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ORIGINAL ARTICLE

Clinical study evaluating the discrepancy of two different impression techniques of four implants in an edentulous jaw

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Abstract
Objectives Precise implant-supported prosthodontics requires accurate impressions. Many in vitro studies comparing different implant impression techniques were performed. The purpose of this in vivo study was to compare the discrepancy of two different impression techniques of implants clinically.
Material and methods Four implants were inserted nearly bilateral in ten edentulous jaws. From each jaw, two different impressions (A, transfer; B, splinted pick-up) were taken. Respectively two stone casts of each jaw were produced and scan bodies were mounted on the lab analogues to digitize the casts. One scan body of the digitized casts was each superimposed and the deviations of the remaining three scan bodies were measured three dimensionally. The fit of the suprareconstructions was evaluated clinically on both casts and in the mouth.
Results The mean discrepancy of scan body 2 was 192 μm (±96), 282 μm (±97) for scan body 3, and 366 μm (±114) for scan body 4. The discrepancies between two scan bodies were statistically significant ($p \leq 0.010$; ANOVA test). Comparing the data with the span between the scan bodies, a linear regression line could be drawn to show the dependency between the misfit and the length of the span. Clinically, the fit on the cast produced by the splinted pick-up technique was favorable.
Conclusions The discrepancy between the splinted pick-up impression technique and the transfer technique were in a range with clinical influence.
Clinical relevance For better accuracy of implant-supported prosthodontics, the splinted pick-up technique should be used for impressions of four implants evenly spread in edentulous jaws.

Keywords Implants · Scan bodies · CAD/CAM · Impression · Accuracy

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Introduction

Achieving an absolute passive fit of prosthetic restorations is, due to various error sources, almost impossible [1–3]. Particularly in the case of implant-supported prosthodontics in completely or partially edentulous patients, inaccurate fit of the supra-reconstruction can have negative effects, due to the rigid osseointegration of the dental implants [3–5]. The position and the angulation of the implants have major importance on a precise fit [6–9]. One of the most important factors for a precise fit is the accuracy of the intra-oral impression [10]. Both different impression techniques [11] as well as the impression material have an effect on the accuracy of the intra-oral transfer [9, 12, 13].

Since the early 1990s, in vitro studies have analyzed different impression techniques (indirect technique with closed tray, direct technique with open tray, and direct technique splinted with acrylic resin), whereby the results were extremely non-homogeneous [11]. Earlier studies have investigated impressions of implants with external hexagonal implant–abutment configurations. More recent implant systems have internal configurations with a cone or butt–joint connection. The cone connection was stated to show favorable seal and stability between implant and abutment however, this was refuted by several authors [14–16]. A more precise, reproducible positioning of abutments or impression posts is, however, obtained as a result of a butt–joint connection [17]. Recent studies have investigated the accuracy of impressions with implants exhibiting internal implant–abutment connections [6, 18–21].

To date, the discrepancies of different implant impression techniques were mostly measured mechanically [11]. As a result of the introduction of CAD/CAM technology into dentistry, the preliminary digitized models can be compared and superimposed and the deviations recorded digitally [21, 22].

The goal of this clinical study was to compare two different techniques (transfer and splinted pick-up techniques) for making impression of four implants with an internal butt–joint connection inserted in an edentulous upper or lower jaw.

Both stone casts resulting from the two different impressions were recorded digitally and compared. It was hypothesized that different impression techniques will influence the accuracy of the resulting master casts.

Material and methods

Patients presented with an edentulous jaw in the maxilla or mandible and the demand to be rehabilitated with bar-retained implant-supported removable dental prostheses (RDPs) were included in this study.

The positions of the implants were determined by a positioning guide, fabricated as a copy of the setup or the removable full denture. The precise implant positions were clearly defined by titanium CT tubes (CT Tube, Camlog Biotechnologies, Wimsheim, Germany). The inner diameter of the CT tube fitted to the pilot drill of the implant system and guided the position of the first drilling. Implant planning was performed three dimensionally by a panoramic radiograph (Gendex OrthOralix 9200, KaVo Dental GmbH, Biberach, Germany) and a cephalometric radiograph (Orthopantomograph 10E, Sirona, Bensheim, Germany) in the mandible, by a cone beam computer tomography (DVT) (Galileos, Sirona, Bensheim, Germany) in the maxilla. Through a crestal incision, the implants (Screwline Promote Plus ø3.8 mm and/or ø4.3 mm; Camlog Biotechnologies, Wimsheim, Germany) were placed using a positioning guide with the CT-tube.

Four two-piece dental implants were placed nearly bilaterally in ten edentulous jaws (seven maxillae, three mandibles). The location and the implant diameter and length are shown in Table 1.

For the osseointegration of the implants 3 month in the mandible and 5 months in the maxillae were allowed. Four weeks after second-stage surgery, subsequently two different impression techniques were performed:

Technique 1 Transfer impression posts with plastic caps (Camlog) were screwed in the implants and an impression was taken with an individualized custom tray (Master Impression Tray, Water Pik, Ft. Collins, CO, USA) (Fig. 1). Following the removal of the impression from the mouth, the transfer impression caps were unscrewed from the implants, lab analogues (Camlog) were screwed thereto and they were repositioned into the plastic caps fixed in the impression. The implants were rinsed with 0.2 % chlorhexidine and healing caps were screwed into the implants.

Technique 2 On the stone casts produced by impression technique 1, pick-up impression posts were screwed in the lab analogues and splinted with acrylic resin bars (anaxAcryl RS, anaxdent GmbH, Stuttgart, Germany) with an edge length of 4×4 mm. The bars were sectioned in the center between the impression posts with a cutting wheel (width 0.5 mm). The impression posts with the resin bars were screwed in the respective implant of the respective patient (Fig. 2). The separations were examined for patency and reconnected with acrylic resin (anaxAcryl RS) in two sequences: first, the bars between the implants in the lateral area on the left- and the right-hand side, following 5-min polymerization of the resin; secondly, the bar between the implants in frontal area. After polymerization of the resin (5 min), the impression was made with an individual open-bite custom tray (Lightplast, Dreve Dentamid GmbH, Unna, Germany). The trans-occlusal screws were loosened after setting of the impression material and the impression was removed from the mouth. The lab analogues (Camlog) were screwed to the impression posts fixed in the impression. Again the implants were rinsed with 0.2 % chlorhexidine and healing caps were screwed into the implants.

Table 1 Location (FDI) and size of inserted implants

Patient	Position 1	Implant size	Position 2	Implant size	Position 3	Implant size	Position 4	Implant size
1 BR U	34	3.8/13	32	3.8/13	42	3.8/13	44	3.8/13
2 BR O	14	3.8/13	12	3.8/11	22	3.8/11	24	3.8/13
3 FG U	34	3.8/13	32	3.8/13	42	3.8/13	44	3.8/13
4 FG O	14	4.3/11	11	4.3/13	21	4.3/13	24	4.3/11
5WA U	34	4.3/13	32	4.3/13	42	4.3/13	44	4.3/13
6WA O	15	4.3/13	11	4.3/13	21	4.3/13	25	4.3/13
7 BK O	15	3.8/11	12	3.8/11	22	3.8/11	25	3.8/11
8 HI O	15	3.8/11	13	3.8/13	23	3.8/11	25	4.3/13
9 JJ O	15	3.8/13	11	3.8/13	21	3.8/13	25	3.8/13
10 LG O	14	3.8/13	11	3.8/11	21	3.8/11	24	3.8/13

All impressions were made with regular-body polyether impression material (Impregum, 3 M-Espe, Seefeld, Germany). Impressions remained in the mouth for 5 min, counted from the start of mixing [23]. Four hours after taking the impression [23] the casts were fabricated (Rocky Mountain Sahara; Klasse IV Dental GmbH, Augsburg, Germany). All casts were stored at room temperature for 2 weeks before measurement [24].

Scan bodies (Camlog) were seated on the lab analogues of the cast of patient 1 produced pursuant to impression technique 1 clockwise with a defined torque of 5 Ncm (Torque Control; Camlog) [21]. The cast was placed in a white-light scanner (Everest Scan Pro; KaVo, Biberach, Germany) for scanning the entire arch (Fig. 3).

When the first scan was completed, the object support was taken out of the scanner and the cast was removed from the object support. Each scan body was detached from the lab analogues one by one and reattached exactly into the same region on the lab analogues of the second stone cast, produced pursuant to impression technique 2, of patient 1. Again the scan bodies were fixed clockwise with a defined torque of 5 Ncm. The second stone cast was inserted into the object support and scanned again with data storage. Following this scan, the stone casts from patients 2 to 10 were processed in the same manner; hence, the Standard Tesselation Language (STL) data of 20 scans (patients 1–10 and respectively two stone casts produced by means of impression techniques 1 and 2) were available. As the dental stone used for the casts was specifically developed for the scanning technique, opaqueing with scan powder was not required [21, 22].

Evaluating the positions of the scan bodies and accordingly of the implants, the STL data were imported and processed with an inspection software (geomagic Qualify® 2012; Geomagic, Morrisville, USA) for data comparison. The scan of the stone cast produced pursuant to impression technique 1 was used as reference and compared with the stone cast produced by impression technique 2. To avoid errors caused by the jaw and the gingiva, all parts of the jaw were blanked out for superimposition of the two digital cast models. Only the distal scan body 1 of the stone casts in the first (maxilla) or third (mandible) quadrant was superimposed by the software (Fig. 4). The surface of each scan body was defined by about 40,250 triangles. The best fit of

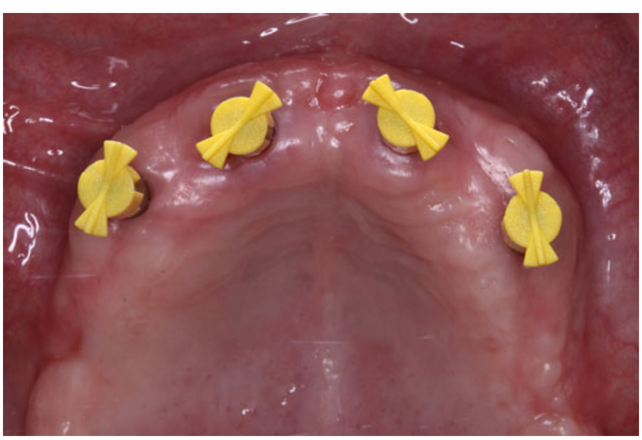

Fig. 1 Transfer impression posts with plastic caps screwed in the implants for the impression with closed tray

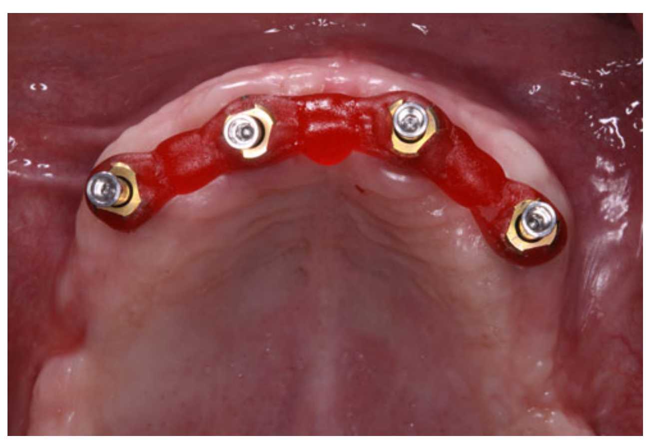

Fig. 2 Splinted pick-up impression copings in the implants for the impression with open tray

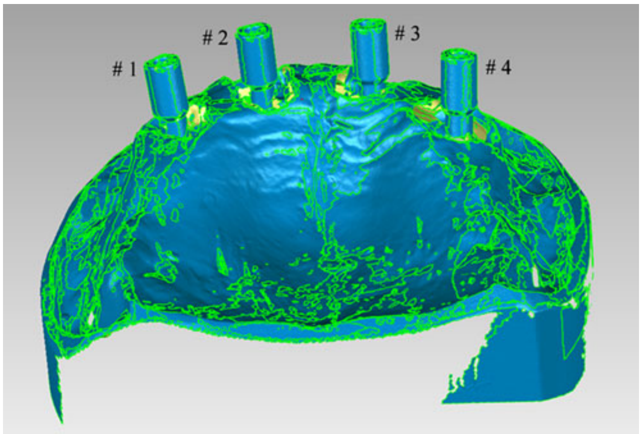

Fig. 3 Digitized model with scan bodies 1, 2, 3, and 4

scan body 1 was calculated by the geomagic Qualify® software. Additionally, the software calculated the mean discrepancy of scan body 1 of the two casts for each superimposition. This can be expected as the systematic error of the superimposition [21].

When the best fit of scan body 1 was found, the discrepancies of the three scan bodies 2, 3, and 4 were calculated by the inspection software, so the deviation between the two stone casts produced by impression technique 1 and 2 were calculated three dimensionally. This procedure was done with all ten patients.

The calculated discrepancies of the three scan bodies 2, 3, and 4 per patient were imported into a statistics program (SPSS 20.0, SPSS Inc., Chicago, USA). The distribution of the data was tested by the Kolmogorow–Smirnow test. Data were compared by the ANOVA test. The level of statistical significance was set at 5 %.

All bar-retained reconstructions were fabricated on the casts produced by impression technique 2 (splinted pick-up technique). The precise fit of the ten bars was tested with the Sheffield test on both casts (produced by impression techniques 1 and 2) and in the mouth. Therefore, the bars were fixed only with one prosthodontic screw (Camlog) in the distal lab analogue or implant 1 (first quadrant in the maxilla and third quadrant in the mandible) of the stone casts or in the mouth. The fit of the bars on the lab analogues or implants 2–4 was evaluated by one prosthodontist with “poor,” “acceptable,” or “good” and the results were noted. “Poor” was noted when the misfit was seen with magnification glasses×2.0, “acceptable” when the misfit was seen with magnification glasses ×4.3, and “good” when no misfit was seen with magnification glasses×4.3 (clinical experience of the prosthodontist). At this, the test on the two different casts was blinded.

Results

Superimposition of scan body 1 exhibited discrepancies of 14 μm (±4 μm).

For the maxillae, the calculated pooled mean discrepancies of scan body 2 was 233 μm (±84), 324 μm (±85) for scan body 3, and 412 μm (±104) for scan body 4.

For the mandible, the calculated pooled mean discrepancies of scan body 2 was 96 μm (±18), 183 μm (±17) for scan body 3, and 259 μm (±45) for scan body 4 (Table 2).

For both, maxilla and mandible, the calculated pooled mean discrepancies of scan body 2 was 192 μm (±96), 282 μm (±97) for scan body 3, and 366 μm (±114) for scan body 4 (Fig. 5).

Comparing the data with the span between scan bodies 1–2, 1–3, and 1–4, a linear regression line could be drawn to show the dependency between the misfit and the length of the span (Fig. 6).

The data were normally distributed; therefore, the ANOVA test could be used for the statistical analyses. The two techniques showed statistically significant results concerning discrepancy. The discrepancies of scan body 2 differed significantly from that of scan body 4 ($p \leq 0.010$; Scheffe test). There was no significant discrepancies between scan bodies 2 to 3 ($p=0.224$; Scheffe test) and also scan bodies 3 to 4 ($p=0.332$; Scheffe test) (Fig. 5).

The fit of the bars on the casts produced by impression technique 2 (splinted pick-up technique) and in the mouth

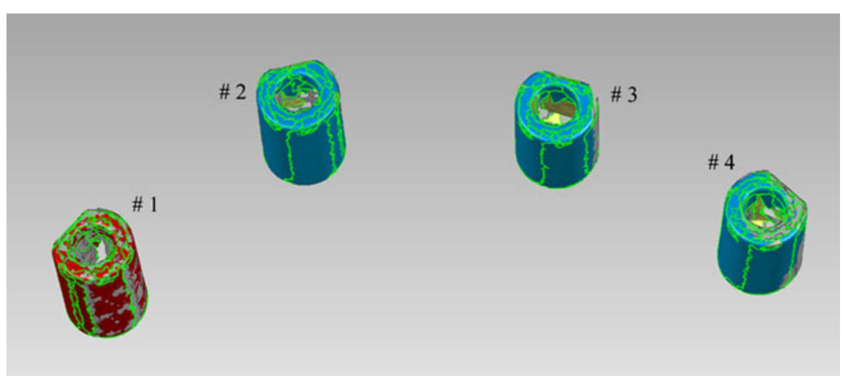

Fig. 4 Scan body 1 superimpositioned using the inspection software

Table 2 Calculated mean discrepancies of scan bodies 2, 3, and 4 of all patients; scan body 1 shows the systematic error

Scan body	Maxilla n=7 (µm)	Mandible n=3 (µm)	Difference Maxilla–mandible (µm)	Total n=10 (µm)
1	13	18	5	14
2	233	96	137	192
3	324	183	141	282
4	412	259	153	366
Mean of 2, 3, 4	323	179	144	280

was stated by the prosthodontist ten times with good. The fit of the bars on the casts produced by impression technique 1 (transfer technique) was stated four times with acceptable, six times with poor.

Discussion

There was a difference between the two resulting master casts, and therefore the accuracy of the transferred implants produced pursuant to the splinted pick-up technique and the transfer technique, so the working hypothesis can be accepted. However, there was only a statistically significant difference between scan bodies 2–4, no statistically significant differences were found between scan bodies 2–3 and 3–4. Also, no preference to the accuracy of one of the two impression techniques can be given because of the measured misfit.

These results are corresponding to most available literature. To date there are only in vitro studies which compare the transfer to the pick-up technique [6, 7, 20, 21, 25–34]. Eight of these studies showed differences between impressions with the transfer and the pick-up technique. Seven of these studies found nearly no differences between the two techniques.

In a review, Lee reported using the pick-up or transfer technique to produce useful results for three implants at the most. For more than three implants, the impression technique with splinted impression posts and open-bite trays should be used to ensure a precise transfer of the implant position to the stone cast [11]. Therefore it can hypothesized that the splinted pick-up technique provides the better results in this clinical study. This was also stated by the evaluation of the supra-reconstruction on the different casts and in the mouth by the prosthodontist. However, it seems to be obvious, that the fit on the casts of the splinted technique was superior because the supra-reconstructions were fabricated on these casts. The fit of the bar reconstruction in the mouth was tested clinically with the Sheffield test. All bars fitted nearly passive and therefore it can be assumed that the fit of bar reconstructions of four implants in an edentulous ridge can be achieved by a splinted pick-up impression technique. From a critical point of view, the differences between the fit of the supra reconstruction on the two different casts (evaluated by the prosthodontist) showed only the differences between the two impression techniques. However, no conclusion can be drawn because of the accuracy of the two techniques and therefore no statement can be given to the fit of bar reconstructions when fabricated by the transfer technique.

Also the accuracy of the impression of intra-oral implants depends, besides the number, on the angulation of the implants to each other [6–8]. If multiple implants are inserted parallel to each other, there will be no horizontal shift in the transfer; if the implants are positioned angled, the rotational misfit leads to a horizontal discrepancy. An

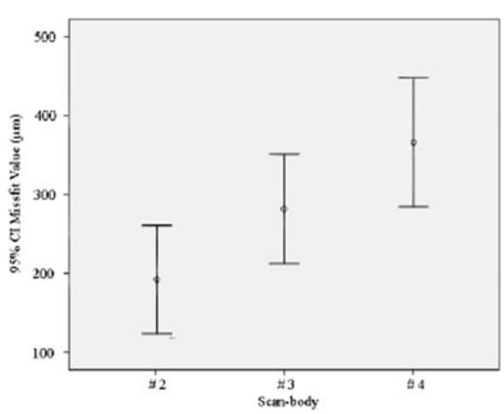

Fig. 5 Mean discrepancies of scan bodies 2, 3, and 4 (bars represent 95 % of calculated data)

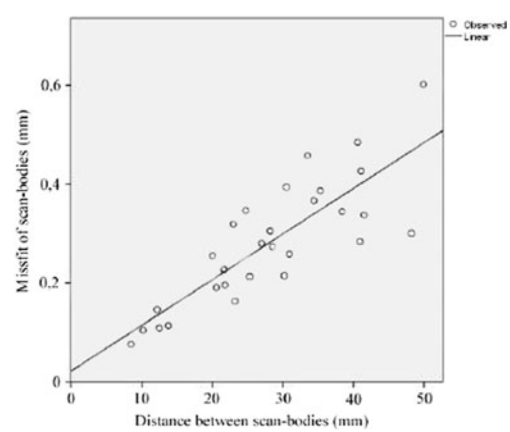

Fig. 6 Linear regression line showing the dependency between the misfit and the length of the span between the implants

angulation of 20° and a rotational freedom of 1.5° can result in a horizontal misfit of up to 127 μm [35]. The implants in this study were placed with the surgical positioning guide correlated to the anatomic conditions of the edentulous jaws. In the mandibles, the implants were placed almost parallel, in the maxillae divergent due to the shape of the alveolar bone. This could be the reason why the discrepancies between the upper and the lower jaws differed 137 μm in scan body 2, 141 μm in scan body 3, and 153 μm in scan body 4. However, the number of only three mandibles was very small and the angulations of the four implants in this investigation were not measured.

The scans with the white light scanner, described above, were sufficiently precise. The systematic error was quoted with 5 μm for scanning these stone models [21]. KaVo stated a systematic error for the Everest Scan Pro scanning, a complete jaw of 8–20 μm (personal communication). The same scanner was used for a previous study with a comparable experimental setup. However, the trueness was measured to be 12 μm and the precision was calculated to be 5 μm.

Del Corso reported a systematic error between 14 and 21 μm, simulating an intra-oral data capturing in an in vitro simulation [36]. Mehl described the systematic error of extra oral optical measurement systems for scanning stone casts to be 20 μm or less [37].

For the superimposition of the two models, resulting pursuant of the two impression techniques, scan bodies 2, 3, and 4 and all parts of the alveolar crest were blanked out. Only scan body 1 was superimposed. The scan bodies have been designed for digitizing of the inner configuration of dental implants and their shape is designed for precise superimposition of the space coordinates X, Y, and Z [21, 22]. The systematic error of the superimposition of scan body 1 in this clinical study with the used software (geomagic Qualify®) was 14 μm. In a previous in vitro study, the systematic error of the superimposition of these scan bodies was calculated with 12 μm by another inspection software (COMETInspect® plus 4.5 (Steinbichler Optotechnik, Neubeuern, Germany)) [21].

It was noticeable that the discrepancies of the scan bodies in this study increased from scan bodies 2 to 3 and 4. Also the distances increased from scan bodies 1 to 2, 3, and 4. In a previous in vitro study, all data from scan bodies 2, 3, and 4 were pooled to calculate the mean discrepancy independent of the distances between the scan bodies [21]. In this study, a regression line was drawn from the discrepancies relating to the distances. It could be shown that there was almost a linear correlation. On the one hand, it is obvious that discrepancies due to a lack of precision of the transfer from the mouth to the stone cast lead to greater misfit as the span between the implants increases. On the other hand, a small error by the superimposition of scan body 1 would have a tremendous effect on the position of the other scan bodies, especially on scan body with the longest distance. In summary, the evaluated discrepancies in this study will be an addition of inaccuracy of the impression transfer and the error of the superimposition of scan body 1.

Comparing the data (discrepancy between transfer and splinted pick-up technique) from the in vitro study (44 μm) [21] to this in vivo study (280 μm), a huge difference of 236 μm becomes obvious. This shows that results of an in vitro study with defined conditions cannot be transferred directly into the clinical situation.

In summary, the discrepancies of 192 μm for scan body 2, 282 μm for scan body 3, and 366 μm for scan body 4 seem to be very high. Lee described in his review of in vitro studies discrepancies at the connection level from 0.11 to 136 μm [11]. However, the data of the presented study are means from the complete scan body misfit, beginning at the connection level up to the top. The discrepancy will increase as more coronal the measurements are performed.

Conclusions

Within the limitations of this clinical study, the following conclusions can be drawn:

1. Impression technique influences the accuracy of implant transfer.
2. Splinted pick-up technique showed significantly different results than transfer technique; however, due to this investigation, no technique can be preferred because of accuracy; referring to the clinical experience of the prosthodontist, the splinted pick-up technique will be favorable.
3. Delivering of long-span prosthodontic rehabilitations come along with higher misfit in comparison to short-span rehabilitations.

Conflict of interest The authors declare that they have no conflict of interest.

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