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Evaluation of an Innovative Digital Assessment Tool in Dental Anatomy

[1]Mir Afsary Wahed, *Assistant Professor, Department of Dental Anatomy, Dhaka Dental College, Dhaka, Bangladesh.*
[2]Raziuddin Khan, *Professor and Head, Dept. Department of Dental Anatomy, Dhaka Dental College, Dhaka, Bangladesh.*
[3]Shakil Mahmood, *Lecturer, Department of Dental Anatomy, Dhaka Dental College, Dhaka, Bangladesh.*
[4]MD. Ziaul Haq Bhuiyan, *Associate Professor, Dept. Of Radiology and Imaging, Uttara Adhunik medical College, Dhaka, Bangladesh.*
Corresponding Author: *Mir Afsary Wahed, Assistant Professor, Department of Dental Anatomy, Dhaka Dental College, Dhaka, Bangladesh.*

ABSTRACT:
Background: *Digital assessment tool has the potential to provide a bias-free evaluation instrument for practical examination grading. E4D Compare software was designed for teaching institutions to allow comparison between scanned models prepared by students and master models prepared by instructors. A cutting-edge technology that offers quick evaluation on students' work and abilities is the E4D Compare software. It should provide consistent results even when using various scanners, each of which may have slightly varied calibrations by nature.*
Objective: *The purpose of this study was to assess potential inconsistencies in evaluation in dental anatomy projects using the E4D Compare software, which was based on four distinct NEVO scanners. The relationship between the digital and visual scores was also assessed.*
Methods: *A total of 28 maxillary left central incisor projects were assessed. Out of them, four operators completed thirty wax-ups, five of which included regular dentoform teeth. Each project received five scores: one from four separate NEVO scanners and one from an instructor who graded it visually. A member of the faculty who instructs the dental anatomy course graded the 28 projects without seeing them. Each of the four NEVO scanners (D4D Technologies, Richardson, TX, USA) was scanned by a single operator. To create a score, the photos were positioned in relation to the gold standard with a tolerance of 0.3 mm. The project's score indicated the percentage match with the gold standard. The four NEO scanners' scores were compared to see if there was a significant difference; if so, one-way ANOVA with repeated measurements was employed. To find any differences between the average scores of the four NEVO scanners and the visual scores, a paired-sample t-test was employed. Pearson's correlation test was used to assess the relationship between visual and average scores of NEVO scanners.*
Results: *There was no significant difference in mean scores among four different NEVO scanners [F (3, 102) = 2.27, p = 0.0852 one-way ANOVA with repeated measures]. Moreover, the data provided strong evidence that a significant difference existed between visual and digital scores (p = 0.0217; a paired sample t-test). Mean visual scores were significantly lower than digital scores (72.4 vs 75.1).*
Conclusion: *The E4D Compare program correlates well with visual evaluations and offers consistent results even when multiple scanners are utilized.*
Keywords: *Computer-assisted learning/computer-assisted simulation (CAL/CAS), Dental anatomy, E4D Compare software.*

I. INTRODUCTION:

The goal of the dental anatomy course, which is offered to first-year dental students is to give students a foundational understanding of dental anatomy and terminology that will carry over into subsequent courses throughout their academic careers. Its goal is to help students acquire the psychomotor abilities required to accurately replicate tooth shapes in wax so they can use those abilities in their future clinical work.

Dental education has been using digital technology to offer a more effective and impartial grading medium as digital dentistry develops. Student dentists can assess their work differently when they can use scanning technology to produce a digital three-dimensional duplicate of the tooth or teeth. These digital copies are also used by faculty members to assess laboratory tasks completed by students. Digital technology offers a

fresh approach to assessment; nonetheless, concerns have persisted about how to apply this technology to fairly grade practical exams.

Dental students utilize heated tools to apply wax on a tooth peg during preclinical dental anatomy laboratory sessions in order to replicate tooth morphology. This process is based on the dental anatomy curriculum, which is presented in lecture style prior to each laboratory session. During these lab sessions, faculty members are assigned to help students with their dental anatomy projects. A group of students is given a faculty member to look at and suggest changes for the wax-up. Laboratory settings have been linked to certain limitations, including low instructor-to-student ratios and the regularity with which instructors deliver feedback [1]. Nonetheless, laboratory sessions continue to be essential for student learning as they support the development of hand skills, manual dexterity, and psychomotor skills [2].

Students have expressed anxiety about the frequency of input yet receiving it in person has presented further difficulties. Students' end-of-term evaluations have revealed a misperception of the degree of helpful criticism from faculty members that is standard in preclinical courses [3]. There are numerous formal and anecdotal findings claiming that a number of human factors lead to the flaws in visual inspection. There may be a great deal of dispute when various faculty evaluators visually inspect student work [4]. One possible benefit of digital technology is that it might offer an impartial way of assessment and evaluation.

Assessments are a vital part of education because they give students the feedback, they need to encourage self-reflection. In a laboratory setting, dentistry students are often evaluated in two areas: daily grades and laboratory practical [5]. As "a complex behavior or ability essential for the general dentist to begin independent, unsupervised dental practice," competence is defined by the American Dental Education Association (ADEA) and is typically assessed in a formative manner, encouraging students towards it [6].

The typical way that instructor's grade both daily laboratory projects and practical exams is by visual grading. It is very advised to calibrate instructors and to use clear and concise rubrics [7]. Clearly defined rubrics help teachers educate more effectively and encourage uniformity in teacher grading [8]. Despite the implementation of standardized rubrics by dental schools and the calibration of instructors, visual grading remains vulnerable to restrictions due to subjectivity and variation across examiners. Additionally, because visual grading takes a long time and instructors eventually get tired, it may be impaired [9].

There are still significant problems that need to be addressed in the dental anatomy course, such as how to evaluate these projects and how to give appropriate feedback for self-assessment to establish lifelong learning. In the past, instructors engaging in the course have added points based on predetermined criteria to calculate the grade and have utilized a pre-established checklist to provide continual feedback during the course (Table 1). The limitations of this visual examination include subjectivity, weariness, and inconsistency among graders, all of which take time [10]. The most common worry raised by students in their post-course comments is the discrepancy among faculty members, which could have a detrimental impact on their performance and learning process [11].

Table 1: Dental anatomy visual scoring check-list of tooth #9

Contact areas, embrasures and line angles	Correct	Error
Mesial contact	visual contact, correct width and position	Open wide narrow too gingival too facial too lingual irregular
Distal contact	visual contact, correct width and position	wide narrow too gingival too facial too lingual irregular
MF embrasure	normal contour	closed open irregular
MF line angle	correct shape and position	too straight too angle too sharp too round too facial too lingual
MG embrasure	normal contour	closed open irregular
MI embrasure	normal contour	closed open irregular point angle sharp-round
DF embrasure	normal contour	closed open irregular
DF line angle	correct shape and position	too straight too angle too sharp too round too facial too lingual
DG embrasure	normal contour	closed open irregular
DI embrasure	normal contour	closed open irregular point angle sharp-round
ML embrasure	normal contour	closed open irregular
DL embrasure	normal contour	closed open irregular

Facial and lingual contours	Correct	Error
Facial contour, M-D	correct	convex concave flat irregular
Facial contour, I-G	correct	convex concave flat irregular
Facial position, F-L	correct	too facial too lingual
Lingual position, F-L	correct	too facial too lingual
Lingual contour, M-D	correct	convex concave flat irregular
Lingual contour, I-G	correct	convex concave flat irregular
ML marginal ridge	proper location, height, width well defined	too mesial too distal too high too low wrong slant too wide too narrow too sharp
DL marginal ridge	proper location, height, width well defined	too mesial too distal too high too low wrong slant too wide too narrow too sharp
Cingulum	normal height and shape	too high too low too flat too bulky
Lingual fossa	normal depth, width and position	shallow deep too large too small misplaced
Incisal edge and surface finish of wax-up	Correct	Error
Incisal edge shape	correct	convex concave irregular
Incisal edge length: Position	correct	too incisal too gingival
Slope	correct	incline mesiogingivally incline distogingivally
Incisal edge thickness	correct	thick faciolingually thin faciolingually irregular
Finish of wax-up	smooth, shiny, free of pits and scratches	dull pitted scratched irregular not blended

With the introduction of computer-assisted learning and grading technologies, faculty workloads have been reduced and the grading system has showed significant promise in terms of objectivity [12]. A blue laser-powered digital equipment (Nevo scanner, D4D Technologies, Richardson, TX, USA) provides great scanning image quality at a quick video-rate speed and user-friendliness.

The scans are processed quickly by a laptop computer that is linked to the E4D Design Center. By using this innovative technology, students can create a high-quality 3-D virtual model of their project and instantly compare it to the gold standard set by the course director to get feedback on any disparities [13].

In a dental classroom, one scanner for every 10 pupils is the optimal ratio [3]. In order to ensure that every student has a good teaching and learning experience, multiple scanners are typically used. Consistent scores are anticipated even when using various scanners, each of which may have small calibration variations of its own. Since the advent of digital technology, there has been a dearth of data regarding the accuracy with which various scanners relate to one another and the degree to which faculty visual scores correspond with scores produced by the digital assessment method.

This study used the E4D Compare program, which is based on four distinct NEVO scanners, to investigate possible disparities in assessment in dental anatomy projects. The link between the digital and visual scores was also assessed.

The following two hypotheses were put to the test: (1) there will be no correlation between visual and digital scores; and (2) the E4D Compare program will produce consistent grades even when multiple scanners are employed.

II. METHODOLOGY:

Dental anatomy wax-up of tooth: The maxillary left central incisor (#9) was employed in this investigation's examination. Thirty projects total, waxed up independently by four operators (junior dental students) using the wax-addition procedure outlined in the UICOD Dental Anatomy Manual. Three hours was the maximum time permitted for the wax-up, and this is also the amount of time students are given throughout the dental anatomy course to demonstrate their waxing ability. Furthermore, included for assessment were five dentoform teeth of tooth #9. For evaluational purposes, the original Kilgore typodont tooth was also the gold standard. For every project, there were five scores: four from NEVO scanners 1 through 4 and one from an instructor.

Visual evaluation of wax-ups and typodont teeth: A faculty member who teaches the dental anatomy course was blinded, and they used the UICOD Dental Anatomy Course checklist to grade each of the 28 projects. The three categories on the checklist were surface finish, incisal edge, facial and lingual contour, contact regions, embrasure, and line angles, for a total of twenty-three criteria. For evaluation purposes, the final score was transformed to a percentage score based on the addition of accurate criteria.

Scanning and digital evaluation: All projects were scanned using four NEVO scanners (NEVO 1 to 4, D4D Technologies, Richardson, TX, USA) by a single operator who also initiated the file setup. After ensuring that the images had the correct data density, they were matched to the gold standard and a general score was produced, with a tolerance level of 0.3 mm (Figs 1 to 6). This number represented the software's calculation of the project's percentage match to the gold standard.

Data analysis: The four NEVO scanners' scores were compared to each other using a one-way ANOVA with repeated measurements to look for any significant differences. To find out whether there was a difference between the average grades of the four NEVO scanners and the visual grades, a paired-sample t-test was used. The association between the average NEVO scanning grades and visual grades was evaluated using Pearson's correlation test. A significance level of 0.05 was applied to all tests, and SAS® System version 9.3 (SAS Institute Inc., Cary, NC, USA) was used for statistical analyses.

III. RESULT:

For this study, 28 teeth were utilized. Each tooth has five scores collected using five distinct ways (four from the NEVO scanners and one from an instructor). An overview of the descriptive statistics for the five evaluation methods' scores is shown in Table 2.

(1) Detecting the difference in scores among the four NEVO scanners.

The data were analyzed using the one-way ANOVA with repeated measures. This analysis revealed no significant difference in mean scores among the four scanners ($p = 0.0852$).

(2) Detecting the difference in scores between visual and NEVO evaluation methods.

Table 2: Descriptive statistics for visual and NEVO scores

Variable	Frequency	Mean (SD)
NEVO_1	28	74.57 (11.10)
NEVO_2	28	72.17 (12.28)
NEVO_3	28	73.23 (11.87)
NEVO_4	28	72.53 (12.30)
NEVO_AVE	28	73.13 (11.53)
VIS_SCORE	28	71.40 (11.35)

There was a significant difference in scores between visual and NEVO evaluation methods. The data revealed that the mean scores from visual evaluation method were significantly lower than those obtained from the NEVO evaluation method (mean score: 71.4 vs 73.1) (Table 2). Note that the average scores of four scanners (NEVO_AVE) were used for the comparisons.

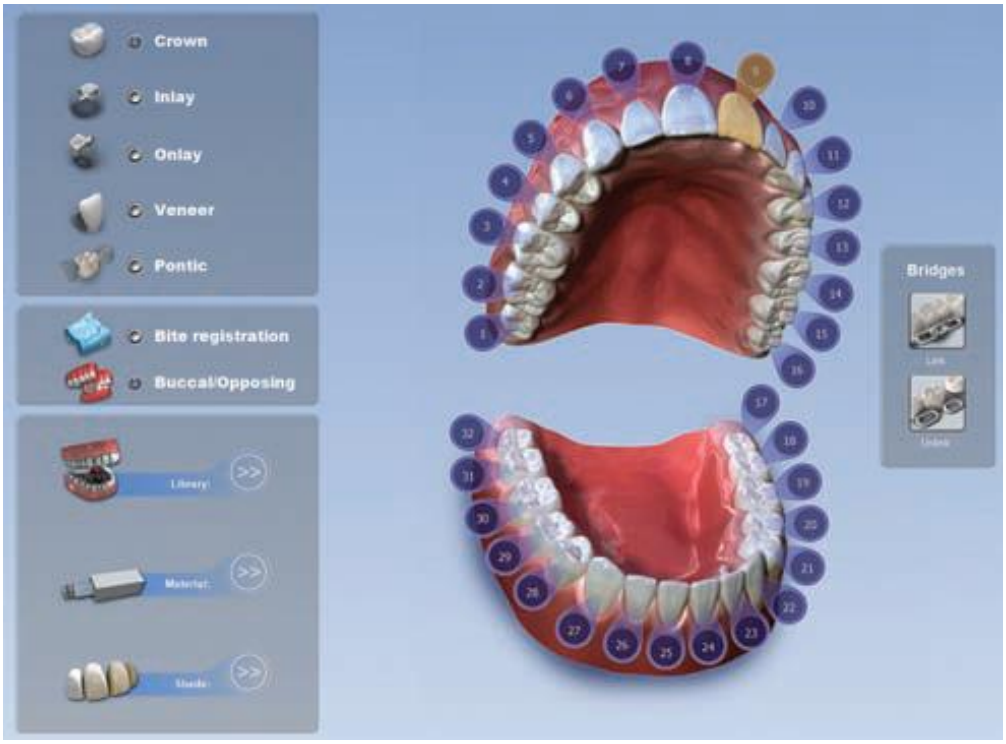

Fig. 1: Set-up in design center (Origin by Lam et al. 2015)

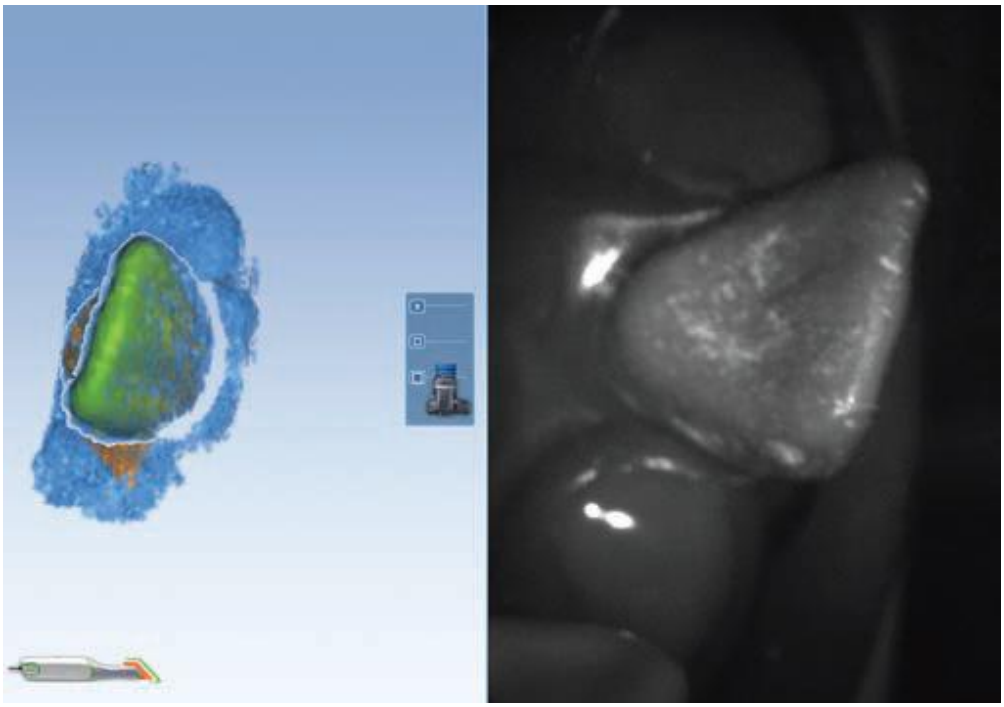

Fig. 2: Scanning with NEVO scanner (Origin by Lam et al. 2015))

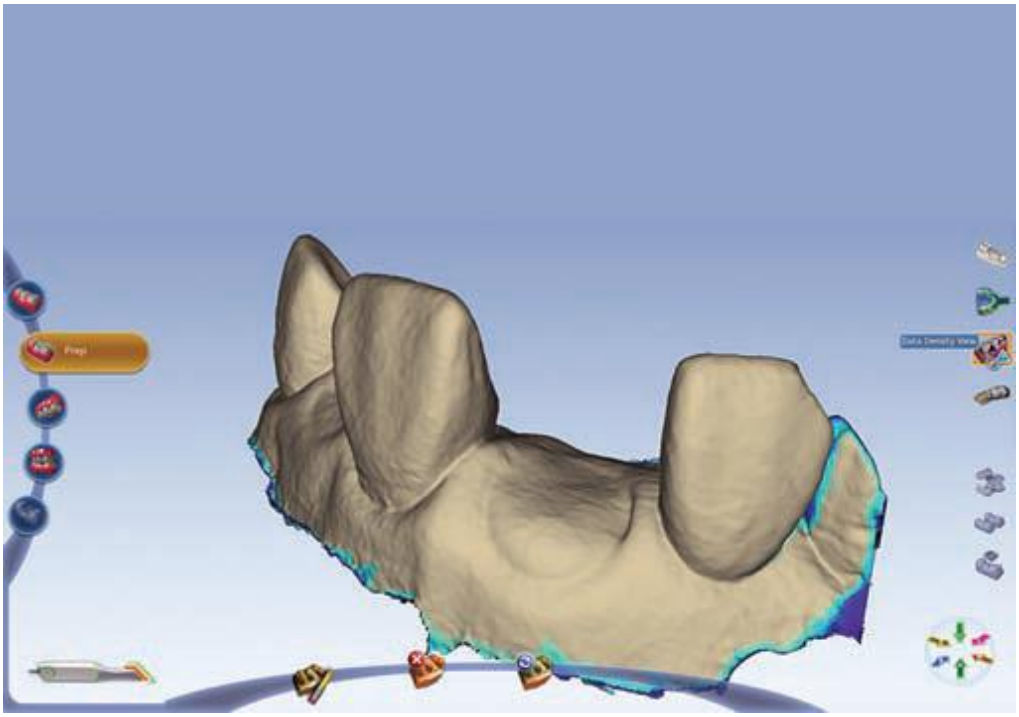

Fig. 3: Data density check of virtual model (Origin by Lam et al. 2015)

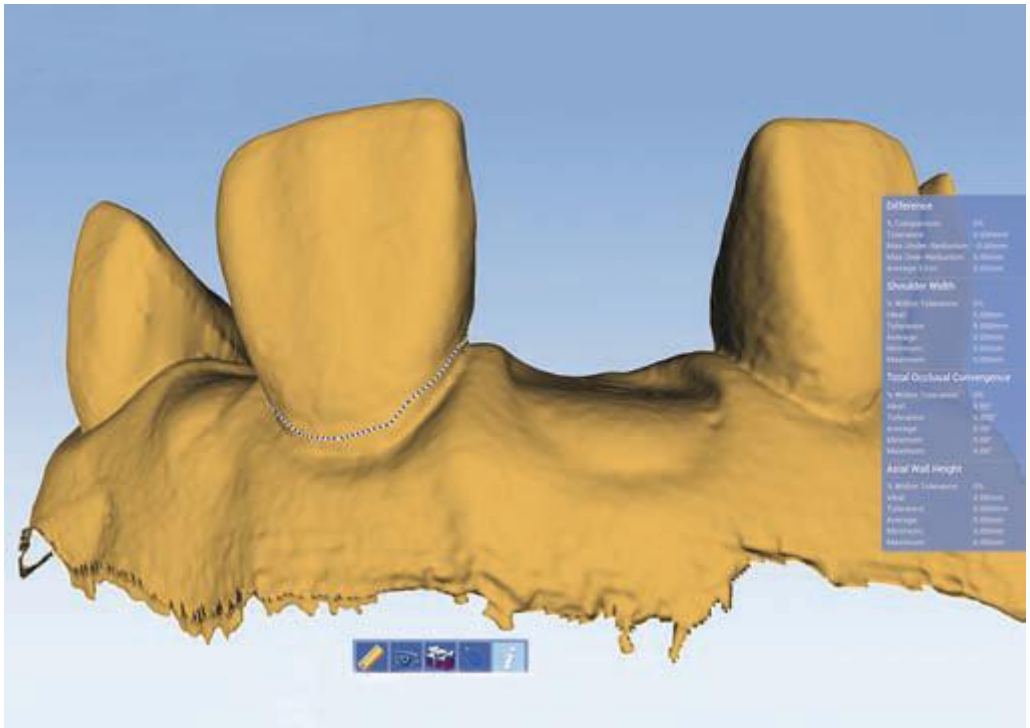

Fig. 4: Margin drawing in E4D compare software (Origin by Lam et al. 2015)

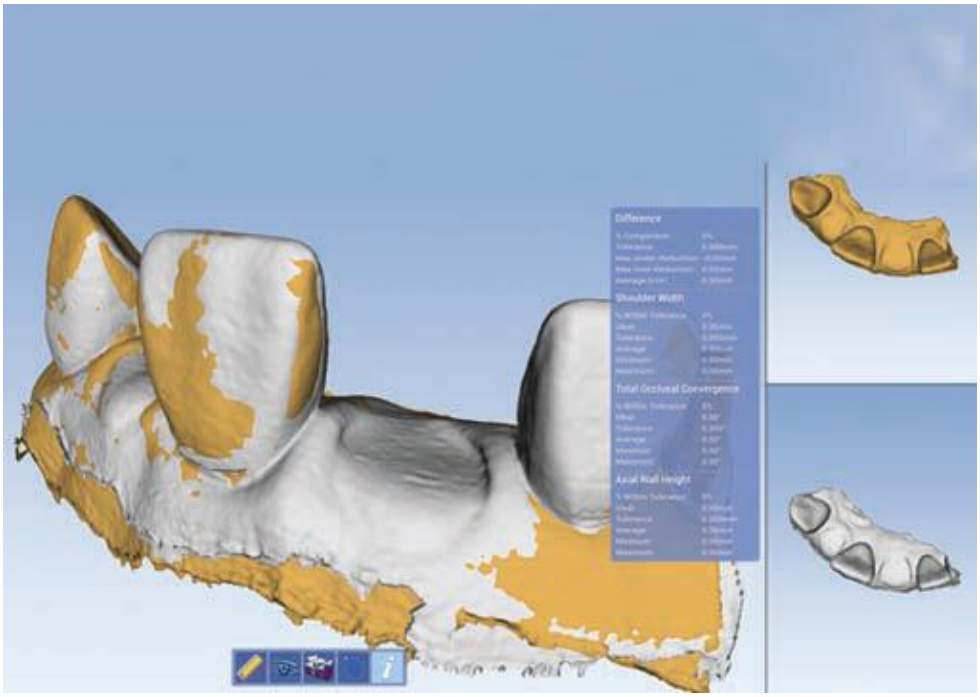

Fig. 5: Alignment of project to master model (Origin by Lam et al. 2015)

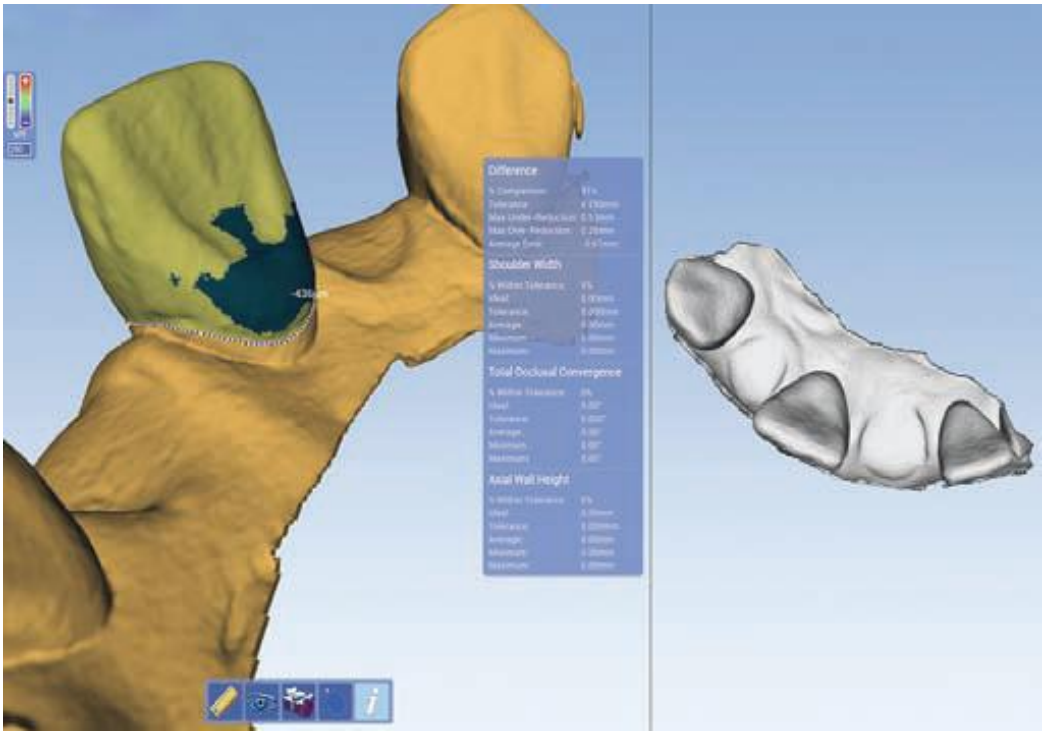

Fig. 6: Comparison of project to master model in E4D compare software (Origin by Lam et al. 2015)

IV. DISCUSSION:

Digital technology has recently been incorporated into the dental curriculum, and it has become one of the school's goals to prepare future dentists in becoming proficient in digital dentistry. Consequently, the restorative dentistry division had undertaken the necessary efforts to update the dental anatomy module and incorporate the use of digital scanning and E4D compare software in the preclinical setting with the aim of improving the students' educational experience and performance.

Digitization through innovative technology has become an integral part of contemporary dental practice. The increasing use of computer-aided design and computer-aided manufacturing (CAD/CAM) technology, which supports the idea of same-day preparation and delivery, is a manifestation of this trend. The

use of restorations made using this method has greatly improved dental laboratories and clinical dentistry, despite a heated initial controversy. It also represents one of the first achievements of digital dentistry [14, 15].

Many dental schools are actively working to integrate computer-assisted learning and computer-assisted simulation (CAL/CAS) systems into their curricula due to the effectiveness of CAD/CAM techniques in the clinical setting. The goal of this is to keep dental students up to date with the most recent technological advancements and ready for the dynamic, ever-changing practice environment they may encounter in the future. Actively integrating new technologies has been seen as a top objective at the UICOD.

A Technology Committee has been formed to design the active integration of digital dentistry into the curriculum, ensuring that these concepts are appropriately integrated both vertically and horizontally as students advance from freshman to senior year.

The design process has given careful consideration to gathering data supporting the applicability and advantages of digital technology in the pre-clinic simulation clinic. In an effort to solve these problems, the study presented here was created to test the reliability of employing numerous scanners as well as the relationship between the faculty members' visual evaluations and the results of the digital assessment tool.

Our first premise was confirmed by the data: even with varied scanners, the E4D Compare program produced consistent scores. This indicates that the operator was able to produce effective data density virtual models and that all four of the NEVO scanners were calibrated correctly, as evidenced by the consistent scores each project received. This relates to other research that shown good intraclass correlation of 0.93 to 0.98 while assessing the repeatability of digital evaluation using the same scanner at several times [3, 4]. Good samples from the visual paradigm may often be rated as poor samples in the digital paradigm, and vice versa, therefore high repeatability does not always imply valid evaluation.

To investigate this possibility, the correlation between the ratings from the visual and digital evaluations was utilized. Our second hypothesis was not supported by the data, which showed a significant link between the visual and digital ratings.

The fact that high marks were consistently assessed as high and bad grades as low across the two approaches shows that this tool might also be utilized for official grading in competencies. This partially validates the validity of using digital technology to assess students' work. It is crucial to note that the scores from the visual and NEVO evaluation methods differed significantly, with the visual evaluation yielding lower ratings than the digital evaluation approach. Changing the tolerance level and giving more leeway for the digital evaluation method could compensate for this difference.

Digital assessment technologies are being implemented in dental clinics to improve patient care. However, to support the time and money required to integrate this technology into the curriculum, there are still a lot of concerns that need to be resolved. The results of a systematic review examining the efficacy of computer-aided, self-instructional programs in dental education have been inconsistent. While some studies found no difference in knowledge gain between CAL and other learning strategies, others found the opposite, suggesting that CAL offered a significant advantage [16]. This is a significant problem that has to be investigated in more research on the application of digital assessment tools for self-directed learning.

Another digital evaluation software is currently available, prep- Check (Sirona Dental, Bensheim, Germany). Similar to E4D compare, prep Check was designed to assist students in obtaining objective and consistent feedback on their wax-ups or tooth preparations. Kwon et al in 2015 determined that between E4D Compare and prepCheck there were no different impacts on the students' performance. Students were given a survey to rate their experience with digital scanning/evaluation softwares and were found to be nearly split on their sentiments regarding the difficulties in learning and completing a digital evaluation. The least favourable responses were to the question of whether the technologies should be incorporated into the curriculum. This was especially true in the case of prep-Check; none of the students using this system felt that it should be purchased and implemented. However, the authors reported these results could be attributed to non-strategic integration of this technology into the curriculum [17]. Callan et al in 2014 compared two different versions of E4D software to determine whether either could be expected to deliver consistent and reliable comparative results. The results of their study suggested that the auto-align feature available in E4D Compare versions 2.0 (and version 3.0.0.8 which is used in the present study) compared with version 1.0 greatly increased interrater and intrarater agreement when comparing students' preparation of a full gold crown to an ideal preparation. Additionally, they concluded that further studies were necessary to determine the appropriate tolerance level to be applied when comparing student and ideal preparations/wax-ups [18].

Will students' technical performance really improve as a result of using these devices? Additionally, in order to successfully incorporate new technology into the curriculum, educational institutions must create a strategic plan and secure funding for adequate faculty training. This will enable the instructors teaching this technology to approach the task with enthusiasm rather than seeing it as an extra workload.

Finally, it is imperative to foster a culture of accountability for learning among students [19]. The viewpoint of students in the adoption of new technologies is so crucial and must be taken into account.

Consequently, further research is needed to determine whether or not students believe that this technology aids in their professional growth and helps them get ready for the workforce.

V. CONCLUSION:

The ideal E4D software tolerance that closely matches faculty grades differs according to the tooth type. The software provided consistent grades and correlated well with faculty grades. Students' self-assessment skills improved as they proceeded throughout the course. Further studies are necessary to ascertain the role of the E4D software in improving students' self-assessment skills. Future advancement in digital scanning that can produce an unaltered scanned image which reflects the true surface integrity and smoothness of the wax may help optimise the digital grading method.

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