

An Initial Evaluation of Virtual Reality Simulation in Teaching Pre-clinical Operative Dentistry in a UK Setting

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Abstract - The use of virtual reality (VR) training in dentistry is a recent innovation and little research has been conducted to evaluate its use. For each preclinical exercise carried out the VR software currently records a final mark for the procedure, the time taken to complete the procedure and the number of 'internal' assessments carried out by the student. The aims of this study were two fold; a critical appraisal of the software by the students using a structured feedback together with an assessment of any link between the preparation time, final mark and number of evaluations. Sixteen 2nd year undergraduate dental students spent 6 hours cutting an unlimited number of Class I cavities and Class II cavities. The final mark awarded by the VR software together with the overall preparation time and number of evaluations for each cavity were recorded. For the Class I cavity the mean mark obtained was 66.8, the mean preparation time was 12.5 mins and the mean number of evaluations was 6.7. For the Class II cavity the mean mark was 26.5, the mean preparation time was 18 mins and the mean number of evaluations was 7.0. Final marks were also stratified into quartiles (0-24, 25-49, 50-74, 75-100). For the Class II cavity the time taken to complete the cavity and the number of evaluations made were greater for those cavities that gained a mark of 50 or more. In conclusion, this initial evaluation of the DentSim VR package was a generally positive undergraduate educational experience. The class II cavity was more difficult to cut than the class I which was reflected in the mean scores. There was also a trend towards higher marks being associated with longer preparation times and more evaluations during the preparation.

KEY WORDS: Education, Virtual reality, Pre-clinical dentistry, Operative dentistry

INTRODUCTION

For many years computer simulators have been used to train commercial and air force aviation pilots, but their size and expense has inhibited their widespread introduction into clinical dentistry. With the ever-increasing expansion in computing power and speed, coupled with miniaturisation, the use of computer simulators is becoming more commonplace. Within medicine, the use of virtual reality (VR) has been slowly integrated into surgical practice as it is essential for trainees to master complex surgical procedures prior to performing these on patients¹.

Within Restorative Dentistry a central competence for any dentist is the ability to prepare and restore carious tooth tissue. Traditionally, dental schools have relied heavily on teaching in phantom head laboratories to develop these competencies, where students practice on extracted or typodont teeth in mannequin heads. Within the UK, the General Dental Council expects each school to deliver this form of teaching in a specialised 'clinical skills' classroom². However, this form of instruction is limited by the level of realism provided and the quality and consistency

of feedback given by tutors³. Within professional training there is also increasing emphasis on the standardisation of teaching protocols and objective evaluation⁴.

Over the last five years or so, a computer based dental VR patient (DentSim) has been developed. The simulator consists of a conventional mannequin head and torso which carry conventional plastic teeth. The unit also carries an operator light, integrated suction, a high speed handpiece and triple syringe. In addition to this a set of 5 infra-red light emitting diodes (LEDs) are incorporated into the mandibular region of the phantom head and a further 16 are embedded into the base of the high speed hand piece. Movements of the tip of the bur in the hand piece are tracked by two infra-red cameras mounted above the operator. Finally, a flat panel monitor attached to the operator light stand provides real-time virtual images to the student.

The integrated software displays the individual tooth layers, including the pulp together with the size and morphology of a typical carious lesion. Preparations may be viewed from multiple operator-defined angles at varying magnifications^{5,6}. From a teaching perspective, the most innovative part of the software is the ability for the student to stop at any time during the preparation and 'self-evaluate' progress relative to an optimal, tutor defined, preparation. The software also allows the student to evaluate their preparation in various bucco-lingual slices throughout the tooth.

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A small number of studies^{4,6} have investigated whether this new technology provides further benefit in addition to traditional phantom head based training. The approach adopted thus far was to provide additional training with the VR simulators in addition to the traditional phantom head teaching and assess outcomes by marks achieved in termly tests. These initial studies have provided equivocal results, with one study⁶ showing an improvement with 6-10 hours of additional VR training while the second study⁵ showed no improvement. However, the outcome measures used in both studies used two blinded examiners to assess the cavities in termly tests. Assessment of cavities using a 'glance and grade' type system is highly variable³ and it is possible that the variability in marking these termly tests masked any benefit provided by the additional VR training.

Cardiff University Dental School installed eight DentSim units during the summer of 2004. A pilot study was undertaken with two principal aims:-

- A critical appraisal of the software by the students using a structured feedback session
- To assess any correlation between the preparation time, final mark and number of evaluations.

MATERIALS AND METHODS

Sixteen 2nd year undergraduate students (nine female and eight male) were randomly selected, by lottery, from the whole year of 55 students. A total of sixteen students were included in the study for purely pragmatic reasons as this allowed assessment of one morning and one afternoon group of students with minimal disruption to the teaching timetable.

The students had just completed their pre-clinical course in Conservative Dentistry and were allotted two three-hour sessions for additional training on the DentSim units. During the first three-hour session they were tasked with cutting a Class I cavity in a lower left first molar and in the second session they were tasked with cutting a Class II DO cavity in an upper first molar.

During the session each student was supplied with a millimetre graduated periodontal probe, a mouth mirror and straight probe. All preparations were completed with the same ISO standard pear-shaped tungsten carbide bur and there was no limit on the number of preparations that each student could carry out.

During these sessions the software recorded the time taken to complete the restoration, the number of evaluations carried out for each restoration and a final mark. A decision was made during the initial planning of the study to hide the mark gained for each procedure from the student, as knowledge of marks lost during the procedure may of had a negative impact on their performance, particularly as they were novices as far as the simulators were concerned.

Feedback session

At the end of these two introductory sessions a feedback session was held with the students working in groups of four. Each group was asked to reach a consensus about the three things they liked about the VR training and

three things they disliked. These were then discussed at a plenary session.

Statistical analyses

Each variable of mark, time and number of evaluations for the Class I and Class II cavities was compared using unpaired Student 't' tests with the level for statistical significance set at $p < 0.05$.

RESULTS

DentSim data

Table 1 shows the results for the final mark, total preparation time and number of evaluations for both the Class I and Class II cavities. For the Class I cavity the mean mark was 66.6, although the range of marks was broad ranging from 0-98. For the Class II cavity the mean mark was much lower at 26.5, although the range of marks was again broad ranging from 0-91.

Each variable of mark, time and number of evaluations for both the Class I and Class II cavities was compared using unpaired Student 't' tests. The marks for the Class I cavity were highly statistically significantly different from the Class II cavity at the $p < 0.0001$ level. Similarly, the mean preparation times for the Class I and II cavities were also highly statistically significantly different at the $p < 0.0001$ level. The only variable which was not significantly different was the mean number of evaluations undertaken.

Table 2 shows the data for this study divided into quartiles (0-24, 25-49, 50-74 and 75-100) together with their associated variables of preparation time and number of evaluations for both the Class I and II cavities.

Feedback session

The results from the feedback session identified three major advantages and disadvantages perceived by the students. The three major advantages identified were:-

- Easy to change teeth and carry out a relatively large number of preparations in one session
- Work at their own pace and monitor their own progress without having to wait for a supervisors input
- Ability to examine their own cavity in different cross-sections

The three major disadvantages identified were:-

- The LEDs that communicated with the overhead cameras were easy to block
- Plastic teeth were used rather than real teeth
- The marking scheme was overly critical

DISCUSSION

DentSim data

Overall, there was a wide spread in the values of the three variables investigated suggesting a wide range of capabilities in these second year students. The mean mark for the Class I cavity was much higher than the Class II cavity

Table 1. Overall mark, preparation time and number of evaluations for both cavities

	Class I (n = 91)			Class II (n = 85)		
	Mean	SD	Range	Mean	SD	Range
Mark	66.8	28.9	0-98	26.5	30.3	0-91
Preparation time	12.5	5.2	2.4-27.8	18.0	8.4	5.2-47.9
No. evaluations	6.7	3.54	1-18	7.0	4.6	1-23

Table 2. Stratified data

Class I (n=91)

Mark range	Time (mins)	Evaluations	Mean score	Number
0-24	15.0 (5.7)	7.0 (3.4)	7.0 (9.0)	14
25-49	9.07 (3.3)	5.21 (3.1)	40.0 (5.5)	5
50-74	12.4 (3.9)	7.0 (2.9)	62.6 (7.5)	16
75-100	12.2 (5.23)	6.6 (3.8)	85.2 (6.3)	56

Class II (n=85)

Mark range	Time (mins)	Evaluations	Mean score	Number
0-24	16.7 (8.0)	6.2 (4.43)	7.1 (8.8)	58
25-49	-	-	-	-
50-74	21.1 (10.2)	9.3 (5.3)	58.2 (6.1)	16
75-100	18.6 (4.3)	8.4 (2.2)	82.7 (5.2)	11

(66.8 vs 26.5) which further supports the belief that Class II cavities are much more difficult to prepare.

The students took longer to cut the class II cavities (18 mins) compared to the occlusal cavity (12.5 mins) which is probably a reflection of this increased clinical difficulty. Various workers have examined the time taken to complete amalgam restorations.

For Class I restorations provided within an NHS environment the treatment time was very short at 4 mins. For Class II amalgam restorations the times varied more widely from 14.7-30 mins^{7,9} with the longer treatment periods being recorded in University based studies. The general practice study of Chadwick *et al*⁹ reported the shortest total treatment time of 14.7 mins.

It is important to note that the preparation times reported in this study do not include the time taken to 'self assess' the cavities and therefore only includes the time taken to prepare the cavities. Not surprisingly, the preparation time of 12.5 mins reported in this study for the Class I cavity is much longer than the 4 mins reported by Chadwick *et al*⁹. For the Class II restorations the 18 mins cavity preparation time reported for the Class II cavity in this study is similar to the 14.7 mins reported by Chadwick *et al*⁹. However, it must be remembered that there are two fundamental differences between this study and those reported previously. Firstly, the treatment times reported in the literature are the total treatment times for completion of the restoration rather than just the time spent preparing the cavity as reported in this study. The only study reporting a preparation time for clinical Class II cavities was that of Advocaat *et al*⁸ that reported a mean preparation time of 9.2 mins, which is similar to the preparation time reported here.

Secondly, the treatment times reported previously were of procedures carried out by experienced dental practitioners with much greater clinical experience than our cohort of students. It is therefore not too surprising that many of the overall treatment times were shorter than the preparation times reported here.

During this preliminary study, the students were allowed to carry out an unlimited number of evaluations during cavity preparation. Although the number of evaluations varied widely (Table 1) the mean number of evaluations undertaken was remarkably similar for both cavity types (Class I 6.7; Class II 7.0). This was a surprising finding as the Class II cavity preparation is usually assumed to be a more demanding procedure.

There appeared to be no correlation between the time taken to complete either the Class I or II restorations and the final mark. This was again a surprising finding, as a longer preparation time might indicate a more careful and measured approach resulting in a superior end product. Similarly, it would suggest that a more careful student would carry out a greater number of evaluations during the preparation producing a higher grade. An alternative explanation could be that the cavities gaining relatively poor marks were being completed quickly with a small number of evaluations. A further confounding variable might be that once a student identifies a mistake, they take more time and carry out further evaluations in an attempt to correct this mistake.

To investigate this problem further, the data was stratified into quartiles of 0-24, 25-49, 50-74 and 75-100 for both Class I and II cavities (Table 2). Unfortunately, no Class II cavities were graded in the 25-49 band.

The time taken to complete the Class I cavities for each of the four mark bands is similar at 9-15 mins as was the mean number of evaluations at 5.2-7 (Table 2). For the Class II cavities, the time taken to complete the restorations was shorter with the low mark band (0-24) at 16.7 mins compared to the higher mark bands at 18.6-21.1 mins. Similarly, the number of evaluations made with the low mark band (0-24) were lower at 6.2 compared with the higher mark bands (50-74; 9.3 and 75-100; 8.4). These findings tentatively suggest that for the Class II cavities at least, the cavities in the low mark band were completed more quickly and with a smaller number of evaluations than the cavities gaining higher marks.

Many dental schools continue to use the Class II cavity as a 'make or break' examination before allowing the student into the clinical environment. It could also be argued that these findings suggest that the preparation of a Class II may be more discriminatory than a Class I cavity and may justify its continued use as a competency assessment.

However, these findings must be tempered with a certain amount of caution as the number of Class II cavities in the two higher mark bands were relatively small with 16 in the 50-74 band and 11 in the 75-100 band. Never the less, these findings provide sufficient positive findings to warrant further investigations with a much larger sample size over a longer time period.

Feedback session

The feedback from the students about their initial VR experience was generally positive. The major advantage perceived by the students was that they could work at their own pace without having to wait for a supervisor to grade their work which has been commented on in previous evaluations of this VR set up^{5,6}.

However, there were also some negative aspects noted. It was easy for novice operators to block the communication pathway between the handpiece and the cameras with their wrist, but with time and practice this problem was overcome.

The problems with plastic teeth is more difficult to resolve. This cohort of students had already completed their preliminary preclinical course in operative dentistry using extracted human teeth and probably found it more difficult to return to cutting plastic teeth. With junior students who initially start their 'cutting careers' with plastic teeth, this is less likely to be a problem. The comments about the software being over-critical in its evaluation of student work may be due to poor familiarity with the software. In any case, the evaluation parameters can be set to suit individual institution's needs so that this problem can easily be overcome.

In conclusion, this initial evaluation of the DentSim units found that it was a generally positive educational experience. The class II cavity was more difficult to cut than the class I which was reflected in the mean scores. There was also a trend towards higher marks being associated with longer preparation times and more evaluations during the preparation. This is worthy of further investigation using a larger cohort of students.

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