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ORIGINAL ARTICLE

Evaluation of impression accuracy for a four-implant mandibular model—a digital approach

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Abstract Implant-supported prosthodontics requires precise impressions to achieve a passive fit. Since the early 1990s, in vitro studies comparing different implant impression techniques were performed, capturing the data mostly mechanically. The purpose of this study was to evaluate the accuracy of three different impression techniques digitally. Dental implants were inserted bilaterally in ten polymer lower-arch models at the positions of the first molars and canines. From each original model, three different impressions (A, transfer; B, pick-up; and C, splinted pick-up) were taken. Scan-bodies were mounted on the implants of the polymer and on the lab analogues of the stone models and digitized. The scan-body in position 36 (FDI) of the digitized original and master casts were each superimposed, and the deviations of the remaining three scan-bodies were measured three-dimensionally. The systematic error of digitizing the models was 13 μm for the polymer and 5 μm for the stone model. The mean discrepancies of the original model to the stone casts were 124 μm (±34) μm for the transfer technique, 116 (±46) μm for the pick-up technique, and 80 (±25) μm for the splinted pick-up technique. There were statistically significant discrepancies between the evaluated impression techniques ($p \leq 0.025$; ANOVA test). The splinted pick-up impression showed the least deviation between original and stone model; transfer and pick-up techniques showed similar results. 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 a 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]. Besides the use of various casting techniques can be decisive for the precision [14].

Since the early 1990s, in vitro studies have analyzed different impression techniques (indirect technique with closed tray, direct technique with open tray, 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-join connection. The cone connection was stated to show favorable seal and stability between implant and abutment; however, this was refuted by several authors [15–17]. A more precise, reproducible positioning of abutments or impression posts is, however, obtained as a result of a butt-join abutment connection [18]. Recent studies have investigated the accuracy of impressions with implants exhibiting internal implant-abutment connections [6, 19–21].

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

The goal of this study was to compare three different impression techniques (transfer-, pick-up-, and splinted pick-up-technique) of four implants with an internal butt-join abutment connection inserted in an edentulous lower-jaw model. Both the stone casts resulting from the impressions and the original model were recorded digitally and compared.

It was hypothesized that different impression techniques will influence the accuracy of the resulting master models.

Materials and methods

Four two-piece dental implants (Screwline Promote ø4.3/13 mm; Camlog Biotechnologies, Wimsheim, Germany) were placed at the sites of the first molars and canines bilaterally in ten edentulous mandibular models (B-3 NM J UK; Frasaco, Tettnang, Germany). The implants were placed non-parallel free-handed with a lingual angulation in FDI-positions 36 and 46, simulating a common clinical situation. Subsequently, three 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 original model, the transfer impression caps were unscrewed from the original model; lab analogues (Camlog) were screwed thereto, and they were repositioned into the plastic caps fixed in the impression.

Technique 2: Screw-fixed pick-up impression posts (Camlog) were screwed in the implants, and an impression was taken with an open-bite custom tray (Fig. 2). After setting-time of the impression material, the trans-occlusal screws were loosened and the impression removed from the original model. The lab analogues (Camlog) were screwed to the impression posts fixed in the impression, thereby the lab analogues were held with a hemostatic forceps, to minimize the chance of accidental displacement [22].

Technique 3: On the stone casts produced by impression technique 2, 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 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 model (Fig. 3). The separations were examined for patency and reconnected with acrylic resin (anaxAcryl RS) in two sequences: first, the bar between the implants in areas 36, 33 and 43, 46; following 5-min hardening of the resin; second, the bar between the implants in areas 33, and 43. After polymerization of the resin (5 min), the impression was made with an open-bite custom tray. The trans-occlusal screws were loosened after setting of the impression material, and the impression was removed from the original model. The lab analogues (Camlog) were screwed to the impression posts fixed in the impression.

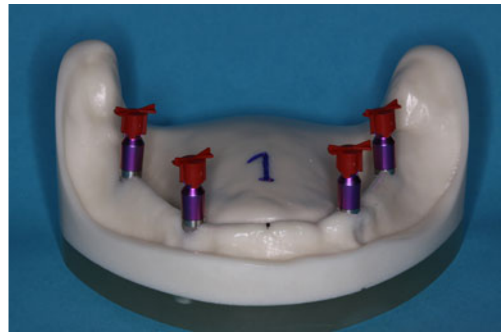

Fig. 1 Original polymer model with transfer impression copings

Fig. 2 Original polymer model with pick-up impression copings

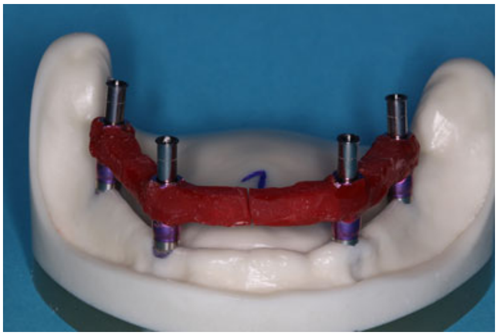

Fig. 3 Original polymer model with splinted pick-up impression copings (before splinting)

All impressions were made with regular-body polyether impression material (Impregum, 3 M-Espe, Seefeld, Germany). Impressions remained on the model for 8 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 [22].

Cover screws (Camlog) were seated on the dental implants in the Frasaco model (original model), which was matted by applying contrast spray (Met-L-Check Cleaner; Met-L-Check, Santa Monica, USA). The applied contrast spray was used because of its control and better measurability. In unpublished pilot studies, the authors determined that Met-L-Check Cleaner made uniform layers of approximately 10 μm while other tested sprays produced layers of up to 100 μm. The cover screws were removed, and scan-bodies (Camlog) were seated on the implants clockwise with a defined torque of 5 Ncm (torque control; Camlog) (personal communication with Camlog Biotechnologies). The original model was placed in a white-light scanner (Everest Scan Pro; KaVo, Biberach, Germany) for scanning the entire lower arch (Fig. 4).

When the first scan was completed, the object support was taken out of the scanner and the original model was removed from the object support. Each scan-body was detached from the implants one by one and reattached exactly into the same region on the lab analogues of the stone cast, produced pursuant to impression technique 1, clockwise at a defined torque of 5 Ncm. The stone cast was inserted into the object support and scanned again with data storage. Following this scan, the stone casts produced by means of impression techniques 2 und 3 were processed in the same manner. As the dental stone used for the cast was specifically developed for the scanning technique, opaqueing with scan powder was not required. This was repeated with the original model nos. 2–10 and the corresponding casts, hence the STL data (standard tesselation language) of 40 scans (original model nos. 1–10 and respectively three stone casts produced by means of impression techniques 1, 2, und 3) were available.

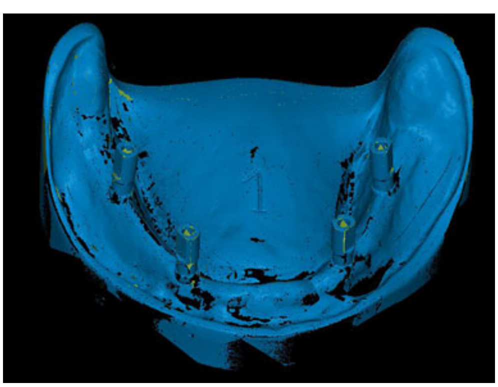

Fig. 4 Digitized original model with scan-bodies

In a previous study, the systematic error of digitizing the polymer and the stone model was calculated. Results of 13 (±3 μm) for the original model and 5 (±2 μm) for the lab casts were found [24].

Evaluating the positions of the scan-bodies and accordingly of the implants the STL data were imported and processed with an inspection software (COMETInspect® plus 4.5; Steinbichler Optotechnik, Neubeuern, Germany) for data comparison. The scan of the original model (control) was used as reference and compared with the three stone cast models produced by impression techniques 1, 2, und 3. To avoid errors caused by the jaw and the gingiva, all parts of the jaw were blanked out for superimposition of the three digital cast models (target models 1–3). Only the scan-body of the control and the target models in region 36 were superimposed by the software (Fig. 5). The surface of each scan-body was defined by about 40.250 triangles. For the best fit, a three-run iterative approach (search radius, 1, 0.5, and 0.1 mm, and 5° search angle) was used. Additionally, the software calculated the mean discrepancy of the scan-body of the control model and the target model for each superimposition. This can be expected as the systematic error of the superimposition. When the best fit of region 36 was found, the discrepancies of the three scan-bodies in regions 33, 43, and 46 were calculated and the STL data were saved. For the calculation of the deviations, the STL data from the inspection software

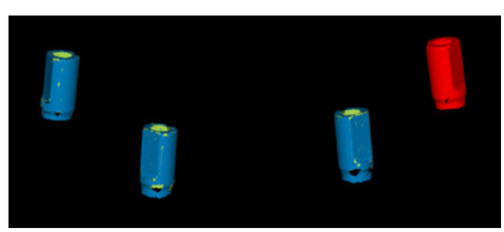

Fig. 5 Scan-body in region 36 superimposed using the inspection software

were imported into a program developed by the LMU Munich. With this software, the surface of each digitized model (equivalent to the four scan-bodies in regions 36, 33, 43, and 46) was defined by 45.000 measurement points. The software calculated the deviation of every measurement point between the original model and the stone models produced by impression techniques 1, 2, and 3 and calculated the mean discrepancy for each model three-dimensionally. This procedure was done with ten original models.

The calculated discrepancies of each 45.000 point per group were imported into a statistics program (SPSS 17.0, SPSS Inc., Chicago, USA). Data were compared by the ANOVA test and the Tamhane post hoc test. The level of statistical significance was set at 5%.

Results

Superimposition of the scan-bodies in position 36 exhibited discrepancies of 12 (±3 μm). The calculated pooled mean discrepancies of the scan-bodies in regions 33, 43, and 46 were 124 (±34 μm) for the transfer technique, 116 (±46 μm) for the pick-up technique, and 80 (±25 μm) for the splinted pick-up technique.

The pooled mean discrepancies of the scan-bodies in regions 33, 43, and 46 of the original models 1–10 and the stone casts, fabricated by the different impression techniques, are shown in Table 1.

The three techniques showed statistically significant results concerning accuracy. The discrepancies of the transfer technique differed significantly from that of the splinted pick-up technique ($p \leq 0.014$; Tamhane test). There were no significant discrepancies of the splinted to the non-splinted pick-up technique ($p \leq 0.120$; Tamhane test) and from the transfer to the non-splinted pick-up technique ($p \leq 0.981$; Tamhane test; Fig. 6).

Table 1 Calculated mean discrepancies of the scan-bodies in regions 33, 43, and 46 of the original models 1–10 and the stone casts, fabricated by the different impression techniques

Model	Transfer, μm	Pick-up, μm	Pick-up splinted, μm
1	114	57	82
2	117	88	109
3	79	158	46
4	149	135	74
5	153	96	98
6	160	170	76
7	161	159	55
8	88	54	54
9	80	173	109
10	146	97	114
Mean	124	116	80

Discussion

The most accurate impression was the splinted pick-up technique; the non-splinted pick-up technique was more precise than the transfer technique, so the working hypothesis can be accepted. However, there were only statistically significant differences between the splinted pick-up and the transfer technique.

The results correspond to most available literature. There are studies which compare the transfer with the pick-up technique [6, 7, 21, 25–34]. Two of these studies showed more accurate impressions with the transfer; five showed better results with the pick-up technique. Seven of these studies found none of the two techniques to be superior. Also comparing the splinted and non-splinted pick-up techniques, some authors prefer the non-splinted impression posts [35, 36], while others showed that impressions that use splinted posts produce better results [6, 19, 21, 29, 37–39]. However, this is a controversial issue, as various studies found neither of the two techniques to be superior [14, 20, 25–28, 40].

In a review, Lee reported 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]. Also, the accuracy of the impression of intra-oral implants depends on, besides the number, the angulation of the implants to each other

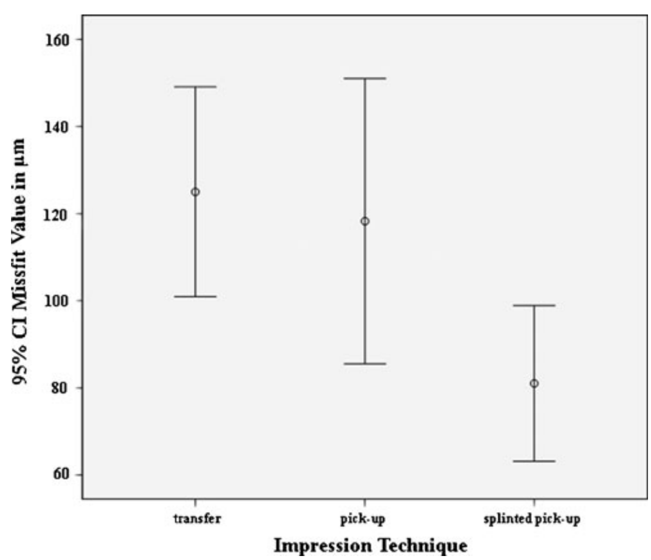

Fig. 6 Mean discrepancies of the different impression transfer techniques (*bars* representing 95% of calculated data)

[6–8]. The implants in this study were not placed parallel but free-handedly and correlated to the anatomic conditions of a lower jaw. Therefore, the ten original models were not identical. However, the study design of this in vitro study was very close to the clinical situation.

The scans with the white-light scanner, described above, with a systematic error of 13 μm for the original model and 5 μm for the stone model were sufficiently precise. KaVo states a systematic error for the Everest Scan Pro, scanning a complete jaw of 8–20 μm (personal communication). Del Corso reported a systematic error between 14 and 21 μm, simulating an intra-oral data capturing in an in vitro simulation [41]. Mehl described the systematic error of extra-oral optical measurement systems for scanning stone casts to be 20 μm or less [42].

For the superimposition of the control and the target models, the scan-bodies in regions 33, 43, and 46 and all parts of the alveolar crest of the control were blanked out. Only the scan-bodies in region 36 were 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 [24]. However, a small error by the superimposition of the scan-bodies in region 36 would have a tremendous effect on the position of the other scan-bodies, especially on the scan-body with the longest distance. Therefore, the authors pooled the discrepancies and calculated the mean instead of calculation the discrepancy of every scan-body. Hence, the measured results cannot be transferred directly into the clinical situation, but the measured data make different impression techniques evaluated in this study comparable.

Comparing three techniques of intra-oral implant impressions, there will be a question: Is the impression technique the only crucial factor for accurate transfer or are there other possibilities for misfit? Ma described tolerances between the implant and the impression copings, abutment replicas, and abutments from 22–100 μm [43]. These discrepancies are not only caused by machining tolerances but also by the different designs of the positional indexes [44]. The positional index is dependent on the internal and external implant-abutment connection [45]. Semper described the rotational freedom of abutments showing three different geometric patterns from 1.4° to 3.7° [46]. Based on these data, an implant with an internal connection showing rotational freedom of 1.4° was used in this study.

If multiple implants are parallel-inserted, there will be no horizontal shift in the transfer; if the implants are positioned angled, the rotational misfit leads to a horizontal discrepancy. An angulation of 20° and a rotational freedom of 1.5° can result in a horizontal misfit of up to 127 μm [47]. Comparing the misfit of the three techniques (124 μm transfer technique, 116 μm pick-up technique, and 80 μm splinted pick-up technique), the results of the mentioned study are in the same range as the results of this study. The angulations of the four implants in this investigation were not measured, but the implants were not inserted parallel. Lee described in his review the discrepancies at the connection level from 0.11 to 136 μm [11]. 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 measurements are performed.

Conclusions

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

1. Impression technique influences the accuracy of implant transfer.
2. Splinted pick-up technique showed significantly more accurate results than transfer technique, whereas no statistical difference between the splinted and non-splinted pick-up techniques was observed.

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

References

1. Kan JY, Rungcharassaeng K, Bohsali K, Goodacre CJ, Lang BR (1999) Clinical methods for evaluating implant framework fit. J Prosthet Dent 81:7–13
2. Cheshire PD, Hobkirk JA (1996) An in vivo quantitative analysis of the fit of Nobel Biocare implant superstructures. J Oral Rehabil 23:782–789
3. Sahin S, Cehreli MC (2001) The significance of passive framework fit in implant prosthodontics: current status. Implant Dent 10:85–92
4. Kallus T, Bessing C (1994) Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5 years. Int J Oral Maxillofac Implant 9:169–178
5. Chee W, Jivraj S (2006) Impression techniques for implant dentistry. Br Dent J 201:429–432
6. Assuncao WG, Filho HG, Zaniquelli O (2004) Evaluation of transfer impressions for osseointegrated implants at various angulations. Implant Dent 13:358–366
7. Carr AB (1991) Comparison of impression techniques for a five-implant mandibular model. Int J Oral Maxillofac Implant 6:448–455
8. Assuncao WG, Britto RC, Ricardo Barao VA, Delben JA, dos Santos PH (2010) Evaluation of impression accuracy for implant at various angulations. Implant Dent 19:167–174
9. Sorrentino R, Gherlone EF, Calesini G, Zarone F (2010) Effect of implant angulation, connection length, and impression material on the dimensional accuracy of implant impressions: an in vitro comparative study. Clin Implant Dent Relat Res 12(Suppl 1):e63–e76

10. (2000) State of industry. Lab Manage Today 16:9–15.
11. Lee H, So JS, Hochstedler JL, Ercoli C (2008) The accuracy of implant impressions: a systematic review. J Prosthet Dent 100:285–291
12. Al-Bakri IA, Hussey D, Al-Omari WM (2007) The dimensional accuracy of four impression techniques with the use of addition silicone impression materials. J Clin Dent 18:29–33
13. Spector MR, Donovan TE, Nicholls JI (1990) An evaluation of impression techniques for osseointegrated implants. J Prosthet Dent 63:444–447
14. Hsu CC, Millstein PL, Stein RS (1993) A comparative analysis of the accuracy of implant transfer techniques. J Prosthet Dent 69:588–593
15. Harder S, Dimaczek B, Acil Y, Terheyden H, Freitag-Wolf S, Kern M (2010) Molecular leakage at implant-abutment connection—in vitro investigation of tightness of internal conical implant-abutment connections against endotoxin penetration. Clin Oral Investig 14:427–432
16. Steinebrunner L, Wolfart S, Ludwig K, Kern M (2008) Implant-abutment interface design affects fatigue and fracture strength of implants. Clin Oral Implants Res 19:1276–1284
17. Aloise JP, Curcio R, Laporta MZ, Rossi L, da Silva AM, Rapoport A (2010) Microbial leakage through the implant-abutment interface of Morse taper implants in vitro. Clin Oral Implants Res 21:328–335
18. Semper W, Heberer S, Mehrhof J, Schink T, Nelson K (2010) Effects of repeated manual disassembly and reassembly on the positional stability of various implant-abutment complexes: an experimental study. Int J Oral Maxillofac Implant 25:86–94
19. Vigolo P, Fonzi F, Majzoub Z, Cordioli G (2004) An evaluation of impression techniques for multiple internal connection implant prostheses. J Prosthet Dent 92:470–476
20. Kim S, Nicholls JI, Han CH, Lee KW (2006) Displacement of implant components from impressions to definitive casts. Int J Oral Maxillofac Implant 21:747–755
21. Cabral LM, Guedes CG (2007) Comparative analysis of 4 impression techniques for implants. Implant Dent 16:187–194
22. Del'Acqua MA, Chavez AM, Compagnoni MA, Molo Fde A Jr (2010) Accuracy of impression techniques for an implant-supported prosthesis. Int J Oral Maxillofac Implant 25:715–721
23. Luthardt RG, Walter MH, Quaas S, Koch R, Rudolph H (2010) Comparison of the three-dimensional correctness of impression techniques: a randomized controlled trial. Quintessence Int 41:845–853
24. Stimmelmayr M, Güth JF, Erdelt K, Edelhoff D, Beuer F (2010) Digital evaluationof the reproducibility of implant scan-body fit—an in vitro study. Clin Oral Investig. doi:10.1007/s00784-011-0564-5
25. Barrett MG, de Rijk WG, Burgess JO (1993) The accuracy of six impression techniques for osseointegrated implants. J Prosthodont 2:75–82
26. Del'Acqua MA, Arioli-Filho JN, Compagnoni MA, Mollo Fde A Jr (2008) Accuracy of impression and pouring techniques for an implant-supported prosthesis. Int J Oral Maxillofac Implant 23:226–236
27. Herbst D, Nel JC, Driessen CH, Becker PJ (2000) Evaluation of impression accuracy for osseointegrated implant supported superstructures. J Prosthet Dent 83:555–561
28. Humphries RM, Yaman P, Bloem TJ (1990) The accuracy of implant master casts constructed from transfer impressions. Int J Oral Maxillofac Implant 5:331–336
29. Naconecy MM, Teixeira ER, Shinkai RS, Frasca LC, Cervieri A (2004) Evaluation of the accuracy of 3 transfer techniques for implant-supported prostheses with multiple abutments. Int J Oral Maxillofac Implant 19:192–198
30. Carr AB (1992) Comparison of impression techniques for a two-implant 15-degree divergent model. Int J Oral Maxillofac Implant 7:468–475
31. Conrad HJ, Pesun IJ, DeLong R, Hodges JS (2007) Accuracy of two impression techniques with angulated implants. J Prosthet Dent 97:349–356
32. Daoudi MF, Setchell DJ, Searson LJ (2004) An evaluation of three implant level impression techniques for single tooth implant. Eur J Prosthodont Restor Dent 12:9–14
33. De La Cruz JE, Funkenbusch PD, Ercoli C, Moss ME, Graser GN, Tallents RH (2002) Verification jig for implant-supported prostheses: a comparison of standard impressions with verification jigs made of different materials. J Prosthet Dent 88:329–336
34. Wenz HJ, Hertrampf K (2008) Accuracy of impressions and casts using different implant impression techniques in a multi-implant system with an internal hex connection. Int J Oral Maxillofac Implant 23:39–47
35. Burawi G, Houston F, Byrne D, Claffey N (1997) A comparison of the dimensional accuracy of the splinted and unsplinted impression techniques for the Bone-Lock implant system. J Prosthet Dent 77:68–75
36. Inturregui JA, Aquilino SA, Ryther JS, Lund PS (1993) Evaluation of three impression techniques for osseointegrated oral implants. J Prosthet Dent 69:503–509
37. Assif D, Fenton A, Zarb G, Schmitt A (1992) Comparative accuracy of implant impression procedures. Int J Periodontic Restor Dent 12:112–121
38. Assif D, Marshak B, Schmidt A (1996) Accuracy of implant impression techniques. Int J Oral Maxillofac Implant 11:216–222
39. Vigolo P, Majzoub Z, Cordioli G (2003) Evaluation of the accuracy of three techniques used for multiple implant abutment impressions. J Prosthet Dent 89:186–192
40. Choi JH, Lim YJ, Yim SH, Kim CW (2007) Evaluation of the accuracy of implant-level impression techniques for internal-connection implant prostheses in parallel and divergent models. Int J Oral Maxillofac Implant 22:761–768
41. Del Corso M, Aba G, Vazquez L, Dargaud J, Dohan Ehrenfest DM (2009) Optical three-dimensional scanning acquisition of the position of osseointegrated implants: an in vitro study to determine method accuracy and operational feasibility. Clin Implant Dent Relat Res 11:214–221
42. Mehl A, Ender A, Mormann W, Attin T (2009) Accuracy testing of a new intraoral 3D camera. Int J Comput Dent 12:11–28
43. Ma T, Nicholls JI, Rubenstein JE (1997) Tolerance measurements of various implant components. Int J Oral Maxillofac Implant 12:371–375
44. Semper W, Kraft S, Kruger T, Nelson K (2009) Theoretical considerations: implant positional index design. J Dent Res 88:725–730
45. Binon PP (2000) Implants and components: entering the new millennium. Int J Oral Maxillofac Implant 15:76–94
46. Semper W, Kraft S, Kruger T, Nelson K (2009) Theoretical optimum of implant positional index design. J Dent Res 88:731–735
47. Semper W, Kraft S, Mehrhof J, Nelson K (2010) Impact of abutment rotation and angulation on marginal fit: theoretical considerations. Int J Oral Maxillofac Implant 25:752–758