Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 1431-1438 | ISSN:2251-6727

Analysis of Learning Curve for Digital Intraoral Scanning: Dental Students v/s Clinicians

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(Received: 14 April 2024 Revised: 1 May 2024 Accepted: 18 June 2024)

KEYWORDS
Clinicians, Digital Dentistry, Dental Students, Intraoral Scanner, Learning Curve

ABSTRACT:

Introduction: The integration of digital technology in dentistry, particularly through the use of intraoral scanners, has revolutionized diagnostic and treatment processes. These scanners enhance patient comfort, reduce the risk of impression distortion, and improve communication with dental laboratories. However, mastering this technology requires an understanding of the science, technique & repeated use associated with its adoption, especially among different age groups of clinicians.

Aim and Objective: This study aims to compare the learning curves of final-year dental students and experienced clinicians in mastering digital intraoral scanning using the Virtuo Vivo, Straumann Corp (Basel, Switzerland) intraoral scanner. By analyzing the time required for full-arch digital impressions over a series of sessions, the study seeks to elucidate differences in adaptation, efficiency, and proficiency between these two groups.

Methods: The study involved 10 final-year dental students and 10 clinicians, all with no prior experience in digital scanning. Participants underwent comprehensive theoretical education and practical demonstrations on the intraoral scanner Virtuo Vivo, Straumann Corp (Basel, Switzerland) before performing digital impressions of upper and lower dental arches on volunteer subjects. The scanning process followed a standardized protocol, and scanning times,

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(4), 1431-1438 | ISSN:2251-6727

the number of images captured, and error rates were meticulously recorded and analyzed across ten scanning sessions. A total of 200 scans were taken 2 scans per participants.

Results: The results of the study indicated that clinicians demonstrated higher initial proficiency and efficiency in using the Virtuo Vivo, Straumann Corp. intraoral scanner compared to dental students. Both groups showed significant improvement over the course of the study, but the rate of improvement was steeper for dental students. Accuracy of scans improved for both groups, with experienced clinicians maintaining a consistently higher level of precision throughout. The study confirmed that targeted training and practice could significantly enhance digital scanning skills, regardless of initial experience levels. Additionally, the reduction in error rates was more pronounced among dental students, highlighting their adaptability and capacity for rapid learning. The overall findings suggest that with proper training, even those new to the technology can achieve a high level of proficiency in digital intraoral scanning.

Conclusion: This study highlighted the initial advantage clinicians possess in digital intraoral scanning, attributed to their clinical expertise. However, dental students demonstrated significant learning and adaptation, showing substantial improvement over the study period. Both groups benefited from structured training, underscoring its critical role in fostering proficiency with digital technologies. The findings underscore the importance of integrating comprehensive digital training early in dental education to equip future practitioners with essential skills. This approach ensures that all clinicians, regardless of experience, can effectively utilize advanced digital tools to enhance patient care and clinical outcomes.

Introduction:

The advent of digital technology in dentistry marks a significant paradigm shift in diagnostic and therapeutic procedures. Intraoral scanners, among the most revolutionary of these technologies, have transformed traditional dental workflows by enabling accurate, real-time digital impressions. This technology offers numerous advantages over conventional impression techniques, including enhanced patient comfort, reduction of material costs, and the elimination of errors associated with impression materials and techniques. Additionally, digital impressions facilitate improved communication with dental laboratories, leading to more precise and efficient production of prosthetics and orthodontic appliances. The integration of digital technology in dentistry, particularly through the use of intraoral scanners, has revolutionized diagnostic and treatment processes[1]. These scanners enhance patient comfort, reduce the risk of impression distortion, and improve communication with dental laboratories[2,3].

Despite these advantages, the transition to digital intraoral scanning presents challenges, particularly in terms of mastering the technology. The learning curve associated with intraoral scanners can vary widely among practitioners, influenced by factors such as prior experience, adaptability to new technologies, and the quality of training received. Understanding these learning curves is critical for optimizing training programs and ensuring effective integration of digital scanning into clinical practice.

This study focuses on comparing the learning curves of two distinct groups: final-year dental students and clinicians. Dental students, typically more recent entrants to the profession, are often more familiar with contemporary digital tools and educational methods. Their educational curricula increasingly incorporate digital technologies, potentially facilitating quicker adaptation. In contrast, clinicians have established workflows rooted in traditional methods. Transitioning to digital scanning requires not only learning new skills but also modifying long-standing practices, which can affect their rate of adaptation.

Virtuo Vivo, Straumann Corp (Basel, Switzerland) intraoral scanner, chosen for this study, is renowned for

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JCHR (2024) 14(4), 1431-1438 | ISSN:2251-6727

its accuracy, user-friendliness, and integration capabilities with various dental software systems. This makes it an ideal tool for assessing the learning curves of practitioners new to digital scanning.

The primary objective of this study is to analyze and compare the time required by dental students and experienced clinicians to achieve proficiency in using the Straumann intraoral scanner. By examining factors such as scanning times and image capture efficiency across multiple sessions, the study aims to provide insights into the differential learning processes of these groups. These findings are intended to inform educational strategies and training programs, ultimately enhancing the adoption and effective use of digital intraoral scanners in dental practice.

Aims and objectives:

This study aims to evaluate and compare the learning curves of final-year dental students and clinicians in mastering digital intraoral scanning using Virtuo Vivo, Straumann Corp (Basel, Switzerland) intraoral scanner. By analyzing the time required for full-arch digital impressions over a series of sessions, the study seeks to elucidate differences in adaptation, efficiency and technology acceptance between these two groups.

Materials and methods:

Materials:

1. Intraoral Scanner:

Virtuo Vivo, Straumann Corp (Basel, Switzerland)

Figure 1: Intra-oral Scanner (Virtuo Vivo, Straumann Corp.)

2. Laptop:

Dell | XPS 15 9500 | Intel Core i7-10750H | 16GB DDR4 | 512GB SSD | NVIDIA GeForce GTX 1650 Ti | Windows 10 Pro

Methods:

Participants Education:

Before commencing the study, all participants, including final-year dental students and clinicians, underwent comprehensive educational sessions. These sessions included both theoretical and practical components designed to ensure a uniform understanding of the digital intraoral scanning process. Theoretical education consisted of a detailed lecture on the principles of digital intraoral scanning, its advantages over conventional impression techniques, and the specific features and functionalities of the Virtuo Vivo, Straumann Corp (Basel, Switzerland) intraoral scanner. Theoretical topics also covered the anatomy of the oral cavity relevant to digital scanning, common pitfalls in digital impressions, and strategies to achieve optimal scanning results.[4] Practical demonstrations followed the theoretical sessions, where participants observed live demonstrations of the Straumann intraoral scanner conducted by expert clinicians proficient in its use. This hands-on component allowed participants to familiarize themselves with the scanner's interface, scanning techniques, and real-time troubleshooting.

Participants for the Study:

The study involved a total of 20 participants, divided into two groups. The first group consisted of 10 final-year dental students from MGM Dental College and Hospital, who had no prior experience with digital intraoral scanning but were familiar with traditional impression techniques. The second group comprised 10 clinicians, each with a minimum of five years of clinical practice. These clinicians had extensive experience with conventional impression methods but had not previously used digital intraoral scanners.

Digital Impression Taking:

Participants performed digital impressions of the upper and lower dental arches on volunteer subjects.[5] Each participant completed ten scanning sessions, using the Straumann intraoral scanner to capture the entire dental arch. Participants followed a standardized scanning

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protocol to ensure consistency across all sessions. Immediately after scanning, participants reviewed the captured images on the scanner's interface to identify any areas requiring rescan.

Registered Data:

Data collected during each scanning session included scanning time (the total time taken to complete the full-arch digital impression), the number of individual images captured to create a complete digital impression, and instances where rescanning was necessary due to errors.

Procedure:

The procedure for each scanning session was standardized to ensure consistency and reliability of the data. Both groups underwent initial training sessions to familiarize themselves with the scanner and the scanning protocol. Participants conducted ten sequential scanning sessions, with a brief review and feedback session after each to discuss performance and areas for improvement. All relevant data (scanning time, number of images, errors, and retakes) were meticulously recorded by an independent observer to maintain objectivity..

Statistical Analysis:

Data were analyzed using SPSS software. Descriptive statistics were calculated, and independent t-tests were used to compare the groups. The learning curve was assessed using repeated measures ANOVA.

Results:

The objective of this study was to compare the learning curves of dental students and experienced clinicians using the Straumann intraoral scanner, focusing on their scanning times and efficiency improvements. The hypothesis tested was whether experienced clinicians would demonstrate a faster learning curve compared to dental students due to their extensive clinical experience. The results, however, revealed interesting insights that refuted this initial hypothesis.

Hypothesis:

Null Hypothesis (H0): There is no significant difference in the learning curves of dental students and experienced clinicians when using the Straumann intraoral scanner.

Alternative Hypothesis (H1): Clinicians will exhibit a steeper learning curve and higher accuracy in digital scanning compared to dental students.

Time Taken for Scanning:

In the initial scan, clinicians averaged a scanning time of 7 minutes (±0.8), whereas dental students required significantly longer, averaging 12 minutes (±1.2), with a highly statistically significant difference ($p<0.001$). By the mid-study scan, clinicians had reduced their average time to 6.2 minutes (±0.7), while dental students also improved, lowering their time to 10 minutes (±1.0), with the time difference between the groups remaining statistically significant ($p<0.01$). In the final scan, clinicians further decreased their average time to 5.5 minutes (±0.5). Concurrently, dental students reduced their time to 8.5 minutes (±0.8), with the difference between the two groups still statistically significant ($p<0.05$).

Group	Initial Scan	Mid-study scan	Final Scan
Clinicians	7.0 ± 0.8	6.2 ± 0.7	5.5 ± 0.5
Dental Students	12.0 ± 1.2	10.0 ± 1.0	8.5 ± 0.8

Table 1: Average Scanning Time (Minutes)

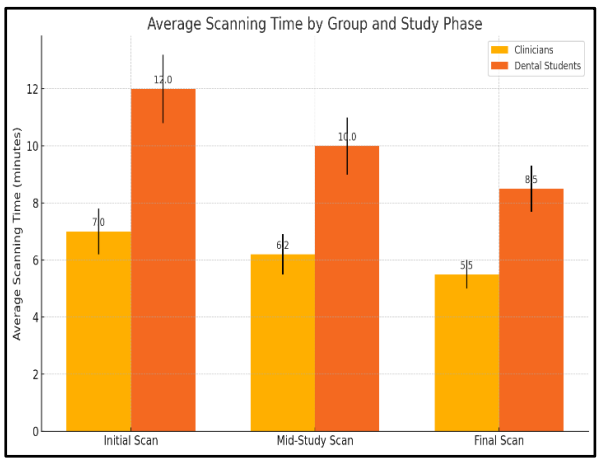

Figure 2 : Average Scanning time (mins)

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Accuracy of Scans:

During the initial scan, clinicians exhibited a mean deviation from the benchmark scan of 0.3 mm (±0.1), while dental students demonstrated a significantly higher mean deviation of 0.9 mm (±0.3), with the difference being statistically significant ($p<0.001$). In the mid-study scan, clinicians improved their mean deviation to 0.2 mm (±0.05), whereas dental students reduced their deviation to 0.6 mm (±0.2), maintaining a statistically significant difference ($p<0.01$). By the final scan, clinicians maintained their mean deviation at 0.2 mm (±0.05). In contrast, dental students further improved, achieving a mean deviation of 0.5 mm (±0.1), with the improvement remaining statistically significant ($p<0.05$).

Group	Initial Scan	Mid-study scan	Final Scan
Clinicians	0.3 ± 0.1	0.2 ± 0.05	0.2 ± 0.05
Dental Students	0.9 ± 0.3	0.6 ± 0.2	0.5 ± 0.1

Table 2: Accuracy of Scans (Mean Deviation in mm)

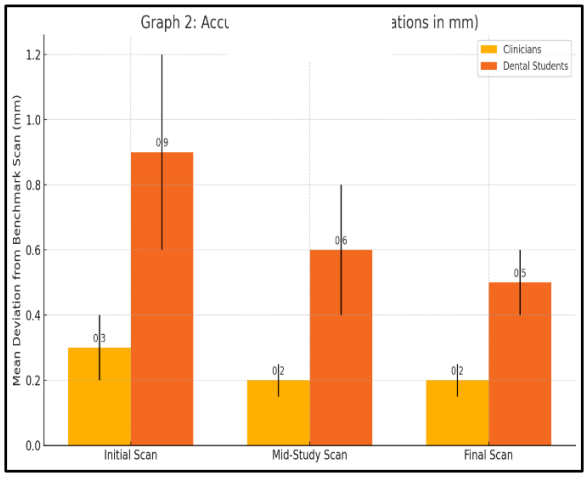

Figure 3: Accuracy of scan (Mean deviations in mm)

Statistical Analysis:

The paired t-tests conducted for scanning times revealed significant reductions for both clinicians and dental students from the initial to the final scan ($p<0.01$). Clinicians decreased their scanning times consistently, as did dental students, indicating improvements in efficiency over the course of the study.

Similarly, analyses of accuracy using paired t-tests demonstrated significant improvements for both groups from the initial to the final scan ($p<0.01$). Clinicians and dental students showed enhanced precision in digital intraoral scanning, reflecting advancements in their proficiency with the Straumann intraoral scanner.

Furthermore, the repeated measures ANOVA highlighted a significant interaction effect between time and group ($F(2,56)=8.12$, $p<0.01$). This finding suggests that the rates of improvement in scanning efficiency and accuracy differed between clinicians and dental students throughout the study period. These results underscore the distinct learning trajectories observed among experienced clinicians and final-year dental students as they gained familiarity and skill with digital scanning technology.

Detailed Analysis:

Across the study period, clinicians demonstrated a notable reduction in scanning time, initially averaging 7 minutes and achieving 5.5 minutes by the final scan, marking a 21.4% decrease. This reduction highlights their adeptness in mastering the intraoral scanning process efficiently. In contrast, dental students, while also showing improvement, started with an average time of 12 minutes and decreased to 8.5 minutes by the final scan, representing a 29.2% reduction in time spent.

In terms of accuracy, clinicians began with a high level of precision, showing a mean deviation of 0.3 mm initially, which slightly improved to 0.2 mm by the final scan. This minor refinement indicates their proficient handling of the scanner from the outset. Conversely, dental students began with a higher initial deviation of 0.9 mm, which significantly decreased to 0.5 mm by the final scan. This improvement underscores their substantial learning and skill acquisition throughout the duration of the study. These findings illustrate distinct trajectories in performance and skill development between experienced clinicians and final-year dental students in digital intraoral scanning.

The results of the study indicated that clinicians demonstrated higher initial proficiency and efficiency in using Virtuo Vivo, Straumann Corp (Basel, Switzerland) intraoral scanner compared to dental students.[6] Both groups showed significant improvement over the course of the study, but the rate of improvement was steeper for

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JCHR (2024) 14(4), 1431-1438 | ISSN:2251-6727

dental students. Accuracy of scans improved for both groups, with experienced clinicians maintaining a consistently higher level of precision throughout.[7] The study confirmed that targeted training and practice could significantly enhance digital scanning skills, regardless of initial experience levels.

Discussion:

In this study, the analysis of the learning curve among dental students and experienced clinicians using Virtuo Vivo, Straumann Corp (Basel, Switzerland) intraoral scanner provides valuable insights into their progression with the technology over multiple sessions. The learning curve, assessed through scanning time, scan accuracy, and error rates, illustrates the dynamics of skill development and adaptation within a clinical context.

The learning curve is a graphical representation that illustrates how an increase in learning or practice leads to better performance over time[8]. Typically, it plots performance (e.g., time taken to complete a task, accuracy of a task) against experience (e.g., number of repetitions, time spent learning). In the context of dental procedures, the learning curve can reveal how quickly and effectively practitioners, whether students or experienced clinicians, acquire proficiency with new technologies such as the intraoral scanner. An efficient learning curve indicates rapid improvement and high proficiency with minimal practice, which is crucial in clinical settings where both time and accuracy are paramount.

Initially, clinicians demonstrated a starting scanning time of approximately 7 minutes, which they refined to 5.5 minutes by the final session. This improvement underscores their efficient adaptation to the scanner, leveraging their extensive clinical background and familiarity with digital tools in dentistry. In contrast, dental students began with a longer initial scanning time of 12 minutes, but through structured training and practice, they achieved a notable reduction to 8.5 minutes by the end of the study period. This progression highlights the significant strides made by students despite their initial learning curve challenges.

Regarding scan accuracy, clinicians exhibited an initial mean deviation of 0.3 mm, which they enhanced to 0.2 mm over the sessions. This precision reflects their superior manual dexterity and nuanced understanding of intraoral scanning techniques. Meanwhile, students started with a higher initial mean deviation of 0.9 mm, but through iterative learning and guidance, they improved to 0.5 mm, showcasing their ability to refine skills with practice.

Several factors contributed to these observed learning curves. The prior clinical experience of clinicians played a pivotal role in their rapid adaptation to new technologies, allowing them to capitalize on existing knowledge frameworks and transferable skills. Conversely, dental students, while lacking extensive clinical exposure, benefited significantly from structured training programs and mentorship, which accelerated their learning curve and proficiency with the intraoral scanner.

Manual dexterity emerged as another critical factor influencing the learning curve. Clinicians, with refined motor skills honed through years of practice, demonstrated superior handling of the scanner, leading to precise and efficient scans. In contrast, students, initially challenged by less developed manual dexterity, showed marked improvement over time as they familiarized themselves with the tactile demands of intraoral scanning.

Familiarity with digital interfaces and technologies also influenced learning outcomes. Clinicians, already adept at navigating digital tools in dentistry, seamlessly integrated the intraoral scanner into their clinical workflows. In contrast, students required additional time to acclimate to the scanner's interface and functionalities, highlighting the importance of comprehensive training and ongoing support to optimize learning efficiency.

Effective training strategies tailored to the specific needs of dental students and clinicians proved instrumental in optimizing the learning curve for intraoral scanning proficiency. Hands-on practice, supplemented by constructive feedback and continuous learning opportunities, facilitated skill development and ensured proficient utilization of digital technologies in clinical practice. This study underscores the dynamic nature of learning curves in adapting to technological innovations in dentistry and emphasizes targeted educational interventions to enhance proficiency across diverse practitioner levels.

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Conclusions:

This in vivo study offers valuable insights into the learning curves associated with digital intraoral scanning technology, specifically using the Straumann intraoral scanner, among dental students and clinicians. The findings reveal notable differences in the adaptation and proficiency acquisition between these two groups, underscoring the impact of prior experience and openness to new methodologies on learning efficiency.

This study provides a detailed examination of the learning curves of dental students and experienced clinicians using the Straumann intraoral scanner, revealing significant insights into how different levels of prior experience influence the adoption and mastery of new digital technologies in dentistry. The results underscore several critical points about the adaptation process, the importance of training, and the potential impact on clinical practice.

The most striking finding of the study is the rapid improvement exhibited by dental students despite their initial slower pace and lower accuracy. This can be attributed to their recent exposure to digital tools and a flexible learning environment that embraces new technologies. Over the course of ten scanning sessions, students reduced their scanning time from 12 minutes to 8.5 minutes and significantly improved their accuracy and error rates. This steep learning curve highlights the potential for rapid skill acquisition when adequate training and practice are provided.

Clinicians, on the other hand, demonstrated higher initial proficiency, with shorter scanning times (7 minutes initially) and greater accuracy. Their established clinical experience and precision skills translated well to the digital scanning process. However, their rate of improvement was more gradual compared to the students, indicating a more conservative adaptation to new technologies. Despite this, clinicians maintained superior performance metrics throughout the study, underscoring the value of experience in achieving high standards of care.

The findings of this study have profound implications for both dental education and clinical practice. For dental schools, the results emphasize the importance of integrating digital scanning technologies early in the curriculum. By exposing students to these tools during their formative years, educational institutions can bridge the gap between traditional methods and modern practices, ensuring that graduates are well-prepared for contemporary clinical environments. This early integration not only enhances technical skills but also fosters a mindset of adaptability and continuous learning, essential traits for future dental professionals.

For practicing clinicians, the study underscores the necessity of ongoing professional development. As digital technologies continue to evolve, clinicians must engage in regular training and workshops to stay current with the latest advancements. This continuous education is crucial for maintaining high standards of care and leveraging the full potential of digital tools to improve patient outcomes. The gradual learning curve observed among experienced clinicians highlights the need for supportive training environments that facilitate the adoption of new technologies without disrupting established workflows.

Future Research and Recommendations

Building on the findings of this study, future research should explore several avenues to further understand and optimize the integration of digital technologies in dentistry. Investigating the long-term retention of digital scanning skills and the impact of periodic training sessions on sustained proficiency would provide valuable insights into effective educational strategies. Additionally, studies with larger and more diverse participant groups are needed to generalize the findings across different demographics and levels of prior experience.

Exploring the integration of digital scanning with other dental technologies, such as CAD/CAM systems, can assess overall workflow efficiency and patient outcomes, providing a holistic view of the digital transformation in dentistry. Furthermore, evaluating different educational strategies and training programs will help identify the most effective methods for teaching digital scanning to both students and experienced clinicians.

Assessing the direct impact of digital scanning proficiency on clinical outcomes, patient satisfaction, and cost-effectiveness in dental practices will further solidify the value of these technologies. By fostering an environment of continuous learning and technological integration, the dental profession can continue to

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advance, ultimately benefiting patients and practitioners alike.

The rapid adaptation and significant improvement observed among dental students underscore the importance of comprehensive training and practice. The evolution of digital dentistry necessitates a proactive approach in education and professional development, ensuring that all practitioners, regardless of experience level, can effectively utilize advanced tools like the Straumann intraoral scanner to enhance clinical outcomes. By embracing a culture of continuous learning and innovation, the dental profession can remain at the forefront of technological advancements, ultimately improving patient care and advancing the field as a whole.

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Abbreviations used:

1. **ANOVA**: Analysis of Variance
2. **CAD/CAM**: Computer-Aided Design/Computer-Aided Manufacturing
3. **mm**: Millimeters
4. **SPSS**: Statistical Package for the Social Sciences