EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
Vol. 70, 461:471, January, 2024
Print ISSN 0070-9484 • Online ISSN 2090-2360
Fixed Prosthodontics and Dental Materials
Submit Date : 01-11-2023 • Accept Date : 10-12-2023 • Available online: 10-01-2024 • DOI : 10.21608/EDJ.2023.245517.2763

ACCURACY OF DIFFERENT DIGITAL DATA ACQUISITION WORK FLOWS FOR FULL ARCH MAXILLARY IMPLANT PROSTHESES (AN INVITRO STUDY)

Noha Mohamed El Hussieny Fayad* , Ahmed Khaled Aboelfadl** *and* Dina Essam Bahig*

ABSTRACT

The purpose of this study was to evaluate the accuracy of different digital data acquisition workflows for the construction of full arch maxillary implant prostheses.

Material and methods: Five implants were equally distributed in an educational maxillary edentulous resin model. Then, five scan bodies were attached to the implants and scanned by a 3D industrial scanner for reference STL file. This research investigated four different methods for data acquisition. It included 4 groups, Pentamix: conventional impressions were taken by vinylpolysiloxanesilicone VPS (Pentamix) and poured into a cast, Identium: impressions were taken by vinylsiloxanether (VSE Identium) and poured into cast, TRIOS 4: Trios 4 intraoral scanner was used to scan the model after attaching the scan bodies and Primescan: Primescan intraoral scanner was used to scan the model as same steps as TRIOS 4. Each group was further divided into splinted and non- splinted. Forty eight scans (12 scans for each group) of the casts which were obtained by the conventional impression were done using the industrial scanner. Forty eight scans (12 scans for each group) were directly obtained from scanning of the educational model. Accuracy were measured and compared to the reference STL file using color mapping geomagic control x software.

Results: Statistically significant difference between the acquisition technique and between splinting and non-splinting technique was reported with ($p<0.001$). However, the differences between both Pentamix and Identium was ($p=0.635$) and both digital intra oral scanning ISO techniques was ($p=0.989$) which were statistically insignificant with P. Value of 0.000.

Conclusion: Splinting of scan bodies during intraoral scanning is critical for accuracy in full arch implant supported prosthesis to limit the stitching errors that occur and help elevate the inaccuracy related to conventional impression techniques. With the development of new technologies it is possible to obtain accurate results using intraoral scanners that can replace the traditional methods with competent accuracy.

KEYWORDS: Intra oral scanning, splinting, full arch , vinyl poly siloxane

* Lecturer Oral and Maxillofacial Prosthodontics Department Faculty of Dentistry Ain Shams University
** Professor of Fixed Prosthodontics, Faculty of Dentistry, Ain Shams University, Guest Researcher, Bonn University

INTRODUCTION

In recent dentistry, the restoration of the edentulous mandible with implant supported prostheses has become an effective and reliable treatment option. Implant-supported prosthesis success depends on the ability to achieve an accurate passive fit on connecting it to multiple implant abutments. An accurate impression is considered a key factor in order to achieve passive fit. Passive fit or passive adaptation has been defined as a strictly tolerated metal to metal interface between an implant superstructure and the implant abutments. [1,2]

Destructive stresses are generated in non-passive supra-structures on connecting them to the respective abutments. These stresses can lead to many mechanical failures and multiple complications later on. Non-passive fit supra structure generates destructive stresses in a screw-retained prosthesis when connected to the abutments, which may lead to multiple complications and mechanical failures. Such failures include implant screw loosening and component fracture, fracture of ceramic veneer, occlusal inaccuracy and potential implant fracture with crestal bone loss. Therefore, every attempt is made to produce an accurate master cast to be used in fabrication of the most attainable passive fit of the superstructure. [3-6]

Different clinical as well as laboratory factors play a role in the dimensional accuracy of the master cast, including the impression technique, the impression material used and the properties of the stone as well as the machining tolerance of all prosthetic components, connection type, andfinal implant angulation. [1]

Various data aquisition techniques are used in Implant-supported prosthesis which can be a conventional, semi digital or digital work-flow. In all workflows making an impression is the essential first step prior to the subsequent fabrication of a dental prosthesis. [7]

Many impression materials are now available in the market to serve this purpose as Polyether (PE) for its inherent hydrophilicity along with its rigidity. The limitations of PE include liability of causing allergic tissue reactions, its poor tear strength and very short working time. Moreover, a problem may arise due to its high stiffness after setting making its removal from the mouth quiet challenging. On the other hand, Polyvinyl siloxane (PVS), has good flow properties and more flexibility with excellent dimensional accuracy, making it the material of choice for cases with bony undercuts. Yet PVS also shows some inherent limitations as short working time and its need for expensive equipment is required to perform the procedure. In 2006 a hybrid of polyvinyl siloxane and polyether (VPES) (SENN, GC America, USA) was introduced. It combined the best features of both PE &PVS impression materials like excellent material flow, high hydrophilicity and high tear strength which made it an excellent choice for implant impression materials . [8-11]

Digital impression technique as part of the digital workflow for recording impression can be either direct or indirect, splinted, or non-splinted. The indirect workflow starts by making a conventional impression on implants, the virtual model is then digitized by using a desktop extra oral scanner and scan bodies in the laboratory. [12,!3]

Moreover, Indirect digital impression workflow using laboratory or desktop scanners can be used. This method utilises either direct impression scanning or scanning of the resultant stone cast representing the edentulous dental arch. It has the ability to build an object digitally from the data collected from the 3D point digital coordinate system. The main drawback of indirect digital impression workflow using desktop scanners is the dimensional changes that occur during impression material setting and the accuracy of the final stone cast , the risk of displacement of the impression material from the special tray, dimensional changes that occur during impression disinfection and patient dissatisfaction if there is a need to retake the impression. [14-15]

Direct digital impression workflow involves the use of intraoral scan bodies (ISBs) and an intraoral scanner (IOS) to obtain an optical scan derived directly from the perspective patient's mouth. [13]

Direct Digital impression eliminates the errors with the conventional impression technique and pouring stone casts where there is no need for tray selection and where we can avoid dimensional change resulting from the impression material polymerization during setting, disinfection, and while shipping to the lab. One of the greatest benefits of digital direct impression technique is the patient comfort and avoiding gag reflex that may occur with conventional impression technique and an additional advantage is the ability to send and store direct digital impression data electronically. [16]

One of the main keys for successful direct digital impression technique using intra oral scanners is the use of scan bodies but there are many challenges associated with the full arch scanning as limited reference points and the absence of anatomic irregularities. Besides, intra oral scanners can't distinguish the multiple scan bodies because of their identical cylindrical geometry when using them to record an accurate digital impression which produces some errors in 3D visualization and mathematical interpretation. So the scanner can confuse the different scan bodies, interpreting them as only one. [17,18]

The splinting during impression procedure either for transfer coping in conventional impression technique or for scan bodies in digital intra oral impression workflow improves the accuracy of the impression. [19]

In conventional impression technique, splinting of the transfer copings helps increase their inherent stability. This is useful initially on taking the impression and later during the fabrication of the final model. Moreover, splinted impression copings aid in the verification of the passive fit. They may also be used in the fabrication of the control model along side with the digital impressions. Lastly, splints can be used as a reliable reference in conventional and digital studies investigating impression accuracy. In digital intra oral impression technique splinting of scan bodies increases the overall accuracy of the digital impression. [20-24]

With the appearance of new methods of different data acquisition, it is necessary to research the accuracy of each one; to obtain the highest degree of passive fit in the final prosthesis, so the question was which one is most accurate and does splinting affect the overall accuracy of conventional and digital techniques?.

The null hypothesis of this study is that there is no difference in the accuracy of different digital data acquisition work flows used for full arch maxillary implant prostheses.

MATERIALS AND METHODS

Model data collection and virtual master model designing and fabrication.

Scanning of the educational upper completely edentulous epoxy model was done using a desktop scanner to obtain STL file of the virtual epoxy model the sites of the five implants were virtually planned using DDS pro software (Czestochowa, Poland) where five virtually planned parallel holes equally distributed were done with two at the premolar region, two at the canines and one at the midline for manual insertion of implants (3.7mm in diameter x 10.5mm in length j dental evolution). They were named respectively A, B, C, D and E. The design was exported to Exocad soft ware (Exocad GmbH, Darmstadt, Germany) to manufacture the master model. The exported digital file was converted to STL format. The file was then printed to obtain the physical master model.

Implant insertion

Implants drilling was done sequentially in the printed master model according to the manufacturer's instructions .

Resin debris was removed by water irrigation inorder to assure that the implant reaches the planned depth. A 35Ncm primary stability was achieved by dipping the implant in freshly mixed resin then attaching the implant to the hand piece implant carrier to firmly attach the implant to the printed model.

Scan body attachment and reference master model scanning

Scan bodies were securely attached to the implants and screwed into place at a 10 N/cm torque then scanned using an industrial scanner (Atos core 2005m, GOM GmbH, Braunshweig, Germany) to be used as a reference for the comparative analysis to the other casts. Fig (1)

Grouping of the study groups:

Four groups were included in this study,Pentamix: conventional impressions were taken by vinyl poly siloxane silicone VPS (Pentamix), Identium: impressions were taken by vinylsiloxanether (VSE Identium), Trios : intra oral scanning (IOS) was done using Trios 4 after attaching the scan bodies and Primescan: intra oral scanning was done using Primescan after attaching the scan bodies. Each group was further divided into splinted and non-splinted.

Pentamix and Identium Non splinting groups

Open top tray impression copings were attached to the implants with a 10 N/cm torque ratchet. Then, two impressions were made without splinting. The first one using vinylsiloxanether (VSE Identium kettenbach Gmbh, Eschenburg, Germany) and the second using polyvinylsiloxane (PVS Pentamix, 3M ESPE, Seefeld, Germany), and were left to set according to the manufacturer's instructions under 50 n/cm vertical load using the universal testing machine to ensure seating load standardization.

After the impressions were set, the copings were unfastened. Removal of the tray was accomplished in a vertical direction with the impression copings embedded in the impression. The implant analogues were then fastened. The impressions were then poured using type IV dental stone, with a constant water powder ratio. After two hours, the casts were separated from the impressions and were accuratly coded for future measurements.

The non-splinted scan bodies were attached to the casts which were scanned 12 times using industrial scanner (Atos core 2005m, GOM GmbH, Braunshweig, Germany). Fig. (2) to ensure standerdisation of the procedure the same operator conducted all of the laboratory steps.

Pentamix and Identium Splinting groups

This procedure was repeated after splinting of the implants using Duralay self -cure acrylic resin. The casts were also marked for future measurements and scanned 12 times for each group using industrial scanner (Atos core 2005m, GOM GmbH, Braunshweig, Germany) with a total of forty eight scans.fig (3)

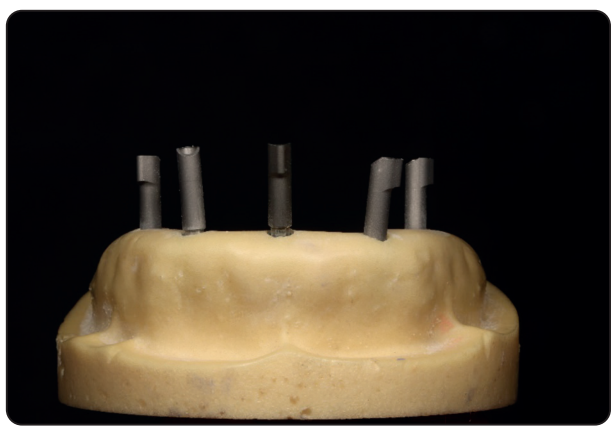
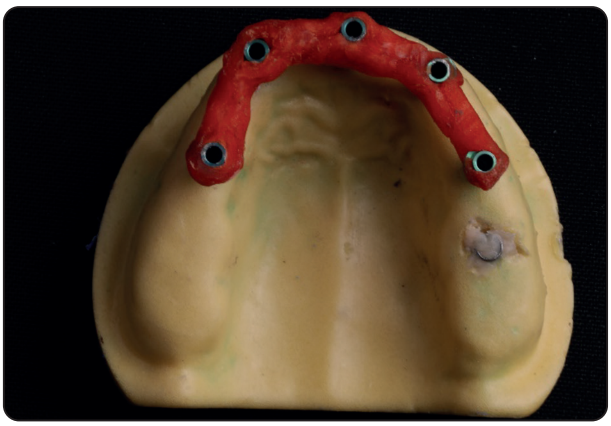


Fig. (1) Scan bodies attached to maxillary resin cast with five implants

Fig. (2) Scan bodies attached to the implant analogues to be scanned



Fig, (3): Five splinted transfer implant analogue for open top impression technique

Primescan and Trios 4 non splinting and splinting groups

For the digital scan, scan bodies were fastened at a 10 N/cm to the implants in the resin upper educational model and scanned by 2 different intraoral scanners in accordance with the manufacturer's instructions before and after splinting. Fig (4) The scans were obtained by Primescan (Dentsply Sirona, Erlangen, Germany) and Trios 4 (3 shape dental system, Copenhagen, Denmark). The scan bodies were splinted and the scans were repeated by the use of both the scanners. The model was scanned 12 times for each group with a total of forty eight scans.

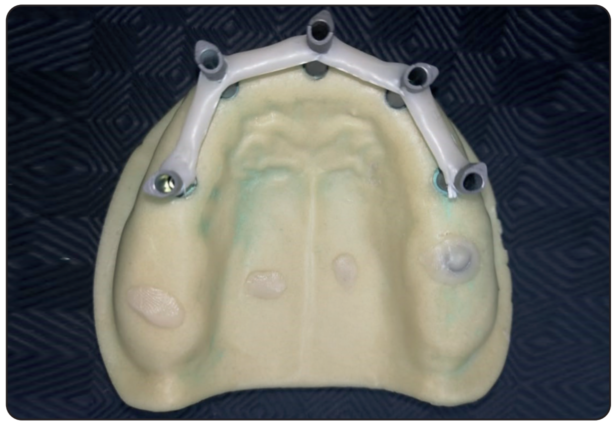


Fig. (4) Five scan bodies attached to the five implants in the upper resin maxillary model

Accuracy measurement

To measure the accuracy the scans were saved in an STL format fig (5,6) then all the virtual models were superimposed on the reference model using Geomagic software (geomagic Qualify 2013, Geomagic, Morrisville NC, USA). The best fit feature was then used in the superimposition of the reference scan on the other scans. The implant orifices served as easy assembly points. Horizontal deviation was detected at 8 points around the orifices of the implants using the software 3D compare feature,

After this step color maps that represented 0.1 mm positive or negative deviation were used to reflect any possible deviation between the two scans. fig. (7) The obtained results were represented in RMS which is calculated by the superimposition of two scans and the square phase difference at the assigned points was calculated. The total of these represented squares was calculated and then divided by the total number of points to obtain the RMS.

Statistical methodology and sample size

Data were analyzed using R statistical analysis software version 4.1.3 for Windows Shapiro-Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test that revealed significance level set at $p<0.05$ within

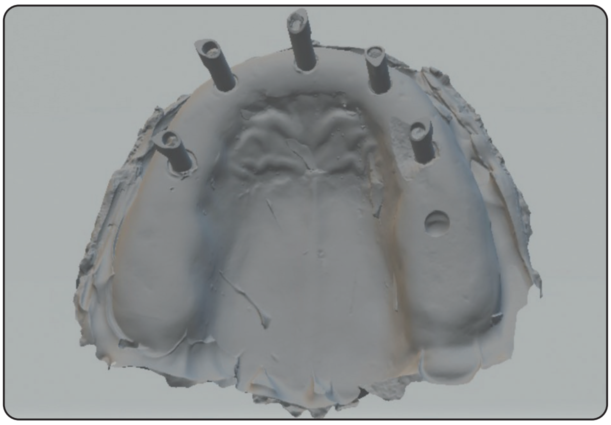


Fig. (5) STL file for pentamix and identium groups

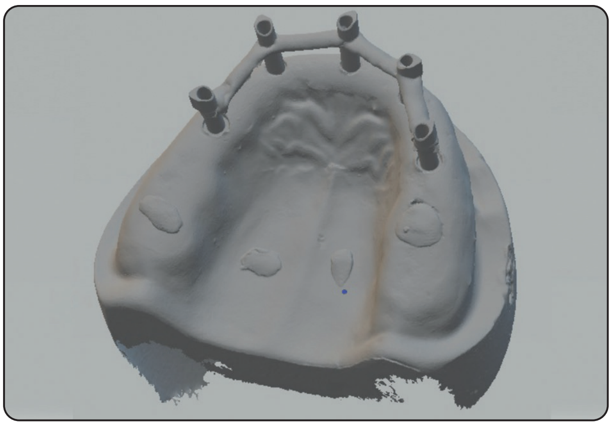
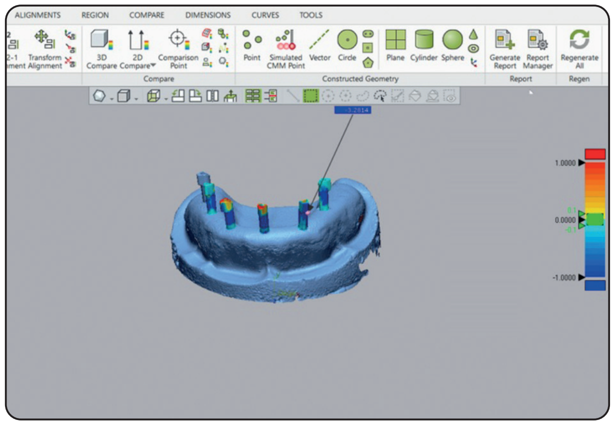


Fig (6) STL file of splinted scan bodies attached to the implants in resin model

all tests. Data showed parametric distribution and variance homogeneity and were analyzed using two-way mixed model ANOVA followed by estimated marginal means comparisons using t-test with p-value adjustment using Tukey's method.

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between tested groups regarding accuracy. By adopting an alpha (α) level of (0.05), a beta (β) of (0.2) (i.e. power=80%) and an effect size (f) of (1.36) calculated based on the results of a previous study [25] the minimum required sample size (n) was found to be (24) samples (i.e. 3 samples per group).



Fig, (7) Color mapping for accuracy using geomagic control X software

RESULTS

Two-way mixed model ANOVA test showed that there was a significant interaction between acquisition technique (conventional impression technique and IOS technique) and between splinting and non-splinting technique with ($p<0.001$). Comparisons of estimated marginal means for acquisition technique presented in table (1) showed that for splinted samples, in conventional impression techniques (i.e. Pentamix and Identium) had significantly higher values than digital scanning techniques ($p<0.001$). However, the differences between both conventional impression techniques (i.e. Pentamix and Identium) was ($p=0.635$) and both digital IOS techniques was ($p=0.989$) which were statistically insignificant. For non-splinted samples, comparisons showed Identium to have significantly higher value than other techniques with ($p<0.001$) while comparing Pentamix with the two IOS the differences between them was statistically insignificant ($p>0.05$). Comparisons of marginal means for the effect of splinting presented in table (2) showed that within all techniques, non-splinted samples had significantly higher values than splinted ones ($p<0.001$). Mean and standard deviation values for RMS are presented in figures (8) .

TABLE (1) Comparison of estimated marginal means for the effect of acquisition technique

Splinting	Contrasts	EMM difference	95% CI		t-value	p-value
			Lower	*Upper*		
	Pentamix - Identium	-0.05	-0.18	0.07	-1.20	**0.635**
	Pentamix - TRIOS	0.41	0.28	0.53	8.85	**<0.001***
	Pentamix - Primescan	0.39	0.27	0.52	8.53	**<0.001***
	Identium - TRIOS	0.46	0.33	0.59	10.04	**<0.001***
	Identium - Primescan	0.45	0.32	0.57	9.73	**<0.001***
	TRIOS – Primescan	-0.01	-0.14	0.11	-0.32	**0.989**
	Pentamix - Identium	-0.45	-0.58	-0.33	-9.89	**<0.001***
	Pentamix - TRIOS	-0.01	-0.14	0.12	-0.23	**0.996**
	Pentamix - Primescan	-0.09	-0.22	0.04	-1.96	**0.232**
	Identium - TRIOS	0.44	0.32	0.57	9.66	**<0.001***
	Identium - Primescan	0.36	0.24	0.49	7.93	**<0.001***
	TRIOS – Primescan	-0.08	-0.21	0.05	-1.73	**0.331**

EMM= Estimated marginal means, CI= confidence interval,*significant (p<0.05)

TABLE (2) Comparison of estimated marginal means for the effect of splinting

Technique	Contrasts	EMM difference	95% CI		t-value	p-value
			Lower	*Upper*		
		-0.05	-0.07	-0.03	-5.12	**<0.001***
Identium		-0.45	-0.47	-0.43	-48.61	**<0.001***
TRIOS		-0.46	-0.48	-0.44	-50.53	**<0.001***
Primescan		-0.53	-0.55	-0.51	-57.61	**<0.001***

EMM= Estimated marginal means, CI= confidence interval,*significant

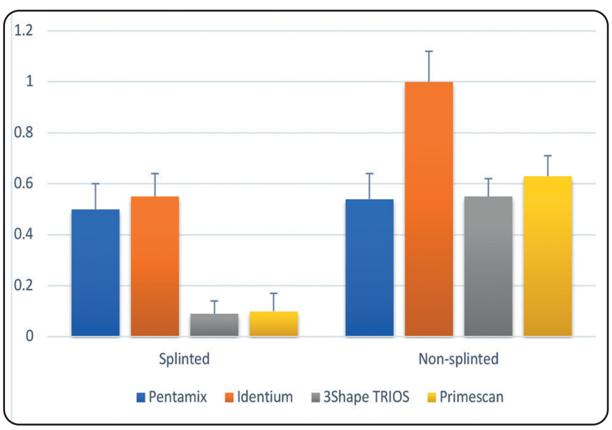


Fig. (8) Bar chart showing mean and standard deviation values for the root mean square RMS (mm) with in splinting and non splinting in the two studied groups conventional impression techniques and intra oral scanner technique

DISCUSSION

Oral rehabilitation of patients with implant especially full arch rehabilitation and their longitudinal effectiveness is affected by passive fit. Long term implant supported prosthesis success depends on the implant impression precision. Impression precision directly relies on two essential factors, the impression material being used and the impression technique. (26)

The quality of the digital scans relates to the ultimate fit of the final prosthesis. Therefore, accuracy is important. The known threshold for prosthesis misfit is considered to be 150 mm generally. This average assures no clinical complications are encountered. (27,28-30)

Regarding to this study findings the acquisition technique IOS showed better accuracy and trueness in compare to conventional impression technique which was matching to the finding in other in vitro and in vivo comparative studies that reported that several conventional and digital impressions taken with variable IOS systems differ significantly in the accuracy. (16,31 ,32)

Digital IOS acquisition technique gave many advantages in comparison to conventional impression technique as increased patient comfort, convenience to the practitioner, the application of advanced technology, data storage and a time savvy digital prosthetic work flow. (28) In study by **Gherlone et al.** reported that the digital impression technique significantly saved time when compared to the conventional impression technique (7:57 ±3:08 versus 18:23 ±5:38 minutes). (33)

Other studies did not agree with the finding in this study where it was found that conventional impression techniques were more accurate than IOS technique. These studies have observed that the digital workflow for data acquisition comes with its own challenges which are usually related to the operator's skill and experience. A previous study conducted by **Giménez et al.** observed that each practitioner has a unique learning curve and a lot of practice is needed to make or reproduce accurate intraoral scans by the use of digital impression making technique. (34,35)

Results of this study showed that splinting in the two acquisition techniques showed better accuracy than non-splinting. But splinting was critical for the conventional impression technique as splinting of transfer coping showed increased accuracy. As many studies considered that the gold standard to prevent the movement of the impression coping which can lead to distortion of the final impression was splinting. Splinting has also been proved to eliminate errors occurring during the setting of the impression material resulting in less dimensional changes thus ensuring the master cast accuracy. (36,37)

Splinting of the scan bodies with the two scanners used with IOS technique in this study was not essential as in conventional impression technique. IOS may be divided into four different types according to the optical method that is used to capture data. Optical coherence tomography, confocal microscopy, active wavefront sampling and active triangulation, are the most common utilized techniques. (38)

Intra oral scanners in this study were the trios and primescan that showed high accuracy in compare to other available IOS as CEREC omnicam. As both IOS trios and primescan are based on confocal capturing technology while CEREC Omnicam is based on active triangulation technology. (38-39)

However implant supported prosthesis in completely edentulous cases have some challenges as the scanned surface lacks reference points between point clouds of scan bodies which produces improper stitching of the images with compounding errors including imprecise and noisy mesh. In completely edentulous arches one of the biggest challenges is that the large scanned surface area which can lead to angulation errors. These errors lead to an increase in the risk of accumulation of registration errors in the patched 3D surfaces, especially in the edentulous mandible when compared to dentate arches. So splinting of scan bodies is highly recommended during using IOS to decrease such error. (28,40,41)

Regarding the result of non-splinting in the two data acquisition techniques, the two intra oral scanners and PVS showed more accuracy than VSE. As VSE showed more dimensional change in comparison to PVS while intra oral scanner eliminated any change for dimensional change as no impression material is used. **Techkouhie A et al.** suggested that non splinted PVS has the smallest change (–0.15%), followed by polyether (–0.2%). The vinyl siloxane ethers (VSE) have a dimensional change of ≈ –0.2% which is still acceptable. (42,43)

As to the use of VSE it has been proven useful in the impression procedures of prepared teeth to manufacture fixed prosthodontics. When used for this procedure it has proved to have a superior tensile strength in comparison to polyether or PVS. Its high flow ability along with its high tensile strength makes it a good candidate for recording finish lines and narrow crevicular preparation areas. But the precision of implant impressions does not seem to benefit from this property due to the absence of specific finish line. (26)

CONCLUSION

Within the limitation of this study splinting of scan bodies is essential to manage stitching error that occurs with IOS to provide more accurate results with passive fit and for the elimination of inaccuracy related to dimensional changes in conventional impressions. The accuracy value of intra oral scanners is near zero as it eliminates the inaccuracy occurring due to dimensional changes occurring in the used materials.

REFERENCES

1. Herbst D, Nel JC, Driessen CH, Becker PJ. Evaluation of impression accuracy for osseointegrated implant supported superstructures. The Journal of prosthetic dentistry. 2000 May 1;83(5):555-61.
2. Mizumoto RM, Yilmaz B, McGlumphy EA, Seidt J, Johnston WM. Accuracy of different digital scanning techniques and scan bodies for complete-arch implant-supported prostheses. J Prosthet Dent. 2020;123(1):96–104.
3. Papaspyridakos P, Hirayama H, Chen CJ, Ho CH, Chronopoulos V, Weber HP. Full-arch implant fixed prostheses: a comparative study on the effect of connection type and impression technique on accuracy of fit. Clinical oral implants research. 2016 Sep;27(9):1099-105.
4. Lee H, So JS, Hochstedler JL, Ercoli C. The accuracy of implant impressions: a systematic review. The Journal of prosthetic dentistry. 2008 Oct 1;100(4):285-91.
5. Alikhasi M, Siadat H, Rahimian S. The effect of implant angulation on the transfer accuracy of external-connection implants. Clinical implant dentistry and related research. 2015 Aug;17(4):822-9.
6. Aguilar ML, Elias A, Vizcarrondo CE, Psoter WJ. Analysis of three-dimensional distortion of two impression materials in the transfer of dental implants. The Journal of prosthetic dentistry. 2010 Apr 1;103(4):202-9.
7. Flügge T, van der Meer WJ, Gonzalez BG, Vach K, Wismeijer D, Wang P. The accuracy of different dental impression techniques for implant-supported dental prostheses: A systematic review and meta-analysis. Vol. 29, Clinical Oral Implants Research. 2018. p. 374–92.
8. Khan SA, Singh S, Neyaz N, Jaiswal MM, Tanwar AS, Singh A. Comparison of dimensional accuracy of three different impression materials using three different techniques for implant impressions: An in vitro study. The Journal of Contemporary Dental Practice. 2021 Feb 1;22(2):172-8.
9. Enkling N, Bayer S, Jöhren P, et al. Vinylsiloxanether: a new impression material. clinical study of implant impressions with vinylsiloxanether versus polyether materials. Clin Implant Dent Relat Res 2012;14(1):144–51. DOI: 10.1111/j.1708-8208.2009.00240.x
10. Gupta S, Narayan AI, Balakrishnan D. In Vitro Comparative Evaluation of Different Types of Impression Trays and Impression Materials on the Accuracy of Open Tray Implant Impressions: A Pilot Study. Int J Dent. 2017;2017:6306530. DOI: 10.1155/2017/6306530.

11. 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):149–157. DOI: 10.11607/jomi.2070.

12. Rudolph H, Salmen H, Moldan M, Kuhn K, Sichwardt V, Wöstmann B, Luthardt RG. Accuracy of intraoral and extraoral digital data acquisition for dental restorations. Journal of Applied Oral Science. 2016 Jan;24:85-94.

13. Güth JF, Keul C, Stimmelmayr M, Beuer F, Edelhoff D. Accuracy of digital models obtained by direct and indirect data capturing. Clin Oral Investig. 2013;17(4):1201–8.

14. Mandelli F, Gherlone E, Gastaldi G, Ferrari M. Evaluation of the accuracy of extraoral laboratory scanners with a single-tooth abutment model: A 3D analysis. J Prosthodont Res. 2017 Oct;61(4):363–70.

15. Ellakany P, Tantawi M El, Mahrous AA, Al-Harbi F. Evaluation of the Accuracy of Digital Impressions Obtained from Intraoral and Extraoral Dental Scanners with Different CAD/CAM Scanning Technologies: An In Vitro Study. J Prosthodont. 2022 Apr;31(4):314–9.

16. Amin S, Weber HP, Finkelman M, El Rafie K, Kudara Y, Papaspyridakos P. Digital vs. conventional full-arch implant impressions: A comparative study. Clinical oral implants research. 2017 Nov;28(11):1360-7.

17. Andriessen FS, Rijkens DR, Van Der Meer WJ, Wismeijer DW. Applicability and accuracy of an intraoral scanner for scanning multiple implants in edentulous mandibles: A pilot study. J Prosthet Dent. 2014 Mar;111(3):186–94.

18. 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. J Prosthet Dent. 2013;109(1):52.

19. Rutkunas V, Bilius V, Simonaitis T, Auskalnis L, Jurgilevicius J, Akulauskas M. The effect of different implant impression splinting techniques and time on the dimensional accuracy: An in vitro study. Journal of Dentistry. 2022 Nov 1;126:104267.

20. 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. The Journal of Contemporary Dental Practice. 2018 Aug 1;19(8):1005-12.

21. De Avila ED, de Matos Moraes F, Castanharo SM, Del'Acqua MA, de Assis Mollo Jr F. Effect of splinting in accuracy of two implant impression techniques. Journal of Oral Implantology. 2014 Dec;40(6):633-9.

22. Filho HG, Mazaro JV, Vedovatto E, Assunçao WG, Santos PH. Accuracy of impression techniques for Impants. Part 2–comparison of splinting techniques. Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry. 2009 Feb;18(2):172-6.

23. Elshenawy EA, Alam-Eldein AM, Abd Elfatah FA. Cast accuracy obtained from different impression techniques at different implant angulations (in vitro study). International journal of implant dentistry. 2018 Dec;4(1):1-9.

24. Soares CJ, RODRIGUES MD, VILELA AB, PFEIFER CS, TANTBIROJN D, VERSLUIS A. Polymerization shrinkage stress of composite resins and resin cements– What do we need to know?. Brazilian oral research. 2017 Aug 28;31.

25. Imburgia M, Logozzo S, Hauschild U, Veronesi G, Mangano C, Mangano FG. Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study. BMC oral health. 2017 Dec;17:1-3.

26. Tabesh M, Alikhasi M, Siadat H. A comparison of implant impression precision: Different materials and techniques. Journal of clinical and experimental dentistry. 2018 Feb;10(2):e151.

27. Papaspyridakos P, Chen C-J, Gallucci GO, Doukoudakis A, Weber H-P, Chronopoulos V. Accuracy of implant impressions for partially and completely edentulous patients: a systematic review. Int J Oral Maxillofac Implants. 2014;29:836-45.

28. Wulfman C, Naveau A, Rignon-Bret C. Digital scanning for complete-arch implant-supported restorations: A systematic review. The Journal of prosthetic dentistry. 2020 Aug 1;124(2):161-7

29. Jemt T, Lie A. Accuracy of implant-supported prostheses in the edentulous jaw: analysis of precision of fit between cast gold-alloy frameworks and master modelsby means of a three-dimensional photogrammetric technique. Clin Oral Implants Res 1995;6:172-80.

30. . Buzayan MM, Yunus NB. Passive fit in screw retained multi-unit implant prosthesis understanding and achieving: A review of the literature. J Indian Prosthodont Soc 2014;14:16-23.

31. Ender A, Attin T, Mehl A. In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. The Journal of prosthetic dentistry. 2016 Mar 1;115(3):313-20.

32. Ender, A. , Mehl, A. In-vitro evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence International 2015;46: 9–17.

33. Gherlone E, Capparé P, Vinci R, Ferrini F, Gastaldi G, Crespi R. Conventional versus digital impressions for "All-on-Four" restorations. Int J Oral Maxillofac Implants 2016;31:324-30.

34. Giménez B, Özcan M, Martinez-Rus F, Pradíes G. Accuracy of a digital impression system based on active wavefront sampling technology for implants considering operator experience, implant angulation, and depth. Clin Implant Dent Relat Res 2015;17 Suppl 1:e54-64.

35. Shaikh M, Lakha T, Kheur S, Qamri B, Kheur M. Do digital impressions have a greater accuracy for full-arch implant-supported reconstructions compared to conventional impressions? An in vitro study. The Journal of Indian Prosthodontic Society. 2022 Oct 1;22(4):398-404.

36. Öngül D, Gökçen-Röhlig B, Şermet B, Keskin H. A comparative analysis of the accuracy of different direct impression techniques for multiple implants. Australian dental journal. 2012 Jun;57(2):184-9.

37. Baig MR. Accuracy of impressions of multiple implants in the edentulous arch: a systematic review. Int J Oral Maxillofac Implants. 2014 Jul 1;29(4):869-0.

38. Yehia A, Abo El Fadl A, El Sergany O, Ebeid K. Effect of different span lengths with different total occlusal convergence on the accuracy of intraoral scanners. Journal of Prosthodontics. 2023.

39. Nulty AB. A comparison of full arch trueness and precision of nine intra-oral digital scanners and four lab digital scanners. Dent J. 2021;9:75.

40. Giménez, B.; Pradíes, G.; Martínez-Rus, F.; Özcan, M. Accuracy of two digital implant impression systems based on confocal microscopy with variations in customized software and clinical parameters. Int. J. Oral Maxillofac. Implant. 2015, 30, 56–64.

41. Huang R, Liu Y, Huang B, Zhang C, Chen Z, Li Z. Improved scanning accuracy with newly designed scan bodies: An in vitro study comparing digital versus conventional impression techniques for complete-arch implant rehabilitation. Clinical Oral Implants Research. 2020 Jul;31(7):625-33.

42. Balkenhol M, Wöstmann B, Kanehira M, Finger WJ. Shark fin test and impression quality: a correlation analysis. J Dent 2007; 35:409-415.

43. Shetty RM, Bhandari GR, Mehta D. Vinyl polysiloxane ether: a breakthrough in elastomeric impression material. World J Dent. 2014 Apr;5(2):134-7.