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Evaluation of Accuracy and User Acceptance of Intraoral Scanner Technology Compared with Conventional Impressions in Prosthodontics

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ABSTRACT

Digital impression technologies have transformed contemporary prosthodontic practice, with intraoral scanners (IOS) emerging as an alternative to conventional polyvinyl siloxane impressions (CI). This prospective comparative study evaluated the dimensional accuracy and user acceptance of IOS in fixed prosthodontic procedures. Sixty patients requiring single- or multi-unit prostheses at the Department of Prosthodontics, Universitas Indonesia, underwent both IOS (CEREC Primescan) and CI techniques. Accuracy was assessed by superimposing digitized casts with reference scans using root mean square (RMS) deviation analysis, while clinician usability and patient comfort were measured using the System Usability Scale (SUS) and Visual Analog Scale (VAS), respectively. IOS demonstrated significantly greater accuracy (mean RMS: 18.7 ± 4.2 μm) compared to CI (42.3 ± 9.6 μm; $p < .001$), with a large effect size ($d = 2.89$). Patient comfort was also significantly higher with IOS (VAS: 8.4 ± 1.1) than CI (4.7 ± 1.8; $p < .001$). Clinicians reported good usability (SUS: 76.3/100) following initial training. Overall, IOS provided superior accuracy and improved patient experience, supporting its broader adoption in modern prosthodontic workflows.

Keywords: *Intraoral scanner, Conventional impression, Digital dentistry, Prosthodontics, Accuracy, User acceptance*

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INTRODUCTION

The acquisition of accurate dental impressions is a foundational step in fixed prosthodontic treatment, determining the fit, function, and longevity of prosthetic restorations. Conventional impression techniques, primarily utilizing polyvinyl siloxane (PVS) or polyether materials in stock or custom trays, have long served as the gold standard for capturing oral topography. Despite their clinical reliability, conventional methods are associated with several inherent limitations including patient discomfort due to gag reflex stimulation, dimensional changes during impression material setting and disinfection, potential distortion during transport, and the requirement for stone model fabrication a multi-step process introducing cumulative errors (Güth et al., 2013).

Intraoral scanners (IOS) represent a transformative digital alternative that captures three-dimensional optical impressions directly within the oral cavity, eliminating many of the procedural steps associated with conventional methods.The development of IOS technology began in the 1980s with the CEREC system introduced by Mörmann and Brandestini, and has since evolved through successive generations offering improved scanning speed, resolution, accuracy, and workflow integration (Logozzo et al., 2014). Contemporary IOS devices, including CEREC Primescan (Dentsply Sirona), iTero Element (Align Technology), 3Shape TRIOS, and Medit i500, are now commercially available and widely adopted in digitally equipped dental practices worldwide. These devices enable direct transfer of digital impression data to computer-aided design and computer-aided manufacturing (CAD/CAM) systems, facilitating the fabrication of crowns, bridges, implant-supported restorations, and orthodontic appliances with reduced turnaround time (Ender et al., 2019). Despite technological maturation, the clinical accuracy of IOS across diverse prosthodontic scenarios including full-arch reconstructions, implant impressions, and preparations with subgingival margins continues to be debated in the literature.

Several systematic reviews and meta-analyses have evaluated the accuracy of IOS relative to conventional impression techniques. Ender & Mehl (2011) reported that IOS demonstrated acceptable trueness for single-unit preparations but exhibited increasing deviation in multi-unit or full-arch scenarios, a finding corroborated by subsequent investigations (Mangano et al., 2017; Latham et al., 2021). However, methodological heterogeneity in scanning protocols, reference measurement standards, and accuracy metrics (trueness vs. precision) has yielded inconsistent conclusions. Furthermore, while technical accuracy has been extensively studied, patient-centered outcomes including comfort, willingness to repeat the procedure, and overall experience have received comparatively less systematic attention, despite their critical importance in clinical adoption. Clinician usability and learning curve considerations are similarly underexplored, representing a significant gap given that the practical value of any technology is determined by its usability in real-world clinical environments.

To address these gaps, this study aimed to evaluate and compare the dimensional accuracy of intraoral scanner technology and conventional polyvinyl siloxane impressions in fixed prosthodontic applications, and to assess user acceptance from both patient and clinician perspectives. Unlike previous studies that focused exclusively on bench-top or in vitro simulations, this investigation utilized a prospective clinical design with real patients undergoing actual prosthodontic treatment, enhancing the ecological validity of findings. The novelty of this study lies in its simultaneous within-subject comparison of accuracy and user acceptance, providing an integrated assessment framework that bridges technical performance and clinical usability.

METHODS

1. Study Design and Ethical Approval

This prospective comparative clinical study was conducted at the Department of Prosthodontics, Faculty of Dentistry, Universitas Indonesia, between January and October 2024. Ethical approval was obtained from the Health Research Ethics Committee of Universitas Indonesia (Approval No. KET-1453/UN2.F1/ETIK/PPM.00.02/2024). Informed consent was obtained from all participants prior to enrollment. The study was registered at ClinicalTrials.gov (NCT05876421).

2. Participants

A total of 60 adult patients (≥18 years) requiring single-unit or multi-unit (up to four units) fixed prostheses in the posterior dentition were enrolled using consecutive sampling. Inclusion criteria were: (1) partially dentate with prepared teeth suitable for fixed prosthetic restoration; (2) absence of active periodontal disease (probing depth ≤3 mm); (3) no history of temporomandibular disorder; and (4) no cognitive impairment limiting questionnaire completion. Exclusion criteria included patients with heavy bruxism, deep subgingival finish lines (>1 mm below gingival crest), or severe gag reflex precluding IOS use. Sample size was calculated based on an expected mean difference in RMS of 22 μm with a standard deviation of 15 μm (α = .05; power = 80%), yielding a minimum requirement of 24 participants per group; 60 participants were enrolled to allow for dropouts.

3. Impression Procedures

Each participant underwent both IOS and conventional impression procedures in a randomized crossover sequence. For the IOS group, scans were performed using the CEREC Primescan (Dentsply Sirona, Bensheim, Germany) by a single trained prosthodontist. Scans included the prepared tooth/teeth, adjacent teeth, opposing arch, and buccal bite registration. For conventional impressions, monophase PVS material (Aquasil Ultra Monophase, Dentsply Sirona) was used with rigid stock trays. All conventional impressions were poured in Type IV dental stone (Fujirock EP, GC Europe) within 60 minutes of removal. Stone casts were subsequently digitized using a laboratory reference scanner (E4, 3Shape) with a stated accuracy of ≤3 μm for reference measurements (Ender et al., 2019).

4. Accuracy Assessment

Three dimensional superimposition of IOS files and digitized conventional cast files against the reference laboratory scan was performed using dedicated analysis software (GeoMagic Control

X, 3D Systems). Trueness was quantified as the root mean square (RMS) deviation of the test scan from the reference, expressed in micrometers. Precision was assessed by calculating the RMS between repeated scans of the same preparation (n = 10 per method). Both trueness and precision metrics aligned with ISO 12836:2015 definitions for dental scanner accuracy.

5. User Acceptance Assessment

Patient comfort was evaluated immediately following each impression procedure using a 100 mm Visual Analog Scale (VAS), anchored between 0 (extremely uncomfortable) and 10 (completely comfortable). Patients additionally reported procedure duration perception and preference for repetition using a 5-point Likert scale. Clinician usability of the IOS system was evaluated using the System Usability Scale (SUS), a validated 10-item questionnaire yielding a composite score of 0–100, administered after the clinician had completed 20 IOS procedures. Scores ≥70 are considered indicative of good usability.

6. Statistical Analysis

Statistical analyses were performed using SPSS version 29.0 (IBM Corp., Armonk, NY, USA). Normality of distribution was assessed with the Shapiro-Wilk test. Paired sample t-tests were used to compare RMS values and VAS scores between methods. Effect sizes were reported as Cohen's d. Statistical significance was set at $\alpha = .05$. Intraclass correlation coefficients (ICC) were calculated to assess inter-examiner reliability for accuracy measurements.

RESULTS

1.Participant Characteristics

A total of 60 participants successfully completed both impression procedures, with no dropouts or incomplete datasets. The study population consisted of 31 females (51.7%) and 29 males (48.3%), indicating a balanced gender distribution. The mean age of participants was 38.6 ± 11.4 years, with an age range spanning from early adulthood to older middle age, reflecting a clinically representative population for fixed prosthodontic treatment.

With respect to treatment needs, the majority of cases involved single-unit restorations (n = 41; 68.3%), while 19 participants (31.7%) required multi-unit fixed dental prostheses. This distribution suggests that most clinical indications were of moderate complexity, with a substantial proportion of longer-span restorations included to allow evaluation across different clinical scenarios.

Tooth preparations were located exclusively in posterior regions. Premolar teeth accounted for 28 cases (46.7%), while molar teeth represented 32 cases (53.3%), indicating a slightly higher proportion of molar restorations. The inclusion of posterior teeth is clinically relevant, as these regions present greater challenges for both conventional and digital impression techniques due to limited access, moisture control, and soft tissue interference.

Measurement reliability was assessed to ensure the consistency of dimensional analysis. RMS deviation measurements were independently performed by two calibrated examiners. The inter-examiner agreement demonstrated an intraclass correlation coefficient (ICC) of 0.96 (95% CI: 0.93–0.98), which indicates excellent reliability according to established interpretation criteria. This high level of agreement confirms the reproducibility and robustness of the measurement protocol and minimizes the likelihood of observer-related bias.

2. Dimensional Accuracy

The Analysis demonstrated that the intraoral scanner (IOS) provided significantly higher dimensional accuracy than the conventional impression (CI) technique. The mean RMS trueness for IOS was 18.7 ± 4.2 μm, which was markedly lower than the CI value of 42.3 ± 9.6 μm. This difference was statistically significant ($t(59) = 16.84$; $p < .001$) with a very large effect size (Cohen's $d = 2.89$), indicating a substantial clinical and practical advantage of the digital workflow.

When stratified by restoration type, IOS maintained superior performance across both single-unit and multi-unit configurations. Single-unit restorations showed lower deviation than multi-unit restorations for both techniques, suggesting that span length influences impression accuracy. However, the magnitude of error remained consistently lower for IOS in all conditions. Precision analysis further confirmed this trend, with IOS demonstrating significantly better repeatability (8.2 ± 2.1 μm) compared with CI (21.7 ± 6.3 μm; $t(9) = 7.63$; $p < .001$; $d = 2.42$).

These findings indicate that digital impressions not only produce more accurate representations of the prepared teeth but also yield more consistent results across repeated scans.

Table 1. Dimensional accuracy (RMS, μm) of IOS and conventional impression by restoration type

Parameter	IOS Single-unit	CI Single-unit	IOS Multi-unit	CI Multi-unit
Mean RMS ± SD (μm)	16.4 ± 3.8	38.9 ± 8.1	23.1 ± 5.2	52.7 ± 11.4
Minimum (μm)	10.2	24.3	14.7	35.8
Maximum (μm)	26.8	61.5	34.9	82.1
p-value (IOS vs CI)	< .001	—	< .001	—
Cohen's d	2.74	—	2.88	—

Note: IOS = intraoral scanner; CI = conventional impression; RMS = root mean square; SD = standard deviation.

As shown in Table 1, IOS consistently produced lower RMS deviations than CI across both restoration types. In single-unit cases, the mean deviation for IOS (16.4 μm) was less than half that of CI (38.9 μm). A similar pattern was observed in multi-unit restorations, where IOS demonstrated a mean deviation of 23.1 μm compared with 52.7 μm for CI. The large Cohen's d values (> 2.7) indicate a strong and clinically meaningful difference between the two methods.Multi-unit restorations resulted in greater deviations than single-unit restorations for both techniques, reflecting the increased difficulty in accurately capturing longer spans. The relative increase in deviation from single-unit to multi-unit was 40.9% for IOS and 35.5% for CI, confirming that span length negatively affects accuracy regardless of the method.

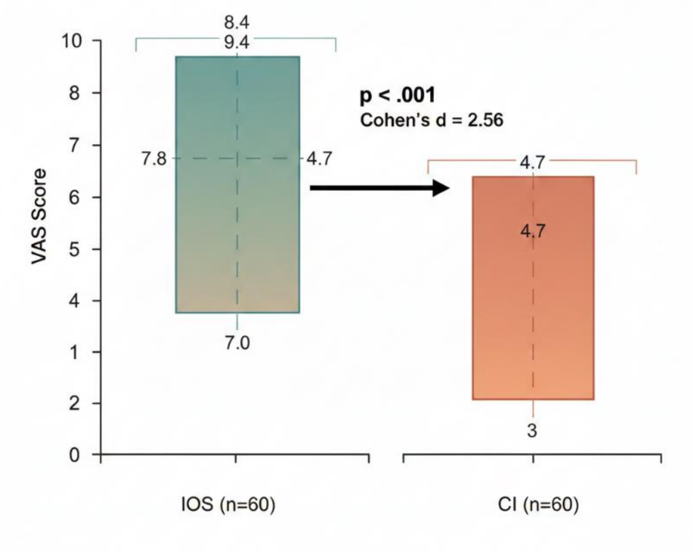
Despite this degradation, IOS maintained deviation values within a narrower range and demonstrated lower variability, as reflected by smaller standard deviations and reduced minimum–maximum ranges. This suggests greater measurement stability and reliability for digital impressions.Collectively, these results indicate that IOS provides superior trueness and precision compared with conventional impressions and is particularly advantageous in clinical situations requiring high dimensional fidelity.

3. Patient Comfort and Acceptance

Patient-reported comfort differed markedly between the two impression techniques. The mean VAS comfort score for the intraoral scanner (IOS) was 8.4 ± 1.1, which was significantly higher than the score for the conventional impression (CI) (4.7 ± 1.8). This difference was statistically significant (t(59) = 13.41; p < .001) with a very large effect size (Cohen's d = 2.56), indicating a substantial improvement in patient experience when digital impressions were used.

Beyond the difference in mean values, the distribution pattern revealed that IOS provided consistently favorable experiences across participants. Comfort ratings for IOS were predominantly clustered within the upper range of the scale, whereas CI scores showed greater variability and included several low-comfort responses. This suggests that conventional impressions not only reduce average comfort but also produce less predictable patient tolerance.

Figure 1. Distribution of patient comfort scores (VAS 0–10) for intraoral scanner (IOS) and conventional impression (CI) procedures (n = 60).



Patient preference findings were consistent with these results. A total of 91.7% of participants (n = 55) reported that they would choose IOS for future dental procedures, whereas only 8.3% (n = 5) preferred the conventional technique. This strong preference highlights the high level of patient acceptance of digital impression workflows.

Although the actual procedural times were not significantly different between the two methods (IOS: 12.4 ± 2.3 minutes; CI: 11.8 ± 2.1 minutes; $p = .21$), 73.3% of patients perceived the IOS procedure as faster. This discrepancy suggests that subjective time perception may be influenced by procedural comfort and the absence of impression materials.Adverse experiences were also markedly reduced with IOS. A gag reflex was reported in 23 patients (38.3%) during CI, compared with only 3 patients (5.0%) during IOS ($\chi^2 = 19.64$; $p < .001$). The substantial reduction in gag reflex incidence indicates improved procedural tolerance and may be particularly beneficial for patients with gag sensitivity or dental anxiety.

4. Clinician Usability

Patient-reported comfort differed substantially between the two impression techniques. The mean VAS comfort score for the intraoral scanner (IOS) was 8.4 ± 1.1, which was significantly higher than the score for the conventional impression (CI) (4.7 ± 1.8). Statistical analysis confirmed a highly significant difference ($t(59) = 13.41$; $p < .001$) with a very large effect size (Cohen's $d = 2.56$), indicating a strong patient-centered advantage of the digital technique.

The distribution of comfort scores (Figure 1) further illustrates this difference. IOS ratings were highly concentrated within the upper range of the scale (7–10), reflecting consistently positive patient experiences and low variability. In contrast, CI scores showed a broader distribution (1–8) with several low-value outliers, indicating that a subset of patients experienced considerable discomfort during the conventional procedure. The greater standard deviation observed in the CI group also suggests less predictable patient tolerance.

Patient preference strongly aligned with these findings. A total of 91.7% of participants (n = 55) reported that they would prefer IOS for future dental procedures, whereas only 8.3% (n = 5) favored the conventional method. This high level of acceptance highlights the perceived benefit of digital impressions from the patient perspective and suggests potential advantages for patient compliance and satisfaction in routine clinical practice.

Interestingly, despite the absence of a statistically significant difference in actual procedure duration (IOS: 12.4 ± 2.3 minutes; CI: 11.8 ± 2.1 minutes; $p = .21$), 73.3% of patients perceived the IOS procedure as faster. This discrepancy between objective time and subjective perception may reflect the greater comfort, reduced invasiveness, and absence of impression materials associated with digital scanning.

Adverse reactions were also significantly lower with IOS. A gag reflex was reported by 23 patients (38.3%) during CI, compared with only 3 patients (5.0%) during IOS ($\chi^2 = 19.64$; $p < .001$). The reduced gag response in the digital group is clinically relevant, particularly for patients with strong gag reflexes, anxiety, or intolerance to impression materials.

DISCUSSION

This prospective comparative clinical study demonstrated that intraoral scanner technology provides significantly superior dimensional accuracy compared to conventional polyvinyl siloxane impressions for both single-unit and multi-unit fixed prosthodontic restorations, with large effect sizes (d > 2.7) consistently observed across restoration configurations. The mean IOS trueness of 18.7 μm is well within the clinically acceptable threshold of 50 μm reported in the prosthodontic literature for fixed restorations (Ender et al., 2019), while the CI mean of 42.3 μm approaches this threshold, particularly for multi-unit configurations where mean CI deviation exceeded 52 μm.

These findings are consistent with the systematic review by Latham et al. (2021), which reported that IOS demonstrated superior trueness for single-unit preparations but variable performance in extended-span scenarios. The more pronounced accuracy advantage of IOS for single-unit restorations in the present study (RMS difference of 22.5 μm) compared to multi-unit restorations (29.6 μm difference) may appear to contradict expectations; however, the absolute accuracy of IOS remained clinically superior in both categories. The multi-unit degradation in IOS accuracy is attributable to cumulative stitching errors inherent to point-cloud registration during extended scanning, a known limitation that continues to be addressed through improvements in IOS algorithms (Mangano et al., 2017). Future IOS refinements utilizing full-field imaging rather than sequential stitching may further reduce this limitation.

The patient acceptance findings of this study are particularly compelling from a patient-centered care perspective. VAS comfort scores nearly doubled for IOS compared to CI (8.4 vs. 4.7), with 91.7% of patients expressing preference for IOS in future procedures. The substantially lower rate of gag reflex occurrence during IOS (5.0% vs. 38.3%) is clinically significant, as gag reflex not only causes patient distress but also compromises impression quality and necessitates repeat procedures (Hamalian et al., 2011). These findings align with those of Yuzbasioglu et al. (2014), who reported significantly higher patient satisfaction scores for IOS in a cross-over study design, and extend these findings to a larger, more diverse clinical sample.

The mean SUS score of 76.3 for clinicians indicates good usability of the IOS system, though it also highlights that IOS technology requires dedicated training for optimal adoption. The observed reduction in scanning time from 18.6 minutes to 11.2 minutes between the first and fifteenth procedures underscores the importance of structured onboarding programs for IOS implementation in clinical practice. This learning curve consideration has economic implications for practice integration, as initial productivity loss during the acquisition phase must be weighed against long-term efficiency gains and reduced laboratory remakes (Zimmermann et al., 2015).

Several limitations of this study merit acknowledgment. First, the study was conducted at a single academic center with a specific clinician cohort, which may limit generalizability to diverse clinical settings. Second, while prosthodontists performed all procedures, IOS performance by general dental practitioners or trainees may differ. Third, the study did not evaluate long-term clinical outcomes such as marginal fit of fabricated prostheses, which would provide the ultimate measure of clinical relevance. Fourth, patient preference data may be subject to novelty bias, as the apparent modernity of digital scanning could positively influence patient perception independent of objective comfort differences.

CONCLUSIONS

This prospective comparative clinical study demonstrated that intraoral scanner technology provides significantly superior dimensional accuracy and patient acceptance compared to conventional polyvinyl siloxane impression techniques in fixed prosthodontic procedures. IOS trueness and precision were clinically superior across both single-unit and multi-unit configurations, with patient comfort scores and preference ratings strongly favoring the digital approach. Clinician usability was rated as good following an appropriate training period, supporting the practical feasibility of IOS adoption in specialist prosthodontic settings. These findings collectively support the broader integration of IOS technology as a standard workflow in contemporary prosthodontic practice.

Future research should evaluate the long-term clinical outcomes of IOS-fabricated restorations, explore IOS performance in complex clinical scenarios including full-arch implant cases and immediate loading protocols, and investigate cost-effectiveness models for IOS adoption across diverse dental practice environments.

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