https://doi.org/10.4047/jap.2025.17.6.367

Accuracy assessment of intraoral scanning versus conventional impressions in edentulous patients with flabby ridges: a prospective clinical study

Dina Mohamed Elawady[1], Ahmed Yehia Abdel-Moneim[1], Ahmed Yaseen Alqutaibi[2]*, Sherin Samir Matta[1]
[1]Department of Prosthodontics, Faculty of Dentistry, October University for Modern Sciences and Arts, Giza, Egypt
[2]Substitutive Dental Sciences Department, College of Dentistry, Taibah University, Madinah, Saudi Arabia

ORCID
Dina Mohamed Elawady
https://orcid.org/0000-0002-8407-4749
Ahmed Yehia Abdel-Moneim
https://orcid.org/0009-0004-6129-4660
Ahmed Yaseen Alqutaibi
https://orcid.org/0000-0001-6536-8269
Sherin Samir Matta
https://orcid.org/0009-0001-1658-7649

PURPOSE. This prospective clinical study aimed to evaluate the accuracy of intraoral scanning (IOS) as an alternative to the conventional window technique impression (WTI) for recording maxillary flabby ridges in edentulous patients. **MATERIALS AND METHODS.** Twelve edentulous participants with maxillary flabby ridges underwent both IOS (TRIOS 5, 3Shape, Denmark) and WTI. WTI impressions were made using zinc oxide-eugenol paste and plaster of Paris as the reference. All scans were exported in STL format. Accuracy was assessed via trueness and precision, using RMS, average negative, and average positive deviations, calculated with Medit Compare software. **RESULTS.** IOS showed significantly higher trueness than WTI in RMS (mean difference (MD) = -0.11, 95% CI: -0.15 to -0.06, P = .0001) and average negative deviation (MD = 0.13, 95% CI: 0.07 to 0.19, P = .0001). The average positive deviation had no significant difference (MD = 0.02, 95% CI: -0.01 to 0.05, P = .11). In terms of precision, IOS had significantly higher precision across all parameters: RMS (MD = 0.23, 95% CI: 0.21 to 0.26, P = .0001), average positive deviation (MD = 0.14, 95% CI: 0.11 to 0.17, P = .0001), and average negative deviation (MD = -0.15, 95% CI: -0.17 to -0.13, P = .0001). **CONCLUSION.** This study suggests that IOS may provide improved accuracy compared to the conventional window impression technique for capturing maxillary flabby ridges in edentulous patients. Further research with larger sample size and clinical outcome assessments is needed to confirm its efficacy. [J Adv Prosthodont 2025;17:367-79]

KEYWORDS
Digital impression; Flabby ridge; IOS; Trueness; Precision; Window technique

Corresponding author
Ahmed Yaseen Alqutaibi
Substitutive Dental Sciences Department, College of Dentistry, Taibah University, Prince Nayef Road, 42353, Madinah, Saudi Arabia
Tel +966552884839
E-mail am01012002@gmail.com

Received July 7, 2025 / **Last Revision** September 15, 2025 / **Accepted** September 29, 2025

https://doi.org/10.4047/jap.2025.17.6.367

INTRODUCTION

The objective of complete denture prosthodontics is to rehabilitate edentulous patients by restoring function and aesthetics. Complete dentures remain one of the most popular and successful prosthetic treatment options for edentulous patients facing systemic, anatomical, and/or economic constraints, as highlighted by research on the care of edentulous individuals.[1]

A flabby ridge is defined as mobile soft tissue located on the superficial aspect of the alveolar ridge.[2] The primary challenge associated with a flabby ridge is the fabrication of a stable denture, as the flabby tissues are easily displaced under occlusal forces. This displacement results in compromised denture retention due to the loss of the peripheral seal. The presence of flabby tissues compromises not only the stability but also the support and retention of complete dentures unless these tissues are appropriately managed using specialized impression techniques.[3]

Several impression techniques have been recommended for the management of flabby ridges, all of which aim to record the flabby contours with minimal tissue displacement.[4] One technique that has gained acceptance among clinicians is the window technique impression (WTI), which employs double spacers, multiple relief holes, or a window tray method in the area of the flabby tissue.[5] However, the main limitation of WTI and other conventional impression methods is their technical complexity and the propensity to produce unstable and non-retentive dentures. Additionally, the window technique may lead to difficulties in controlling and uniformly applying impression materials, particularly low-viscosity substances.[6,7] Some researchers have suggested that mucostatic impression procedures may not fully utilize the available tissue support, potentially resulting in concerns regarding the mobility of the denture base relative to the supporting tissues.[8]

The emergence of intraoral scanning (IOS) offers an efficient alternative to conventional impressions, enhancing patient comfort by eliminating trays and impression materials and enabling seamless integration with CAD-CAM workflows for denture design and fabrication.[9,10] Newly developed scanners can capture highly accurate full-arch impressions in less time; however, scanning fully edentulous arches remains challenging.[11-14] Additional limitations include a significant operator learning curve, higher equipment costs, and potential interference from reflective tissues or saliva.[12-14] Despite these challenges, multiple studies have validated the reliability of contemporary IOS for completely edentulous arches.[15-17] Therefore, the IOS has the potential to accurately capture the detailed contours of the flabby edentulous ridge without exerting physical pressure on the tissues. This capability may address the challenges associated with accurate registration using conventional impressions, as the viscoelastic properties and varying resiliency of flabby tissues present significant difficulties.[6,7]

This prospective clinical study aimed to evaluate the trueness and precision of IOS as an alternative to WTI for recording maxillary flabby ridges. The hypothesis of this study posited that IOS can demonstrate higher accuracy concerning both trueness and precision when compared to WTI for fully edentulous patients with maxillary flabby ridges. The null hypothesis stated that there is no significant difference in the trueness and precision of IOS compared to WTI in the registration of flabby ridges.

MATERIALS AND METHODS

To determine the sample size, estimations were derived from a prior study conducted by Chebib *et al*.,[11] which indicated that the identification of a true difference of 100 µm, with a standard deviation of 200 µm and a statistical power of 0.80, would be adequate for rejecting the null hypothesis. The type I error rate was established at 0.05. Consequently, a total of twelve participants were incorporated into the study.

This research was conducted within the Department of Prosthodontics at the Faculty of Dentistry, October University For Modern Sciences and Arts. Ethical approval was obtained from the MSA University Ethics Committee under reference number REC-D-42010-4. The study adhered to the ethical standards outlined in the Declaration of Helsinki regarding research involving human subjects. Additionally, the study was registered with ClinicalTrials.gov under the identifier

NCT07037407.

Participants meeting the inclusion criteria were subsequently enrolled in the study after being informed about the study's aim and providing their signed informed consent. The inclusion criteria for participant selection were as follows: completely edentulous patients with a maxillary flabby ridge (localized flabby tissues in the premaxillary region) (Fig. 1); absence of infectious diseases; systemic good health (ASA-1/ASA-2); age ranging from 50 to 75 years; and the ability to cooperate throughout the data collection process. Exclusion criteria included: the presence of any remaining teeth; failure to understand the study's procedures and objectives; ridge irregularities; ridge scarring; and limited mouth opening.

After the participants were enrolled in the study, a digital impression of the maxilla for each patient was obtained using an intraoral scanner (TRIOS 5; 3Shape A/S, Copenhagen, Denmark) to generate the test files. A specialized soft tissue scan retractor (Flexi Triple C Retractor, Polyamide PA06, DRdent Products Inc., Cairo, Egypt) (Fig. 2) was designed with a resilient yet sufficiently rigid framework to fit into the vestibular area. The configuration of the frame allowed for extension beyond the distal end of the alveolar process, facilitating unobstructed movement of the scanning head. Prior to the scanning process, a meticulous cleansing of the edentulous ridge was conducted, followed by the removal of any residual saliva.

The scanning process started at the crest of the ridge on one side and progressed along the residual ridge until reaching the canine-incisor region. At this juncture, a zig-zag scanning pattern was employed to capture both the crest and the anterior palatal slope. The pathway then continued in a straight line along the ridge's crest to the opposite side. Subsequently, the scanner head was utilized to capture the buccal aspect, moving in a straight line to the contralateral buccal side. The scanning then encompassed the palatal incline of the tuberosity and advanced anteriorly along the posterior palatal incline until it reconnected with the previously scanned anterior palatal slope. Finally, the scanning proceeded in a backward direction across to the opposite side, ensuring comprehensive coverage of the entire palatal region.

Five intraoral scans were conducted for each of the maxillary flabby ridges. During the scanning process, minor deviations were adjusted using the cropping tool within the scanner's software to eliminate extraneous elements and to rescan any areas that were lost. In instances of significant deflections that could not be corrected through rescanning, the altered images were discarded, and a new scan was initiated. Only complete, high-quality digital images exhibiting smooth and accurate details were accepted. All IOS procedures were executed by an experienced operator to ensure standardization. The arithmetic mean of the deviations from these comparisons was calcu-

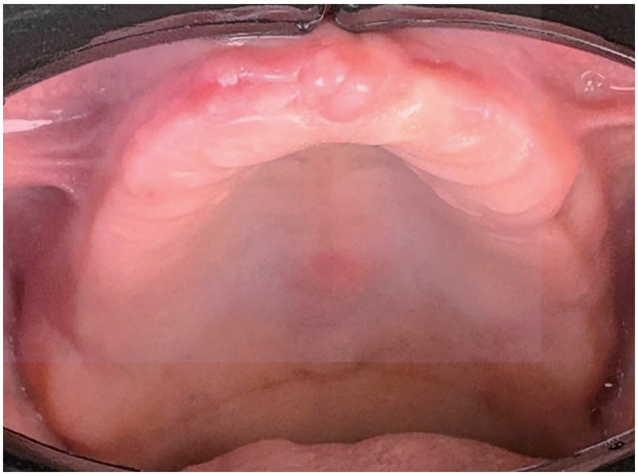

Fig. 1. Intraoral view of the maxillary arch with flabby ridge.

Fig. 2. Specialized scan retractor; Flexi Triple C-Retractor featuring 3 pre-sized retractors to allow flexibility in accommodating different arch sizes. Lack of handle and framework rigidity allows effective soft tissue retraction.

https://doi.org/10.4047/jap.2025.17.6.367

lated to quantify precision.

For each patient, the intraoral scans (IOS) were transferred using the intraoral scanner's software (Trios 5; 3Shape, Copenhagen, Denmark) to the Standard Tessellation Language (STL) format (Fig. 3).

Once the digital impression was completed, the conventional impression procedure was initiated using WTI. The process began with taking a primary impression of the edentulous maxilla using an irreversible hydrocolloid alginate material (Tropicalgin, ZhermackSpA, Badia Polesine, Italy) and stock edentulous trays. Anterior maxillary flabby tissues were palpated and identified intraorally using large ball burnishers, and the outlines were marked with an indelible pencil. The alginate impression was repositioned in the patient's mouth, and the markings made with the indelible pencil were transferred onto the impression surface. The impression was subsequently poured using Type III dental stone (Kulzer, Hanau, Germany), and a sheet of modeling wax was adapted as a spacer with incorporated square-shaped openings to function as stops.

For each patient, five maxillary custom trays were fabricated in the laboratory using auto-polymerizing acrylic resin. The custom trays were designed with a handle placed centrally in the palate. Initially, the trays were tried in the mouth to eliminate any muscular interference. The custom trays were then modified in the area of the flabby tissues, guided by the indelible pencil marks on the primary cast.

For each patient, five final impressions were obtained using polyvinyl siloxane (PVS) material. Initially, tray adhesive (Adhesive PVS, Coten) was uniformly applied along the borders of the tray. Subsequently, putty PVS (Elite HD+ soft putty, Zhermack) was utilized to contour the tray borders and document the functional movements of the surrounding tissues. Following this, a layer of medium body PVS (Elite HD+ Medium Body, Zhermack) was applied to the tray to facilitate the final impression. The tray was then inserted into the patient's mouth, and the patient was instructed to perform functional movements. Afterward, the medium body material was excised from the premaxillary region, where flabby tissue was present, and perforations were created in that section of the tray. Light body PVS (Elite HD+ Light Body, Zhermack) was subsequently applied to the perforated area to capture the anterior region while the tissue remained at rest. The impression was meticulously examined to ensure the accurate reproduction of the flabby tissue in its undistorted state. Once the material had fully set, the impression was gently removed from the patient's mouth.

To fabricate the reference cast, a gold standard WTI impression was subsequently obtained for each patient utilizing zinc oxide eugenol paste (Kelly's Zn Oxide and Eugenol Impression Paste, Water Pik, Inc., Fort Collins, CO, USA). Border molding of the custom trays was conducted using a tracing compound (green stick). A light application of impression plaster was administered to the flabby ridge area with a small brush. The prepared impression tray, which was filled with zinc oxide eugenol paste, was then positioned over the coated plaster. Following the complete setting of the material, the impression was carefully removed from the patient's mouth. This impression was subsequently poured into a cast composed of improved dental stone (Dental Stone Type III, Kulzer, Germany) to create the reference cast. All WTI impressions utilizing PVS or ZOE with Plaster of Paris procedures were conducted by a skilled operator to ensure standardization.

The scans of the five corresponding PVS WTI impressions (Fig. 4) and the scan of the corresponding gold standard WTI poured cast (Fig. 5) were exported to the STL format, which is also compatible with other software programs for reverse engineering and further analyses. These were conducted using a desktop extraoral scanner (3Shape D2000 Lab Scanner, Copenhagen, Denmark). The scanner is equipped with four 5 MP cameras and Blue LED Multi-line technology, achieving an accuracy of 5 µm (ISO) / 8 µm. Prior to analysis, artifacts such as air bubbles and voids on the palatal surface of the WTI models were digitally removed to avoid interference with RMS and superimposition outcomes.

For all participants, the conventional steps of complete denture construction were performed, and the dentures were delivered.[18]

The accuracy of impressions obtained through IOS and WTI was evaluated using two primary criteria: trueness and precision, which served as the outcome

Fig. 3. The STL of the maxillary arch captured with intraoral scanning.

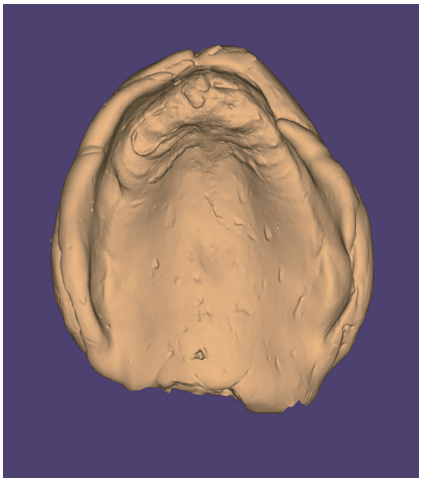

Fig. 4. The STL of the maxillary arch captured with WTI.

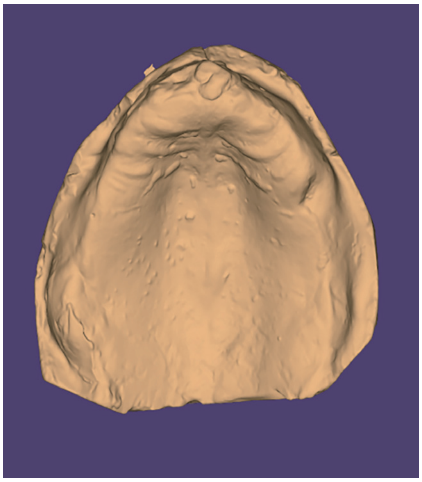

Fig. 5. STL of the maxillary arch from the gold-standard WTI poured cast.

measures.

Trueness: For the WTI group, trueness was assessed by measuring the surface deflection between the STL files of the reference cast and the WTI (Fig. 6). In the case of the IOS group, trueness was evaluated by measuring the surface deviation between the STL files of the reference cast and the IOS (Fig. 7).

Precision: Precision of the IOS was determined after controlling for all surrounding factors. This involved scanning the maxillary edentulous ridge five times, superimposing the resulting scans, and analyzing the deviations among them. The STL files of the five intraoral scans recorded for each participant were compared. Initially, the first scan was designated as the reference and compared against the second, third, fourth, and fifth impressions. Subsequently, the second scan served as the reference and was compared with the first, third, fourth, and fifth scans. This process was repeated for all five IOS impressions, and the arithmetic mean of the deviations was subsequently calculated. For the precision of the WTI, the scans of the five window technique impressions were superimposed on one another, and deviations among them were assessed in a manner analogous to that employed for the IOS (Figs. 8 and 9).

For each arch in every participant, the three-dimensional distance between the reference cast scan, IOS, and the corresponding WTI scan was measured using a systematic procedure. The STL files of the IOS, WTI, and reference cast were imported into a software program (Medit Design v.2.1.4; Medit, Seoul, Korea). The following analysis settings were utilized in the Medit app: Exclude Low Fidelity Data (OFF), Remove Outlier by Sigma (OFF), Sigma Multiplier (1.5), Calculation Method (Normal to Data Surface), and Percentile Range of Interest (80).

A two-phase best-fit alignment procedure was implemented, utilizing the poured cast as the reference and treating the IOS and WTI being treated as test objects. Initially, an automatic alignment was conducted using the Medit Design software, followed by manual refinement involving three anatomical landmarks: one point located on the incisive papilla anteriorly and two points positioned posteriorly on each side of the ridge. Grids were employed to guide the positioning of points and to ensure consistency across patients. The alignment strategy adopted a whole-arch approach, referencing stable anatomical areas whenever feasible, while also incorporating the anterior flabby ridge region to facilitate comprehensive registration. This methodology was selected to enhance accuracy by anchoring the alignment to reproducible and minimally compressible landmarks.

Error control was achieved by performing two step alignment: first automatic alignment and second by manual alignment by using three points, one anterior point (incisive papilla) and two posterior points one on each side of the ridge using the grids to align

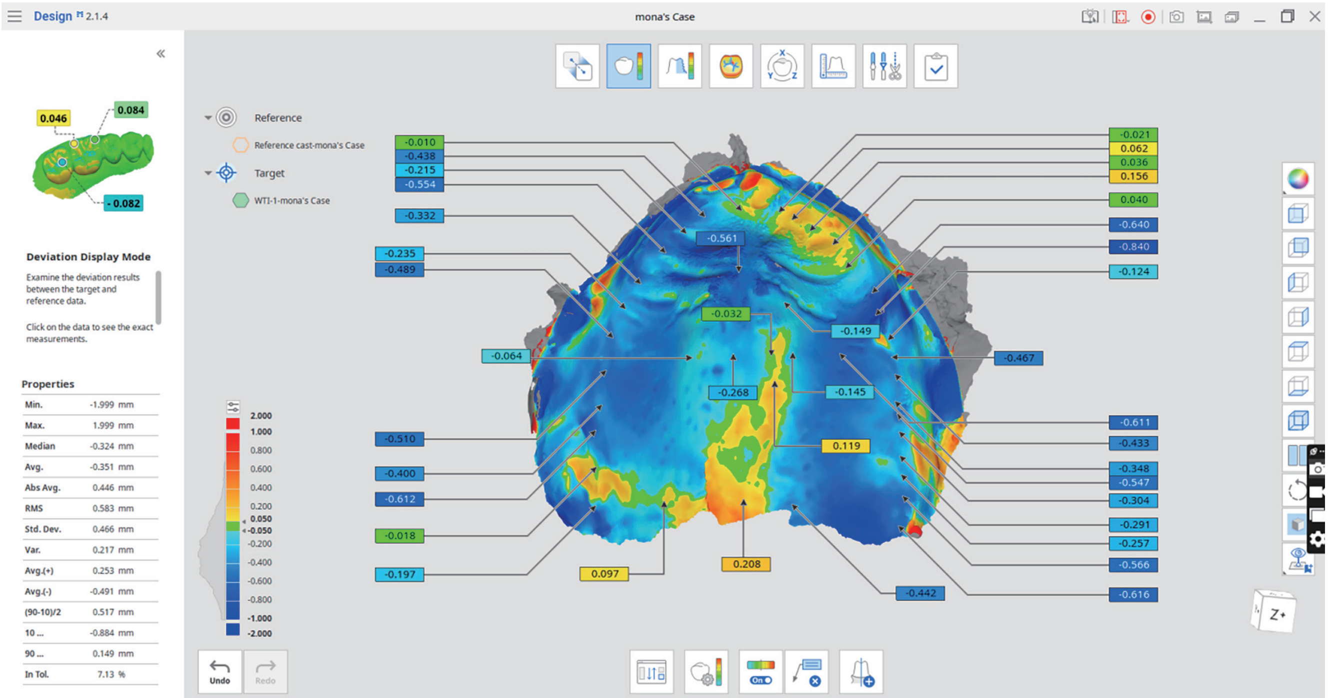

Fig. 6. Trueness color map of WTI.

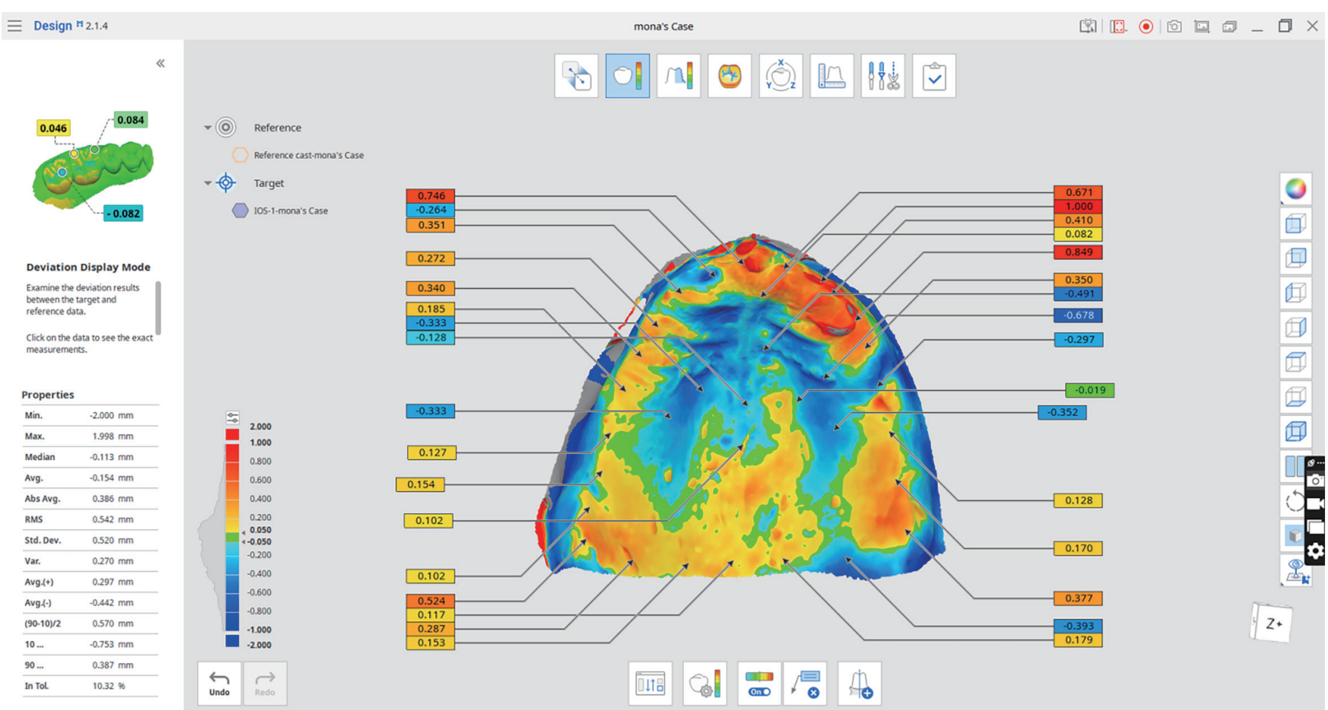

Fig. 7. Trueness color map of IOS.

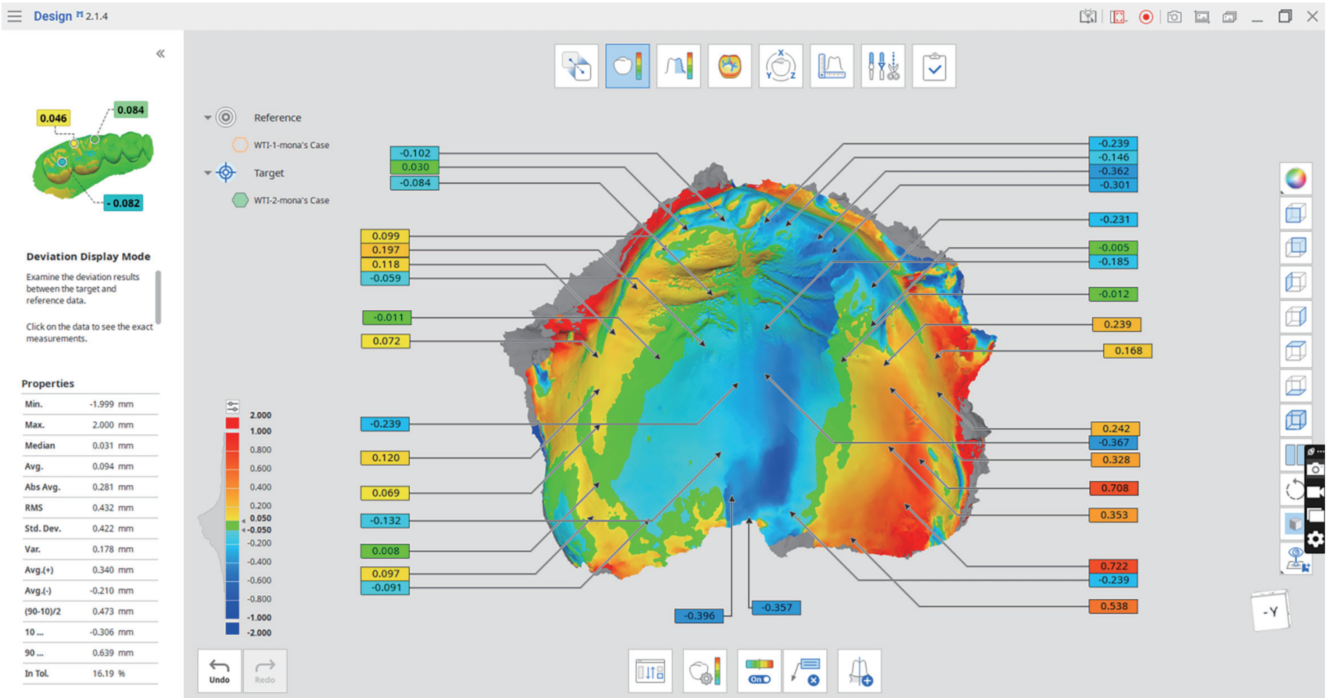

Fig. 8. Precision color map of WTI.

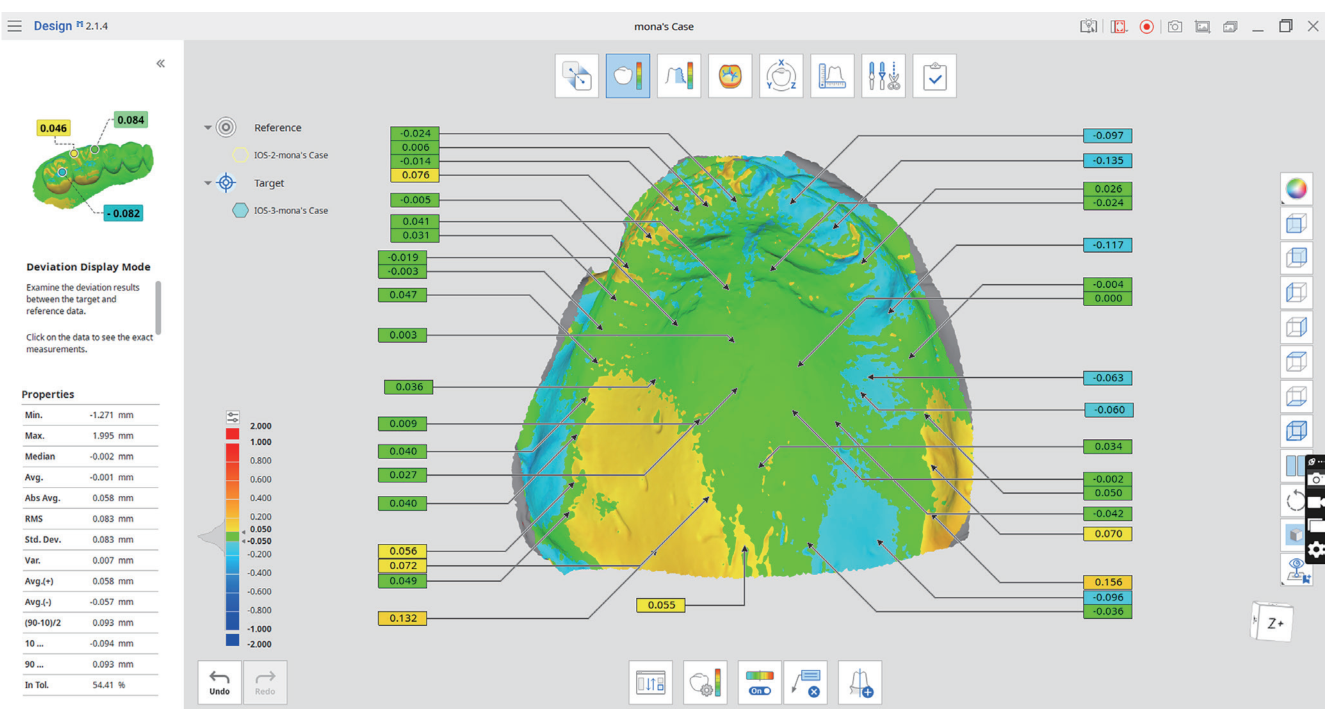

Fig. 9. Precision color map of IOS.

https://doi.org/10.4047/jap.2025.17.6.367

the points according to the anatomy based on every patient's landmark specifically.

In terms of acceptance thresholds, although the Medit software does not provide a fixed user-controlled value, alignment accuracy was assessed through visual inspection to check for surface intersections. In our workflow, alignment below 300 µm were considered acceptable, with values under 100 µm being optimal. These steps ensured that the alignment process remained consistent and reproducible across all datasets.

To ensure measurement reliability, multiple assessments were performed. The first two analyses, spaced one week apart, were conducted by the same investigator, while a third analysis was carried out by a second independent examiner. Both examiners were trained and calibrated using five previous patient scans not included in this study. Reliability was evaluated using intra-class correlation coefficients, with intra- and inter-observer values of 0.92 and 0.95, respectively.

Statistical analyses were conducted using SPSS 27®, GraphPad Prism®, and Microsoft Excel 2016. All quantitative data were expressed as minimum, maximum, median, mean, and standard deviation (SD) values, and normality was assessed using the Shapiro-Wilk and Kolmogorov-Smirnov tests, which indicated that the data were normally distributed. Consequently, an independent t-test was employed to compare differences between groups. The significance level was established at $P < .05$.

RESULTS

The trueness of IOS and WTI techniques was assessed by comparing RMS values, average positive deviations (Average +), and average negative deviations (Average −) using a paired t-test (Table 1 and Figure 10).

- RMS Values: The mean RMS value for IOS was 0.50 ± 0.04, whereas for WTI, it was 0.60 ± 0.06. The mean difference of -0.11 was statistically significant (P = .0001), indicating a significantly lower deviation (enhanced accuracy) in the IOS group compared to WTI.
- Average Positive Deviations (Average +): The mean Average + value for IOS was 0.36 ± 0.02, while for WTI, it was 0.38 ± 0.05. The mean difference of 0.02 was not statistically significant (P = .11), suggesting that the positive deviations between the two groups were comparable.
- Average Negative Deviations (Average −): The mean Average − value for IOS was -0.39 ± 0.07, in contrast to -0.52 ± 0.08 for WTI. The mean difference of 0.13 was statistically significant (P = .0001), indicating that the IOS group exhibited significantly less negative deviation compared to WTI.

The precision of IOS and WTI techniques was assessed by comparing root mean square (RMS) values, average positive deviations (Average +), and average negative deviations (Average −) using a paired t-test (Table 2 and Figure 11).

- RMS Values: The mean RMS value for IOS was 0.07 ± 0.02, whereas for WTI, it was 0.31 ± 0.05. The

Table 1. Descriptive results of trueness in IOS and WTI regarding RMS, Average + and Average − comparison between groups using Paired t test

Parameter	Group	Minimum	Maximum	Median	Mean	SD	Mean difference	SE difference	95% CI of difference	*P* value
RMS	IOS	0.42	0.56	0.51	0.50	0.04	-0.11	0.02	-0.15 to -0.06	.0001*
	WTI	0.55	0.67	0.56	0.60	0.06				
Average +	IOS	0.34	0.38	0.34	0.36	0.02	0.02	0.01	-0.01 to 0.05	.11
	WTI	0.30	0.48	0.39	0.38	0.05				
Average −	IOS	-0.48	-0.21	-0.41	-0.39	0.07	0.13	0.03	0.07 to 0.19	.0001*
	WTI	-0.63	-0.46	-0.47	-0.52	0.08				

*Significant difference as $P \leq .05$.

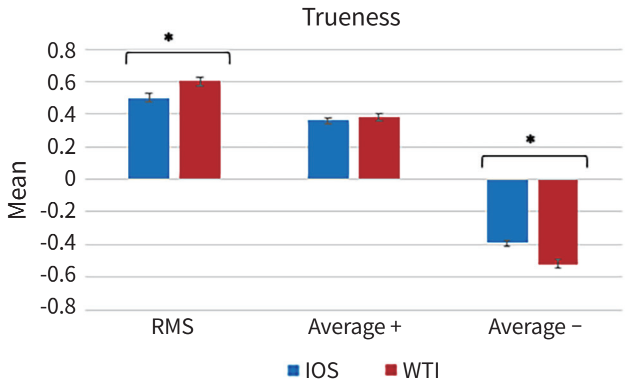

Fig. 10. Bar chart showing trueness in IOS and WTI regarding RMS, Average + and Average −.

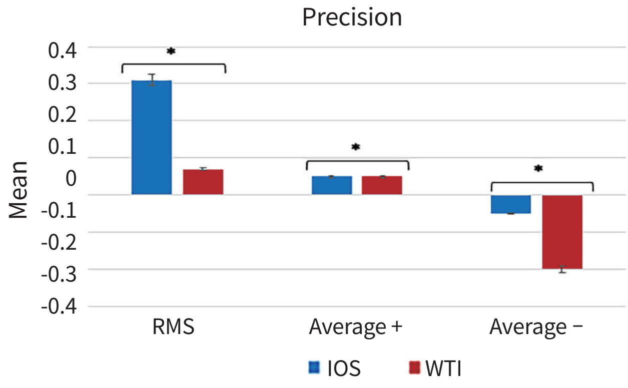

Fig. 11. Bar chart showing precision in IOS and WTI regarding RMS, Average + and Average −.

Table 2. Descriptive results of precision in IOS and WTI regarding RMS, Average + and Average − comparison between groups using Paired t test

Parameter	Group	Minimum	Maximum	Median	Mean	SD	Mean difference	SE difference	95% CI of difference	*P* value
RMS	IOS	0.05	0.09	0.08	0.07	0.02	0.23	0.01	0.21 to 0.26	.0001*
	WTI	0.24	0.42	0.31	0.31	0.05				
Average +	IOS	0.03	0.06	0.06	0.05	0.01	0.14	0.01	0.11 to 0.17	.0001*
	WTI	0.13	0.32	0.19	0.19	0.05				
Average −	IOS	-0.06	-0.03	-0.06	-0.05	0.02	-0.15	0.01	-0.17 to -0.13	.0001*
	WTI	-0.23	-0.12	-0.21	-0.20	0.03				

*Significant difference as $P \leq .05$.

mean difference of 0.23 was statistically significant (P = .0001), indicating a significantly higher precision in the IOS group compared to WTI group.

- Average Positive Deviations (Average +): The mean Average + value for IOS was 0.05 ± 0.01, and for WTI, it was 0.19 ± 0.05. The mean difference of 0.14 was statistically significant (P = .0001), further demonstrating greater precision (smaller positive deviations) in the IOS group.
- Average Negative Deviations (Average −): The mean Average − value for IOS was -0.05 ± 0.02, while for WTI, it was -0.20 ± 0.03. The mean difference of -0.15 was statistically significant (P = .0001), confirming that IOS exhibited significantly smaller negative deviations, reflecting higher precision.

DISCUSSION

This study aimed to evaluate the accuracy—specifically the trueness and precision—of intraoral scanning (IOS) compared to the conventional WTI in recording flabby edentulous tissues. The statistical findings revealed significant advantages favoring IOS in both parameters, leading to the acceptance of the study hypothesis and the rejection of the null hypothesis.

The WTI method has long been established for registering flabby edentulous ridges; however, its limitations are well documented. These include the potential for tissue displacement during impression taking, which may result in compromised denture retention, instability, and dislodgment. Moreover, achieving uniform application of low-viscosity materials is challenging, particularly in maxillary cases, due to gravitational influences and patient positioning. The frequently used impression compounds are often mucocompressive, negatively affecting surface detail reproduction.[3] Although PVS materials are commonly employed due to their availability in various viscosities, their precise and consistent application remains a concern.[19]

In contrast, IOS offers several advantages. It enhances patient comfort by eliminating impression materials and reducing the gag reflex, increases efficiency by minimizing chair time, and reduces technique sensitivity and errors linked to material distortion. Additionally, it supports improved communication through 3D visualization and removes the need for physical models, thus addressing key limitations of conventional methods.[9,10,20]

Multiple studies have confirmed the viability of IOS in recording edentulous arches. Al-Dulaijan *et al*.[20] reported that the TRIOS scanner demonstrated statistically higher precision than conventional PVS impressions. Although other studies found no statistically significant differences between IOS and conventional methods, they nonetheless support the clinical validity of IOS in edentulous cases.[20-22]

This study utilized the TRIOS 5 scanner (3Shape A/S, Copenhagen, Denmark), which has been widely recommended for scanning edentulous arches due to its proven accuracy and reduced sensitivity to operator technique.[17] Its performance is attributed to optimized algorithms capable of capturing edentulous soft tissues effectively. All IOS procedures in this study were conducted by the same experienced operator to ensure consistency and eliminate operator bias.[23,24]

To improve soft tissue visibility during scanning, a custom-designed retractor was employed. Unlike traditional retractors, it lacked a handle and rigid framework, allowing gentle retraction of lips and cheeks without compressing tissues—a factor that could otherwise impact scan accuracy.[25] The scanning strategy followed protocols outlined by Osman and Alharbi[16] and Elawady *et al*.,[17] both of whom emphasized that the scanning pathway plays a more critical role than the anatomical morphology being scanned.

The inclusion criteria were carefully selected to create a homogenous sample, thereby reducing confounding variables and enhancing internal and external validity. The study focused on the premaxillary region, a common site of flabby tissue and a clinically challenging area. Patients with oral or systemic infections were excluded to avoid potential distortions in mucosal conditions that could affect impression accuracy. Furthermore, only ASA I and II patients were included to minimize systemic factors that could compromise tissue response or healing.[26] The selected age range of 50 – 75 years reflects the demographic most affected by edentulism and ensures sufficient cognitive and physical ability to participate.

To establish a reference model, the study utilized the window technique with zinc oxide-eugenol and plaster materials, regarded as the gold standard for flabby ridge cases.[27,28] This reference model was digitally scanned to provide a benchmark against which the IOS and WTI impressions were evaluated.

According to ISO 5725-1, accuracy comprises both trueness and precision.[29] Trueness refers to the degree to which an impression replicates the actual anatomy by measuring deviation from the reference model, while precision reflects the repeatability of the technique.

Color-coded heat maps visually represented deviations, with yellow areas indicating high accuracy and blue reflecting greater inaccuracies.[16,17] IOS scans predominantly showed yellow regions, suggesting better trueness, whereas WTI scans displayed more extensive blue areas. The digital workflow of IOS minimizes common sources of distortion, such as polymerization shrinkage and handling errors, and allows real-time error detection and mucostatic tissue capture without direct pressure. Negative deviations were smaller in IOS than WTI, indicating that WTI may compress or distort flabby tissue more, potentially compromising anatomical fidelity. Regarding precision, IOS again outperformed WTI, with color maps confirming higher consistency and reproducibility. This enhanced reliability is particularly important in flabby tissue cases, where minor inconsistencies can have a notable impact.[9,10,30]

The improved trueness and precision of IOS have significant clinical implications. More accurate capture of maxillary flabby ridges can lead to better denture adaptation and reduced adjustments, while greater reproducibility enhances the consistency of prosthetic fabrication. Clinically, these advantages may translate into improved denture fit, increased patient comfort, and enhanced long-term functionality by minimizing uneven pressure on supporting tissues and reducing the risk of sore spots or instability. Overall, these findings support IOS as a reliable digital alternative for managing complex edentulous cases with flabby ridges.

To the authors' knowledge, no prior studies have objectively evaluated IOS accuracy specifically in flabby ridge scenarios. Although one related study comparing IOS to conventional techniques found an advantage for traditional methods in soft tissue response, its reliance on subjective assessment limits generalizability.[31] In contrast, our study utilized quantifiable metrics, offering a more objective evaluation of IOS performance in a challenging clinical context. The findings contribute to a growing body of evidence supporting IOS as a reliable option for flabby ridge registration.

Despite employing a rigorous methodology, this study has limitations. The small and homogeneous sample size may restrict the generalizability of the findings, particularly in light of the anatomical variability present in flabby ridges. Additionally, the use of the ZOE paste and plaster reference model may apply pressure on the flabby ridge tissue, potentially resulting in slight tissue displacement. Although this technique was conducted by experienced prosthodontists with the intention of minimizing such effects, the possibility of minor compression cannot be entirely ruled out. Furthermore, operator dependency, particularly in relation to IOS, remains a concern despite efforts at standardization. Conducting the study in a controlled clinical environment does not fully account for real-world variables, such as patient movement or saliva. Moreover, the study's exclusive focus on maxillary flabby tissues limits its applicability to other anatomical regions. Importantly, patient-related outcomes—such as comfort and clinical usability—were not evaluated. Despite attempts to mitigate the influence of movable mucosa during alignment, the application of whole-arch registration inherently involved the anterior flabby ridge, which is prone to distortion and mobility. Deviation values were not specifically calculated within a region of interest (ROI) characterized by flabby tissue, as this approach could lead to the averaging of significant differences. Consequently, the potential dilution of tissue-specific discrepancies between intraoral scanning and conventional impressions must be acknowledged. This limitation highlights the need for more precise ROI methodologies in future research, particularly by excluding highly deformable regions to more accurately isolate and assess discrepancies in flabby tissues.

Future research should include larger, multicenter trials to assess inter-operator variability and generalize findings across diverse populations. Investigations should extend to mandibular edentulous cases and incorporate patient-centered outcomes, such as comfort, satisfaction, and functional performance. *In vivo* evaluation of tissue displacement and the integration of AI-assisted scanning technologies may further enhance the accuracy and clinical applicability of IOS for managing flabby ridge. Furthermore, future studies should consider implementing evaluator blinding through data masking techniques, such as standardizing file naming conventions and applying peripheral trimming to scanned datasets, to minimize recognition bias and improve the reliability of comparative assessments.

CONCLUSION

This prospective clinical study demonstrates that IOS provides higher trueness and precision than the conventional WTI for recording maxillary flabby ridges in fully edentulous patients. Clinically, this suggests that IOS may offer a reliable digital alternative for capturing accurate prosthodontic records, potentially improving patient comfort and workflow efficiency. Future research should investigate these findings in larger patient cohorts and evaluate long-term clinical outcomes, such as denture fit, function, and patient satisfaction, to confirm the practical benefits of IOS in routine prosthodontic practice.

REFERENCES

1. Lee DJ, Saponaro PC. Management of edentulous pa-

tients. Dent Clin North Am 2019;63:249-61.
2. The glossary of prosthodontic terms. J Prosthet Dent 2005;94:10-92.
3. Bute SA, Bansod A, Beri A. Striving for excellence: fabrication of complete denture in a patient with flabby ridges using specialized impression technique. Cureus 2024;16:e62976.
4. Singla HN, Chopra S. Impression technique for management of flabby ridge patients-an overview. J Adv Med Dent Scie Res 2023;11:87-90.
5. Zilpilwar N, Nimonkar S, Dubey SA, Belkhode V. Addressing flabby ridges in complete denture patients: a case report. Cureus 2024;16:e64006.
6. Gupta AR, Dhamande MM, Kambala SR, Dubey SA, Pathak A, Tawade SU, Rathi R. Clinical dilemma: flabby ridges and the quest for aesthetic denture fit. Cureus 2024;16:e66367.
7. Habib S, Alshehri WS, Alyousef S. Window technique for the final impression of a maxillary flabby ridge: a case report of an edentulous patient. Cureus 2025;17: e77508.
8. Showkat R, Sharma A, Kumar S, Kaura SM. Management of flabby ridge using Hobkirk's technique: a case report. Eur J Dent Oral Health 2020;1:12.
9. Zarbakhsh A, Jalalian E, Samiei N, Mahgoli MH, Kaseb Ghane H. Accuracy of digital impression taking using intraoral scanner versus the conventional technique. Front Dent 2021;18:6.
10. Ştefănescu C-L, Zaharia A, Murineanu RM, Puşcaşu CG, Sachelarie L, Grigorian M. Flabby ridge, a challenge for making complete dentures. Appl Sci 2021;11:7386.
11. Chebib N, Kalberer N, Srinivasan M, Maniewicz S, Perneger T, Müller F. Edentulous jaw impression techniques: an in vivo comparison of trueness. J Prosthet Dent 2019;121:623-30.
12. Hack G, Liberman L, Vach K, Tchorz JP, Kohal RJ, Patzelt SBM. Computerized optical impression making of edentulous jaws - an in vivo feasibility study. J Prosthodont Res 2020;64:444-53.
13. D'Arienzo LF, Borracchini A. Comparison of the suitability of intra-oral scanning with conventional impression of edentulous maxilla in vivo: a preliminary study. J Osseointegr 2018;10:115-20.
14. Jung S, Park C, Yang HS, Lim HP, Yun KD, Ying Z, Park SW. Comparison of different impression techniques for edentulous jaws using three-dimensional analysis. J Adv Prosthodont 2019;11:179-86.
15. Osman RB, Alharbi NM. Influence of scan technology on the accuracy and speed of intraoral scanning systems for the edentulous maxilla: an in vitro study. J Prosthodont 2023;32:821-8.
16. Osman R, Alharbi N. Does the palatal vault form have an influence on the scan time and accuracy of intraoral scans of completely edentulous arches? An in-vitro study. J Adv Prosthodont 2022;14:294-304.
17. Elawady DMA, Ibrahim WI, Ghanem RG, Osman RB. Palatal vault configuration and its influence on intraoral scan time and accuracy in completely edentulous arches: a prospective clinical study. J Adv Prosthodont 2024;16:201-11.
18. Winkler S. Essentials of complete denture prosthodontics. 2nd ed. New York: Medical Publishing; 1988.
19. Labban N. Management of the flabby ridge using a modified window technique and polyvinylsiloxane impression material. Saudi Dent J 2018;30:89-93.
20. Al-Dulaijan YA, Alalawi H, Gad MM, Al-Qarni FD, Fouda SM, Ellakany P. Trueness and precision of complete denture digital impression compared to conventional impression: an in vitro study. PeerJ 2025;13:e19075.
21. Cao R, Zhang S, Li L, Qiu P, Xu H, Cao Y. Accuracy of intraoral scanning versus conventional impressions for partial edentulous patients with maxillary defects. Sci Rep 2023;13:16773.
22. Lo Russo L, Caradonna G, Troiano G, Salamini A, Guida L, Ciavarella D. Three-dimensional differences between intraoral scans and conventional impressions of edentulous jaws: a clinical study. J Prosthet Dent 2020;123:264-8.
23. Canullo L, Colombo M, Menini M, Sorge P, Pesce P. Trueness of intraoral scanners considering operator experience and three different implant scenarios: a preliminary report. Int J Prosthodont 2021;34:250-3.
24. Pesce P, Bagnasco F, Pancini N, Colombo M, Canullo L, Pera F, Bressan E, Annunziata M, Menini M. Trueness of intraoral scanners in implant-supported rehabilitations: an in vitro analysis on the effect of operators' experience and implant number. J Clin Med 2021;10: 5917.
25. Masri G, Mortada R, Hatoum K, Al Harbi N, Boulos P, Salameh Z. Evaluation of the adaptation of complete dentures fabricated using intraoral scanning and conventional techniques. J Contemp Dent Pract 2020;21:

1384-8.
26. American Society of Anesthesiologists. Statement on ASA physical status classification system. Amended December 13, 2020. Available at: https://www.asahq.org/standards-and-practice-parameters/statement-on-asa-physical-status-classification-system
27. Watson RM. Impression technique for maxillary fibrous ridge. Br Dent J 1970;128:552.
28. Liddelow KP. The prosthetic treatment of the elderly. Br Dent J 1964;117:392-4.
29. ISO 5725-1. Accuracy (trueness and precision) of measurement methods and results. Part 1: general principles and definitions. International Standards Organization (ISO); Geneva; Switzerland, 1994.
30. Singh RK, Patil N, Datta A, Pattedar A, Billesh NK. Impression techniques for management of flabby ridges in complete denture patients: a review of literature. Int J Appl Dent Sci 2022;8:31-6.
31. Elkafrawy GM, Asal SA, El-Sheikh AM. Digital versus conventional impression technique for flabby ridge in complete denture construction. Tanta Dent J 2021;18:109-13.