The accuracy of implant impressions: A systematic review

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Statement of problem. Various implant impression techniques, such as the splint, pick-up, and transfer techniques, have been introduced, and some techniques may be more accurate than others. Also, clinically, some factors, including the angulation or depth of implants, may affect the accuracy of the implant impressions.

Purpose. The purposes of this review were to: (1) investigate the accuracy of published implant impression techniques, and (2) examine the clinical factors affecting implant impression accuracy.

Material and methods. An electronic search was performed in June 2008 of MEDLINE, EMBASE, and Cochrane Library databases with the key words implant, implants, impression, and impressions. To be included, the study had to investigate the accuracy of implant impressions and be published in an English peer-reviewed journal. In addition, a hand search was performed to enrich the results for the time period from January 1980 to May 2008. After executing the search strategies, 41 articles were selected to be included in the review process.

Results. All of the selected articles were in vitro studies. Of the 17 studies that compared the accuracy between the splint and nonsplint techniques, 7 advocated the splint technique, 3 advocated the nonsplint technique, and 7 reported no difference. Fourteen studies compared the accuracy of pick-up and transfer impression techniques, and 5 showed more accurate impression with the pick-up techniques, 2 with the transfer technique, and 7 showed no difference. The number of implants affected the comparison of the pick-up and splint techniques. Eleven studies compared the accuracy of polyether and vinyl polysiloxane (VPS), and 10 of 11 reported no difference between the 2 materials. Four studies examined the effect of implant angulation on the accuracy of impressions. Two studies reported higher accuracy with straight implants, while the other 2 reported there was no angulation effect.

Conclusions. The review of abutment level or implant level internal connection implants indicated that more studies reported greater accuracy with the splint technique than with the nonsplint technique. For situations in which there were 3 or fewer implants, most studies showed no difference between the pick-up and transfer techniques, whereas for 4 or more implants, more studies showed higher accuracy with the pick-up technique. Polyether and VPS were the recommended materials for the implant impressions. (J Prosthet Dent 2008;100:285-291)

Clinical Implications

For a situation in which 3 or fewer implants are placed, either the pick-up or transfer technique may be used. The use of polyether or vinyl polysiloxane is recommended for implant impressions.

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A dental impression is a negative imprint of an oral structure used to produce a positive replica of the structure for use as a permanent record or in the production of a dental restoration or prosthesis.[1] Since the accuracy of the impression affects the accuracy of the definitive cast, an accurate impression is essential to fabricate a prosthesis with good fit. An inaccurate impression may result in prosthesis misfit, which may lead to mechanical and/or biological complications. Screw loosening, screw fracture, implant fracture, and occlusal inaccuracy have been reported as mechanical complications arising from prosthesis misfit.[2-7] Biologically, marginal discrepancy from misfit may cause unfavorable soft and/or hard tissue reactions due to increased plaque accumulation.[8-10] Even though obtaining absolute passive fit is practically impossible,[11] minimizing the misfit to prevent possible complications is a generally accepted goal of prosthodontic implant procedures.

To date, various implant impression techniques, such as splint, pick-up, and transfer techniques, have been introduced and investigated for accuracy. Other factors related to the accuracy of the implant impression, including the angulation or depth of implants, have also been studied. However, the results were not always consistent, and various studies reported greater accuracy with different impression techniques. The purposes of the present review were to investigate the accuracy of reported implant impression techniques and to examine the clinical factors affecting the implant impression accuracy.

MATERIAL AND METHODS

Electronic searches were performed in June 2008 from MEDLINE, EMBASE, and Cochrane Library databases with the key words *implant*, *implants*, *impression*, and *impressions*. No publication year limit was used, so that the search could include the first available year of the particular database to June 2008. The key words were typed in combination form ((implant OR implants) AND (impression OR impressions)), then the "limit to English" function was executed for MEDLINE and EMBASE. As a result, 647 and 436 articles were found in MEDLINE and EMBASE, respectively. Thirty-two, 19, and 1 article(s) were found in the Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, and Health Technology Assessment Database, respectively.

The abstracts of the articles were retrieved, reviewed, and sorted based on the following inclusion and exclusion criteria. To be included in the study, the article had to be published in an English peer-reviewed journal and be an experimental study investigating the accuracy of implant impressions. Excluded were the following: clinical or technical reports simply describing a particular material or technique, structurally incomplete publications such as abstracts only, and review articles. In addition, a hand search of the following journals was performed to enrich the results for the time period from January 1980 to May 2008: *The Journal of Prosthetic Dentistry*, *The International Journal of Oral and Maxillofacial Implants*, *The International Journal of Prosthodontics*, *Implant Dentistry*, *The International Journal of Periodontics and Restorative Dentistry*, *Journal of Prosthodontics*, *Clinical Oral Implants Research*, and *Clinical Implant Dentistry and Related Research*. After executing the search strategies, 41 articles were selected.

RESULTS

All of the selected articles were in vitro studies. Seventeen studies compared the accuracy between the splint and nonsplint techniques (Table I).[12-28] Of the 17 studies, 7 advocated the splint technique,[13,18,21-24,26] 3 advocated the nonsplint technique,[14,17,19] and 7 reported no difference between them.[12,15,16,20,25,27,28] It was found that more studies reported more accurate implant impressions with the splint technique than with the nonsplint technique.

Fourteen studies compared the accuracy of pick-up and transfer impression techniques (Table II).[12,15,17,20,22,24,26,28-34] Of the 14 studies, 5 showed more accurate impressions with the nonsplinted pick-up technique,[15,17,24,28,31] 2 with the transfer technique,[12,30] and 7 showed no difference between them.[20,22,26,29,32-34] In addition to the simple comparative finding, a relation was found between the impression techniques (pick-up and transfer) and number of implants. There were 5 studies using 3 or fewer implants,[26,29,30,32,33] and 4 showed no difference between the pick-up and transfer techniques.[26,29,32,33] The single remaining study showed more accurate impressions with the transfer technique.[30] Nine studies compared the accuracy of pick-up and transfer impression techniques in situations in which 4 or more implants were placed.[12,15,17,20,22,24,28,31,34] Five showed more accurate impressions with the pick-up technique,[15,17,24,28,31] 1 with the transfer technique,[12] and 3 showed no difference.[20,22,34] For situations in which there were 3 or fewer implants, most studies showed no difference between the pick-up and transfer techniques, whereas for situations in which there were 4 or more implants, more studies showed more accurate impressions with the pick-up technique than the transfer technique. There were 4 studies that examined the accuracy of the snap-fit impression technique.[19,35-37] Two studies reported the snap-fit technique was more accurate than the pick-up technique,[19,37] 1 reported the snap-fit technique was more accurate than the transfer technique,[35] and 1 reported there was no difference between the snap-fit and pick-up technique.[36]

Eleven studies compared the accuracy of polyether and VPS impression materials.[15,24,34-42] Ten of 11 reported no difference between the 2 materials,[15,24,34-41] and only 1 study reported that VPS was more accu-

Table 1. Studies comparing accuracy of splint and nonsplint impression techniques

Author (Year)	Implant Number	Specimen Number	Splint Material	Splint Method	Impression Material	Implant Manufacturer	Connection Level	Impression Accuracy
Humphries et al[12] (1990)	4	4	AAR	Splint 30 min before impression	VPS	N	A	No difference
Assif et al[13] (1992)	5	15	AAR	Polymerize on individual copings, then join 15 min before impression	PE	N	A	Spint better
Inturregui et al[14] (1993)	2	10	Impression plaster AAR	Splint and wait for 10 minutes Splint, section, then rejoin 15 min before impression	PE	N	A	Nonsplint better
Barrett et al[15] (1993)	6	8	DF + AAR	Splint 10 min before impression	VPS	N	A	No difference
Hsu et al[16] (1993)	4	14	DF + AAR Stainless steel orthodontic wire + AAR AAR	Splint 20 min before impression Splint 20 min before impression Polymerize on individual copings, then join 20 min before impression	PE	N	A	No difference
Phillips et al[17] (1994)	5	15	DF + AAR	Splint	PE	N	A	Nonsplint better
Assif et al[18] (1996)	5	15	AAR	Splint Splint copings to custom tray	PE	N	A	Splint better No difference
Burawi et al[19] (1997)	5	15	DF + AAR	Splint 24 h before impression, section, then rejoin 15 min before impression	VPS	SL	A	Nonsplint better
Herbst et al[20] (2000)	5	4	DF + AAR	Splint 20 min before impression	VPS	SI	A	No difference
Vigolo et al[21] (2003)	6	15	AAR	Splint 1 day before impression, section, then rejoin just before impression	PE	B	A	Spint better
Naconecy et al[22] (2004)	5	5	Steel pin + AAR	Splint 30 min before impression	PE	N	A	Splint better
Vigolo et al[23] (2004)	4	15	AAR	Splint 1 day before impression, section, then rejoin just before impression	PE	B	I-I	Splint better
Assuncao et al[24] (2004)	4	5	AAR	Splint	Polysulfide, PE, VPS, condensation silicone	C	I-I	Splint better
Kim et al[25] (2006)	5	5	Light-polymerizing resin	Splint, section, then rejoin before impression	PE	N	A	No difference
Cabral et al[26] (2007)	2	15	DF + AAR	Splint 3 min before impression Splint 17 min, section, then rejoin before impression	VPS	SIN	I-I	Splint better
Choi et al[27] (2007)	2	10	AAR	Splint, section, then rejoin 15 min before impression	VPS	AT	I-I	No difference
Del' Acqua et al[28] (2008)	4	5	AAR	Splint, section, then rejoin before impression	PE	C	A	No difference

AAR: autoploymerizing acrylic resin; DF: dental floss; VPS: vinyl polysiloxane; PE: polyether
N: Nobel Biocare AB, Göteborg, Sweden; SL: Stryker Leibinger GmbH, Freiburg, Germany; SI: Southern Implants, Irene, South Africa; B: Biomet 3i, Palm Beach Gardens, Fla;
C: Conexão Prothesis System Ltda, São Paulo, Brazil; SIN: Sistema de Implante Nacional Ltda, São Paulo, Brazil; AT: Astra Tech AB, Mölndal, Sweden
A: abutment; I-I: implant internal

TABLE II. Studies comparing accuracy of transfer and pick-up impression techniques

Author (Year)	Implant Number	Specimen Number	Impression Material	Implant Manufacturer	Connection Level	Impression Accuracy
Humphries et al[12] (1990)	4	4	VPS	N	A	T
Carr[31] (1991)	5	7	PE	N	A	P
Carr[32] (1992)	2	10	PE	N	A	No difference
Barrett et al[15] (1993)	6	8	VPS	N	A	P
Phillips et al[17] (1994)	5	15	PE	N	A	P
Herbst et al[20] (2000)	5	4	VPS	SI	A	No difference
De La Cruz et al[30] (2002)	3	10	VPS	N	A	T
Naconecy et al[22] (2004)	5	5	PE	N	A	No difference
Daoudi et al[29] (2004)	1	10	VPS	N	I-E	No difference
Assuncao et al[24] (2004)	4	5	Polysulfide, PE, VPS, condensation silicone	C	I-I	P
Conrad et al[33] (2007)	3	10	VPS	B	I-E	No difference
Cabral et al[26] (2007)	2	15	VPS	SIN	I-I	No difference
Wenz et al[34] (2008)	5	5	VPS	DF	I-I	No difference
Del' Acqua et al[28] (2008)	4	5	PE	C	A	P

VPS: vinyl polysiloxane; PE: polyether; T: transfer impression was superior; P: pick-up impression was superior
N: Nobel Biocare AB; SI: Southern Implants; C: Conexão Prothesis System Ltda; B: Biomet 3i;
SIN: Sistema de Implante Nacional Ltda; DF: Dentsply Friadent, Mannheim, Germany
A: abutment; I-E: implant external;
I-I: implant internal

rate than polyether when the implant was placed deep subgingivally.[42] Four studies examined the effect of implant angulation on the accuracy of impressions.[24,27,31,33] Two studies reported less accurate impressions with angulated implants than with straight implants,[24,31] and the other 2 reported there was no angulation effect.[27,33]

DISCUSSION

Splint versus nonsplint

The splint technique for an implant

impression was introduced along with the development of a metal-acrylic resin implant fixed complete denture for an edentulous jaw.[43] The underlying principle was to connect all the impression copings together using a rigid material to prevent individual coping movement during the impression-making procedure. From the first study examining implant impression accuracy,[12] splinting has been an important subject of investigation.

Even though there was no consistent result for higher accuracy with one technique as opposed to the other, splint or nonsplint, more studies reported more accurate implant impressions with the splint technique than with the nonsplint technique. Some authors suggested possible problems with the splint technique, such as distortion of the splint materials,[44] and fracture of the connection between the splint material and the impression copings.[19] Kim et al[25] investigated the accuracy of the implant impression over multiple laboratory procedures and found that the nonsplint technique was more accurate during the impression-making procedure, while the splint technique was more accurate during the cast fabrication procedure.

Acrylic resin is the material used most often; thus, minimizing the shrinkage of the acrylic resin is the most important factor to ensure an accurate impression using the splint technique. Some authors sectioned the splint material connection, leaving a thin space between, then rejoining with a minimal amount of the same material to minimize the shrinkage,[13,14] or they connected all of the impression copings with splint material, then waited for complete polymerization of the material.[16,22]

It was interesting that more studies advocating the splint technique were found within the more recent literature. Five[21-24,26] out of 7 studies recommending the splint technique were published after 2003, as opposed to 2 older studies[13,18] which appeared before 1996. Advances in splinting material and its manipulation may result in minimizing the distortion. It was also found that internal connection implants were used in recent 4 studies,[23,24,26,27] and 3 of them[23,24,26] demonstrated more accurate impressions with the splint technique. The fourth study did not show any difference between the splint and nonsplint technique.[27] The authors of the present review did not identify any study comparing the splint and nonsplint techniques using external connection implants, and this should be considered when the results are interpreted. Some authors investigated splinting the impression copings to the impression tray, but did not demonstrate an advantage.[18,29,45] Further studies are necessary to discover the relation between the connection method and the effect of the splint technique.

Transfer versus pick-up

Traditionally, there are 2 different implant impression techniques for transferring the impression copings from the implant to the impression. The transfer technique uses tapered copings and a closed tray to make an impression. The copings are connected to the implants, and an impression is made and separated from the mouth, leaving the copings intraorally. The copings are removed and connected to the implant analogs, and then the coping-analog assemblies are reinserted in the impression before fabricating the definitive cast.

Conversely, the pick-up impression uses square copings and an open tray (a tray with an opening), allowing the coronal ends of the impression coping screw to be exposed. Before separating the implants, the copings are unscrewed to be removed along with the impression. The implant analogs are connected to the copings to fabricate the definitive cast.

As mentioned previously, 14 studies compared the accuracy of pick-up and transfer impression techniques,[12,15,17,20,22,24,26,28-34] and 2 studies showed more accurate impressions with the transfer technique.[12,30] However, the results of 1 of the 2 studies were questionable because the experimental design was not clinically relevant and favored the transfer technique.[30] Also, it was the only study that advocated the transfer technique when 3 or fewer implants were placed.

Daoudi et al[46] investigated repositioning of the copings after making the transfer impression by 3 different groups of people: senior dentists, postgraduate dental students, and dental technicians. The copings never returned to the original position and this was believed to be the primary source of error in the transfer impression technique. This error could be multiplied when the impression is made in situations of multiple implant placement. It was found that for situations in which there were 4 or more implants, more studies showed more accurate impressions with the pick-up technique than the transfer technique.

Some implant manufacturers have developed a snap-fit plastic impression coping. This technique is not a pick-up impression because it does not require an open tray, but instead uses a closed tray. It is not a transfer impression, either, because the plastic impression copings are picked up in the impression. The snap-fit technique may be a reliable impression-making technique.

Impression materials

Various impression materials were tested, but polyether and VPS were used most frequently. There were 11 studies comparing the accuracy of polyether and VPS,[15,24,34-42] and 10 studies reported that the accuracy did not differ.[15,24,34-41] Lee et al[42] reported that putty and light-body combination VPS impression material was more accurate than medium-body polyether impression material when the implant was placed deep subgingivally. Wenz[34] investigated different mixing methods of the impression materials. According to the study, the

2-step VPS method involves making the first impression using putty only, to create space inside of the impression. Subsequently, the impression is filled with light-body impression material, and then the second impression is made. The 1-step method uses both putty and light-body VPS simultaneously. Results indicated that the 2-step VPS impression was significantly less accurate than the 1-step putty and light-body VPS combination impression, the medium-body VPS monophase impression, and the medium-body polyether monophase impression. Wee[39] studied the torque resistance of impression materials and reported that polyether material showed the greatest torque values, which may be favorable for the manipulation of a pick-up impression. Other materials, such as condensation silicone, polysulfide, reversible hydrocolloid, irreversible hydrocolloid, and plaster did not show improved accuracy compared to either polyether or VPS.[15,24,39,40,47]

Coping modification

Liou et al[38] found that the impression copings with different designs showed a different level of impression accuracy. To increase accuracy, the coping was extended or treated with airborne-particle abrasion and impression adhesive.[20,21,48] However, the same surface treatment did not increase the accuracy in another study.[23] Acrylic resin transfer caps and gold machined castable abutments have been introduced to achieve better accuracy.[40,49] Lee et al[42] found that adding a 4-mm piece of the impression coping as an extension on the original impression coping compensated for the inaccuracy of subgingival placement of the implant. These modifications may lead manufacturers to develop new impression coping designs to enhance the accuracy of the impression.

Angulation

Two studies reported less accurate impressions with angulated implants than with straight implants using an experimental cast with 4 or 5 implants.[24,31] On the other hand, 2 other studies that used 2 or 3 implants reported no angulation effect on the accuracy of impressions.[27,33] When multiple implants are placed with different angles, the distortion of the impression material on removal may increase. Also, this effect may be heightened by an increasing number of implants. To determine the relation between the angulation effect and the numbers of the implant, more studies are required.

Other factors affecting impression accuracy

Other studies examined the effects of various factors on the accuracy of implant impressions, such as different connection levels (implant level and abutment level),[35,50] different impression trays,[51] implant depth,[42] and time delay for stone pouring.[41] The studies were too few to draw any conclusions. Further studies, including clinical trials, are required to provide more evidence about clinical factors that affect the implant impression accuracy.

In most clinical situations, an implant impression is made using impression copings, requiring connection to the implant or the abutment. After separating the impression, another connection between the impression coping and an implant analog is required to fabricate a definitive cast. Since the mating between 2 metal components may occur with various spatial relations at the micrometer level, the implant impression has an inherent discrepancy. Ma et al[52] defined it as "machining tolerance" and reported the measured tolerances ranged from 22 μm to 100 μm. Among the 41 studies reviewed for the present study, 9 studies measured linear discrepancy between the definitive cast and experimental model at the connection level,[16,17,21,23,25,30,34,36,40] and the range of the discrepancy was from 0.6 μm to 136 μm. Even though the machining tolerance was not measured separately in these studies, it is believed that a significant amount of the discrepancy might have originated from the machining tolerance. When the results of the studies investigating the implant impression accuracy are interpreted, the machining tolerance should be considered as one of factors affecting accuracy.

CONCLUSIONS

A review of studies of abutment level or implant level internal connection implants revealed that more studies reported greater accuracy of implant impressions with the splint technique than with the nonsplint technique. For situations in which there were 3 or fewer implants, most studies showed no difference between the pick-up and transfer techniques, whereas for situations in which there were 4 or more implants, more studies showed more accurate impressions with the pick-up technique than the transfer technique. Polyether and VPS were the recommended materials for the implant impressions.

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