The Influence of Verification Jig on Framework Fit for Nonsegmented Fixed Implant-Supported Complete Denture

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ABSTRACT

Purpose: The purpose of this retrospective study was to assess if there was a difference in the likelihood of achieving passive fit when an implant-supported full-arch prosthesis framework is fabricated with or without the aid of a verification jig.

Materials and Methods: This investigation was approved by the University of Rochester Research Subject Review Board (protocol #RSRB00038482). Thirty edentulous patients, 49 to 73 years old (mean 61 years old), rehabilitated with a nonsegmented fixed implant-supported complete denture were included in the study. During the restorative process, final impressions were made using the pickup impression technique and elastomeric impression materials. For 16 patients, a verification jig was made (group J), while for the remaining 14 patients, a verification jig was not used (group NJ) and the framework was fabricated directly on the master cast. During the framework try-in appointment, the fit was assessed by clinical (Sheffield test) and radiographic inspection and recorded as passive or nonpassive.

Results: When a verification jig was used (group J, $n = 16$), all frameworks exhibited clinically passive fit, while when a verification jig was not used (group NJ, $n = 14$), only two frameworks fit. This difference was statistically significant ($p < .001$).

Conclusions: Within the limitations of this retrospective study, the fabrication of a verification jig ensured clinically passive fit of metal frameworks in nonsegmented fixed implant-supported complete denture.

KEY WORDS: computer aided prosthetic designs, dental casting technique/instrumentation, dental implants, dental prosthesis, dental prosthesis design/methods, implant-supported, implants restoration

INTRODUCTION

Several authors have suggested that implant-supported prostheses should fit passively on the implants and/or abutments.[1–3] Passive prosthesis fit is deemed important as the limited mobility of implants within bone[1–3] might lead, in the presence of prosthesis misfit, to unwanted level of strain at the bone-implant interface and between implant components, such as screw-joint connections.[4–6] Although a misfit in the framework does not appear to compromise osseointegration of dental implants,[7] it may result in higher incidence of complication such as screw loosening, screw fracture, and occlusal inaccuracies.[4–6,8] While passive fit is deemed important, it has clearly been shown that all the impression techniques currently used generate a variable degree of inaccuracy of the master cast.[9–12] Moreover,

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additional chances for prosthesis misfit are encountered during the laboratory fabrication of the prosthesis due to material dimensional changes[13] and/or equipment inaccuracies and fabrication-related inaccuracies, including casting process inaccuracies and computer-aided design/computer-aided manufacturing (CAM) inaccuracies.[4–6,14]

While a universal protocol to define an acceptable fit is still not available,[15] several clinicians[16–18] have suggested the use of a verification jig to improve the accuracy of the master cast. While the latter are basically case reports and have therefore limited value from an evidence-based standpoint, it is interesting to notice that the only study available in the dental literature on this topic does not seem to suggest that verification jigs made of different resin materials are actually more accurate than conventional impressions with elastomeric materials.[19] Although the latter study suggested no positive advantage for the use of verification jigs, it has to be said that this study[19] was an in vitro study with only three implants placed parallel to each other on a master base. Therefore, it is possible that other clinical variables, such as implant misalignment, residual ridge undercuts, variable depths of implant placement,[12] and variable shapes of implant impression components, might have an influence on the accuracy of implant impressions. It might be possible that, in these clinical situations, the fabrication of a verification jig might improve the accuracy of a master cast. Unfortunately, definitive clinical data on the influence of verification jigs on the proper fitting of an implant-supported prosthesis are lacking. Therefore, the purpose of this retrospective study was to assess if there was a difference in the likelihood of achieving passive fit when an implant-supported prosthesis framework is fabricated with or without the aid of a verification jig.

MATERIALS AND METHODS

This retrospective investigation was approved by the University of Rochester Research Subject Review Board (protocol #RSRB00038482). Treatment records review for the time between January 2005 and December 2009 identified a total of 30 edentulous patients (for a total of 30 edentulous arches, 18 maxillae and 12 mandibles), 49 to 73 years old (mean 61 years old), requiring oral rehabilitation by means of a nonsegmented fixed implant-supported complete denture. For each arch, four to eight dental implants (Straumann Tissue Level and Straumann Bone Level implants, Straumann, Andover, MA, USA) were placed and restored with metal-ceramic or metal-acrylic resin fixed complete dentures, using either a conventional or immediate loading protocol.[20]

During the restorative process, final impressions were made using the pickup impression technique and two elastomeric impression materials (polyether [Permadyne, 3M ESPE, St. Paul, MN, USA] or vinyl polysiloxane [Elite, Zhermack, Badia Polesine, Italy] types). For the patients who had Straumann Tissue Level implants placed, the impression was made at the implant level, while for those who received Straumann Bone Level implants, abutments (Multi-Base Abutments, Straumann) were first placed and then the impression and all subsequent prosthodontic procedures were carried out at the abutment level.

In two patients, who were included in the nonverification group (group NJ), the impression copings were splinted with autopolymerizing acrylic resin (Pattern Resin, GC America, Alsip, IL, USA) at the time of impression, while for all other patients, the impression was done with nonsplinted copings. Implant analogues were then secured to the impression copings, a soft tissue mask was fabricated (Gingitech, Williams Gold Refining Co, Fort Erie, ON, Canada or Permadyne, 3M ESPE), and the impression was poured with type IV dental stone (Resin Rock, Whip Mix, Louisville, KY, USA) to fabricate the master cast. For 16 of the 30 arches, a verification jig was made as outlined later (group J), while for the remaining 14 arches, a verification jig was not used (group NJ) and the framework was fabricated directly on the master cast. For the fabrication of the verification jig, at least 24 hours before the patient visit, impression copings were placed on the master cast, connected to the implant analogues, and splinted with autopolymerizing acrylic resin (Pattern Resin, GC America) with the aid of dental floss and/or orthodontic metal wire (Figures 1 and 2). After the acrylic resin had completely polymerized, the splint thus created was separated using a fine disc (Figure 3). The separated pieces of the jig were then seated on the respective implants in the patient's mouth making sure that they would not touch each other and were then connected by applying a small amount of newly mixed autopolymerizing acrylic resin (Figure 4) in the spaces between the impression copings. The acrylic resin was allowed to polymerize for at least 20 minutes.[21] Once the newly

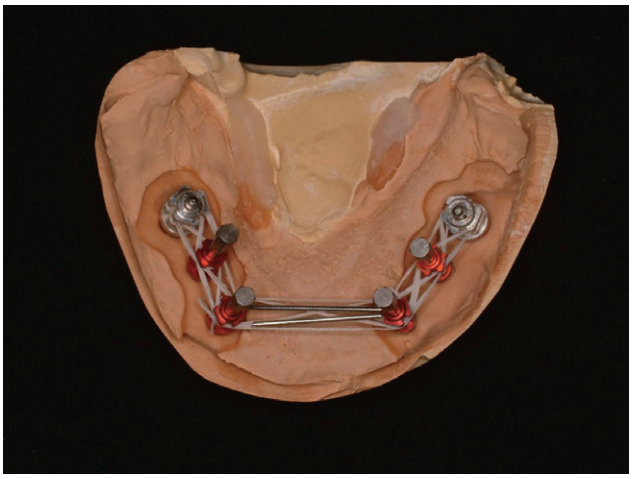

Figure 1 Impression copings were connected to implant analogues and splinted using dental floss and/or metal wire.

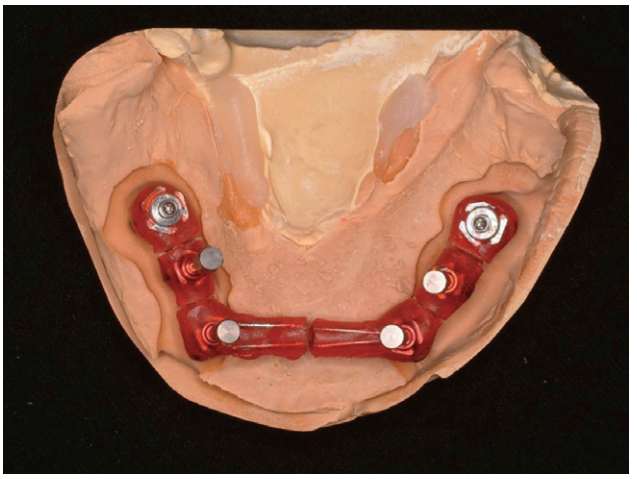

Figure 3 Verification jig was separated into multiple sections.

added acrylic resin had polymerized, the verification jig was unscrewed from the implants and removed from the patient mouth. Implant analogues were then connected to the jig (Figure 5) and the assembly thus obtained was placed in type IV dental stone (Resin Rock, Whip Mix) to obtain an implant position cast[16] (Figure 6). The implant position cast was then used to fabricate and check the fit of the prosthesis metal framework.[16]

The framework fabrication was performed, for all patients, using either a CAM or lost-wax technique (Table 1). For the CAM technique, the framework pattern was made using autopolymerizing acrylic resin (Pattern Resin, GC America) connected to titanium implant abutments (temporary restoration abutment 048.650 for tissue level implants; temporary restoration abutment 024.4370 for bone level implants, Straumann) that were connected on the master cast. The pattern thus obtained was then sent to a manufacturing facility (Nobel Biocare Procera, Göteborg, Sweden) for the CAM of the titanium framework. Four of the five frameworks fabricated with the CAM technique belonged to patients in group J. For the conventional lost-wax technique, the framework fabrication began with connecting the corresponding implant abutment (Synocta abutment 048.602 for tissue level implants, Straumann) to the implant analogues on the master cast. Corresponding prosthetic components (gold coping for bridge 048.632 for tissue level implants and gold coping for bridge 022.4430 for bone level implants, Straumann) were connected on the implant abutments and the

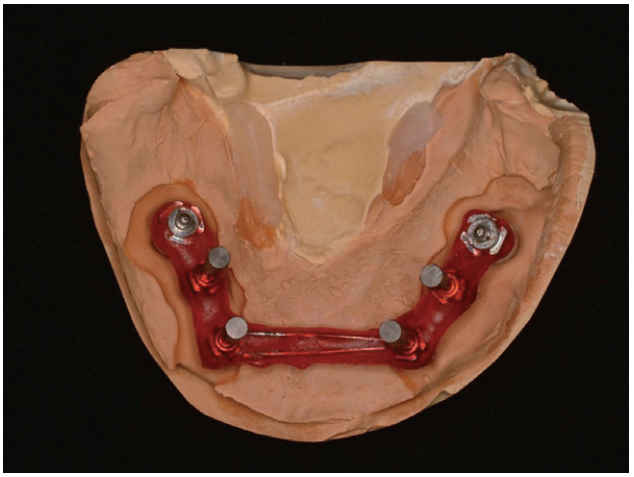

Figure 2 Autopolymerizing acrylic resin was applied to splint impression copings.

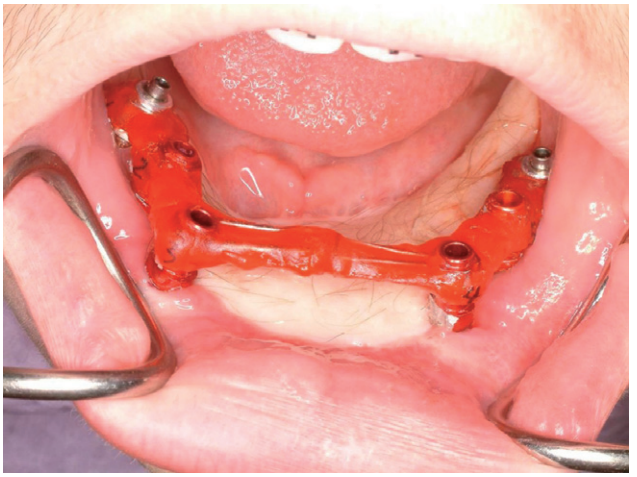

Figure 4 Sections of verification jig were transferred in mouth and rejoined using autopolymerizing acrylic resin.

Figure 5 After removal from mouth, implant analogues were immediately connected to verification jig.

framework pattern was fabricated using autopolymerizing acrylic resin (GC Pattern Resin, GC America). It was then invested (Hi-Temp, Whip Mix) and cast with high-noble metal alloy (Leo, Ivoclar Vivadent, Amherst, NY, USA). The cast frameworks were then carefully divested and remnants of the investment material completely removed with hydrofluoric acid. For all frameworks, the fit of the resin pattern was carefully checked, either on the master cast or the implant position cast, before investing (cast frameworks) or sending the pattern to the manufacturing facility for the CAM process (CAM frameworks). Once the frameworks were fabricated or received, their fit was again checked, either on the master cast or the implant position cast, according to a previously established protocol. According to this protocol,

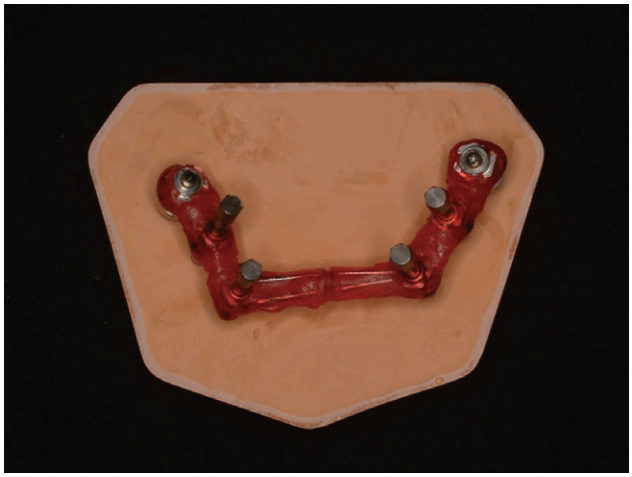

Figure 6 With verification jig, implant position cast was fabricated using type IV dental stone.

TABLE 1 Material Used for Study

Technique	Alloy Used for Fabrication of Framework	Manufacturer Information	*N*
CAM	Titanium	Titanium Alloy* Nobel Biocare Procera	5
Cast	High-noble metal alloy	Leo; Ivoclar Vivadent	25

*Titanium Alloy: Titanium-6aluminum-4vanadium (Ti6Al4V).
CAM = computer-aided manufacturing; N = number of framework fabricated with each technique.

the fit of the framework was controlled with the one-screw technique (Sheffield test).[15] With this protocol, only one screw was placed, at a time, hand-tightened to secure the framework to the cast, and this procedure was repeated for each single implant site. The presence of misfit was visually assessed at each implant site by direct inspection (direct inspection with ×3.5–4.5 magnification loupes). If passive fit was not present on the master cast, the framework was either remade (for CAM frameworks) or soldered (for cast frameworks).

At the clinical try-in appointment, the fit of the framework was again verified using the one-screw technique (Sheffield test),[15] as described earlier, as well as periapical and/or panoramic radiographs. Briefly, upon screwing one of the prosthesis screws, if the clinician found clinically visible (direct inspection with ×3.5–4.5 magnification loupes) or radiographically evident (periapical and/or panoramic radiographs) misfit at any of the remaining implant-prosthesis or abutment-prosthesis interfaces, the prosthesis was deemed nonpassive. Only the presence or absence of fit at the clinical appointment was considered for data analysis.

Data collection for the clinical prosthesis fit was performed by two investigators (AG and CE) by reviewing the patients' chart. A customized Excel spreadsheet (Excel 2003, Microsoft, Redmond, WA, USA) was used for the data collection. Recorded treatment variables included the following: (1) number of implants per patient; (2) use of a verification jig (dichotomous variable: yes or no); and (3) fit of the framework in the patient's mouth (clinical passive fit) (recorded as dichotomous variable: passive or nonpassive) and fabrication technique (cast or CAM).

The clinical fit of the framework (clinical passive fit) in the verification jig group (group J) and in the

TABLE 2 Framework Fit as Result of Verification Jig Fabrication

	Framework Fit		
Verification Jig	Yes	No	Total
Yes	16	0	16
No	2	12	14
Total	18	12	30

Difference is statistically significant ($p < .001$) with Fisher's exact test.

nonverification jig group (group NJ) was statistically compared using exact logistic regression and Fisher's exact test ($\alpha = 0.05$). All analyses were implemented using SAS 9.2 (SAS Institute Inc., Cary, NC, USA).

RESULTS

When a verification jig was used (group J, $n = 16$), all frameworks exhibited clinically passive fit, while when a verification jig was not used (group NJ, $n = 14$), only two frameworks fit (Table 2). Fisher's exact test showed a highly significant correlation between the verification jig and the framework fit ($p < .001$).

DISCUSSION

The null hypothesis investigated in this study was that there would be no significant difference in the clinical fit of the frameworks that were fabricated using a verification jig compared with those fabricated using only an elastomeric impression. As the use of a verification jig was highly correlated with clinical prosthesis fit, the null hypothesis was rejected.

In order to put the result of the present study in perspective and understand its implications, it has to be immediately mentioned that it was not the aim of the study to measure the misfit of the frameworks in terms of absolute measurements. Indeed, this study sought to assess the influence of a verification jig or lack thereof on the likelihood of obtaining a clinically passive fit as assessed by a clinician in the patient's mouth and with the method described herein (Sheffield test). This criterion was used as the authors are not aware of any technique for impression that can ensure an absolute passive fit, which realistically might not even be achievable with current prosthodontic techniques.[15] Therefore, testing the main study variable (use of a verification jig or not) for a defined clinical outcome (clinically passive fit) as identified in this study (Sheffield test) is important to provide the clinician with guidance on whether to incorporate the use of a verification jig during the fabrication of implant frameworks.

For this study, the charts of all patients, with at least one edentulous arch who received an implant-supported prosthesis, were reviewed. Only those with a nonsegmented, cross-arch prosthesis fabricated after recording a conventional polyether or vinyl polysiloxane impression were included in the study. Intuitively, the chance of achieving a clinically acceptable fit is inversely correlated with the number of implant engaged by the prosthesis, so it is reasonable to expect a greater chance of clinically acceptable fit in a two-implant-supported fixed dental prosthesis than it is with greater number of implants. Therefore, while the number of implant varied in each case in this study (four to eight for each arch), only those cases when these implants were connected by a single framework were included in the study. This was done to decrease the possibility that greatly different complete arch prosthesis designs (segmented and nonsegmented) could be included in the database and act as a confounding variable. However, it could be argued that even the inclusion in the same database of prostheses supported by a variable number of implants (four to eight), as it was done in this study, could be deemed inappropriate as it is intuitive as well as that the number of implants connecting a framework increases, so does the chance of having prosthesis misfit. In this regard, however, it is interesting to notice that all the frameworks in group J did exhibit clinical passive fit regardless of the number of implants. Therefore, these data support the concept that the use of a verification jig, at least as described in this study, is an effective method to achieve clinically passive fit of implant prostheses regardless of the number of implants.

It is also interesting to notice that all the cases treated with a verification jig achieved a clinically passive fit of the framework as compared with the use of elastomeric impression where only two cases achieved a clinically acceptable fit. This finding is in contrast with findings from several in vitro studies in which the linear discrepancy of frameworks fabricated on casts obtained by the use of elastomeric impression was reported to range between 15 to 50 µm,[22–24] a discrepancy that would generally be regarded as an acceptable clinical fit of the metal framework. However, to the authors' knowledge, no clinical study has been published to confirm this finding. The reasons of this significant

difference in clinical fit between frameworks fabricated with the use of a verification jig or with only a conventional impression are not clear, but it could be speculated that factors such as implant angulation,[25,26] implant depth,[12] distortion of the impression material, and other patient- and operator-related factors could have played major roles in impression accuracy. Moreover, when fabricating a verification jig as it has been performed in the present study, the acrylic resin surrounding the impression copings, which constitutes the majority of the volume of the jig, undergoes polymerization shrinkage at least 24 hours before the clinical appointment. The authors suggest that, then, rigidly connecting the jig sections in the oral cavity with only a minor amount of acrylic resin ensures greater accuracy of the stone master cast and therefore clinical prosthesis fit.

During the fabrication of a framework, several technical and clinical factors can affect the prosthesis final fit. Technical factors broadly relate to the technique and materials used for the prosthesis fabrication in the laboratory, while clinical factors depend on the implant (depth and angulation), number of implants, and the material and techniques used to record the impression.

Schematically, the influence of technical and clinical factors on framework fit could be separated, in time, by the pouring of the master cast. Indeed, clinical factors affect the final prosthesis fit only by influencing the accuracy of the master cast while, on the other end, technical factors will affect the accuracy of the prosthesis as it fits on the master cast. This distinction is important because if passive fit is verified, as it was done in this study and normally executed in clinical practice, on the master or implant position cast ahead of the placement of the framework in the oral cavity, all technical factors that could generate framework misfit are completely removed from influencing the final clinical fit of the prosthesis. It follows then that, by doing so, framework misfit can only be affected by clinically related factors as described earlier and, of course, by the characteristics of the material used to pour the master cast or implant position cast.

In this study, only one type of dental stone was used to pour all casts, therefore normalizing this factor between groups J and NJ. However, two different elastomeric materials were used to record the impressions. Therefore, it could be argued that one factor that might have influenced the accuracy of the master cast and therefore of the metal framework in the NJ group is the type of elastomeric materials used to record the impression (either polyether or vinyl polysiloxane). However, as it was not one of the aims of this study to assess the influence of a specific impression material on the accuracy of the master cast, the limited sample size made it impossible to run a statistical analysis with enough power to detect a clinically significant difference between the master cast accuracy generated by these two impression materials. Consequently, definitive conclusions on the influence of impression material type on the accuracy of the master cast and metal framework cannot be drawn.

The passive fit of the frameworks was checked on the respective master cast or implant position cast before trying them in the patient's mouth. This was done to ensure that only frameworks that fit the cast were then tried in the patient mouth. As for purpose of data analysis, only the presence or absence of fit in the patient mouth was considered, checking that the fit of the framework on the cast eliminated the possibility that all technical and material factors inherent with the prosthesis fabrication, such as, but not limited to, cast Vs CAM frameworks, type of alloy and veneering material, and eventual soldering of the framework, could affect the likelihood of achieving passive fit.

It could also be argued that the difference in achieving passive fit between groups J and NJ could be due to inappropriate use of the impression materials. While this is a possibility and could have affected the results in the NJ group, the clinicians were instructed and trained for these impression procedures, as well as for the Sheffield test, according to an established protocol.

Two patients in the group NJ were treated with a splint impression technique. For this technique and during the same appointment, the impression copings were splinted using autopolymerizing acrylic resin and incorporated into the final impression. It is interesting to report that none of the frameworks fabricated using the splint impression technique achieved an accurate fit. While, of course, no definitive comparison and cause–effect relationship can be drawn from this limited sample number ($n = 2$), the authors suggest that the time of onset of polymerization shrinkage could play a major role in the overall inaccuracy shown by these two impressions. Indeed, while the verification jig is conventionally manufactured at least 24 hours before the clinical appointment, sectioned, and only luted intraorally

with minor amount of acrylic resin, the splint impression technique is performed intraorally and requires a conspicuous amount of acrylic resin to be layered on the impression coping before the elastomeric impression is recorded. This bulk of acrylic resin material is likely to undergo a consistent contraction, even if separated in independent sections and soldered again during the same appointment. On the other end, it could also be argued that, as the small amount of acrylic resin of the verification jigs also undergoes polymerization shrinkage, even a verification jig will not be absolutely passive. While this is intuitively true, it appears, based on the results of this clinical study, that this dimensional change is not sufficient to negatively affect the clinical fit of framework. This study disagrees with the findings of a previous in vitro study[19] as verification jigs allowed the fabrication of a clinically passive framework in a significantly greater number of cases compared with the cases where a verification jig was not used. This in vitro study[19] used an experimental design that represented an ideal setting for implant impression procedures including the parallel placement, on a stone master base, of three externally hexed implants. These study design features could have allowed the removal of the impression without a significant deformation of the impression material. On the other end, it could be speculated that the clinical nature of the present study, as compared with that of De La Cruz, could have introduced several clinical variables that could be responsible for the recorded lack of accuracy of elastomeric impressions. For example, in a clinical scenario, the impression post engages the implant at variable subgingival depths, therefore decreasing the available surface of the impression post that can be engaged by the impression material. In this light, it has been shown that the apicocoronal placement of an implant affects the horizontal accuracy of elastomeric impressions when the implant location is four or more millimeters below a simulated gingival margin;[12] therefore, it could be possible that the accuracy of the impressions done in this study could have been affected by the depth of implant placement. In addition, in the De La Cruz's study, the three implants were externally hexed and aligned parallel to each other, while in the current study, four to eight implants with an internal connection design were placed in actual patients, therefore and likely, not exactly parallel to each other. Moreover, the present study differs from that of De La Cruz from an experimental standpoint, which ultimately limits the possibility of comparing these two studies. Indeed, while the current study defined clinically passive fit by means of widely used test (Sheffield test), the study by De La Cruz quantified fit by three-dimensional absolute measurements.

In the current study, the use of a verification jig demonstrated to be a valid method to achieve clinically passive fit of the metal frameworks regardless of fabrication technique (CAM or lost-wax technique) and number of implants connected by the framework. While the use of a verification jig requires a dedicated appointment, therefore potentially appearing to increase treatment cost, it is suggested by the authors that its use might actually be beneficial, not only to increase framework accuracy but also to avoid costly sectioning, luting, and soldering procedures that might be caused by inaccurate framework fit.

Even though the current study advocates the use of a verification jig and, to our knowledge, is the first clinical study to do so, the clinician should be reminded that the retrospective nature of the study still warrants the testing of the study hypothesis in a prospective randomized clinical trial.

CONCLUSIONS

In conclusion, this study showed that the fabrication of a verification jig ensures clinically passive fit of metal frameworks in nonsegmented fixed implant-supported complete denture.

REFERENCES

1. Zarb GA, Albrektsson T. Aspects of biomechanical considerations. In: Brånemark P-I, ed. Tissue-integrated prostheses: osseointegration in clinical dentistry-1. Chicago, IL: Quintessence Publishing, 1985:117–128.
2. Zarb GA, Symington JM. Osseointegrated dental implants: preliminary report on a replication study. J Prosthet Dent 1983; 50:271–276.
3. Wicks RA, deRijk WG, Windeler AS. An evaluation of fit in osseointegrated implant components using torque/turn analysis. J Prosthodont 1994; 3:206–212.
4. Worthington P, Bolender CL, Taylor TD. The Swedish system of osseointegrated implants: problems and complications encountered during a 4-year trial period. Int J Oral Maxillofac Surg 1987; 2:77–84.
5. Jemt T, Lindén B, Lekholm U. Failures and complications in 127 consecutively placed fixed partial prostheses supported by Brånemark implants: from prosthetic treatment to first annual checkup. Int J Oral Maxillofac Surg 1992; 7:40–44.

6. Brunski JB. Biomechanical factors affecting the bone-dental implant interface. Clin Mater 1992; 10:153–201.
7. Carr AB, Gerard DA, Larsen PE. The response of bone in primates around unloaded dental implants supporting prostheses with different levels of fit. J Prosthet Dent 1996; 76:500–509.
8. Kallus T, Bessing C. Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5 years. Int J Oral Maxillofac Implants 1994; 9:169–178.
9. 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.
10. Assif D, Nissan J, Varsano I, Singer A. Accuracy of implant impression splinted techniques: effect of splinting material. Int J Oral Maxillofac Implants 1999; 14:885–888.
11. Lorenzoni M, Pertl C, Penkner K, et al. Comparison of the transfer precision of three different impression materials in combination with transfer caps for the Frialit-2 system. J Oral Rehabil 2000; 27:629–638.
12. Lee H, So JS, Hochstedler JL, Ercoli C. The accuracy of implant impressions: a systematic review. J Prosthet Dent 2008; 100:285–291.
13. Anusavice KJ. Casting investments and procedures. In: Phillips RW, ed. Phillips' science of dental materials-11. St. Louis: W.B. Saunders Company, 2003:295–347.
14. Kapos T, Ashy LM, Gallucci GO, Weber H-P, Wismeijer D. Computer-aided design and computer-assisted manufacturing in prosthetic implant dentistry. Int J Oral Maxillofac Surg 2009; 24 (Suppl):110–117.
15. Kan JY, Rungcharassaeng K, Bohsali K, Goodacre CJ, Lang BR. Clinical methods for evaluating implant framework fit. J Prosthet Dent 1999; 81:7–13.
16. Hebel KS, Galindo D, Gajjar RC. Implant position record and implant position cast: minimizing errors, procedures and patient visits in the fabrication of the milled-bar prosthesis. J Prosthet Dent 2000; 83:107–116.
17. Yanase RT, Binon PP, Jemt T, Gulbransen HJ, Parel S. Current issues forum. How do you test a cast framework fit or a full-arch fixed implant-supported prosthesis? Int J Oral Maxillofac Implants 1994; 9:471–474.
18. McCartney JW, Pearson R. Segmental framework matrix: master cast verification, corrected cast guide, and analog transfer template for implant-supported prostheses. J Prosthet Dent 1994; 71:197–200.
19. La Cruz de JE, Funkenbusch PD, Ercoli C, et al. Verification jig for implant-supported prostheses: a comparison of standard impressions with verification jigs made of different materials. J Prosthet Dent 2002; 88:329–336.
20. Gallucci GO, Morton D, Weber H-P. Loading protocols for dental implants in edentulous patients. Int J Oral Maxillofac Surg 2009; 24 (Suppl):132–146.
21. Mojon P, Oberholzer JP, Meyer JM, Belser UC. Polymerization shrinkage of index and pattern acrylic resins. J Prosthet Dent 1990; 64:684–688.
22. Akça K, Cehreli MC. Accuracy of 2 impression techniques for ITI implants. Int J Oral Maxillofac Implants 2004; 19:517–523.
23. Vigolo P, Fonzi F, Majzoub Z, Cordioli G. An evaluation of impression techniques for multiple internal connection implant prostheses. J Prosthet Dent 2004; 92:470–476.
24. Kim S, Nicholls JI, Han C-H, Lee K-W. Displacement of implant components from impressions to definitive casts. Int J Oral Maxillofac Implants 2006; 21:747–755.
25. Carr AB. Comparison of impression techniques for a two-implant 15-degree divergent model. Int J Oral Maxillofac Implants 1992; 7:468–475.
26. Assunção WG, Filho HG, Zaniquelli O. Evaluation of transfer impressions for osseointegrated implants at various angulations. Implant Dent 2004; 13:358–366.