adaptation of the abutment into the corresponding fixture was assessed. The evaluation aimed at determining the precision of fit between the bearing surfaces and the top of the external hexagon of the implant with the superior surface of the internal hexagon of the abutment. The adaptation of each abutment was scored from 0 (perfect adaptation), 1 (no complete adaptation) to 2 (clear evidence of no adaptation). Two operators made scores in double blind and in case of different scores the case was re-evaluated and an agreement was found.

SEM examination

All the specimens were embedded in acrylic resin (Technovit 2100e, Kuler, Werheim, Germany) and cut using a low speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) under water-cooling. All the abutments were then cut parallel to the mesio-distal direction of the scalloped abutment margin and observed under SEM (JSM 6060 LV, JEOL, Tokyo, Japan). To assign a score to each interface fit, the inner adaptation under SEM (as marginal gap between the fixture and the abutment) was digitally measured with a freeware image analysis software (15). In particular a 0 score was assigned to gaps not exceeding 5 microns (perfect adaptation), a score of 1 was assigned to gaps greater than 5 microns but not exceeding 20 microns (no complete adaptation), and finally 2 was assigned to gaps greater than 20 microns (clear evidence of no adaptation). Two independent operators blindly evaluated the serial images according to the above-mentioned scale.

Statistical analysis

Kappa coefficient was computed to evaluate interobserver agreement. The Kruskal-Wallis test was applied to assess statistical significance among the adaptation scores between the six experimental groups. The level of significance was set at $p<0.05$. Altman-Bland's method (16) was employed to check the agreement between the implant/abutment fit measured by SEM and x-rays.

Results

No disagreement between the operators resulted with a Kappa coefficient of 1. All the abutment groups showed satisfactory adaptation by both X-ray and SEM evaluation. All the groups scored zero with regard to radiographic adaptation (figure 1). SEM evaluation demonstrated mean internal gaps (figure 2) not higher than 5 microns in all the groups and consequently a zero score was assigned to all the groups. No statistically significant differences were found (table 1). Radiographic examination scores were in perfect agreement with SEM scores with limits of agreement calculated by the Altman-Bland's method of 0.

Discussion

Aiming at improved reliability and aesthetic outcomes of implant-supported restorations, continuous strives are put

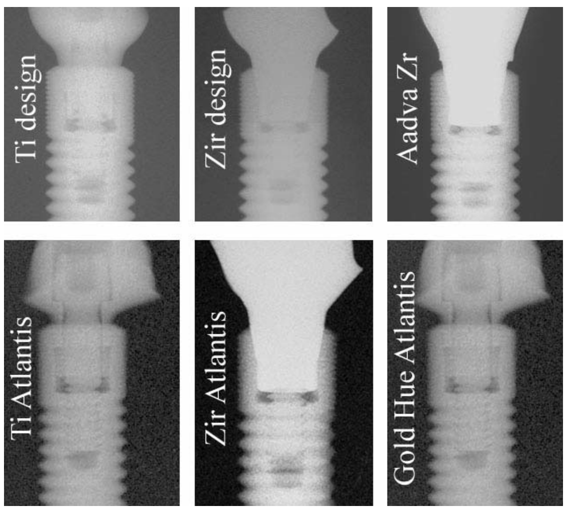

Figure 1 - From left, radiographic adaptation of Ti-design, Zir-design and Aadva Zr abutments.

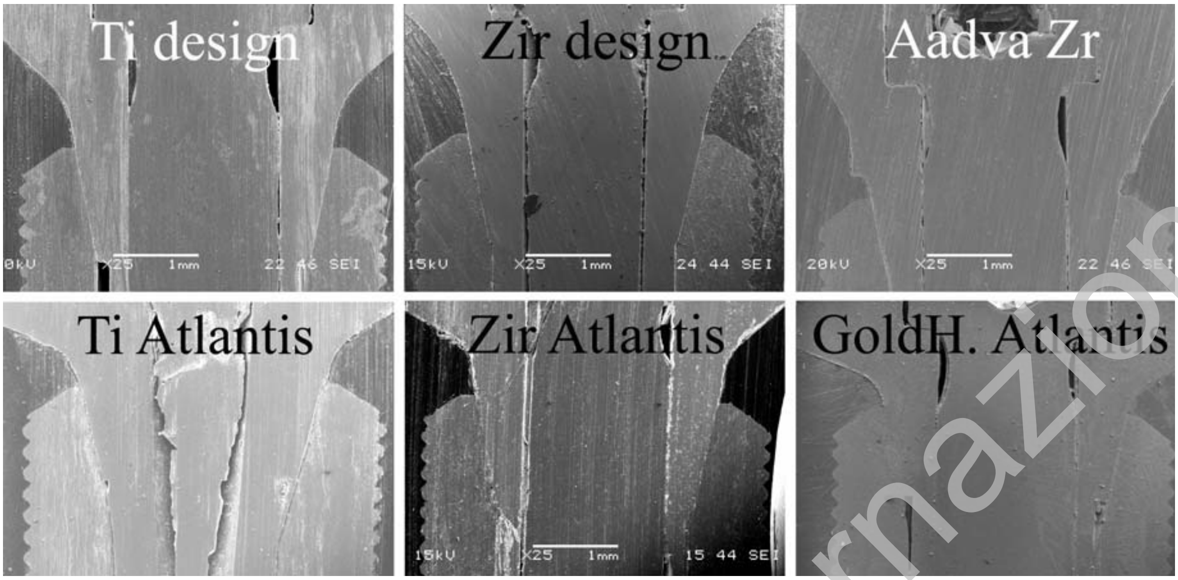

Figure 2 - SEM images of the adaptation at the inner aspect of the implant abutment interface after cross sectioning.

Table 1 - Scores related to abutments' adaptation to Osseospeed fixtures.

	RX Score			SEM Score		
	0	1	2	0	1	2
Ti Design	12	-	-	12	-	-
Zir Design	12	-	-	12	-	-
Aadva Zr	12	-	-	12	-	-
Ti Atlantis	12	-	-	12	-	-
Zir Atlantis	12	-	-	12	-	-
Gold Hue Atlantis	12	-	-	12	-	-

Legend: Rx Score = score performed by X-ray (0 = perfect adaptation; 1 = no complete adaptation; 2 = clear evidence of no adaptation); SEM Score = score of internal adaptation performed by SEM (0 = gap less than 5 microns between fixture and abutment, perfect adaptation; 1 = when the gap was between 5 and 20 microns, no complete adaptation; 2 = when it was higher than 20 microns, clear evidence of no adaptation).

in the advancement of prosthetic components and techniques. At present the use of zirconia and CAD/CAM processing is the forefront of the prosthetic technology. Zirconia abutments could be used when bluish halo of titanium through thin soft tissues is of concern (3). In addition for enhanced matching to patient's tissues (17) premade abutments can be customized in the laboratory by grinding or they can be obtained through CAD/CAM processing with. Little literature at present evaluates the fit of these new prosthetic components.

In this study a null-hypothesis of no differences in the fit of Atlantis and Aadva CAD/CAM abutments to Astra Tech implants as compared with the fit of Astra Tech proprietary zirconia and titanium abutments is accepted. As a consequence, at least for the tested implant system, and as far as marginal adaptation is concerned, Aadva and Atlantis CAD/CAM abutments seem a suitable alternative to stock abutments when a fully customized prosthesis is desired.

All the abutments, when examined from the inner aspect, showed a gap never exceeding 5 microns. A very good marginal adaptation, among the best between several tested systems, was already documented for the Astra Tech titanium abutment (18). Nevertheless, much as precisely fitting, Astra Tech abutments are not able to prevent experimental bacterial (18) or endotoxin leakage (19) similarly to others systems on the market (18). Nevertheless, because a tight fit between implant and abutment is desirable for optimal mechanical stability of the interface (4), the observation that both stock zirconia abutments and CAD/CAM abutments obtained with the Atlantis and Aadva systems are able to replicate the same precise marginal adaptation of Astra's conical design connection seems of interest.

The marginal precision together with the mechanical reliability of Atlantis zirconia abutments was already tested in a previous study where they were found to be acceptable for clinical use (20). Similarly this study, where the evaluation of Atlantis abutments was extended to all the available materials, showed that their fit to the fixture is comparable to that of stock titanium abutments.

Conversely to the best of authors' knowledge no previous studies ever evaluated the marginal fit of Aadva abutments. It is also of interest to highlight that, opposite to the uniform smoothness of stock abutments, SEM analysis of the Aadva abutment surface showed large shallow grooves apparently as a result of the machining procedure, such grooves were also present on Atlantis abutments although they appeared much smaller. In any case such grooves were absent in the area of the abutment that interfaces with the implant and therefore, possibly, they were not jeopardizing marginal adaptation (figure 3). The influence of such grooves on soft tissues and clinical outcomes is at present unknown. Therefore, although good results emerged from this investigation, further research is desirable on the Aadva system.

The data regarding the fit of the CAD/CAM abutments here investigated are analogous to the fit of CAD/CAM zirconia external connection abutments that never exceeded 5 microns of gap even after dynamic loading (21). Never-

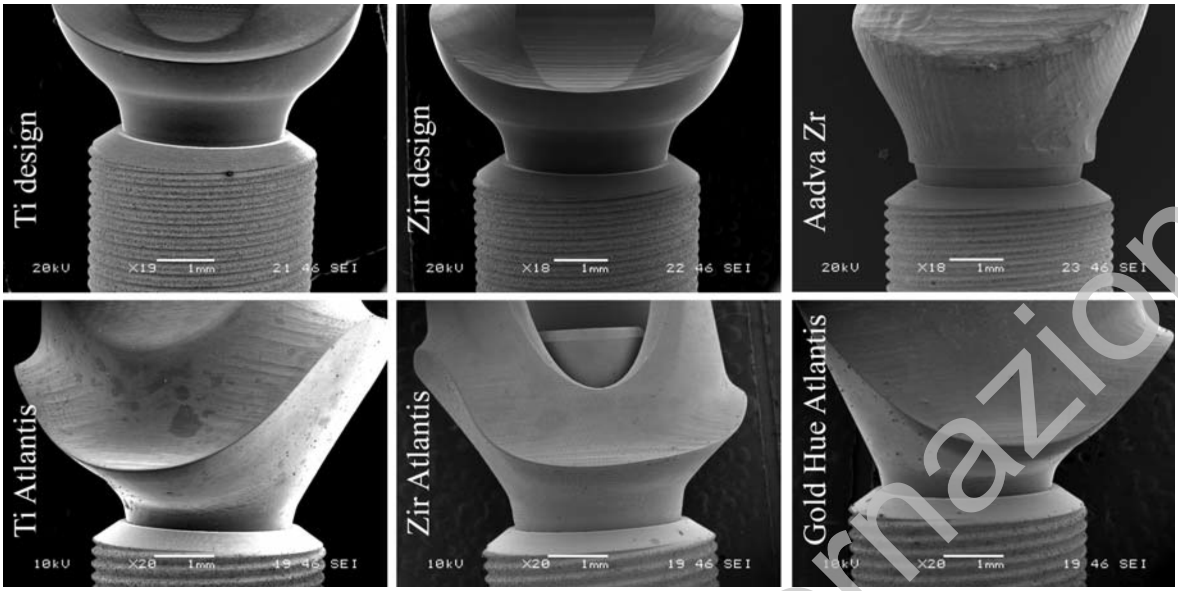

Figure 3 - Low magnification of all the investigated abutments. Opposite to Astra abutment, Aadva abutment surface showed large shallow grooves apparently as a result of the machining procedure. However the portion that interfaces with the implant was free from such grooves thus leaving unaffected marginal adaptation.

theless, it has to be taken into consideration, that the configuration of the external connection systems, with the presence of a marginal bevel, makes gap data not easily comparable (21).
Additionally with regard to the clinical applicability of this study, radiographic evaluation of the implant abutment fit has been described as a sufficient consistent way to evaluate clinically precise abutment seating, especially in case of subgingival location of the above-mentioned interface. However, it has also been pointed out that, for a reliable evaluation, orthogonal angulation is mandatory, as small angulations deviations hide the presence of a gap. The agreement here found between SEM and x-ray evaluation of the marginal adaptation seems of relevance. Consequently, it is reasonable to say that, when precise radiographic orthogonal orientation is attained like in this study, clinicians can control abutment adaptation on Astra Tech implants by intraoral x-rays as radiographic adaptation corresponds to precise microscopic seating.
In conclusion Aadva and Atlantis CAD/CAM abutments showed a fit to the Astra Tech fixture that was comparable to the stock titanium and zirconia abutments. In-vivo studies are needed to evaluate the clinical results of the investigated CAD/CAM abutment systems.

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