Evaluation of the Accuracy of Implant-Level Impression Techniques for Internal-Connection Implant Prostheses in Parallel and Divergent Models

Jung-Han Choi, DDS, MSD[1]/Young-Jun Lim, DDS, MSD, PhD[2]/Soon-Ho Yim, DDS, MSD, PhD[3]/
Chang-Whe Kim, DDS, MSD, PhD[4]

Purpose: *This study evaluated the accuracy of 2 implant-level impression techniques (direct nonsplinted and splinted) for the fabrication of multi-unit internal-connection implant restorations in 2 simulated clinical settings (parallel and divergent) using a laboratory model.* ***Materials and Methods:*** *A dental stone master model was fabricated with 2 pairs of implant replicas. One pair simulated a parallel clinical condition and the other an 8-degree–divergent condition. Ten stone casts were made from vinyl polysiloxane impressions of the master model for each impression technique. Half of the samples were created by a direct nonsplinted technique (square impression copings, custom tray), and the other half were made by a direct splinted technique (square impression copings splinted with autopolymerizing acrylic resin, custom tray). Four strain gauges were fixed on each metal framework to measure the degree of framework deformation for each stone cast in half-Wheatstone-bridge formations. Deformation readings were made twice in 4 directions (anterior, posterior, superior, and inferior). Deformation data were analyzed using repeated-measures analysis of variance at a .05 level of significance.* ***Results:*** *No significant difference in deformation was found between the direct nonsplinted and splinted samples in either simulated clinical condition (P > .05). No significant difference in deformation was found between the techniques regardless of condition (P > .05).* ***Conclusions:*** *Within the limitations of this study, using a 2-implant model, the accuracy of implant-level impressions for internal-connection implant restorations was similar for the direct nonsplinted and splinted techniques in settings with divergence up to 8 degrees.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:761–768

Key words: *implant divergence, implant-level impression, internal connection implant, strain gauge*

Endosseous dental implant therapy has been shown to be quite successful for the restoration of fully and partially edentulous patients.[1–4] It is believed that a completely successful result can be achieved only through the fabrication of passively fitting prostheses,[5,6] because dental implants are not supported by a periodontal ligament, which can compensate for a certain degree of misfit in fixed partial dentures.[7,8] The absence of a passive fit may lead to mechanical and biological failures of implant-supported restorations and osseointegrated implants, such as fracture or loosening of screws, retention of biofilm, and even loss of osseointegration.[9–15] However, the clinical and laboratory variables intrinsic to restorative treatment make it difficult to fabricate prostheses with a passive fit.

Impression techniques are particularly important in the fabrication of accurate working casts.[16] Several impression techniques have been proposed to achieve a definitive cast that will ensure the passive fit of prostheses on osseointegrated implants. To ensure maximum accuracy, Brånemark et al[17] emphasized the importance of splinting impression copings together intraorally before making an impression. Although this splinted technique is both popular and accurate,[16,18–20] it is also time-consum-

[1]Clinical Assistant Professor, Department of Prosthodontics, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, South Korea; Graduate Student, Department of Prosthodontics & Dental Research Institute, College of Dentistry, Seoul National University, Seoul, South Korea.
[2]Assistant Professor, Department of Prosthodontics & Dental Research Institute, College of Dentistry, Seoul National University, Seoul, South Korea.
[3]Professor, Department of Prosthodontics, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, South Korea.
[4]Professor, Department of Prosthodontics & Dental Research Institute, College of Dentistry, Seoul National University, Seoul, South Korea.

Correspondence to: Dr Chang-Whe Kim, Department of Prosthodontics and Dental Research Institute, College of Dentistry, Seoul National University, 28 Yeongeon-dong, Jongno-gu, Seoul 110-749, South Korea. Fax: +82 2 3410 0038.
E-mail: cjhan@smc.samsung.co.kr

Fig 1 Superior view of the master model with 4 internal-connection implant replicas. Square impression copings were connected to show the angulation of the replicas. The pair on the left represents the divergent condition, and the pair on the right represents the parallel condition.

ing to connect the impression copings with acrylic resin. A number of studies[21–24] have shown no significant difference in the accuracy of acrylic resin splinted and nonsplinted impression techniques, and Inturregui et al[25] and Burawi et al[26] found that the nonsplinted technique was more accurate than the splinted one. In spite of the expected advantages of splinted impression copings, the splinted technique does not always make more accurate casts than the nonsplinted technique.

Implant-level impression making permits selection of the most appropriate abutments in the laboratory with abutment selection kits, which is helpful for situations where vertical space and/or angulation of the abutment are difficult to determine intraorally. In addition, it facilitates replacement of the healing caps by eliminating the need to cover the abutments with temporary restorations or protective caps.[27] In particular, when the restoration connects directly to the implants, as in cases of insufficient vertical space, the definitive cast is obtained by an implant-level impression.

A lack of parallelism between implants and between implants and teeth is commonly encountered in implant prosthodontics and may create an undesirable path of withdrawal and subsequent distortion of the impression. The external-hexagon implant has a relatively short hexagon to which the impression components mate. In contrast, some implants with internal abutment connections have longer walls of relative parallelism that could make withdrawal of an impression more difficult. The Astra ST implant (Astra Tech, Mölndal, Sweden) is characterized by an 11-degree taper and a relatively long hexagon on the internal connection. This connection structure may affect the accuracy of the implant-level impression technique.

Previous studies[6,16,18,19,21–26,28] have evaluated the accuracy of various implant impression techniques at the abutment level using external-hexagon implants. Few studies have examined the accuracy of implant-level impression techniques for internal-connection implants. The purpose of this in vitro study was to evaluate the accuracy of 2 different implant-level impression techniques (direct nonsplinted and splinted) for the creation of multi-unit internal-connection (Astra Tech) implant-supported prostheses in a laboratory model simulating 2 different clinical conditions (parallel and divergent).

MATERIALS AND METHODS

Fabrication of the Master Model

A preliminary master model simulating a linear residual ridge was fabricated in dental stone. Four holes were made on the ridge to reproduce 2 different clinical conditions to be treated with 2-implant restorations. The 2 holes in each pair were made 10 mm apart from edge to edge. One hole had an angulation of 8 degrees toward the posterior; the remaining 3 holes were not angulated. Thus, 1 pair simulated a divergent condition, and the other pair simulated a parallel condition (Fig 1). A divergence of 8 degrees was selected based on previous trials demonstrating that 8 degrees was the maximum divergence that permitted removal of the splinted impression copings used in this study. Four implant replicas (Fixture Replica ST 22509; Astra Tech) were placed in the holes with acrylic resin (Pattern Resin; GC Corporation, Tokyo, Japan). Two rectangular frameworks (6 mm × 4 mm × 20 mm) simulating prostheses connecting directly to the implants were waxed with 4 abutments (Cast-to Abutment ST 22829; Astra Tech) and cast in type IV gold alloy (Jel-4; Jelenko, Armonk, New York, NY). All measurements were made on these metal frameworks. The 4 implant replicas were removed from the preliminary master model and screwed to the metal frameworks. These framework-replica structures were then fixed in the holes filled with acrylic resin using a milling machine. This procedure was similar to one used in previous studies[16,19,29] to fabricate a master model. The internal-connection implant replicas used in this study had longer walls of relative parallelism, which made withdrawal of the impression more difficult, resulting in the transfer of a higher level of stress to the replicas during the procedure. To fabricate a master model with a passive fit to the 2 metal frameworks and ensure the positional stability of the implant replicas throughout the experiment, a low-consistency vinyl polysiloxane (Examixfine; GC Corporation) pickup impression was made with a custom tray fabricated by a wax relief procedure on the preliminary master model with the 2 metal frameworks. Four new implant replicas were screwed to the 2 metal frameworks inside the impression, and the impression was poured with type IV dental stone (GC Fujirock EP; GC Europe, Leuven, Belgium). The end result was a master model with 4 implant replicas embedded directly into dental stone. A groove was made on the base of the master model to standardize the tray position during impression making. This master model was used as the standard for all the impressions (Fig 1).

Fabrication of Custom Trays

Standardized custom trays were made with light-polymerizing resin (Fegura Tray; Feguramed, Buchen, Germany). Two layers of baseplate wax spacers (Kerr, Romulus, MI) were placed on the master model with square impression copings (Fixture Impression Pick-up ST short 22847; Astra Tech) to ensure uniform thickness of the impression material. An irreversible hydrocolloid impression (Kromafaze; Cadco Dental Products, Oxnard, CA) was made to obtain a single cast on which all custom trays were fabricated. Twenty trays were made on this cast, 10 trays for each technique. Four holes were made on the upper section of the tray to allow access to the guide pins. The trays were stored at room temperature for 24 hours before impression making.[30,31]

Splinting of Impression Copings

The square impression copings were connected with acrylic resin (Pattern Resin; GC Corporation) before use in the direct splinted technique. A mold was made with vinyl polysiloxane putty impression material (Exafine; GC Corporation) to standardize the dimension of the acrylic resin splints for each specimen. Acrylic resin was poured into the mold and allowed to set for 15 minutes.[25] The splinted impression copings were removed from the master model, and the excess resin was trimmed away (Fig 2). Fifteen minutes[25] before impression making, the acrylic resin splints were sectioned equidistant from the 2 impression copings and reconnected with an incremental application technique to minimize the polymerization shrinkage of the resin during polymerization.[32,33]

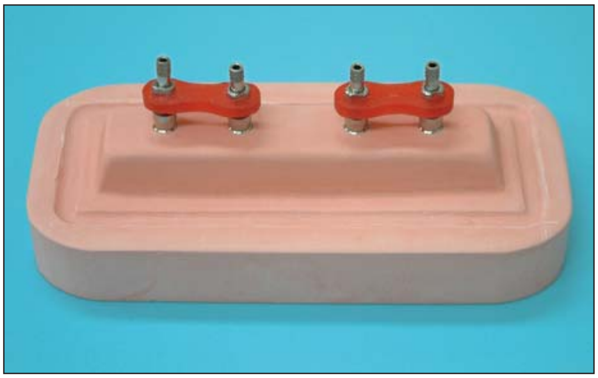


Fig 2 Splinted impression technique. Square impression copings were joined together with autopolymerizing acrylic resin using a vinyl polysiloxane putty mold to standardize the resin splint dimension.

Impression Procedures and Specimen Preparation

Ten impressions with square impression copings were made for each of 2 different impression techniques. The appropriate adhesive was applied to the custom trays 15 minutes before impression making.[34] Low-consistency vinyl polysiloxane (Examixfine; GC Corporation) was used as an impression material for all procedures. A dispenser was used to standardize all mixtures. Vinyl polysiloxane was meticulously syringed around the impression copings to ensure complete coverage of the copings and loaded inside the custom trays. The impression trays were lowered over the master model until the trays were fully seated on the positioning groove and then held in position during the polymerization period with finger pressure. The impressions were allowed to set for twice the normal setting time (8 minutes instead of the usual 4) to ensure complete polymerization at room temperature.[35] The guide pins were unscrewed, and the custom trays were removed from the master model. Implant replicas were manually fastened to the impression copings in the impressions; care was taken to avoid rotating the copings. Each impression was poured with vacuum-mixed type IV dental stone and allowed to rest for 1 hour for complete setting. All stone casts were stored at room temperature for a minimum of 24 hours before measurement. All clinical and laboratory procedures were performed by a single well-trained operator.

Assessment of Accuracy

Four strain gauges (120 Ω; gauge length 1 mm; KFG-1-120-C1-11, Kyowa, Japan) were bonded to each metal framework (superior, inferior, anterior, and posterior faces midway between abutments) with a special cyanoacrylate (M-Bond 200; Vishay Micro-Measurements, Raleigh, NC) to measure the framework deformation of each stone cast. These strain gauges were assembled longitudinally between abutments. Each pair of strain gauges formed a connection denoted a "half Wheatstone bridge," which constituted 1 channel for evaluating deformation.[16] In this way, 2 reading channels for each metal framework were established. Channel 1 measured the vertical deformation (superior-inferior) of the metal frame-

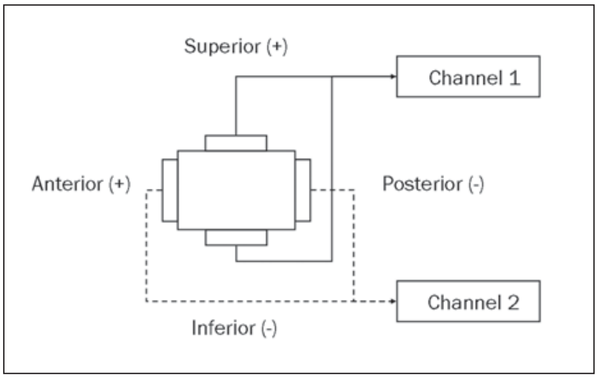


Fig 3 Cross section of the metal framework showing the strain gauge setup.

works, and channel 2 measured the horizontal deformation (anterior-posterior; Fig 3). Positive values for channels 1 and 2 represented the bending of the metal framework upward and forward, respectively. Channel signals were improved by a dynamic signal conditioning strain amplifier (CTA-1000; Curiosity Technology, Seoul, Korea), converted into digital signals using a 16-byte resolution converter (DAQCard-AI-16XE-50; USA National Instruments, Austin, TX), and processed with custom software (DA-1700B; Cas Korea, Seoul, Korea). Channel signals were originally measured in millivolts and then converted into microstrain units (μm/m). Measurements could be made to the level of 1 μm/m. Prior to the deformation readings on the stone casts, the metal frameworks were seated on the master model. The screws (abutment screw 22568; Astra Tech) were tightened to 10 Ncm using a torque controller (Torque Wrench 24075; Astra Tech) so that the strain gauges would be calibrated to zero. This procedure discharged any residual stress, because it was impossible to achieve a completely accurate fit between the metal frameworks and the master model. The lack of a perfect fit probably resulted from the setting expansion of the dental stone.

The metal frameworks were seated on each stone cast, and screws were tightened to 10 Ncm using a torque controller with the same tightening sequence. Readings were made twice on each stone cast. To guarantee the same degree of screw wear between the techniques, measurement was performed in an alternating sequence between the samples of the 2 techniques. After the first readings of the 20 specimens were completed, another series of readings was performed using a new set of screws. A single well-trained examiner blinded to the impression technique examined all stone casts to read the deformation of the metal frameworks. Deformation data of 2 readings were analyzed using repeated-measures analysis of variance (ANOVA) at a .05 level of statistical significance. The single-measure intraclass correlation coefficient (ICC) was calculated to analyze the agreement of the 2 readings.

RESULTS

Tables 1 and 2 display the measured deformation for the 2 impression techniques applied to the parallel and divergent clinical conditions, respectively. In the parallel condition, repeated-measures analysis of variance revealed no statistically significant differences in deformation between direct nonsplinted technique samples and direct splinted technique samples in either channel ($P = .92$ for channel 1 and $P = .70$ for channel 2; Table 1). No statistically significant differences were found between the impression techniques in either channel in the divergent condition ($P = .33$ for channel 1 and $P = .32$ for channel 2; Table 2). The ICCs ranged from 0.2044 to 0.4380 (Tables 1 and 2).

Repeated-measures ANOVA was used to evaluate the effect of the impression technique and the underlying condition on deformation (Table 3). There were no differences in deformation between the 2 impression techniques, regardless of condition, in either channel ($P = .40$ for channel 1 and $P = .72$ for channel 2). There was also no difference in deformation between the parallel and divergent conditions, regardless of the impression technique, in channel 1 ($P = .30$). In channel 2, however, statistically significant differences in deformation were found between the 2 conditions, regardless of impression technique ($P < .001$).

DISCUSSION

Successful implant prosthodontics relies on passively fitting prostheses.[5,6] An important factor that influences precision of fit is impression accuracy. Most reports[6,16,18,19,21–26,28] in the dental literature have evaluated the accuracy of impression techniques using external-hexagon implants, but internal-connection implants have a different connection geometry. Some internal-connection implants have longer walls of relative parallelism that could make withdrawal of an impression more difficult, resulting in the transfer of a higher level of stress to the impression copings during the impression procedure.

Table 1 Comparison of Deformation (μm/m) for Impression Techniques Applied to a Parallel Condition

		1st reading		2nd reading			
	n	Mean	SD	Mean	SD	*P**	ICC†
Channel 1							
Nonsplinted	10	−1116.1	259.8	−1359.1	295.4	.92	.4380
Splinted	10	−1093.1	119.7	−1363.1	152.3		
Channel 2							
Nonsplinted	10	116.8	36.2	124.0	31.9	.70	.2044
Splinted	10	130.2	29.4	119.0	22.7		

*Differences between both techniques were evaluated by repeated-measures analysis of variance. $P < .05$ level was considered significant.
†Single-measure ICC between the 2 readings.

Table 2 Comparison of Deformation (μm/m) for Impression Techniques Applied to a Divergent Condition

		1st reading		2nd reading			
	n	Mean	SD	Mean	SD	*P**	ICC†
Channel 1							
Nonsplinted	10	−983.0	288.4	−1443.6	393.3	.33	.2767
Splinted	10	−853.0	226.5	−1338.1	243.3		
Channel 2							
Nonsplinted	10	57.2	31.1	79.5	23.7	.32	.2242
Splinted	10	43.2	25.4	75.0	17.7		

*Differences between both techniques were evaluated by repeated-measures analysis of variance. $P < .05$ was considered significant.
†Single-measure ICC between the 2 readings.

This study evaluated the accuracy of 2 different implant-level impression techniques used for the fabrication of multi-unit implant restorations. To assess the effect of the connection configuration on the accuracy of the impression techniques, 2 different clinical situations, parallel implants and implants that diverged by 8 degrees, were simulated. The Astra ST implant used in this study has an 11-degree taper and a lower hexagon with parallel walls on the internal connection. The maximum divergence between Astra ST implants permitting the removal of the splinted impression copings and the seating of the metal frameworks is determined by the spaces between the hexagons of the implants and coronal components, such as impression copings and abutments. The use of an 8-degree divergence was based on prior trials using a rigid acrylic resin beam.

The impression material used in this study was a low-consistency vinyl polysiloxane. Although polyether has been suggested as the material of choice for implant impression procedures,[17,36] a more elastic impression material could hypothetically reduce the permanent deformation of the impression.[20] Low-consistency vinyl polysiloxane was also more advantageous in this study because the implants used caused a higher level of stress to the impression copings during the impression procedure. In addition, the advantages of polyether are the same as those of the splinted impression technique. Therefore, the use of a more elastic impression material is advantageous in evaluating the effect of splinting impression copings on impression accuracy.

Table 3 Repeated-Measures ANOVA for Channels as a Function of Impression Technique and Simulated Clinical Condition

	F	Degree of freedom	*P*
Channel 1			
Techniques	0.73	(1, 37)	.40
Conditions	1.11	(1, 37)	.30
Channel 2			
Techniques	0.13	(1, 37)	.72
Conditions	70.35	(1, 37)	< .001*

*Statistically significant.

In this study, the direct nonsplinted and splinted techniques similarly reproduced the implant position in both parallel and 8-degree divergent conditions (Tables 1 and 2). In the splinted technique, the splinting of the impression copings with acrylic resin could be an advantage.[19,37–39] The splinting of impression copings has been shown to be a primary factor for

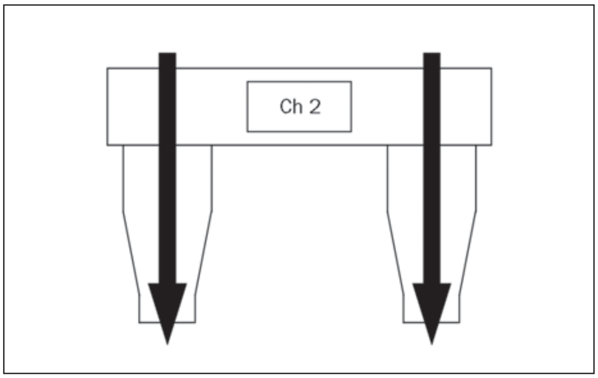


Fig 4a Schematic representation of the effect of the screw axis on the deformation value of channel 2. Channel 2 measures horizontal (anterior-posterior) deformation perpendicular to the screw axis, making the strain values of channel 2 less dependent on deformation caused by an inaccurate fit in the 2-implant model than channel 1.

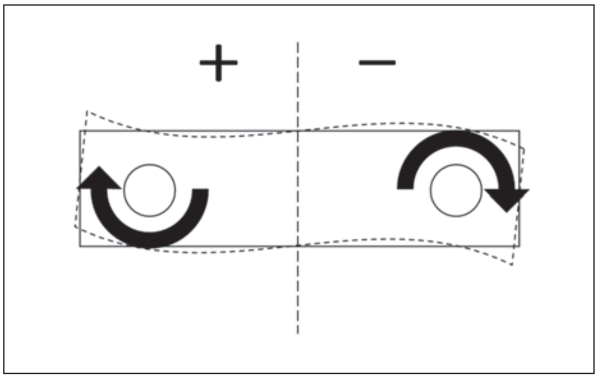


Fig 4b Schematic representation of the effect of strain gauge position on the deformation value of channel 2. If strain gauges are located in the left side of the midline between the 2 screw holes, channel 2 shows a positive value because of the direction of the screw tightening force and the friction between the screws and the framework.

increasing the fitting precision of the restorative complex regardless of the impression material.[18–20,28,29,37,38] To avoid problems related to resin polymerization contraction, the resin scaffold should be prepared 1 day in advance, and the final connection should be performed just before the impression procedure.[28]

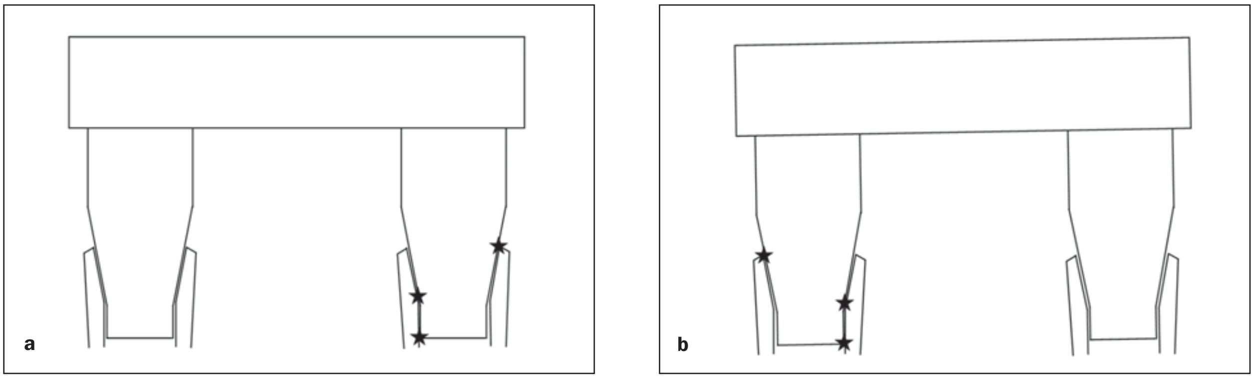
However, connecting the impression copings with acrylic resin is a time-consuming procedure. The results of this study suggest that displacement of the internal-connection impression copings during impression removal and replica connection in the direct nonsplinted technique can be controlled by the elastic impression material and an experienced practitioner to an extent similar to that observed with the direct splinted technique.

Vigolo et al[20] studied the accuracy of the 3 implant-level impression techniques with the Osseotite Certain Implant System, another type of internal-connection implant. They reported that the splinted technique resulted in more accurate definitive casts when multiple internal-connection implants with an almost parallel configuration were to be restored. Their study evaluated the accuracy of the impression techniques by measuring only 2 selected linear distances between the external edges of the most mesial and distal implant replica heads using a profile projector. Since inaccuracy was expressed in only 2 dimensions, information was lost. Furthermore, assessment of the total assembly fit was impossible.[16] Strain gauges enable the measurement of deformation in multiple directions with high sensitivity. The half Wheatstone bridge used in this study is more advantageous in evaluating the deformation of a framework than the quarter Wheatstone bridge used in many previous studies.[16]

In the present study, the deformation values of channel 2 were relatively small compared with those of channel 1; they were also significantly lower in the divergent condition than in the parallel condition, regardless of impression technique (Tables 1, 2, and 3). However, in a 2-implant model, the deformation values of channel 2 are dependent on the locations of the 2 strain gauges (1 anterior and 1 posterior) between the 2 screw holes, because of the direction of the screw-tightening force and the friction between the screws and framework (Figs 4a and 4b). In this study, in spite of efforts to locate the strain gauges midway between the 2 screw holes, the strain gauges composing channel 2 might not have been located in the center. Moreover, the gauges of the parallel condition might have been located further from the center than those of the divergent condition.

Watanabe et al[40] reported that screw-tightening order affects the magnitude of strain on an imprecise superstructure. In the case of the internal-connection implants used in the present study, framework seating sequences also may affect the deformation values of the inaccurate superstructure because of the connection design, which causes initial locking only by framework seating and without screw tightening (Figs 5a and 5b). Although the same screw-tightening sequence was used in this study, different framework seating sequences might have been used accidentally. The low ICCs (0.2044 to 0.4380; Tables 1 and 2) in this study might be attributable mainly to imperfect fit and different seating sequences of the metal frameworks.

No samples in the 2 impression-technique groups showed perfect fit with the metal frameworks in this study. If implant replicas are displaced equally, the deformation of the framework may be greater in the



Figs 5a and 5b Schematic representation of the effect of framework seating sequences on deformation values of the framework on an inaccurate stone cast. Although the same screw-tightening sequence is used for the 2–implant-supported framework, different seating sequences (*a*: right to left and *b*: left to right) may cause different initial contact points and, therefore, may deform the framework differently.

internal-connection implant used in this study than in an external-hexagon implant. In other words, when the accuracy of an impression is evaluated by the deformation of the framework, the inaccuracy of the impression would be exaggerated in internal-connection implants with longer walls of relative parallelism. Further studies of the effects of different connection systems on the stress of superstructures are needed.

In this study, there were no significant differences in deformation between the 2 impression techniques within an 8-degree divergence. Clinically, divergence between implants may often be greater than 8 degrees (eg, 10 degrees[23] or 15 degrees[41]). In such cases, removal of rigidly splinted internal-connection impression copings may be impossible, thereby necessitating the use of nonsplinted impression copings.[20] Further studies covering the much greater divergence commonly encountered in implant prosthodontics are required to evaluate the effect of connection geometry on the accuracy of implant-level impression techniques. Studies with other internal-connection implant systems, such as the Astra Tech implant system without an internal hexagon, and other impression techniques are also needed.

CONCLUSIONS

Taking into account the limitations of this study, using a 2-implant model, the accuracy of implant-level impressions for internal-connection implant restorations was similar between the direct nonsplinted and splinted techniques where divergence was 8 degrees or less.

REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
2. Brånemark P-I. Osseointegration and its experimental background. J Prosthet Dent 1983;50:399–410.
3. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: The Toronto study. Part I: Surgical results. J Prosthet Dent 1990;63:451–457.
4. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: The Toronto Study. Part II: The prosthetic results. J Prosthet Dent 1990;64:53–61.
5. Lundqvist S, Carlsson GE. Maxillary fixed prostheses on osseointegrated dental implants. J Prosthet Dent 1983;50: 262–270.
6. Spector MR, Donovan TE, Nicholls JI. An evaluation of impression techniques for osseointegrated implants. J Prosthet Dent 1990;63:444–447.
7. Rudd KD, O'Leary TJ, Stumpf AJ Jr. Horizontal Tooth Mobility In Carefully Screened Subjects. Techn Docum Rep Sam-Tdr-64-12. Tech Doc Rep U S Air Force Syst Command Electron Syst Div 1964;94:1–6.
8. Sekine H, Komiyama Y, Hotta H, Yoshida K. Mobility characteristics and tactile sensitivity of osseointegrated fixture-supporting systems. In: van Steenberghe D (ed). Tissue Integration in Oral Maxillofacial Reconstruction. Amsterdam: Excerpta Medica, 1986:326–332.
9. 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.
10. 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.
11. Binon PP. The effect of implant/abutment hexagonal misfit on screw joint stability. Int J Prosthodont 1996;9:149–160.
12. Isidor F. Loss of osseointegration caused by occlusal load of oral implants. A clinical and radiographic study in monkeys. Clin Oral Implants Res 1996;7:143–152.
13. Isidor F. Histological evaluation of peri-implant bone at implants subjected to occlusal overload or plaque accumulation. Clin Oral Implants Res 1997;8:1–9.

14. Isidor F. Mobility assessment with the Periotest system in relation to histologic findings of oral implants. Int J Oral Maxillofac Implants 1998;13:377–383.
15. Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: Current status. Implant Dent 2001;10:85–92.
16. Naconecy MM, Teixeira ER, Shinkai RS, Frasca LC, Cervieri A. Evaluation of the accuracy of 3 transfer techniques for implant-supported prostheses with multiple abutments. Int J Oral Maxillofac Implants 2004;19:192–198.
17. Brånemark P-I, Zarb G, Albrektsson T. Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:11–12, 253–257.
18. Assif D, Fenton A, Zarb G, Schmitt A. Comparative accuracy of implant impression procedures. Int J Periodontics Restorative Dent 1992;12:112–121.
19. Assif D, Marshak B, Schmidt A. Accuracy of implant impression techniques. Int J Oral Maxillofac Implants 1996;11:216–222.
20. 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.
21. Humphries RM, Yaman P, Bloem TJ. The accuracy of implant master casts constructed from transfer impressions. Int J Oral Maxillofac Implants 1990;5:331–336.
22. Hsu CC, Millstein PL, Stein RS. A comparative analysis of the accuracy of implant transfer techniques. J Prosthet Dent 1993; 69:588–593.
23. Phillips KM, Nicholls JI, Ma T, Rubenstein J. The accuracy of three implant impression techniques: A three-dimensional analysis. Int J Oral Maxillofac Implants 1994;9:533–540.
24. Herbst D, Nel JC, Driessen CH, Becker PJ. Evaluation of impression accuracy for osseointegrated implant supported superstructures. J Prosthet Dent 2000;83:555–561.
25. Inturregui JA, Aquilino SA, Ryther JS, Lund PS. Evaluation of three impression techniques for osseointegrated oral implants. J Prosthet Dent 1993;69:503–509.
26. 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.
27. Bartlett DW, Greenwood R, Howe L. The suitability of head-of-implant and conventional abutment impression techniques for implant-retained 3 unit bridges: An in vitro study. Eur J Prosthodont Restorative Dent 2002;10:163–166.
28. Vigolo P, Majzoub Z, Cordioli G. Evaluation of the accuracy of three techniques used for multiple implant abutment impressions. J Prosthet Dent 2003;89:186–192.
29. 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.
30. Pagniano RP, Scheid RC, Clowson RL, Dagefoerde RO, Zardiackas LD. Linear dimensional change of acrylic resins used in the fabrication of custom trays. J Prosthet Dent 1982; 47:279–283.
31. Goldfogel M, Harvey WL, Winter D. Dimensional change of acrylic resin tray materials. J Prosthet Dent 1985;54:284–286.
32. Mojon P, Oberholzer JP, Meyer JM, Belser UC. Polymerization shrinkage of index and pattern acrylic resins. J Prosthet Dent 1990;64:684–688.
33. Assif D, Marshak B, Nissan J. A modified impression technique for implant-supported restoration. J Prosthet Dent 1994;71: 589–591.
34. Davis GB, Moser JB, Brinsden GI. The bonding properties of elastomer tray adhesives. J Prosthet Dent 1976;36:278–285.
35. Revised American Dental Association Specification no. 19 for Non-aqueous, Elastomeric Dental Impression Materials. J Am Dent Assoc 1977;94:733–741.
36. Taylor R, Bergman G. Laboratory Techniques for the Brånemark System. Chicago: Quintessence, 1990:22–38.
37. Nissan J, Gross M, Shifman A, Assif D. Stress levels for well-fitting implant superstructures as a function of tightening force levels, tightening sequence, and different operators. J Prosthet Dent 2001;86:20–23.
38. Fenton A, Assif D, Zarb G, Schmitt A. The accuracy of implant impression procedures [abstract 1065]. J Dent Res 1991;70: 399.
39. Carr AB. Comparison of impression techniques for a five-implant mandibular model. Int J Oral Maxillofac Implants 1991;6:448–455.
40. Watanabe F, Uno I, Hata Y, Neuendorff G, Kirsch A. Analysis of stress distribution in a screw-retained implant prosthesis. Int J Oral Maxillofac Implants 2000;15:209–218.
41. Carr AB. Comparison of impression techniques for a two-implant 15-degree divergent model. Int J Oral Maxillofac Implants 1992;7:468–475.