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Original Article

Dentistry Section

Assessment of Operator Experience on the Accuracy and Time Required for Intraoral Scanning with Three Different Scanners: A Prospective Study

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ABSTRACT

Introduction: Digital workflows in orthodontics increasingly rely on Intraoral Scanning (IOS) due to their advantages in efficiency, patient comfort, and precision. However, the impact of operator experience on scan performance remains a critical factor, especially with the introduction of new scanning technologies.

Aim: To evaluate the influence of operator experience on scanning time and accuracy using three different Intraoral Scanners (IOS).

Materials and Methods: The present prospective study was conducted at Saveetha Dental College, Chennai, Tamil Nadu, India from November 2024 to December 2024. Twenty adult participants underwent IOS performed by three operators with differing levels of experience: high (>50 scans), moderate (10-50 scans), and low (<10 scans). The study design was based on operator experience levels, with three subgroups corresponding to the type of IOS used: TRIOS 5 (3Shape), Runyes Three-dimensional (3D) and Cerec Primescan AC. Each participant was scanned nine times, once by each operator using all three scanners, resulting in a total of 180 intraoral scans. Outcome measures included scanning time and accuracy. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) software, with intergroup differences assessed by Analysis of Variance (ANOVA) and correlations analysed using Kendall's tau. A p-value of ≤0.05 was considered significant.

Results: Scanning time was significantly influenced by operator experience (p<0.05), with highly experienced operators completing scans faster with the different scanners. Operator experience did not significantly affect scan accuracy (p>0.05). TRIOS 5 demonstrated the shortest scan times (1.24±0.14 minutes), while Primescan AC required the longest (5.78±0.64 minutes).

Conclusion: Operators with high experience required less time to scan, irrespective of the scanner type used. The accuracy of scanning doesn't depend on the operator's experience or the type of scanner used. Clinically, enhancing operator skill can improve workflow efficiency and patient comfort without compromising scan quality.

Keywords: Digital orthodontics, Digital workflow, Operator proficiency, Scan precision

INTRODUCTION

The IOSs have emerged as a prominent and evolving technology in digital orthodontics, playing a pivotal role in advancing diagnostic accuracy and treatment efficiency [1,2]. The IOS provides multiple advantages, such as improved patient acceptance and comfort, minimised distortions, reduced risk of gagging, a common issue with traditional impression methods, real-time 3D visualisation and assessment of preparations, enhanced cost and time efficiency, streamlined communication with the dental laboratory, and efficient digital data storage [3-6]. Accuracy with IOSs depends on factors including operator-related, patient-related, and IOS-related variables [7-9]. Operator-related variables such as scanning technique, experience level, and familiarity with scanner software affect image stitching and data accuracy, with inexperienced operators often producing greater deviations and longer scan times [7,10]. Patient-related factors, including saliva, limited mouth opening, tooth geometry, and movement, can compromise image capture and increase distortion, particularly in full-arch scans [7,10]. Scanner-related factors-such as optical technology, calibration, scanning algorithms, and ambient lighting, also determine the trueness and precision of digital impressions [10]. These factors collectively influence clinical outcomes by affecting the fit and accuracy of prostheses, aligners, and other dental appliances, ultimately determining treatment efficiency and patient comfort [7,10].

Resende CCD et al., in an in-vitro study investigated the influence of operator experience on scanning accuracy and efficiency [11]. Their findings indicated that as the operator's experience increased, the time required for scanning decreased. Similarly, Patzelt SBM et al., conducted a series of studies to assess the accuracy and efficiency of three to four IOS [12,13]. Their results demonstrated that most scanners exhibited comparable accuracy, while the digital workflow proved to be more time-efficient compared to conventional methods. Thomas AA et al., (2023) investigated the influence of operator experience on IOS time and accuracy using two distinct IOS systems (TRIOS 3, 3Shape, and i500, Medit) [14]. Since then, numerous new scanners and technologies have been introduced. Although operator experience has been investigated with older scanners such as TRIOS 3 and i500, there is limited evidence on how clinician proficiency influences the performance of newer generation scanners such as TRIOS 5. Furthermore, no study has compared operator experience across three distinct IOS systems with different scanning technologies. The present study uniquely evaluates both time efficiency and accuracy of TRIOS 5, Runyes 3D, and Cerec Primescan AC across three operator experience levels, providing valuable insights into their practical efficiency and usability in addition to operator-friendliness.

Such comparisons are essential for selecting systems that not only streamline clinical workflows but also enhance convenience for clinicians and ultimately improve patient satisfaction. Therefore, the present study was undertaken to assess how the operator's level of experience influences the performance of different IOS systems in

terms of clinical efficiency and precision. The aim of this study was to evaluate the impact of operator experience on IOS using three distinct systems-Runyes 3D IOS with 3D True Colour technology, TRIOS 5 (3Shape), and Cerec Primescan AC. The primary objective was to compare the scanning time among operators with different levels of experience, while the secondary objective was to determine whether operator experience affects the accuracy of intraoral scans obtained using these scanner systems.

The null hypothesis of this study was that the operator's experience did not influence the scanning time and accuracy of the intraoral scans taken. The alternate hypothesis of the study was that the operator's experience influences the scanning time and accuracy of the intraoral scans taken.

MATERIALS AND METHODS

The present prospective study was conducted from November 2024 to December 2024, at the Department of Orthodontics, Saveetha Dental College, and was approved by the Scientific Review Board of Saveetha Dental College and Hospitals (SRB/SDC/ORTHO 2301/24/441).

Sample size calculation: The sample size was determined using G*Power 3.1 software (Franz Faul, University of Kiel, Germany). Based on the mean scanning times (186.22 s, 189.88 s, and 242.77s) reported by Resende CCD et al., the sample size was calculated, and 20 participants were included in the study [11]. The statistical power was set to 0.80 with an effect size of 0.64. Three groups were established based on operator experience level (high, moderate, and low), with each group further subdivided according to the type of IOS used. Each participant underwent nine IOS sessions, one with each of the three IOS types performed by operators representing three different experience levels, resulting in a total of 180 intraoral scans. All scanning sessions for a given participant were performed over two consecutive days, with adequate rest intervals between scans to minimise patient fatigue and operator bias.

Inclusion and Exclusion criteria: The inclusion criteria consisted of adult subjects ranging between 20 to 35 requiring orthodontic correction with all permanent teeth present from second molar to second molar, while excluding subjects with metal or gold crown restorations, tooth agenesis, attrited canines and molars, missing teeth, and proximal or occlusal caries [14]. Informed consent was obtained from all participants prior to their inclusion in the study.

Study Procedure

The IOS of subjects was performed using different scanners by three operators with varying degrees of scanning proficiency [Table/Fig-1].

Group-1 (High experience): Final-year postgraduate resident in orthodontics with over two years of clinical experience and >50 prior scans.

Group-2 (Moderate experience): First-year postgraduate resident with about one year of experience and 10-50 prior scans.

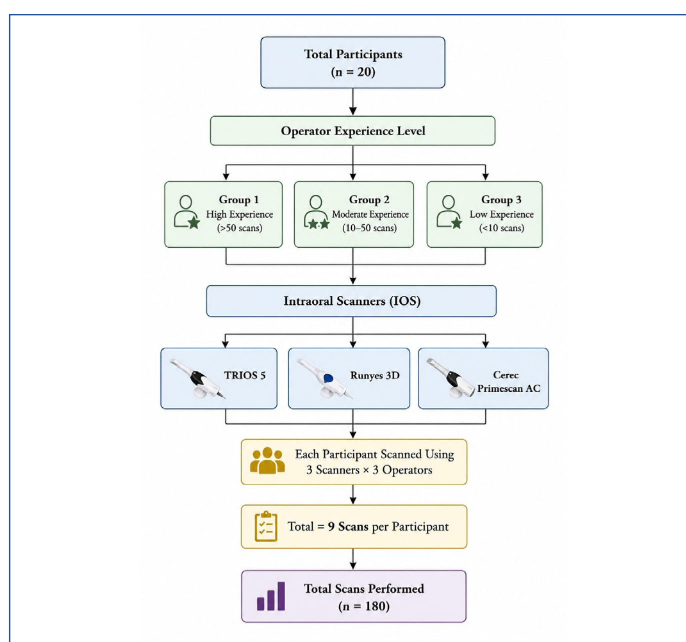
Group-3 (Low Experience): Final-year undergraduate student with basic IOS training and <10 prior scans.

All operators underwent standardised training on scanning protocols before the study to ensure uniformity. Three distinct scanners were used to carry out the IOS of the subjects.

1. TRIOS 5. (3Shape, Copenhagen, Denmark)
2. Runyes3D IOS with 3d true colour technology.
3. Cerec Primescan AC scanner, Cerec 5 software. (Dentsply, Sirona)

Outcomes assessed:

1. Scanning time
2. Scanning accuracy



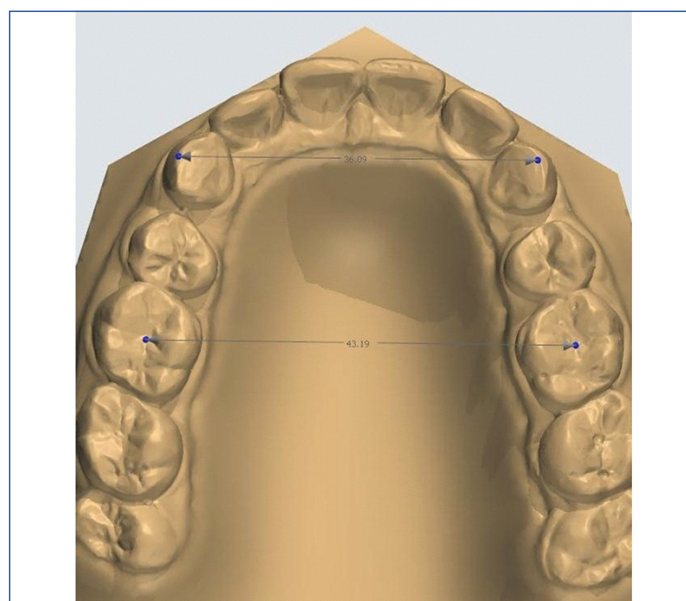
[Table/Fig-1]: Flowchart depicting the grouping of participants based on operator experience and scanner type.

Scanning time: For the assessment of scanning time, the duration was recorded in minutes, starting from the initiation of the scanning process and continuing until the complete generation of the 3D intraoral scan on the screen using a digital timer.

Scanning accuracy: All the acquired digital impressions were exported in Standard Tessellation Language (STL) file format, which is a widely accepted 3D file format for dental models. These STL files were then imported into the 3D Ortho Analyser software (3Shape, Copenhagen, Denmark) for dimensional analysis. The analysis of the scanned images was performed by the primary investigator (author), who was calibrated in the use of the software prior to the study to ensure measurement consistency and reliability.

For each digital model, two linear measurements were obtained [Table/Fig-2]:

1. **Inter-Canine Width (ICW):** Measured as the linear distance between the cusp tips of the right and left permanent canines.
2. **Inter-Molar Width (IMW):** Measured as the linear distance between the central fossae of the right and left permanent first molars.



[Table/Fig-2]: Linear transverse measurements obtained from the digital models: Inter-Canine Width (ICW), measured as the linear distance between the cusp tips of the right and left permanent canines, and Inter-Molar Width (IMW), measured as the linear distance between the central fossae of the right and left permanent first molars.

To maintain standardisation, the measurements were carried out in the same lighting conditions and using the same calibrated computer system. All measurements were taken individually for each operator experience level (high, moderate, and low) and for each scanner type (TRIOS 5, Runyes 3D, and Cerec Primescan AC).

STATISTICAL ANALYSIS

To perform descriptive statistics, the data of scanning time and measurements of accuracy were tabulated in an Excel file and imported into IBM SPSS software version 23.0. The parameters that were evaluated had a normal distribution, as indicated by the Shapiro-Wilk test ($p<0.05$). The intergroup variation in scanning time was evaluated using One-way ANOVA and the correlation between operator experience and accuracy across the three groups employing TRIOS 5, Runyes, and Cerec Primescan AC scanner respectively, was ascertained using Kendall's tau correlation test.

RESULTS

Scanning time was significantly high for low-experience operators when compared with medium and high-experience operators for all the types of IOSs ($p<0.05$) [Table/Fig-3]. [Table/Fig-4-6] depicts the post-hoc results of the intergroup difference in scanning time with Runyes, TRIOS 5 and the Primescan scanner, respectively. Post-hoc comparisons revealed statistically significant differences in scanning times between high, moderate and low experience operators for all the scanners ($p<0.001$). One-way ANOVA tests were performed to evaluate the effect of operator experience within each scanner and the effect of scanner type within each experience group [Table/Fig-7]. Kendall's Tau's correlation test revealed that operator experience doesn't influence the accuracy of the scans taken ($p>0.05$) [Table/Fig-8].

DISCUSSION

With the advent of evolving digital technologies in dentistry, IOS have largely replaced conventional plaster models due to their time efficiency and elimination of the need for extensive physical storage space [13,15-17]. Enhanced patient preference is reported with IOS, also they streamline the clinical workflow, offering increased efficiency and enhanced comfort for both patients and practitioners [16,18]. IOSs may introduce intrinsic alignment errors within their software, and it remains uncertain how factors such as the scanning time, type of scan, and operator expertise influence final outcomes [19,20]. Therefore, evaluating the impact of experience of operator on scanning accuracy is of significant importance.

Given the increasing reliance on digital workflows in orthodontics, especially with clear aligner systems and the documented patient preference, particularly due to shorter chairside time, it is essential to evaluate the time efficiency of different IOS [21]. From both the patient's and clinician's perspectives, minimising scanning time enhances the overall treatment experience, particularly in paediatric populations where cooperation is often limited. This underscores the importance of selecting IOSs that not only offer optimal accuracy but also in time efficiency.

In terms of scanning time, irrespective of operator experience level, the PrimeScan system required the longest scan times, whereas the Trios device consistently achieved the shortest scan durations across all groups. According to this study, the operator experience has a significant impact on scanning duration ($p<0.05$) with the HE operators taking less time for IOS than both ME and LE personnel. This finding is consistent with the previous literature evidence. Sun L et al., in their study reported that as operator expertise rises, scanning time is expected to decrease [22]. Also, Thomas AA et al., conducted a prospective clinical trial comparing two IOSs, TRIOS 3 (3Shape) and i500 (Medit) and found that less experienced operators required significantly more time to complete scans compared to their more experienced counterparts. Additionally, it was reported that scanning with the i500 took more time than with the TRIOS 3, indicating that the scanner type also plays a role in scanning efficiency [14]. Similarly, Resende CCD et al., (2020) evaluated the influence of operator experience, scanner type, and scan size on the accuracy of 3D scans, concluding that less experienced operators had longer scanning times. The study also reported an improvement in scan accuracy with increased operator experience, which contrasts with the findings of the present study [11]. This discrepancy may be attributed to differences in study design and methodology.

In terms of accuracy, assessed with ICW and Inter-Molar Width (IMW) Changes on 3D models using 3Shape ortho analyser software, all scanners in this study showed minimal variability in performance across different operator experience levels, suggesting

Variables	Type of scanners	High Experience (HE) Mean±SD	Moderate Experience (ME) Mean±SD	Low Experience (LE) Mean±SD	F	p-value
Time (min)	TRIOS 5	1.24±0.14	1.38±0.14	1.66±0.27	23.32	<0.001
ICW (mm)		33.62±1.83	33.41±0.97	33.31±0.99		0.65
IMW (mm)		50.06±3.38	49.69±3.24	50.17±2.52		0.68
Time (min)	Runyes	2.39±0.57	3.25±0.51	4.41±0.69	66.63	<0.001
ICW (mm)		33.60±0.93	33.62±1.38	33.60±0.93		0.70
IMW (mm)		50.10±2.47	49.91±2.44	50.06±2.16		0.69
Time (min)	Cerec Primescan AC	5.78±0.64	6.63±0.51	7.76±0.50	63.79	<0.001
ICW		33.18±1.30	33.59±1.33	33.39±1.21		0.71
IMW		49.98±3.28	49.78±3.15	50.05±2.59		0.73

[Table/Fig-3]: Mean±SD of scanning time (s), ICW, and IMW (mm) for all study groups and results of One-way ANOVA evaluating intergroup differences in scanning time and accuracy.
Statistical analysis was performed using One-way ANOVA for comparing means among groups. p-value <0.05 was considered statistically significant.
Abbreviations: HE: High experience; ME: Moderate experience; LE: Low experience; ICW: Inter-canine width; IMW: Inter-molar width; SD: Standard deviation

Levels of experience	Mean difference	p-value	95% Confidence interval Lower bound	95% Confidence interval Upper bound
High experience/Low experience /Moderate experience	-0.41 -0.13	0.00 0.09	-0.56 -0.28	-0.26 0.17
Moderate experience /Low experience /High experience	-0.28 0.13	0.00 0.09	-0.43 -0.01	-.013 0.28
Low experience/Moderate experience /High experience	0.28 0.41	0.00 0.00	0 .13 0.26	0.43 0.56

[Table/Fig-4]: Post-hoc analysis of scanning times for operators with high, moderate, and low experience levels using TRIOS 5.
One-way analysis of variance (ANOVA) with post-hoc pairwise comparisons (Tukey's HSD) was used to compare mean scanning times among high, moderate, and low experience operators for the TRIOS 5 scanner. A p-value <0.05 was considered statistically significant. Abbreviations: HE: High experience; ME: Moderate experience; LE: Low experience

Levels of experience	Mean difference	p-value	95% Confidence interval	
			Lower bound	Upper bound
High experience/Low experience /Moderate experience	-2.02 -2.02	0.00 0.00	-2.50 -2.50	-1.53 -1.53
Moderate experience/Low experience /High experience	0.00 2.02	1.00 0.00	-0.48 1.53	0.48 2.50
Low experience/Moderate experience /High experience	0.00 2.02	1.00 0.00	-0.48 1.53	0.48 2.50

[Table/Fig-5]: Post-hoc analysis of scanning times for operators with high, moderate, and low experience levels using Runyes.
One-way ANOVA followed by Tukey's post-hoc tests was employed to compare scanning times among high, moderate, and low experience operators using the Runyes scanner. Statistical significance was set at p<0.05. Abbreviations: HE: High experience; ME: Moderate experience; LE: Low experience

Levels of experience	Mean difference	p-value	95% Confidence interval	
			Lower bound	Upper bound
High experience/Low experience /Moderate experience	-1.97 -0.85	0.00 0.00	-2.41 -1.27	-1.55 -0.42
Moderate experience/Low experience /High experience	-1.12 0.85	0.00 0.00	-1.54 -0.42	-0.70 1.27
Low experience/Moderate experience /High experience	1.12 1.97	0.00 0.00	0.70 1.55	1.54 2.40

[Table/Fig-6]: Post-hoc analysis of scanning times for operators with high, moderate, and low experience levels using Cerec Primescan AC.
One-way ANOVA with Tukey's post-hoc comparisons was performed to assess differences in scanning times between high, moderate, and low experience operators using the Cerec Primescan AC scanner. A p-value <0.05 indicated significance. Abbreviations: HE: High experience; ME: Moderate experience; LE: Low experience

Groups	Scan time in minutes Mean±SD	F value	p-value
High experience (TRIOS 5)	1.24±0.14	52.4	<0.001
High experience (Runyes)	2.39±0.51		
High experience (Primescan)	5.78±0.64		
Moderate experience (TRIOS 5)	1.38±0.14	68.9	<0.001
Moderate experience (Runyes)	4.41±0.69		
Moderate experience (Primescan)	6.63±0.51		
Low experience (TRIOS 5)	1.66±0.27	74.1	<0.001
Low experience (Runyes)	4.81±0.70		
Low experience (Primescan)	7.76±0.50		

[Table/Fig-7]: Comparison of scanning time of different Intraoral Scanners (IOS) within groups by One-way ANOVA.
Scan time differences between TRIOS 5, Runyes, and Primescan were analysed within each operator experience level using One-way ANOVA. Statistical significance was set at p<0.05, and values reported as p<0.001 represent highly significant differences

Measurement	Group	Kendall's Tau-b correlation value (τ)	p-value
Intercanine width	Runyes	0.00	1.00
	Trios	0.04	0.65
	Prime	0.05	0.61
Intermolar width	Runyes	0.00	0.95
	Trios	0.00	0.99
	Prime	0.01	0.88

[Table/Fig-8]: Correlation between operator experience and arch widths (intercanine and intermolar) across three groups.
Kendall's tau-b correlation analysis was used to evaluate the relationship between operator experience and arch width measurements (intercanine and intermolar widths). A p-value <0.05 was considered statistically significant. Abbreviations: ICW: Inter-canine width; IMW: Intermolar width

stable dimensional reliability. TRIOS 5 demonstrated the least variation in ICW and IMW measurements, indicating consistent scanning accuracy irrespective of operator experience. While Runyes and Primescan also exhibited comparable accuracy, slightly higher variability was noted, particularly in the moderate- and low-experience groups. The results of the present study show that the accuracy of the scans doesn't depend on the experience levels of the operator (p>0.05). Therefore, the null hypothesis for scanning accuracy is accepted whereas for scanning time, it is rejected.

The selection of scanners (TRIOS 5, Runyes 3D, and Primescan), for this study was based on the fact that they represent distinct IOS technologies, allowing for a comprehensive comparison of performance across different platforms. TRIOS 5, the latest among them has demonstrated superior precision compared to Primescan in recent literature [23]. However, to date, there is a lack of published studies directly comparing operator-related factors such as ease of use or scanning efficiency between TRIOS 5, Runyes, and Primescan. This gap in existing literature underscores the need to evaluate how operator experience impacts scanning efficiency across these distinct IOSs.

Although operator experience plays a role, it is not the only factor influencing the outcome. As highlighted by Mangano A et al., it remains unclear whether one scanner device is superior to another, and this uncertainty is compounded by the limited information provided by manufacturers regarding their recommended scanning technology [16]. With the growing reliance on digital technology in orthodontics, it becomes increasingly important to validate and compare different IOSs in terms of ease of usage to ensure efficiency and convenience.

Clinicians should recognise that operator proficiency primarily influences the efficiency of IOS rather than the quality of the digital impression. This study highlights that with proper training, even less experienced practitioners can produce scans with reliable dimensional accuracy, reducing dependency on expert users. Selecting scanners that integrate seamlessly into clinical workflows, such as TRIOS 5, can further enhance practice productivity by minimising scanning time and improving patient comfort. Embracing digital scanning technology facilitates streamlined communication with dental laboratories, reduces material costs, and mitigates errors associated with conventional impressions. Consequently, IOS represents a valuable tool for optimising orthodontic treatment delivery, making it essential for clinicians to balance device capabilities with targeted operator training to maximise both efficiency and accuracy in patient care.

Limitation(s)

In the current study, operator experience was classified by the number of previous scans performed, although experience relies on subjective criteria and less experienced users may sometimes outperform experts and vice versa, introducing unaccounted variability. Only three scanner systems were evaluated, limiting generalisability to newer IOS devices. Given the rapid pace of IOS innovation, further studies are needed to assess performance of the latest-generation scanners and updated scanning protocols.

CONCLUSION(S)

Operators with higher experience levels demonstrated significantly reduced IOS times. TRIOS 5 showed the shortest scanning durations among the scanners evaluated, enhancing clinical efficiency. The accuracy of digital impressions, measured by inter-canine and IMWs, was not influenced by operator experience. Scanner type did not significantly affect scan precision, indicating consistent reliability across devices. These findings support adopting modern IOSs to improve workflow efficiency while maintaining accuracy, regardless of operator skill level.

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