Evaluation of the accuracy of three techniques used for multiple implant abutment impressions

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Statement of problem. Movement of pick-up type impression copings inside the impression material during clinical and laboratory phases may cause inaccuracy in transferring the spatial position of implants from the oral cavity to the master cast. As a consequence, the laboratory technician may fabricate a restoration that requires corrective procedures.

Purpose. This in vitro study evaluated the accuracy of 3 different impression techniques using polyether impression material to obtain a master cast for the fabrication of a prosthesis that would fit passively on multiple implants.

Material and methods. A machined metal model with 6 implants and abutments and a corresponding, passively fitting, matching metal template were fabricated. A total of 45 medium-consistency polyether impressions (Impregum Penta) of this model were made with pick-up type square impression copings. Three groups of 15 each were made with different impression techniques: in group 1, nonmodified square impression copings were used; in group 2, square impression copings were used and joined together with autopolymerizing acrylic resin before the impression procedure; and in group 3, square impression copings previously airborne particle–abraded and coated with the manufacturer-recommended impression adhesive were used. The matching metal template, which had been passively fit to the metal model so that it encountered no visually perceptible resistance or rocking on the abutments, was used as the control for evaluation of the accuracy of passive fit. A single calibrated and blinded examiner visually evaluated each cast. Positional accuracy of the abutments was numerically assessed with an optical scanner at original magnification $\times$ 10, which provided measurements to within 2 μm of the variations of the casts with respect to the horizontal distances between the 2 most posterior abutments and the 2 most anterior abutments. Data were analyzed with a 1-way analysis of variance at α=.05, followed by the Student Newman-Keuls method (P=.05).

Results. Visual examination of the casts from group 1 revealed discrepancies between 1 or more abutments and the metal template. Visual analysis of the master casts from groups 2 and 3 revealed close alignment of the metal template on all 6 abutments. One-way analysis of variance analyzed the numerical data obtained with the optical scanner and revealed significant differences among the 3 impression techniques (P<.001). The Newman-Keuls procedure disclosed significant differences between the groups, with group 2 and 3 casts being significantly more accurate than group 1 casts (P=.05). The distance between abutments 1 and 6 compared to the standard metal model was 33.83 μm (SD $\pm$ 5.4) greater on group 2 casts, 31.72 μm (SD $\pm$ 4.6) greater on group 3 casts, and 78.16 μm (SD $\pm$ 22.14) greater on group 1 casts. Distances between the most anterior abutments were also greater than those recorded on the metal model. The distance was 31.42 μm (SD $\pm$ 7.6) greater on group 2 casts, 30.34 μm (SD $\pm$ 6.4) greater on group 3 casts, and 67.91 μm (SD $\pm$ 15.34) greater on group 1 casts.

Conclusion. Within the limitations of this study, improved accuracy of the master cast was achieved when the impression technique involved square impression copings joined together with autopolymerizing acrylic resin or square impression copings that had been airborne particle–abraded and adhesive-coated. (J Prosthet Dent 2003;89:186-92.)

CLINICAL IMPLICATIONS

The results of this study suggested that splinting implant impression copings with autopolymerizing resin or airborne particle abrading and coating the copings with impression adhesive before impression making should result in more accurate working casts. Because splinting with resin is not the preferred option when an immediate loading multiple implant impression is made, the airborne particle abrasion/impression adhesive technique should be considered.

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The connection of a fixed partial denture (FPD) to osseointegrated implants produces a unified structure in which the FPD, the implants, and the investing bone act as a unit.[1-3] Any misalignment of the FPD to the osseointegrated implants, visible or not, is believed to induce internal stresses in the FPD, the implants, and the bone matrix.[4,5] An endosteal implant distributes the physiologic loads imposed on it to the surrounding supporting tissues.[6] Implant units, unlike natural teeth cushioned in their alveoli by periodontal fibers, are somewhat intolerant of movement in their adaptation to the demands of the metal supporting structure. The slight mobility of osseointegrated implants is ascribed to the "elasticity" of the investing bone.[7]

There is a general awareness that the installation of implants and subsequent prostheses can effect changes in the metastable matrix of supporting bone.[4,5] Whether the changes will be destructive or constructive in any given situation is not entirely predictable. It has been suggested that forced tightening of the metal supporting structure can result in microfractures of bone, zones of marginal ischemia, and healing with a nonmineralized attachment to the implant.[4] Others have suggested that there may be an as-yet undetermined optimum (or at least adequate) stress distribution dictated by design and material that will encourage maintenance of marginal bone proximal to the implant.[8,9] There is significant uncertainty with regard to the range of stress that may be clinically tolerable with respect to the long-term salutary retention of these devices. A successful result is believed to be fully achieved only through the fabrication of passively fitting prostheses.[10,11]

Several impression techniques have been suggested to achieve a master cast that will ensure the passive fit of a prosthesis on osseointegrated implants. To ensure maximum accuracy, Brånemark et al[1] emphasized the importance of splinting transfer copings together, intraorally, before registration of the impression. The same technique has been used by others with minor modifications.[12-18] Assif et al[19] compared the accuracy of 3 implant impression techniques with the use of 3 different splinting materials. Significantly more accurate results were obtained with techniques in which autopolymerizing acrylic resin or impression plaster (rather than dual-polymerizing acrylic resin) was used as the splinting material. Humphries et al,[20] Hsu et al,[21] and Herbst et al[22] found no significant differences between the values obtained with acrylic-splinted versus unsplinted copings in impression techniques. Burawi et al[23] reported that the splinted technique exhibited more deviation from the master cast than the unsplinted technique.

More complicated and time-consuming techniques to achieve passively fitting prostheses have been described by other authors in situations involving multiple implant restorations. Carr and Master[24] described a metallic impression coping system, featuring a crosswing design that was rotated into contact with an adjacent coping and connected with autopolymerizing acrylic resin. This process simulated the framework reorientation procedure and could be considered a potential substitute for the verification cast procedure in the framework fabrication process.

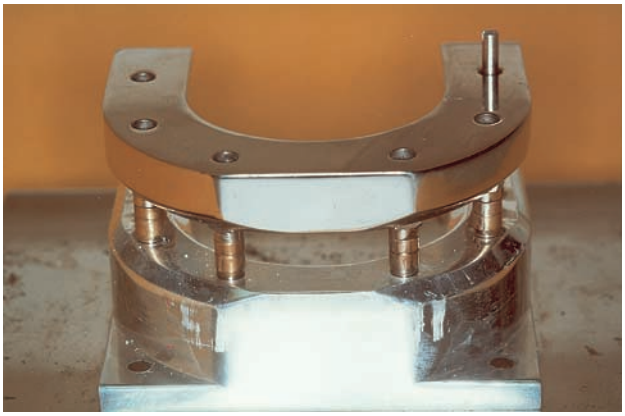

Fig. 1. Machined metal model with 6 implants and abutments and passively fitting matching template.

In a previous study, Vigolo et al[25] evaluated the accuracy of master casts obtained with the use of square pick-up impression copings for single tooth replacement. The copings were used as sold by the manufacturer or modified through airborne particle abrasion and the coating of their roughened surfaces with impression adhesive before final impression procedures. Improved precision of the impression was achieved when the adhesive-coated copings were used. The purpose of this in vitro study was to evaluate the accuracy of 3 different polyether impression techniques using polyether impression material to obtain a master cast for the fabrication of a prosthesis that would fit passively on multiple implants.

MATERIAL AND METHODS

A machined stainless steel metal arch with 6 standard threaded 3.75 × 10 mm implants (Implant Innovations Inc, Palm Beach Gardens, Fla.) and standard abutments (AB300; Implant Innovations Inc)[26] was fabricated to serve as a model simulating a clinical situation. A matching metal template with embedded squared impression copings (SQIC7; Implant Innovations Inc) was machined to fit passively onto the metal arch (Fig. 1) without encountering visually perceptible resistance or rocking on the abutments, as described by White.[27] The 6 implants with the corresponding standard abutments in the metal model were sequentially numbered 1 through 6 from left to right (Fig. 2). The template was secured to the abutments of the metal model with 10-mm flat-head guide pins (Implant Innovations Inc). These pins were screwed into place (one at a time to allow detection of

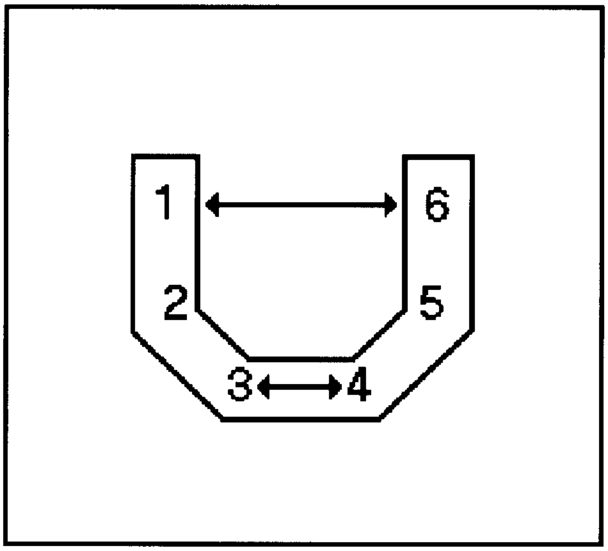

Fig. 2. Schematic representation of metal model. Implants and abutments were numbered 1 to 6. Distance between most posterior abutments (1 and 6) was 50.428 mm and between most anterior abutments (3 and 4) was 20.878 mm.

any variation from a passive fit[27]) with the aid of a calibrated torque wrench (Torque Driver CATDO; Implant Innovations Inc) limited to 10 Ncm, as recommended by the manufacturer.

Forty-five identical 2-mm-thick custom impression trays were made with light-polymerizing composite methacrylate resin (Palatray XL; Heraeus Kulzer GmbH & Co, Wehrheim, Germany) that was prepared according to the manufacturer's instructions. For this purpose, the 6 implants with the corresponding standard abutments in the metal model were covered by 2 layers of baseplate wax (Tenasyle; Imadent, Torino, Italy) to allow a consistent thickness of impression material, and an irreversible hydrocolloid impression was made to obtain a single cast on which all custom trays were molded. Tray stops between each implant and the corresponding standard abutment were incorporated. Three location marks (circular depressions 2 mm wide and 1 mm deep) were made on the base of the metal model (2 posterior marks between implant number 1 and implant number 6, 1 anterior mark between implant number 3 and implant number 4) and included in the impression trays to standardize tray positioning during impression making. The impression trays, which had 6 windows to allow access for the copings screws, were coated with polyether adhesive (Impregum; ESPE, Seefeld, Germany) 1 hour before each impression was made. The squared pick-up impression copings (SQIC7; Implant Innovations Inc) were secured with 10-mm flat-head guide pins on the abutments. Forty-five medium consistency polyether impressions (Impregum Penta; ESPE) were made in accordance with the manufacturer's directions. The impression material was machine-mixed (Pentamix; ESPE), and part of the material was meticulously syringed around the impression copings to ensure complete coverage of the copings themselves. The remaining impression material was used to load the impression tray. The impression trays were maintained in position with hand pressure throughout the setting time. Five minutes were allowed for the setting of the impression material. Fifteen impressions with square pick-up impression copings were made for each of 3 different impression techniques represented by groups 1 through 3.

In group 1, nonmodified impression copings were used (Fig. 3, *A*). Each impression tray was seated, and the material was allowed to set as indicated. The guide pins were removed so that the transfer copings remained in the impression when the tray was removed.

In group 2, resin-splinted impression copings were used (Duralay; Reliance Dental Manufacturing, Worth, Ill.) (Fig 3, *B*). The acrylic splint was fabricated 1 day before the impression procedure and divided into 5 separate pieces. The pieces were reconnected just before the impression procedure with an incremental application technique to minimize the resin setting distortion.[28,29] The impression tray was seated, and the impression material was allowed to set. The guide pins were removed so that the splinted transfer copings remained in the impression when the tray was removed from the metal model.

In group 3, impression copings that had been airborne particle–abraded and coated with adhesive (Impregum; ESPE), as previously described,[25] were used (Fig. 3, *C*). The impression trays were seated and the impression material allowed to set. The guide pins were removed so that the modified transfer copings remained in the impression when the tray was removed from the metal model.

Matching abutment replicas (LA200; Implant Innovations Inc) were screwed into the squared impression copings in the impressions. The casts were formed with the Zeiser system (Girrbach Dental GmbH, Pforzheim, Germany) according to the manufacturer's instructions to avoid problems related to stone expansion.[21,26,30,31] Impressions were placed on the impression tray carrier and boxed with a moldable silicone material (Combisil; Girrbach Dental GmbH). Two holes were drilled in the baseplates for each removable section, and pins were thermoplastically adapted in the Plexiglas baseplates. Die stone (New Fuji Rock; GC Corp, Tokyo, Japan) was used in accordance with the manufacturer's instructions. The impressions were filled with die stone, and the Plexiglas baseplates with the pins in place were carefully positioned in the filled impressions. After 1 hour the impressions with casts were separated from the Plexiglas baseplates, leaving the die pins embedded in the stone casts.

The casts were retrieved from the impressions after 24 hours and sectioned to provide 13 removable dies each.

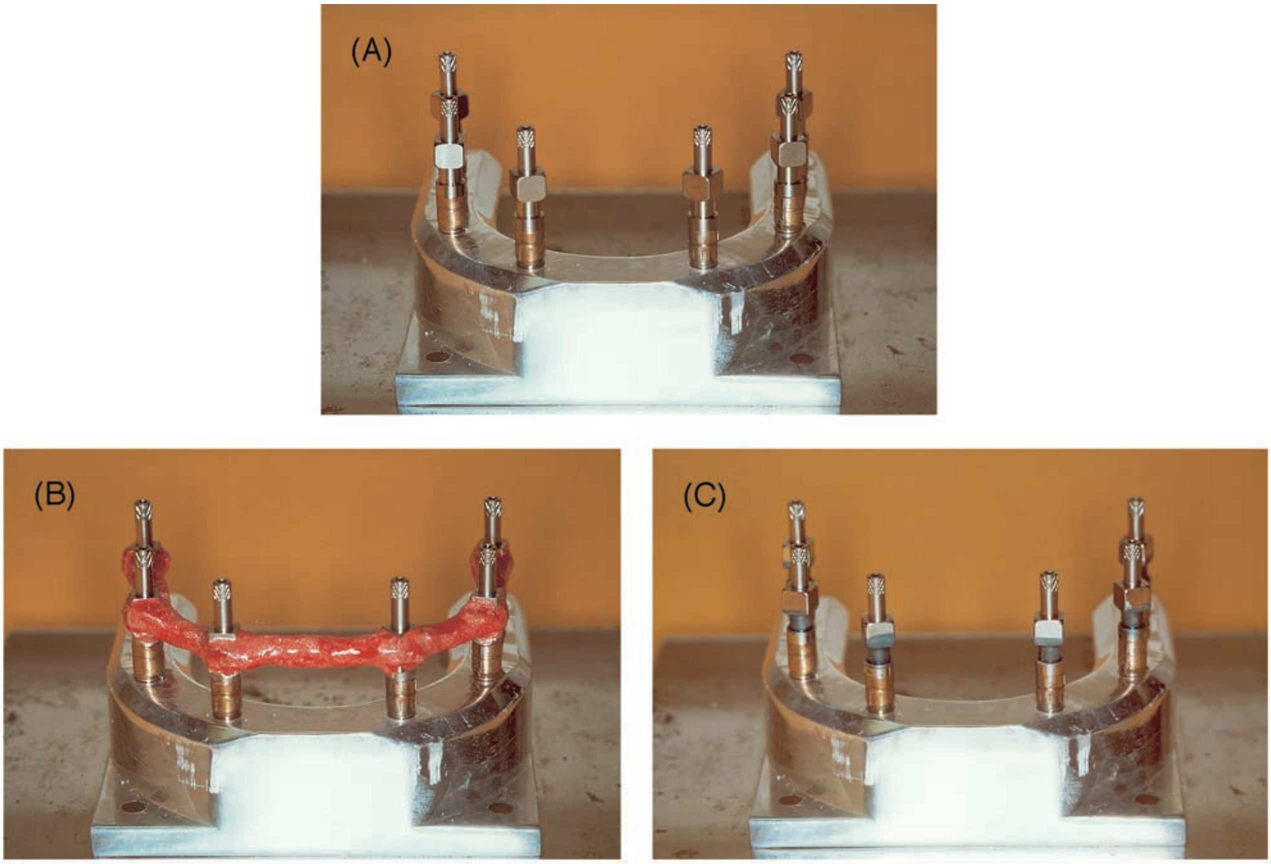

Fig. 3. A, Non-modified square impression copings (group 1). **B,** Nonmodified square impression copings rigidly splinted with acrylic resin prior to impression procedure (group 2). **C,** Square impression copings previously airborne particle–abraded and coated with impression adhesive (group 3).

All casts were stored at room temperature for a minimum of 24 hours before measurements were made. The metal template that had been passively fit to the metal model was used as the control to evaluate the accuracy of a passive fit; a single calibrated and blinded examiner evaluated all casts. Fit was assessed visually both at initial placement and during the sequential engagement of the individual guide pins (limited to a torque of 10 Ncm). The thick Plexiglas baseplate of the Zeiser system permitted correct repositioning of the dies[21,26,30,31] but did not tolerate movement of the dies when the template was seated.

Deviations from passive fit of the metal template on the different master casts were assessed at original magnification ×10 with a Nikon Profile Projector (model V-12, No. 123222; Nikon Corp, Nippon Kogaku, Japan). This device, composed of a screen with horizontal and vertical reference lines, had a movable table to allow positioning on the screen of the object being studied. It had a light source that projected a magnified image of the object onto the screen in the form of a shadow so that the sharp edges of the projected silhouetted form of the abutments became the reference points of measurement. All casts were secured to a universally movable surveyor table (Ney, Hartford, Conn.) and adjusted to identical positions on the screen using the horizontal reference line as a guide to assure that the abutments of all casts were at the same level during the measurements. The Nikon Profile Projector was calibrated to measure, within 2 μm, the variations of groups 1 through 3 casts from the metal model with respect to the horizontal distances between the 2 most posterior abutments (1 and 6) and the 2 most anterior abutments (3 and 4) (Fig 2). All measurements were recorded by the same blinded operator. Operator variability was assessed using 10 repeated measurements of the distances between the 2 most posterior abutments the 2 most anterior abutments in 1 randomly selected master cast from each group. Data were analyzed with a 1-way analysis of variance at α=.05 and n = 15, followed by Student Newman-Keuls multiple comparison procedures to evaluate groups means (P=.05).

RESULTS

Relative to intraoperator variability, standard deviations of the 10 repeated measurements were 3.3 μm and 3.5 μm for the distance between the most posterior and

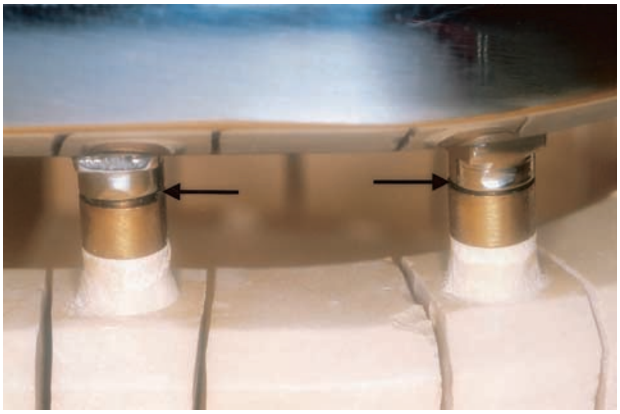

Fig. 4. View of clearly visible discrepancies *(arrows)* between 2 abutments and template on master cast obtained from group 1 impression.

most anterior abutments, respectively, in the master cast selected from group 1. The corresponding values were 3.6 μm and 3.3 μm, respectively, for the group 2 master cast and 3.5 μm and 3.4 μm, respectively, for the group 3 master cast. These small standard deviations indicated the reliability of the measurement method.

None of the casts in group 1 allowed for the matching metal template to be seated and screwed in place without perceptible resistance on the abutments. A cursory examination revealed visible discrepancies between 1 or more abutments and the metal template (Fig. 4). Conversely, the metal template could be passively seated without perceptible rocking on all casts in groups 2 and 3. These casts displayed close alignment with the metal template on all 6 abutments.

With the use of the optical scanner, numerical differences in changes in abutment position were evaluated. One-way analysis of variance (Table 1) revealed significant differences for both horizontal distances ($P<.001$) between master casts from groups 1 and 2 and between master casts from groups 1 and 3. Overall discrepancies in both distances were greater in group 1 master casts than group 2 or 3 master casts.

Horizontal variations between the standard metal model and the 3 groups with respect to abutments 1 and 6 (posterior) and abutments 3 and 4 (anterior) were analyzed with the Newman-Keuls test. Distances between the 2 most posterior abutments were all greater than those recorded on the metal model; group 1 variation from the master model was significantly greater than that of groups 2 and 3 ($P=.05$). The distance between abutments 1 and 6 was 50.428 mm on the standard metal model. The distance was 33.83 μm (SD ± 5.4) greater on group 2 casts, 31.72 μm (SD ± 4.6) greater on group 3 casts, and 78.16 μm (SD ± 22.14) greater on group 1 casts (Table 2). Distances between the most anterior abutments were also greater than those recorded on the metal model; group 1 variation from the master model was significantly greater than that of groups 2 and 3 ($P=.05$). The distance between abutments 3 and 4 was 20.878 mm on the standard metal model. The distance was 31.42 μm (SD ± 7.6) greater on group 2 casts, 30.34 (SD ± 6.4) μm greater on group 3 casts, and 67.91 μm (SD ± 15.34) greater on group 1 casts (Table 2).

Table I. One-way ANOVA on horizontal distances measured between posterior and anterior abutments on master casts obtained with 3 different impression techniques

	ANOVA	
Distance	**F(P)**	**Scheffe contrasts (groups)**
Between posterior abutments 1 and 6	10.60*	1>2,3
Between anterior abutments 3 and 4	10.86*	1>2,3

*$P<.001$.

DISCUSSION

In implant prosthodontics, a successful result can be fully achieved only when passively fitting prostheses are fabricated. The application of undue torque to screws during attachment of the superstructure to the abutments can jeopardize the outcome. If a clinically passive fit is not achieved and the metal supporting structure rocks intraorally, the metal framework is usually sectioned, repositioned, and soldered. To eliminate discrepancies in fit (even those not visually detectable), it is essential that work be done on a master cast that reproduces, as accurately as possible, the position of the abutments in the patient's mouth.

An important factor that influences precision of fit is impression accuracy. In this study splinting the impression copings with acrylic resin or airborne particle–abrading and coating them with the manufacturer-recommended adhesive in the impression phase improved the accuracy of the final master casts. These results suggest the importance of avoiding movement of the impression copings inside the impression material throughout procedures associated with fabrication of the master cast. Unscrewing the guide pins from the impression copings when the tray is removed from the mouth or screwing the matching abutment replicas in the impression may cause minor movement and thus influence cast accuracy.

The results of this study suggest that when impression copings are connected with acrylic resin, more accurate master casts can be obtained than when unconnected and unmodified impression copings are used. These results are in agreement with previous research.[1,15-20] However, connecting the impression copings with acrylic resin is a time-consuming procedure. To avoid problems related to resin polymerization con-

Table II. Variations between the metal model and the 3 impression groups with respect to the horizontal distance between the posterior abutments (1 and 6) and the horizontal distance between the anterior abutments (3 and 4)

Impression group	N	Horizontal distance between the posterior abutments (1 and 6)		Horizontal distance between the anterior abutments (3 and 4)	
		Mean (μm)	SD ($\pm$)	Mean (μm)	SD ($\pm$)
Group 1: Nonmodified, non-splinted square impression copings	15	78.16	22.14	67.91	15.34
Group 2: Splinted square impression copings	15	33.83*	5.4	31.42*	7.6
Group 3: Airborne particle–abraded and adhesive-coated square impression copings	15	31.72*	4.6	30.34*	6.4

*Accurate master casts were obtained.

traction, the resin scaffold should be prepared 1 day in advance, and the final connection should be performed just before the impression procedure.[28,29] A simpler procedure, roughening the external surface of the pick-up impression copings and applying an adhesive coating to it, was used in this study to create a firmer connection between the impression copings and the impression material. Differences in the accuracy of casts obtained with these 2 procedures were not significant. In contradiction to the results of earlier studies,[20-23] both systems yielded significantly more precise master casts than those obtained with unsplinted and unmodified impression copings. The spatial orientation of the abutment replicas on master casts obtained from impression groups 2 and 3 corresponded closely to the hypothetical intraoral spatial position of the abutment heads.

Theoretically, airborne particle abrasion and adhesive coating of the impression copings should decrease the degree of micromovement of the copings inside the impression material from impression making to impression pouring. It should also lead to the fabrication of a master cast that closely replicates the clinical situation, as shown in a previous study on impression techniques in single tooth implant reconstruction.[25] Intimate contact between the impression material and the impression copings resulting from the application of impression adhesive seems to reduce the freedom of movement of the impression copings inside the impression material during clinical and laboratory phases. Consequently, the laboratory technician can fabricate a restoration that may require fewer corrective procedures. This technique is routinely chosen when an immediate loading multiple implant impression has to be made. In these cases, intraorally splinting the impression copings with the acrylic resin is not the preferred option. There is no available time to construct prefabricated resin blocks to be joined by small amounts of acrylic resin during the impression phase, and there is the risk of interfering with the healing process of the recently operated tissue with the contact of the resin monomer. The simpler and less time-consuming procedure of airborne particle–abrading and coating the copings with impression adhesive before impression making is usually the privileged choice.

It is important to fabricate a precise master cast in implant prostheses. Of the 3 impression techniques analyzed in this study, the impressions in groups 2 and 3 demonstrated a higher degree of precision. It is of interest that throughout this investigation the accurate reproduction of abutment position was never accomplished. Interabutment distances in the group 2 and 3 master casts expanded from approximately 31 to 34 μm for the posterior regions and from 30 to 31 μm for the anterior regions. In clinical terms, this implies that the precise fit by definition of a superstructure may be unattainable and that the terms precision and fit are relative to the clinical estimate of the operator. It should also be noted that, because of the limitations of this study, only horizontal movements of the impression copings were detected. More research in this area should be performed to evaluate eventual tridimensional movements of pick-up impression copings inside the impression material.

CONCLUSIONS

Within the limitations of this study, accurate master casts were obtained with impression techniques that made use of impression copings rigidly splinted with autopolymerizing acrylic resin and impression copings airborne particle–abraded and coated with the manufacturer-recommended impression adhesive. Working casts retrieved from pick-up impressions with the nonmodified implant impression copings were statistically less accurate than casts from square impression copings joined together with autopolymerizing acrylic resin before the impression procedure and square impression copings previously airborne particle–abraded and coated with the manufacturer-recommended impression adhesive, which did not differ from each other.

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REFERENCES

1. Brånemark PI, Zarb GA, Albrektsson T. Tissue-integrated prostheses. Osseointegration in clinical dentistry. Chicago: Quintessence; 1985. p. 11-12, 253-7.
2. Adell R. Clinical results of osseointegrated implants supporting fixed prostheses in edentulous jaws. J Prosthet Dent 1983;50:251-4.
3. Zarb GA, Zarb FL. Tissue integrated dental prostheses. Quintessence Int 1985;16:39-42.
4. Skalak R. Biomechanical considerations in osseointegrated prostheses. J Prosthet Dent 1983;49:843-8.
5. Brunski JB. Biomechanics of oral implants: future research directions. J Dent Educ 1988;52:775-87.
6. Lemons JE, Bidez MW. Endosteal implant biomaterials and biomechanics. In: McKinney RV Jr, editor. Endosteal dental implants. St. Louis: Mosby; 1991. p. 27-36.
7. Schnitman PA, Rubenstein JE, Whorle PS, DaSilva JD, Koch GG. Implants for partial edentulism. J Dent Educ 1988;52:725-36.
8. Roberts WE, Smith RK, Zilberman Y, Mozsary PG, Smith RS. Osseous adaptation to continuous loading of rigid endosseous implants. Am J Orthod 1984;86:95-111.
9. Sullivan DY. Prosthetic considerations for the utilization of osseointegrated fixtures in the partially edentulous arch. Int J Oral Maxillofac Implants 1986;1:39-45.
10. Lundqvist S, Carlsson GE. Maxillary fixed prostheses on osseointegrated dental implants. J Prosthet Dent 1983;50:262-70.
11. Spector MR, Donovan TE, Nicholls JI. An evaluation of impression techniques for osseointegrated implants. J Prosthet Dent 1990;63:444-7.
12. Sutherland JK, Hallam RF. Soldering technique for osseointegrated implant prostheses. J Prosthet Dent 1990;63:242-4.
13. Loos LG. A fixed prosthodontic technique for mandibular osseointegrated titanium implants. J Prosthet Dent 1986;55:232-42.
14. Fredrickson EJ, Gress ML. Laboratory procedures for an osseointegrated implant prosthesis. QDT Yearbook 1988;12:15-37.
15. Beumer J 3rd, Lewis SG. The Brånemark implant system. Clinical and laboratory procedures. St. Louis: Ishiyaku EuroAmerica; 1989. p. 66-7.
16. Hobo S, Ichida E, Garcia LT. Osseointegration and occlusal rehabilitation. Chicago: Quintessence; 1989. p. 174-6.
17. Taylor R, Bergman G. Laboratory techniques for the Brånemark system. Chicago: Quintessence; 1990. p. 22-38.
18. Assif D, Marshak B, Schmidt A. Accuracy of implant impression techniques. Int J Oral Maxillofac Implants 1996;11:216-22.
19. Assif D, Nissan J, Varsano I, Singer A. Accuracy of implant impression splinted techniques: effect of splinting material. Int J Oral Maxillofac Implants 1999;14:885-8.
20. Humphries RM, Yaman P, Bloem TJ. The accuracy of implant master casts constructed from transfer impressions. Int J Oral Maxillofac Implants 1990;5:331-6.
21. Hsu CC, Millstein PL, Stein RS. A comparative analysis of the accuracy of implant transfer techniques. J Prosthet Dent 1993;69:588-93.
22. Herbst D, Nel JC, Driessen CH, Becker PJ. Evaluation of impression accuracy for osseointegrated implant supported superstructures. J Prosthet Dent 2000;83:555-61.
23. Burawi G, Houston F, Byrne D, Claffey N. A comparison of the dimensional accuracy of the splinted and unsplinted impression techniques for the Bone-Lock implant system. J Prosthet Dent 1997;77:68-75.
24. Carr AB, Master J. The accuracy of implant verification casts compared with casts produced from a rigid transfer coping technique. J Prosthodont 1996;5:248-52.
25. Vigolo P, Majzoub Z, Cordioli GP. In vitro comparison of master cast accuracy in single-tooth implant replacement. J Prosthet Dent 2000;83:562-6.
26. Vigolo P, Millstein PL. Evaluation of master cast techniques for multiple abutment implant prostheses. Int J Oral Maxillofac Implants 1993;8:439-46.
27. White GE. Osseointegrated dental technology. 1st ed. London: Quintessence; 1993. p. 61.
28. Mojon P, Oberholzer JP, Meyer JM, Belser UC. Polymerization shrinkage of index and pattern acrylic resins. J Prosthet Dent 1990;64:684-8.
29. Assif D, Marshak B, Nissan J. A modified impression technique for implant-supported restoration. J Prosthet Dent 1994;71:589-91.
30. Martignoni M, Schonenberger A. Precision Fixed Prosthodontics: Clinical and Laboratory Aspects. Chicago: Quintessence; 1990. p. 187.
31. Aramouni P, Millstein P. A comparison of the accuracy of two removable die systems with intact working casts. Int J Prosthodont 1993; 533-9.

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