Section A-Research paper

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Comparison of Accuracy of Implant Casts Made Through Digital and Conventional Methods

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Objectives: To evaluate and compare dimensional accuracy of casts of implant supported complete denture prostheses obtained through digital means and conventional means

Methods: 4 implant analogues were placed in mandibular edentulous model. 10 casts for each groups were fabricated. Digital casts were fabricated using intra oral scanner and 3D printer. Conventional casts were fabricated by open tray splinted impression and pouring with die stone. Master model and all the obtained casts were digitised using lab scanner and the accuracy was measured digitally using Exocad software.

Conclusion: Both conventional open tray splinted impression technique and digital impression technique are acceptably accurate for fabrication of the prostheses. Both conventional cast pouring technique and digital 3D printing technique are acceptably accurate for fabrication of the prostheses.

Keywords: Implant impression, 3D printing, Digital workflow, Intra oral scanner, Lab scanner, Open tray impression.

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Introduction: Obtaining the exact replica of what is present in patient's mouth is one of the most important factor in fabrication of any prosthesis. In the past years many methods and techniques have been used for obtaining the accurate replica of the oral and extra oral tissues and in turn producing best results for prosthetics. This remains true for implant-supported prostheses, for which impression techniques have been directly adapted from traditional Prosthodontics. An essential first step in the fabrication process is the accurate three-dimensional (3D) capture and transfer of the implant position from the mouth to the definitive cast via an impression.[1].

The introduction of digital impressions using intra- oral optical scanner (IOS) into the fields of fixed and implant prosthodontics have achieved this goal. It carries advantages, of the eliminating of tray selection, reduces the risks of distortion while impression making, pouring cast, disinfection, and shipping to the laboratory. It has increased patient comfort and acceptance and finally electronic storage as digital information, leading to better efficiency and reduced cost[2].

Patients now demand timesaving and more comfortable treatment options. Intraoral scanning in association with computer-aided design and computer-aided manufacture (CAD-CAM) technology may optimize the treatment workflow by more comfort of the patient and accuracy comparable to the conventional treatment[3].

In recent years the digital workflow techniques are taking over the conventional techniques both for making impression and fabrication of the master cast. The introduction of high resolution intra oral scanners and technologies to convert the data into standard tessellation language format and then to mill or to print the accurate models or casts has made the process of obtaining the master cast much easier and less time consuming. In vitro studies showed a comparable level on accuracy and precision between conventional impression making procedures and different IOS systems for dentulous full arches[2-4].

Till now, the accuracy of the full arch of a stereolithographic model for implant treatment is not yet known. In the fabrication of implant supported dental prosthesis, there is need to check the dimensional accuracy of 3D printed casts as compared to stone casts fabricated using conventional impression techniques to determine if the former methods are truly superior to the latter conventional techniques[5].

Different techniques are used both in conventional and digital workflow techniques like in conventional splinting of impression copings, open tray vs closed tray techniques, different impression materials. In digital method many types of intra- oral scanners are

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available for obtaining data of the implants. Research on digital implant impressions is limited to a few case reports[6].

The currently existing studies compares the accuracy of partially edentulous implant casts obtained through digital workflow method versus conventional methods. There is a need to check the accuracy of completely edentulous implant casts fabricated using conventional and digital workflow method.

Methodology: Sample size was estimated from a study conducted by Bohner L et al titled: Accuracy of casts fabricated by digital and conventional implant impressions.
Sample size was calculated based on the dimensional accuracy between conventional casts and stereolithographic casts, using the following formula:

$$\mathbf{n = (Z_{\alpha/2}+Z_{\beta})^2 *2*\sigma^2 / d^2,}$$

$Z_{\alpha/2}$ = 1.96% at 95% confidence interval

Z_{β} = 2.33 at 99% power of the study

σ^2 = 1094.9629

d= 76

n = **6.97 = 7 per group**

Therefore, according to the N value obtained in the formula, the sample size estimated for the study was rounded off to 10 in each group.

All the steps involved in the study were performed by a single observer for avoiding the discrepancies caused by multiple observers.

Fabrication of master model (MM): A completely edentulous mandibular model was fabricated with four tissue level implants. A complete edentulous mandibular jaw model (Dentium MHMN M. Tech Korea. Co, Ltd) was used for fabrication of master model. Sequential osteotomy was performed (Ki AG20SAIYANG MICROTEC CO, LTD. Distributed by Dentium handpiece and WH 01 ICT motor Dentium CO, LTD dispenser). Four implant analogues [Dentium 4.0-10.0 mm FXS4010(D)] were placed in the model perpendicular to the base of the cast and parallel to each other at canine and molar regions(Fig. 1).

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Group 1: Conventional casts (CC): Acrylic custom trays were fabricated. Access hole for the impression copings were made at the area where implants were placed in the model. Modelling wax was used as spacer for fabrication of special trays. Open tray impression copings (Dentium DPU4511HE) were attached to the implant analogues. The four impression copings were splinted. First by joining them with the dental floss (Thermoseal ICPA) and then applying self cure pattern resin on it (GC CORPORATION TOKYO JAPAN). Once the resin set the resin splint was sectioned in-between each implant and again the pattern resin was applied to re-join the splint to compensate for polymerisation shrinkage of resin (Fig. 2).

Tray adhesive (3M VPS Tray adhesive 3M Deutschland GmbH)was applied on to the custom tray. Using open tray impression technique, the light body (Variotime EN ISO 4823, type 3, light Kulzer GmbH Leipziger Strabe 2 63450 Hanau Germany) was placed on the impression copings and the mixed putty material (Variotime EN ISO 4823, type 0, putty Kulzer GmbH Leipziger Strabe 2 63450 Hanau Germany) was loaded to the custom tray and the impression was made. Once the material completely set the impression copings were unscrewed and the impression was retrieved. The lab analogues (Dentium DAN38)were attached to the impression copings and the cast was poured with type 4 high strength low expansion die stone(Gem Stone SHRUTHI PRODUCTS)(Fig.3 and Fig.4).

Fig 1: Edentulous mandibular jaw model

Fig. 2: Splinting of impression copings

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Fig. 3: Lab analogues attached

Fig. 4: Conventional casts (CC) to the impression

Group 2: Digital Model (DM): Scan bodies (Dentium4847) were placed on the implants of the master model (MM). 10 digital impressions of the master model were made using intra oral scanner (Dentsply Sirona Primescan AC) (Fig. 5) and the data was exported in standard tessellation language (STL) format for 3D printing digital model (DM). From the obtained STL data ten 3D casts were printed using 3D printing machine with resin (SHINING3D and Hangzhou SHINING 3D Dental Technology Ltd Dental Model Resin) (Fig. 6).

Fig. 5: Scanning with intra oral scanner

Fig. 6: 3D printed digital models (DM)

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Digitalization of the casts: All the 3D print casts (DM), the master model (MM) and the stone casts (CC) were digitalized by scanning them with a high accuracy extra oral scanner. It will record the position of the scan body on the cast and the scanned data is used to know the position of the implant using software (Fig. 7).

Fig.7: Extra oral scanner

STL superimposition procedure: Dimensional accuracy of the cast produced was compared between the groups digitally (Dental CAD 3.0)at implant tip level (TL) and abutment head level (HL) (Fig.8, Fig.9 and Fig 10).

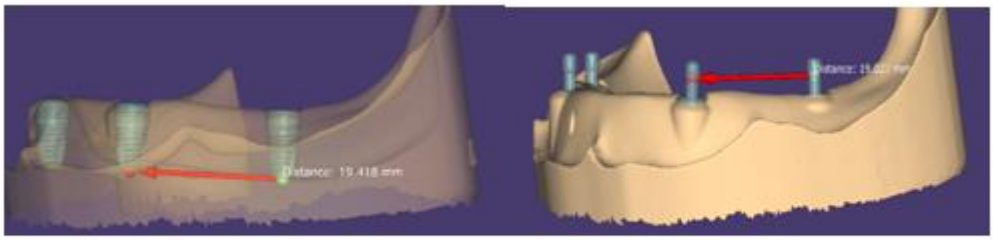

Fig.8: CAD software linear measurement of TL and HL.

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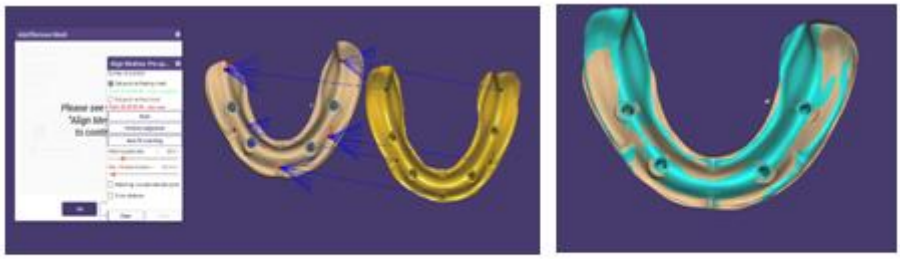


Fig.9: CAD softwaresuperimpositions of scan data of all models (MM, CC, DM)

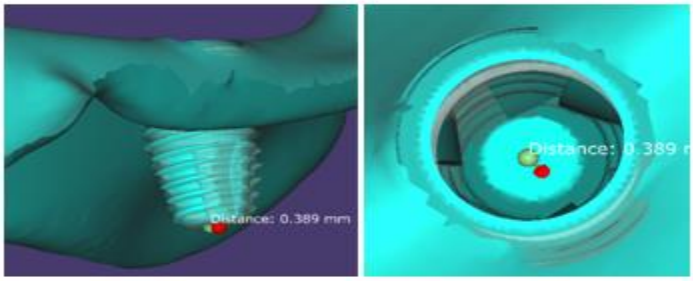
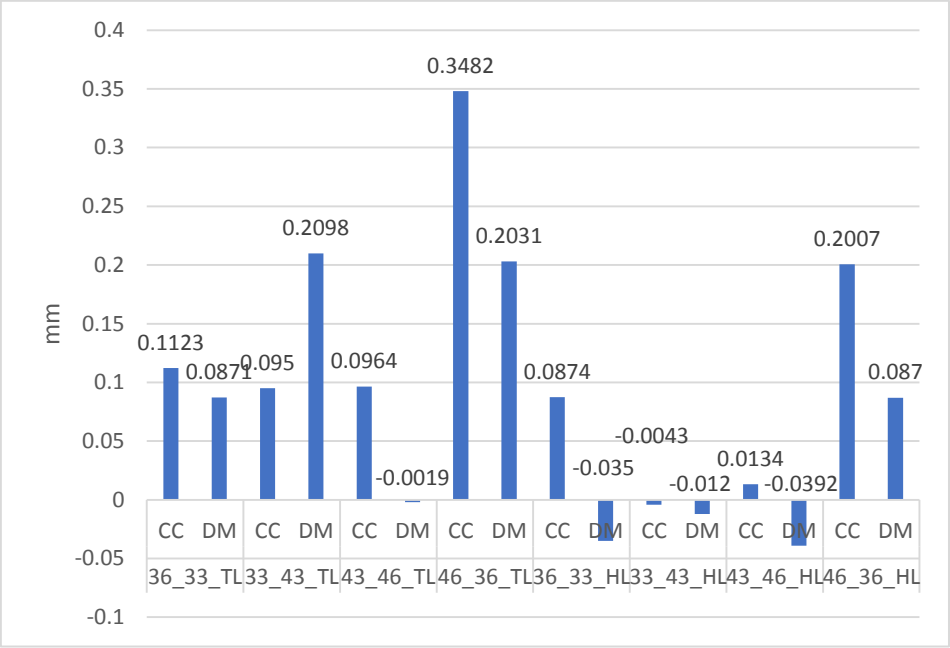


Fig. 10: CAD software deviation measurement at TL point after superimposition of two scan data.

Results: The data was collected, coded and fed in SPSS for statistical analysis. The level of significance was set at 0.05 at 95% confidence interval.



Graph 01: Mean of the difference in the various measurement of CC (conventional cast) and DM (digital model).

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Table 02: Table showing the comparison of different measurements between CC and DM

Tooth Region and levels	Group	Mean	Std. Deviation	t	Df	Sig. (2-tailed)
36_33_TL	CC	.1123	.07101	.410	18	.686
	DM	.0871	.18077			
33_43_TL	CC	.0950	.09120	-1.273	18	.219
	DM	.2098	.27009			
43_46_TL	CC	.0964	.12147	1.157	18	.262
	DM	-.0019	.23960			
46_36_TL	CC	.3482	.11881	3.068	18	.007
	DM	.2031	.09083			
36_33_HL	CC	.0874	.05247	3.446	18	.003
	DM	-.0350	.09930			
33_43_HL	CC	-.0043	.09731	.105	18	.918
	DM	-.0120	.21140			
43_46_HL	CC	.0134	.05641	1.828	18	.084
	DM	-.0392	.07138			
46_36_HL	CC	.2007	.09450	2.718	18	.014
	DM	.0870	.09256			

Inspection of QQ plot revealed that all the measurements in the CC and DM groups was normally distributed and that there was homogeneity of variance as assessed by Levene's test for equality of Variances. Therefore, an independent T test was run on the data with the 95percentage confidence interval. It was found that the following measurement showed significant difference between the CC and DM group.

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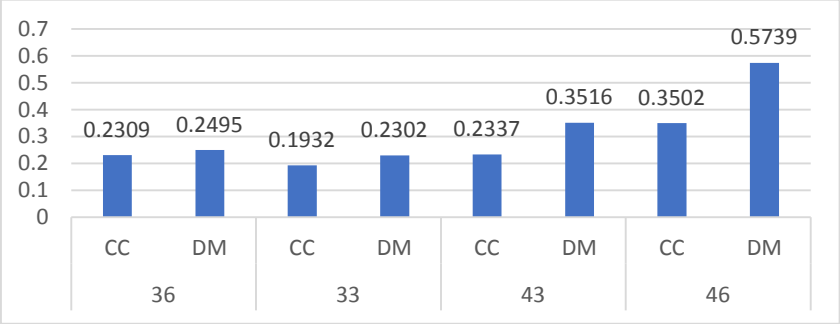

Graph 3: Mean measurements at implant site in CC and DM

Table 4: Table comparing the mean measurement at implant site between CC and DM

Tooth region	Group	Mean	Std. Deviation	t	df	Sig. (2-tailed)
36	CC	.2309	.10585	-.345	18	.734
	DM	.2495	.13357			
33	CC	.1932	.05657	-.643	18	.528
	DM	.2302	.17283			
43	CC	.2337	.09536	-1.393	18	.180
	DM	.3516	.25000			
46	CC	.3502	.21570	-2.792	18	.012
	DM	.5739	.13297			

Inspection of QQ plot revealed that all the measurements in the CC and DM groups was normally distributed and that there was homogeneity of variance as assessed by Levene's test for equality of Variances. Therefore, an independent T test was run on the data with the 95 percentage confidence interval. It was found that the following measurement showed significant difference between the CC and DM group.

Discussion: In implant supported prosthesis, misfit of prosthesis, which may lead to biological and/or mechanical complications can be caused by an inaccurate impression. Screw loosening, implant fracture, screw fracture, and occlusal inaccuracy are the reported mechanical complications arising due to prosthesis misfit. Other biological complication may

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also be seen due to plaque accumulation in case of prosthetic misfit. While there is some evidence that prosthesis mismatch may not influence osseointegration, there is also evidence that it is more likely to cause mechanical complications like component fracture or loosening[7]. Regarding material of choice, studies suggest that in case of parallel implants both polyether and polyvinyl siloxane yielded no significant difference. But for nonparallel implants, polyvinylsiloxane yielded better results[8]. In this study polyvinylsiloxane elastomeric impression material was used.

Implant impressions can be made either by closed tray/indirect technique or open tray/direct technique. Studies suggest that direct/open tray techniques result in more accurate impressions. The impression coping design for both the techniques are usually different. In direct impression technique the impression copings are placed on implants, tightened, and impression material is loaded into the tray and the tray is placed in mouth. Once the material sets the impression coping screws are unscrewed and picked up in the impression[7].

The accuracy of the impression also depends on number of implants and angulation between implants. Some studies have shown that the better accuracy of direct implant impression technique is seen mainly in case of multiple implants where there are more than 3 implants[7]. The studies also suggest that use of custom trays result in more accurate impressions than use of stock trays for open tray impression techniques. This could be due to closer adaptation of the tray and also could be due to optimum space for impression material[9]. In this study open tray splinting technique was used and impression was made using custom fabricated acrylic tray as the model was completely edentulous and had 4 implant analogues.

In presence of multiple implants, the implant impression copings can be splinted together before making direct impressions. Many methods are available for splinting the impression copings. The most commonly used method is the splinting of impressions copings using acrylic resins. In the cases where inter implant distance is more, like that of in complete edentulous arches, initially dental floss is used to splint impression copings over which acrylic resin is applied and cured. After resin sets, to compensate for polymerisation shrinkage the splint joint is sectioned and it is again joined. The reason for better accuracy in splinted impressions is that during attachment of lab analogues or abutments splinting prevents the movement of the impression copings[10]. Multiple implants placed which are non-parallel to each other prevents splinting of implants if the angulation is more than that the path of insertion of impression copings permit[11]. In open tray technique, the error may be during removal of impression and during attachment of lab analogues. Splinting of

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impression copings were done in this study to minimise the displacement of the impression copings and resin was used to splint and it was sectioned and re-attached to compensate for polymerisation shrinkage.

Digitization can be done either by intra oral scanning or by scanning the impression or by scanning the stone model[12]. For obtaining the cast in digital workflow method, either additive manufacturing i.e., 3D printing can be used or subtractive manufacturing i.e., milling can be done[13]. The prosthesis fabrication can be planned directly using the software or on the models obtained by prototyping like 3D printing. In this study digitization of the master model was done using intra oral scanner and the prototype was obtained using 3D printing of the scanned data.

The digital workflow techniques have demonstrated satisfactory results. The digital workflow is also superior with respect to patient comfort and doctor's convenience[9]. The accuracy of the impression or the prostheses produced also depends on the type of scanner or software or prototyping or milling system used[14,15]. In the current study the STL (Standard Tessellation Language) data obtained from intra oral scanner was 3D printed using DLP (Digital Light Processing) method. The lab scanner used for digitization of the casts for measuring the accuracy uses surface powder for scanning. The 3Shape E1 lab scanner used here works on structured light.

The success of implant supported prostheses rehabilitation can be measured under four categories. i.e., a) longevity and survival, b) physiological impact, c) psychological effect and d) economic factors. The digital workflow is advantageous in patient's and doctor's perspective. It avoids steps like impression making, disinfection, cast pouring and other manual laboratory procedures. It also avoids chance of patient risk factors like gagging, cross infection and extra appointments[4]. As the number of steps involved increases, the chances for error, duration of treatment and cost of the treatment also increases.

The steps that would have caused discrepancy from master model to study model in digital group could be improper placement of scan bodies on the master model, improper scanning using intraoral scanner and improper placement of the digital analogues in the 3D printed model. But all these steps are not very technique sensitive. The reminder of the possibilities of error in digital workflow lies on the accuracy or the precision of the scanner and the 3D printer. Recent advances have led to the innovation or development that has ruled out the chances of such errors. When it comes to conventional method, the error can be in attaching the impression copings to implant analogues, splinting the impression copings,

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making the impression, retrieval of tray from mouth, attachment of lab analogues to impression copings, pouring of casts and retrieval of casts. In the accuracy check, 3 linear measurements showed significantly better precision of inter implant distance for 3D printed casts. In deviation only one implant position was significantly deviated in 3D printed casts. Overall accuracy of casts for fabrication of prosthesis were within the acceptable value for both the types of workflow. Considering the facts that in digital workflow the time required, the material required, the steps involved and the patient comfort are superior to that of conventional method, digital workflow is promising for future. Meanwhile availability of the equipment like scanners and 3D printers are the limitations of this method. More availability and use of universal components like scan bodies can further increase the easiness to use and popularity of digital workflow.

Limitations of the study is that, it was an in-vitro study and there might be slight differences in real patient scenarios. In this study only one conventional impression technique and material was compared with digital techniques using one scanner and one 3D printer. Also only complete edentulous mandibular cast for fixed implant supported prosthesis was compared. Further studies can be done using different scanners, printing technologies and impression materials to know the different outcomes.

Conclusion: From this in vitro study it can be concluded that

a) Both conventional open tray splinted impression technique and digital impression technique are acceptably accurate for fabrication of the prostheses.
b) Both conventional cast pouring technique and digital 3D printing technique are acceptably accurate for fabrication of the prostheses.
c) Considering the patient and doctors comforts digital workflow is advantageous over conventional workflow.

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