Accuracy of Impressions and Casts Using Different Implant Impression Techniques in a Multi-implant System with an Internal Hex Connection

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Purpose: *The aim of this study was to investigate the deviations of the implant positions of both impressions and casts using different impression materials and techniques. Furthermore, the existence of a correlation between the deviations of the impression and those of the cast was investigated.* ***Materials and Methods:*** *A reference model was fabricated with 5 Frialit-2 implants parallel to each other. In a standardized experimental setting, 5 stone casts were produced with 5 different techniques using polyether (A) or polyvinyl siloxane (B through E). In 3 groups, a direct technique was used with a medium-viscosity material or a putty-tray material in combination with a light-viscosity syringe material (A to C). In 2 groups, an indirect technique (either 1-step [group D] or 2-step [group E] was used with a putty-tray material in combination with a light-viscosity syringe material. The center-to-center distances were measured for impressions and casts in the horizontal plane using a computer-aided microscope, and the relative and absolute deviations compared to the reference model were calculated. Analysis of variance followed by the post-hoc Scheffé test (parametric data) or the Kruskal-Wallis test followed by pair-wise Mann-Whitney tests (nonparametric data) were used for statistical analyses. Deviations of impressions were compared with their respective casts using paired* t *tests and the Pearson correlation coefficient.* ***Results:*** *No significant differences for the relative deviations were found for impressions (−5 to −8 µm) or casts (+7 to +16 µm). Group E produced significantly higher absolute deviations for impressions (38 µm) and casts (39 µm) compared to the other groups (11 to 18 µm and 17 to 23 µm, respectively). A significant correlation between deviation of the impression and its respective cast was found for every group (*r *= 0.40 to 0.80) except group D.* ***Conclusions:*** *The distortions in the horizontal plane of the casts obtained from the impression techniques of groups A to D would probably not affect the clinical fit of implant-retained superstructures. Because of the high variation of deviations (−113 to +124 µm), the 2-step technique cannot be recommended. The method to measure both impression and cast provided a better understanding of how inaccuracies are caused.* INT J ORAL MAXILLOFAC IMPLANTS 2008;23:39–47

Key words: *dental implants, impression materials, impression technique, transfer coping*

Implant restoration offers an important and well-accepted treatment concept in dentistry. Increasing scientific evidence supports the use of osseointegrated implants for the oral rehabilitation of patients,[1–9] and the number of prosthetic restorations partially or totally retained by osseointegrated dental implants is steadily increasing. Accuracy of impressions and casts is of great importance for the fabrication of precisely fitting implant-retained prostheses and consequently for the long-term clinical success of these restorations.

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Two basic impression techniques are commonly used for the transfer of the implant positions from the intraoral situation to a working cast: the direct (open tray) technique and the indirect (closed tray) technique. In the direct technique, the transfer copings remain in the impression and have to be unscrewed before the impression can be removed from the mouth. In the indirect technique, the transfer copings are retained on the implants upon removal of the impression and have to be repositioned in their respective imprints of the impression.

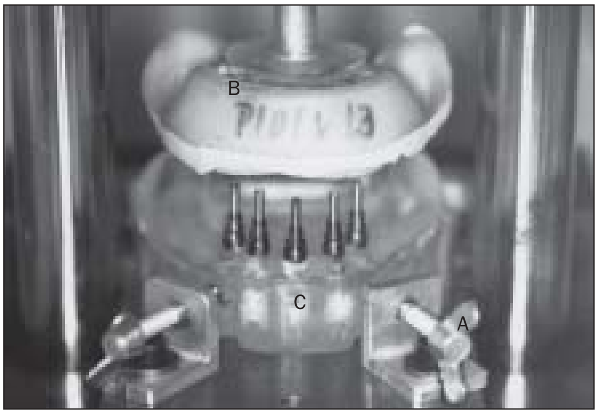


Fig 1 Impression tray/platform assembly with reference cast. Base platform (A) with cylindric posts secured to reference cast (C) and custom tray (B) connected with acrylic resin to the central screw of the upper platform.

Many in vitro investigations have investigated whether the accuracy of the direct technique could be improved by splinting the transfer copings. Different methods and materials have been tested to splint the transfer copings, such as impression plaster,[10,11] dual-cure acrylic resin,[10] autopolymerizing acrylic resin alone[10–16] or in combination with dental floss,[15,17–19] orthodontic wire,[15] prefabricated acrylic resin bars,[20] and carbon steel pins.[21] Furthermore, transfer copings have been directly connected with an acrylic resin custom tray.[12] To minimize shrinkage of the resin splint during polymerization, either the acrylic resin must be applied in an incremental application technique[12] or the completed splint must be sectioned between the copings with a thin disk and joined together again using a bead-brushing technique.[11]

The results of the studies on this topic have been inconsistent. In some studies splinting improved the accuracy of the resulting working cast,[12,13,21] but other investigators found no improvement compared to direct nonsplinted[11,15,18,22] or indirect techniques.[17–19,22] The use of airborne-particle-abraded transfer copings coated with an impression adhesive did not improve accuracy in comparison with splinting.[13,16]

The indirect technique is less complicated and has some clinical advantages.[23] However, inaccuracies can result if the transfer copings are not replaced correctly into the impression,[17] and accuracy can be influenced by the design of the transfer copings.[24] Some investigations have found the indirect technique to be less accurate[14,25,26] than the direct technique, but other authors have found no significant difference between the 2 techniques.[18,22] In response to investigations reporting problems correctly replacing the impression copings into the impression,[17,24] some manufacturers developed 2-piece transfer systems in which a resin transfer cap is placed onto the transfer coping prior to impression taking. The resin cap remains in the impression and should improve the accuracy of repositioning the transfer coping and the resulting cast.[19,27] Using this technique resulted in dimensional accuracy similar to that achieved with a nonsplinted direct technique[23] or even a splinted direct technique[19] or an indirect technique.[27] Of the impression materials that have been investigated, polyether and addition-cured silicone (polyvinyl siloxane) resulted in the most accurate casts.[14,18,27,28]

In most cited studies accuracy of the impression technique was evaluated indirectly by measuring dimensional changes of the casts in relation to a reference cast.[13–15,17,18,22,23,26–28] Alternatively, the distortion[10–12,21] or fit[19,25] of a fabricated superstructure on the resulting casts was assessed and compared to the distortion or fit of the superstructure on the reference cast.

If both the impression and cast could be included in the assessment of the dimensional changes that occur in the fabrication of the casts, the development of inaccuracies with different techniques could be better understood. The aim of this study was to investigate the deviations of the implant positions of both impressions and casts using different impression materials and techniques. Furthermore, the existence of a correlation between the deviations of the impression and those of the cast was investigated.

MATERIALS AND METHODS

Fabrication of the Reference Cast

Based on a patient case, a reference model of an edentulous mandible was produced in a transparent acrylic resin (Palapress; Heraeus Kulzer, Hanau, Germany), including 5 Frialit-2 implants (15 mm long and 4.5 mm wide; Dentsply Friadent, Mannheim, Germany) parallel to each other in the interforaminal region (Fig 1).

Fabrication of Custom Trays

A cast analogous to the reference model was poured in type IV stone (Moldastone; Heraeus Kulzer) prepared to the manufacturer's specifications and was utilized for the production of the custom trays. A silicone spacer (Provil P soft; Heraeus Kulzer) was placed on the cast in the interforaminal region to ensure a uniform thickness of the impression material. The custom trays were made from 3-mm-thick light-cured resin plates (Palatray; Heraeus Kulzer). To allow access to the transfer coping screws, the trays were perforated for the direct technique in the interforaminal region. Baseplate wax was positioned over the

Table 1 Characteristics of the 5 Investigated Impression Procedures

Group	Viscosity	Technique	Material	Brand (Manufacturer)
A	Monophase	Direct	Polyether	Impregum Penta (3M Espe, Seefeld, Germany)
B	Monophase	Direct	Polyvinyl siloxane	Monopren transfer (Kettenbach, Eschenburg, Germany)
C	Putty/Wash	Direct	Polyvinyl siloxane	Provil P soft/Provil M C.D. (Heraeus Kulzer, Hanau, Germany)
D	Putty/Wash	Indirect	Polyvinyl siloxane	Provil P soft/Provil M C.D. (Heraeus Kulzer, Hanau, Germany)
E	Putty/Wash (2-step)	Indirect	Polyvinyl siloxane	Provil P soft/Provil M C.D. (Heraeus Kulzer, Hanau, Germany)

access window to maintain similar dimensions superior to the transfer coping for both the direct and indirect techniques.

Impression Procedures

To standardize the impression procedures, the reference model was secured to a platform with 2 parallel cylindric posts 30 mm in diameter to provide a consistent path of insertion and removal (Fig 1). A third cylindric post was used to provide a constant stopping point for the impression tray platform. The custom trays were connected to the central screw of the upper platform with acrylic resin in an optimal position, enabling a uniform thickness of 3 mm for the impression material for all experiments.

Five different groups of impression procedures were investigated (Table 1). In 3 groups (A to C), an open-tray (direct) technique was performed with either a medium-viscosity material (A, B) or a putty-tray material in combination with a light-viscosity syringe material (C). In the other 2 groups, the closed-tray (indirect) technique was used with a putty-tray material in combination with a light-viscosity syringe material either in a 1-step (D) or 2-step technique (E). As described by Lehmann and Lindemann,[29] the first impression of the 2-step technique was made using only the putty-tray material. Then the impression was separated from the reference model, undercuts were removed, and 2 grooves 1 mm wide and 1 mm deep were cut into the putty material at the mesial and distal sides of the imprints of the copings. After application of the syringe material around the transfer copings, the tray with the putty material was replaced onto the reference model, and a force of 200 N was applied for 7 seconds.[29] The material was then allowed to set without the application of any additional force.

For each group 5 impressions were made and measured after 24 hours. They were then poured with vacuum-mixed type IV dental stone (Moldastone; Heraeus Kulzer) prepared to the manufacturer's specifications (150 g powder/31 mL water). The resulting master casts were measured 24 hours after measurement of the impression. The impression was measured for a second time immediately after removal of the impression from the fabricated cast. Tapered transfer copings with either a long screw (OL 1615) for the direct technique or a short screw (4305) for the indirect technique were used for all impressions. When the transfer copings were connected with the implants or the analogs (D4.5 45-4050), a manual torque controller with the recommended force of 14 Ncm was used to standardize the force.

Assessment of Accuracy

To measure the center-to-center distances between the 5 implants in the horizontal plane, a computer-aided microscope MS 2 in combination with the measuring software OMS (Uhl, Wetzlar, Germany) was used to determine the coordinates of the center points of the implants. The Pythagorean theorem was used to calculate the distance between the coordinates of 2 implants (Fig 2).

The measuring capability of the microscope was < 1 µm. To determine the measuring accuracy in the actual experimental setting, the distances between the 5 implants of the reference model were measured 15 times (Table 2). Between every measurement the reference model was removed from the motor-driven measuring table, and the position of the table was changed. The reference model was then repositioned. The resulting mean value was taken as the reference distance to compare the accuracy of the impressions and working casts. For evaluation of the accuracy, the 10 distances were categorized as short, medium, or long (Table 2).

To evaluate the dimensional changes of the impressions and casts, the deviations (shortening or lengthening) of the center-to-center distance between all implants were calculated (relative accu-

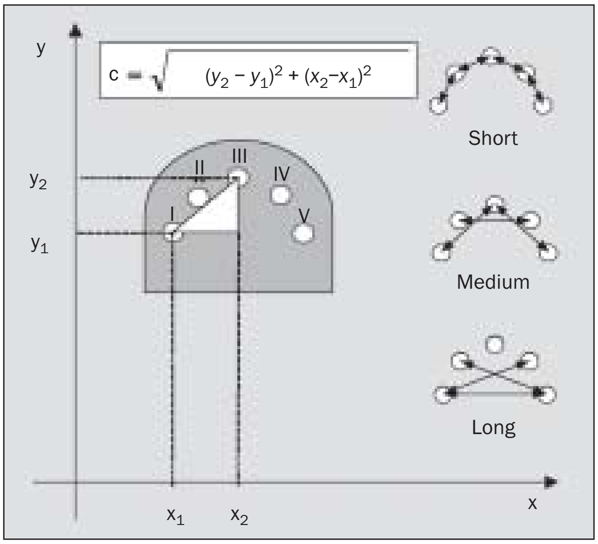


Fig 2 Center-to-center distance (c) between the implants was calculated using the Pythagorean theorem. The 10 resulting distances were grouped by length into subdivisions of short, medium, and long.

Table 2 Measuring Accuracy: Mean Values, Standard Deviation (SD), and Range of the 10 Measured Distances in μm Between the 5 Implants of the Reference Cast

	Mean (n = 15)	SD	Range
Short			
I → II	9,550	4	−5 to 10
II → III	9,925	5	−11 to 9
III → IV	8,872	5	−8 to 11
IV → V	9,057	6	−8 to 13
Medium			
I → III	18,903	4	−8 to 7
II → IV	17,552	5	−10 to 9
III → V	17,233	6	−11 to 7
Long			
I → IV	25,005	5	−10 to 8
I → V	23,992	4	−6 to 8
II → V	29,278	4	−8 to 8

racy), and the absolute values of the deviations were used to analyze the overall accuracy of the investigated technique (absolute accuracy).

Statistical Analysis

The data were analyzed for normal distribution with the Kolmogorov-Smirnov test. Analysis of variance (ANOVA) followed by the post-hoc Scheffé test were used for parametric data, and the Kruskal-Wallis test followed by pairwise Mann-Whitney tests were used for nonparametric data. To compare the deviations of the impressions with those of their respective casts and also to compare the impressions before and after pouring, the paired *t* test was performed, and Pearson's correlation coefficient was calculated. $P < .05$ was considered significant, and $P < .01$ was considered highly significant.

Results

No significant differences in the deviations of impressions and casts could be detected between distances of short, medium, or long length for all 5 groups. Therefore, the following results are based on the measurements of all 10 distances between the 5 implants. The results of the relative deviation are shown in Fig 3. No significant differences were found between the 5 procedures, with mean values for the relative deviation ranging from –5 μm to –8 μm for the impressions and from +7 μm to +16 μm for the working casts (Table 3). The mean deviation of group B was significantly different from those of groups A and C for the impressions after pouring. The results of the absolute values of the deviations are shown in Fig 4. The 2-step direct impression procedure (group E) was significantly less accurate than the other groups, with median deviations approximately twice as high as those found for the other techniques (38 μm for the impression and 39 μm for the working cast; Table 4). The median absolute deviation of the group A impressions (11 μm) was significantly smaller than those of groups C (17 μm) or D (18 μm), but these significant differences could not be detected in the absolute deviations of the casts. The median deviations of the impression after pouring were significantly higher in group E (30 μm) compared with groups A (20 μm) and C (18 μm) and in group B (25 μm) compared with group C.

The differences between the relative deviations of the impression and the working cast were significant within each group (paired *t* test, Table 5). A significant correlation (Pearson's correlation coefficient) between the deviation of the impression and the deviation of the working cast was found for every group except group D (Fig 5, Table 5). Significant differences between the impression before and after pouring were only found in groups groups A, B, and C, but significant correlations between the deviations could be detected in each group (Table 5).

Fig 3 Box-plot diagram of the relative deviations (shortening or lengthening of the distances of the reference cast) for the impression, the working cast, and the impression after pouring for the 5 investigated procedures (for group codes, see Table 1).

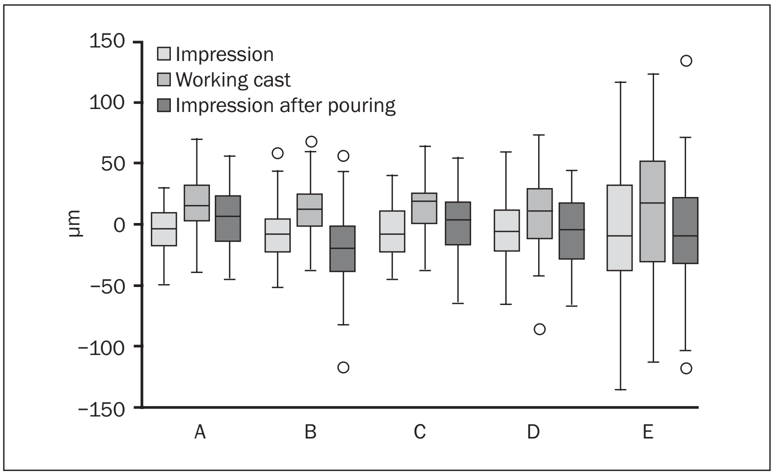
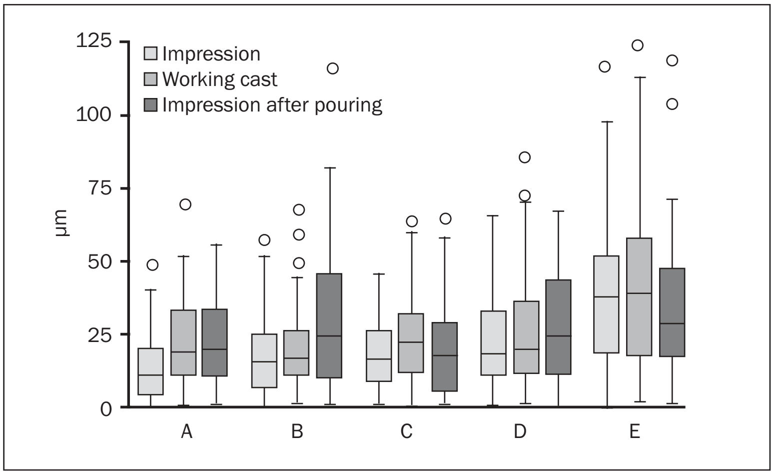


Table 3 Mean and SD for the Relative Accuracy (Shortening or Lengthening of the Reference Distances) for the 5 Impression Procedures in µm

	Group A		Group B		Group C		Group D		Group E	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Impression	−5	18[a]	−6	22[a]	−7	22[a]	−8	29[a]	−7	49[a]
Working cast	16	23[a]	13	22[a]	12	25[a]	7	31[a]	14	51[a]
Impression after pouring	4	25[a]	−22	35[b]	1	27[a]	−9	32[ab]	−4	47[ab]

Mean values followed by the same letter do not significantly differ (Scheffé test; $P < .05$).

Fig 4 Box-plot diagram of the absolute deviations for the impression, the working cast, and the impression after pouring for the 5 investigated procedures (for group codes, see Table 1).



DISCUSSION

The term *passive fit,* with regard to the relationship of a prosthetic superstructure to its underlying implant abutments, appears with increasing regularity in the literature. As yet, no definition or parameters have been established as to what constitutes a passive fit.[12]

The results of this study underline that even with standardized in vitro conditions the exact spatial reproduction of the implant positions in a working cast poured from an impression is not obtainable. The results of the mean relative deviations represent the typical inherent dimensional changes of the materials involved. The finding that the deviations in the horizontal plane are not affected by increased distances of the implant positions is in accordance with other studies.[13,16,17,23,28]

The median absolute distortion values of master casts and impressions measured in this investigation without splinting the transfer copings were small,

Table 4 Median of the Absolute Accuracy (Absolute Value of Deviation) in μm and Statistically Significant Differences Between the 5 Impression Procedures

	Impression					Working cast					Impression after pouring				
Groups	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
Median	11	15	17	18	38	19	17	23	20	39	20	25	18	25	30
Pair-wise Mann-Whitney test															
B	NS					NS					NS				
C	*	NS				NS	NS				NS	*			
D	**	NS	NS			NS	NS	NS			NS	NS	NS		
E	**	**	**	**		**	**	**	**		**	NS	**	NS	
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E

NS = nonsignificant; **Statistically significant at .01 level of significance, *statistically significant at .05 level of significance.

Table 5 Correlation Analysis of the Relative Deviations: Impression vs Working Cast and Impression Before vs After Pouring

	Group A	**Group B**	**Group C**	**Group D**	**Group E**
Impression vs working cast					
P (paired *t* test)	.001	.001	.001	.025	.001
r (Pearson correlation coefficient)	0.40**	0.58**	0.40**	−0.14	0.80**
Impression before vs after pouring					
P (paired *t* test)	.006	.002	.041	.722	.217
r (Pearson correlation coefficient)	0.47**	0.35*	0.37**	0.52**	0.91**

**Statistically significant at .01 level of significance, *statistically significant at .05 level of significance.

especially those of groups A to D (11 to 23 μm). They were comparable to those measured by Wee[28] for casts fabricated with a direct nonsplinted impression technique using polyether or polyvinyl siloxane. Vigolo et al[13,16] found mean distortions in the horizontal plane of 15 to 78 μm for direct polyether impressions using either splinted, nonsplinted, or nonsplinted transfer copings with a modified surface. In other investigations, mean values ranged from 20 to 180 μm[17] or 41 to 67 μm[15] or were about 100 μm.[27] It has also been shown that inaccuracies increase with decreasing implant angulation (90 to 65 degrees) in relation to the horizontal surface.[14] Thus, the aforementioned distortion values would have probably been larger if the implants had not been placed parallel to each other.

In this investigation, using polyether or polyvinyl siloxane of different viscosities in a 1-step direct or indirect technique resulted in very precise casts with no significant differences between the materials. Polyether and polyvinyl siloxane are the recommended materials for implant impressions[23,24,27,30] and have performed better then polysulfide[28] or hydrocolloid.[27] Although polyether had been the material of choice in most investigations, polyvinyl siloxane has become more popular in recent years, especially in a putty/wash technique[18,19] or when using stock trays.[23] It has properties ideally suited for coping transfer, such as excellent resistance to permanent deformation, low strain under compression, and high initial tear resistance.[18]

As the indirect technique is clinically less difficult and helps to save chair time,[15,21] it has increased in popularity in private practice. It has to be considered when using this technique that precision will also depend on the design of the transfer copings. Liou et al[24] found significant differences between the angular deviations of 3 different types of transfer copings that were replaced in impressions made from polyether or polyvinyl siloxane, whereas no significant differences were found between the 2 impression materials.

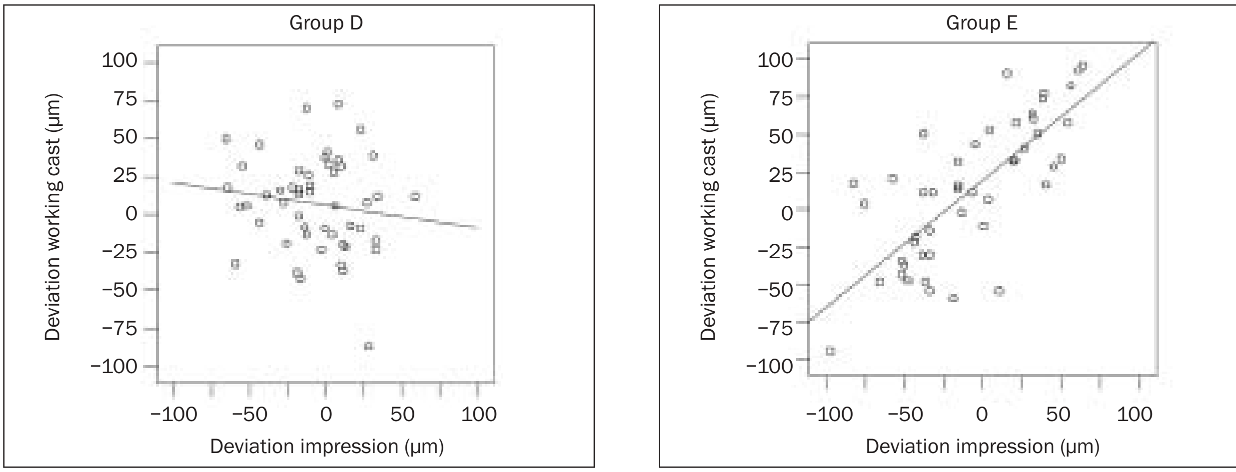


Fig 5 Correlation between the relative deviation of the impression and the working cast illustrated by 2 scatterplots. Whereas in group D no correlation was found ($r = -0.14$), a highly significant correlation was found in group E ($r = 0.80$**).

Furthermore, machining tolerances between mating implant surfaces can contribute to inaccuracies in the fabrication of working casts. There is little information in the literature on machining tolerances of implant components. High tolerances in the range of the discrepancies found in this investigation have been reported for implants with an external-hex connection.[31,32] Obviously, they will be different for the various implant systems and will be an unknown variable in the measurement process.

The only variable between groups C and D in this study was the technique used (direct or indirect)—tray design, impression material, and implant components were the same. Also, the distortions for both impressions and casts were almost identical in these 2 groups. But remarkably, the correlation analysis revealed that, although identical in magnitude, the distortions of the casts fabricated using the direct technique were also, like those in groups A and B, significantly correlated to the deviations of the impressions ($r = 0.40$, $P = .004$), whereas the distortions of the casts fabricated using the indirect technique were not related to the distortions of the impressions ($r = -0.14$, $P = .340$) and were probably caused by replacing the copings back into the impression. In this respect group E served as a "negative control" because it had to be expected that larger distortions of the impression would occur when using a 2-step correction technique.[29] The correlation analysis illustrates that the initial distortion of the impression dominated any inaccuracies caused by replacing the copings ($r = 0.80$, $P < .001$; Fig 5) and that in this indirect technique, contrary to group D, the deviations of impression and cast were highly correlated. This demonstrates that the introduced method of measuring and correlating the deviations in impression and cast improves the understanding and evaluation of the complex procedure of implant position transfer. For further improvement, vertical and angular discrepancies should be included in the measurement process.

An alternative method to evaluate the accuracy of a working cast for an implant superstructure produced by different impression techniques is to use strain gauges for measuring the stress introduced in a "master framework" connected to the abutments of the respective working cast.[10–12,21] One difficulty of this method is the fabrication of the "neutral" reference model: Even when it is fabricated with the framework already completed and attached to the abutment-implant complex, residual stresses were measured when the framework was again connected to the reference model.[11,21] It is also difficult to relate the measured strain values to clinical parameters. Inturregui et al[11] found that a load of about 2 kg produced strain equal to the maximum recorded values in his investigation of a 2-implant model. Millington et al[33] measured stress of a superstructure screwed onto 4 implants introduced by a certain misfit at 1 of the abutments. They found that even in a very simplified in vitro model, moving a certain misfit from an intermediate to an end abutment resulted in totally different stress distributions and strain values. In vivo, the stress introduced by a certain misfit will be influenced by many other components, such as the locations, lengths, and number of implants; the material of the superstructure, and the quality of the bone.[33]

The most challenging task is to evaluate the measured strain values or inaccuracies of impressions and casts for clinical consequences. According to Wee et al, who wrote in 1999 a comprehensive review on strategies to achieve fit in implant prosthodontics, the concept that complications may result from framework misfit appears logical in theory but has not been scientifically proven.[30] Although most authors now emphasize that a "passive fit" of a multi-implant superstructure cannot be achieved, the amount of misfit and resultant stress that can be clinically accepted is still unknown.

Only a few studies have addressed this topic in vivo. Michaels et al evaluated misfitting implant frameworks using a white rabbit tibia model and did not find any significant evidence of implant integration failure.[34] In another animal study, using a primate model to evaluate misfitting implant frameworks, Carr et al found that with no functional loading misfit even improved the quality of the surrounding bone.[35] Miyata et al showed in a histologic monkey study that occlusal overload could cause peri-implant bone resorption when it exceeded a certain level.[36]

Jemt and Book investigated the correlation between prosthesis misfit and marginal bone loss in 2 groups of patients with implant-retained prosthesis in the maxilla.[37] They used an alternative method to measure the coordinates of the center points of implants—the 3-dimensional photogrammetry—which can be applied intraorally.[38,39] This method can be utilized for the fabrication of multiple implant frameworks[40] but is limited to framework fabrication techniques based on a digital platform. It was recently demonstrated that a precision comparable to that of conventional implant impression procedures can be achieved with 3-dimensional photogrammetry.[41]

The study of Jemt and Book was performed prospectively by correlating marginal bone loss during the first year in function and the fit of the fixed prosthesis at the time of placement in 1 patient group and retrospectively by comparing marginal bone loss with the fit of the prostheses 5 years after abutment connection surgery in the second patient group. Mean center-point misfit was about 100 μm in both groups, up to a maximum of 275 μm. No statistical correlation between change of bone level and different parameters of misfit were observed in either group. Furthermore, the authors concluded that the similar distortions in the 2 groups indicated that the implants seemed to be stable and did not move under the load caused by prosthesis misfit, even after several years in function.[37]

Taking this into consideration, the distortions in the horizontal plane found in this investigation seem clinically negligible. Minimal but statistically significant differences between groups A to D measurable in the impression could not be detected again in the casts. The 2-step indirect technique, preferred by some clinicians for a combined tooth-implant abutment transfer, cannot be recommended because of the high variation of deviations (–113 to +124 μm). Although some significant differences could be measured between the impressions before and after pouring, with mean absolute distortion values ranging only from 18 to 30 μm, the fabrication of a second cast of comparable accuracy when needed seems possible. The dimensional discrepancies found in this investigation could be at least partially compensated by cementation of implant superstructures[42] or the intraoral bonding of electroplated gold copings to a cast framework.[43]

CONCLUSIONS

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

1. The exact reproduction of the implant positions in a cast obtained from an impression was not possible even under idealized and standardized conditions in the horizontal plane. The distortions of the casts obtained from the impression techniques of groups A through D would probably not affect the clinical success of implant-retained superstructures.
2. Because of the high variation of deviations (range, –113 to +124 μm), the 2-step indirect technique (E) cannot be recommended.
3. The introduction of a method to include both impression and cast in accuracy measurement provided a better knowledge of how inaccuracies occur (eg, whether they were caused primarily by the impression itself or by the process of repositioning the transfer copings).

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