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Efficacy of Splinted and Non-splinted Direct Impression Techniques for Completely Edentulous Patients Requiring Implant Supported Prostheses- A Systematic Review

Varun Wadhwani[1], Deepak Nallasway[2], Vinay Sivaswamy[3*], Khushali K Shah[4], Subhabrata Maiti[5]

[1]Post graduate student, Department of Prosthodontics and Implantology, Saveetha Dental, College And Hospitals, Saveetha Institute Of Medical And Technical Sciences, Saveetha University, Chennai-600077,Tamil Nadu,India

[2]Professor, Department of Prosthodontics and Implantology, Saveetha Dental College And Hospitals, Saveetha Institute Of Medical And Technical Sciences, Saveetha University, Chennai-600077,Tamil Nadu,India

[3]Associate Professor, Department of Prosthodontics and Implantology, Saveetha Dental, College And Hospitals, Saveetha Institute Of Medical And Technical Sciences, Saveetha University, Chennai-600077,Tamil Nadu,India

[4]Post graduate student, Department of Prosthodontics and Implantology, Saveetha Dental College And Hospitals, Saveetha University, Chennai-600077,Tamil Nadu,India

[5]Associate Professor, Department of Prosthodontics and Implantology, Saveetha Dental College And Hospitals, Saveetha University, Chennai-600077,Tamil Nadu,India

***Corresponding author:** Alaa Noori Sarkees, Assiss. Prof. Community Health Nursing, Department of Nursing, College of Health and Medical Technology, Duhok Polytechnic University, Duhok, Iraq, Email: alaa.noori@dpu.edu.krd

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ABSTRACT

Background: Implants are not as mobile as natural teeth due to the absence of the periodontal ligament, which means that they cannot adapt to distortions and misfit at the implant-abutment interface. The success of implant-supported prostheses largely depends on achieving a passive fit between the implant components. Failure to achieve a passive fit may result in a range of biological and mechanical complications. Therefore, the precision of fit and passivity of implant-supported fixed dental prostheses are heavily influenced by the choice of impression materials and techniques used.

Materials and Methods: The search was performed in electronic database (i.e. PubMed, ScienceDirect, Lilacs, Cochrane Database of Systematic Review, Google Scholar, Europe PMC, Wiley online library) using a combination of controlled vocabulary from January 1, 2010 to March 1, 2021. The combined data was analysed. Factors which affect the accuracy were pinned down and their impact on the outcome was accessed.

Results: The 21 studies which fulfilled the inclusion criteria included 3 clinical and 18 in vitro studies. Most in vitro (10/18) and all clinical studies demonstrated that the splinted technique was more accurate when compared to non- splinted technique. 7 in vitro studies compared various impression materials and showed no statistical difference between poly-ether and polyvinyl siloxane, but 2 studies reported occlusal registration material and impression plaster used for non- splinted impressions to be as accurate as splinted impressions. All of the studies reported open tray technique to be better than

closed tray. 9 in vitro studies reported on the use of different splinting methods as well as modifications for unsplinted impression copings with conflicting results. Although 2 out of 3 studies reported air-abraded, adhesive coated and unilateral extended unsplinted copings to give as accurate results and splinted copings in the accuracy of casts obtained. 9 invitro and 3 clinical studies demonstrated that with the increase in angulation of implants, the accuracy of impressions decreases and splinted copings are preferred while 2 among the in-vitro reported no change in accuracy from 0-15 degrees.

Conclusion: The current literature points towards splinted technique to have better impression accuracy as compared to non- splinted technique but the clinical studies included show serious risk of bias. Angulation of implants play a major factor in influencing the accuracy of impressions made. Angulated implants show less accurate impressions as compared to parallel implants. No difference was observed between traditional impression materials like PVS and PE for the impression technique. Unconventional implant materials like occlusal registration materials have shown promise. Better structured and randomized clinical trials are needed to formulate a definite protocol.

Keywords: *Implant, Systematic, clinical, traditional*

Aim

The aim of this systematic review is to evaluate the efficacy of splinted versus non-splinted direct impression techniques in completely edentulous patients requiring implant supported prostheses.

Structured Question

Is there a difference in the accuracy of splinted and non-splinted direct impression techniques for completely edentulous patients requiring implant supported prostheses?

PICO Analysis

Population: Completely edentulous patients/ models
Intervention: Non-splinted implant impression
Comparison: Splinted implant impression
Outcome: Accuracy, Fit of framework
Study design: Clinical and in vitro studies

Null Hypothesis

There is no difference between the accuracy of non-splinted and splinted direct impression technique for full arch implant prostheses.

Alternate Hypothesis

There is a difference between the accuracy of non-splinted and splinted direct impression technique for full arch implant prostheses.

INTRODUCTION

The field of implant technology has undergone significant advancements in recent years, with new techniques and materials emerging. These developments, coupled with the long-term success of implants, have made implant-supported prostheses the preferred treatment option for restoring both function and aesthetics in edentulous patients(1). Several in-vivo studies have demonstrated the long-term efficacy of this kind of treatment approach(2)(3). As endosseous implants are osseointegrated (functional ankylosis) with alvelolar bone, they don't have the inherent mobility as provided by the periodontal ligament of natural teeth. Hence, they cannot accommodate distortions and misfit at implant-abutment interface. (4). Achieving a passive fit between implant components and the prosthetic superstructure is crucial for the success of implant-supported prostheses. When passive fit cannot be achieved, several biological and mechanical complications may arise, such as screw loosening or fracture, increased plaque accumulation, loss of osseointegration, or even implant fracture. Therefore, ensuring a passive fit is essential for minimizing the risk of complications and achieving optimal treatment outcomes.(5)

Impression materials and techniques are fundamental in the precision of fit and passivity of implant-supported fixed dental prostheses.(6). Various factors involved in implant impression precision have been investigated in literature

(e.g., impression material and technique adopted, splinting of impression copings, implant angulation, and depth)(7)(8,9)(10). There are currently two primary impression techniques for replicating the implant position as in the oral cavity to the working model: the direct impression procedure (also known as the open-tray technique) and the indirect impression procedure (also known as the closed-tray technique). In the direct impression technique, the transfer copings for impression are captured within the impression when its removed from the oral cavity. In the indirect technique, the transfer impression copings remain attached to the implants as the impression is removed and are later repositioned into the impression. According to most research studies, the direct, open tray, or pick-up method is superior to the indirect, closed tray, or transfer technique, as it produces less distortion, particularly for multi-unit implant impressions.(9)(11)(11,12)(13)(14)

With direct technique, both splinting and non splinting (with certain modifications) of impression copings to improve the accuracy of the impression have been advocated.Acrylic resin and dental plaster have traditionally been used to splint impression copings, but the effect of these materials in maintaining the accurate inter-implant positions during direct impression transfers and fabrication of precise implant cast is not clear(15)(16) Studies have demonstrated that bite registration elastomers, prefabricated acrylic/metal bars, and other rigid materials can have a positive impact on the accuracy of multi-unit implant impressions. This is due to their ability to maintain dimensional stability and rigidity during the impression-taking process. As a result, these materials are often recommended for use when capturing implant positions to achieve the best possible treatment outcomes.(17)(18)

There have been inconsistent findings in the current research pool concerning the accuracy of direct non-splinted and direct- splinted techniques for implant-supported prostheses(6). While some studies have shown that direct-splinted transfer impression techniques show more accuracy than direct/non-splinted impression procedures,(19)(20)(21) other studies have reported the opposite.(22)(23) However, few studies have revealed that there is no statistical significant difference in-between the splinted and non-splinted impression techniques.(24)(25)(26)

These results are majorly based on in vitro studies and the few clinical studies which are present are non-randomised.(27). No definite technique has been recommended for varied clinical situations that might be encountered in a completely edentulous patient where full arch implant placement has to be carried out. Therefore the aim of the current systematic review is to evaluate the efficacy of splinted versus non-splinted direct impression techniques in completely edentulous patients requiring implant supported prostheses and formulate a definitive protocol.

METHODOLOGY

The current systematic review is conducted in accordance with the guidelines provided for Transparent reporting of Systematic Reviews and Meta-Analysis (PRISMA Statement)(28). The goal of this systematic review was to mainly assess and compare the accuracy of splinted implant impression techniques to the non-splinted ones. In addition, the review aimed to evaluate the impact of various factors on implant impression accuracy, such as impression materials, splinting materials, and implant angulation.

Search Strategy

For identification of the studies included or considered for this review, detailed search strategies were developed for the database searched. The MEDLINE search used the combination of controlled vocabulary and free text terms in English. 7 databases were used-

PubMed
ScienceDirect
Lilacs
Cochrane Database of Systematic Review
Google Scholar
Europe PMC
Wiley online library

The time period extended from January 1, 2010 to March 1 2021. The search strategy included the following keyword combinations: (((((Full arch implant prostheses) OR (full mouth Implant prostheses)) OR (edentulous patients)) OR (Hybrid prostheses)) OR (splinted implant prostheses)) OR (Hybrid denture) AND ((((Non splinted implant impression) OR (open tray impression)) OR (Direct implant impression)) OR (Direct impression technique)) OR (Open tray impression technique) AND ((((Splinted implant impression) OR (open tray impression)) OR (Direct implant impression)) OR (Direct impression technique)) OR (Open tray impression technique) AND (((Accuracy) OR (passive fit)) OR (precision)) OR (Passivity)

Search	Actions	Details	Query	Results
#5	•••	>	Search: **#1 AND #2 AND #3 AND #4**	68
#4	•••	>	Search: **(((Accuracy) OR (passive fit)) OR (precision)) OR (Passivity)**	804,033
#3	•••	>	Search: **((((Splinted implant impression) OR (open tray impression)) OR (Direct implant impression)) OR (Direct impression technique)) OR (Open tray impression technique)**	1,782
#2	•••	>	Search: **((((Non splinted implant impression) OR (open tray impression)) OR (Direct implant impression)) OR (Direct impression technique)) OR (Open tray impression technique)**	1,687
#1	•••	>	Search: **(((((Full arch implant prostheses) OR (full mouth Implant prostheses)) OR (edentulous patients)) OR (Hybrid prostheses)) OR (splinted implant prostheses)) OR (Hybrid denture)**	19,087

FIGURE 1: The search methodology employed (P I C O from #1 to #4 respectively)

Inclusion Criteria

- Studies conducted on completely edentulous patients or models indicated for implant supported prosthesis
- Comparison of non splinted and splinted direct impression techniques
- English language articles were considered
- Accuracy assessment and methodology mentioned
- In vitro and in vivo studies
- All literature published on and after 2010

Exclusion Criteria

- Partially edentulous patients/ models
- Case reports and reviews
- Only one method of direct impression used (splinted or non-splinted)
- Multiple publications of the same literature.
- All literature published before 2010

Selection Strategy and Data Collection

The search for relevant articles was conducted using the keywords and databases mentioned earlier, with duplicates removed through electronic means. Two reviewers (ADS and VB) screened the titles and abstracts of the remaining citations for potential inclusion based on pre-determined criteria. Full-text versions of the selected articles were obtained and independently screened by the two reviewers according to the inclusion and exclusion criteria. Figure 2 illustrates the screening process. Data were collected using a standardized electronic spreadsheet, which included details such as study design, edentulous jaw, number of implants, impression techniques used, connection type,

abutment angulations, accuracy method, implant brand, splint method and material, impression material, and impression accuracy results.

Risk of bias assessment

The assessment of the risk of bias was performed using the risk of bias in non-randomized studies of intervention (ROBINS-I) tool(29). The risk of bias in the selected studies was assessed for potential confounding factors, such as missing information on implant angulation, use of both techniques on the same patient, and impressions made by a single clinician. Other factors that were evaluated included participant selection, intervention classification, deviations from the intended intervention, missing data, outcome measurement, and selection of reported results. Each included study was ranked independently by the reviewers, with any disagreements resolved through discussion. In vitro studies were not subjected to bias analysis as no suitable tool is available for this purpose(30).

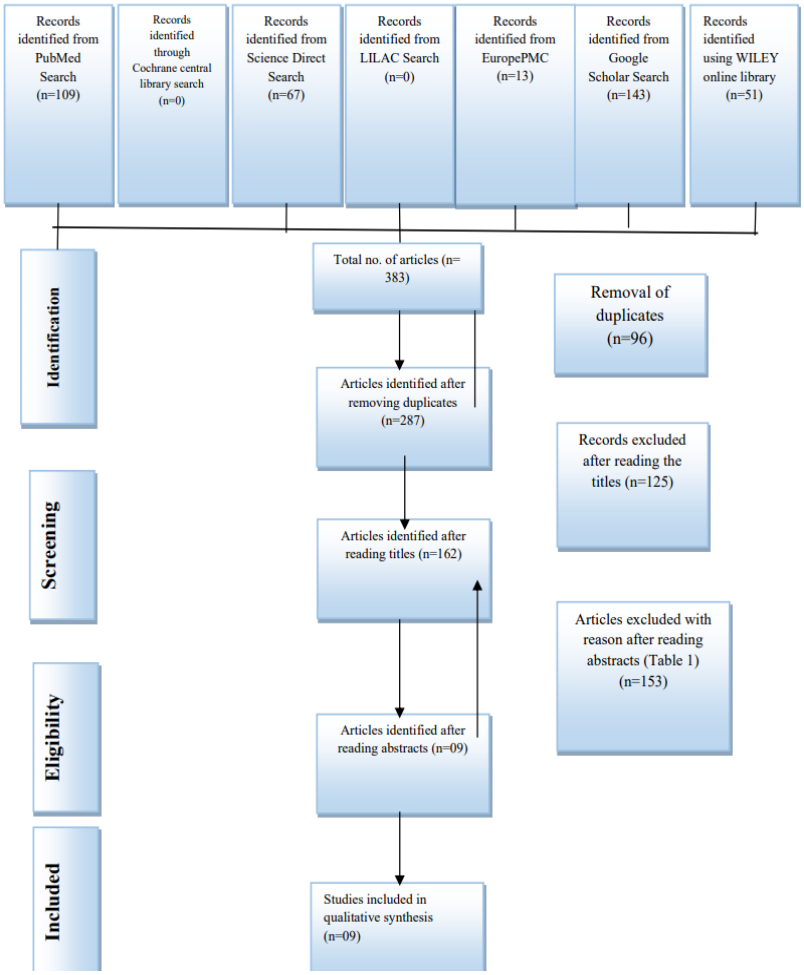

FIGURE 2: Prisma flowchart

TABLE 1: Excluded studies and the reason for exclusion

S.no.	Author	Year	Reason of Exclusion
1	Kim K R et al	2019	Comparison between the splinted and non-splinted impression techniques not made.
2	Huang R et al	2020	
3	Ozan O et al	2019	

4	Osman M et al	2019	
5	Roig E et al	2019	Full arch Implant models not used
6	Ozcelik et al	2018	Comparison between the splinted and non-splinted impression techniques not made
7	Dang L et al	2020	
8	Liu Y et al	2019	
9	Ribeiro et al	2018	
10	Badwal A S et al	2019	
11	Nishioka R S et al	2018	Comparison done for only 3-unit implant prostheses
12	Bratis M et al	2018	Comparison between the splinted and non-splinted impression techniques not made
13	Basaki K et al	2017	
14	Selvaraj S et al	2016	
15	Di Fiore A et al	2015	
16	Saboury et al	2017	Full arch Implant models not used
17	Kurtulmus-Yilmaz S et al	2014	Comparison done on partially edentulous models
18	Alshawaf B et al	2018	Comparison done on partially edentulous models
19	Gallucci G O et al	2011	Comparison done on partially edentulous models
20	Bergin J M et al	2013	Comparison between the splinted and non-splinted impression techniques not made
21	Beyabanaki E et al	2017	Full arch Implant models not used
22	Revilla-Leòn M et al	2018	Comparison between the splinted and non-splinted impression techniques not made
23	Al-Abdullah K et al	2013	
24	Roig E et al	2021	
25	Enkling N et al	2012	Comparison done on partially edentulous models
26	Tarib N A et al	2012	Full arch Implant models not used
27	Alikhasi M et al	2018	Comparison between the splinted and non-splinted impression techniques not made
28	Knechtle N	2021	
29	Chaudhary N K et al	2021	
30	Tandon A et al	2018	
31	Tuwaijri et al	2018	Comparison between the splinted and non-splinted impression techniques not made
32	George J S et al	2019	
33	Banjar A et al	2020	
34	Sallam H I et al	2016	
35	Abdalla M F et al	2016	
36	Al-Mahdy et al	2017	
37	Chochlidakis K et al	2020	
38	Amin S et al	2016	
39	Gupta et al	2016	

TABLE 2: Characteristics of included studies (OT- Open Tray, CT- Closed Tray, DI- Digital Impressions, S- Splinted, NS- Non-Splinted, NR- Not Reported, DF- Dental Floss)

Author and Year	Study design	Edentulous jaw	No. of Implants	Impression technique	Accuracy method	Implant Brand	Splint Method	Splint Material	Connection type	Angulation	Impression accuracy
Martínez-Rus et al 2013	In vitro	Maxilla	6	CT, OT-NS, OT-S	3D	Zimmer Dental, Carlsbad, CA	-Splint with prefab metal framework -Splint, section, rejoin	-Impression plaster -Duralay resin	Internal	0, 15, 30 degrees	Splinted more accurate
Castro et al 2018	In vitro	Mandible	4	OT-S, OT- NS	3D	INP; Sistema de Implantes Nacional e de Próteses Comércio Ltda, São Paulo, Brazil	Splint, section, rejoin	Palavit G	External	Parallel	No difference
Richi et al 2020	In vitro	Maxilla	6	OT-S, OT- NS	3D	T6 4110; Nucle OSS, Menderes, İzmir, Turkey	Splint, section, rejoin	Pattern Resin LS	Internal	0, 10, 20 degrees	Splinted more accurate
Baig et al 2017	In vitro	Mandible	6	OT-S, OT- NS	3D	Straumann, Basel, Switzerland	-Splint, section, rejoin -Splint -Splint	-GC pattern resin -Ramitec -GC Exabite II NDS	Internal	Parallel	No difference

Buzayan et al 2013	In vitro	Mandible	6	OT-S, OT- NS	3D	Straumann, Basel, Switzerland	-Splint, section, rejoin -Splint -Splint	-Duralay -Ramitec -Exabite	Internal	Parallel	No difference
Khorshid et al 2018	Clinical	Maxilla	6	OT-S, OT- NS	3D	Not specified	Splint	Duralay resin	NS	Angulated, NR	Splinted more accurate
Ghanem et al 2014	In vitro	Mandible	4	OT-S, OT- NS	2D	TUT Dental implants, Egyptian Co. for Dental Implants, Cairo, Egypt	Splint, section, rejoin	Duralay resin	Internal	Parallel	Splinted more accurate
Ramasubhramaniam et al 2010	In vitro	Mandible	4	OT-S, OT- NS	3D	Nobel Replace Select, Nobel Biocare	-Splint, section, rejoin -Splint -Splint	-GC pattern resin -Imprint bite -Ramitec	Internal	Parallel	Splinted more accurate
Ribeiro et al 2018	In vitro	Maxilla	4	OT-S, OT- NS, CT, DI	3D	Klockner Implant System SA, Barcelona, Spain	-Splint, section, rejoin	GC pattern resin	Internal	0, 15 degrees	Splinted more accurate
Mostafa et al 2010	In vitro	Mandible	4	OT-S, OT- NS	2D	Microdent Implant System, Microdent	Splint with prefab. Acrylic bars	GC pattern resin	Internal	Parallel	No difference

Shankar Y et al 2016	In vitro	Mandible	6	OT-S, OT- NS	3D	ADIN Dental Implant Systems Ltd., Afula, Israel	-Splint, section, rejoin -Splint	-GC pattern resin -Plastic rod + GC pattern resin	Internal	0, 10, 20 degrees	Splinted more accurate
Shankar S et al 2020	In vitro	Maxilla	4	OT-S, OT- NS	3D	Dentium Implant India Pvt. Ltd, Bengaluru, India	-Splint, section, rejoin -Splint with prefab bar	-GC pattern resin - Titaniu m	Internal	Angulated, NR	Splinted more accurate
Menini et al 2017	In vitro	NR	4	OT-S, OT- NS, CT, DI	3D	Biomet 3i, Palm Beach Gardens, FL, USA	Splint	Duralay resin	External	Parallel	No difference
Papaspyridakos et al 2011	Clinical	Maxilla/ Mandible	5 to 8	OT-S, OT- NS	2D	Nobel Biocare, Bråne mark	Splint, section, rejoin	DF and Triad gel	External	Angulated, NR	Splinted more accurate
Papaspyridakos et al 2015	In vitro	Mandible	5	OT-S, OT- NS, DI	3D	Straumann, Basel, Switzerland	Splint, section, rejoin	Triad gel	Internal	0, 10, 15 degrees	Splinted more accurate
Papazoglu et al 2019	In vitro	Mandible	4	OT-S, OT- NS, CT	3D	Xive; Dentsply Sirona	Splint, section, rejoin	GC pattern resin	Internal	Parallel	No difference
Pera et al 2015	In vitro	NR	4	OT-S, OT- NS, CT	3D	Biomet 3i, Palm Beach Gardens, FL	Splint	Duralay resin	External	Angulated, NR	No difference

Pujari et al 2014	In vitro	Maxilla	4	OT-S, OT- NS	3D	LifeCare Devices Pvt Ltd, Mumbai, India	Splint, section, rejoin	DPI- RR cold cure	Internal	Parallel	Splinted more accurate
Elshenawy et al 2018	In vitro	Mandible	3	OT-S, OT- NS, CT	3D	Osseo Link USA	Splint, section, rejoin	Acrostone cold cure	Internal	0, 15, 30 degrees	Splinted more accurate
Tsagkalidis et al 2015	In vitro	Maxilla	6	OT-S, OT- NS, CT	3D	Dr Ihde Dental AG, GmbH	Splint, section, rejoin	Duralay resin	Internal	0, 15, 25 degrees	Splinted more accurate
Papaspyridakos et al 2012	Clinical	Maxilla/ Mandible	5 to 8	OT-S, OT- NS	2D	Nobel Biocare, Bråne mark	Splint, section , rejoin	DF and Triad gel	External	Angulated, NR	Splinted more accurate

TABLE 3: ROBINS-I Risk of bias analysis for non randomised clinical trials for the included studies

Author and year of publication	Confounding	Selection of participants	Classification of interventions	Deviations from intended interventions	Missing data	Measurement of outcomes	Selection of reported results	Overall
Papaspyridakos et al 2011	Moderate	Moderate	Low	Moderate	Low	Low	Low	Moderate
Papaspyridakos et al 2012	Serious	Moderate	Low	Moderate	Low	Low	Low	Serious
Khorshid et al 2018	Serious	Moderate	Low	Moderate	Low	Low	Moderate	Serious

RESULTS

Search results

The first search of the keywords yielded 258 hits after which 77 were discarded as they were duplicates. The subsequent analysis of the titles identified 155 studies. The abstract investigation revealed 60 articles. Among the 60 studies selected for full analysis, 21 articles were selected for final inclusion. The remaining 39 studies excluded along with the reason for exclusion are mentioned in Table 1.

Characteristics of the Included studies

Following the full text analysis, three clinical and 18 in-vitro studies met review's inclusion criteria and were used for the statistical analysis. It should be noted that dissimilar two- dimensional (2D) and three- dimensional (3D) measurement tools were used to assess accuracy. Comparing the studies was challenging because some used 3D equipment but only measured 2D horizontal distances for comparison. Optical scanning and an designing software for superimposition of scanned data sets are now considered as precise and efficient techniques to measure and compare discrepancies between different groups in a three dimensional microscopic level. This technique is recommended for future investigations. The details of the studies included are presented in Table 2.

Risk Of Bias

The risk of bias judgements in ROBINS-I including pre-, at-, and post-intervention domains are depicted in Table 3. 2 of the included clinical studies were evaluated to have an overall serious risk of bias and one has an overall moderate risk of bias.

Summary statistics

Impression Materials Used

7 in-vitro studies included in this review compared various impression materials used for the two different impression techniques.(10)(8)(7,31)(25) (31)(26,32).

3 of the studies reported no difference between polyvinyl siloxane (PVS) and polyether (7,8,31), one reported polyether to be better(32) while one reported PVS gave better results(25).

2 in-vitro studies used a newer impression material- Vinylpolyether siloxane (VPES) among which 1 reported similar results as polyether(10) while the other reported VPES to be more accurate (7).

2 studies used unconventional implant impression materials like- occlusal registration material and impression plaster, both of which reported better accuracy than conventional impression materials(26,31)

Impression Technique

Closed tray versus Open tray

7 in-vitro studies compared open tray technique with a closed tray technique and all of them reported open tray to be more accurate.(9,11,12,21,26,31)(33)

Splinted versus Non- Splinted

18 laboratory and 3 in- vivo studies compared the accuracy of splinted vs. non- splinted impression techniques. 8 laboratory studies reported no difference between splinting and not splinting the implants during open tray impression.(8,10–12,24–26,31) and 10 in vitro studies reported splinted technique to be significantly better than non- splinted (9)(7,17,20,21,32–36)

All 3 clinical studies displayed that the splinted impressions were more accurate than the non-splinted impressions and recommended the former for clinical use. (19,37,38)

Various Splinted Materials

9 in vitro studies used various splinting materials or modifications of non splinted impression copings. 2 studies used preformed metal bars to splint the copings and compared it with acrylic resin. One reported metal splinted to be more accurate (36) while the other one reported no difference (9).

3 studies compared bite registration PE , PVS and autopolymerizing acrylic resin as splinting materials. 2 of them reported no difference (10,25) while one demonstrated bite registration PE to be more accurate followed by acrylic resin and bite registration PVS(17). 1 study used plastic rods (stirrer) to splint and reported it to be not as accurate as acrylic splinted impressions.(7). 3 in vitro studies compared conventional acrylic splinting with modifications of unsplinted copings like air abrasion followed by impression adhesive coating , unilateral acrylic extensions. 2 studies reported modified unsplinted impressions to be as accurate as

acrylic splinted impressions.(8,35) while one study showed splinted to be superior (32).

Digital versus Conventional Impression

3 in vitro studies compared conventional splinted open tray impressions with a digital technique. One reported digital to be better(12), one demonstrated digital to be better for parallel implants but similar as conventional for angulated implants(11) and one showed no difference between the two (20).

Implant Angulation

Regarding Implant angulation, 9 invitro and three in-vivo studies elaborated on accuracy outcomes in respect to implants placed with various angulations. The three clinical studies did not focus on the details of the implant angulation but reported that splinted technique was clinically better than non splinted technique for angulated implants.(19,37,38).

5 of the 9 in-vitro studies demonstrated that splinted implant technique was statistically significantly better than non-splinted or close tray while taking the impression for angulated implants(7,9,11,21,34). 2 studies reported that angulation till 15° did not affect the accuracy of implant impression.(20,33) 2 studies did not specify the implant angulations and no correlation was made (26,36).

DISCUSSION

Among 258 initial hits, 21 studies were included in the present review which included 3 clinical and 18 in vitro studies. The primary objective of this systematic review was to elaborate on and compare the accuracy of splinted implant impression technique with non-splinted ones. The secondary goals were to assess various impression materials, splinting materials used, and implant angulation's effect on the accuracy of full arch implant impressions.

In implant prosthodontics, only when passively fitting prostheses are fabricated, can a good result be obtained. When attaching the superstructure to the abutments, excessive torque on the screws will jeopardize the result. Designing should be performed on a master cast that reproduces the location of the abutments in the patient's mouth as precisely as possible so as to eliminate fit discrepancies. The accuracy of the impression made is a significant factor that affects precision of fit.(39)

Impression Materials

Only in vitro studies evaluated differences between various impression materials with varied observations. The general agreement among the studies reviewed was that polyether (PE) is the preferred material for achieving precise orientation of implant analogs in the laboratory master casts. This could be attributed to the greater rigidity of PE compared to regular body polyvinyl siloxane (PVS), which helps to prevent motion of the impression transfer copings within the impression material.(40). A newer impression material, PVES showed comparable results to PE and PVS if not more accurate(7,10). Use of more rigid materials like occlusal registration material and impression plaster produced more accurate impressions.(26,31). Although use of such materials is only advised for completely edentulous patients as these materials cannot be retrieved from undercuts. The findings of this review are in full accordance with those supporting that such rigid materials could offer remarkable advantages for implant impressions in patients with full-arch rehabilitations(41)(42). Though clinical feasibility of using such materials in daily practice is questionable(43).

Impression Technique

Included in-vitro studies had a unanimous conclusion that open tray was significantly better as compared to close tay impressions and has been established in the past studies (44)(45)(46)(46,47)

Based on 18 in vitro and 3 clinical studies, the scientific evidence regarding splinted vs non-splinted techniques supports the use of splinting impression copings for full arch implant impressions. These findings are consistent with previous research that suggests splinting leads to better reproduction of implant positions in the resulting cast.(48)(49)(50)(6)(27).The splinting

technique requires more time for impression making compared to the non-splinting method. However, it has been recommended to maintain a more precise interimplant relationship and avoid rotation of impression copings in the impression during fastening of the implant analog, which is a drawback of the direct impression method(17)(51). Taking into account the clinical studies, 2 of them displayed a serious risk of confounding in form that separate technique was followed for different individuals(38), and accuracy was measured on casts instead in patient's mouths(19). All of the clinical studies showed the confounding in not reporting the implant angulations.

Studies included in the current review (only in vitro) reported contradicting results on the comparison of accuracy of digital versus a conventional impression technique and drawing out concrete results is not possible(52).Notably, however, numerous factors pertaining to the oral cavity can influence the accuracy of optical impressions, including lack of space, patient movement, and saliva flow (53). Therefore, in vivo studies investigating full-arch impressions acquired via digital intraoral impression techniques are necessary.p;'result by splinting of angulated implants. .(20,33)

Splinting Material

According to the current review, acrylic resin is commonly used for splinting impression copings.(6)To minimize the adverse effects of polymerization shrinkage, it is recommended to separate the autopolymerizing resin (AR) splint after polymerization and reconnect it with a small amount of the same material. Research shows that 80% of the AR shrinkage occurs within the first 17 minutes(54). The splint, section, and rejoin method was followed by 15 in vitro and 2 clinical studies included in the review.

Use of more rigid materials than AR to splint like prefabricated metal bars and bite registration PE material is slowly gaining popularity(55). Even modifications of unsplinted copings showed comparable accuracy to AR splinted coping impressions. These results were similar to as observed by other authors(50)(56). Although, the in vitro studies which reported on the outcome used only parallel implants, which can be a confounding factor while taking impressions(57).

Implant Angulation

Implant angulation is an important factor that can affect the accuracy of implant impressions. Impressions made with angulated implants may result in lower accuracy compared to those made with parallel implants. This can be attributed to the distortion of the impression material caused by the different angulations of the implants. The higher forces required to remove the impression copings after the impression material has set may also contribute to this distortion(58,59)(47). Most of the studies included in the review reported that splinted impressions were more accurate for angulated implants. However, two in- vitro studies displayed no significant difference in between splinted and non-splinted impressions in implant angulations up to 15°. The varying results can be attributed to the differences in evaluating impression accuracy, number of implants, degree of angulation, and impression material used. Thus, more controlled studies are required to establish a standardized protocol.

Accuracy Assessment

Different methods have been used to evaluate the accuracy of implant impressions, including coordinate measuring machines, travelling microscopes, CT scans, and optical scanning. However, it is important to note that the machining tolerance, which refers to the rotational displacement that can occur during the connection of prosthetic components, is an unknown variable that can affect the accuracy measurements.(60) This tolerance cannot be controlled by the clinician, and it varies between different implant systems. Therefore, it is crucial to consider the potential impact of machining tolerance when interpreting the results of accuracy assessments(61)(62).

Study Setting

Among the 3 included clinical studies, two reported that both impression techniques were

performed on the same individual while in one, it was performed for different individuals and comparison was done. This is indicative of a weak internal validity of the systematic review. Nevertheless, included studies showed a pan-global distribution indicative of a strong external validity for the current review. ROBINS-I tool was used to assess risk of bias for the non randomised clinical studies and revealed 2 out of three clinical studies to have serious risk of bias overall and due to confounding, while one showed moderate risk of bias. This brings the level of evidence of the current review into question.

Limitations & Future scope

The available data for the systematic review is limited as it mainly comprises in-vitro studies. Only three non-randomized clinical studies from the past decade could be identified. The use of in-vitro setups in the majority of studies reduces the informative value of the data for clinicians. The decision to use either splinted or non-splinted implant impressions should be based on available data for the accuracy of each technique. Hence, evidence-based data and randomized clinical trials are essential to support clinical guidelines. The current literature does not provide high-quality evidence to support the selection of a specific impression technique.

CONCLUSIONS

Inspite of the limitations of the present systematic review, the following conclusions can be drawn:

Although the current literature points to the splinted technique to give more accurate impressions, the clinical studies lack internal validity with serious risk of bias for confounding. Therefore further regulated and randomised clinical trials are needed to formulate a proper protocol for impression technique to be used.

Impressions made with angulated implants are less accurate than those made with parallel implants. However more clinical studies are required to establish a definite connection between various angulations of implant and accuracy of it's impression.

The open tray impression technique was more accurate than the close tray impression techniques for completely edetulous patients.

There is no difference between the traditional impression materials like PVS and PE used for the two techniques. Unconventional implant materials like occlusal registration materials have shown promising results, but lack standardized evidence for clinical acceptance.

REFERENCES

1. P TLA, S BG, A JP. Knowledge and Awareness of Dental Implant Treatment versus Fixed Partial Dentures. J Long Term Eff Med Implants. 2020;30(2):103–11.
2. Buser D, Janner SFM, Wittneben JG, Brägger U, Ramseier CA, Salvi GE. 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched surface: a retrospective study in 303 partially edentulous patients. Clin Implant Dent Relat Res. 2012 Dec;14(6):839–51.
3. Ravald N, Dahlgren S, Teiwik A, Gröndahl K. Long-term evaluation of Astra Tech and Brånemark implants in patients treated with full-arch bridges. Results after 12-15 years [Internet]. Vol. 24, Clinical Oral Implants Research. 2013. p. 1144–51. Available from: http://dx.doi.org/10.1111/j.1600-0501.2012.02524.x
4. Jemt T, Hjalmarsson L. In Vitro Measurements of Precision of Fit of Implant-Supported Frameworks. A Comparison between "Virtual" and "Physical" Assessments of Fit Using Two Different Techniques of Measurements [Internet]. Vol. 14, Clinical Implant Dentistry and Related Research. 2012. p. e175–82. Available from: http://dx.doi.org/10.1111/j.1708-8208.2011.00416.x
5. Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: current status. Implant Dent. 2001;10(2):85–92.
6. Lee H, So JS, Hochstedler JL, Ercoli C. The accuracy of implant impressions: a systematic review. J Prosthet Dent. 2008 Oct;100(4):285–91.
7. Shankar Y, Sahoo S, Krishna M, Kumar P, Kumar T, Narula S. Accuracy of implant impressions using various impression techniques and impression materials [Internet]. Vol. 6, Journal of Dental Implants. 2016. p. 29.

Available from: http://dx.doi.org/10.4103/0974-6781.190384

8. Mostafa TMN, Elgendy MNM, Kashef NA, Halim MM. Evaluation of the precision of three implant transfer impression techniques using two elastomeric impression materials. Int J Prosthodont. 2010 Nov;23(6):525–8.
9. Martínez-Rus F, García C, Santamaría A, Özcan M, Pradíes G. Accuracy of Definitive Casts Using 4 Implant-Level Impression Techniques in a Scenario of Multi-Implant System With Different Implant Angulations and Subgingival Alignment Levels [Internet]. Vol. 22, Implant Dentistry. 2013. p. 268–76. Available from: http://dx.doi.org/10.1097/id.0b013e3182920dc5
10. Baig MR, Buzayan MM, Yunus N. Accuracy of a new elastomeric impression material for complete-arch dental implant impressions. J Investig Clin Dent. 2018 May;9(2):e12320.
11. Ribeiro P, Herrero-Climent M, Díaz-Castro C, Ríos-Santos JV, Padrós R, Mur JG, et al. Accuracy of Implant Casts Generated with Conventional and Digital Impressions—An In Vitro Study [Internet]. Vol. 15, International Journal of Environmental Research and Public Health. 2018. p. 1599. Available from: http://dx.doi.org/10.3390/ijerph15081599
12. Menini M, Setti P, Pera F, Pera P, Pesce P. Accuracy of multi-unit implant impression: traditional techniques versus a digital procedure. Clin Oral Investig. 2018 Apr;22(3):1253–62.
13. Moreira AHJ, Rodrigues NF, Pinho ACM, Fonseca JC, Vilaça JL. Accuracy Comparison of Implant Impression Techniques: A Systematic Review. Clin Implant Dent Relat Res. 2015 Oct;17 Suppl 2:e751–64.
14. Agarwal S, Ashok V, Maiti S. Open- or Closed-Tray Impression Technique in Implant Prosthesis: A Dentist's Perspective. J Long Term Eff Med Implants. 2020;30(3):193–8.
15. Choi JH, Lim YJ, Yim SH, Kim CW. Evaluation of the accuracy of implant-level impression techniques for internal-connection implant prostheses in parallel and divergent models. Int J Oral Maxillofac Implants. 2007 Sep;22(5):761–8.
16. Assif D, Nissan J, Varsano I, Singer A. Accuracy of implant impression splinted techniques: effect of splinting material. Int J Oral Maxillofac Implants. 1999 Nov;14(6):885–8.
17. 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 Jan;25(1):38–44.
18. Duraisamy R, Krishnan CS, Ramasubramanian H, Sampathkumar J, Mariappan S, Navarasampatti SA. Compatibility of Nonoriginal Abutments With Implants: Evaluation of Microgap at the Implant-Abutment Interface, With Original and Nonoriginal Abutments. Implant Dent [Internet]. 2019 Jun [cited 2023 May 5];28(3). Available from: https://pubmed.ncbi.nlm.nih.gov/31124826/
19. 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 Jun;23(6):676–81.
20. Papaspyridakos P, Gallucci GO, Chen CJ, Hanssen S, Naert I, Vandenberghe B. Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. Clin Oral Implants Res. 2016 Apr;27(4):465–72.
21. Elshenawy EA, Alam-Eldein AM, Abd Elfatah FA. Cast accuracy obtained from different impression techniques at different implant angulations (in vitro study). Int J Implant Dent. 2018 Mar 20;4(1):9.
22. 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 [Internet]. Vol. 77, The Journal of Prosthetic Dentistry. 1997. p. 68–75. Available from: http://dx.doi.org/10.1016/s0022-3913(97)70209-9
23. Inturregui JA, Aquilino SA, Ryther JS, Lund PS. Evaluation of three impression techniques for osseointegrated oral implants [Internet]. Vol. 69, The Journal of Prosthetic Dentistry. 1993. p. 503–9. Available from: http://dx.doi.org/10.1016/0022-3913(93)90160-p
24. Castro RA, Moretti KP, Jóias RP, Da ANA PA, Jóias RM. Evaluation of the accuracy between splinting and non-splintingimpression techniques for multiple implants [Internet]. Vol. 3, Rio de Janeiro Dental Journal (Revista Científica do CRO-RJ). 2018. p. 37–42. Available from: http://dx.doi.org/10.29327/24816.3.3-7
25. Buzayan M, Baig MR, Yunus N. Evaluation of accuracy of complete-arch multiple-unit abutment-level dental implant impressions using different impression and splinting materials. Int

J Oral Maxillofac Implants. 2013 Nov;28(6):1512–20.
26. Pera F, Pesce P, Bevilacqua M, Setti P, Menini M. Analysis of Different Impression Techniques and Materials on Multiple Implants Through 3-Dimensional Laser Scanner. Implant Dent. 2016 Apr;25(2):232–7.
27. Papaspyridakos P, Chen CJ, Gallucci GO, Doukoudakis A, Weber HP, Chronopoulos V. Accuracy of implant impressions for partially and completely edentulous patients: a systematic review. Int J Oral Maxillofac Implants. 2014 Jul;29(4):836–45.
28. Page MJ, McKenzie J, Bossuyt P, Boutron I, Hoffmann T, Mulrow C d., et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews [Internet]. Available from: http://dx.doi.org/10.31222/osf.io/v7gm2
29. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016 Oct 12;355:i4919.
30. Russo LL, Lo Russo L, Caradonna G, Biancardino M, De Lillo A, Troiano G, et al. Digital versus conventional workflow for the fabrication of multiunit fixed prostheses: A systematic review and meta-analysis of vertical marginal fit in controlled in vitro studies [Internet]. Vol. 122, The Journal of Prosthetic Dentistry. 2019. p. 435–40. Available from: http://dx.doi.org/10.1016/j.prosdent.2018.12.001
31. Papazoglou E, Wee AG, Carr AB, Urban I, Margaritis V. Accuracy of complete-arch implant impression made with occlusal registration material. J Prosthet Dent. 2020 Jan;123(1):143–8.
32. Pujari M, Garg P, Prithviraj DR. Evaluation of accuracy of casts of multiple internal connection implant prosthesis obtained from different impression materials and techniques: an in vitro study. J Oral Implantol. 2014 Apr;40(2):137–45.
33. Tsagkalidis G, Tortopidis D, Mpikos P, Kaisarlis G, Koidis P. Accuracy of 3 different impression techniques for internal connection angulated implants. J Prosthet Dent. 2015 Oct;114(4):517–23.
34. Richi MW, Wafa Richi M, Kurtulmus-Yilmaz S, Ozan O. Comparison of the accuracy of different impression procedures in case of multiple and angulated implants [Internet]. Vol. 16, Head & Face Medicine. 2020. Available from: http://dx.doi.org/10.1186/s13005-020-00225-3
35. Ghanem RA, Nassani MZ, Baroudi K, Fattah AA. Dimensional accuracy of different techniques used for complete-arch multi-implant impressions [Internet]. Vol. 7, Journal of Investigative and Clinical Dentistry. 2016. p. 225–31. Available from: http://dx.doi.org/10.1111/jicd.12160
36. Shankar SD, Doddamani S. To evaluate and compare the accuracy of definitive casts using various splinting methods on implant level impressions in All-on-Four treatment: An study. J Indian Prosthodont Soc. 2020 Apr;20(2):193–201.
37. Papaspyridakos P, Lal K, White GS, Weber HP, Gallucci GO. Effect of splinted and nonsplinted impression techniques on the accuracy of fit of fixed implant prostheses in edentulous patients: a comparative study. Int J Oral Maxillofac Implants. 2011 Nov;26(6):1267–72.
38. Khorshid H. The Effect of two different impression techniques on the passivity of fit of implant supported prosthesis placed in completely edentulous maxillae [Internet]. Vol. 64, Egyptian Dental Journal. 2018. p. 2697–705. Available from: http://dx.doi.org/10.21608/edj.2018.77267
39. Buzayan MM, Yunus NB. Passive Fit in Screw Retained Multi-unit Implant Prosthesis Understanding and Achieving: A Review of the Literature [Internet]. Vol. 14, The Journal of Indian Prosthodontic Society. 2014. p. 16–23. Available from: http://dx.doi.org/10.1007/s13191-013-0343-x
40. Del'Acqua MA, Chávez AM, Amaral ALC, Compagnoni MA, Mollo F de A Jr. Comparison of impression techniques and materials for an implant-supported prosthesis. Int J Oral Maxillofac Implants. 2010 Jul;25(4):771–6.
41. Eid N. An implant impression technique using a plaster splinting index combined with a silicone impression. J Prosthet Dent. 2004 Dec;92(6):575–7.
42. Saini HS, Jain S, Kumar S, Aggarwal R, Choudhary S, Reddy NK. Evaluating the Effect of Different Impression Techniques and Splinting Methods on the Dimensional Accuracy of Multiple Implant Impressions: An in vitro Study. J Contemp Dent Pract. 2018 Aug 1;19(8):1005–12.
43. Kushali R, Maiti S, Girija SAS, Jessy P. Evaluation of Microbial Leakage at Implant Abutment Interfact for Different Implant Systems: An In Vitro Study. J Long Term Eff Med Implants [Internet]. 2022 [cited 2023 May

5];32(2). Available from: https://pubmed.ncbi.nlm.nih.gov/35695631/

44. Al Quran FA, Rashdan BA, Zomar AAA, Weiner S. Passive fit and accuracy of three dental implant impression techniques. Quintessence Int. 2012 Feb;43(2):119–25.
45. Del'acqua MA, de Avila ÉD, Amaral ÂLC, Pinelli LAP, de Assis Mollo F Jr. Comparison of the accuracy of plastic and metal stock trays for implant impressions. Int J Oral Maxillofac Implants. 2012 May;27(3):544–50.
46. Fernandez MA, de Mendoza CYP, Platt JA, Levon JA, Hovijitra ST, Nimmo A. A Comparative Study of the Accuracy between Plastic and Metal Impression Transfer Copings for Implant Restorations [Internet]. Vol. 22, Journal of Prosthodontics. 2013. p. 367–76. Available from: http://dx.doi.org/10.1111/jopr.12015
47. Mpikos P, Kafantaris N, 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 Nov;27(6):1422–8.
48. Cabral LM, Guedes CG. Comparative Analysis of 4 Impression Techniques for Implants [Internet]. Vol. 16, Implant Dentistry. 2007. p. 187–94. Available from: http://dx.doi.org/10.1097/id.0b013e3180587b3f
49. Naconecy MM, Teixeira ER, Shinkai RSA, Frasca LCF, Cervieri A. Evaluation of the accuracy of 3 transfer techniques for implant-supported prostheses with multiple abutments. Int J Oral Maxillofac Implants. 2004 Mar;19(2):192–8.
50. Vigolo P, Majzoub Z, Cordioli G. Evaluation of the accuracy of three techniques used for multiple implant abutment impressions. J Prosthet Dent. 2003 Feb;89(2):186–92.
51. Yuvashree CS, Venugopalan S, Nesappan T, Antony SDP. Comparing Closed Tray Implant Impression Techniques Using Snap-On and Impression Analogues on a Clinical Radiographic Scale. J Long Term Eff Med Implants. 2021;31(1):1–6.
52. Kachhara S, Nallaswamy D, Ganapathy DM, Sivaswamy V, Rajaraman V. Assessment of intraoral scanning technology for multiple implant impressions - A systematic review and meta-analysis. J Indian Prosthodont Soc. 2020 Apr 7;20(2):141–52.
53. Brosky ME, Major RJ, DeLong R, Hodges JS. Evaluation of dental arch reproduction using three-dimensional optical digitization. J Prosthet Dent. 2003 Nov;90(5):434–40.
54. Mojon P, Oberholzer JP, Meyer JM, Belser UC. Polymerization shrinkage of index and pattern acrylic resins. J Prosthet Dent. 1990 Dec;64(6):684–8.
55. Carr AB, Master J. The accuracy of implant verification casts compared with casts produced from a rigid transfer coping technique. J Prosthodont. 1996 Dec;5(4):248–52.
56. Herbst D, Nel JC, Driessen CH, Becker PJ. Evaluation of impression accuracy for osseointegrated implant supported superstructures. J Prosthet Dent. 2000 May;83(5):555–61.
57. Balaji GS. Evaluation Of Bond Strength Of Splinting Material To The Teeth After Thermocycling - An In Vitro Study. 2021 Sep 22 [cited 2023 May 5]; Available from: https://zenodo.org/record/5702251
58. Assuncao WG, Filho HG, Zaniquelli O. Evaluation of Transfer Impressions for Osseointegrated Implants at Various Angulations [Internet]. Vol. 13, Implant Dentistry. 2004. p. 358–66. Available from: http://dx.doi.org/10.1097/01.id.0000144509.58901.f7
59. 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 [Internet]. Vol. 12, Clinical Implant Dentistry and Related Research. 2009. p. e63–76. Available from: http://dx.doi.org/10.1111/j.1708-8208.2009.00167.x
60. Kim S, Nicholls JI, Han CH, Lee KW. Displacement of implant components from impressions to definitive casts. Int J Oral Maxillofac Implants. 2006 Sep;21(5):747–55.
61. Cheshire PD, Hobkirk JA. An in vivo quantitative analysis of the fit of Nobel Biocare implant superstructures [Internet]. Vol. 23, Journal of Oral Rehabilitation. 1996. p. 782–9. Available from: http://dx.doi.org/10.1046/j.1365-2842.1996.d01-193.x
62. Ma T, Nicholls JI, Rubenstein JE. Tolerance measurements of various implant components. Int J Oral Maxillofac Implants. 1997 May;12(3):371–5.