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Effect of digitized conventional versus digital impression on telescopic prosthesis fit passivity (invitro study)

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ABSTRACT
Background: For the creation of implant prostheses with passive fit, an accurate implant imprint is a crucial need. In order to record the position of four parallel implants, this in vitro investigation compared the accuracy of digital impressions taken by laboratory scanner systems to open tray conventional impressions (splinted and non-splinted) by the use of PVS impression material. **Methods:** Total of three edentulous 3D-printed casts was made with 4 virtually designed parallel rooms to receive 4 parallel implants with telescopic abutments. After printing, each implant was installed in one of the 4 virtually designed parallel rooms to ensure parallelism of all 4 implants, installed in canine and premolar areas bilaterally. A total of 60 Co/Cr frameworks were fabricated by CAD/CAM milling. In each group 20 Co/Cr frameworks were fabricated by conventional non-splinted open tray implant level impression (G1: NSOTI), conventional splinted open tray implant level impression (G2: SOTI), or digital impression using laboratory scanner (G3: DI). The fitting surfaces of 20 Co/Cr milled frameworks in each group were scanned by laboratory scanner and the STL files of the 20 impressions were used to evaluate the passive fit of all frameworks by superimposition. **Results:** Digital impressions generally tended to yield more accurate results for linear deviation. The splinted conventional imprint and the digital impression showed no significant difference regarding the linear deviation. The accuracy of the splinted conventional impressions was significantly higher than that of the non-splinted conventional impressions. Moreover, the accuracy of the digital impressions was significantly higher than that of the non-splinted conventional impressions. Furthermore, in all tested impression techniques there is no significant difference regarding the linear accuracy of each of the 4 parallel implants**.** **Conclusions:** The digital impression demonstrated considerably less disparity and better passive fit as compared to the traditional open-tray imprint without splint. The accuracy results of the digital impression and the traditional open-tray impression with splint were comparable. Compared to the conventional open-tray impression without splint, the passive fit and discrepancy of the conventional open-tray imprint with splint were noticeably superior.

Keywords: Conventional impression; Digital impression;Fit passivity; Telescopic prosthesis

I. Introduction

Implant-supported prosthesis (ISP) can significantly increase patients' masticatory efficiencywhen compared to conventional dentures. Deformation of the impression and plaster model, as well as variations in the implant's position, are the reasons for non-passive fit of ISP (Bi et al., 2022). Implant cast accuracy is influenced by numerous clinical and laboratory parameters, including impression material and method. Implant quantity and angulation, splinting and nonsplinting imprint coping, splinting material type, and die stone characteristics (Stefos et al., 2018).

The conventional open-tray impressions have been shown to be better than closed-tray impressions, despite the availability of various impression procedures. For fully edentulous jaws, the splinted open-tray technique is currently the standard procedure, and this impression produced satisfactory clinical outcomes (Mangano et al., 2018). During the conventional impression procedure, patients may experience some discomfort from, such as trouble breathing, difficulty opening their mouths, and tooth sensitivity (Gallardo et al., 2018). In certain situations, it can be challenging to correctly replicate conventional impressions, particularly when there is a large angle between implants or when long-span implant scanning is involved (Joda et al., 2017).

Since digital impressions eliminate the need for trays and lessen patients' oral sensation, they have become more and more common as dental impression procedures have advanced in recent years (Ahmed et al., 2024). The intricate procedures needed for traditional impression techniques, like pouring, cleaning, and transporting molds to the lab, are eliminated by digital imprint techniques (Bi et al., 2022).

A mismatch of the framework due to an inaccurate imprint puts stress on the implant and results in mechanical and biological issues. such as screw fracture and loosening, which results in an ill-fitting framework and implant and framework fracture (Singh et al., 2022). Conventional approaches contain procedures that are thought to introduce errors, which may become more obvious with more comprehensive frameworks (Emara et al., 2025).

Nonetheless, the digital data enhanced communication between the dentist, dental team, and patients and provided professionals with a 3D previsualization of the implant prosthodontic space and preparation. Therefore, compared to traditional cast frames, Computer-Assisted Manufacturing/ Computer-Assisted Machine (CAD/CAM) manufactured frameworks exhibit a more reliable and excellent passive fit (Emara et al., 2025).

For indirect methods (extraoral scanning), the digitalization is derived from the imprint or cast, while for direct approaches (intraoral scanning), the digital impression can be completed either directly or indirectly. Intraoral scanners are used to capture the images straight from the mouth (Güth et al., 2013).

When comparing digital impressions with traditional approaches, several authors found that the former were less accurate than the latter (Alshawaf et al., 2018). While one author showed that digital and conventional procedures are identical (Papaspyridakos et al., 2016). Another showed that digital methods are more accurate (Lee and Gallucci, 2013). According to the null hypothesis of the present study, there is no difference in passive fitness depending on the impression technique (conventional or digital) regarding the topograpic changes in the fitting surface of telescopic attachments.

II. Material and methods

2.1. Sample size calculation and sample grouping

For this investigation, a minimum sample size of 33 samples is required. The sample was gathered in accordance with Sicilia et al.'s earlier research (Sicilia et al., 2024). For this investigation, the power sample size was more than 80%, the significance threshold was 0.05, the confidence interval was 95%, and the actual power was 95.87 percent. A computer application (G*Power 3.1.9 Software, informer.com, USA) was used to calculate the total sample size. An oversizing of the sample will be done to compensate for the potential failure and increase the validity of the results so the total sample size will be 60.

A total of 3 mandibular acrylic models with 4 parallel implant analogues were utilized to construct 60 overdentures frameworks with telescopic attachment by three different impression techniques (n=20);

conventional non-splinted open tray implant level impression (NSOTI), conventional splinted open tray implant level impression (SOTI), and digital impression using laboratory scanner (DI).

2.2. Acrylic resin models construction procedures

For the production of 3D printed acrylic resin models, a ready-made gypsum totally edentulous mandibular cast (Ramses Medical Products Factory, Alexandria, Egypt) was used as a model. A desktop dental laboratory scanner with a stereo camera (Up3d UP360+, Glorious Dental Materials Co., Ltd., China) that uses the triangulation principle was used to scan the gypsum cast and create a standard tessellation language (STL) file. The virtual master 3D printed acrylic models were created using the gypsum cast STL file as a reference file (Peng et al., 2018).

The CAD software was used to construct four 3D digital virtual models of a fully edentulous mandibular cast with space for four parallel implant mimics at the canine and second premolar locations bilaterally. The virtual abutment replicas were imported using the Blender for Dental Component module's digital library (Blender Dentistry CAD software version 2.93.5, Australia). The abutments have to be positioned correctly in order for the virtual implant mimics to function at their exact place (Figure 1). The STL file for the finished master model was sent to a 3D slicer software (Chitubox, China). By the use of 3D-printable resin liquid (Dental Sand A2, Harz Labs, Russia), a total of 40 working acrylic resin models were 3D-printed using the final master model's STL file, which included the four virtual implant mimics rooms. To verify the overall correctness of the finished master model, a digital light processing (DLP) 3D-printing process was performed using a 3D printer (Photon, Anycubic, China) at a resolution of 50 µm. Every 3D-printed acrylic resin model was post-processed in compliance with the manufacturer's instructions. The manufacturer recommended that the cure cycle be set at 60 ºC for 30 minutes in ultraviolet (UV) polymerization unit (bre.Lux power Unit 2, Bredent, Germany)(El Tarabishi NHM, 2024).

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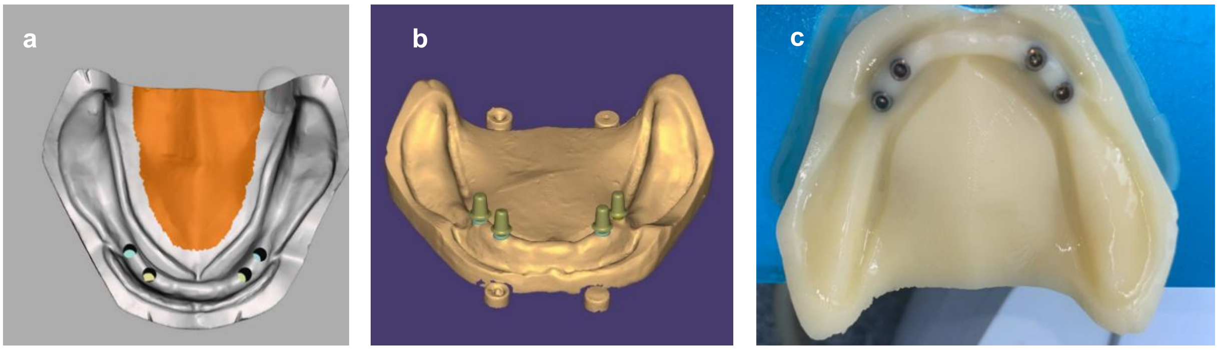

Figure 1: a) STL file of the 3D resin modelwith 4 virtual implant analogues rooms; b) STL file of the 3D resin model with 4 virtual implant abutments in parallel position; and c) 3D printed acrylic models.

2.3. Implant installation

The four implants in each resin model were positioned parallel to one another and at the location of the canine and second premolar teeth without any angulation (their longitudinal axis was perpendicular to the plane of the resin model). Each implant with impression copping and scan body was place in its pre-designated location in each 3D-printed resin model and cemented in place using a soft mixture of clear self-cured acrylic resin (PMMA, Acrostone Cold Cure Ortho Acryl, Acrostone Co., Egypt). The analogue connection was placed 0.5 mm above the resin block's surface to prevent minor undercuts that can exacerbate impression deformations. The cast was left in place until the soft acrylic resin had completely cured for 30 minutes at least (El Naggar, 2024, Gómez-Polo et al., 2024).Four conical-shaped open tray imprint transfers (Roott, Egypt) were then affixed to each of the four implants. The stock plastic tray was examined to ensure that it sat properly and didn't rock. Each implant was given its own hole, and the open tray transfer was examined to make sure it was visible through the tray.

2.4. Conventional open tray impression procedures

For non-splinted impression, a Polyvinyl siloxane (PVC) impression material in light and putty consistencies (Zhermack Elite, Italy) was used in the two phase one step technique for the open tray impression. As directed by the manufacturer, the material was allowed to set. A single operator took all of the imprints. Following material setting, open tray transfers were unscrewed, the impression was taken out, and it was carefully examined to see if there was any separation between the impression material and the tray. Additionally, the impression material was examined to make sure it covered every part of the cast, and it was confirmed that there was no movement of the open tray transfers within the impression material. After attaching implant mimics to the transfers, type III dental stone (Model Hard Stone, ENRST HIRNICHS Dental GmbH, Germany) was used to pour the entire imprint right away, and it was allowed to set completely (El Naggar, 2024, Pellew and Dudley, 2024). After complete setting, the impressions were then removed from stone casts. A total of 20 conventional open tray impressions of the master model were made with the same manner.

For splinted impression, the four rounded openings in a stock plastic tray were combined to make room for the impression copings that are splinted. In the splinted impression technique, the self-curing acrylic resin material (Clear Cold Cure Ortho Acryl, Acrostone Co., Egypt) was used to connects impression copings. The resin splints had a minimum thickness of 3 mm and an approximate 2 mm of thickness surrounding the impression copings (Patil et al., 2023). Then, the open tray impression procedures were accomplished in the same way as previously mentioned.

A total of 40 conventional open tray impressions (20 from splinted and 20 from non-splinted) of the master model were made with the same manner. A lab scanner was then used to scan the produced 20 stone models, producing 20 virtual models. The obtained data from each cast scan was stored in a computer file in STL format.

2.5. Digital impression

On each 3D-printed acrylic model, four scan bodies were attached to the four implants A, B, C, and D, correspondingly. The cast was placed on the movable part of the extra-oral scanner (Up3d UP360+, Glorious Dental Materials Co., Ltd., China), which sets the scanning triangle and performs accurate scanning to produce an STL file. Software and an extra-oral scanner were used to scan the entire cast. Each acrylic model was sprayed with a CAD/CAM scanning spray to hide the reflective surface and facilitate scanning (Alikhasi et al., 2018, El Naggar, 2024).A total of 20 digital impressions of the master model were made with the same manner. The obtained data from each scan was stored in a computer file in STL format.

2.6. Fabrication of the overdenture telescopic framework

A CAD program was used to produce a total of 60 virtual telescopic complete overdenture prosthetic models. After exporting the STL files (from the scanning of the stone cast "Scan A" or from the digital impression "Scan B", a virtual telescopic overdenture framework (VTOF) was created using CAD software for both virtual casts. The design of the telescopic overdenture framework was used as a reference to validate later frame scans to create all of the virtual scans. The virtual telescopic overdenture framework was designed to cover all implants and having a secondary crown hall for the telescopic overdenture framework to fit into telescopic implants.

A 5-axis milling machine (EDX5. EMAR, Egypt) was used to mill 40 cobalt/chromium (Co/Cr) framework for the previously designated STL files (Figure 18). Ultimately, 20 telescopic complete overdenture frameworks from the conventional open tray impression group and 20 from the digital impression group were acquired (Figure 2)(Gómez-Polo et al., 2024). A fresh set of burs was utilized for every telescopic complete overdenture structure.

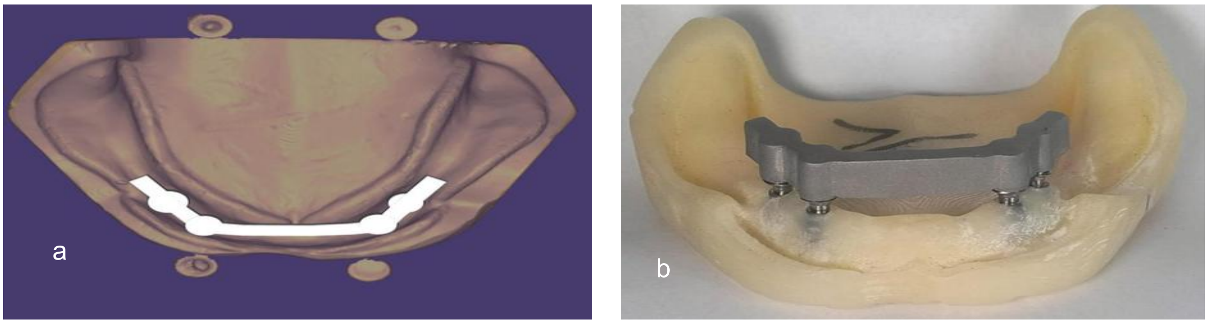

Figure 2: Fabrication of the overdenture telescopic framework; a) A virtual telescopic complete overdenture prosthetic structure; and b) A milled telescopic complete overdenture Co/Cr framework.

2.7. Data acquisition and comparisons

The test STL files for each impression technique were created by scanning the intaglio surface of each milled telescopic overdenture frameworks obtained by digital impression or conventional open tray impression with lab scanner. The obtained data was stored in a computer file in STL format (Test scans).

An alignment between the virtual and actual telescopic overdenture frameworks obtained from the 3D-printed cast (digital impression) and stone casts (conventional open tray impression) was carried out using the 3D software on the STL files. For all digital pairs (actual and virtual telescopic overdenture frameworks), the secondary crowns were selected as landmarks for alignment. To verify correctness, the aligned portions of the two telescopic overdenture frameworks were subsequently assessed.

A gradient chromatic scale, a feature of 3D software, and a cross-section of the telescopic overdenture frameworks were used to achieve the assessment. This tool demonstrated the micron discrepancies between the virtual and actual telescopic overdenture frameworks.

By using the best-fit alignment technique, an alignment was obtained, which can be confirmed using a color map and assessment sections (Figure 3). The best-fitting between the four secondary crowns was not acceptable if there was an inaccuracy exceeding 40 microns when matched.

STL files were obtained for each combination, and test samples were created by linking four secondary crowns to the four analogic equivalents of the 40 test models. The program was used to do the framework STL files comparisons. The program was loaded with the test STL files under analysis and the virtual (VTOF) STL data (reference file).

The superimposition was achieved by setting the Y-axis to zero and imposing the requirement that the circumferences of the four zero-degree secondary crowns be concentric to the axis origin, the concentricity towards the axis was achieved. A Z-axis rotation of the test file on the reference was carried out. The linear displacement was measured and were computed in millimeters. For every comparison, this procedure was carried out again. Forty linear measurements in total were acquired (Alikhasi et al., 2018).

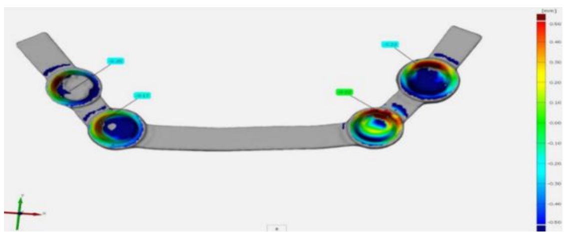

Figure 3: A color map showing the fit between reference STL file and test STL file.

2.8. Statistical analysis

IBM SPSS Statistics (Armonk, New York, United States) is a statistical program that processed all of the measurements that were gathered. The Shapiro-Wilk test for normalcy was used to put up preliminary statistical analysis. The associations between the variables were examined using an ANOVA-test, and p-values were found. The Tukey test was used for intergroup comparison. The 95% confidence level and 0.05 threshold for statistical significance were established.

III. Results

The results revealed that there is no significant difference regarding the linear distortion man values in (mm) between the four implants for each of DI, NSOTI, and SOTI (Table 1).

However, regarding the impression technique, the results showed that, with regard to the implant position (A, B, C, or D), there is a statistically significant difference between the linear distortion man values in (mm) of DI, NSOTI, and SOTI. The NSOTI have substantially greater linear distortion values than SOTI. On the other hand, the DI has a much lower linear distortion mean value (Table 1).

Moreover, there was a statistically significant difference between the NSOTI group and the SOTI group, as well as between the NSOTI group and the DI, according to intergroup comparison. Nevertheless, there was no discernible difference between the conventional impression with splint group and the digital impression group (Table 1).

Table 1: The mean and SD linear distortion values (mm) for digital and conventional impressions at each implant A

	Implant A		Implant B		Implant C		Implant D		p-value
	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	
DI	0.125^{B}	0.039	0.130^{B}	0.029	0.110^{B}	0.019	0.113^{B}	0.016	0.072 Ns
NSOTI	0.179^{A}	0.032	0.177^{A}	0.027	0.163^{A}	0.028	0.178^{A}	0.027	0.287 Ns
SOTI	0.146^{B}	0.035	0.141^{B}	0.029	0.126^{B}	0.026	0.128^{B}	0.021	0.074 Ns
p-value	<0.001*		<0.001*		<0.0001*		<0.0001*		

*; Significant at P<0.05. Ns; Non-significant at P>0.05. SD= Standard deviation. Different litters mean statistically significant.

IV. Discussion

The main concept of passive fit given by a number of definitions is an implant-supported framework that, when the prosthesis-implant interface is maximally congruent, does not put any pressure on the prosthetic, implant, or surrounding structures (Katsoulis et al., 2017). Therefore, in the current investigation passive fit is chosen as a test property because it is an essential component of the osseointegrated prosthesis's success and longevity is its passive fit to the underlying structures. Moreover, internal stresses are thought to be induced in the prosthesis' framework, the implants, and the surrounding bone by any mismatch of the framework to the osseointegrated implants, whether or not this is clinically visible (El Naggar, 2024).

In the current study, the conventional impression technique is used as the standard technique because it was stated that the traditional workflow for implant prosthetic rehabilitations has long been the most popular method in clinical practice, despite the fact that it involves multiple manual manufacturing steps, skilled dental technicians, and impression materials that are subject to dimensional variations (El Naggar, 2024). Moreover, the open tray impression technique is used in the current study because it was found that the open tray impression technique, which produced more accurate results than the closed-tray technique (Saini et al., 2018).

In the present investigation used PVS impression material is used to record the open tray impression in full arch implant-supported prosthesis in accordance with previous study that examined the accuracy and dimensional stability of high-rigid vinyl polysiloxane, PVS, and polyether impression materials. The findings demonstrated that they did not differ statistically significantly. Full-arch implant-supported prostheses can be made using any of the three impression materials (Kurella et al., 2020).

A number of procedure changes were suggested to improve implant impression accuracy. This included designing trays, using more robust material, splinting impression copings, and altering impression copings. Thus, comparing splinted and non-splinted copings is one of the study's objectives (Abduo and Palamara, 2021, Elshenawy et al., 2018). Even though the extra processes in implant impression, including splinting impression copings, have a propensity to increase implant impression accuracy, they are technique-sensitive and require more materials and clinical time (Papaspyridakos et al., 2014).

Moreover, digital impressions eliminate the need for impression materials, trays, and laboratory model fabrication, thereby lowering possible sources of error (Uniyal, 2025). Research has shown that digital impressions can be highly accurate and repeatable, particularly when there are several implants (Ahlholm et al., 2018).

However, the milled implant supported prosthesis for all groups in the current study was made using a digital impression using an extra-oral scanner to eliminate the dimensional inaccuracies resulting from pouring the impression. Additionally, all the inaccuracies from the conventional steps of framework construction were eliminated due to the use of the milling CAD/CAM technology, and the milled framework will have a better fit and more contacts with the underlying implant than the cast framework (El Naggar, 2024).

The study's findings showed that digital impressions were generally more accurate than traditional impressions. This was noted for the linear deviation, accuracy, and truthfulness. This superiority became clear for the non-splinted implants model, where digital impressions were more error-prone than conventional impressions, particularly the non-splinted approach. As a result, the theory that the various digital impressions and the traditional implant impressions are identical was disproved.

According to this study, digital impressions were more accurate than conventional impressions in terms of passive fit. These results are consistent with earlier studies that demonstrated digital impression techniques can improve prosthesis results by reducing mistakes related to material deformation and operator handling (Uniyal, 2025 , Kahya Karaca and Akca, 2024). Additionally, a prior comprehensive analysis revealed that, in some clinical situations, digital impressions showed considerably lower variation than conventional impressions, indicating improved spatial accuracy (Park et al., 2025).

In the current investigation, there will always be linear variations, which would account for the different gap distance or marginal discrepancies at implants A, B, C, and D in all impression techniques due to the complexity of the full-arch implant-supported restoration. These findings are consistent with those of an earlier study that found that it is very difficult to achieve passive fit for a full-arch implant-supported restoration due to the numerous clinical and laboratory procedures involved, and that there will always be marginal discrepancies at different implants (El Naggar, 2024).

The findings of the current study revealed that when the four implants are parallel, the accuracy of splinted impressions was superior to non-splinted impressions for all assessed variables. This may be because of the four implants model; the non-splinted impressions deteriorated more than the splinted impressions, and when the impression is removed from the model, the impression material surrounding the impression copings deforms, some of which cannot be fully recovered (Abduo and Palamara, 2021, Elshenawy et al., 2018).

Conversely, splinting reduced the displacement of the copings within the impression upon removal from the model by joining the two impression copings together (Kim et al., 2006). In the end, the impression copings were less susceptible to individual displacement during the pouring and impression-making processes. Additionally, as the implant replicas are being fitted, the resin splint will stop the impression copings from rotating within the set impression material (Abduo and Palamara, 2021).In agreement with the findings of the current investigation, numerous prior investigations have found that the splinted impression technique is preferable to the non-splinted impression technique (Abduo and Palamara, 2021, Elshenawy et al., 2018, Kim et al., 2006, Basaki et al., 2017). Moreover, it was stated that compared to intraoral splinting, splinting impression copings in a lab setting might produce more accurate results (Abduo and Palamara, 2021).

According to the findings of the current investigation for parallel implant models, there is no significant difference between the observations from the conventional impressions with acrylic splint and digital impressions, however, the worse outcomes for the non-splinted impressions. This supports research conducted in vitro that found that the results of digital and traditional splinted impressions are similar (Abduo and Palamara, 2021). Nevertheless, the superiority of digital impressions is probably due to the fact that they are not impacted by deformation of the imprint material during removal of impression in accordance with the typical impressions (Alikhasi et al., 2018, Chia et al., 2017).

Previous study discovered that digital implant impressions are just as accurate as splinted conventional implant impressions, which is consistent with the results of this investigation. Furthermore, for individuals who are entirely edentulous, the splinted, implant-level imprint approach is more accurate than the non-splinted one (Papaspyridakos et al., 2016).The precision of the scanning surface and the stitching between the many images, which progressively accumulates mistakes with each step, are responsible for the defects in the digital imprints. The inter-implant distance deviation is the most noticeable fault pattern. The mathematical conversion of the scan body's scanned surface to the parametric scan body and implant surfaces is an additional source of error (Kim et al., 2019, Basaki et al., 2017). Moreover, it was stated that the digital impression has demonstrated the reduction of the margin of error caused by conventional impression taking and cast production methods because digital impressions are instantly sent and saved/stocked electronically for the fabrication of definitive prosthetic restorations, improving workflow efficiency (Naggar, 2024).

V. Conclusion

The digital impression demonstrated considerably less disparity and better passive fit as compared to the traditional open-tray imprint without splint. The accuracy results of the digital impression and the traditional open-tray impression with splint were comparable. Compared to the conventional open-tray impression without splint, the passive fit and discrepancy of the conventional open-tray imprint with splint were noticeably superior.

Disclosure

The author reports no conflicts of interest in this work.

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