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Relationship between Radiographic Misfit and Clinical Outcomes in Immediately Loaded Complete-Arch Fixed Implant-Supported Prostheses in Edentulous Patients

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Keywords
Dental implant; conversion prosthesis; misfit; implant survival; prosthesis survival.

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The authors declare that they have no conflict of interest.

Accepted August 16, 2019

doi: 10.1111/jopr.13105

Abstract

Purpose: To examine if an uncorrected radiographically detected immediate postoperative misfit (implant level or abutment level) in immediately loaded conversion prosthesis plays a significant role in early implant or prosthesis failure. In addition, clinical characteristics related to type of arch, implant position, type of implant, implant orientation, type of connection, and type of surgery were analyzed relative to their relationship to early implant or prosthesis failure.
Materials and Methods: Immediate postoperative and subsequent follow-up panoramic radiographs of 425 arches with immediately loaded complete-arch fixed implant-supported prostheses were screened in a retrospective analysis. Implants with misfit and nonmisfit within a given arch were summarized separately with respect to each clinical characteristic and the difference between misfit and nonmisfit groups was tested using a mixed-effects logistic regression model with a patient-specific random intercept. A p-value <0.05 was determined to be statistically significant.
Results: A total of 2025 implants from 311 patients were identified in the 425 arches that were screened for radiographic misfit. A total of 48 implants with misfit were found within 33 arches (23 patients) for a 2.4% prevalence rate. Among the misfit implants, two failures were documented during the healing phase for an early implant survival rate of 95.8%. Five conversion prostheses with misfit fractured during the healing phase for early prosthesis survival rate of 84.8%. None of the clinical variables analyzed were significantly associated with the misfit status ($p < 0.05$).
Conclusions: The results from this retrospective study showed that misfit in immediately loaded complete-arch fixed implant-supported prostheses may not play a detrimental role in the implant survival but may affect survival of the conversion prostheses.

Over the past 25 years, innovative protocols have allowed patients to receive dental implants and an interim complete-arch fixed implant-supported prosthesis (CAFIP) fabricated from acrylic resin material, the same day.[1,2] The interim CAFIP can either be fabricated by direct or indirect conversion of the patient's complete denture or digitally fabricated and luted to the titanium cylinders over the implants.[2] Advancements in implant geometry and improved knowledge and understanding of tilting implants, now allows a CAFIP to be anchored to as little as four implants.[3,4] Dental implants used for CAFIPs have demonstrated high survival rates up to 20 years.[5,6] According to a meta-analysis by Papaspyridakos et al, implants in the mandible had 98% cumulative survival rate at 10-year follow-up.[5] Further, Lambert et al reported 88% survival rate in the maxilla at 15-year follow-up.[6] The high survival rates compared to traditional machined surface implants has been attributed to the advancements of implant engineering and implant surface technology.[7] Furthermore, the splinting effect demonstrated with the attachment of an interim CAFIP during the 3-month healing phase has shown to improve clinical outcomes.[8]

Though passive fit has been hard to define by the dental community, it is generally accepted that absence of misfit should be a clinical goal during prosthodontic treatment.[9] Passive fit is thought to reduce unnecessary biomechanical strain at the implant to prosthesis interface and minimize biomechanical complications.[9] There are two types of misfit described in the literature- horizontal misfit (misfit in the mesial-distal or buccal-lingual direction) and vertical misfit (misfit in coronal-apical direction).[10] The significance of a misfit at the implant-prosthesis junction in osseointegrated implants has been exclusive to osseointegrated implants, and debated in the literature without any definitive guidelines because misfit was not recognized as a determinantal factor.[10] Historically, a gap at the interface was considered a normal occurrence up to 150 μm.[11]

During the immediate loading procedure, one of the primary goals is to achieve passive fit of the conversion prosthesis with all implants in the arch.[2] However, passive fit may not always be achievable due to various prosthetic fabrication techniques, mismatch of components, inherent material distortions and soft or hard tissue interferences, and therefore, an "open gap" between any of the interfaces can occur. Even in a flapless scenario, monolithic polymethyl methyl methacrylate (PMMA) CAFIPs have documented to have misfit in the dental literature. In a study by Landazuri-Del Barrio et al,[12] 13 of 16 patients who received flapless-guided surgery and an immediately loaded monolithic PMMA CAFIP demonstrated misfit between the abutment and temporary cylinder. The authors claimed that prefabricated monolithic CAFIPs have clinical drawbacks and the conversion prosthesis should be created based on the precise orientation of the implants at time of surgery. In another recent study, Yilmaz et al[13] showed adjustments with laser welding was typically needed for immediate metal-resin CAFIPs to correct misfit. Implant manufacturers have previously attempted to offset misfit in the flapless scenario by creating specific components called as "guided abutments" that allow compensation of vertical misfit up to 0.4 mm at the abutment-prosthesis interface. These self-adjusting abutments are typically used to mitigate thick soft tissues present in the flapless surgery protocol.[14]

Currently available tools for the clinician to verify passive fit of prosthetic components over implants include: (1) plain visual examination; (2) use of a disclosing medium to aid in visual examination; (3) tactile feedback from palpation; (4) tactile feedback from a one-screw test; (5) tactile feedback from a dental plastic explorer; (6) tactile feedback from screw-clamping force, and (7) radiographs.[9] Common to all of these techniques is that they are not objective and not reproducible. Moreover, passive fit between an abutment and implant is more difficult to verify in implants with internal connection using the above techniques and do not provide confidence of passive fit to the clinician.

Dental radiography to verify accurate fit ("seating") of prosthetic components is not novel to the dental literature. It has been the standard of care for decades to assess marginal adaptation of tooth-borne crowns, inlays, onlays, etc.[15,16] It allows the practitioner to examine components that cannot be verified clinically through visual or tactile feedback. With respect to CAFIP, the panoramic radiograph anecdotally is the standard radiograph that is used postoperatively by clinicians worldwide. It has advantages over periapical radiographs since the entire maxilla and mandible can be visualized along with important anatomic sites such as mandibular canal/foramina and maxillary sinuses.[16] In addition, due to bone reduction procedures that alter the anatomy of a patient's jaw with respect to the adjacent structures, conventional periapical radiographs are cumbersome to take, or not feasible. A panoramic radiograph is readily taken postoperatively to also assess final implant orientation and assess any misfit of the interim CAFIP over the implants. Most practitioners also take a secondary panoramic radiograph after 3 or 4 months of healing to study any early marginal bone loss around the implants. However, issues with standardization between two panoramic radiographs can be argued and present a major limitation to studies using radiographic analysis.[17]

Presently, there is no literature that has examined the clinical outcomes of uncorrected misfit in the immediate load scenario. Therefore, the purpose of this retrospective study was to determine if an uncorrected radiographically detected misfit in an immediately loaded CAFIP, plays a significant role in early implant or prosthesis survival rates. In addition, clinical characteristics, such as type of arch (maxilla/mandible), implant position (anterior/posterior), type of implant (alveolar/extra maxillary), implant orientation (tilted/straight), connection (external/internal), surgery type (free-hand/guided), in relation to misfit were analyzed relative to their relationship to early implant or prosthesis failures.

Materials and methods

This observational study was approved by the Institutional Review Board at the University of Connecticut Health Center (#17-168-3.1). From two distinct private clinics (Pi Dental Center, Ft. Washington, PA and Cloverleaf Dental Center, Meriden, CT), a total of 425 arches comprising 311 patients treated for CAFIP were screened based on predetermined inclusion and exclusion criteria. The inclusion criteria were: (1) treatments where an interim CAFIP was immediately loaded in one or both jaws; (2) the availability of an immediate postoperative panoramic radiograph as well as follow-up radiographs after insertion of definitive prosthesis; (3) a clearly recognizable vertical radiographic misfit on at least one of the supporting implants at implant level, or abutment level, or prosthesis level; and (4) clearly deducible chart notes with all data related to implants, abutments, and prosthesis. The exclusion criteria were: (1) conversion prostheses that were not immediately loaded; (2) panoramic radiographs that showed no detectable misfit; (3) images with poor resolution or undiagnostic quality; and (4) images with partially edentulous rehabilitation.

Panoramic radiographs that were identified according to the inclusion criteria had all personal identifiers removed. Demographic information, including age and gender, were recorded for analysis. In addition, clinical characteristics, such as type of arch (maxilla/mandible), implant position (anterior/posterior), type of implant (alveolar/extra maxillary), implant orientation (tilted/straight), connection (external/internal), surgery type (free hand/guided), were examined. One investigator screened all 2025 implants for detection of radiographic misfit.

Immediate postoperative panoramic radiographs were first analyzed in patients with immediately loaded all-acrylic resin CAFIPs to observe misfit (horizontal or vertical) between prosthesis and abutment/implant (Fig 1). Postoperative panoramic radiographs with the definitive prosthesis panoramic radiographs of the same patients were then analyzed to observe if the implant with misfit was still present and supported

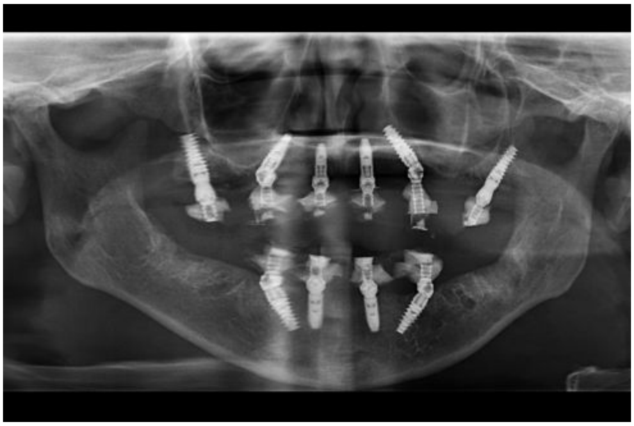

Figure 1 Example of an immediate postoperative panoramic radiograph demonstrating radiographic misfit at the abutment-prosthesis interface at site no. 13. This misfit was not corrected during the healing phase of 4 months.

Figure 2 Example of a postinsertion panoramic radiograph of the definitive prosthesis demonstrating presence of the implant and supporting the definitive prosthesis, indicating early survival of the implant.

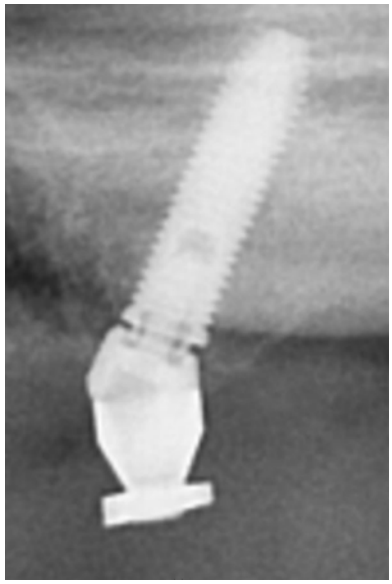

Figure 3 Example of a radiographic misfit at the implant-abutment junction in an immediately loaded complete-arch fixed implant-supported prosthesis.

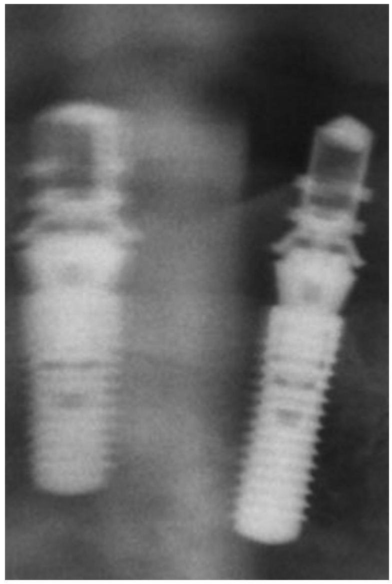

Figure 4 Example of a radiographic misfit at the abutment-prosthesis junction in an immediately loaded complete-arch fixed implant-supported prosthesis. Note that the titanium cylinders are incorporated into the prosthesis, thus, making it an abutment-prosthesis junction.

the definitive prosthesis (Fig 2). The type of misfit was then identified as occurring at either: (1) implant-abutment junction; (2) abutment-prosthesis junction; or (3) implant-prosthesis junction as seen in tissue-level implants (Fig 3–5).

Thorough analysis of patient's electronic records and any additional radiographs were also performed to rule out the inclusion of treatments that received any subsequent clinical intervention to correct the misfit. Patient chart records and implant database systems were searched to determine if any implant or prosthesis failures occurred and at what point in time (months since implant was placed). For the purpose of this study, early implant failure was defined as loss of an implant before insertion of the definitive prosthesis. It was hypothesized that if misfit had any detrimental role, it could cause failure of the implants to osseointegrate because of undue forces that are magnified when passive fit is not achieved. Implant database systems were also searched to gather important data such as surgery dates, failure dates, and information on desired covariates. Implant data were recorded and fragmented into categorical variables in Microsoft Excel. Percent prevalence and survival rates for desired variables were analyzed. No attempt was made to obtain a matched control from implants in arches without any detectable radiographic misfit. Comparison was only made between implants with misfit and implants without misfit in the same arch, where at least one implant had a radiographically detected misfit.

All of the statistical analyses were performed with the statistical software R 3.5.1 (R Core Team (2018). R: A language

Figure 5 Example of a radiographic misfit at the implant-prosthesis junction in an immediately complete-arch fixed implant-supported prosthesis. This was typically seen in tissue-level implants.

and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria (http://www.R-project.org/). Misfit and nonmisfit implants within a given arch were summarized separately with respect to each clinical characteristic and the difference between misfit and nonmisfit groups was tested using a mixed-effects logistic regression model with a patient-specific random intercept. A p-value of <0.05 was chosen to reject any foreseeable null hypotheses related to comparison between survival rates and misfit.

Results

All measurements were conducted by one operator. The age range of patients in this study was from 32 to 89 years of age (Table 1). The gender distribution for misfit was 58% female and 42% male (Table 2). Out of 2025 implants screened, 48 implants demonstrated radiographically detectible misfit of the interim CAFIP in vertical direction. This finding was seen in 33 arches comprising of 27 patients. In these 33 arches, the combined number of misfit and nonmisfit implants equated to 182 samples (48 misfit and 134 nonmisfit implants) (Table 1). Patient's chart records showed that all 48 misfits were uncorrected during the healing phase and there was no evidence of any clinical intervention. After a 3- or 4-month healing period for the implants, the prostheses were removed and subsequent procedures for fabricating the definitive prosthesis were performed using standard prosthodontic principles.

The percent prevalence of total misfit and the analyzed covariates, such as arch type, implant position, type of implant, implant orientation, implant-to-abutment connection, surgery type and total number of implants per arch, are presented in Table 2. Out of 48 implants with misfits, two implants had early failure (Table 1). No implants failed thereafter as recorded in the postoperative radiographs with the definitive prosthesis, as well as patient's chart records. This equated to a 95.8% early implant survival rate among implants with misfits. Both implant failures occurred in the maxillary arch and the interim CAFIP associated with both implants did not fracture during the healing phase. Both failed implants had adequate primary stability at the time of insertion. The first failure was an alveolar, axially placed implant in the posterior region of the maxilla, where six implants in total had been placed. A free-hand surgical protocol was used. The implant had an internal connection and the misfit was at the abutment to prosthesis junction. At the time of implant failure, another implant was placed in an adjacent site and immediately loaded within the interim CAFIP. Based on the post-treatment radiograph with the definitive prosthesis and patient's chart records, no subsequent failure was noted. The second failure was an extramaxillary (pterygoid), tilted implant in the posterior region of the maxilla. A free-hand surgical protocol was used. The implant had an external connection and the misfit was at the abutment to prosthesis junction. Six implants were placed in the arch. The failed implant site was ignored and another implant was not placed.

Out of the 33 arches with misfit prostheses, five arches experienced fractures of the interim CAFIPs during healing phase. This equated to an early prosthesis survival rate of 84.8%. Each CAFIP only fractured once. The prostheses were fabricated using conventional methods using the conversion

Table 1 Summary of implants and interim prostheses analyzed in this retrospective study to assess misfit in the immediate load scenario

Total number of patient charts screened	311
Total number of arches screened	425
Total number of implants screened	2025
Age range of patients screened (in years)	32-89
Total number of implants in the arches where misfit occurred	182
Total number of implants associated with radiographic misfit	48
Total number of implants not associated with radiographic misfit	134
Total number of arches associated with radiographic misfit	33
Total number of patients associated with radiographic misfit	27
Total number of implant failures	2
Total number of arches associated with misfit and prosthesis complications	5
Total number of patients associated with misfit and prosthesis complications	4

Table 2 Prevalence of demographic and clinical covariates in the combined 182 implants (misfit and nonmisfit) in arches where misfit occurred

	Misfit ($n = 48$)	Nonmisfit ($n = 134$)	Combined ($n = 182$)	*p*-value
Arch				0.876
Mandible	12 (25%)	32 (24%)	44 (24%)	
Maxilla	36 (75%)	102 (76%)	138 (76%)	
Gender				0.798
Female	28 (58%)	81 (60%)	109 (60%)	
Male	20 (42%)	53 (40%)	73 (40%)	
Misfit present				
No	0 (0%)	134 (100%)	134 (74%)	
Yes	48 (100%)	0 (0%)	48 (26%)	
Surgery type				0.520
Free hand	42 (88%)	112 (84%)	154 (85%)	
Guided	6 (12%)	22 (16%)	28 (15%)	
Misfit implant position				0.549
Anterior	21 (44%)	52 (39%)	73 (40%)	
Posterior	27 (56%)	82 (61%)	109 (60%)	
Implant location				0.897
Alveolar	35 (73%)	99 (74%)	134 (74%)	
Extramaxillary	13 (27%)	35 (26%)	48 (26%)	
Implant orientation				
Straight	21 (44%)	56 (42%)	77 (42%)	
Tilted	27 (56%)	78 (58%)	105 (58%)	
Total number of implants (per arch)	5.6 ± 1.61	5.81 ± 1.58	5.76 ± 1.58	0.431
Implant-abutment connection				0.818
External	31 (65%)	89 (66%)	120 (66%)	
Internal	17 (35%)	45 (34%)	62 (34%)	
Misfit location				0.156
Abutment level	46 (96%)	133 (99%)	179 (98%)	
Implant level	2 (4%)	1 (1%)	3 (2%)	
Implant failure				
No	46 (96%)	134 (100%)	180 (99%)	
Yes	2 (4%)	0 (0%)	2 (1%)	
Prosthesis failure				0.375
No	43 (90%)	113 (84%)	156 (86%)	
Yes	5 (10%)	21 (16%)	26 (14%)	

prosthesis protocol,[2] and were repaired with autopolymerizing acrylic resin material. After repair, no further complications with the prostheses resulted during the healing phase. There were no prosthetic complications after delivery of the definitive prostheses. Three of the five interim, CAFIPs had one misfit associated with them and one prosthesis had a total of two misfits. This equated a total of five misfits involved in five fractured interim CAFIPs (10.4%) (Table 2).

Discussion

The purpose of this study was to understand if an uncorrected immediate postoperative radiographic misfit in immediately loaded conversion prosthesis plays any role in early implant or prosthesis failures. The overall prevalence of radiographic misfit in the complete-arch immediate load scenario from this large sample retrospective analysis across two distinct implant centers was determined to be very low at 2.4% and its relationship to early implant failure was insignificant. This low incidence is a clinically favorable finding of this study.

Successful osseointegration of dental implants is recognized as a multifactorial process. However, in the immediate loaded CAFIP scenario, perhaps the most important aspect is adequate primary stability.[18] Furthermore, the splinting effect demonstrated with the attachment of an interim CAFIP during the 3-month healing phase has shown positive clinical benefit.[8] From the results of this study, it can be suggested that radiographically detected misfit may not play a detrimental role in early implant survival, as long as adequate primary stability is achieved at the time of surgery. Furthermore if, the cross-arch splinting effect is achieved with an intact interim CAFIP of sufficient thickness, the effect of misfit on implant failure may be minimal. However, misfit may result in fracture of the interim all-acrylic resin CAFIP but further research is needed on whether reinforced or modern higher strength monolithic materials can withstand the effect of misfit.

Five of the 33 arches where misfit was present experienced a fracture of the interim CAFIP during the 3- to 4-month healing period. All of these prostheses were deemed to have adequate prosthetic space by the treating clinicians. This correlated to a 15.2% early prosthesis complication rate. In comparison, a 2016 study by Drago[19] examined the frequency and type of prosthetic complications in immediately loaded CAFIPs. His study reported that 18% of 191 CAFIPs needed repair, but there was no mention of prevalence of radiographic misfit. Furthermore, it has been reported that fracture rate of conversion prostheses can be higher if prosthetic space requirements were not satisfied by adequate bone reduction.[20]

Interim prostheses usually lack a metal reinforcement framework and are typically fabricated of polymethyl methacrylate due to simplicity, ease of adjustments, and reduced cost to the patient and clinician.[2] However, the all-acrylic resin material may undergo flexure and fatigue with time due to the inherent nature of the material and will eventually fracture. It is possible many authors[4,19] who have reported on high rates of fracture of the conversion prosthesis may not have considered the presence of misfit. Further clinical research is needed to rule out whether misfit is an important factor in fracture of the conversion prosthesis. Therefore, the results from this study suggest misfit may contribute to the survival of interim CAFIPs, but the overall complication of interim CAFIP fracture is still multifactorial.

Finally, dental arch, implant position, type of implant, implant orientation connection, surgery type, and total number of implants per arch were all analyzed and determined to be statistically insignificant in relation to misfits in the immediate load scenario. It was hypothesized that a greater number of implants per arch would produce more misfits. The rationale is based upon more implant/abutment or abutment/prosthesis interfaces per arch, the more chance for misfit. However, the data from this study were unable to support this hypothesis due to the low failure rate of the implants.

The use of panoramic radiographs for misfit evaluation is a limitation of this study. Although the panoramic radiograph is the standard radiograph exposed in the complete-arch rehabilitation, there are issues with standardization and distortion between each exposure.[17] Therefore, it can be argued that lack of detection of radiographic misfit by the authors, does not imply that additional samples of misfit would not exist. In addition, the presence of artifact within these radiographs could have produced false negative or false positives but the study investigators paid careful attention to rule out this error. Another limitation to this study is that no correlation was possible between peak insertion torque and implants with misfit because of the low failure rate. The study also did not have a true control group to compare survival rates of implants in arches without any radiographic misfit, because we assumed that obtaining matched controls for the low samples of radiographic misfit (with low failure rate of implants with misfit) would have resulted in spurious conclusions, such as misfit providing a beneficial or protective outcome, for implant survival. Future research is needed to examine this hypothesis.

Research examining misfit in the immediately loaded CAFIP has immense benefits due to the rising popularity of this procedure. Results from this study can help practitioners to determine the clinical importance of misfit in immediately loaded CAFIPs. It may also aid clinicians to achieve better clinical confidence and aid in decision making whether to correct a misfit if they detected a postoperative radiographic misfit in an immediately loaded CAFIP.

Conclusions

The overall prevalence of radiographically detectable misfit from 425 immediately loaded complete-arch all-acrylic interim prosthesis encompassing 2025 implants from 311 patients was low (2.4%). Among the 48 implants with radiographic misfit, two failures were documented during the healing phase for an early implant failure rate of 95.8% among implants associated with misfit suggesting that misfit may not play a detrimental role in implant survival during the osseointegration period. Five conversion prostheses with radiographic misfit fractured during the healing phase for early prosthesis survival rate was 84.8%, indicating that misfit may be an important factor in the survival of the conversion prostheses. Covariates, such as type of arch, implant position, type of implant, implant orientation, prosthetic connection, surgery type, and total number of implants per arch, did not have any significant association with radiographic misfit.

Acknowledgments

Authors would like to thank the staff of Pi Dental Center, Ft. Washington, PA and Cloverleaf Dental Center, Meriden, CT for their valuable assistance in data collection for this project. This research was funded by the Greater New York Academy of Prosthodontics.

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