Does the Learning Curve for Intraoral Scanning Vary Depending on the Device?

Keywords

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ABSTRACT

Objectives: Digital impressions using intraoral scanners (IOS) are replacing conventional impressions, requiring a learning process. This study compared the learning curves of 29 dentists with no prior IOS experience, randomly assigned to groups: Eagle, Omnicam-AF, and IS-3700. Methods: After a lecture, participants performed three full scans (maxilla, mandible, and occlusion record) on a phantom and completed a survey about their experience. Scanning times to achieve adequate scans were recorded, and Wright's model was used to estimate the number of trials required for proficiency. Statistical analyses used Kruskal-Wallis and Chi-Square tests. Results: Proficiency was achieved after 10 trials with Eagle and 11 trials with Omnicam-AF and IS-3700. Participants using IS-3700 reached the plateau faster (167.9 s) than those using Eagle (245.5 s, P=0.041) and Omnicam-AF (260.6 s, P=0.014). While all groups appreciated the time-saving benefits over conventional impressions, 60-70% identified the need for further training. Conclusion: Despite similar trials required for proficiency, differences in average scanning times suggest that IOS characteristics may influence learning efficiency and user perceptions. Clinical Relevance: Understanding learning curves and device-specific performance can help optimize IOS training programs and guide clinicians in adopting digital workflows effectively.

INTRODUCTION

There is a transition between conventional and digital impressions through intraoral scanning (IOS) happening in dentistry.[1,2] In the face of this progress in the new technology adoption lifecycle[3] the IOS learning curve has gained interest among older and new dental professionals, dental professors and dental schools. IOS devices may vary in terms of size, weight, imaging technology, light, storage characteristics, software, field of view, depth, accuracy and prices.[2,4-13] Regardless of the characteristics and image capture technology, all images are processed and transformed into a triangular mesh format file, STL (standard triangle language). Once this file and, consequently, the virtual cast of the patient have been obtained, it is possible to carry out planning and treatment by using specialized design software and then proceed to milling or tridimensional (3D) printing.[1,2,4] In this way, IOS replaces conventional casting with advantages such as in an accurate and digital image, reducing the operating time, being more bio and eco safe and improving patient comfort.[1,2] It also requires a considerable investment of effort from the part of professionals and professors, and this period is known as the learning curve process.

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In order to achieve aptitude in a task, it is necessary to develop a trajectory called learning curve. This curve describes the performance of learners in the learning process by doing a relationship between time (or other variable) and repetition. It also indicates where the curve stabilizes in a plateau fashion or after how many repetitions proficiency is achieved.[14,15] Some criteria can be used to characterize the learning curve, which can be divided into three stages: initial performance stage ("starting point in the learning process"); the plateau or asymptote, the stage at which performance levels off ("learning plateau"); and the speed with which a stage of performance is reached ("learning rate"). Thus, it can be said that efficiency in performing a task is directly related to practicing it. As practice increases, performance improves and the effort required to perform the same task decreases.[14-18,33]

In dentistry, research on the process of learning new techniques and adopting new technologies is scarce. Regarding IOS, most studies primarily focus on assessing accuracy, comparing different devices, or evaluating the differences between conventional and digital workflows.[5,19-26] Among the research related to the IOS learning curve, studies have explored the performance of professionals based on their academic backgrounds.[23,27] However, few studies have examined how different IOS devices influence the learning process.[14,28] A relevant point is that the aforementioned studies draw their conclusions without mention the moment of the learning curve plateau, making it unclear to determine the number of trials to achieve proficiency.[23,27-33]

There are other studies that have also investigated the influence of different IOS devices on the learning process, but none of these studies included a comprehensive analysis of learning rates and performance parameters.[23,27-33] Kim *et al.*[27] (2016) evaluated the experience curve of professionals with different levels of experience with two different IOS devices: iTero and Trios and monitored the decrease in scanning time. They observed that although scanning time decreased with training for both devices, Trios always maintained a lower average time compared to iTero, confirming the influence of the type of device on the learning process. However, this study was restricted to evaluating only two types of devices and did not reach the plateau of the curve. In contrast, in the study by Al Hamad *et al.*[14] (2020) the learning rate, plateau range and degree of difficulty in IOS scanning by prosthetic residents were examined by using a prediction model. Nevertheless, this study only investigated a single device, which is a limiting factor, as these devices have very particular characteristics that can possibly influence the performance of the individual; therefore, it would be interesting to evaluate the learning curve with different IOS devices.

To the best of our knowledge, there are no studies evaluating the learning curve with more than two IOS devices and predicting the plateau or proficiency and its "moment". In view of this and the large number of devices on the market and their different characteristics, the aim of this study was to compare the learning curves among three different IOS within a population of dentists with no previous experience in intraoral scanning, as well as to evaluate user satisfaction. The null hypothesis is that there is no difference in the learning curve regardless of the IOS device.

MATERIAL AND METHODS

STUDY DESIGN

This cross-sectional observational study was approved by the Local Research Ethics Committee (CAAE: 65933522.5.0000.5419). This study was conducted at Ribeirão Preto School of Dentistry, University of São Paulo (USP), Ribeirão Preto, São Paulo, Brazil.. The sample size was calculated according results in literature[27] and a pilot study and considering a level of confidence of 95% and a power test of 80% (G*Power v 3.1.9.7; Heinrich-Heine-Universität Düsseldorf). The minimum total sample size was 15, thus, the number of participants included was 30 dental professionals (doctors in dental surgery). They were included according to the criteria of having any previous experience with scanning and without any physical limitations. One participant dropped out during the course of the study, so in the end, there were 29 participants - 18 women and 11 men, with a medium age of 35 (minimum 27 and maximum 52 years); the average time they had obtained their DDS degree was 10 years. The variable assessed was the time taken to properly complete a scan (maxilla, mandible and occlusion record). The variation factor analyzed was the three different types of intraoral scanner. At the end of all the scans, each participant answered a questionnaire that assessed their perceptions. The participants selected were randomly divided into three groups, one for each IOS device (*Table 1*).

PHANTOM HEAD SPECIFICATIONS

To reproduce a clinical situation, a phantom manikin head (8000; Manequins Odontológicos, Marília, São Paulo, Brasil) and a complete dentate manikin (Manequim Odontológico Flex, P-Oclusal, São Paulo, São Paulo, Brasil) were used to simulate oral cavity of patient. This phantom was positioned so that the participant could adjust the height and angle to make it comfortable and ergonomic for them.

PRE-SCAN STEP

After signing the informed consent form, the participants received a 3-hour lecture on intraoral scanning and the particularities of each device used in the study by an experienced professor in the field. At the end, a demonstration of scanning a complete arch on a manikin positioned on a phantom was carried out by the same professor. The participants were divided into three groups for each scanner with a supervisor. All the scans were carried out in the same room, where the only light used was that of the room itself (400 lux).

Table 1. Technical information of the three intraoral scanning devices used in the study and their respective computers.

	IOS – I	IOS – II	IOS – III
Manufacturer	Dabi Atlante	Dentsply Sirona	Dexis
Model	Eagle IOS	Omnicam AF	IS 3700
Software	Eagle IOS - 3.8.0804.2	Connect 5.2	IS ScanFlow 1.0.9.502
Weight	150 g	313 g	316 g
Dimensions	256 x 43 x 43 mm	223 x 50 x 40 mm	218 x 36 x 58 mm
Tip size	18 x 16 mm	16.1 x 16.2 mm	-
Scanner technology	Triangulation	Optical Triangulation	Triangulation
Image Capture mode	Digitizing and continuously accumulating depth and color data	Continuous data capture	Color Video
Type of light	LED, structured light	White LED depolarized with visible spectral area	LED, structured light
Frames per second (FPS)	Up to 35	Up to 12	-
Depth	Up to 12 mm	Up to 15 mm	-2 to 12 mm
Field of view (FOV)	12 x 14 mm	10 x 11 mm	13 x 13 mm
Accuracy	14 µm - 35 µm	31.8 µm	30.4µm
Computer configuration	Dell G15, i7 12th - 16Gb RAM - NVIDEA RTX 3060 6Gb	Dell G7, i7 - 32Gb RAM - GeForce RTX 2060	Avell A70 MOB, i7 11th - 32Gb RAM - GeForce RTX 3060

SPECIFICATIONS OF INTRAORAL SCANNERS

The three scanners used in the study differ in terms of dimensions, tip size, handle ergonomics, speed of capture, technology of image capture, field of view and accuracy, as shown in Table 1.

SCAN STEP

During the study, one participant dropped out, so groups were as follows: Eagle=10 (Dabi Atlante, São Paulo, Brasil); Omnicam AF=09 (Dentsply Sirona, Bensheim, Germany); IS 3700=10 (Dexis, Pennsylvania, United States). Each participant underwent 3 complete scans (maxilla, mandible, and occlusion record) on a manikin with complete healthy dentition, following the scanning technique recommended by the manufacturer *(Figure 1)*. The scans were carried out under the supervision of an experienced professional, in a single session with an interval of 30 minutes among them to not cause fatigue to the participants. The time to reach an adequate procedure of intraoral scanning was registered by the supervisor using a stopwatch, who was also responsible for attesting that such procedure was adequate, similarly happens on the teaching of other dental procedures. The time started to be recorded when the participant informed, they were ready to start the procedure and ended when the participant completed an adequate scan, according to the supervisor, with possible corrections, if necessary. For the scan to be valid and considered satisfactory, it had to meet certain requirements, such as accurately copying all the tooth surfaces - buccal, occlusal, palatal/lingual - with a 2 mm gingival margin and no gaps or overlaps in the mesh. If the scan showed any errors, the participant had to correct them until they were adequate, and the time taken for these corrections was counted together. In the end, each participant underwent 3 scans, which, considering the 29 participants, resulted in a total of 87 scans.

POST-SCAN STEP

A post-scan questionnaire was given to each participant with the aim of assessing knowledge and perception of the experience after the scans - based on a previous study.[34]

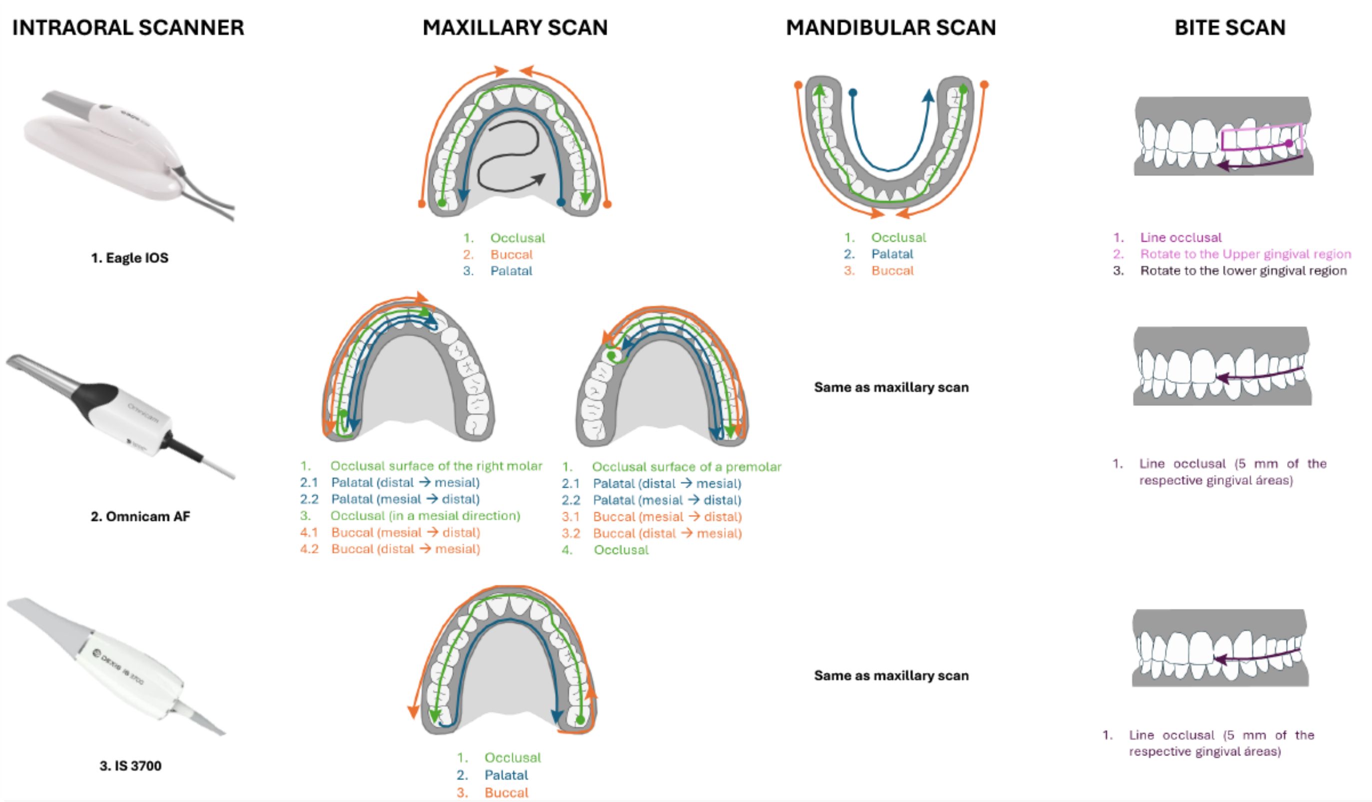

Figure 1: Scanning techniques for each scanner.

DATA ANALYSIS

The Wright model was applied to estimate the learning curve based on studies involving IOS and learning curve.[14,16,33] It is log-linear and uses the following mathematics: $Y_{(X)}=Y1X^b$. Where Y(x) is the average time of the impressions, Y1 is the time of the first impression, and X is the time. Expression b (-1<b<0) is the slope of the learning curve that represents the students' learning rate (0<LR<1) and can be obtained by the formula: b=log LR/log 2. LR means the degree of improvement of working time in relation to the previous time. Furthermore, the closer the value of b is to -1, the greater the learning speed and the faster the task adaptation.[14-18,33] Thus, based on three scans, a learning curve prediction was made considering 500 repetitions. To determine the plateau, the maximum variation time among trials of 10 seconds was considered insignificant from a practical point of view. The Shapiro-Wilks test was used to assess normality of the data distribution, and it was concluded that there was no normal distribution. The Chi-Square test was used to compare the relative frequencies among the groups' questionnaire responses. Wright's model was used to estimate the learning curve. The Kruskal-Wallis's test was then used to compare the learning curves among the three groups. As there were three groups, a post-hoc Mann-Whitney test was carried out to compare the groups in pairs and thus determine precisely where the difference occurred. In all tests, the level of significance was set at P<.05 and calculations were performed by using software (SPSS 26 software, 2019; Minitab 21.2, 2022; Excel Office, 2010).

RESULTS

The learners reached proficiency after a similar number of trials, however the time employed to reach such a plateau in the learning curve was significantly different, thus the null hypothesis was partially rejected. The mean intraoral scanning times for the three IOS groups in the 1st trial and the plateau are shown in Figure 2 and Table 2. The intraoral scanning learning curves with evidence of plateaus for each group are shown in Figure 3 and 4. The frequencies of responses to the questionnaire are shown in Figure 5. In the first trial, the following average times observed were 504.9 s Eagle, 573.2 s

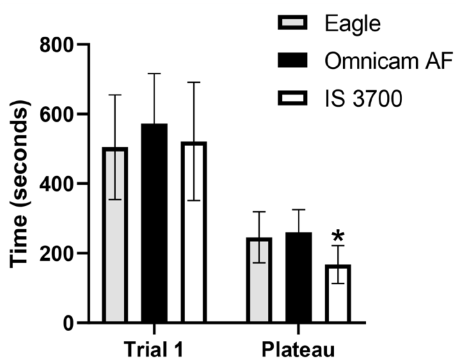

Figure 2: Comparison* of the average values of time in the first trial and plateau per IOS.

*This figure shows the initial and plateau averages for each IOS. [*] represents statistical differences among groups. In this case, IS 3700 was different from Eagle (P=.041) and Omnicam (P=.014).

Table 2. Description the results of initial and plateau trials in seconds.

			Mean	Median	Standard Deviation	N	IC
Initial	Trial 1	IOS-I	504.9	498.5	150.4	10	93.2
		IOS-II	573.2	609	143.3	9	93.6
		IOS-III	521.2	565.5	169.8	10	105.3
Plateau	Trial 10	IOS-I	245.5	242.4	73.2	10	45.3
	Trial 11	IOS-II	260.6	276.8	65.2	9	42.6
	Trial 11	IOS-III	167.9	182.2	54.7	10	33.9

*N, number of participants per group; IC, confidence interval.

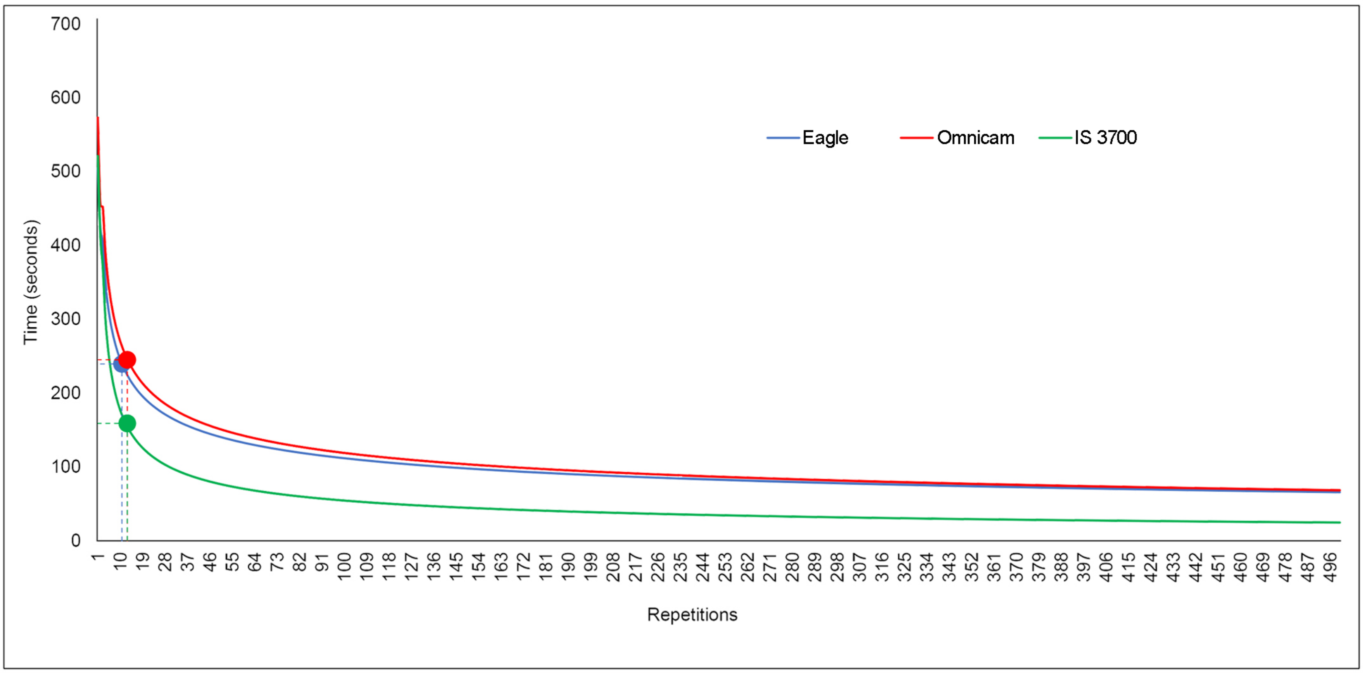

Figure 3: The learning curves of the different IOS.

Omnicam AF and 521.2 s IS 3700 and when comparing the time among them, there is no statistical difference in this trial (P>.05). In relation to the plateau, they occurred in similar moments for the three devices. The plateau occurred for the Eagle in trial 10 with an average time of 245.5 s, for Omnicam AF in trial 11 with an average of 260.6 s and for the IS 3700 also occurred in trial 11 with an average of 167.9 s. Considering the plateau time, IS 3700 was different from Eagle (P=.041) and Omnicam AF (P=.014). Additionally, Eagle and Omnicam AF were similar among them. Although the plateaus occurred at similar times, they all had different initial and final time values. As the number of repetitions increased, the times of all the scanners decreased. The differences among the groups start to appear more emphatically from trial 10 onwards *(Figure 2)*. In relation to the answers from the questionnaire and the participants' perceptions *(Figure 5)*, it can be seen that overall, the participants considered intraoral scanning a positive experience. Concerning the participants' perceptions surveyed, for the level of difficulty, Omnicam AF (44%) users found it more difficult when compared to Eagle (10%) and IS 3700 (10%) being not significant (P=.089). Besides, participants considered the experience similarly (P=.153) positive for Omnicam AF (11%), Eagle (40%) and IS 3700 (11%) and that IOS can save time compared with conventional impression Omnicam AF (89%), Eagle (100%) and IS 3700 (10%), (P=.937). Lastly, participants mostly and similarly (P=.466) agreed that more training was needed (60-70%).

DISCUSSION

Based on the results obtained it is possible to discuss that the number of trials to reach proficiency with the three tested IOS was similar, nevertheless the entire process of learning varied differently depending on the type of IOS and this has an influence on the time it takes the individual to reach proficiency on the scanning process. These findings are relevant for professionals that are planning to replace conventional impressions with digital and also for professors and schools of dentistry as it helps to discuss the IOS learning process.

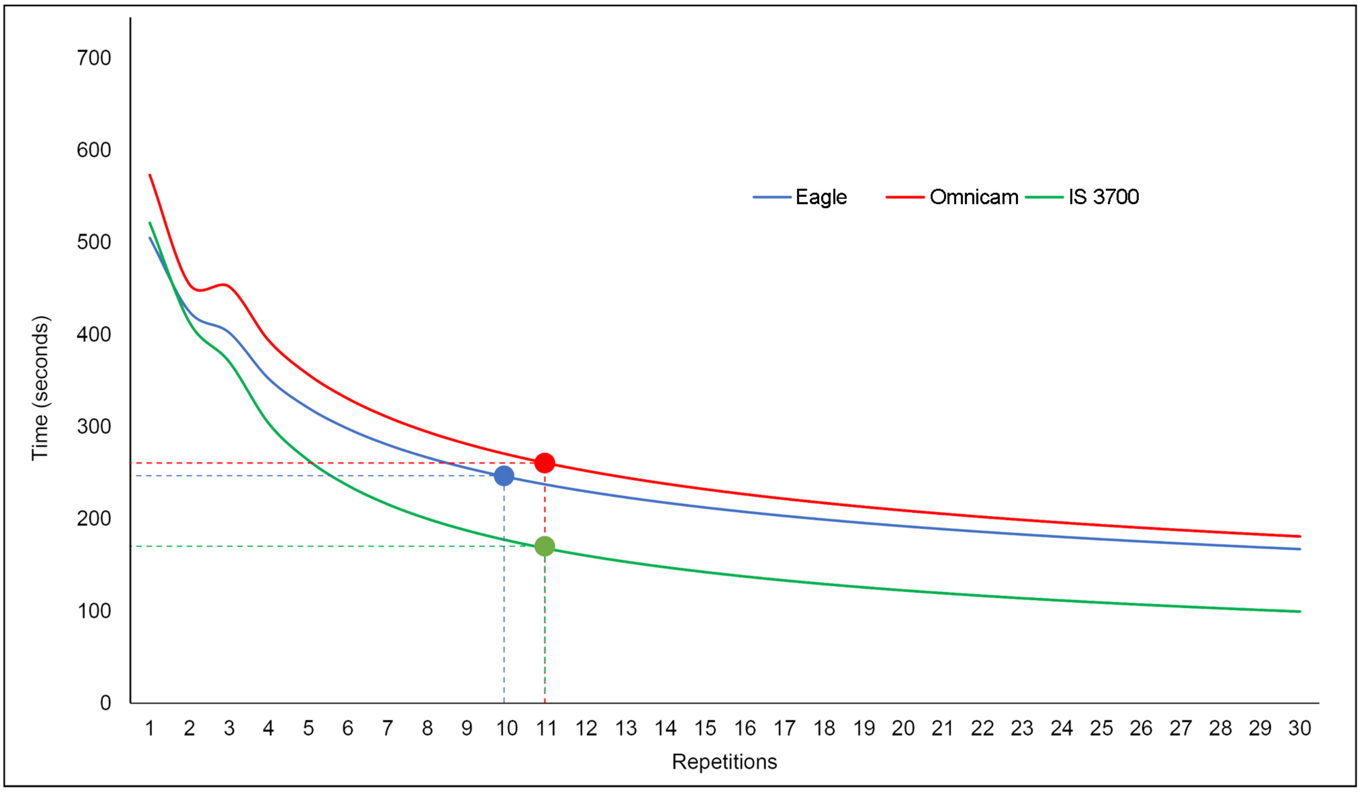

Figure 4: Evidenced view of the plateau in the learning curves of the different IOS.

Comparing the results of this study with similar literature, Al Hamad *et al.*[14] (2020) showed that nine repetitions per individual were needed for prosthodontic residents reaching 80% of proficiency with Omnicam AF, which is one of the IOSs that was also analyzed in this study. Their results showed that in the first trial, the average time was 373 seconds, which decreased to 195 seconds by the ninth trial, corresponding to approximately 70% to 90% of the plateau. In this study, the same device had an average time of 573.2 seconds in the first trial, reaching a plateau at 260.6 seconds. The times were different, but both showed a considerable reduction in the time between the first trial and the plateau, showing that the participant had a good learning performance. Similarly to Al Hamad *et al.*[14] and this study, Boo *et al.*[33] (2023) observed the learning curve of learners by using wired and wireless IOS. They predicted 600 trials and a significant difference between learning curves was found up to the sixth attempt, nevertheless the IOS proficiency moment was not discussed. In addition, according to the participants' perceptions, they preferred the IOS wired, due to the faster capture speed, lighter weight and less heating on the IOS body, indicating that the characteristics of IOS can influence the learning process.

In this study, the time requested in the first trial was similar among IOS, as well as the number of trials to reach the proficiency (plateau of the curve). Nevertheless, when the plateau was reached, the participants in the IS 3700 group were showing a lower time compared to Eagle and Omnicam AF. In this context, a point to discuss is that the learning rate of participants who used the IS 3700 was greater as it decreased in time throughout the repetition even with a slightly longer initial time. Indeed, the IS 3700 exhibits a steeper slope in the curve, as depicted in Figure 3 and 4. This suggests that participants learning with IS 3700 (having the second-longest time in the initial trial) swiftly adapted to the task, leading to a more substantial degree of improvement. These differences among the learning process could be justified possibly based on IOS features such as weight, imaging technology and characteristics related to the software that can influence this learning process as well.[6-8]

In this sense, in a general view, IOS consists of a handheld camera, a laptop computer and the software; nevertheless, IOSs can differ broadly among each other. Literature have shown differences among the accuracy of digital models depending on the type of technology for image acquisition (e.g. confocal microscopy, video, photo and other)[1,2,10] size of the IOS head,[11-13] the number of frames per second (FPS) the device can achieve,[10,12] the software which drives the image capture and processing.[8,30] Concerning the IOSs used in this study, they were broadly different as we can observe in Table 1. Discussing the technical features that could influence in the learning process we can cite for example, the size of the tip, as larger tip can perform faster digitalization, nevertheless, makes it more difficult to target certain areas. The weight and design can influence as well, and in this sense, it is expected that the larger and heavier can be more uncomfortable, however in this study, IS 3700 was 316 g, while Eagle was 150 g and Omnicam AF was 313 g, thus, it is suggested that maybe it can be a minor concern when comparing other features. Another influencing factor can be the computer and software, as described in others studies.[8,30] For the software to work well, you need a powerful computer that allows you to capture directly

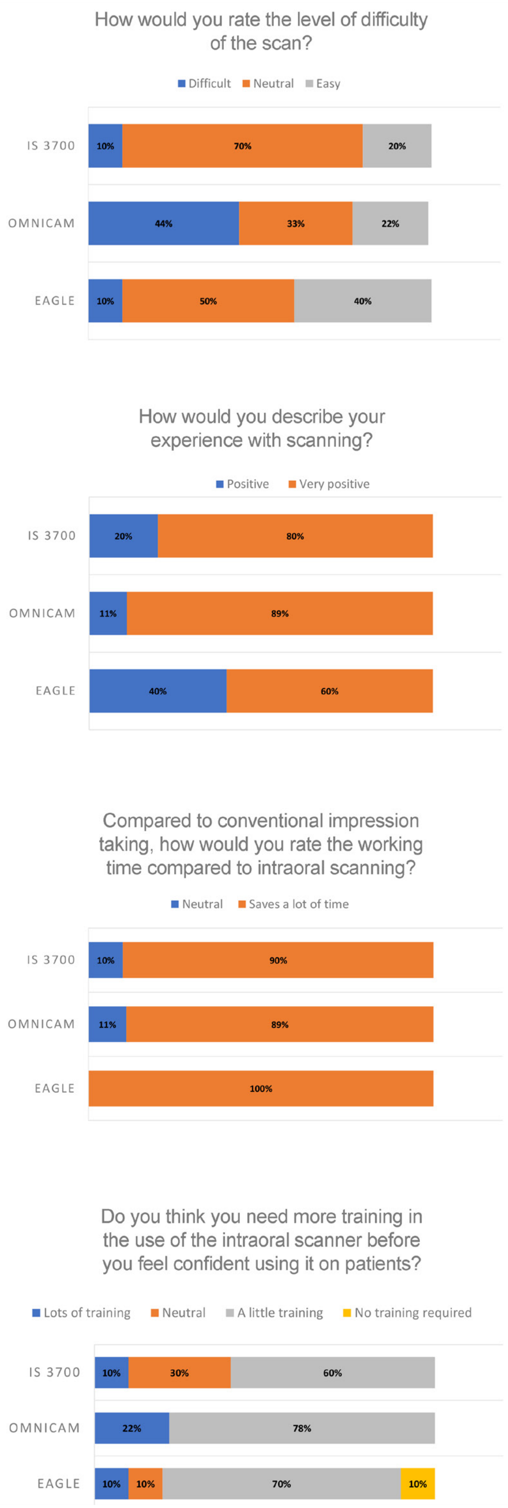

Figure 5: Frequency of answers* obtained from the questionnaire application.

*The answers described in the table are in accordance with what the participants said. For the first question: "How would you rate the level of difficulty of the scan?" The options were: very difficult, difficult, neutral, easy, very easy. The second question: "How would you describe your experience with scanning?" The options were: very negative, negative, neutral, positive, very positive. The third question: "Compared to conventional impression taking, how would you rate the working time compared to intraoral scanning?" The options were: spend a lot of time, neutral, saves a lot of time. The fourth question: "Do you think you need more training in the use of the intraoral scanner before you feel confident using it on patients?" The options were: a lot of training, neutral, a little training, no training needed. There was no statistically significant difference among the groups (P>.05).

and without interruption. These factors are directly related to the individual's learning curve with the IOS, and knowing them allows you to choose the most suitable devices for each person. In this sense, it is relevant to point out that IOS technology is being improved overtime and possibly its learning curve. Monitoring the learning curve according to IOS technology development is interesting and needed. Unfortunately, the literature does not present studies on the learning curve with the primary IOS; perhaps if this data were available, it might be possible to observe a greater number of attempts as well as longer scan times throughout the process.

Training and repetition are important and necessary when it comes to the learning curve, as this is the only way to achieve proficiency, but another important point is the individual's perception of the experience. In this study, the participants were dental professionals used to obtaining their impressions in a conventional mode and that had never entered in contact with IOS, but were interested in the process of replacing conventional with digital workflow into their offices. Despite their inability with IOS they had a positive experience with their respective IOS agreeing with other studies that also evaluated the individual's perception.[9,14,34] It is worth mentioning that the dropout in this study occurred in the Omnicam AF group and was due to a participant that considered "the time spent in a scan was too extensive". Interestingly, the Omnicam AF group showed the higher mean for initial time. Also, regarding the level of difficulty, participants in these groups found the scanning process more difficult (44%) compared with the other groups. In this context, the device used by group II is a well-known and high quality IOS but maybe its features can be more challenging for initial learners. Additionally, concerning the matter of additional training, this group generally believes that more training is needed before safely scanning a patient.

Regarding the participants' perceptions of the learning process, they wrote in the questionnaire factors that could interfere with the acquisition of digital impressions. Based on their considerations, characteristics such as the IOS's weight, capture speed, tip size, software, and the laptop to which the IOS is connected may influence the process. In this context, the participants in this study were having their first practical experience with an IOS, using only one device during their training, which likely shaped their opinions about its technical features. Thus, it is hypothesized that the three-hour introductory course on IOS conducted before the scanning procedure may also have influenced the assumptions made on the questionnaire. While previous studies in the literature have assessed the learning process with IOS, none have directly made comparisons between devices.

Regarding the limitations of this study, one notable factor is the absence of real clinical conditions, such as saliva, tongue, limited mouth opening, edentulous spaces, dental implants, prostheses, and other situations inherent to actual patients. These factors, not addressed in this study, could make digital impressions more challenging than those performed on a phantom, potentially increasing complexity and time required.

This study used three devices, among many available nowadays. Although it can be a limitation considering the options, some features of these three IOS are similar with other devices and can help in the comparison. Thus, for future studies, it would be interesting to compare the learning process with different IOSs and especially, considering the clinical practice of digitizing a patient. Moreover, future in vivo studies concerning the learning curve for intraoral scanning should be developed to allow for comparison purposes with the simulation of its use on phantom manikin heads.

CONCLUSION

According to the results presented in this study, the initial scanning time for the phantom manikin was similar for learners, as was the number of trials required to reach proficiency. However, the scanning time at proficiency was significantly lower for the IS 3700. Further in vivo studies involving patients and different intraoral challenges are needed.

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REFERENCES

1. Richert, R., Goujat, A., Venet, L., Viguie, G., Viennot, S., Robinson, P., *et al.* Intraoral scanner technologies: A review to make a successful impression. *J Healthc Eng* 2017; **2017**:8427595.
2. Mangano, F., Gandolfi, A., Luongo, G. and Logozzo, S. Intraoral scanners in dentistry: A review of the current literature. *BMC Oral Health* 2017; **17**:149.
3. Rogers, Everett. *Diffusion of Innovations.* 5th ed. Simon and Schuster; 2003. p. 20-480.
4. Kihara, H., Hatakeyama, W., Komine, F., Takafuji, K., Takahashi, T., Yokota, J., *et al.* Accuracy and practicality of intraoral scanner in dentistry: A literature review. *J Prosthodont Res* 2020; **64**:109–113.
5. Kernen, F., Schlager, S., Seidel Alvarez, V., Mehrhof, J., Vach, K., Kohal, R., *et al.* Accuracy of intraoral scans: An *in vivo* study of different scanning devices. *J Prosthet Dent* 2022; **128**:1303–1309.
6. Revilla-León, M., Kois, D.E. and Kois, J.C. A guide for maximizing the accuracy of intraoral digital scans. Part 1: Operator factors. *J Esthet Restor Dent* 2023; **35**:230–240.
7. Róth, I., Czigola, A., Fehér, D., Vitai, V., Joós-Kovács, G.L., Hermann, P., *et al.* Digital intraoral scanner devices: A validation study based on common evaluation criteria. *BMC Oral Health* 2022; **22**:140.
8. Zarauz, C., Pradíes, G.J., Chebib, N., Dönmez, M.B., Karasan, D. and Sailer, I. Influence of age, training, intraoral scanner, and software version on the scan accuracy of inexperienced operators. *J Prosthodont* 2023; **32**:135–141.
9. Al-Hassiny, A., Végh, D., Bányai, D., Végh, Á., Géczi, Z., Borbély, J., *et al.* User experience of intraoral scanners in dentistry: Transnational questionnaire study. *Int Dent J* 2023; **73**:754–759.
10. Osman, R.B. and Alharbi, N.M. 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**:821–828.
11. Resende, C.C.D., Barbosa, T.A.Q., Moura, G.F., Tavares, L.D.N., Rizzante, F.A.P., George, F.M., *et al.* Influence of operator experience, scanner type, and scan size on 3D scans. *J Prosthet Dent* 2021; **125**:294–299.
12. An, H., Langas, E.E. and Gill, A.S. Effect of scanning speed, scanning pattern, and tip size on the accuracy of intraoral digital scans. *J Prosthet Dent* 2022; **3913**:00326–2.
13. Hayama, H., Fueki, K., Wadachi, J. and Wakabayashi, N. Trueness and precision of digital impressions obtained using an intraoral scanner with different head size in the partially edentulous mandible. *J Prosthodont Res* 2018; **62**:347–352.
14. Al Hamad, K.Q. Learning curve of intraoral scanning by prosthodontic residents. *J Prosthet Dent* 2020; **123**:277–283.
15. Schunk, D.H. *Learning Theories, an Educational Perspective.* 6th ed. Pearson Education Inc, 2012. p. 38–40.
16. Feldman, L.S., Cao, J., Andalib, A., Fraser, S. and Fried, G.M. A method to characterize the learning curve for performance of a fundamental laparoscopic simulator task: Defining "learning plateau" and "learning rate". *Surgery* 2009; **146**:381–386.
17. Ramsay, C.R., Grant, A.M., Wallace, S.A., Garthwaite, P.H., Monk, A.F. and Russell, I.T. Statistical assessment of the learning curves of health technologies. *Health Technol Assess* 2001; **5**:1–79.
18. Chambers, D. Learning curves: What do dental students learn from repeated practice of clinical procedures? *J Dent Educ* 2012; **76**:291–302.
19. Amornvit, P., Rokaya, D. and Sanohkan, S. Comparison of accuracy of current ten intraoral scanners. *Biomed Res Int* 2021; 2673040.
20. Ender, A. and Mehl, A. *In-vitro* evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. *Quintessence Int* 2015; **46**:9–17.
21. Wesemann, C., Muallah, J., Mah, J. and Bumann, A. Accuracy and efficiency of full-arch digitalization and 3D printing: A comparison between desktop model scanners, an intraoral scanner, a CBCT model scan, and stereolithographic 3D printing. *Quintessence Int* 2017; **48**:41–50.
22. Emara, A., Sharma, N., Halbeisen, F.S., Msallem, B. and Thieringer, F.M. Comparative evaluation of digitization of diagnostic dental cast (plaster) models using different scanning technologies. *Dent J (Basel)* 2020; **8**:79.
23. Lim, J.H., Park, J.M., Kim, M., Heo, S.J. and Myung, J.Y. Comparison of digital intraoral scanner reproducibility and image trueness considering repetitive experience. *J Prosthet Dent* 2018; **119**:225–232.
24. Kulczyk, T., Rychlik, M., Lorkiewicz-Muszyńska, D., Abreu-Głowacka, M., Czajka-Jakubowska, A., Przystańska, A. Computed tomography versus optical scanning: A comparison of different methods of 3D data acquisition for tooth replication. *Biomed Res Int* 2019; 4985121.
25. Rhee, Y.K., Huh, Y.H., Cho, L.R. and Park, C.J. Comparison of intraoral scanning and conventional impression techniques using 3-dimensional superimposition. *J Adv Prosthodont* 2015; **7**:460–467.
26. Park, H.R., Park, J.M., Chun, Y.S., Lee, K.N. and Kim, M. Changes in views on digital intraoral scanners among dental hygienists after training in digital impression taking. *BMC Oral Health* 2015; **15**:151.
27. Kim, J., Park, J.M., Kim, M., Heo, S.J., Shin, I.H. and Kim, M. Comparison of experience curves between two 3-dimensional intraoral scanners. *J Prosthet Dent* 2016; **116**:221–230.

28. Róth, I., Czigola, A., Joós-Kovács, G.L., Dalos, M., Hermann, P. and Borbély, J. Learning curve of digital intraoral scanning - an *in vivo* study. *BMC Oral Health* 2020; **20**:287.
29. Zarauz, C., Sailer, I., Pitta, J., Robles-Medina, M., Hussein, A.A. and Pradíes, G. Influence of age and scanning system on the learning curve of experienced and novel intraoral scanner operators: A multi-centric clinical trial. *J Dent* 2021; **115**:103860.
30. Zarauz, C., Pradíes, G.J., Chebib, N., Dönmez, M.B., Karasan, D. and Sailer, I. Influence of age, training, intraoral scanner, and software version on the scan accuracy of inexperienced operators. *J Prosthodont* 2023; **32**:135–141.
31. Waldecker, M., Trebing, C., Rues, S., Behnisch, R., Rammelsberg, P. and Bömicke, W. Effects of training on the execution of complete-arch scans. Part 1: Scanning time. *Int J Prosthodont* 2021; **34**:21–26.
32. Waldecker, M., Rues, S., Trebing, C., Behnisch, R., Rammelsberg, P. and Bömicke, W. Effects of training on the execution of complete-arch scans. Part 2: Scanning accuracy. *Int J Prosthodont* 2021; **34**:27–36.
33. Koo, B., Son, K., Lee, J.M., Kim, S.Y., Jin, M.U. and Lee, K.B. Prediction of learning curves of wired and wireless intraoral scanners. *Sci Rep* 2023; **13**:21661.
34. Ahmed, K.E., Peres, K.G., Peres, M.A., Evans, J.L., Quaranta, A. and Burrow, M.F. Operators matter - An assessment of the expectations, perceptions, and performance of dentists, postgraduate students, and dental prosthetist students using intraoral scanning. *J Dent* 2021; **105**:103572.