Accuracy Comparison of Implant Impression Techniques: A Systematic Review

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ABSTRACT

Background: Several studies link the seamless fit of implant-supported prosthesis with the accuracy of the dental impression technique obtained during acquisition. In addition, factors such as implant angulation and coping shape contribute to implant misfit.

Purpose: The aim of this study was to identify the most accurate impression technique and factors affecting the impression accuracy.

Material and Methods: A systematic review of peer-reviewed literature was conducted analyzing articles published between 2009 and 2013. The following search terms were used: implant impression, impression accuracy, and implant misfit. A total of 417 articles were identified; 32 were selected for review.

Results: All 32 selected studies refer to in vitro studies. Fourteen articles compare open and closed impression technique, 8 advocate the open technique, and 6 report similar results. Other 14 articles evaluate splinted and non-splinted techniques; all advocating the splinted technique. Polyether material usage was reported in nine; six studies tested vinyl polysiloxane and one study used irreversible hydrocolloid. Eight studies evaluated different copings designs. Intraoral optical devices were compared in four studies.

Conclusions: The most accurate results were achieved with two configurations: (1) the optical intraoral system with powder and (2) the open technique with splinted squared transfer copings, using polyether as impression material.

KEY WORDS: dental prosthesis, implant impression, implant misfit, impression accuracy, optical scanning

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Conflicts of Interest: The authors declare that there is no conflict of interest.

DOI 10.1111/cid.12310

INTRODUCTION

Every phase in the production of an implant-supported prosthesis influences the fit between implants and the final prosthesis. One of the most critical steps for the long-term success of implant prosthesis is the accuracy during the impression procedure,[1,2] which is affected by factors such as the impression material, implant position, angulation, and depth.[3–5]

As suggested by several authors, obtaining an absolute passive fit is practically impossible, especially in partially or completely edentulous patients. However, in such cases, misfit tolerances are accepted, given that it does not lead to future implant complications.[6,7]

The most common complications in implant-supported bridge are twofold: mechanical and biological. Screw loosening is one of the most observed mechanical complications, often leading to instability and implant or screw fracture, which in turn may encompass the repair or replacement of the prosthesis. Biological complications are frequently related to soft and hard tissue reactions due to increased dental plaque accumulation.[8–12]

Several impression techniques and materials have been proposed to achieve master casts ensuring acceptable prosthesis passive fits. The most common techniques are the closed (transfer), the open (direct), and the splinted technique, while the most used impression materials are polyether (PE) and vinyl polysiloxane (VPS).

Despite the existence of other surveys investigating impression techniques accuracy, no consensus has been achieved among them, and the different works present heterogeneous results.[2]

Choosing the most accurate technique and material for each particular case has become a challenging task for practitioners, which have to cope with an ever greater and more complex set of techniques and materials. Recent developments over the traditional impression techniques include optical devices (intraoral scanners) as a solution to both ease the procedure and overcome the inherent accuracy problems of impression techniques.[13]

MATERIAL AND METHODS

Selection Criteria

Electronic searches of English peer-reviewed literature were conducted in March 2013 in Medline/PubMed, Scopus, and ISI Web of Science databases with the following search terms: implant impression, implant accuracy, and superstructure misfit. Only publications between 2009 and 2013 were included without considering further constraints.

Search Methods

The following combination of keywords was used in the search: (implant(s) AND impression(s)) OR (impression accuracy) OR (superstructure misfit). As a result, 417 articles from Medline/PubMed, Scopus, and ISI Web of Science databases were analyzed.

In addition to the database results, a manual search was performed on the following journals: *The International Journal of Oral & Maxillofacial Implants*, *Clinical Oral Implants Research*, *Journal of Prosthodontics*, *The Journal of Prosthetic Dentistry*, *The International Journal of Prosthodontics*, and *Implant Dentistry*. The manual search was conducted by one reviewer and checked by a second reviewer.

Data Collection

Articles' abstracts were retrieved, reviewed, and sorted, based on the following inclusion and exclusion criteria. To be included in the study, the articles had to be published in an English peer-reviewed journal and be a study investigating the accuracy of implant impression techniques. Articles with the following characteristics were excluded: publications simply describing a particular material or technique, structurally incomplete publications such as abstracts only, and review articles. Assessment of article eligibility was performed independently by two reviewers. The remaining authors provided critical revision of the manuscript for important intellectual content and helped in disagreements between article selection.

Data Analysis

From the search strategies, a total of 31 articles were selected to be reviewed, and whenever possible identifying the most accurate impression technique in each study.

RESULTS

Description of Studies

All the selected studies refer to in vitro studies.[4,5,13–41] Table 1 compares the accuracy between open and closed impression techniques, impression materials, and coping types,[5,17,20–25,29,32–34,36,38] referring 14 articles, from which 8 advocate the open technique[20,21,25,29,32–34,38] and 6 report similar results for both techniques.[5,17,22–24,36] It was verified that a predominant use of square copings was associated to the open technique.

Table 2 compares the accuracy between splinted and non-splinted impression techniques,[4,14–16,18,19,27–29,31,37,39–41] resuming the analysis of 14 articles, where all advocate the splinted technique. It was also verified that there was a predominant use of square copings in 10 of the 14 studies.[4,14,18,19,27–29,31,40,41]

In what refers to impression materials, 18 studies employed PE impression material (9 from Table 1[5,17,20,23–25,29,34,36] and 9 from Table 2[4,14–16,18,27,29,31,37]), 14 studies tested VPS (8 from Table 1[5,20–22,24,32,33,38] and 6 from Table 2[19,27,28,39–41]), and 1 study used irreversible hydrocolloid,[40] without showing any significant differences between them. However, a preference for PE impression material was verified.

TABLE 1 Accuracy Comparison of Direct (Open) and Indirect (Closed) Impression Techniques, Impression Materials, and Coping Types

Author (Year)	In Vivo/ In Vitro	Impression Material	Method	Brand	Coping	Implant Number	Groups (Casts)	Best Accuracy
Aguilar and colleagues (2010)[24]	In vitro	PE/VPS	G1: Direct (open) technique with PE G2: Direct (open) technique with VPS	Z	S	5	2 (10)	Similar
Sorrentino and colleagues (2010)[5]	In vitro	PE/VPS	G1, G2: Control G3, G4: Open technique, parallel, short versus standard coping with PE G5, G6: Open technique, nonparallel, short versus standard coping with PE G7, G8: Open technique, parallel, short versus standard coping with VPS G9, G10: Open technique, nonparallel, short versus standard coping with VPS	WIX	S	4	2 + 8 (10)	VPS for nonparallel PE for parallel implants
Del'Acqua and colleagues (2010)[20]	In vitro	PE/VPS	G1: Open technique with squared copings and PE G2: Open technique with squared copings and VPS G3: Open technique with sandblasted adhesive squared copings and PE G4: Open technique with sandblasted adhesive squared copings and VPS	CPS	S/SAS	4	4 (5)	Squared copings with PE
Jo and colleagues (2010)[32]	In vitro	VPS	G1: Open technique with short copings and VPS G2: Open technique with long copings and VPS G3: Closed technique with short copings and VPS G4: Closed technique with long copings and VPS	OS	S/T	3	4 (10)	Open with long copings
Kwon and colleagues (2011)[25]	In vitro	PE	G1: Open technique with copings and PE G2: Closed technique without copings and PE	W	S	3	2 (10)	Open
Alikhasi and colleagues (2011)[36]	In vitro	PE	G1: Closed technique with plastic copings G2: Closed technique with tapered copings G3: Open technique with squared copings	D	S/T	2	3 (7)	Similar
Gallucci and colleagues (2011)[17]	In vitro	PE	G1: Closed technique with plastic copings G2: Open technique with squared copings	ST	S	2	2 (11)	Similar
Simeone and colleagues (2011)[34]	In vitro	PE	G1: Open technique, standard tray with squared copings G2: Open technique, modular tray with squared copings	CB	S	6	2 (5)	Open with modular tray
Del'Acqua and colleagues (2012)[21]	In vitro	VPS	G1: Closed technique, tapered copings with metal stock tray G2: Open technique, splinted square copings with metal stock tray G3: Closed technique, tapered copings with plastic stock tray G4: Open technique, splinted square copings with plastic stock tray	CPS	S/T	4	4 (5)	Similar (with metal stock tray)
Eliasson and Ortorp (2012)[38]	In vitro	VPS	G1: Open technique with squared copings G2: Closed technique with encode abutments	B	S/E	6	2 (15)	Open

TABLE 1 Continued

Author (Year)	In Vivo/ In Vitro	Impression Material	Method	Brand	Coping	Implant Number	Groups (Casts)	Best Accuracy
Rashidan and colleagues (2012)[23]	In vitro	PE	G1: Closed technique with tapered copings (Dentium) G2: Closed technique with tapered copings (Nobel) G3: Open technique with square copings (Dentium) G4: Open technique with square copings (Nobel)	D/NB	S/T	5	4 (10)	Similar Nobel is less inaccurate
Stimmelmayr and colleagues (2012)[29]	In vitro	PE	G1: Closed technique with plastic caps G2: Open technique with square copings G3: Copings splinted, sectioned, and luted with acrylic resin	CB	S	4	3 (10)	Open
Fernandez and colleagues (2013)[22]	In vitro	VPS	G1: Closed technique with plastic copings (Nobel) G2: Closed technique with plastic copings (Straumann) G3: Closed technique with metal copings (Nobel) G4: Open technique with metal copings (Straumann)	NB/ST	SP/M	4	4 (5)	Similar Metal is more accurate
Howell and colleagues (2013)[33]	In vitro	VPS	G1: Open technique with square abutments G2: Closed technique with tapered abutments G3: Closed technique with encode abutments	B	S/T/E	4	3 (4)	Open

B = Biomet; CB = Camlog; CPS = Conexão Sistemas de Prótese; D = Dentium; E = encode; G = group; M = metal; NB = Nobel Biocare; OS = OSSTEM; PE = polyether; S = square; SAS = sandblasted adhesive squared; SP = Snap-On; ST = Straumann; T = tapered; VPS = vinyl polysiloxane; W = Warantec; WIX = Winsix Implant System; Z = Zimmer Dental.

In what concerns to splint materials, five studies evaluate the outcome with dental floss (DF) and autopolymerizing acrylic resin (AAR)[14,15,18,27,31] and four studies also compare AAR against composite resin or metal.[19,28,39,41] Uncommon splint materials were evaluated in one study, showing AAR with DF to be the most accurate.[27]

Ten studies evaluate different coping types.[19–23,31–33,36,38] From these, seven studies advocate the open technique with square copings as the most accurate,[20,21,29,33,38] and three studies report similar results between copings.[22,23,36] In addition, four studies use plastic copings[17,22,29,36] and one of these also evaluates Snap-On impression copings,[22] finding similar results for this case as well.

A different number of implants were used along the studies, with seven studies (four from Table 1[17,25,32,36] and three from Table 2[18,39,40]) considering less than four implants, and from these, three studies considering only two implants.[17,18,36] Twenty studies consider four or more implants and up to a maximum of six implants.[4,5,15,16,19–24,27–29,31,33,34,37,38,41] Comparing the open and closed techniques when four or more implants are employed, six studies advocate the open technique[20,21,29,33,34,38] and four studies show similar results for both techniques.[5,22–24] When using less than four implants, two studies show no differences between techniques,[17,36] and two advocate the open technique.[25,32] One study evaluates the effect of implant angulation on the impression accuracy, reporting no major implications related to this factor, even though suggesting the possibility that nonparallel implants may affect accuracy.[5]

For the sake of completeness, the accuracy of optical devices for implant impression[13,26,30,35] was also compared in Table 3. This table encompasses four in vitro studies, with three studies evaluating external scanners[26,30,35] and one study evaluating three intraoral scanners.[13] All studies used custom-made implant markers to reduce reflection, reporting an average error similar to the traditional impression techniques.

TABLE 2 Accuracy of Splinted and Non-Splinted Impression Techniques, Impression Materials, and Coping Types

Author (Year)	In Vivo/ Vitro	Impression Material	Splint Material	Method	Brand	Coping	Implant Number	Groups (Casts)	Best Accuracy
Filho and colleagues (2009)[18]	In vitro	PE	AR/DF	G1: Direct technique without connection of the square copings and open trays G2: Copings splinted with dental floss and AAR G3: Copings splinted with dental floss and AAR, sectioned, and luted with AAR G4: Copings splinted with prefabricated AAR bar	CPS	S	2	4 (6)	Splinted with prefabricated AAR bar
Del'Acqua and colleagues (2010)[19]	In vitro	VPS	AR/CR	G1: Square copings splinted with CR G2: Square copings non-splinted G3: Modified square copings non-splinted	CPS	S/MS	4	3 (5)	Splinted with CR
Del Acqua and colleagues (2010)[41]	In vitro	VPS	AR/M	G1: Copings and metal splinted with AR G2: Splinted resin bar, sectioned and luted with AR	CPS	S	4	2 (5)	Splinted with metal bar
Lee and colleagues (2010)[39]	In vitro	VPS	AR/M	G1: Non-splinted G2: Acrylic resin, sectioned and luted with AR G3: Metal splinted resin cement	NB	T	3	3 (10)	Splinted
Yamamoto and colleagues (2010)[40]	In vitro	VPS/IH	AR	G1: Irreversible hydrocolloid non-splinted G2: Irreversible hydrocolloid splinted, sectioned, and luted with AR G3: PVS non-splinted G4: PVS splinted, sectioned, and luted with AR	CPS	S	3	4 (5)	Splinted
Assunção and colleagues (2010)[4]	In vitro	PE	AR	G1: Splinted with self-curing acrylic resin G2: Splinted with condensation silicone (scratched)	CPS	S	4	2 (10)	Splinted with AR
Lee and Cho (2011)[27]	In vitro	PE/VPS	AR/DF/VPS/IP	G1: Copings splinted with AAR, sectioned, and luted with AR G2: Copings splinted with AAR G3: Copings with impression plaster and then PE impression material G4: Copings splinted with impression plaster over dental floss G5: Copings splinted with VPS bite registration material	NB	S	6	5 (5)	Splinted with AAR and sectioned
Papaspyridakos and colleagues (2011)[14]	In vitro	PE	AR/DF	G1: Copings splinted with AR and dental floss, sectioned, and luted with AR G2: Non-splinted copings	NB	S	–	2 (13)	Splinted
Faria and colleagues (2011)[31]	In vitro	PE	AR/DF	G1: Tapered copings without splint G2: Square copings without splint G3: Square copings splinted with dental floss and AR G4: Control group – metallic superstructure	ND	S/T	4	4 (5)	Splinted with dental floss and AR
Papaspyridakos and colleagues (2012)[15]	In vitro	PE	AR/DF	G1: Copings splinted with AR and dental floss, sectioned, and luted with AR G2: Non-splinted copings	–	–	6	2 (6)	Splinted
Stimmelmayr and colleagues (2012)[16]	In vitro	PE	AR	G1: Non-splinted with plastic caps G2: Copings splinted with AR, sectioned, and luted with AR	CB	–	4	2 (10)	Splinted favorable
Avila and colleagues (2012)[28]	In vitro	VPS	PR/M	G1: Square copings without splint G2: Square copings and metal bars splinted with PR	CPS	S	4	2 (5)	Splinted with metal bar

TABLE 2 Continued

Author (Year)	In Vivo/ Vitro	Impression Material	Splint Material	Method	Brand	Coping	Implant Number	Groups (Casts)	Best Accuracy
Stimmelmayr and colleagues (2012)[29]	In vitro	PE	AR	G1: Non-splinted with plastic caps (closed) G2: Non-splinted copings (open) G3: Copings splinted with AR, sectioned, and luted with AR	CB	S	4	3 (10)	Splinted
Ongül and colleagues (2012)[37]	In vitro	PE	AR	G1: Screw-on synOcta impression copings (SSICs) non-splinted G2: SSIC splinted with AR bar G3: SSIC splinted with two separate AR bars, sectioned G4: SSIC splinted with light-curing CR bar G5: SSIC splinted with two light-curing CR bars, sectioned	ST	O	6	5 (5)	Splinted with AR bar

AR = resin; AAR = autopolymerizing acrylic resin; CB = Camlog; CPS = Conexão Sistemas de Prótese; CR = composite resin; DF = dental floss; G = group; IH = irreversible hydrocolloid; IP = impression plaster; M = metal; MS = modified squared; NB = Nobel Biocare; ND = Neodent; O = synOcta; PE = polyether; PR = pattern resin; S = square; ST = Straumann; T = tapered; VPS = vinyl polysiloxane.

DISCUSSION

Direct versus Indirect

Conventionally, implant impressions are obtained from either direct (open tray) or indirect (closed tray) techniques. The direct technique uses square copings with long retaining screws and custom open trays with holes, which lines up with the transfers when the impression is taken. Next, the copings are unscrewed by removing the retaining screws from the implants, allowing the copings to be removed along with the impression. After removing the impression tray, the implant replicas were connected to the copings and sent to the laboratory.[42]

The impression using the indirect technique typically uses tapered copings and closed trays that match the height of the transfer. Subsequently, heavy body impression material is injected around the impression coping and into the tray, performing an impression that is then separated from the mouth, leaving the copings intraorally. The copings are then removed from the implants, connected to implant replicas, and positioned in its corresponding place in the impression. Finally, the assembled set is sent to the laboratory.[43]

For both direct and indirect impression techniques, impression copings and replicas are essential to fabricate an implant definitive cast. The accuracy of the definitive cast depends on the displacement level between its replicas and the impression copings.[44,45]

From the 14 studies,[5,17,20–25,29,32–34,36,38] none advocated the indirect (closed) technique. Although six of these studies reported similar results between both techniques, other sources of inaccuracy were identified other than the impression technique, such as angulation or coping shape.[5,17,22–24,36]

In situations where four or more implants are used, a greater number of studies showed accurate impressions with the open technique. For three or fewer implants, half of the studies consider the open technique as the one offering the best accuracy.

In addition, one study reported a similar accuracy between snap-fit plastic impression copings and metal copings.[22] Nevertheless, this study also reports on the breakage and distortion of the impression cap engaging the implant shoulder, compromising its reliability.

Impression Material

Several authors state on the importance of the impression material and its effect on the accuracy of the intraoral coping acquisition. To this end, several impression materials have been tested in the literature.[4,5,13–41] The comparison provided in Tables 1 and 2 shows that PE and VPS were the most used impression materials.

TABLE 3 Accuracy of Optical Devices for Implant Impression

Author (Year)	In Vivo/Vitro	Markers	Scanner	Method	Brand	Implant Number	Casts Number (Acquisitions)	Conclusion
Del Corso and colleagues (2009)[35]	In vitro	Ceramic cylindric (white opaque)	Steinbichler COMET VZ250	G1: Fringe pattern light	3i	5	2 (9)	• Promising for imaging-acquiring technology • Marker standardization is needed
Stimmelmayr and colleagues (2012)[26]	In vitro	PEEK Polymer (Camlog)	Everest Scan Pro	G1: White-light scanner	CB	4	1 (10)	• Currently, conventional impression and white-light scanning seems more precise • Improvement is needed for reproducible fit of the scan bodies
Van der Meer and colleagues (2012)[13]	In vitro	PEEK Cylinders (Createch)	CEREC/iTero/ Lava COS	G1: Light stripe projection and active triangulation (with Optispray) G2: Parallel confocal imaging technique (no powder) G3: Active wavefront sampling (with Lava Powder)	–	3	3 (10)	• Lava COS resulted in the smallest and most consistent errors • In Lava COS, the angulation errors were very consistent • Expected increase in distance and/or angular errors over the length of the arch due to an accumulation of registration errors
Ono and colleagues (2012)[30]	In vitro	Titanium/paper markers	Micron Tracker 2 Sx60	G1: Three-dimensional position and orientation of each marker	NB	4	1 (3)	• Positions and orientations of dental implants acquired accurately and rapidly • Shorter time to obtain an impression than the conventional method • Proposed method with acceptable accuracy

3i = 3i Implant Innovations; CB = Camlog; G = group; NB = Nobel Biocare.

Aguilar and colleagues[24] reported similar distortion effects between PE and VPS for the Paragon system transfer, using machine mixing and the direct impression technique. VPS demonstrates a statistically significant superior accuracy for perpendicularity distortion of 0.64°.

Sorrentino and colleagues[5] reported a higher accuracy for addition silicone in the presence of nonparallel implants, whereas PE achieved the best results with parallel implants and standard impression copings.

Del'Acqua and colleagues[20] and Lee and Cho[27] studied the impression accuracy as a function of impression technique and impression material. Results suggest that PE material produces better outcomes than VPS bite registration material. This could be explained by the greater rigidity of PE, which prevents movements of the impression copings inside the impression material.

Yamamoto and colleagues[40] compared two impression materials, namely irreversible hydrocolloid and VPS, showing that the irreversible hydrocolloid impression technique without splint leads to worse results. There was no significant difference between impression techniques using splinted impression copings, irrespective of the impression material.

Within the limitations of this review, the most used and accurate impression material reported was PE, followed by VPS.

Splinted versus Non-Splinted

Various techniques have been introduced in order to improve impression accuracy. Among these, the splinted technique is one of the most important methods mentioned in the literature, gaining popularity over the years and proven to be the most accurate – even though contrary opinions[46] still remain.

The splinted technique for implant impression was first introduced along with the development of a metal–acrylic resin implant for an edentulous jaw.[47] The method encompasses the connection of all copings with an acrylic resin to prevent individual coping movement and achieve rotation stabilization during the impression procedure. The procedure ends with the transfer of not only the copings but also its splinted connections to the impression material.[48] This technique has been an important topic of investigation, with several studies examining its accuracy. Despite having no general consistent accuracy conclusion in the literature,[2] recent studies report increased accuracy implant impressions with the splinted technique.[4,14–16,18,19,27–29,31,37,39–41]

Nevertheless, authors have identified potential problems with the splinted technique, such as fracture of the connection between the splint material and the impression copings, in particular due to shrinkage of the splint material.[49]

From the 14 studies assessed in this review, all advocate the splinted over the non-splinted technique.[4,14–16,18,19,27–29,31,37,39–41] This could be due to advances in splinting material and manipulation that helped minimize the distortion and fracture of the connection.

In fact, a series of improvements in the splinted technique can be identified in recent literature, with eight studies advocating sectioning and lute of the splint material as a solution to improve accuracy and prevent shrinkage.[14–16,27,29,39–41]

Splint Material

Several splint materials were tested in the analyzed literature, with AAR being the most frequently used. Filho and colleagues[18] compared splinted techniques with Acrylic Resin (AR) and DF on two angled implants (at 65° and 90°), with and without sectioning. Among the splinted techniques, the AR with DF without sectioning presented the worst results in angulation when compared with the ground truth. On the other hand, the prefabricated AR bar showed the most accurate results among the splinted techniques.

Lee and Cho[27] evaluated five different splinted impression techniques. The group presenting the best results was the one where sectioned AR was used, followed by rejoining for shrinkage compensation. Although perfect duplication of the master model was impossible in all groups, minimal distortion was found to be associated with impression methods using resin splinting for more than 24 hours. Adequate polymerization time and compensation process seemed to be the main reasons for the greater accuracy results.

A reduction of material shrinkage could potentiate a passive fit of the final structure. For this purpose, some authors also evaluated metal bars for splinting impression copings. Avila and colleagues,[28] Del Acqua and colleagues,[41] and Lee and colleagues[39] evaluated the accuracy of metal bars as splint material against implants with AR and implants without splint. The achieving results revealed statistically significant differences between the techniques, with metal bars being the most accurate. The increased splint rigidity of metal bars to withstand forces of distortion plays an important role in preventing permanent deformation of the splint by the stress that occurs when obtaining the impression for fabrication of the working cast. Metal bars also avoid AR polymerization and further sectioning and rejoining.[41]

Independent of the splint material used, all authors acknowledge the splinted technique as the most accurate over the non-splinted technique. Within the splinted techniques, the sectioned resin bar and rejoined with AR is the most commonly used. Overall, 8 out of 10 studies evaluating this specific technique reported it as the most accurate, mainly because of the positive effects of rejoining the AR bar with a minimal amount of the same material to minimize the effects of polymerization shrinkage.[14–16,18,27,29,37,39–41]

Coping Design

Literature shows that the square and tapered copings are the most frequently used in various implant systems.

Rashidan and colleagues[23] reported better accuracy when using less retentive shape impression copings (Replace Select) compared with more retentive ones (Implantium) in impressions made with PE impression material. The implant systems used in this study have the same length, although different geometry (tapered and square). More indentation was found to improve retention in the impression material, but material deformation could also result in inaccuracy. Overall, the author identified the coping shape has the major factor influencing impression accuracy.

Howell and colleagues[33] and Eliasson and Ortorp[38] evaluated and compared the accuracy of similar implant placements in working casts using impressions of digitally coded healing abutments. The encode technology presented higher accuracy levels of mean center point displacement compared with the conventional technique. Nevertheless, the registered average of 35 μm in vertical displacement seemed precise enough for single crowns, short-span, implant-supported fixed partial prostheses.[38] The encode system was found to be less accurate when compared with direct and indirect technique in the parallel implant group.[33]

Del'Acqua and colleagues[20] investigated the effect of surface treatment with sandblasted adhesive copings, without presenting significant advantages in dimensional accuracy over non-sandblasted square copings.

Del'Acqua and colleagues[19] further evaluated the implications of modified square copings in the production of more accurate casts. To this end, an additional 2 mm extension on each side of the coping was added using AR. These modifications resulted in significant differences when compared with the non-modified coping (51.20 ± 22.77 μm vs 96.14 ± 32.55 μm). The author reported that the material used during the impression coping acquisition is not relevant, but on the contrary, the change in coping shape has a greater impact in cast accuracy. Overall, the study shows that the coping modification reduces the possibility of displacement while tightening the abutment analogs.

Alikhasi and colleagues[36] also pointed that many implant systems provide tactile feel, even though, in some cases, the dentist may not feel the snap and improperly assume that the transfer coping is properly seated. It was also found that plastic impression copings presented greater variance and poor fitting, ultimately leading to irregularities. Although plastic snap coping displacements in the three directions presented no statistical significance, angular displacement was found to be significant when compared with metal copings.

It was also found that casts fabricated from plastic impression copings are less accurate than casts made from metal impression transfer copings. Fernandez and colleagues[22] report breakage and distortion of the impression cap engaging the implant shoulder, providing evidence that casts fabricated from plastic impression copings are less accurate.

This evidence strongly suggests that the enhancement of coping design may increase impression accuracy significantly.

Angulation

The inaccuracy of impressions is often associated to the angulation of implants, with several studies investigating accuracy variations of parallel and non-parallel implants.[4,5,17,18,33,39]

Filho and colleagues[18] evaluated the effect of implant angulation in splinted techniques using a metal cast with two implants, one at 90° and another with a significant angulation of 65°. The in vitro experiment involved different splinted techniques (AR with DF, AR with DF sectioned and luted, prefabricated AR bar) and square copings, which were used to produce 24 replicas of the original metal cast. These replicas were then compared with the original metal cast, showing that on average, the angulated implant (65°) presented the highest differences in angulation (0.817° ± 0.734°), and the straight implant (90°) presents the lowest angulation difference (0.282° ± 0.203°). Also, regardless of the splinted technique used, the angulated implant always presents the worst accuracy in comparison with the straight implant in all splinted techniques.

Howell and colleagues[33] and Lee and colleagues[39] also reported the influence of angulated implants in the direct or indirect technique. Vertical gaps up to 183 μm were registered and associated with implant angulation with the indirect technique. Minimizing these gaps is essential to minimize forces between implant and support structure.

Sorrentino and colleagues[5] evaluated the influence of different impression materials and lengths of impression coping connections on nonparallel implants. The authors reported a direct relation between impression inaccuracies and the forces required for the impression removal. On the other hand, the study showed that the addition silicon produced more accurate casts for nonparallel implants.

Assunção and colleagues[4] evaluated the influence of implant angulation at 90°, 80°, 75°, and 65°. The authors reported a direct relationship between accuracy and implant angle, with lower implant angles (65°) corresponding to higher levels of misfit (1.46°), mainly when using condensation silicone as splinting material.

Furthermore, Stimmelmayr and colleagues[29] also acknowledged machining tolerances and the different designs of positional indexes, beside angulation, as factors for implant misfit.

In a study with seven patients, Gallucci and colleagues[17] suggest that for multi-unit partially edentulous situations, with implants having less than 10° of angulation, the technique employed (direct or indirect) has no significant statistical influence.

Other factors also play an important role in impression accuracy, such as the number of implants, the proximity of the adjacent tooth (causing minimal space for impression materials), and implant height. To this extent, more studies are required to characterize these and other factors that could increase inaccuracies.[5,33]

Custom Tray

In conventional prosthodontics procedures, custom standard individual tray (ST) is usually used for the impression procedure. The direct technique uses a standard single ST unit, over which custom holes are made by a dentist for accessing the coping projections. In contrast, the indirect technique uses standard trays with no holes.

Existing studies typically evaluate and report inaccuracies due to impression material, impression technique, coping design, and implant angulation, without ever referring potential influences of impression trays.

However, Simeone and colleagues[34] evaluated the accuracy of a custom modular individual tray (MIT), with six implants screwed with 45° of misalignment to simulate the most unfavorable conditions. The MIT is composed of a single base structure with slots for fitting individual modules aligned with the position of each implant. When using the MIT, a polymerizing material is injected between the base structure, the individual modules, and the copings, gluing all these elements together in a single piece. With this procedure, the authors reported a lower percentage of permanent distortions in the most critical phase of impression taking, the impression removal. Linear displacements were reduced by 55% and angular displacements reduced by 65% with the MIT vs ST. Results show that this procedure may provide a solution for the displacement reduction in impression copings, overcoming the inaccuracies reported in nonparallel implant impressions, and help increase the passive fit in implant-supported bridges.

Optical Impression

Since the early 1980s, Mörmann proposed a method for fabricating ceramic restorations using computer-aided design/computer-aided manufacturing (CAD/CAM) technology as an alternative to conventional restorations.[50]

For CAD/CAM-assisted fabrication, digitization of the clinical situation is a prerequisite. For this, two techniques of data capturing are available: intraoral scanning and digitizing the casts made from conventional impressions, the latter usually carried on by scanning the cast in the dental lab.[26]

Measuring the relationship between dental implants in the oral cavity directly and reproducing them outside the oral cavity without taking impressions, and fabricating models overcome some problems of the indirect method. These problems include measurement errors between the oral cavity and the model, and the long chair time for impression taking.

Manufacturers offer scan bodies for digitizing implants, which can be clipped or screw-retained on the implants during scanning. The fit of these scan bodies is decisive for a high-precision transfer of the implant position and inclination, which is important for the fabrication of prosthodontics.

Del Corso and colleagues[35] evaluated an external optoelectronic device employing fringe light patterns, with the device manufacturer declaring an accuracy between 20 and 40 μm. Independent of the dimension being considered for the marker screwed at the implant, the bias error value of the three-dimensional light fringe system was situated between 14 and 21 μm. These results provide promising outcomes for this technique as an alternative to traditional impression techniques, although manufacturer standardization is still required. While results report good accuracy for implant position in a cast, the apparatus for an external optoelectronic device is not yet suitable for real dental office application.

Van der Meer and colleagues[13] evaluated three commercial intraoral optical devices, namely CEREC, iTero, and Lava COS. The analyzed scanners have different technologies to determine the spatial coordinates of the scanned object, using either white or blue light, with or without powder, and resorting to a point-and-click image acquisition method or live video.

Apart from the technological differences, image registration of adjacent surfaces, in order to create a three-dimensional surface bigger than the field of view of the intraoral device, could increase position and/or angular errors over the length of the arch, because of the accumulation of registration errors. Nevertheless, the authors reported a mean distance error as low as 12.7 μm and an angular error of 0.2° with the Lava COS system. The authors suggest that the achieved results strongly rely on the 20 fps of the video scanner and the usage of powder particles as markers. However, optimal results depend on using a high-accuracy scanning protocol, which was found to involve an initial calibration with a calibration block, followed by a slow zigzag scanning of the dentition.

Clinical Judgment

Prosthodontics is a multistep discipline, requiring the highest precision in every step for a successful outcome. The impression step is of particular relevance to the matter of implant accuracy, first because it is not yet a standardized process and secondly because the dentist must take into account innumerous aspects, such as coping shape and size, implant angulation, and impression material. Given the individual variability and numerous specificities of each patient, for instance bone density, arch asymmetry, or surface morphology, the dentist's experience and assessment of each case are still of utmost importance in the process of choosing the most suitable tools and impression materials to achieve the best treatment results. Although several manufactures are attempting to create standardized impression procedures, either using a traditional or a digital approach, currently such innovative and homogenous procedure is still lacking. Ultimately, it is up to the dentist and laboratory technician's experience and responsibility to recognize factors and interpret errors to determine its effect on the desired treatment outcome.

CONCLUSIONS

A review of 32 studies with relevance to evaluate the accuracy of impression techniques reveled that in 14 studies (direct vs indirect), more advocate the direct technique (open) as the most accurate in comparison with the indirect technique (closed). The splinted technique was also evaluated in other 14 studies (splinted vs non-splinted), with all authors favoring it over the non-splinted technique. Within the splinted techniques, the sectioned resin bar followed by rejoining with AR is the most regularly used. The most consistent and accurate impressions were obtained with the splinted technique, followed by the direct technique, and finally the indirect technique.

In general and regardless of the technique used, studies reported more accurate results with the use of PE as impression material, followed by VPS.

While impression materials and techniques revealed to be relevant factors in obtaining accurate implant impressions, coping design has also shown to play an important role in avoiding coping displacement. To this end, square and tapered copings were the most used in various implant systems, with studies reporting that coping shape has more impact on impression accuracy than impression material.

Recently developed optical techniques were also assessed, with benefits for both patient and dentist as the digital data (position and angle) are extracted directly from the patient maxilla. The proposed digital technique could overcome some of the errors associated with traditional impression (impression material shrinkage and technique, coping shapes, and implant angulations) and cast production. While these systems have proven to be very accurate (as low as 12.7 μm), a rigid protocol must be followed to accurately obtain a complete dental arch (slow zigzag scanning and calibration). This leads to a user's dependable system, whose accuracy is directly related to the user experience. To further improve these systems, a powder-free acquisition should be considered as the powder introduces a thinly offset layer over the surface.

Within the limitations of this review, one concludes that implant misfits can be minimized if the impression is performed using an optical intraoral system with powder. Alternatively, using the traditional impression techniques, the most successful impressions are achieved using the open technique with splinted (sectioned and then luted) squared transfer copings and PE as impression material. When possible, parallel implants and MIT are also advised.

ACKNOWLEDGMENTS

This work has been supported by FCT – Fundação para a Ciência e Tecnologia in the scope of the Ph.D. grant SFRH/BD/68270/2010, project EXPL/BBB-BMD/2146/2013 and within the Project Scope UID/CEC/00319/2013.

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