Accuracy of Implant Impressions for Partially and Completely Edentulous Patients: A Systematic Review

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Purpose: *To compare the accuracy of digital and conventional impression techniques for partially and completely edentulous patients and to determine the effect of different variables on the accuracy outcomes.* ***Materials and Methods:*** *An electronic and manual search was conducted to identify studies reporting on the accuracy of implant impressions. Pooled data were descriptively analyzed. Factors affecting the accuracy were identified, and their impact on accuracy outcomes was assessed.* ***Results:*** *The 76 studies that fulfilled the inclusion criteria featured 4 clinical studies and 72 in vitro studies. Studies were grouped according to edentulism; 41 reported on completely edentulous and 35 on partially edentulous patients. For completely edentulous patients, most in vitro studies and all three clinical studies demonstrated better accuracy with the splinted vs the nonsplinted technique (15 studies, splint; 1, nonsplint; 9, no difference). One clinical study and half of the in vitro studies reported better accuracy with the open-tray vs the closed-tray technique (10 studies, open-tray; 1, closed-tray; 10, no difference). For partially edentulous patients, one clinical study and most in vitro studies showed better accuracy with the splinted vs the nonsplinted technique (8 studies, splint; 2, nonsplint; 3, no difference). The majority of in vitro studies showed better accuracy with the open-tray vs the closed-tray technique (10 studies, open-tray; 1, closed-tray; 7, no difference), but the only clinical study reported no difference.* ***Conclusion:*** *The splinted impression technique is more accurate for both partially and completely edentulous patients. The open-tray technique is more accurate than the closed-tray for completely edentulous patients, but for partially edentulous patients there seems to be no difference. The impression material (polyether or polyvinylsiloxane) has no effect on the accuracy. The implant angulation affects the accuracy of implant impressions, while there are insufficient studies for the effect of implant connection type. Further accuracy studies are needed regarding digital implant impressions.* INT J ORAL MAXILLOFAC IMPLANTS 2014;29:836–845. doi: 10.11607/jomi.3625

Key words: *accuracy, dental implants, digital impressions, edentulous, implant impressions, impression techniques*

Oral rehabilitation of partially and completely edentulous patients with dental implants is currently routine procedure, and clinical studies have proven the longitudinal effectiveness of this treatment modality.[1,2] Because endosseous implants are functionally ankylosed with direct contact to the bone, they lack the inherent mobility of the periodontal ligament. Hence, they cannot accommodate distortions or misfit at the implant-abutment interface.[3] Although absolute passive fit of implant fixed complete dental prostheses

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is not yet attainable, it is still unclear what degree of prosthesis misfit will lead to biologic or technical complications.[4,5] Screw loosening and/or fracture, implant fractures, and prosthetic-component strain and fracture have been related to prosthesis misfit.[6,7]

The clinical fit of an implant prosthesis at the implant-abutment junction is directly dependent on the accuracy of impression technique and cast fabrication.[3–5] Hence, an accurate implant impression is necessary to generate an accurate definitive cast, which is the milestone for the fabrication of an accurately fitting prosthesis. The advent of computer-aided design/computer-assisted manufacturing (CAD/CAM) technology improved the framework fabrication procedures and increased the precision of fit of implant prostheses.[8,9]

There are several clinical and laboratory variables that affect the accuracy of an implant cast, namely, impression and pouring techniques, impression material and die stone properties, machining tolerance of prosthetic components, and implant angulation and/or depth.[10–12] One of the most significant factors is the impression procedure. Various implant impression techniques have been used to generate a definitive cast that will ensure the accurate clinical fit of implant fixed complete dental prostheses. Previous in vitro studies have compared different impression techniques, but there has been controversy over which technique is most accurate. The necessity of splinting the impression copings has been advocated in several studies, while others have shown no difference.[11,13]

Digital implant dentistry has transformed the relationship between the dentist and the laboratory. As a part of this trend, digital impressions have been the most significant factor in this changing relationship. Digital impression systems capture digital data that are used to replicate the intraoral hard and soft tissues and replace elastomeric impression materials. There are two types of digital impression technology; one type captures the images as digital photographs, which the software "stitches" together, providing dentists with a series of images. The other type of digital impression technology captures the images as digital video. Digital optical scanners are also safe, but some systems require powder-coating before scanning to ensure that all parts of the impression are properly recorded. Digital impression scanners eliminate tray selection, dispensing and setting of impression materials, disinfection, and impression shipping to the laboratory, while increased patient comfort may be an additional advantage.[14] Additionally, digital impressions may increase efficiency because it is possible to email the digital impression to the laboratory, rather than sending a conventional impression or stone model via regular mail. The digital impression file can be stored electronically, which eliminates space management issues, supports a paper-free practice, and contributes to efficient record keeping. Limitations pertain to the additional cost of purchasing an intraoral scanner and the learning curve for adjusting to the new treatment modality. Digital impressions for tooth-supported prostheses are currently being used and are gaining popularity.[14] However, there is currently a paucity of scientific data regarding digital implant impressions and their accuracy. Research on digital implant impressions is limited to a few in vitro studies and case reports.[15–18]

A previous review on the accuracy of implant impressions did not account for partially vs completely edentulous patients.[11] Instead, the authors extracted the accuracy data from both groups and reported them collectively. This may have pooled the study outcomes, as there are different confounding factors affecting each group. The objectives of this systematic review were (*1*) to compare the accuracy outcomes of digital and conventional impression techniques for partially and completely edentulous patients separately, and (*2*) to determine the effect of different variables on the accuracy outcomes with each impression technique.

MATERIALS AND METHODS

This systematic review was conducted in accordance with the guidelines of Transparent Reporting of Systematic Reviews and Meta-Analyses (PRISMA Statement).[19]

Focused Question

What is the effect of the splinted impression technique compared to digital and conventional impression techniques on the accuracy of implant impressions for partially and completely edentulous patients?

Search Strategy

Three Internet sources were used to search for eligible articles (published, early view online) in English. These databases included MEDLINE/PubMed, EMBASE (Excerpta Medical Database by Elsevier), and Cochrane Central Register of Controlled Trials (CENTRAL). Additionally, the following journals were hand searched for potentially relevant articles: *Clinical Oral Implants Research*, *Clinical Implant Dentistry and Related Research*, *International Journal of Oral and Maxillofacial Implants*, *Implant Dentistry*, *International Journal of Prosthodontics*, *Journal of Prosthetic Dentistry*, and *Journal of Oral Implantology*. The time period extended from January 1, 1980 to September 1, 2013. The search strategy included the following keyword combinations (MeSH and free-text terms): "implant" AND "impressions," "implant impressions" AND "accuracy," "implant impressions" AND "digital," "implant impressions" AND "passive fit," "implant casts" AND "accuracy," and "implant" AND "impression techniques."

The inclusion criteria were as follows:

- Both clinical and in vitro studies were considered.
- Articles should be in English language.
- The studies should report on implant impressions for partially and/or completely edentulous situations.
- The studies should be comparative and compare different impression techniques.
- The studies should report on accuracy assessment and methodology.

Selection Strategy and Data Collection

Articles were collected in reference manager software (EndNote 9, Thomson Reuters), and duplicates were discarded electronically. Titles and abstracts were initially screened by two calibrated reviewers (C-JC and PP) for potential inclusion. If no abstract was available in the database, the abstract of the printed article was used. If the title and abstract did not provide sufficient information regarding the inclusion criteria, the full report was obtained as well. All titles and abstracts selected by the two reviewers were discussed individually for full-text reading inclusion. The selected articles were then obtained in full text. The full-text reading of related publications was carried out independently by two reviewers. The electronic search was supplemented by a manual search of the bibliographies of all full-text articles that were selected from the initial search. Interreviewer agreement was always determined with the use of Cohen's kappa statistics (κ-score). In cases where information was not clear, the issue was elucidated by contacting the authors of the pertinent study via email. Data collection was performed using a standardized electronic spreadsheet.

Quality Assessment

The assessment of study quality was performed for the included articles. In the case of cohort studies, the methodological quality assessment of the studies was based on the Newcastle–Ottawa Quality Assessment Scale.[20] The risk of bias was assessed independently by two reviewers (C-JC and PP), who scored the methodological quality of the included studies. No assessment scale was used for the quality assessment of in vitro studies.

Statistical Analysis

For this study, only descriptive analysis was performed due to the inherent nature of the data, and the results were pooled for analysis (EndNote 9). The following information was extracted from the included articles: study design, edentulous jaw, implant number, impression technique, connection type, abutment angulations, accuracy method, implant brand, splint method, splint material, impression material, and the results of impression accuracy.

RESULTS

Included Studies

The initial search yielded 2,879 hits after discarding duplicate references. The subsequent search at the title level exhibited 407 titles (κ-score = 0.85), and further screening at the abstract level identified 126 abstracts (κ-score = 0.95). The independent abstract investigation revealed 88 articles for full-text reading (κ-score = 0.95). Of the 88 articles selected for full-text reading, 76 studies were finally selected for inclusion (Fig 1). The 12 excluded studies and the reasons for exclusion are shown in Table 1 (see online version at www.quintpub.com).[21–32]

Characteristics of Included Studies

The full-text reading yielded 4 clinical and 72 in vitro studies, which satisfied the inclusion criteria and were used for statistical analysis (Tables 2 and 3 [see online version]). Of the 76 included studies, 41 were investigations of impressions for completely edentulous patients.[4,13,33–71] For partially edentulous patients, 30 pertinent studies were found, while another 5 studies were investigations of single-tooth implant impressions.[72–106] For the purpose of descriptive analysis, the impression studies were divided into studies for either partially or completely edentulous patients (Fig 2).

Pertaining to the methodology of accuracy assessment, it must be highlighted that various two-dimensional (2D) and three-dimensional (3D) techniques were employed for accuracy assessment. Comparing different studies was difficult because some of the included articles utilized equipment for 3D measurements but only used 2D horizontal measurements in the comparison of accuracy. Optical scanning and dedicated software for superimposition of the scanning data sets is currently an efficient and precise technique to measure and compare the 3D discrepancies at the microscopic level between different groups and seems to be the recommended technique for future investigations.[66]

Completely Edentulous Patients

Twenty-two in vitro and three clinical studies compared the accuracy of splinted vs nonsplinted impression techniques (see Table 2).[4,13,35–37,39,40,43,45,47,51–55,57,58,60,61,64–68,71] Twelve in vitro studies reported that the splinted technique was more accurate than the nonsplinted

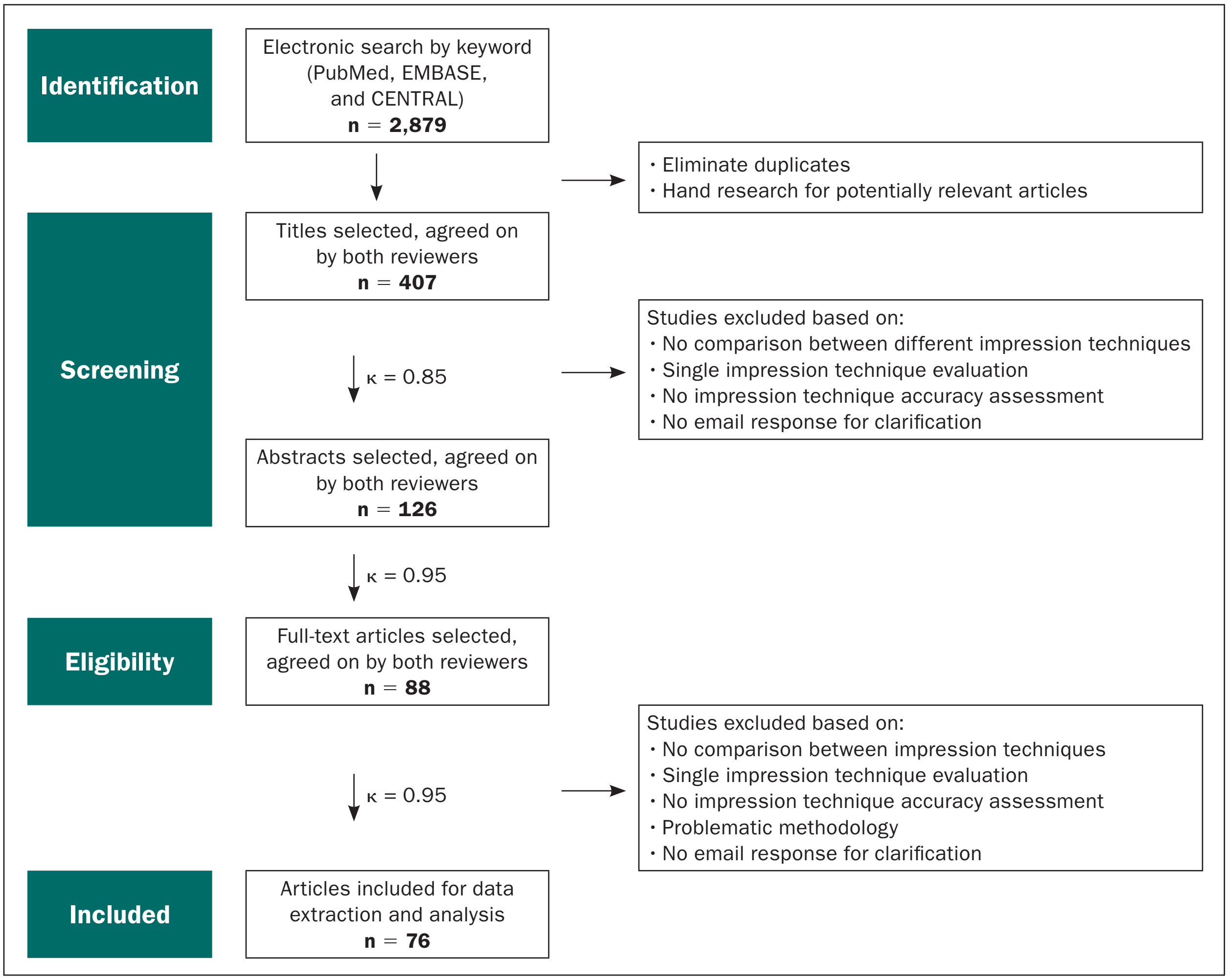

Fig 1 Search strategy.

technique,[35–37,39,47,51,57,60,61,65,67,68] nine in vitro studies reported that there was no difference,[40,43,45,52–55,58,64] and one in vitro study[71] reported that the nonsplinted technique was more accurate (Table 4 [see online version]). The three clinical studies demonstrated that the splinted technique was more accurate than the nonsplinted technique and recommended this technique for clinical use.[4,13,66]

Twenty in vitro and 1 clinical study compared the accuracy with open-tray (direct, pickup) vs closed-tray (indirect, transfer) impression techniques (Table 5 [see online version]).[35,36,40–43,45,48,49,52,54,57–60,63–66,70,71] Nine in vitro studies reported that the open-tray technique was more accurate than the closed-tray for completely edentulous patients,[35,36,40,42,57,58,60,65,71] 10 in vitro studies reported no difference,[43,45,48,49,52,54,59,63,64,70] and 1 in vitro study reported that the closed-tray was more accurate.[41] One clinical study reported that the open-tray was more accurate.[66]

Twelve in vitro studies compared the accuracy of impression techniques with different impression materials (Table 6 [see online version]).[33,34,38,40,43,46,50,58,62,64,69,70] Eleven in vitro studies reported no difference between polyether and polyvinylsiloxane (PVS),[33,34,38,40,43,50,58,62,64,69,70] while one in vitro study reported better accuracy with polyether.[46]

Regarding implant angulation, six in vitro and three clinical studies reported on accuracy outcomes with angulated implants (Table 7 [see online version]).[4,13,33,34,57,59,61,65,66] The three clinical studies did not focus on the details of implant angulation but reported that the splinted technique was clinically better than nonsplinted or closed-tray techniques with angulated implants.[4,13,66] Three out of six in vitro studies reported that splinted technique was more accurate when making an impression of angulated implants.[57,61,65] One in vitro study[34] reported that for a buccal angulation of 10 degrees, the impressions were more accurate with polyether than PVS, whereas another in vitro study[33] on the same 10-degree buccal angulation showed no difference between polyether and PVS impressions.

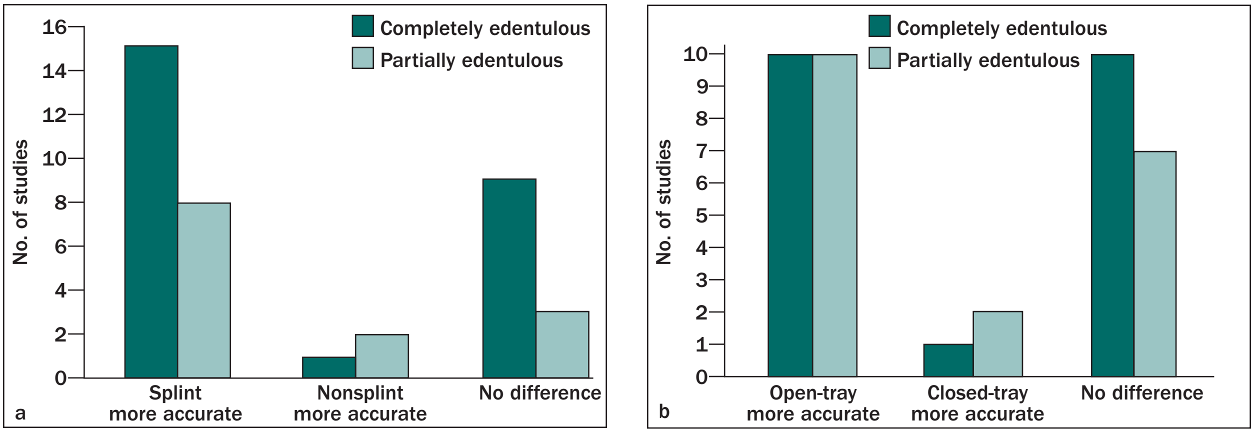

Fig 2 Schematic diagram with studies and accuracy outcomes for *(a)* splinted vs nonsplinted and *(b)* open-tray vs closed-tray impression techniques.

Another in vitro study[59] reported on the effect of implant angulation in an eight-implant edentulous maxillary jaw with four internal connection and four external connection implants with a bilateral split-mouth design. They reported that implant impression accuracy was affected by angulated implants, especially at 25 degrees. No studies were found assessing the effect of internal vs external connection or implant vs abutment level on implant impression accuracy.

Partially Edentulous Patients

Thirteen in vitro studies compared the accuracy of splinted vs nonsplinted impression techniques (see Table 3).[72,75–78,81,85,88,92–94,96,99,106] Eight in vitro studies reported that the splinted technique was more accurate than the nonsplinted technique,[76–78,85,92,94,96,106] three in vitro studies reported that there was no difference,[81,93,99] and two in vitro studies reported that the nonsplinted was more accurate (see Table 4).[75,88]

There were 18 in vitro and 1 clinical study that compared the accuracy with open-tray (direct, pickup) vs closed-tray (indirect, transfer) impression techniques (see Table 5).[72,73,76,78–80,82,83,86,87,90,92–94,96,98,100,101,105] Ten in vitro studies reported that the open-tray technique was more accurate than the closed-tray for partially edentulous patients,[76,78,87,90,92–94,96,98,100] seven in vitro studies reported that there was no difference,[72,73,79,82,83,101,105] and one in vitro study reported that the closed-tray was more accurate.[80] One clinical study reported that there was no difference between open- and closed-tray technique.[86]

Ten in vitro studies compared the accuracy of impression techniques with polyether, PVS, and various other impression materials (see Table 6).[72,76,80,94,95,98–100,102,105] Eight in vitro studies reported no difference between polyether and PVS,[72,76,80,94,98,100,102,105] while one study reported better accuracy with PVS vs alginate.[99] One study reported better accuracy with PVS for angulated implants and better accuracy with polyether for parallel implants.[95]

Regarding implant angulation, 1 clinical and 15 in vitro studies reported on impression accuracy outcomes with angulated implants (see Table 7).[74–77,79,81,82,85–87,89,90,92–95] One clinical study[86] reported no difference in the clinical accuracy between open- and closed-tray impression techniques for partially edentulous patients with two implants and up to 10 degrees angulation. Nine in vitro studies reported on two implant scenarios with internal or external connections and reported that angulation of more than 20 degrees affected accuracy, but the clinical significance is unknown.[75,77,79,81,85,87,89,93,94] Choi et al[81] (2007) and Carr[79] (1992) reported that angulation up to 15 degrees had no effect on accuracy, while Jang et al[89] (2011) reported that angulation greater than 20 degrees negatively affected the accuracy. At angulation of 25 degrees, Rutkunas et al[94] and Filho et al[85] both reported that the splinted technique was more accurate, whereas Assunção et al[75,77] (2008) reported contradictory results at angulation of 25 degrees, with one study showing greater accuracy with the splinted technique and another study showing more accurate results with the nonsplinted. When implant angulation was 30 degrees, Howell et al[87] (2013) reported that the open-tray technique was more accurate than closed-tray.

Three in vitro studies reported on three implant scenarios with internal or external connections and reported that angulation up to 15 degrees did not affect accuracy, but the clinical significance is unknown.[82,90,92] Splinted technique was better at angulation of 30 degrees and 40 degrees according to the results of one study.[92] Three in vitro studies reported on four implant scenarios with internal or external connections and reported that angulation up to 5 degrees did not affect accuracy and that for angulations more than 20 degrees the splinted technique was better.[74,76,95]

No studies were found assessing the effect of internal and external connections on implant impression accuracy. Four in vitro studies reported on comparisons of impression accuracy at the implant vs abutment/cementable abutment level.[73,91,94,97] One in vitro study[94] reported on accuracy when comparing impressions at the implant level and abutment level and found no difference. Three in vitro studies[73,91,97] compared impression accuracy at the implant level vs the cementable abutment level. One study reported no difference,[73] while two studies reported greater accuracy at the implant level compared with the cementable abutment level.[91,97] Another in vitro study by Wegner et al[105] (2013) compared two different internal connections with a split-mouth design and reported that the type of internal connection affects the accuracy of the implant impression.

Single-Tooth Spaces

Two studies compared the accuracy of single-tooth implant impressions with open-tray (direct) vs closed-tray (indirect) techniques (see Table 3).[100,101] One study reported no difference, and the other study reported that the open-tray technique was more accurate.

One study compared the accuracy of implant impressions with different impression materials and reported no difference.[102] Two studies compared the accuracy of impressions with unmodified vs modified impression copings.[103,104] They reported better accuracy with modified copings. In conclusion, for single implant impressions it seems that there is no difference in the accuracy of different impression techniques.

Digital Impressions

The digital impressions seem to eliminate errors and material defects such as voids, air bubbles, inadequate polymerization, or distortions. With digital impression technology, repeated scanning can be performed to easily capture a revised impression and to improve the previous virtual model, in case it is deemed not acceptable.[17] There were no comparative studies on accuracy of digital implant impressions for completely edentulous patients. For partially edentulous patients, there were only three accuracy studies, with mixed results. An in vitro study by Howell et al reported that the digital implant impressions were less accurate than the conventional open-tray technique.[87] It should be noted that this study included implants with 30 degrees angulation. A second in vitro study with two implant scenarios reported that the splinted technique was more accurate than the digital one, both at 10 degrees and 30 degrees angulation.[106] Finally, an in vitro study by Eliasson et al comparing the accuracy of casts made from conventional impressions vs extraoral scanning (Encode Impression System, Biomet 3i) reported no difference.[84] The current trend today is the utilization of intraoral scanners to achieve a total digital workflow, from implant planning to definitive restoration. This is contrary to the conventional impression procedure and restoration fabrication, which potentially involves multiple materials, more steps, and potentially more room for error.[107]

DISCUSSION

The primary purpose of this systematic review was to evaluate the accuracy of splinted implant impression techniques compared with different conventional and digital impression techniques. The secondary outcomes were to assess the effect of impression materials, implant angulation, and connection type on the accuracy of implant impressions.

For completely edentulous patients, the scientific evidence on splinted vs nonsplinted techniques relied on 22 in vitro and 3 clinical studies[4,13,35–37,39,40,43,45,47,51–55,57,58,60,61,64–68,71] and supports (15 studies, splint; 1, nonsplint; 9, no difference) the technique of splinting the impression copings for implant impressions.

The scientific evidence on the accuracy with open-tray (direct, pickup) vs closed-tray (indirect, transfer) impression techniques was based on 20 in vitro and 1 clinical study[35,36,40–43,45,48,49,52,54,57–60,63–66,70,71] and supports (11 studies, open-tray; 1, closed-tray; 10, no difference) open-tray implant impression techniques. The scientific evidence on the accuracy of impression techniques with different impression materials relied on 12 in vitro studies[33,34,38,40,43,46,50,58,62,64,69,70] and demonstrates no difference (11 studies, no difference; 1, polyether more accurate) between PVS and polyether. Regarding implant angulation, 6 in vitro and 3 clinical studies reported on accuracy outcomes with angulated implants.[4,13,33,34,57,59,61,65,66] The scientific evidence from 3 clinical studies and most in vitro studies reported that the splinted technique was clinically more accurate than nonsplinted or closed-tray techniques[4,13,66] and that implant angulation affects accuracy. No studies were found assessing the effect of internal vs external connection or implant vs abutment level impressions on implant impression accuracy.

For partially edentulous patients, the scientific evidence on splinted vs nonsplinted techniques was based on 13 in vitro studies[72,75–78,81,85,88,92–94,96,99,106] and supports (8 studies, splint; 2, nonsplint; 3, no difference) splinted impression techniques. The scientific evidence on the accuracy with open-tray (direct, pickup) vs closed-tray (indirect, transfer) impression techniques was based on 18 in vitro and 1 clinical study[72,73,76,78–80,82,83,86,87,90,92–94,96,98,100,101,105] and shows

(10 studies, open-tray; 1, closed-tray; 7, no difference) no significant difference between open-tray and closed-tray implant impression techniques. The scientific evidence on the accuracy of impression techniques with different impression materials relied on 10 in vitro studies[72,76,80,94,95,98–100,102,105] and shows no difference between polyether and PVS. Regarding implant angulation, the scientific evidence was based on 1 clinical and 15 in vitro studies[74–77,79,81,82,85–87,89,90,92–95]. The one clinical study[86] reported no difference in the clinical accuracy between open- and closed-tray impression techniques for partially edentulous patients with two implants and up to 10 degrees angulation, while most in vitro studies showed that angulation more than 20 degrees affects accuracy.[75,77,79,81,85,87,89,93,94] No studies were found assessing the effect of internal and external connection on implant impression accuracy.

Most of the studies used polymethyl methacrylate (PMMA) autopolymerizing acrylic resin as the splinting material of choice, coupled with dental floss or metal bars. Sectioning and reconnection of the resin splint has been advocated, because an in vitro study showed that the total polymerization shrinkage of Duralay acylic resin (Reliance Dental) at 1 day was 7.9% and that 80% of the shrinkage occurred within 17 minutes of mixing at room temperature.[108] Moreover, the use of new splinting materials such as composite resin or visible light polymerizing acrylic resin resulted in better results.[13,47,66]

In regard to the methodology of accuracy assessment, several methods have been employed to measure and quantify the 3D discrepancies on the x-, y-, and z-axis between the implant casts produced with different impression techniques, including computerized coordinate measuring machine, traveling microscope, computerized tomography (CT) scan, and, recently, optical scanning and digitization.[11] In regard to the machining tolerance, it has been shown that paired prosthetic components may be rotationally displaced during connection to their respective parts,[55] and this displacement cannot be controlled by the clinician.[10,12] Hence, errors occur during connection of impression copings to the implants intraorally and to the implant analogs in the laboratory, respectively. The machining tolerance differs between different implant systems and is an unknown variable in the accuracy measurements.

Since 2007, several digital impression scanners have emerged in the market. Dedicated 3D digital scanners for implant impressions include the iTero Digital Impression System (Cadent) and the Lava Chairside Oral Scanner (3M ESPE), whereas digital scanners with prosthesis design software and in-office milling capabilities include the CEREC Bluecam (Sirona Dental Systems) and E4D Dentist (D4D Technologies). With these systems, the definitive prostheses are fabricated in the laboratory on master casts created from the digital scanning data, as opposed to stone casts made from conventional impressions.[14] New digital impression scanners with continuous data acquisition instead of single-image stitching include the CEREC Omnicam (Sirona Dental Systems), 3M True Definition Scanner (3M ESPE), and TRIOS scanner (3Shape).

Digital impression scanners eliminate tray selection, dispensing and setting of impression materials, disinfection, and impression shipping to the laboratory. Patient comfort and education are additional advantages. Moreover, the laboratory saves time by not having to pour base and pin models, cut and trim dies, or articulate casts. Digital scanning datasets are stored on computer hard drives, whereas conventional stone casts must be stored physically, which often requires extra space in the dental office, and are subject to damage.

Digital impressions for tooth-supported prostheses are being used with considerable success.[109–111] For full-arch cases, a recent in vitro study by Ender and Mehl reported promising results with digital impressions, although they were inferior to the conventional technique.[112] In terms of digital impressions for implant-supported prostheses, the present review revealed a paucity of scientific data limited to case reports with single implant crowns.[15,16,107] There were no comparative studies on accuracy of digital implant impressions for completely edentulous patients. Only two clinical reports elaborated on the digital workflow for fabrication of a complete arch prosthesis from impression to delivery.[17,18] Another recent clinical study on mandibular overdentures supported by two implants reported that intraoral digital scanning resulted in accuracy that was too unpredictable to be recommended for routine clinical use.[113] For partially edentulous patients, there were only three accuracy studies with mixed results, making conclusions impossible. Digital implant dentistry is gaining increasing popularity and is showcasing good potential; however, further studies are needed to assess the clinical accuracy of digital vs conventional implant impression techniques.

CONCLUSIONS

Under the limitations of the present study, the following conclusions may be drawn:

1. The splinted impression technique was more accurate than the nonsplinted conventional impression techniques for both partially and completely edentulous patients.
2. The open-tray impression technique was more accurate than the closed-tray impression technique

for completely edentulous patients, but there seems to be no difference for partially edentulous patients.

3. The accuracy of implant impressions is not affected by the impression material (polyether and addition PVS) for both partially and completely edentulous patients.
4. The accuracy of implant impressions is affected by the implant angulation when it is greater than 20 degrees for partially and completely edentulous patients.
5. Insufficient data exist on the effect of implant connection type on the accuracy of implant impressions.
6. Insufficient data exist on digital impression techniques; further studies are necessary.

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Table 1 Excluded Studies and Reasons for Exclusion

Study	Reasons for exclusion
Alikhasi et al[21] 2013	No comparison between different impression techniques; single impression technique evaluation with copings under repeated use
Cerqueira et al[24] 2012	No comparison between different impression techniques; comparison of three different splinting materials without impression
Karl et al[27] 2012	No impression technique accuracy assessment; evaluation of the accuracy of CAD/CAM vs cast three-unit FPDs fabricated on casts from two different techniques
Lopes et al[29] 2013	Photoelastic analysis study; no comparison between different impression techniques; comparison of three different splinting materials without impression
Lopes et al[30] 2013	Photoelastic analysis study; no comparison between different impression techniques; comparison of four different splinting resins without impression
Simeone et al[31] 2011	No comparison between different impression techniques; single impression technique evaluation
Del Corso et al[25] 2009	No comparison between different impression techniques; single impression technique evaluation
Holst et al[26] 2007	Evaluation of the effect of time on impression dimensional stability; no cast fabrication from the impression technique
Burns et al[22] 2003	No comparison between different impression techniques; single impression technique evaluation with two different trays
Wee et al[32] 1998	No comparison between different impression techniques; single impression technique evaluation with three different materials for cast fabrication
Carr and Master[23] 1996	No comparison between different impression techniques; single impression technique evaluation
Liou et al[28] 1993	No comparison between different impression techniques; accuracy assessment of coping-analog assembly placement in closed-tray impressions

FPD = fixed partial denture.

Table 2 Characteristics of Included Studies with Completely Edentulous Patients

Article	Study design	Edentulous jaw	No. of implants	Impression technique	Accuracy method	Implant brand
Akalin et al[34] 2013	In vitro	Maxilla	6	OT–NS	2D	AstraTech
Fernandez et al[49] 2013	In vitro	Mandible	4	OT–NS, CT	2D	Nobel Biocare Replace; tissue-level Straumann
Martinez-Rus et al[57] 2013	In vitro	Maxilla	6	CT, OT–NS, OT–S	3D	Zimmer Screw-Vent
Stimmelmayr et al[66] 2013	Clinical	Mandible	4	OT–S, CT	3D	Cam-Log
Al Quran et al[35] 2012	In vitro	Maxilla	4	OT–S, OT–NS, CT	2D	Sybron Pitt Easy
Avila et al[39] 2012	In vitro	Mandible	4	OT–S, OT–NS	3D	Conexao
Chang et al[43] 2012	In vitro	Mandible	5	OT–S, OT–NS, CT	2D	Sybron Pro TL
Del'Acqua et al[48] 2012	In vitro	Mandible	4	OT–S, CT	3D	Conexao
Ferreira et al[50] 2012	In vitro	Mandible	4	OT–S, CT	2D	Neodent
Mpikos et al[59] 2012	In vitro	Maxilla	8	OT–NS, CT	3D	Dr Ihde Dental
Ongül et al[61] 2012	In vitro	Maxilla	6	OT–S, OT–NS	3D	Tissue-level Straumann
Papaspyridakos et al[13] 2012	Clinical	Maxilla/ Mandible	5 to 8	OT–S, OT–NS	3D	Nobel Biocare Brånemark
Rashidan et al[63] 2012	In vitro	Mandible	5	OT–NS, CT	3D	Nobel Biocare Replace; Implantium
Stimmelmayr et al[65] 2012	In vitro	Mandible	4	OT–S, OT–NS, CT	3D	Cam-Log
Lee and Cho[56] 2011	In vitro	Mandible	6	OT–S	3D	Nobel Biocare Brånemark
Papaspyridakos et al[4] 2011	Clinical	Maxilla/ Mandible	5 to 8	OT–S, OT–NS	2D	Nobel Biocare Brånemark
Aguilar et al[33] 2010	In vitro	Mandible	5	OT–NS	3D	Zimmer Paragon Spectra-Cone
Del'Acqua et al[44] 2010	In vitro	Mandible	4	OT–S, OT–NS	3D	Conexao

Table 2 *continued* Characteristics of Included Studies with Completely Edentulous Patients

Article	Study design	Edentulous jaw	No. of implants	Impression technique	Accuracy method	Implant brand
Del'Acqua et al[46] 2010	In vitro	Mandible	4	OT–NS	3D	Conexao
Del'Acqua et al[47] 2010	In vitro	Mandible	4	OT–S	3D	Conexao
Hariharan et al[51] 2010	In vitro	Mandible	4	OT–S, OT–NS	3D	Nobel Biocare Replace
Mostafa et al[58] 2010	In vitro	Mandible	4	CT, OT–NS, OT–S	2D	Microdent
Del'Acqua et al[45] 2008	In vitro	Mandible	4	OT–S, OT–NS, CT	3D	Conexao
Wenz and Hertrampf[70] 2008	In vitro	Mandible	5	OT–NS, CT	2D	Friadent Dentsply Frialit-2
Kim et al[55] 2006	In vitro	Mandible	5	OT–S, OT–NS	3D	Nobel Biocare Brånemark
Ortorp et al[62] 2005	In vitro	Mandible	5	OT–NS, photogrammetry	3D	Nobel Biocare Brånemark
Naconecy et al[60] 2004	In vitro	Mandible	5	OT–S, OT–NS, CT	3D	Nobel Biocare Brånemark
Vigolo et al[67] 2004	In vitro	Maxilla	4	OT–S, OT–NS	2D	Biomet 3i
Vigolo et al[68] 2003	In vitro	Mandible	6	OT–S, OT–NS	2D	Biomet 3i
Herbst et al[52] 2000	In vitro	Mandible	5	OT–S, OT–NS, CT	3D	Southern
Wee[69] 2000	In vitro	Mandible	5	OT–NS	3D	Nobel Biocare Brånemark
Assif et al[38] 1999	In vitro	Mandible	5	OT–S, OT–NS	3D	Nobel Biocare Brånemark
Burawi et al[41] 1997	In vitro	Mandible	5	OT–S, CT	2D	Bone-Lock
Assif et al[37] 1996	In vitro	Mandible	5	OT–S, OT–NS	3D	Nobel Biocare Brånemark
Phillips et al[71] 1994	In vitro	Mandible	5	OT–S, OT–NS, CT	3D	Nobel Biocare Brånemark
Barrett et al[40] 1993	In vitro	Mandible	6	OT–S, OT–NS, CT	3D	Nobel Biocare Brånemark
Hsu et al[53] 1993	In vitro	Mandible	4	OT–S, OT–NS	3D	Nobel Biocare Brånemark
Assif et al[36] 1992	In vitro	Mandible	5	OT–S, OT–NS, CT	2D	Nobel Biocare Brånemark
Carr[42] 1991	In vitro	Mandible	5	OT–NS, CT	2D	Nobel Biocare Brånemark
Humphries et al[54] 1990	In vitro	Mandible	4	OT–S, OT–NS, CT	3D	Nobel Biocare Brånemark
Spector et al[64] 1990	In vitro	Mandible	6	OT–S, CT	3D	Nobel Biocare Brånemark

OT = open-tray; CT = closed-tray; S = splinted; NS = nonsplinted.

Table 3 Characteristics of Included Studies with Partially Edentulous Patients

Article	Study design	Type of edentulism	No. of implants	Impression technique	Accuracy method	Implant brand
Al-Abdullah et al[106] 2013	In vitro	Not anatomic	2	OT–S, digital	3D	Biomet 3i
Howell et al[87] 2013	In vitro	Kennedy Class I mandible	4	OT–NS, CT, digital	3D	Biomet 3i
Wegner et al[105] 2013	In vitro	Kennedy Class I maxilla	6	OT–NS, CT	3D	Tissue-level Straumann; Semados Bego
Eliasson and Ortorp[84] 2012	In vitro	Kennedy Class I maxilla	3	OT–NS, digital	3D	Biomet 3i
Rutkunas et al[94] 2012	In vitro	Not anatomical	2	OT–S, CT	2D	EZ plus Megagen
Tarib et al[96] 2012	In vitro	Partially edentulous	2	OT–S, OT–NS, CT	2D	Osstem
Alikhasi et al[73] 2011	In vitro	Kennedy Class II maxilla	2	OT–NS, CT	3D	Implantium
Gallucci et al[86] 2011	Clinical	Partially edentulous	2	OT–NS, CT	3D	Bone-level Straumann
Jang et al[89] 2011	In vitro	Not anatomical	2	OT–NS	2D	Implantium
Kwon et al[91] 2011	In vitro	Kennedy Class II maxilla	3	OT–NS, cementable abutment impression	3D	Warantec
Assunção et al[74] 2010	In vitro	Not anatomical	4	OT–S	2D	Conexao
Jo et al[90] 2010	In vitro	Not anatomical	3	OT–NS, CT	2D	Osstem

Table 3 *continued* Characteristics of Included Studies with Partially Edentulous Patients

Article	Study design	Type of edentulism	No. of implants	Impression technique	Accuracy method	Implant brand
Lee et al[92] 2010	In vitro	Not anatomical	3	OT–NS, CT	2D	Nobel Biocare Brånemark
Sorrentino et al[95] 2010	In vitro	Not anatomical	4	OT–NS	2D	Winsix
Yamamoto et al[99] 2010	In vitro	Not anatomical	3	OT–S, OT–NS	3D	Conexao
Filho et al[85] 2009	In vitro	Not anatomical	2	OT–S, OT–NS	2D	Conexao
Lee et al[93] 2009	In vitro	Not anatomical	2	OT–S, OT–NS, CT	2D	AstraTech
Assunção et al[75] 2008	In vitro	Not anatomical	2	OT–S, OT–NS	2D	Conexao
Assunção et al[77] 2008	In vitro	Not anatomical	2	OT–S, OT–NS	2D	Conexao
Walker et al[97] 2008	In vitro	Not anatomical	3	CT	2D	Nobel Biocare Replace
Wöstmann et al[98] 2008	In vitro	Kennedy Class I maxilla	4	OT–NS, CT	3D	XiVe Dentsply Friadent
Cabral and Guedes[78] 2007	In vitro	Not anatomical	2	OT–S, OT–NS, CT	2D	SIN
Choi et al[81] 2007	In vitro	Not anatomical	2	OT–S, OT–NS	Strain gauges	AstraTech
Conrad et al[82] 2007	In vitro	Not anatomical	3	OT–NS, CT	3D	Biomet 3i
Cehreli and Akça[80] 2006	In vitro	Not anatomical	4	OT–NS, CT	Strain gauges	Tissue-level Straumann
Vigolo et al[103] 2005	In vitro	Partially edentulous	1	OT	2D	Biomet 3i
Akça and Cehreli[72] 2004	In vitro	Not anatomical	4	OT–NS, CT	3D	Tissue-level Straumann
Assunção et al[76] 2004	In vitro	Not anatomical	4	OT–S, OT–NS, CT	2D	Conexao
Daoudi et al[101] 2004	In vitro	Partially edentulous	1	OT, CT, OT–S	3D	Nobel Biocare Brånemark
De la cruz et al[83] 2002	In vitro	Not anatomical	3	OT–NS, CT	2D	SteriOss
Daoudi et al[100] 2001	In vitro	Partially edentulous	1	OT, CT	3D	Nobel Biocare Brånemark
Lorenzoni et al[102] 2000	In vitro	Partially edentulous	1	CT	3D	Friadent Dentsply Frialit-2
Vigolo et al[104] 2000	In vitro	Partially edentulous	1	OT	2D	Biomet 3i
Inturregui et al[88] 1993	In vitro	Not anatomical	2	OT–S, OT–NS	Strain gauges	Nobel Biocare Brånemark
Carr[79] 1992	In vitro	Kennedy Class II mandible	2	OT–NS, CT	2D	Nobel Biocare Brånemark

Table 4 Studies Comparing Splinted Versus Nonsplinted Impression Techniques

Article	No. of implants	Impression technique	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Completely edentulous							
Martinez-Rus et al[57] 2013	6	OT–S, OT–NS, CT	Splint with DF and resin, section, rejoin Splint with plaster and metal framework	Duralay* resin Plaster with metal framework	Internal	Parallel/ 15 degrees/ 30 degrees	Splint more accurate
Stimmelmayr et al[66] 2013	4	OT–S, CT	Splint with prefab bars, section, rejoin	anaxAcryl resin	Internal	Angulated, NR	Splint more accurate
Al Quran et al[35] 2012	4	OT–S, OT–NS, CT	Splint, section, rejoin	Pattern resin	Internal	Parallel	Splint more accurate
Avila et al[39] 2012	4	OT–S, OT–NS	Splint with metal bars	Pattern resin and metal bars	External, AL	Parallel	Splint more accurate
Chang et al[43] 2012	5	OT–S, OT–NS, CT	Splint, section, rejoin	Pattern resin	Internal	Parallel	No difference

Table 4 *continued* Studies Comparing Splinted Versus Nonsplinted Impression Techniques

Article	No. of implants	Impression technique	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Ongül et al[61] 2012	6	OT–S, OT–NS	Splint with prefab bars, section, rejoin Splint with prefab bars	Duralay resin Composite resin	Internal	Angulated, NR	Splint more accurate
Papaspyridakos et al[13] 2012	5 to 8	OT–S, OT–NS	Splint, section, rejoin	DF and Triad† gel	External, IL	Angulated, NR	Splint more accurate
Stimmelmayr et al[65] 2012	4	OT–S, OT–NS, CT	Splint with prefab bars, section, rejoin	anaxAcryl‡ resin	Internal	Angulated, NR	Splint more accurate
Papaspyridakos[4] et al 2011	5 to 8	OT–S, OT–NS	Splint, section, rejoin	DF and Triad gel	External, IL	Angulated, NR	Splint more accurate
Del'Acqua et al[44] 2010	4	OT–S, OT–NS	Splint with prefab composite bars, section, rejoin	Z100§ composite resin	External, AL	Parallel	Splint more accurate
Hariharan et al[51] 2010	4	OT–S, OT–NS	Splint with prefab bars, section, rejoin	Pattern resin Bite registration material	Internal	Parallel	Splint more accurate
Mostafa et al[58] 2010	4	OT–S, OT–NS, CT	Splint with prefab bars	Pattern resin	External, IL	Parallel	No difference
Del'Acqua et al[45] 2008	4	OT–S, OT–NS, CT	Splint with prefab bars, section, rejoin	Duralay resin	External, AL	Parallel	No difference
Kim et al[55] 2006	5	OT–S OT–NS	Splint, section and rejoin	Triad gel	External, AL	Parallel	No difference
Naconecy et al[60] 2004	5	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	Splint more accurate
Vigolo et al[67] 2004	4	OT–S, OT–NS	Splint, section, rejoin	Duralay resin	Internal	Parallel	Splint more accurate
Vigolo et al[68] 2003	6	OT–S, OT–NS	Splint, section, rejoin	Duralay resin	External, AL	Parallel	Splint more accurate
Herbst et al[52] 2000	5	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	No difference
Assif et al[37] 1996	5	OT–S, OT–NS, OT	Splint Splint copings to the tray	Duralay resin	External, AL	Parallel	Splint more accurate
Phillips et al[71] 1994	5	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	Nonsplint more accurate
Barrett et al[40] 1993	6	OT–S, OT–NS CT	Splint	Duralay resin	External, AL	Parallel	No difference
Hsu et al[53] 1993	4	OT–S, OT–NS	Splint	Duralay resin DF and Duralay resin Wire and Duralay resin	External, AL	Parallel	No difference
Assif et al[36] 1992	5	OT–S, OT–NS, CT	Splint with prefab bars, Section, rejoin	Duralay resin	External, AL	Parallel	Splint more accurate
Humphries et al[54] 1990	4	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	No difference
Spector et al[64] 1990	6	OT–S, CT	Splint with DF and resin	Duralay resin	External, AL	Parallel	No difference
Partially edentulous							
Al-Abdullah et al[106] 2013	2	OT-S, DIGITAL	Splint, section, rejoin	Pattern resin	Internal	10 degrees/ 30 degrees	Splint more accurate
Rutkunas et al[94] 2012	2	OT-S, OT-S, CT	Splint with DF and resin, section, rejoin	Pattern resin	IL and AL	5 degrees/ 25 degrees	Splint more accurate

Table 4 *continued* Studies Comparing Splinted Versus Nonsplinted Impression Techniques

Article	No. of implants	Impression technique	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Tarib et al[96] 2012	2	OT–S, OT–NS, CT	Splint Splint with DF and resin, section, rejoin	Duralay resin	Internal	Parallel	Splint more accurate
Lee et al[92] 2010	3	OT–S, CT	Splint, section, rejoin	Pattern resin	External, IL	Parallel/ 30 degrees/ 40 degrees	Splint more accurate
Yamamoto et al[99] 2010	3	OT–S, OT–NS	Splint prefab bars	Duralay resin	External, IL	Parallel	No difference
Filho et al[85] 2009	2	OT–S, OT–NS	Splint Splint, section, rejoin Splint prefab bars	DF and Duralay resin	External, IL	25 degrees	Splint more accurate
Lee et al[93] 2009	2	OT–S, OT–NS, CT	Splint, section, rejoin	Pattern resin	Internal	10 degrees	No difference
Assunção et al[75] 2008	2	OT–S, OT–NS	Splint	DF and Duralay resin	External, iIL	25 degrees	Nonsplint more accurate
Assunção et al[77] 2008	2	OT–S, OT–NS	Splint prefab bars	Duralay resin composite resin	External, IL	25 degrees	Splint more accurate
Cabral and Guedes[78] 2007	2	OT–S, OT–NS, CT	Splint Splint, section, rejoin	Pattern resin	Internal	Parallel	Splint more accurate
Choi et al[81] 2007	2	OT–S, OT–NS	Splint with prefab bars, section, rejoin	Pattern resin	Internal	Parallel/ 8 degrees	No difference
Assunção et al[76] 2004	4	OT–S, OT–NS, CT	Splint	Duralay resin	External, IL	Parallel/ 10 degrees/ 15 degrees/ 20 degrees	Splint more accurate
Inturregui et al[88] 1993	2	OT–S, OT–NS	Splint, section, rejoin Splint with plaster	Duralay resin	External, AL	Parallel	Nonsplint more accurate

AL = abutment level; CT = closed-tray; DF = dental floss; IL = implant level; NR = not reported; OT = open-tray; S = splinted; NS = nonsplinted. *Reliance Dental †Dentsply ‡Anaxdent §3M ESPE

Table 5 Studies Comparing Open-Tray Versus Closed-Tray Impression Techniques

Article	Edentulous jaw	No. of implants	Impression technique	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Completely edentulous								
Fernandez et al[49] 2013	Mandible	4	OT–S, CT	–	–	Internal	Angulated, NR	No difference
Martinez-Rus et al[57] 2013	Maxilla	6	OT–S, OT–NS, CT	Splint with DF and resin, section, rejoin Splint with plaster and metal framework	Duralay resin Plaster with metal framework	Internal	Parallel/ 15 degrees/ 30 degrees	OT more accurate
Stimmelmayr et al[66] 2013	Mandible	4	OT–S, CT	Splint with prefab bars, section, rejoin	anaxAcryl resin	Internal	Angulated, NR	OT more accurate
Al Quran et al[35] 2012	Maxilla	4	OT–S, OT–NS, CT	Splint, section, rejoin	Pattern resin	Internal	Parallel	OT more accurate
Chang et al[43] 2012	Mandible	5	OT–S, OT–NS, CT	Splint, section, rejoin	Pattern resin	Internal	Parallel	No difference
Del'Acqua et al[48] 2012	Mandible	4	OT–S, CT	Splint with metal bars	Duralay resin	External, AL	Parallel	No difference
Mpikos et al[59] 2012	Maxilla	8	OT–NS, CT	–	–	External, IL and internal	Parallel/ 15 degrees /25 degrees	No difference

Table 5 *continued* Studies Comparing Open-Tray Versus Closed-Tray Impression Techniques

Article	Edentulous jaw	No. of implants	Impression technique	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Rashidan et al[63] 2012	Mandible	5	OT–NS, CT	–	–	Internal	Parallel	No difference
Stimmelmayr et al[65] 2012	Mandible	4	OT–S, OT–NS, CT	Splint with prefab bars, section, rejoin	anaxAcryl resin	Internal	Angulated, NR	OT more accurate
Mostafa et al[58] 2010	Mandible	4	OT–S, OT–NS, CT	Splint with prefab bars	Pattern resin	External, IL	Parallel	OT more accurate
Del'Acqua et al[45] 2008	Mandible	4	OT–S, OT–NS, CT	Splint with prefab bars, section, rejoin	Duralay resin	External, AL	Parallel	No difference
Wenz and Hertrampf[70] 2008	Mandible	5	OT–NS, CT	–	–	Internal	Parallel	No difference
Naconecy et al[60] 2004	Mandible	5	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	OT more accurate
Herbst et al[52] 2000	Mandible	5	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	No difference
Burawi et al[41] 1997	Mandible	5	OT–S, CT	Splint, section, rejoin	Duralay resin	External, AL	Parallel	CT more accurate
Phillips et al[71] 1994	Mandible	5	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	OT more accurate
Barrett et al[40] 1993	Mandible	6	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	OT more accurate
Assif et al[36] 1992	Mandible	5	OT–S, OT–NS, CT	Splint with prefab bars, section, rejoin	Duralay resin	External, AL	Parallel	OT more accurate
Carr[42] 1991	Mandible	5	OT–NS, CT	–	–	External, AL	Parallel	OT more accurate
Humphries et al[54] 1990	Mandible	4	OT–S, OT–NS, CT	Splint	Duralay resin	External, AL	Parallel	No difference
Spector et al[64] 1990	Mandible	6	OT–S, CT	Splint with DF and resin	Duralay resin	External, AL	Parallel	No difference
Partially edentulous								
Howell et al[87] 2013	Kennedy Class I mandible	4	OT–NS, CT, DIGITAL	–	–	Internal	Parallel/ 30 degrees	OT more accurate
Wegner et al[105] 2013	Kennedy Class I maxilla	6	OT–NS, CT	–	–	Internal	Parallel	No difference
Rutkunas et al[94] 2012	Not anatomical partially	2	OT–S, OT–S, CT	Splint with DF and resin, section, rejoin	Pattern resin	AL and IL	5 degrees / 25 degrees	OT more accurate
Tarib et al[96] 2012	Partially edentulous	2	OT–S, OT–NS, CT	Splint Splint with DF and resin, section, rejoin	Duralay resin	Internal	Parallel	OT more accurate
Alikhasi et al[73] 2011	Kennedy class II maxilla	2	OT–NS, CT, OT–NS	–	–	Internal,IL vs cementable AL	Parallel	No difference
Gallucci et al[86] 2011	Partially edentulous	2	OT–NS, CT	–	–	Internal	up to 10 degrees	No difference
Jo et al[90] 2010	Not anatomical partially	3	OT–NS, CT	–	–	Internal	Parallel/ 10 degrees	OT more accurate

Table 5 *continued*   Studies Comparing Open-Tray Versus Closed-Tray Impression Techniques

Article	Edentulous jaw	No. of implants	Impression technique	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Lee et al[92] 2010	Not anatomical partially	3	OT–S, CT	Splint, section, rejoin	Pattern resin	External, IL	Parallel/ 30 degrees/ 40 degrees	OT more accurate
Lee et al[93] 2009	Not anatomical partially	2	OT–S, OT–NS, CT	Splint, section, rejoin	Pattern resin	Internal	10 degrees	OT more accurate
Wöstmann et al[98] 2008	Kennedy class I maxilla	4	OT–NS, CT	–	–	Internal	Parallel	OT more accurate
Cabral and Guedes[78] 2007	Not anatomical partially	2	OT–S, OT–NS, CT	Splint Splint, section, rejoin	Pattern resin	Internal	Parallel	OT more accurate
Conrad et al[82] 2007	Not anatomical partially	3	OT–NS, CT	–	–	External, IL	Parallel/ 5 degrees/ 10 degrees/ 15 degrees	No difference
Cehreli and Akça[80] 2006	Not anatomical partially	4	OT–NS, CT	–	–	Internal	Parallel	CT more accurate
Akça and Cehreli[72] 2004	Not anatomical partially	4	OT–NS, CT	–	–	Internal	Parallel	No difference
Assunção et al[76] 2004	Not anatomical partially	4	OT–S, OT–NS, CT	Splint	Duralay resin	External, IL	Parallel/ 10 degrees/ 15 degrees/ 20 degrees	OT more accurate
Daoudi et al[101] 2004	Partially edentulous	1	OT, CT, OT	–	–	External, IL	–	No difference
De la cruz et al[83] 2002	Not anatomical partially	3	OT–NS, CT	Splint with prefab bars, section, rejoin	Duralay resin Pattern resin Triad gel	External, IL and AL	Parallel	CT more accurate
Daoudi et al[100] 2001	Partially edentulous	1	OT, CT	–	–	External, IL and AL	–	OT more accurate
Carr[79] 1992	Kennedy class II mandible	2	OT–NS, CT	–	–	External, AL	15 degrees	No difference

Table 6   Studies Comparing the Accuracy of Impression Techniques with Different Impression Materials

Article	No. of implants	Impression technique	Impression material	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Completely edentulous								
Akalin et al[34] 2013	6	OT–NS, OT–NS	Polyether/ addition PVS/ condensation PVS	–	–	Internal	Parallel/ 10 degrees	No difference when parallel implants; polyether more accurate when angulated implants
Chang et al[43] 2012	5	OT–S, OT–NS, CT	Polyether/PVS	Splint, section, rejoin	Pattern resin	Internal	Parallel	No difference
Ferreira et al[50] 2012	4	OT–S, CT	Condensation PVS/alginate/ addition PVS	Splint	Pattern resin	Internal	Parallel	No difference

Table 6 *continued* Studies Comparing the Accuracy of Impression Techniques with Different Impression Materials

Article	No. of implants	Impression technique	Impression material	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Aguilar et al[33] 2010	5	OT–NS	Polyether/PVS	–	–	Internal, AL	10 degrees	No difference
Del'Acqua et al[46] 2010	4	OT–NS	Polyether/PVS	–	–	External, AL	Parallel	Polyether more accurate
Mostafa et al[58] 2010	4	CT, OT–NS, OT–S	Polyether/PVS	Splint with prefab bars	Pattern resin	External, IL	Parallel	No difference
Wenz and Hertrampf[70] 2008	5	OT–NS, CT	Polyether/PVS	–	–	Internal	Parallel	No difference
Ortorp et al[62] 2005	5	OT–NS, photogrammetry	Polyether/ plaster	–	–	External, AL	Parallel	No difference
Wee[69] 2000	5	OT–NS	Polyether/PVS/ polysulfide	–	–	External, AL	Parallel	No difference between polyether vs PVS; both more accurate than polysulfide
Assif et al[38] 1999	5	OT–S, OT–NS	Polyether/ plaster	Splint Splint copings to the tray	Duralay resin	External, AL	Parallel	No difference
Barrett et al[40] 1993	6	OT–S, OT–NS, CT	Polyether/ PVS/alginate/ plaster	Splint	Duralay resin	External, AL	Parallel	No difference between polyether, plaster, and PVS
Spector et al[64] 1990	6	OT–S, CT	Polysulfide/ addition PVS/ condensation PVS	Splint with DF and resin	Duralay resin	External, AL	Parallel	No difference
Partially edentulous								
Wegner et al[105] 2013	6	OT–S, CT	Polyether/PVS	–	–	Internal	Parallel	No difference
Rutkunas et al[94] 2012	2	OT–S, OT–S, CT	Polyether/PVS	Splint with DF and resin, section, rejoin	Pattern resin	IL and AL	5 degrees/ 25 degrees	No difference
Sorrentino et al[95] 2010	4	OT–NS	Polyether/PVS	–	–	Internal	Parallel/ 5 degrees	PVS more accurate when angulated implants; polyether more accurate when parallel implants
Yamamoto et al[99] 2010	2	OT–S, OT–NS	PVS/alginate	Splint prefab bars	Duralay resin	External, IL	Parallel	PVS more accurate
Wöstmann et al[98] 2008	4	OT–NS, CT	Polyether/PVS	–	–	Internal	Parallel	No difference
Cehreli and Akça[80] 2006	4	OT–NS, CT	Polyether/PVS	–	–	Internal	Parallel	No difference
Akça and Cehreli[72] 2004	4	OT–NS, CT	Polyether/PVS	–	–	Internal	Parallel	No difference

Table 6 *continued* **Studies Comparing the Accuracy of Impression Techniques with Different Impression Materials**

Article	No. of implants	Impression technique	Impression material	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Assunção et al[76] 2004	4	OT–S, OT–NS, CT	Addition PVS/ condensation PVS/polyether/ polysulfide	Splint	Duralay resin	External, IL	Parallel/ 10 degrees/ 15 degrees/ 20 degrees	No difference between polyether and addition PVS; both more accurate than condensation PVS/ polysulfide
Daoudi et al[100] 2001	1	OT, CT	Polyether/PVS	–	–	External, IL and AL	-	No difference
Lorenzoni et al[102] 2000	1	CT	Polyether/PVS/ alginate	–	–	Internal	-	No difference between polyether and PVS, Both more accurate than alginate

Table 7 **Studies Reporting on Accuracy Outcomes with Angulated Implants**

Article	No. of implants	Impression technique	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Completely edentulous							
Akalin et al[34] 2013	6	OT–NS	–	–	Internal	Parallel/ 10 degrees	No difference when parallel; polyether more accurate at 10 degrees
Martinez-Rus et al[57] 2013	6	OT–S, OT–NS, CT	Splint with DF and resin, section, rejoin Splint with plaster and metal framework	Duralay resin Plaster with metal framework	Internal	Parallel/ 15 degrees/ 30 degrees	Splint more accurate
Stimmelmayr et al[66] 2013	4	OT–S, CT	Splint with prefab bars, section, rejoin	anaxAcryl resin	Internal	Angulated, NR	Splint more accurate
Mpikos et al[59] 2012	8	OT–NS, CT	–	–	External, IL and Internal	Parallel/ 15 degrees/ 25 degrees	No difference
Ongül et al[61] 2012	6	OT–S, OT–NS	Splint with prefab bars with or without section and rejoin	Duralay resin Composite resin	Internal	Angulated, NR	Splint more accurate
Papaspyridakos et al[13] 2012	5 to 8	OT–S, OT–NS	Splint, section, rejoin	DF and Triad gel	External, IL	Angulated, NR	Splint more accurate
Stimmelmayr et al[65] 2012	4	OT–S, OT–NS, CT	Splint with prefab bars, section, rejoin	anaxAcryl resin	Internal	Angulated, NR	Splint more accurate
Papaspyridakos et al[4] 2011	5 to 8	OT–S, OT–NS	Splint, section, rejoin	DF and Triad gel	External, IL	Angulated, NR	Splint more accurate
Aguilar et al[33] 2010	5	OT–NS	–	–	Internal, AL	10 degrees	No difference
Partially edentulous							
Howell et al[87] 2013	4	OT–NS, CT, digital	–	–	Internal	Parallel/ 30 degrees	Open-tray more accurate
Rutkunas et al[94] 2012	2	OT–S, OT–S, CT	Splint with DF and resin, section, rejoin	Pattern resin	Internal	5 degrees/ 25 degrees	No difference at 5 degrees; open-tray splint more accurate at 25 degrees
Gallucci et al[86] 2011	2	OT–NS, CT	–	–	Internal	Up to 10 degrees	No difference

Table 7 *continued* Studies Reporting on Accuracy Outcomes with Angulated Implants

Article	No. of implants	Impression technique	Splint method	Splint material	Connection type	Angulation	Impression accuracy
Jang et al[89] 2011	2	OT–NS	–	–	Internal	Parallel/ 5 degrees/ 10 degrees/ 15 degrees/ 20 degrees	Less than 15 degrees accurate; 20 degrees not accurate
Assunção et al[74] 2010	4	OT–S	Splint	Duralay resin Condensation PVS	External, IL	Parallel/ 10 degrees/ 15 degrees/ 25 degrees	Splint more accurate
Jo et al[90] 2010	3	OT–NS, CT	–	–	Internal	Parallel/ 10 degrees	Open-tray nonsplint more accurate
Lee et al[92] 2010	3	OT–S/CT	Splint, section, rejoin	Pattern resin	External, IL	Parallel/ 30 degrees/ 40 degrees	Open-tray splint more accurate
Sorrentino et al[95] 2010	4	OT–NS	–	–	Internal	Parallel/ 5 degrees	PVS more accurate at 5 degrees; polyether more accurate when parallel
Filho et al[85] 2009	2	OT–S, OT–NS	Splint Splint, section, rejoin Splint prefab bars	DF and Duralay resin	External, IL	25 degrees	Splint more accurate
Lee et al[93] 2009	2	OT–S, OT–NS, CT	Splint, section, rejoin	Pattern resin	Internal	10 degrees	Open-tray more accurate
Assunção et al[75] 2008	2	OT–S, OT–NS	Splint	DF and Duralay resin	External, IL	25 degrees	Nonsplint more accurate
Assunção et al[77] 2008	2	OT–S, OT–NS	Splint prefab bars	Duralay resin Composite resin	External, IL	25 degrees	Splint more accurate
Choi et al[81] 2007	2	OT–S, OT–NS	Splint with prefab bars, section, rejoin	Pattern resin	Internal	Parallel/ 8 degrees	No difference
Conrad et al[82] 2007	3	OT–NS, CT	–	–	External, IL	Parallel/ 5 degrees/ 10 degrees/ 15 degrees	No difference
Assunção et al[76] 2004	4	OT–S, OT–NS, CT	Splint	Duralay resin	External, IL	Parallel/ 10 degrees/ 15 degrees/ 20 degrees	Splint more accurate
Carr[79] 1992	2	OT–NS, CT	–	–	External, AL	15 degrees	No difference