Comparison of digital scanning and polyvinyl siloxane impression techniques by dental students: instructional efficiency and attitudes towards technology

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Abstract

Introduction: With increasing use of digital scanning with restorative procedures in the dental office, it becomes necessary that educational institutions adopt instructional methodology for introducing this technology together with conventional impression techniques.

Objective: To compare the time differences between instructing dental students on digital scanning (DS) (LAVA C.O.S. digital impression system) and a conventional impression technique (CI) (polyvinyl siloxane), and to compare students' attitudes and beliefs towards both techniques.

Materials and methods: Volunteer sophomore dental students ($n = 25$) with no prior experience in clinical impressions were recruited and IRB consent obtained. Participants responded to a pre-and post-exposure questionnaire. Participants were instructed on the use of both DS and CI for a single tooth full coverage crown restoration using a consecutive sequence of video lecture, investigator-led demonstration and independent impression exercise. The time necessary for each step (minutes) was recorded. Statistical significance was calculated using dependent *t*-tests (time measurements) and 2-sample Mann–Whitney (questionnaire responses).

Results: The time spent teaching students was greater for DS than CI for video lecture (15.95 and 10.07 min, $P = 0.0000$), demonstration time (9.06 and 4.70 min, $P = 0.0000$) and impression time (18.17 and 8.59 min, $P = 0.0000$). Prior to the instruction and practice, students considered themselves more familiar with CI (3.96) than DS (1.96) ($P = 0.0000$). After the instruction and practice, participants reported CI technique proved significantly easier than expected (pre-instruction: 3.52 and post-instruction: 4.08, $P = 0.002$). However, overall participants' perception of ease of use for DS was not influenced by this instruction and practice experience (pre-instruction: 3.84 and post-instruction: 3.56, $P = 0.106$). Despite the results, 96% of participants expressed an expectation that DS will become their predominant impression technique during their careers.

Conclusions: Dental students with no clinical experience have high expectations for digital scanning, and despite their initial difficulty, expect it to become their primary impression technique during their professional futures. The instructional time necessary for introducing DS into the curriculum is significantly greater than CI in both classroom (lecture) and clinical simulation settings (investigator-led demonstration).

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Introduction

The first commercially available computer-assisted design/computer-assisted manufacture (CAD/CAM) system for in-office fabrication of coronal restorations was introduced in 1985 (CEREC, Sirona Dental Systems St. Paul, MN, USA) (1). As then, significant technology changes have led to improvements in the quality of digital scans and subsequent restorations (2). In general, these systems can be divided into those that provide intraoral digital scanning only and those that offer both scanning and chairside milling for restoration fabrication (3). In their review of available digital scanning systems, Ting-Shu and Jian indicate digital scanning provides distinct superiority in work efficiency and saving of materials, with the potential of further improvement and increasing use in the future (4).

The contribution of negative dental experiences to patient anxiety has been well established (5–7). However, association between anxiety and avoidance behaviours has not yet been sufficiently defined (8). However, patient preference for digital intraoral scans as rather than conventional impression techniques has been reported (9, 10). Operator preference for digital scans investigating areas such as clinical efficiency, accuracy of digital scan and accuracy of final restoration has also been reported demonstrating reduced impression times with repeated experience (11–13). Data are lacking on the number of experiences necessary to attain clinical competency. Accuracy of conventional impressions has also been compared with accuracy of digital scans and found to be variably comparable (14–17). Whilst some investigators report variable or reduced accuracy of restorations created from digital scans, most demonstrate clinically acceptable restorations using both techniques (18–21).

Academic dental institutions should provide instruction to students such that: '*Graduates should be able to evaluate, assess, and apply current and emerging science and technology to reflect contemporary practice*' (22). In relation to restorative dentistry, whilst material-based (such as polyvinyl siloxane or polyether) impression techniques have yet to become obsolete, dental students should be provided with opportunities to integrate digital scanning technology into their clinical experiences.

The aims of this investigation were three-fold: (i) to compare the time required to instruct inexperienced dental students in the use of conventional material-based impression (polyvinyl siloxane, 3M ESPE, St. Paul, MN, USA) and intraoral digital scanning system (Lava C.O.S, 3M ESPE, St. Paul, MN, USA) for single-crown restorations, (ii) determine their existing familiarity with, and expected or perceived ease of use of various impression techniques, prior to after instruction in both methods and (iii) determine students expectations towards digital scanning system after instruction in both methods.

Materials and methods

The research was approved by the Institutional Review Board (IRB # 13.0242). A total of 25 second-year dental students were recruited who were clinically inexperienced in restorative impression techniques. The study was designed a single group pre-/post-test based on the administration of two questionnaires with matched questions in certain domains and separated by an intervention. The intervention was the instruction in and performance of two impression techniques: conventional material-based impression (polyvinyl siloxane, 3M ESPE) (CI) and intraoral digital scanning system (Lava C.O.S, 3M ESPE) (DS). Individual student performance in each stage of the instruction was timed and compared between techniques. A mannequin and typodont with a full coverage metal crown preparation (abutment position #30) with supragingival finish line was used to simulate a clinical condition for this research. Quadrant impressions were taken by the participants with both impression techniques to obtain similar amounts of clinical information, including operational dentition, opposition dentition and interocclusal record.

Volunteered students completed their participation individually. To begin, each participant filled out a Pre-Instruction Questionnaire with questions relating to following domains: A. Pre-existing familiarity with impression techniques; B1. Expected ease of use level of impression techniques (Table 1).

Participants then watched a video presentation of CI technique after which they were invited to ask questions. Once all questions were answered, participants were taken to the clinical simulation area where a mannequin-based typodont was set-up and an instructor-led demonstration was performed. Participants were encouraged to ask questions. Once all questions were answered, participants completed their own impression, including preparation of armamentarium and, upon completion, demonstrated the impression to the investigator to be evaluated for clinical acceptability. If the impression was unacceptable, the participant reimpressed the typodont. Each step in this process; video lecture, investigator-led demonstration, preparation and impression making, was timed. *Total Teach Time* was defined as video lecture and instructor-led demonstration time, and *Total Execution Time* included preparation and impression making time. If a reimpress was necessary, the times were added to the impression making time.

This same process was repeated for DS, with students participating in a video lecture, investigator-led demonstration, preparation and practical exercise of completing a clinically acceptable impression. *Preparation time* for conventional impressions included time spent assembling the dispensing gun, applying adhesive to the triple tray and positioning the patient. *Preparation time* for digital scanning included time spent powdering the dentition, entering appropriate scan modes and positioning of the patient. If a digital scan was inadequate, the participant returned to their workstation for additional scanning. As for CI, each step in this process was timed.

After instruction in both CI and DS techniques, each participant completed a post-instruction questionnaire relating to the following domains: B2. Perceived ease of use level of impression techniques; and C. Future expectations to digital scanning system (Table 2). All questions in domain B2 were matched to questions in the domain B1 of the pre-instruction questionnaire for ease of comparison.

For efficiency outcomes, each timed portion of the study, the overall mean and standard deviation were calculated and means compared using the dependent t-test. The desired significance level for the whole family of 6 dependent t-tests (Table 3) was set at $\alpha = 0.05$. With the Bonferroni correction for family-wise

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TABLE 1. Pre-instruction questionnaire

Item	Question				
Domain A. Pre-existing familiarity with impression techniques					
1	How familiar are you with digital intraoral impression technology?				
	1 = Very Unfamiliar	2 = Unfamiliar	3 = Neutral	4 = Somewhat Familiar	5 = Very Familiar
2	How familiar are you with taking conventional impressions with polyvinylsiloxane (PVS)?				
	1 = Very Unfamiliar	2 = Unfamiliar	3 = Neutral	4 = Somewhat Familiar	5 = Very Familiar
Domain B1. Expected ease of use level of impression techniques					
3	How easy/difficult do you expect it to be to take digital intraoral impression?				
	1 = Very unfamiliar	2 = Unfamiliar	3 = Neutral	4 = Somewhat familiar	5 = Very familiar
4	How easy/difficult do you expect it to be to take conventional impression?				
	1 = Very unfamiliar	2 = Unfamiliar	3 = Neutral	4 = Somewhat familiar	5 = Very familiar

TABLE 2. Post-instruction questionnaire

Item	Question				
Domain B2. Perceived ease of use level of impression techniques					
5	How easy/difficult did you perceive it to be to take digital intraoral impression?				
	1 = Very difficult	2 = Difficult	3 = Neutral	4 = Easy	5 = Very easy
6	How easy/difficult did you perceive it to be to take conventional impression?				
	1 = Very difficult	2 = Difficult	3 = Neutral	4 = Easy	5 = Very easy
Domain C. Future expectations towards digital scanning system					
7	How many impressions do you think you will need to take before you feel comfortable and competent enough to use a digital scanner on a live patient in the clinic?				
8	Do you expect to have a digital scanner available to you in your first job as a dental professional?				
	☐ Yes	☐ No			
9	Do you expect to use a digital scanner as your primary impression technique at some point in your career?				
	☐ Yes	☐ No			
10	How has learning to use an intraoral scanner changed your opinion of the usefulness of this technology?				
	☐ Worsened	☐ Remained unchanged	☐ Improved		

TABLE 3. Efficiency outcomes measured in minutes

	Conventional	Digital	P value
Instructional Time			
Video Lecture Time	10.07 ± 0.39	15.95 ± 0.86	0.0000*
Demonstration Time	4.70 ± 1.70	9.06 ± 2.17	0.0000*
Total	14.79 ± 1.80	25.13 ± 2.36	0.0000*
Execution Time			
Preparation Time	6.39 ± 3.59	2.10 ± 0.87	0.0000*
Impression Time	8.59 ± 2.37	18.17 ± 3.37	0.0000*
Total	14.77 ± 4.95	20.37 ± 3.57	0.0000*

All data are presented as mean ± SD.
*Statistical significance $P < \alpha = 0.0083$.

TABLE 4. Participants' existing familiarity with impression techniques

	Conventional	Digital	*P* value
Existing familiarity			
Pre-exposure	3.96 ± 0.61 (4)	1.96 ± 1.06 (2)	0.0000*

All data are presented as mean ± SD, and median in parentheses.
Answers ranging from 'Very Unfamiliar = 1' to 'Very Familiar = 5'.
*Statistical significance $P < \alpha = 0.017$.

error, each individual hypothesis was tested at α (0.05/6) = 0.0083. For pre-existing familiarity with impression techniques and expected or perceived ease of use level of impression techniques, each Likert scale questionnaire response from the Domain A and Bs, the mean rank, standard deviation were reported, and Wilcoxon signed-ranks test was used for inferential analysis (Table 4). The Bonferroni correction was applied to achieve a family-wise significance level of $\alpha = 0.05$. With 3 dependent questions, each was tested at α (0.05/3) = 0.017 (Tables 4 and 5). No inferential statistics were calculated for the responses from domain C (Table 6).

Results

Efficiency outcomes

The efficiency outcomes were measured in seconds during the conduction of study for the ease of data recording for the investigators. The results were then converted into the minutes for the ease of understanding and clinical relevance. Table 3 shows the efficiency outcomes measured in minutes (min). Timed results were significantly higher for DS vs. CI in most steps, including *video lecture* (DS, 15.95 ± 0.86 min; CI,

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TABLE 5. Student's perceived ease of use level before and after exposure

	Pre-exposure	Post-exposure	*P* value
Perceived ease of use			
Conventional	3.52 ± 0.77 (4)	4.08 ± 0.57 (4)	0.002*
Digital	3.84 ± 0.85 (4)	3.56 ± 0.96 (4)	0.106

All data are presented as mean ± SD and median in parentheses.
Answers ranging from 'Very Difficult = 1' to 'Very Easy = 5'.
*Statistical significance $P < \alpha = 0.017$.

TABLE 6. Future expectations to digital scanning system (unless otherwise specified, numeric values are total responses, in parentheses are the per cent of all responses)

Question	Response
How many impressions do you think you will need to take before you feel comfortable and competent enough to use a digital scanner on a live patient in the clinic?	Mean = 3.9 SD = 3.09
Do you expect to have a digital scanner available to you in your first job as a dental professional?	Yes = 16 (64%) No = 9 (36%)
Do you expect to use a digital scanner as your primary impression technique at some point in your career?	Yes = 24 (96%) No = 1 (4%)
How has learning to use an intraoral scanner changed your opinion of the usefulness of this technology?	Improved = 18 (72%) Unchanged = 7 (28%) Worsened = 0 (0%)

10.07 ± 0.39 min; $P = 0.0000$), *instructor-led demonstration* (DS, 9.06 ± 2.17 min; CI, 4.70 ± 1.70 min; $P = 0.0000$) and *impression time* (DS, 18.17 ± 3.37 min; CI, 8.59 ± 2.37 min; $P = 0.0000$). Only *preparation time* was significantly higher for CI (DS, 2.10 ± 0.87 min; CI, 6.39 ± 3.59 min; $P = 0.0000$). *Total Teach Time*, including *video lecture* and *instructor-led demonstration*, was significantly higher for DS (DS, 25.13 ± 2.36 min; CI, 14.79 ± 1.80 min; $P = 0.0000$). *Total Execution Time, including preparation and impression time,* was also significantly higher for DS (DS, 20.37 ± 3.57 min; CI, 14.77 ± 4.95 min; $P = 0.0000$).

Pre-existing familiarity with impression techniques (Domain A)

Table 4 shows existing familiarities with CI techniques (3.96 ± 0.61) and DS techniques (1.96 ± 1.06). Prior to the instruction and practice, students were more familiar with CI technique than with DI techniques ($P = 0.0000$).

Expected or perceived ease of use level of impression techniques (Domain B1 and B2)

Table 5 compares questionnaire responses pre- and post-instruction in regard to ease of use level for each impression technique. Participants reported CI technique proved significantly easier than expected ($P = 0.002$). However, overall participants' perception of ease of use for DI was not influenced by experience and instruction ($P = 0.106$).

Future expectations to digital scanning system (Domain C)

Table 6 shows participants' expectations after exposure to a DS system. No inferential statistics were calculated for these responses. Participants expected an average of 3.9 attempts to attain competency, after trying the DS technique. 64% of participants expected to have a digital scanner at their first job, and 96% expected a DS to become their primary impression technique at some point during their professional careers. 72% expressed a positive change in opinion regarding digital scanning following exposure; the remaining 28% stated no change in their opinion. 0% said their opinion of digital scanning worsened due to their exposure to the technology.

Discussion

This study was conducted with a single mannequin and typodont to reduce confounding variables and to simulate the education process for pre-clinical fixed prosthodontics, an approach used previously (23, 24). Lee et al. (23, 24). investigated the clinical efficiency and dental student perceived level of difficulty and preference between conventional material-based impression and intraoral digital scanning technique for dental implant using mannequin-based typodont practice. Based on the 30 participants of second-year dental students, they showed dental students had a lower perceived level of difficulty for the intraoral digital scanning technique compared with the conventional impression techniques and preferred the intraoral digital scanning technique, taking them a shorter time to complete a clinically acceptable impression. In contrast to the results reported by Lee et al. (23, 24), we found that DS took more time to perform than CI with no perceived differences in ease of use. One possible reason for this discrepancy is that Lee et al. used implant 'scan bodies' (scannable impression copings used in implant restoration), rather than a model of a natural tooth crown preparation in the area of tooth #30. A scan body is cylindrical and relatively narrow, allowing the wand tip easy access to all critical areas. During the performance of DS, the researcher noted the use of ineffective movements intended to acquire data in difficult to reach areas. Particularly, the interproximal margins were difficult to bring within the focal distance of the wand tip due to the amount of remaining tooth structure.

We used only one DS technology in this study; the LAVA C.O.S. (3M ESPE, St. Paul, MN, USA). Lee et al. used the iTero (Align Technology Inc, San Jose, CA, USA) whose method of data acquisition varies greatly from the LAVA C.O.S. used in this study. The iTero directs the user in taking still-frame images, whilst the LAVA C.O.S. uses video to capture data and users must decide for themselves how much data are necessary to acquire.

The total time spent teaching was calculated as the combination of time for video lectures and instructor-led

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demonstrations for each impression modality. The significance of these results is the generally increased amount of time required to educate students on the use of DS systems. These results assist educators in designing dental school curricula with the understanding that results will vary with each institution. Implementation into institutional curriculum will be determined by the number of students, DS available and allotted time in clinical simulation areas. However, our results indicate that educating students in the use of DS will likely take longer than CI methods. This difference will be unique for each institution based on their experiences and system-specific with the selected intraoral digital scanner. These experiences should be shared between dental schools so that each can benefit from the experiences of the other. Further research is needed to demonstrate preferred methods for teaching intraoral digital scanning and preferred scanning systems.

In the pre-exposure questionnaire, participants reported a stronger familiarity with conventional material-based impression technique as compared to the digital technique. This is likely the result of previous attendance in classroom lectures on the various impression materials and experience making alginate impressions. Although it should be noted the students had no lectures previously regarding the manner of conventional impression techniques traditionally used in fixed prosthodontics (polyvinylsiloxane and related materials); only the physical characteristics of these materials. It is also more likely students would have seen conventional material-based impressions taken whilst shadowing in the clinic, both as a pre-dental student and as a freshman (D1) dental student.

Existing literature demonstrates operator and patient preferences (9, 10), quality of impression accuracy (14–16) and learning curves that suggest a rapid increase with multiple practice attempts (11–13). Participants also responded positively towards digital impression technology in the questionnaires. Most tellingly, 96% of participants expect digital scanning technology to become their primary impression technique at some point in their career. This suggests dental students' high expectations for this technology, which should be cultivated for research and practical gains. Future research should continue to identify differences between systems and help guide educational techniques to make digital impression education more efficient and effective.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

Time

More didactic and pre-clinical instruction is likely to be needed to introduce dental students to chairside digital scanning systems than currently allotted for PVS education.

Existing familiarity

Students are likely to exhibit less pre-existing familiarity with digital scanning than with PVS impression method.

Perceived ease of use level

After the the instruction and practice:

1. Dental students are likely to perceive that PVS impression technique is easier than they initially anticipated.
2. For the digital scanning, dental students' perception are likely to remain the same as their initial anticipation.

Future expectations

1. Dental students are likely to expect attaining clinical competence quickly with digital scanning.
2. They are likely to have strong positive opinions towards digital scanning after the instruction and practice.
3. Dental students are likely to expect digital scanning systems playing a prominent role during their professional lifetimes.

References

1 Poticny DJ, Klim J. CAD/CAM In-Office Technology: innovations after 25 years for predictable, esthetic outcomes. J Am Dent Assoc 2010: 141: 5S–9S.
2 Luthardt RG, Loos R, Quaas S. Accuracy of intraoral data acquisition in comparison to the conventional impression. Int J Comput Dent 2005: 8: 283–294.
3 Fasbinder D. Using digital technology to enhance restorative dentistry. Compend Contin Educ Dent 2012: 33: 666–672.
4 Ting-Shu S, Jian S. Intraoral digital impression technique: a review. J Prosthodont 2015: 24: 313–321.
5 Oosterink FMD, De Jongh A, Hoogstraten J. Prevalence of dental fear and phobia relative to other fear and phobia subtypes. Eur J Oral Sci 2009: 117: 135–143.
6 Locker D, Shapiro D, Liddell A. Negative dental experiences and their relationship to dental Anxiety. Community Dent Health 1996: 13: 86–92.
7 Maggirias J, Locker D. Five-Year incidence of dental anxiety in an adult population. Community Dent Health 2002: 19: 173–179.
8 Akarslan ZZ, Yildirim Biçer AZ. Influence of gag reflex on dental attendance, dental anxiety, self-reported temporomandibular disorders and prosthetic restorations. J Oral Rehabil 2013: 40: 932–939.
9 Wismeijer D, Mans R, van Genuchten M, Reijers HA. Patients' preferences when comparing analogue implant impressions using a polyether impression material versus digital impressions (Intraoral Scan) of dental implants. Clin Oral Implants Res 2014: 25: 1113–1118.
10 Yuzbasioglu E, Kurt H, Turunc R, Bilir H. Comparison of digital and conventional impression techniques: evaluation of patients' perception, treatment comfort, effectiveness and clinical outcomes. BMC Oral Health 2014: 14: 1–7.
11 Farah JW, Brown L. Integrating the 3M ESPE LAVA Chairside Oral Scanner C.O.S into daily clinical practice. Dent Adv 2009: 12: 1–4.
12 Giménez B, Özcan M, Martínez-Rus G, Pradíes G. Accuracy of a digital impression system based on active wavefront sampling technology for implants considering operator experience, implant angulation, and depth. Clin Implant Dent Relat Res 2015: 17 (Suppl. 1): e54–64.
13 Galhano GA, Pellizzer EP, Mazaro JV. Optical impression systems for CAD/CAM restorations. J Craniofac Surg 2012: 23: e575–e579.
14 Nassar U, Oko A, Adeeb S, El-Rich M, Flores-Mir C. An *in vitro* study on the dimensional stability of a vinyl polyether silicone impression material over a prolonged storage period. J Prosthet Dent 2013: 109: 172–178.

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15 Ender A, Mehl A. Full arch scans: conventional vs digital impressions—an *in vitro* study. Int J Comput Dent 2011: 14: 11–21.
16 Ender A, Mehl A. Accuracy of complete arch dental impressions: a new method of measuring trueness and precision. J Prosthet Dent 2014: 109: 121–128.
17 Kim SY, Kim MJ, Han JS, Yeo IS, Lim YJ, Kwon HB. Accuracy of dies captured by an intraoral digital impression system using parallel confocal imaging. Int J Prosthodont 2013: 26: 161–163.
18 Seelbach P, Brueckel C, Wöstmann B. Accuracy of digital and conventional impression techniques and workflow. Clin Oral Investig 2013: 17: 1759–1764.
19 Neves FD, Prado CJ, Prudente MS, et al. Micro-computed tomography evaluation of marginal fit of lithium disilicate crowns fabricated by using chairside CAD/CAM systems or the heat-pressing technique. J Prosthet Dent 2014: 112: 1134–1140.
20 Anadioti E, Aquilino SA, Qian F. 3D and 2D marginal fit of pressed and CAD/CAM lithium disilicate crowns made from digital and conventional impressions. J Prosthodont 2014: 23: 610–617.
21 Tidehag P, Ottosson K, Sjogren G. Accuracy of ceramic restorations made using an in-office optical scanning technique: an *in vitro* study. Oper Dent 2014: 39: 308–316.
22 Commission on Dental Accreditation. Standard 2-Education Programs, Standard 2-23 Accreditation Standards For Dental Education Programs. Chicago, IL: American Dental Association 2015: 30
23 Lee SJ, Gallucci GO. Digital vs. conventional implant impressions: efficiency outcomes. Clin Oral Implants Res 2013: 24: 111–115.
24 Lee SJ, MacArthur RX IV, Gallucci GO. An evaluation of student and clinician perception of digital and conventional implant impressions. J Prosthet Dent 2013: 110: 420–423.

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