Using MicroCT Scanning Techniques to Assess the Performance of Dental Students’ Tooth Cavity Preparation Skills

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Aims
To use Micro-CT Scanning techniques to compare the results of undergraduate dental students' clinical cavity preparation skills; trained traditionally versus haptically using a virtual reality simulator (hapTEL).

Method
The study took place in a university healthcare undergraduate dental setting in which clinical skills are initially taught through students working on plastic or discarded natural teeth at a Phantom Head workstation. Each of the 77 workstations, shown in Figure 1 is equipped with dental instruments, teeth in a jaw, a chair and most of the equipment seen in a dental surgery.

Figure 1 – Tutors instructing students in the Phantom Head Laboratory

The Bachelor of Dental Surgery undergraduate programme to become a qualified dentist in the UK is five years. The 1-year study discussed in this paper was one of a series of studies conducted between 2008 to 2017 to investigate the impact of teaching year-1 Dental Undergraduate students clinical skills using a virtual haptic dental device (haTEL) designed to simulate the traditional Phantom Head. The students’ clinical skills’ progression is traditionally monitored by tutor observation and assessed by looking at the end result of the pre-clinical task, such as the removal of decayed tissue from a tooth.
The student cohort for this study was 138 Year-1 Dental Undergraduate students being taught removal of caries using plastic teeth in the traditional Phantom-Head Laboratory (n=96, Fig. 1) or virtual teeth using the hapTEL work-stations (n=42, Fig.3). The hapTEL work-station is shown in Figure 2 below.

For the traditionally trained students the task involved learning to use a dental drill to remove simulated decayed tissue from plastic teeth, designed by Frasaco to be similar to the anatomy of real human teeth with different tissue densities to represent the various layers. For the haptically trained students using the hapTEL simulator the students were required to work on a virtual tooth using the hand-piece which provides haptic feedback as with a real drill and stores all the procedures the students conduct (Shahriari-Rad, Cox & Woolford, 2017).
Assessment of students’ skills.

Traditionally, when assessing the students, the tutors are mainly only able to see discreet stages and the final outcome (prepared tooth cavity) of every student because there are too many students to observe at the same time (Shahriari-Rad, 2014). In order to assess the students’ cavity preparation skills more precisely this study involved all students (traditionally and haptically trained) being required to remove simulated caries from a plastic tooth manufactured by Frasaco after the training sessions in Year 1 had been completed.

Assessment-techniques:

A range of assessment methods have been used in the series of studies to measure the effects of the simulation training on students’ learning of fine and gross motor skills and clinical skills (San Diego, Newton, Quinn, Cox & Woolford, 2014). For the study reported in this paper, students in both cohorts were required to excavate carious tissue from a plastic tooth after their training sessions to determine what they had learnt. These teeth shown in Figure 4 were scanned to determine the very fine differences between individual student’s performances and the accuracy of their operations. This involved the following:

1. Micro-CT Scanning of the excavated plastic teeth (n=84) to determine the volume of artificial caries removed, healthy tissue (enamel and dentine) remaining and surface roughness.

2. Micro-CT Scanning of the manufacturer produced cavities (n=10) where the artificial caries had not been removed. In order to investigate the consistency of the manufactured Frasaco teeth.
Figure 5 – Caries lesions in plastic and hapTEL teeth showing increasing caries size from 1 - 4

The teeth used for this study were for Task 3 which had a complex carious lesion extending near to the pulp. The teeth scanned were compared to find out: (a) how consistent was the manufacturing of the individual teeth; (b) how accurately the students prepared a cavity and removed the carious tissue and (c) which cohort of students (traditional or haptically) achieved the most accurate results removing the highest volume of carious tissue without drilling into the pulp or removing too much healthy tissue.

**Scanning techniques**

All 94 plastic teeth were scanned using the Bruker SkyScan 1275 shown in Figure 6. Each Frasaco tooth was loaded and scanned which took about 30 minutes. (Fig. 7)

The variables recorded and calculated included: lower and upper grey threshold, object volume, percentage object volume, object surface, intersection surface, object to surface volume ratio, object surface density and surface convexity index. From these data the amount of volume removed by each student and the mean for the whole cohort can be calculated, and the surface roughness of the operation by each student.
Results

The scans for each tooth showed the sagittal, coronal and axial cross-sections of each tooth, an example of which is shown in Figure 8. The central rod depicted as the same colour as the surroundings is the screw in the plastic tooth which enabled it to be screwed into an artificial plastic jaw before operation.
Figure 8 showing the sagittal, coronal and axial cross-sections of a tooth
The cavity cut by the student can be enhanced through colour to enable the researcher to view the tooth more accurately. (Fig. 8 below)

Figure 9 showing the colour enhanced tooth the identify the cut cavity
The results for the total teeth scanned showed the following:

- Volume (or %) of Caries removal
- Dimensions of the cavity
- Proclivity to tilt the hand-piece (dental drill) to one side or next Angle of entry into the tooth
- Morphometric differences in cavity preparation

The lower and upper grey limit chosen for the analysis was 128 and 255 respectively.

The results for all 94 teeth showed significant variations between the different teeth cut by the individual students for all the relevant variables, a sample of which is shown in Table 1 below.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object volume</td>
<td>15.187 – 33.843</td>
</tr>
<tr>
<td>Percentage of object volume</td>
<td>0.42 – 0.91</td>
</tr>
<tr>
<td>Total volume of pore space</td>
<td>3590 - 3773</td>
</tr>
</tbody>
</table>

Further analysis of the scan data is still in progress but this variation shows that it can reveal accurate differences in the performance of each student and of the original Frasaco teeth enabling us to have more precise measurements of students’ cavity preparation skills than can be obtained using traditional methods.

**Conclusions**

The conclusions to date of this study are that MicroCT affords a quantitative volumetric analysis of dental undergraduate students’ cavity preparation skills and progression in their learning. Furthermore, the scans of the excavated plastic teeth can measure and provide the most permanent and accurate record of students’ clinical skills. Additionally, it has the advantage of both quantitatively and qualitatively (by visual analysis) measuring the surface roughness of the cut cavities which cannot be achieved through any other assessment process.

**References**


Quinn, B. F., Dunne, S., Wilson, N. & Cox, M. J. Micro-CT Analysis of Cavities by Students Trained Haptically or Traditionally. Journal of Dental Research 93(B):797 · June 2014


Shahriari-Rad, A., Cox, M.J. & Woolford, M. Investigating assessment methods for clinical skills using the hapTEL simulator
