A systematic review of the accuracy and the assessment methods of implant impression techniques

Kyoung Rok Kim

The Graduate School

Yonsei University

Department of Dental Science

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Directed by Professor: Sunjai Kim

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Kyoung Rok Kim

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of Kyoung Rok Kim is approved

Thesis supervisor : [Sunjai Kim]

[Chong-Hyun Han: Thesis Committee Member #1]

[Jee Hwan Kim: Thesis Committee Member #2]

The Graduate School

Yonsei University

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Abstract

A systematic review of the accuracy and the assessment methods of implant impression techniques

Kyoung Rok Kim, D.D.S.

Department of Dentistry

the Graduate School, Yonsei University

(Directed by Professor Sunjai Kim, D.D.S., M.S.D., PhD.)

Objectives: The aim of the present systematic review was to evaluate and compare the results of implant impression studies based on the assessment methods used. The characteristics of each assessment method were also analyzed to determine the benefits and disadvantages of each assessment.

Sources and study selection: An electronic search of the PubMed/MEDLINE database was performed in February 2013 using specific search terms and predetermined criteria to identify and assess laboratory studies of the accuracy of implant impression techniques. A final list of articles deemed to be of interest was comprehensively reviewed to ensure that these were suitable for the purpose of this review. The results of the current review were also compared with results from a previous review.

Conclusions: Most studies measured the extent of linear distortion between specific reference points to assess the accuracy of implant impression techniques. The effects of splinting and of different splinting materials on impression accuracy were the most common factors used for comparison. Recently published studies preferred direct to indirect impression and splint to non-splint techniques. The number of studies performed using internal connection implants is increasing.

Key words: implant, impression, accuracy, assessment method

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I. Introduction

The passive fit of an implant prosthesis is considered a significant factor in its long-term success[1] as misfit risks biologic and mechanical failure.[1, 2] Although it is difficult to obtain a complete passive fit, it is important to minimize the discrepancy of fit.[3] Errors in the implant impression procedure during fabrication of the definitive cast can cause misfit of the implant superstructure.[4] Therefore, fabrication of a precise definitive cast that exactly transfers the intraoral positions of the implants or abutments is essential for the long-term stability of the implant prosthesis.[5]

The accuracy of a definitive cast for the production of an implant prosthesis is influenced by the impression technique used,[6] non-parallel placement of implants,[7, 8] depth of the implant position,[9] the type of impression material used,[10] dimensional stability of the gypsum used to fabricate the cast,[11] the die system used,[12] and by the length of the impression copings.[13]

In general, implant impression techniques can be classified as either direct (pick-up) or indirect (transfer). Direct techniques are also described as open tray impression techniques because the tray has an open window for unscrewing the guide pins of the impression copings. These techniques can be subdivided into splint and non-splint techniques.[14, 15] Indirect techniques are also known as closed tray impression techniques. Numerous investigations have compared the accuracy of different impression techniques, impression materials, implant connection systems, and different implant placement situations, but no consistent results have been reported.[16]

Recently, an optical impression technique that uses special healing abutment instead of impression copings was introduced into clinical implant dentistry.[17] Digital impression techniques seem to have several advantages including patient comfort, removal of possible errors associated with elastic materials, and increased cost effectiveness.[18] However, a limited number of studies have assessed these techniques.[17, 19, 20]

Different measurement devices, including profile projectors, microscopes, coordinate measuring machines, and strain gauges, have been used to evaluate the accuracy of implant impression techniques. However, even when the same devices have been used these have been applied differently in different studies. To date, most implant impression studies have just reported on the type of impression technique that produces the most accurate results. There has been no evaluation of the optimal method of assessment or of the benefits and drawbacks of each method.

The purpose of the current systematic review was to evaluate and compare the results of implant impression studies based on the assessment methods used. The distribution of the assessment methods and the characteristics of each measurement method were also analyzed to determine the displacements of the implant components during each impression procedure.

II. Materials and Methods

Search strategy and study selection

A MEDLINE (PubMed) search was performed for laboratory studies published in Dental Journals from January 1, 1990 up to Feb 28, 2013. The search was limited to English- language publications.

The following MeSH (*) or free text (†) words were used for the electronic search:

(dental implants* OR dental abutments* OR oral implants† OR endosseous implants† OR dental prosthesis, implant supported* OR implant restoration†) AND (dental impression technique* OR dental impression materials* OR dental models* OR master casts† OR definitive casts† OR final impression† OR digital impression† OR digital scanning†) AND (dimensional measurement accuracy* OR three dimension† OR distortion† OR displacement† OR fit†)

Seletion of studies

All obtained titles and abstracts were screened independently by 2 reviewers. If the abstract was not available, or if the title and the abstract did not provide sufficient information regarding the inclusion criteria, a full-text article was acquired for screening.

On the basis of the chosen abstracts, full-text articles were selected for independent assessment by the reviewers. In addition, references of the selected publications and of previously published reviews relevant to the present review were searched for eligible studies. In case of any disagreement regarding inclusion, a consensus was reached by discussion. Finally, a selection was made based on the inclusion/exclusion criteria applied to the full-text articles.

Inclusion criteria

The criteria for study inclusion were:

- studies with at least 3 implants
- laboratory studies only

Exclusion criteria

The criteria for study exclusion were

- clinical or technical reports
- ‘only abstracts’ published in journals or conference proceedings
- insufficient information
- review articles
- full-text articles in languages other than English

Data extraction

A data extraction sheet was used by the reviewers to extract the relevant data from the included papers. Information on several parameters was recorded including: author(s), year of publication, implant system, implant-abutment connection type (external or internal, friction-fit or slip-fit), number of implants, position (distribution) of implants, impression level (implant-level or abutment level), impression techniques, and measurement methods. Disagreements regarding data extraction were resolved by discussion.

References from the selected studies were also screened to identify pertinent literature. The initial data search generated 389 articles. Based on the initial screening of the titles and abstracts, 88 papers were selected for full text evaluation. A total of 34 studies were omitted based on the exclusion criteria, and the remaining 54 articles were selected for assessment. One article was included after additional assessment of the articles and their references. In total, 55 articles[6-8, 10, 13-15, 17, 19, 21-66] were selected for the analyses (Fig. 1).

III. Results

1. Assessment methods

The 55 selected studies[6-8, 10, 13-15, 17, 19, 21-66] were classified into 4 main groups based on the assessment methods used (Table 1). These measured the extent of: (1) linear distortion (Table 2) of the implant (or abutment) heads or specific reference points (n = 36),[1-36] (2) angular distortion (Table 3) of the implant (or abutment) long axis (n = 16),[7, 8, 28, 48-58, 60, 65] (3) gap distances (Table 4) between the cylinders of the master framework and of replicas in test casts (n = 10),[14, 27, 36-38, 40, 41, 43, 44, 66] and (4) the strain (Table 5) produced in the master framework (n = 4).[37-40] Figure 2 shows the distribution of studies based on the assessment methods used.

Measurement of linear distortions of reference points (mostly centroids of implant or abutment heads) was the preferred assessment method in the included studies. More than 50% of these (n = 36) compared the amount of linear distortion when comparing the accuracy of the implant impression techniques used.[1-36] Of these 36 studies,[1-36] 17[10, 21-23, 26, 29-33, 45-48, 50-52] were included in the previous systematic review[41] and 19[6, 7, 13, 15, 17, 19, 24, 25, 34, 35, 39, 42, 54-60] were published after the review. The average number of implants was 4.61 per study.

Sixteen studies[7, 8, 28, 48-58, 60, 65] investigated the accuracy of the impression by measuring the angulation change of the long axis of the implants or abutments. Half[8, 29, 38, 43, 45, 57-59] of the studies were included in the previous review[41] and the other 8 studies[20, 21, 26, 29, 32, 34, [36, 42] were published after the review. The average number of implants per study was 4.75, which was similar to that reported in the linear distortion studies.

Nineteen studies[1, 3, 4, 6, 9, 11, 18, 22, 23, 27, 32, 34, 35, 39, 43-47] compared the impression accuracy achieved with direct and indirect techniques. In the previous review,[41] 4 studies[26, 27, 47, 48] reported that the direct impression technique was more accurate. Five studies[8, 31, 33, 53, 63] reported no dimensional difference between the techniques and 1 study[45] reported that the indirect impression technique was more accurate. Since the review, 6 further studies[18, 22, 23, 27, 46, 47] have reported that the direct impression technique is more accurate, 3[32, 34, 35] have reported no dimensional difference between the techniques, and no study has reported that the indirect impression technique is more accurate.

A total of 22 studies[1, 4-7, 11, 12, 14, 16, 21, 23, 26-28, 33, 37, 39, 42, 43, 47-49] compared the impression accuracy of splint and non-splint techniques. In the previous review, 7 studies[7, 12, 14, 37, 39, 42, 43] reported that the splint impression technique was more accurate, 4[1, 4, 5, 16] reported no dimensional difference between techniques, and 2[6, 11] reported that non-splint impression was more accurate. Since the review, 6 studies[26, 27, 33, 47-49] have reported that splint impression is more accurate, 3[21, 23, 28] have reported no dimensional difference between techniques, and no study has reported that non-splint impression is more accurate.

Sixteen studies[7, 8, 10, 24, 25, 28, 32, 39, 42, 45, 47, 49, 50, 54, 64, 66] compared the accuracy of polyether and vinyl polysiloxane impression materials. Nine studies[8, 10, 28, 32, 45, 47, 49, 50, 64] published before the previous review[41] reported no difference between vinyl polysiloxane and polyether. Since then, 2 studies[39, 54] have reported that vinyl polysiloxane is more accurate than polyether and 1 study[66] has reported that polyether is more accurate than vinyl polysiloxane. One study[42] reported no difference between the two materials. One study[24] reported that vinyl polysiloxane achieved a more accurate parallel implant placement and polyether a more accurate non-parallel placement. Another study[7] reported that there was no difference between the two materials in terms of parallel placement of the implants but that polyether achieved a more accurate non-parallel placement than vinyl polysiloxane. Five studies[22, 32, 42, 44, 45] investigated the effect of implant parallelism on impression accuracy. Before the previous review,[41] 1 study[8] advocated parallelism of implants and another study[53] reported that there was no difference in accuracy based on the parallelism or non-parallelism of implants. Since the review, 2 studies[58, 65] have advocated parallelism of implants, but another study[13] has reported no difference in accuracy between parallel and non-parallel implants. Figure 2 shows the distribution of the assessment methods used to measure the accuracy of the impression techniques.

2. Distribution of study designs

Most studies (n = 22)[1, 4-7, 11, 12, 14, 16, 21, 23, 26-28, 33, 37, 39, 43, 44, 48-50] compared the accuracy of implant impressions using different splinting materials for impression copings. Comparison of impression materials[1, 4, 10, 13, 17, 20, 23, 24, 28, 30, 36, 40, 44, 51-53] and of direct versus indirect impression techniques[1, 3, 4, 6, 9, 11, 18, 22, 23, 27, 32, 34, 35, 39, 43-47] was the next most common method. More than 90% of the studies included in this review compared the accuracy of implant impressions using different splinting materials,[5, 11, 21, 25, 26, 33, 38, 39, 42, 48,

[54] impression materials[1, 4, 10, 13, 17, 20, 23, 24, 28, 30, 36, 40, 44, 51-53], and direct versus indirect techniques.[1, 3, 4, 6, 9, 11, 18, 22, 23, 27, 32, 34, 35, 39, 43-47] Less than 10% of studies compared the accuracy of parallel versus non-parallel implants,[22, 32, 41, 43, 44] and of external and internal connections.[32] Only 1 study[29] compared the accuracy of conventional (non-splinted pick up) and digital impression techniques. Figure 3 shows the distribution of studies based on the impression techniques used.

3. Study findings

1) Direct versus Indirect impression techniques

Nineteen studies[1, 3, 4, 6, 9, 11, 18, 22, 23, 27, 32, 34, 35, 39, 43-47] compared the accuracy of implant impressions by comparing direct and indirect impression techniques. Ten studies[1, 3, 4, 6, 9, 11, 39, 43-45] were published before the previous systematic review[41] and 9[18, 22, 23, 27, 32, 34, 35, 46, 47] were published after. Of the most recent 9 studies, 6[18, 22, 23, 27, 45, 46] preferred direct to indirect impression techniques. Three studies[32, 34, 35] reported that there was no significant difference between direct and indirect impression techniques. No study preferred an indirect technique.

2) Splint versus Non-splint techniques and splinting materials used

Twenty-two studies[1, 4-7, 11, 12, 14, 16, 21, 23, 26-28, 33, 37, 39, 43, 44, 48-50] compared the effects of splinting or of the use of different splinting materials on the accuracy of implant impressions. In the previous review,[41] 13 studies[1, 4-7, 11, 12, 14, 16, 37, 39, 43, 44] were included in this category, 5[12, 37, 39, 43, 44] of which reported a preference for a splint technique. Only 1 study[6] advocated a non-splint technique. Nine further studies[21, 23, 26-28, 33, 48-50] were included in the present systematic review, 6[26, 27, 33, 48-50] of which reported a preference for a splint technique over a non-splint technique. No study reported that non-splint techniques resulted in more accurate impressions.

3) Impression materials

Sixteen studies[1, 4, 10, 13, 17, 20, 23, 24, 28, 30, 36, 40, 44, 51-53] compared the accuracy of polyether and vinyl polysiloxane. Nine studies[8, 10, 28, 32, 45, 47, 49, 50, 64] were published before the previous review,[41] none of which reported any significant difference between the 2 materials. Since then, however, 2 studies[39,54] have reported a preference for vinyl polysiloxane over polyether and 1[66] a preference for polyether.

The accuracy of implant impressions was also assessed using different impression materials with different inter-implants angulations. Sorrentino et al.[24] reported that vinyl polysiloxane was more accurate than polyether when implants were parallel, however, polyether produced more accurate results than vinyl polysiloxane when implants were not parallel. Akalin et al.[36] also investigated the angulation of the implant long axes using different impression materials, and they concluded that polyether was more accurate than vinyl polysiloxane for non-parallel implants, but there was no difference between the impression materials for parallel implants.

4) Parallel versus Non-parallel implants

Five studies[22, 32, 41, 43, 44] investigated the effect of implant parallelism on impression accuracy. Three studies[32, 42, 44] reported greater accuracy with parallel implants, but the other 2 studies[22, 44] did not find any significant difference in accuracy between parallel and non-parallel implant placements.

5) External versus Internal

Mpikos and colleagues[32] investigated the effect of impression techniques and implant angulations on the accuracy of implant impressions using both internal and external connection implants. They reported that accuracy was not influenced by impression technique or inter-implant parallelism when external connection implants were used. However, accuracy was significantly influenced by implant parallelism when internal connection implants were used as parallel implant placement resulted in greater accuracy.

6) Conventional versus Digital

Eliasson and Ortorp[57] compared conventional and digital impression techniques and concluded that conventional non-splint pick-up produced more accurate definitive casts than digital impression.

IV. Discussion

The current systematic review analyzed relevant studies of the accuracy of implant impression techniques. This review not only summarized the results of the included studies, but also classified the studies according to the assessment methods used to determine the benefits and disadvantages of each method.

Comparison of the amount of linear distortion was the most frequently used method of evaluating the accuracy of implant impressions. The studies included in this systematic review used one of 4 different evaluation methods to measure the amount of linear distortion: (1) the amount of three-dimensional displacement (Δx, Δy, Δz) of the centroids of implant or abutment heads, (2) the change in linear distance (Δr, $r^2 = x^2 + y^2 + z^2$) between the centroids of implant or abutment heads, (3) the distance between 2 reference points (i.e., the outer surfaces of the implant head), and (4) the closest distance between the long axes of an implant.

Displacement of the implant or abutment head position is the most important factor for evaluating the accuracy of an implant impression, and thus evaluating the amount of displacement of each implant or abutment centroid in 3 axes (X, Y, Z) appears to be the most accurate of the linear distance assessment methods. However, this method has an inherent problem. When an impression technique results in greater displacement in the X-axis direction (Δx) but less displacement in the Y-axis (Δy) or Z-axis direction (Δz) than the other impression technique used in the same investigation, it is difficult to determine which impression technique is more accurate. Therefore, many studies have also assessed the total amount of three-dimensional displacement (Δr) to determine which impression technique is the most accurate. The second method determines the degree of accuracy by measuring the linear distance (in a single plane) between 2 centroids of implant or abutment heads. Even though this method cannot detect the translational rotation of the implant body or long axis, it is still considered a simple and intuitive means of evaluating the accuracy of different impression techniques. The third method is a modified version of the second, and practically it is difficult to locate calipers at the same positions. Simeone et al.[60] measured the closest distance between implant long axes to compare impression techniques. This method cannot detect translational or axial rotation of implants, and the implant position can be moved without changing the closest distance between the inter-implant long axes. Therefore, the researchers also measured changes in the angles between the implant axes and combined the results with the closest distance between the implant long axes.

Angular distortion can be classified into 2 categories: rotation of the implant head around the implant long axis[28, 60] and translational rotation of the implant long axis to a specific reference axis or plane. The XY, YZ, and ZX planes were frequently chosen as the reference plane with the amount of angular change described as $d\theta$XY, $d\theta$YZ, or $d\theta$ZX, respectively. When a specific implant or replica was chosen as a reference axis, the angles between the reference axis and the long axes of the implants were measured and the difference in value between the measurements taken before and after the impression procedure was regarded as the angular distortion. The majority of the angular distortion studies used a coordinate measuring machine or similar equipment to measure the rotations.

Before the previous systematic review,[41] only 1 study[27] had compared impression accuracy by measuring the gap between the master framework and the implant (replica) head. Since then, 9 studies[46-50, 53-56] included in the present review have measured the gap distance between the master framework and the implant, this measuring technique thus appears to be popular among investigators. However, it should be noted that 4[36,37,43,66] of the 9 studies were published by the same research group. This assessment method has one major disadvantage in that the amount of displacement of a specific implant or abutment replica cannot be measured.

Four studies[37-40] in the previous review[41] used strain gauges attached to a master framework to measure the accuracy of definitive casts. No study published since met the inclusion criteria for the present systematic review.

Studies published before the previous systematic review[41] preferred direct to indirect impression techniques and splinting over non-splinting. The previous systematic review[41] reported that the pick-up technique resulted in more accurate results when more than 4 implants were included in the experimental design. Only 1 study[6] reported more accurate results with a non-splinted pick-up impression compared to an auto-polymerized acrylic resin splinted pick-up impression technique. However, the researchers did not measure the position of the replicas in the definitive casts; they only measured the positional change of impression copings in the master model and the impression tray. Kim et al.[16] reported that splint techniques resulted in greater displacement of copings during the impression procedure, but produced less displacement of replicas during cast fabrication. Therefore, study design can also influence study findings. Recent investigations (studies performed after the previous systematic review)[41] have also reported a preference for direct impressions over indirect impressions, and for splinting versus non-splinting techniques. Al Quran et al.[27] reported on the reliability of impression techniques as well as their accuracy. They compared the accuracy of transfer, non-splinted pick-up, and splinted pick-up impression techniques and concluded that the splinted pick-up technique was the most accurate. However, the transfer technique was the most reliable due to its low standard deviation.

Implant/abutment connection types are simply classified as external or internal connections. Of the 29 investigations[18-36, 42, 46-50, 53-56] published since the previous review,[41] 14[19, 21, 22, 24, 26-28, 31-36, 56] used internal connection implants, which reflects the popularity of internal connections in modern implant dentistry. Most internal connection implants have longer or broader implant/abutment connections than external connection implants. The longer and broader connection area can cause displacement of the impression copings during removal of the impression tray. The amount of distortion can also be exaggerated when the implants are not parallel to each other. Sorrentino et al.[24] compared the accuracy of internal connection implant impressions with different implant alignments (parallel versus non-parallel) and coping engagement lengths (1 mm versus 2 mm). When the implants were not parallel, impression copings with a short engagement length produced more accurate results than impression copings with longer engagements.[24] Rashidan et al.[34] compared the accuracy of internal connection implant impression using different coping designs.[60] They reported that less retentive shape copings produced more accurate results than more retentive shape copings. Greater vertical distortion (Δz) was also reported in the more retentive coping group. However, they ignored one important difference other than the shape of impression copings. Two kinds of connections were used in the study: one had an internal slip fit and the other an internal friction fit connection. In contrast to an internal slip fit, an internal friction fit design does not have a vertical stop between components and so there is vertical displacement between the components.[57] It can be concluded that internal friction fit connections have a greater chance of vertical displacement during impression procedures.

Implant parallelism also influences internal connection implants. Mpikos et al.[58] compared the accuracy of impressions performed with different impression techniques (transfer or non-splinted pick-up) using parallel and non-parallel implant placements. They found that the impression accuracy of external connection implants was not influenced by the impression technique or by implant parallelism. However, the accuracy of internal connection implant impressions was significantly influenced by implant parallelism. Sorrentino et al.[24] also reported that more accurate casts were produced when the implant alignment was parallel rather than non-parallel when internal connection implants were used.

Thus, in contrast to findings for external connection implants, the effects of splinting the impression copings when internal connection implants are used appear to be inconsistent. Vigolo et al.[12] reported that non-splinted pick-up techniques were less accurate than auto-polymerized acrylic resin (APAR) splinted pick-up techniques. However, Ongul et al.[33] reported no significant difference between non-splinted and APAR splinted pick-up techniques when 6 implants were buccally placed. The former study used internal slip fit, whereas the latter study used internal friction fit connection implants. As mentioned earlier, internal friction fit connections can produce more vertical errors than internal slip fit connection implants and therefore greater distortion, which may hinder the detection of statistical differences between non-splinted and splinted techniques. Further investigations are needed for a definitive conclusion as to the effect of splinting copings in internal connection implant impressions.

V. Conclusions

Based on the analyses of the studies included in the present review, the conclusions were as follows:

1. Measurement of linear distortion at specific reference points was the most frequently chosen method for assessing the accuracy of the implant impression techniques.

2. Most studies included in this review compared splinting and non-splinting impression copings and the effects of different splinting materials.

3. Recently published studies preferred direct to indirect impression and splint versus non-splint techniques.

4. In contrast to reports of external connection implants, results reported for internal connection implants were inconsistent even though the number of studies of internal connection implants is increasing.

References

1. Humphries RM, Yaman P, Bloem TJ. The accuracy of implant master casts constructed from transfer impressions. Int J Oral Maxillofac Implants 1990;5(4):331-6.
2. Spector MR, Donovan TE, Nicholls JI. An evaluation of impression techniques for osseointegrated implants. J Prosthet Dent 1990;63(4):444-7.
3. Carr AB. Comparison of impression techniques for a five-implant mandibular model. Int J Oral Maxillofac Implants 1991;6(4):448-55.
4. Barrett MG, de Rijk WG, Burgess JO. The accuracy of six impression techniques for osseointegrated implants. J Prosthodont 1993;2(2):75-82.
5. Hsu CC, Millstein PL, Stein RS. A comparative analysis of the accuracy of implant transfer techniques. J Prosthet Dent 1993;69(6):588-93.
6. Phillips KM, Nicholls JI, Ma T, Rubenstein J. The accuracy of three implant impression techniques: a three-dimensional analysis. Int J Oral Maxillofac Implants 1994;3(1):533-40.
7. Carr AB, Master J. The accuracy of implant verification casts compared with casts produced from a rigid transfer coping technique. J Prosthodont 1996;5(4):248-52.
8. Burawi G, Houston F, Byrne D, Claffey N. A comparison of the dimensional accuracy of the splinted and unsplinted impression techniques for the Bone-Lock implant system. J Prosthet Dent 1997;77(1):68-75.
9. Herbst D, Nel JC, Driessen CH, Becker PJ. Evaluation of impression accuracy for osseointegrated implant supported superstructures. J Prosthet Dent 2000;83(5):555-61.
10. Wee AG. Comparison of impression materials for direct multi-implant impressions. J Prosthet Dent 2000;83(3):323-31.
11. De La Cruz JE, Funkenbusch PD, Ercoli C, Moss ME, Graser GN, Tallents RH. Verification jig for implant-supported prostheses: A comparison of standard impressions with verification jigs made of different materials. J Prosthet Dent 2002;88(3):329-36.
12. Vigolo P, Majzoub Z, Cordioli G. Evaluation of the accuracy of three techniques used for multiple implant abutment impressions. J Prosthet Dent 2003;89(2):186-92.
13. Akca K, Cehreli MC. Accuracy of 2 impression techniques for ITI implants. Int J Oral Maxillofac Implants 2004;19(4):517-23.

14. Vigolo P, Fonzi F, Majzoub Z, Cordioli G. An evaluation of impression techniques for multiple internal connection implant prostheses. J Prosthet Dent 2004;92(5):470-6.
15. Ortorp A, Jemt T, Back T. Photogrammetry and conventional impressions for recording implant positions: a comparative laboratory study. Clin Implant Dent Relat Res 2005;7(1):43-50.
16. Kim S, Nicholls JI, Han CH, Lee KW. Displacement of implant components from impressions to definitive casts. Int J Oral Maxillofac Implants 2006;21(5):747-55.
17. Holst S, Blatz MB, Bergler M, Goellner M, Wichmann M. Influence of impression material and time on the 3-dimensional accuracy of implant impressions. Quintessence Int 2007;38(1):67-73.
18. Dullabh HD, Sykes LM. The accuracy of three impression transfer techniques for implant supported prostheses. SADJ 2008;63(8):458, 60-2, 64-5.
19. Walker MP, Ries D, Borello B. Implant cast accuracy as a function of impression techniques and impression material viscosity. Int J Oral Maxillofac Implants 2008;23(4):669-74.
20. Aguilar ML, Elias A, Vizcarrondo CE, Psoter WJ. Analysis of three-dimensional distortion of two impression materials in the transfer of dental implants. J Prosthet Dent 2010;103(4):202-9.
21. Hariharan R, Shankar C, Rajan M, Baig MR, Azhagarasan NS. Evaluation of accuracy of multiple dental implant impressions using various splinting materials. Int J Oral Maxillofac Implants 2010;25(1):38-44.
22. Jo SH, Kim KI, Seo JM, Song KY, Park JM, Ahn SG. Effect of impression coping and implant angulation on the accuracy of implant impressions: an in vitro study. J Adv Prosthodont 2010;2010(4):128-33.
23. Mostafa TM, Elgendy MN, Kashef NA, Halim MM. Evaluation of the precision of three implant transfer impression techniques using two elastomeric impression materials. Int J Prosthodont 2010;23(6):525-8.
24. Sorrentino R, Gherlone EF, Calesini G, Zarone F. Effect of implant angulation, connection length, and impression material on the dimensional accuracy of implant impressions: an in vitro comparative study. Clin Implant Dent Relat Res 2010;12 Suppl 1:e63-76.

25. Lee SJ, Cho SB. Accuracy of five implant impression technique: effect of splinting materials and methods. J Adv Prosthodont 2011;3(4):177-85.
26. Simeone P, Valentini PP, Pizzoferrato R, Scudieri F. Dimensional accuracy of pickup implant impression: an in vitro comparison of novel modular versus standard custom trays. Int J Oral Maxillofac Implants 2011;26(3):538-46.
27. Al Quran FA, Rashdan BA, Zomar AA, Weiner S. Passive fit and accuracy of three dental implant impression techniques. Quintessence Int 2012;43(2):119-25.
28. Chang WG, Vahidi F, Bae KH, Lim BS. Accuracy of three implant impression techniques with different impression materials and stones. The International journal of prosthodontics 2012;25(1):44-7.
29. Eliasson A, Ortorp A. The accuracy of an implant impression technique using digitally coded healing abutments. Clin Implant Dent Relat Res 2012;14 Suppl 1:e30-8.
30. Ferreira VF, Barboza EP, Gouvea CV, Bianchini GM, Mussallem F, Carvalho WR. Comparative study of the polyvinyl siloxane technique with resin-splinted transfer copings used for multiple implant abutment impressions. Implant Dent 2012;21(1):72-6.
31. Holst S, Persson A, Wichmann M, Karl M. Digitizing implant position locators on master casts: comparison of a noncontact scanner and a contact-probe scanner. Int J Oral Maxillofac Implants 2012;27(1):29-35.
32. Mpikos P, Tortopidis D, Galanis C, Kaisarlis G, Koidis P. The effect of impression technique and implant angulation on the impression accuracy of external- and internal-connection implants. Int J Oral Maxillofac Implants 2012;27(6):1422-8.
33. Ongul D, Gokcen-Rohlig B, Sermet B, Keskin H. A comparative analysis of the accuracy of different direct impression techniques for multiple implants. Australian dental journal 2012;57(2):184-9.
34. Rashidan N, Alikhasi M, Samadizadeh S, Beyabanaki E, Kharazifard MJ. Accuracy of implant impressions with different impression coping types and shapes. Clin Implant Dent Relat Res 2012;14(2):218-25.
35. Stimmelmayr M, Erdelt K, Guth JF, Happe A, Beuer F. Evaluation of impression accuracy for a four-implant mandibular model--a digital approach. Clin Oral Investig 2012;16(4):1137-42.

36. Akalin ZF, Ozkan YK, Ekerim A. Effects of implant angulation, impression material, and variation in arch curvature width on implant transfer model accuracy. Int J Oral Maxillofac Implants 2013;28(1):149-57.
37. Assif D, Marshak B, Schmidt A. Accuracy of implant impression techniques. Int J Oral Maxillofac Implants 1996;11(2):216-22.
38. Assif D, Nissan J, Varsano I, Singer A. Accuracy of implant impression splinted techniques: effect of splinting material. Int J Oral Maxillofac Implants 1999;14(6):885-8.
39. Naconecy MM, Teixeira ER, Shinkai RS, Frasca LC, Cervieri A. Evaluation of the accuracy of 3 transfer techniques for implant-supported prostheses with multiple abutments. Int J Oral Maxillofac Implants 2004;19(2):192-8.
40. Cehreli MC, Akca K. Impression techniques and misfit-induced strains on implant-supported superstructures: an in vitro study. Int J Periodontics Restorative Dent 2006;26(4):379-85.
41. Lee H, So JS, Hochstedler JL, Ercoli C. The accuracy of implant impressions: a systematic review. J Prosthet Dent 2008;100(4):285-91.
42. Assuncao WG, Britto RC, Ricardo Barao VA, Delben JA, dos Santos PH. Evaluation of impression accuracy for implant at various angulations. Implant Dent 2010;19(2):167-74.
43. Assif D, Fenton A, Zarb G, Schmitt A. Comparative accuracy of implant impression procedures. Int J Periodontics Restorative Dent 1992;12(2):112-21.
44. Assuncao WG, Filho HG, Zaniquelli O. Evaluation of transfer impressions for osseointegrated implants at various angulations. Implant Dent 2004;13(4):358-66.
45. Conrad HJ, Pesun IJ, DeLong R, Hodges JS. Accuracy of two impression techniques with angulated implants. J Prosthet Dent 2007;97(6):349-56.
46. Lee HJ, Lim YJ, Kim CW, Choi JH, Kim MJ. Accuracy of a proposed implant impression technique using abutments and metal framework. J Adv Prosthodont 2010;2(1):25-31.
47. Faria JC, Silva-Concilio LR, Neves AC, Miranda ME, Teixeira ML. Evaluation of the accuracy of different transfer impression techniques for multiple implants. Braz Oral Res 2011;25(2):163-7.

48. Del'Acqua MA, Chavez AM, Compagnoni MA, Molo Fde A, Jr. Accuracy of impression techniques for an implant-supported prosthesis. Int J Oral Maxillofac Implants 2010;25(4):715-21.
49. Yamamoto E, Marotti J, de Campos TT, Neto PT. Accuracy of four transfer impression techniques for dental implants: a scanning electron microscopic analysis. Int J Oral Maxillofac Implants 2010;25(6):1115-24.
50. Avila ED, Moraes FD, Castanharo SM, Del Acqua MA, Mollo Junior FA. Effect of Splinting in Accuracy of Two Implant Impression Techniques. J Oral Implantol 2012.
51. Liou AD, Nicholls JI, Yuodelis RA, Brudvik JS. Accuracy of replacing three tapered transfer impression copings in two elastomeric impression materials. The International journal of prosthodontics 1993;6(4):377-83.
52. Lorenzoni M, Pertl C, Penkner K, Polansky R, Sedaj B, Wegscheider WA. Comparison of the transfer precision of three different impression materials in combination with transfer caps for the Frialit-2 system. J Oral Rehabil 2000;27(7):629-38.
53. Del'Acqua MA, Chavez AM, Amaral AL, Compagnoni MA, Mollo Fde A, Jr. Comparison of impression techniques and materials for an implant-supported prosthesis. Int J Oral Maxillofac Implants 2010;25(4):771-6.
54. Del Acqua MA, Chavez AM, Castanharo SM, Compagnoni MA, Mollo Fde A, Jr. The effect of splint material rigidity in implant impression techniques. Int J Oral Maxillofac Implants 2010;25(6):1153-8.
55. Del'acqua MA, de Avila ED, Amaral AL, Pinelli LA, de Assis Mollo F, Jr. Comparison of the accuracy of plastic and metal stock trays for implant impressions. Int J Oral Maxillofac Implants 2012;27(3):544-50.
56. Fernandez MA, Paez de Mendoza CY, Platt JA, Levon JA, Hovijitra ST, Nimmo A. A comparative study of the accuracy between plastic and metal impression transfer copings for implant restorations. J Prosthodont 2013;22(5):367-76.
57. Dailey B, Jordan L, Blind O, Tavernier B. Axial displacement of abutments into implants and implant replicas, with the tapered cone-screw internal connection, as a function of tightening torque. Int J Oral Maxillofac Implants 2009;24(2): 251-6.

58. Carr AB. Comparison of impression techniques for a two-implant 15-degree divergent model. Int J Oral Maxillofac Implants 1992;7(4):468-75.
59. Inturregui JA, Aquilino SA, Ryther JS, Lund PS. Evaluation of three impression techniques for osseointegrated oral implants. J Prosthet Dent 1993;69(5): 503-9.
60. Bartlett DW, Greenwood R, Howe L. The suitability of head-of-implant and conventional abutment impression techniques for implant-retained three unit bridges: an in vitro study. The European journal of prosthodontics and restorative dentistry 2002;10(4):163-6.
61. Burns J, Palmer R, Howe L, Wilson R. Accuracy of open tray implant impressions: an in vitro comparison of stock versus custom trays. J Prosthet Dent 2003;89(3):250-5.
62. Bambini F, Ginnetti L, Meme L, Pellecchia M, Selvaggio R. Comparative analysis of direct and indirect implant impression techniques an in vitro study. An in vitro study. Minerva Stomatol 2005;54(6):395-402.
63. Cabral LM, Guedes CG. Comparative analysis of 4 impression techniques for implants. Implant Dent 2007;16(2):187-94.
64. Assuncao WG, Cardoso A, Gomes EA, Tabata LF, dos Santos PH. Accuracy of impression techniques for implants. Part 1-Influence of transfer copings surface abrasion. J Prosthodont 2008;17(8):641-7.
65. Assuncao WG, Gomes EA, Tabata LF, Gennari-Filho H. A comparison of profilometer and AutoCAD software techniques in evaluation of implant angulation in vitro. Int J Oral Maxillofac Implants 2008;23(4):618-22.
66. Assuncao WG, Tabata LF, Cardoso A, Rocha EP, Gomes EA. Prosthetic transfer impression accuracy evaluation for osseointegrated implants. Implant Dent 2008;17(3):248-56.
67. Lee H, Ercoli C, Funkenbusch PD, Feng C. Effect of subgingival depth of implant placement on the dimensional accuracy of the implant impression: an in vitro study. J Prosthet Dent 2008;99(2):107-13.
68. Wostmann B, Rehmann P, Balkenhol M. Influence of impression technique and material on the accuracy of multiple implant impressions. Int J Prosthodont 2008;21(4):299-301.

69. Filho HG, Mazaro JV, Vedovatto E, Assuncao WG, dos Santos PH. Accuracy of impression techniques for implants. Part 2 - comparison of splinting techniques. J Prosthodont 2009;18(2):172-6.
70. Lee YJ, Heo SJ, Koak JY, Kim SK. Accuracy of different impression techniques for internal-connection implants. Int J Oral Maxillofac Implants 2009;24(5):823-30.
71. Assuncao WG, Delben JA, dos Santos PH, Tabata LF, Gomes EA, Barao VA. Evaluation of a two-step pouring technique for implant-supported prostheses impression. Acta Odontol Latinoam 2010;23(1):8-12.
72. Alikhasi M, Siadat H, Monzavi A, Momen-Heravi F. Three-dimensional accuracy of implant and abutment level impression techniques: effect on marginal discrepancy. J Oral Implantol 2011;37(6):649-57.
73. Jang HK, Kim S, Shim JS, Lee KW, Moon HS. Accuracy of impressions for internal-connection implant prostheses with various divergent angles. Int J Oral Maxillofac Implants 2011;26(5):1011-5.
74. Rutkunas V, Sveikata K, Savickas R. Effects of implant angulation, material selection, and impression technique on impression accuracy: a preliminary laboratory study. Int J Prosthodont 2012;25(5):512-5.
75. Tarib NA, Seong TW, Chuen KM, Kun MS, Ahmad M, Kamarudin KH. Evaluation of splinting implant impression techniques: two dimensional analyses. The European journal of prosthodontics and restorative dentistry 2012;20(1):35-9.
76. Howell KJ, McGlumphy EA, Drago C, Knapik G. Comparison of the accuracy of biomet 3i encode robocast technology and conventional implant impression techniques. Int J Oral Maxillofac Implants 2013;28(1):228-40.
77. Jemt T, Back T, Petersson A. Photogrammetry--an alternative to conventional impressions in implant dentistry? A clinical pilot study. The International journal of prosthodontics 1999;12(4):363-8.
78. Papaspyridakos P, Benic GI, Hogsett VL, White GS, Lal K, Gallucci GO. Accuracy of implant casts generated with splinted and non-splinted impression techniques for edentulous patients: an optical scanning study. Clin Oral Implants Res 2012;23(6):676-81.
79. Schmitt JK, Adrian ED, Gardner FM, Gaston ML. A comparison of impression techniques for the CeraOne abutment. J Prosthodont 1994;3(3):145-8.

80. Lechner S, Duckmanton N, Klineberg I. Prosthodontic procedures for implant reconstruction. 2. Post-surgical procedures. Aust Dent J 1992;37(6):427-32.
81. Vigolo P, Millstein PL. Evaluation of master cast techniques for multiple abutment implant prostheses. Int J Oral Maxillofac Implants 1993;8(4):439-46.
82. Wee AG, Schneider RL, Aquilino SA, Huff TL, Lindquist TJ, Williamson DL. Evaluation of the accuracy of solid implant casts. J Prosthodont 1998;7(3):161-9.
83. Cranin AN, Klein M, Ley JP, Andrews J, DiGregorio R. An in vitro comparison of the computerized tomography/CAD-CAM and direct bone impression techniques for subperiosteal implant model generation. J Oral Implantol 1998;24(2):74-9.
84. May KB, Curtis A, Wang RF. Evaluation of the implant master cast by means of the Periotest method. Implant Dent 1999;8(2):133-40.
85. Wee AG, Cheng AC, Eskridge RN. Accuracy of 3 conceptually different die systems used for implant casts. J Prosthet Dent 2002;87(1):23-9.
86. Castilho AA, Kojima AN, Pereira SM, de Vasconcellos DK, Itinoche MK, Faria R, et al. In vitro evaluation of the precision of working casts for implant-supported restoration with multiple abutments. J Appl Oral Sci 2007;15(3):241-6.
87. Del Corso M, Aba G, Vazquez L, Dargaud J, Dohan Ehrenfest DM. Optical three-dimensional scanning acquisition of the position of osseointegrated implants: an in vitro study to determine method accuracy and operational feasibility. Clin Implant Dent Relat Res 2009;11(3):214-21.
88. Kwon JH, Son YH, Han CH, Kim S. Accuracy of implant impressions without impression copings: a three-dimensional analysis. J Prosthet Dent 2011;105(6):367-73.
89. Stimmelmayr M, Guth JF, Erdelt K, Edelhoff D, Beuer F. Digital evaluation of the reproducibility of implant scanbody fit--an in vitro study. Clin Oral Investig 2012;16(3):851-6.
90. Ono S, Yamaguchi S, Kusumoto N, Nakano T, Sohmura T, Yatani H. Optical impression method to measure three-dimensional position and orientation of dental implants using an optical tracker. Clin Oral Implants Res 2012.

Figures

Figure 1. Search strategy for studies related to multi-unit implant impression accuracy

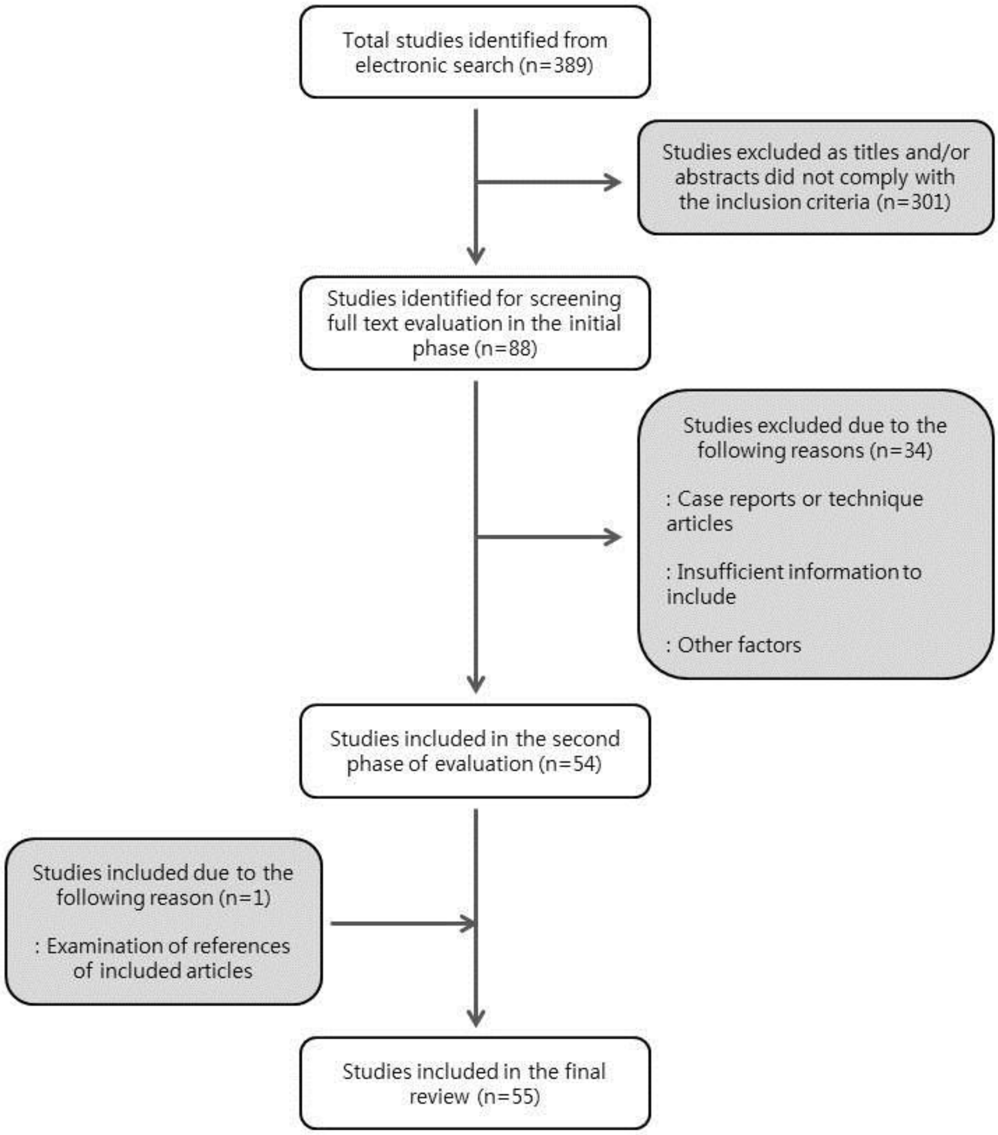


Figure 2. Distribution of assessment methods used in the current review. The values in parentheses show the publication year of the studies concerned, that is (~2008) indicates studies published before the previous systematic review performed in 2008 and (2008~) indicates studies published after the systematic review performed in 2008

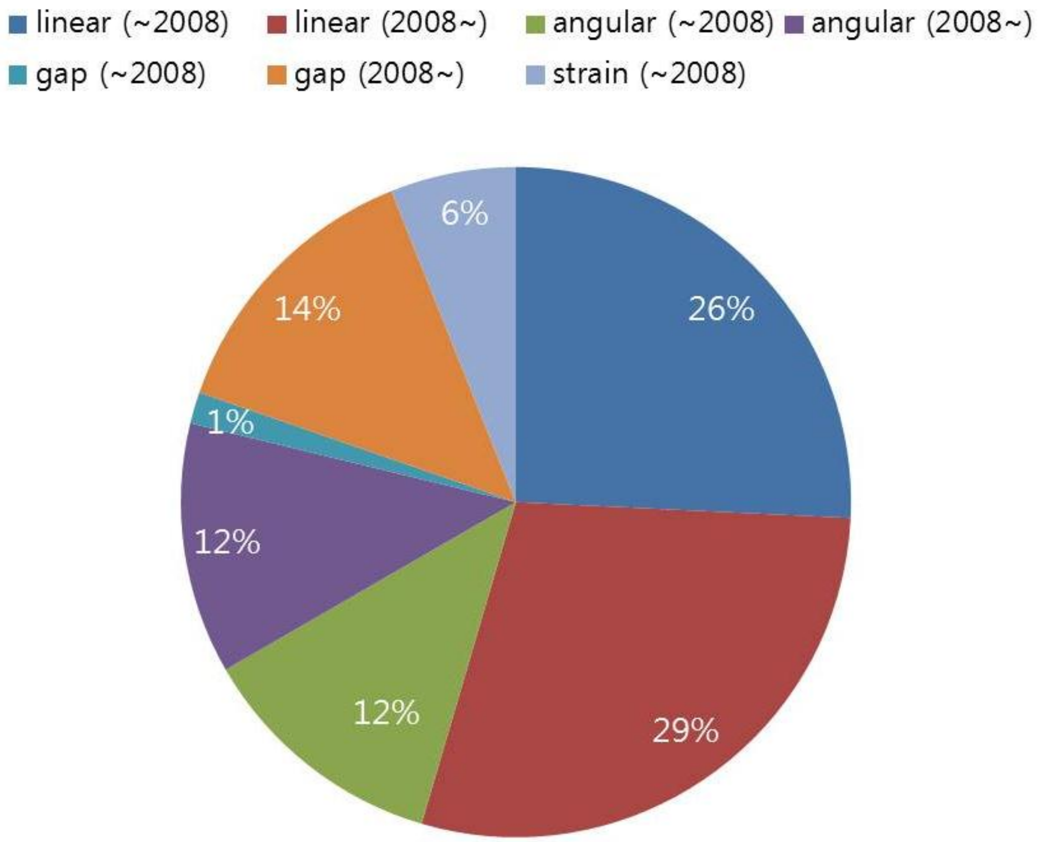
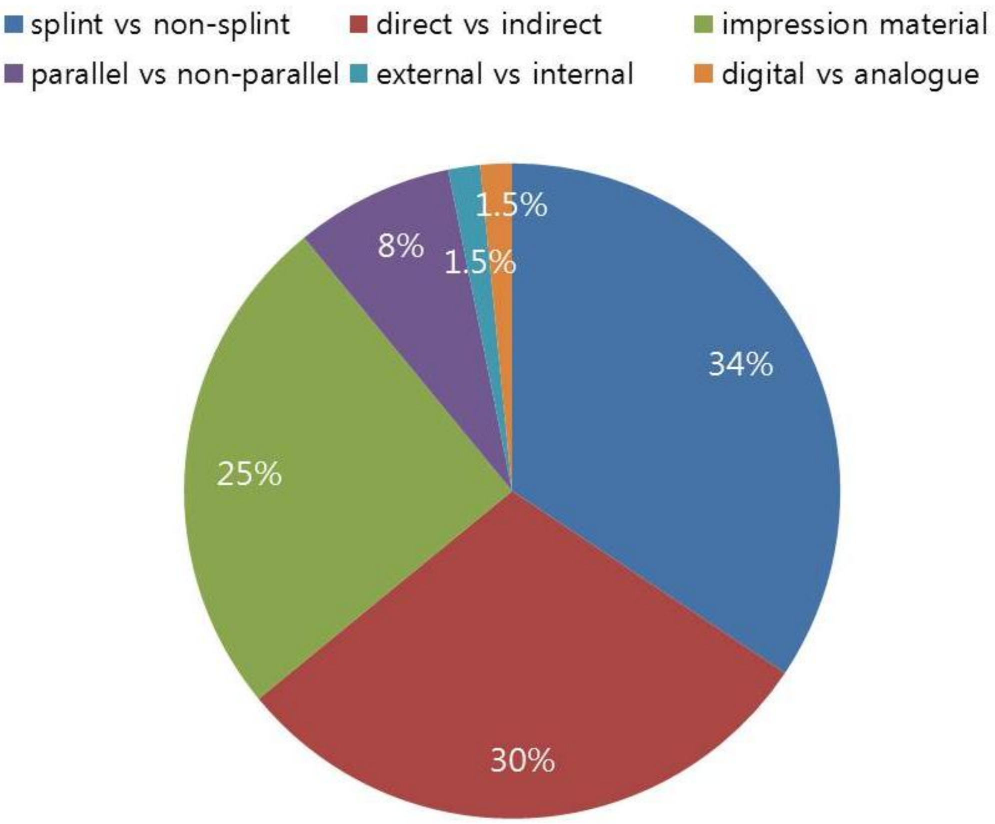


Figure 3. Distribution of impression techniques compared in the included studies



Tables

Table 1. Selected articles on the classification of assessment method

Authors	Year	Connection	No. of implants	Measurement method
Humphries et al [1]	1990	Ext	4	Distance
Spector et al [2]	1990	Ext	6	Distance
Carr et al [3]	1991	Ext	5	Distance
Assif et al [43]	1992	Ext	5	Gap
Barrett et al [4]	1993	Ext	6	Distance
Hsu et al [5]	1993	Ext	4	Distance
Liou et al [51]	1993	Ext	5	angular distortion
Phillips et al [6]	1994	Ext	5	angular distortion, distance
Assif et al [37]	1996	Ext	5	Strain
Carr et al [7]	1996	Ext	4	Distance
Burawi et al [8]	1997	Int	4	Distance
Assif [38]	1999	Ext	5	Strain
Herbst et al [9]	2000	Ext	5	Distance
Lorenzoni et al [52]	2000	Int	8	angular distortion
Wee et al [10]	2000	Ext	5	Distance
Delacruz et al [11]	2002	Ext	3	Distance
Vigolo et al [12]	2003	Int	6	Distance
Akca et al [13]	2004	Int	4	angular distortion, distance
Assuncao et al [44]	2004	Ext	4	angular distortion
Naconecy et al [39]	2004	Ext	5	Strain
Vigolo et al [14]	2004	Int	4	Distance
Ortorp et al [15]	2005	Ext	5	distance,angular distortion
Cehreli et al [40]	2006	Int	4	Strain
Kim et al [16]	2006	Ext	5	angular distortion, distance
Conrad et al [45]	2007	Ext	3	angular distortion
Holst et al [17]	2007	Int	4	Distance

Dullabh et al [18]	2008	Ext	6	Distance
Walker et al [19]	2008	Int	3	Distance
Aguilar et al [20]	2010	Ext	5	angular distortion, distance
Assuncao et al [42]	2010	Ext	4	angular distortion
Del'Acqua et al [54]	2010	Ext	4	Gap
Del'Acqua et al [53]	2010	Ext	4	Gap
Del'Acqua et al [48]	2010	Ext	4	Gap
Hariharan et al [21]	2010	Int	4	angular distortion, distance
Jo et al [22]	2010	Int	3	Distance
Lee et al [46]	2010	Ext	3	Gap
Mostafa et al [23]	2010	Ext	4	distance
Sorrentino et al [24]	2010	Int	4	distance
Yamamoto et al [49]	2010	Ext	3	gap
Faria et al [47]	2011	Ext	4	gap
Lee et al [25]	2011	Ext	6	distance
Simeone et al [26]	2011	Int	6	angular distortion, distance
Al Quran et al [27]	2012	Int	4	Distance
Avila et al [50]	2012	Ext	4	Gap
Chang et al [28]	2012	Int	5	Distance
Del'Acqua et al [55]	2012	Ext	4	Gap
Eliasson & Ottorp [29]	2012	Ext	3	angular distortion, distance
Ferreira et al [30]	2012	Ext	4	distance
Holst et al [31]	2012	Int	5	distance
Mpikos et al [32]	2012	Ext/Int	4 – Ext 4 – Int	angular distortion, distance
Ongul et al [33]	2012	Int	6	distance
Rasgidan et al [34]	2012	Int	5	angular distortion, distance
Stimmelmayr et al [35]	2012	Int	4	distance
Akalin et al [36]	2013	Int	6	angular distortion, distance
Fernandez et al [56]	2013	Int	4	gap

Table 2. Studies comparing the accuracy of impressions by measuring the linear distortion

Authors	Year	Connection	Direct/ Indirect	Splint /Non-splint	Material	Parallel /Non-parallel
Humphries et al [1]	1990	Ext	Indirect better	ND	ND	–
Spector et al [2]	1990	Ext	–	–	–	–
Carr et al [3]	1991	Ext	Direct better	–	–	–
Barrett et al [4]	1993	Ext	Direct better	ND	ND	–
Hsu et al [5]	1993	Ext	–	ND	–	–
Phillips et al [6]	1994	Ext	Direct better	Non-splint better	–	–
Carr et al [7]	1996	Ext	–	–	–	–
Burawi et al [8]	1997	Int	–	–	–	–
Herbst et al [9]	2000	Ext	ND	–	–	–
Wee et al [10]	2000	Ext	–	–	ND	–
Delacruz et al [11]	2002	Ext	ND	Non-splint better	–	–
Vigolo et al [12]	2003	Int	–	Splint better	–	–
Akca et al [13]	2004	Int	–	–	ND	–
Vigolo et al [14]	2004	Int	–	Splint better	–	–
Ortorp et al [15]	2005	Ext	–	–	–	–
Kim et al [16]	2006	Ext	–	ND	–	–
Holst et al [17]	2007	Int	–	–	ND	–
Dullabh et al [18]	2008	Ext	Direct better	–	–	–
Walker et al [19]	2008	Int	–	–	–	–
Aguilar et al [20]	2010	Ext	–	–	VPS better	–

Hariharan et al [21]	2010	Int	–	ND	–	–
Jo et al [22]	2010	Int	Direct better	–	–	ND
Mostafa et al [23]	2010	Ext	Direct better	ND	VPS better	–
Sorrentino et al [24]	2010	Int	–	–	VPS better(P), PE better(NP)	–
Lee et al [25]	2011	Ext	–	–	–	–
Simeone et al [26]	2011	Int	–	Splint better	–	–
Al Quran et al [27]	2012	Int	Direct better	Splint better	–	–
Chang et al [28]	2012	Int	–	ND	ND	–
Eliasson & Ottorp [29]	2012	Ext	–	–	–	–
Ferreira et al [30]	2012	Ext	–	–	–	–
Holst et al [31]	2012	Int	–	–	–	–
Mpikos et al [32]	2012	Ext/Int	ND	–	–	Parallel better
Ongul et al [33]	2012	Int	–	Splint better	–	–
Rashidan et al [34]	2012	Int	ND	–	–	–
Stimmelmayr et al [35]	2012	Int	ND	–	–	–
Akalin et al [36]	2013	Int	–	–	ND(P), PE better(NP)	–

Ext: external connection implant ; Int: internal connection implant ; ND : no difference ; PE: polyether ; VPS: vinyl polysiloxane ; P: parallel ; NP: non-parallel

Table 3. Studies comparing the accuracy of impressions by measuring the angular distortion

Authors	Year	Connection	Direct/Indirect	Splint/Non-splint	Material	Parallel/Non-parallel
Liou et al [51]	1993	Ext	–	–	ND	–
Phillips et al [6]	1994	Ext	Direct better	Non-splint better	–	–
Lorenzoni et al [52]	2000	Int	–	–	ND	–
Akca et al [13]	2004	Int	–	–	ND	–
Assuncao et al [44]	2004	Ext	ND	Splint better	ND	Parallel better
Ortorp et al [15]	2005	Ext	–	–	–	–
Kim et al [16]	2006	Ext	–	ND	–	–
Conrad et al [45]	2007	Ext	ND	–	–	ND
Aguilar et al [20]	2010	Ext	–	–	VPS better	–
Assuncao et al [42]	2010	Ext	–	–	–	Parallel better
Hariharan et al [21]	2010	Int	–	ND	–	–
Simeone et al [26]	2011	Int	–	Splint better	–	–
Eliasson & Ortorp [29]	2012	Ext	–	–	–	–
Mpikos et al [32]	2012	Ext/Int	ND	–	–	Parallel better
Rasgidan et al [34]	2012	Int	ND	–	–	–
Akalin et al [36]	2013	Int	–	–	ND(P), PE better(NP)	–

Ext: external connection implant ; Int: internal connection implant ; ND : no difference ; PE: polyether ; VPS: vinyl polysiloxane ; P: parallel ; NP: non-parallel

Table 4. Studies comparing the accuracy of impressions by measuring the gap distance

Authors	**Year**	**Connection**	**Direct/ Indirect**	**Splint/Non-splint**	**Material**	**Parallel/Non-parallel**
Assif et al [43]	1992	Ext	Direct better	Splint better	–	–
Del'Acqua et al [54]	2010	Ext	–	–	PE better	–
Del'Acqua et al [53]	2010	Ext	–	Splint better	–	–
Del'Acqua et al [48]	2010	Ext	–	–	–	–
Lee et al [46]	2010	Ext	Direct better	–	–	–
Yamamoto et al [49]	2010	Ext	–	Splint better	–	–
Faria et al [47]	2011	Ext	Direct better	ND	–	–
Avila et al [50]	2012	Ext	–	Splint better	–	–
Del'Acqua et al [55]	2012	Ext	–	–	–	–
Fernandez et al [56]	2013	Int	–	–	–	–

Ext: external connection implant ; Int: internal connection implant ; ND : no difference ;
PE: polyether ; VPS: vinyl polysiloxane ; P: parallel ; NP: non-parallel

Table 5. Studies comparing the accuracy of impressions by measuring the strain

Authors	Year	Connection	Direct/ Indirect	Splint/ Non-splint	Material	Parallel/Non-parallel
Assif et al [37]	1996	Ext	–	Splint better	–	–
Assif et al [38]	1999	Ext	–	–	–	–
Naconecy et al [39]	2004	Ext	ND	Splint better	–	–
Cehreli et al [40]	2006	Int	–	–	ND	–

Ext: external connection implant ; Int: internal connection implant ; ND : no difference ; PE: polyether ; VPS: vinyl polysiloxane ; P: parallel ; NP: non-parallel

Table 6. Excluded studies

Author	Year	Reason for exclusion
Carr et al [58]	1992	lack of implants
Inturregui et al [59]	1993	
Bartlett et al [60]	2002	
Burns et al [61]	2003	
Bambini et al [62]	2005	
Carbal et al [63]	2007	
Assuncao et al [64]	2008	
Assuncao et al [65]	2008	
Assuncao et al [66]	2008	
Lee et al. [67]	2008	
Wostmann et al [68]	2008	
Filho et al [69]	2009	
Lee et al [70]	2009	
Assuncao et al [71]	2010	
Alikhasi et al [72]	2011	
Jang et al [73]	2011	
Rutkunas et al [74]	2012	
Tarib et al [75]	2012	
Howell et al [76]	2013	
Jemt et al [77]	1999	clinical subjects
Papaspyridakos et al [78]	2012	
Schmitt et al [79]	1994	lack of information

Lechner et al [80]	1992	
Vigolo et al [81]	1993	
Wee et al [82]	1998	
Cranin et al [83]	1998	
May et al [84]	1999	
Wee et al [85]	2002	other subjects
Castilho et al [86]	2007	
Lee et al [41]	2008	
Del corso et al [87]	2009	
Kwon et al [88]	2011	
Stimmelmayr et al [89]	2012	
Ono et al [90]	2012	

국문요약

임플란트 인상의 측정방법과 정확도에 대한 체계적 보고

<지도 교수 김선재>

연세대학교 대학원 치의학과

김 경 록

연구목적 : 본 체계적 보고는 임플란트 인상 연구들의 결과를 측정방법에 기초하여 평가하고 비교하였다. 각 측정방법의 특성들은 또한 측정방법의 장점과 단점은 규정하기 위해 분석되었다.

연구출처 및 선택 : PubMed/MEDLINE 데이터베이스의 전자 검색이 2013 년 2 월까지 특정한 용어에 따라 시행되었고, 검색된 연구 중 미리 정해진 기준에 부합하는 임플란트 인상 방법의 정확성에 대한 실험실 연구가 평가되었다. 논문의 최종목록은 본 체계적 보고의 목적에 적합한지 확인하기 위해 포괄적으로 평가되었다. 본 체계적 보고의 결과는 또한 앞선 체계적 보고와 비교하였다.

결론 : 대부분의 연구가 임플란트 인상 방법의 정확도를 평가 하기 위해 특정 기준점간의 선형 변형의 정도를 측정하였다. 인상의 정확도에 대한 연결고정의 영향과 다른 연결 고정 물질 영향이 가장 많이 사용된 비교 요소였다. 최근에 발표된 연구들은 간접 직접인상법과 연결고정인상법을 간접인상법과 비연결고정인상법보다 선호하였다. 내부 연결 임플란트를 이용하는 연구의 수가 증가하고 있다.

핵심되는 말 : 임플란트, 인상, 정확도, 측정방법