Using virtual microscopy to deliver an integrated oral pathology course for undergraduate dental students

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In brief

Will interest readers who teach oral pathology at undergraduate and postgraduate level.	Demonstrates a new and enriched method to teach dental undergraduates oral pathology.	Will be useful to those individuals interested in integrating clinical disciplines with oral pathology.

Dental students in the United Kingdom usually study histopathology as part of their undergraduate curriculum and this has traditionally been delivered using light microscopes in laboratory classes. Beginning in 2005, the oral pathology course in Sheffield was gradually modified by the introduction of virtual microscopy with a focus on creating a more integrated, clinically orientated and dynamic approach to student teaching and learning in histopathology. The purpose of this paper is to describe how virtual microscopy has been used to enhance dental students' learning of oral pathology, and its role in facilitating an integrated oral disease curriculum in Sheffield.

Introduction

The teaching of histopathology to dental students has long been part of undergraduate curricula and has traditionally been delivered using light microscopes.[1,2] Dental students are required to learn about the pathological basis of oral diseases so they understand both the clinical features and the rationale for treatment. Over many decades, this was achieved in Sheffield through laboratory sessions, where students were given a clinical scenario and then looked at a number of microscope slides showing characteristic histopathological features to increase their understanding of changes occurring in the tissues. The approach became increasingly untenable due to increases in the number of dental students, insufficient microscopes and the increasing costs of replacing or maintaining microscopes and slides sets. It was also impossible to create large sets of microscope slides showing a similar range of features. In addition, students were unable to access slides and microscopes outside class times, restricting them to outmoded class-based teaching and curtailing self-directed learning. A course evaluation by our 4th year dental students in 2005 revealed that, although they overwhelmingly wished to learn the histological aspects of oral disease, only 8% (4/50) of students believed that microscopes were relevant or appropriate.

In dental education, digital technology and electronic media is integral to computer-assisted learning (CAL) and 'e-learning', which has generated a great deal of discussion.[3] In recent years, virtual microscopy (VM) has been introduced, in which image acquisition involves digitally photographing tissue sections on microscope slides using one or more microscope objectives at one or more focal planes. Multiple high resolution digital images are then pasted together to create a virtual image of the whole tissue section. This technology has been improved greatly in recent years and it is now possible to view entire slides at different magnifications without loss of quality on a standard computer. This nearly perfectly emulates a traditional microscope and a glass slide.[4]

VM has been increasingly used in higher education and shown to improve individual and group learning and enhance the overall learning experience of students.[5–8] As well as teaching applications, it has also been used in multi-disciplinary team meetings, conferences, telepathology and research.

Before 2005, oral pathology class 'practicals' in Sheffield consisted of a set of microscope slides, a microscope and a basic workbook for each student. Each slide had a brief description of the lesion or patient history in the workbook together with a set of related questions. It was felt that this approach did little to integrate oral pathology into a clinical context and made it difficult for students to become enthusiastic or see the relevance of learning about histopathology. A desire to increase student engagement and learning in histopathology led to a new approach to delivering these classes. To begin with, the workbooks were enriched with colour photographs of the clinical conditions and lesions as well as any relevant radiology and students were asked to describe these and arrive at a differential diagnosis. They were then asked to look at and describe still images of relevant or magnified areas of the histology slide which were also included in the workbooks and to arrive at a diagnosis. Following this they were then asked questions about the pathogenesis and management of the disease. However, the introduction of VM where students were able to view virtual histopathological images on a computer became a considerable enabler to this approach.

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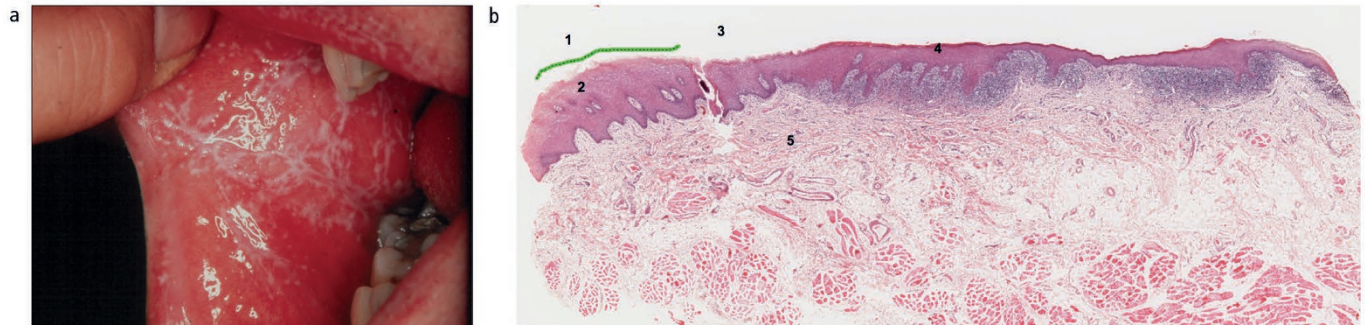

Fig. 1 Example of a case

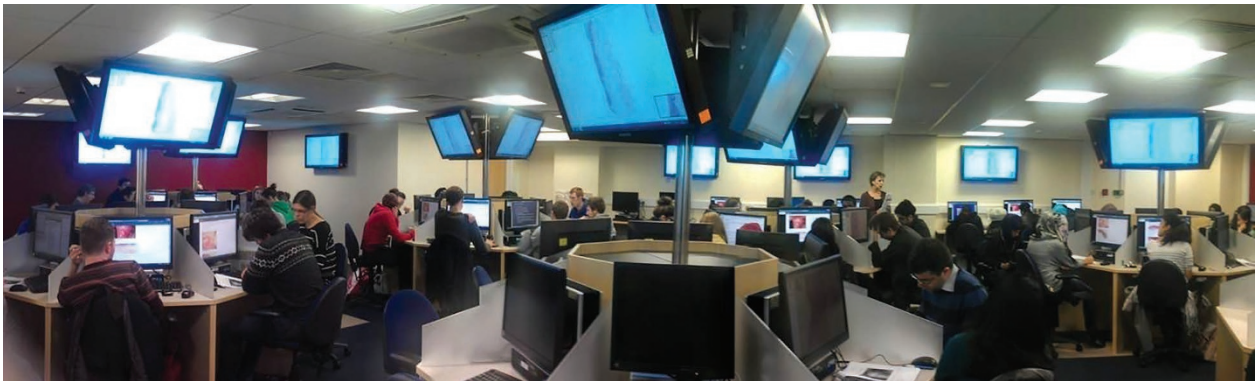

Fig. 2 Whole group activities using large television screens were used to facilitate discussion of each case

It was anticipated that experimenting with VM would enable histopathology teachers to assess whether the technology could enhance the student learning experience by providing a large group of students with readily accessible images, both within the structured environment of a practical class and during their independent learning. In addition it had initially been hoped to assess objectively whether the introduction of VM improved student attainment in our histopathology course but this was not possible for two reasons. Firstly, the entire undergraduate dental curriculum was revised at the same time that VM was introduced, so there were multiple variables which could have affected this outcome. Secondly, the introduction of VM was an iterative process introduced under the busy schedule of two consecutive academic years.

Although VM has been discussed widely in the literature, to our knowledge, there are no reports it has been used to teach oral pathology to dental students within the UK. This report documents both the tutor's and student's experience of the introduction of VM into oral pathology teaching and learning in the undergraduate dental curriculum in Sheffield.

Materials and methods

VM was integrated into two practical classes in oral pathology to 64 dental students during semester 1 of their 4th year. A learning, teaching and development grant (LTDG) from the University of Sheffield was used to cover costs for scanning existing microscope slides and to pay for staff time to make the microscopic imagery available and integrate it into teaching. The LTDG fund also enabled the project leader to draw upon the expertise of staff in the Learning and Teaching Services (LETS) to investigate the technical aspects of scanning slides and accessing digital imagery. This funding was used to help purchase an Aperio slide scanner (Scanscope GL) and appropriate computer facilities for the storage and viewing of the digital images.

The 4th year dental undergraduate course includes seven practical classes. In Semester 1 of 2007-8, two of the practical classes were undertaken using VM accessed via the course's university intranet domain (the remaining five used still histopathological images). The course team integrated the resource in a practical format. Learning activities were supported by a workbook which structured student engagement with microscopic images in order to answer key questions. Unlike traditional glass slides, all virtual images were now annotated to direct students towards the appropriate areas of the slide. Students were able to access the images either individually or in pairs, and they tended to work in small groups to answer questions.

Most cases consisted of a clinical photograph or radiograph of a lesion alongside a matching histological image (Fig. 1). The practical classes are designed to facilitate clinico-pathological correlation where the students are guided through the process of describing what they see on a clinical or radiographic image, determining the special tests required and suggesting a differential diagnosis. They are then asked to view the histopathological image and describe the salient features of the disease process being shown. The student is then asked to give a definitive diagnosis using all the information they have been given, answer questions about the pathogenesis and finally, formulate a treatment plan for the patient. This process means that students do not view histopathology in isolation, but are able to appreciate the case as a whole and in a clinical context, enriching the learning experience.

Students were able to call on the support of a number of tutors, and whole group activities

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Table 1 Student questionnaire showing responses following introduction of virtual microscopy in 2007

To what extent do you agree with the following statements about your experience of using the virtual microscopy resource? 1= Strongly agree; 5=Strongly disagree Percentages of students in each group rounded to the nearest whole number. n = 44						
	1	2	3	4	5	Mode
I found the virtual microscopy viewer easy to access in class	84%	11%	2%	2%	0%	1
Learning how to use the virtual microscopy resource was straightforward	82%	16%	2%	0%	0%	1
The quality of images was excellent	70%	23%	7%	0%	0%	1
I found the annotations on the images useful	30%	45%	18%	7%	0%	2
I was able to use the magnification function with no difficulty	75%	23%	2%	0%	0%	1
I understood the questions associated with the images	64%	32%	5%	0%	0%	1
I found the in-class exercises useful	68%	25%	7%	0%	0%	1
I found the in-class exercises challenging	61%	27%	11%	0%	0%	1
Tutors provided valuable help in using the virtual microscope	70%	16%	14%	0%	0%	1
Reviewing the exercises at the end of the class was useful	91%	7%	2%	0%	0%	1
The lectures provided good preparation for using the virtual microscopy resource	55%	30%	11%	2%	2%	1
I preferred the virtual microscopy resource to the sessions where we used still images	75%	20%	0%	5%	0%	1

using large television screens were used to facilitate discussion of each case (Fig. 2). Students were also able to access the images away from class, and in their own time via workbooks presented on the university's intranet.

The introduction of VM was assessed using:

- A student evaluation questionnaire on VM, which was circulated after students had experienced both the two VM classes and also the five classes using still photographic images. Questionnaire responses were anonymous and participation was voluntary. Responses were measured using a 5-point Likert scale with the following options: 1 (strongly agree), 2 (agree), 3 (neither agree nor disagree), 4 (disagree) and 5 (strongly disagree). The questions were created from discussion between the module lead, other staff that taught on the course and the Learning and Teaching Unit of the University of Sheffield
- A student focus group on VM was held at the end of the course. This was facilitated by the project lead. Attendance at the focus group was voluntary. The focus group was conducted in a quiet office and lasted two hours. The discussion was semi-structured and the project lead used a brief script to make sure key areas were covered
- A reflective discussion between the project lead and the module team.

Results and discussion

Student evaluation questionnaires were returned by a total of 44 students from a course cohort of 64 (a response rate of 69%). A summary of the questionnaire feedback is provided in Table 1. Six students attended the focus group, including one male and five female students.

The student experience of VM was overwhelmingly positive. Out of 44 responses to the questionnaire, 95%, (42/44) agreed or strongly agreed that VM was 'easy to access'; 98% (43/44) that it was straightforward to learn how to use the resource; 98% (43/44) that the magnification function was easy to use; and 93% (41/44) that the quality of images was excellent. The focus group indicated that based on their experiences of conventional microscopy in the first and second years of the course some students were initially sceptical about the quality and ease-of-use of VM, but they found no problems with using the resource. The only feature of VM which students were not quite as positive about was the use of annotations on slides, with only 75% (33/44) indicating that they 'strongly agreed' or 'agreed' that these were useful.

Students were very positive ('strongly agreed' or 'agreed') about the learning activities into which VM was integrated. Questionnaire responses indicated that a large proportion of students were also positive about the in-class exercises 93% (41/44), tutor support 86% (38/44) and the whole-group end-of-class review 98% (43/44).

The focus group reinforced this information, particularly highlighting the importance of tutors and the end-of-class review as crucial components in student confidence about learning. The focus group also highlighted the importance of undertaking the in-class exercises as part of a group within which students could engage in discussion about the images.

Students identified a number of advantages provided by VM to their learning experience compared with conventional microscopy which they had used earlier in the course:

- Students and tutors no longer needed to spend time redirecting and refocusing a conventional microscope in order to view the appropriate feature illustrated in the workbook
- Images could be viewed by more than one person at a time. Students felt more confident that they had viewed the appropriate feature illustrated by the slide by gaining feedback and information from peers and tutors who were simultaneously looking at the same image
- During whole class work, students could view the same image as that presented by the tutor

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Table 2 A further student questionnaire showing responses following introduction of virtual microscopy in 2007

To what extent do you agree that the virtual microscopy resource assisted you in the following areas of oral pathology? 1 = Strongly agree; 5 = Strongly disagree

Percentages of students in each group rounded to the nearest whole number. n = 41

	1	2	3	4	5	Mode
Understanding the pathological basis of oral disease	29%	48%	20%	0%	0%	2
Recognising the clinical features of oral pathology	52%	24%	17%	2%	0	1
Articulating a rationale for clinical treatment	12%	49%	34%	5%	0	2
Feeling confident about your knowledge of oral pathology	32%	44%	20%	5%	0	2
Preparing yourself for future assessment	44%	49%	5%	2%	0	2
Motivating you to study oral pathology	17%	41%	27%	12%	2%	2
Encouraging you to study oral pathology later in your degree	7%	34%	29%	20%	10%	2

- In contrast to still images, students and tutors were able to control the magnification of the image, zooming in on key features and zooming back out in order to understand the wider context in which the feature was situated
- Students found VM to be less taxing on their eyesight and ability to concentrate than conventional microscopy.

Typical open responses from students included: 'I noticed how useful the imaging was when we came to subsequent tutorials when no virtual microscopy was available' and 'It [VM] was really good – I found it so much easier to understand and I did not have a microscope-squinting headache at the end of each session. Please keep this facility'.

Observational evidence from staff involved in VM classes supports this positive account of student learning experiences. Similar to the students, teachers felt that the VM classes made teaching of oral pathology more efficient and enjoyable. Every student examined identical virtual images, enabling greater collaboration both between students and between staff and students. Staff felt they were able to explain the pathological features more easily and were able to help students who had difficulties in understanding. From their interactions with the students, the teaching team also noted students were engaging with oral pathology at a deeper level than in previous years. This was confirmed by a further questionnaire (response rate 41/64; 64%; Table 2) which indicated that students perceived VM to be particularly effective in understanding the pathological basis of oral disease 80% (33/41) and recognising the clinical features of oral pathology 80% (33/41). Students were slightly less convinced that VM had helped their ability to articulate a rationale for clinical treatment 61% (25/41), which may indicate that the learning activities contributing towards this outcome need to be further developed. Questionnaire responses indicated that students perceived VM as contributing towards their confidence about their knowledge of oral pathology 76% (31/41) and preparing themselves for future assessment 93% (38/41). The focus group stated that they were extremely motivated by the assessment needs for the degree, and saw VM as strengthening their ability to engage with assessment tasks.

The questionnaire gained feedback on the impact of VM on student attitudes towards further learning in the field of oral pathology. Fifty-nine percent (24/41) of respondents were positive about the role of VM in motivating them to study oral pathology, while 41% (17/41) of responses were positive about the role of VM in encouraging students to study oral pathology later in their degree. However, students attending the focus group stated that VM had not affected their motivation to study oral pathology, maintaining that their intended career paths as a clinical dentist would not require them to develop specialist skills in this area. Rather, they perceived oral pathology classes as providing them with sufficient background knowledge to interact with specialists later in their career.

Two areas that were highlighted by students from the focus groups were:

- The importance of tutor support to their learning was stressed, and it was suggested that using VM exclusively for independent study in the absence of such support would render the resource much less effective to their learning
- A number of students in the focus group suggested that VM could be used for assessment tasks
- The course team have also considered this possibility. It has been introduced successfully for smaller postgraduate groups, but barriers to extending VM into assessment of large groups of undergraduates include the need to integrate the resource with multiple choice question software, and the need to adhere to assessment standards set out by the professional body.

Our experiences of using VM to teach histopathology are similar to those described in other countries. In Australia, Farah and Maybury found that 77% of their dental students preferred VM to traditional slides and 89% reported enhanced learning.[9] Recent reports from the United States, Brazil and Poland have also indicated a positive impact for VM.[10–12] Dental schools from these countries also used questionnaires to gather student feedback and reported very similar findings, including increased student teamwork, efficiency and ease of use. Other institutions have implemented high-resolution, wall-sized virtual microscopes for teaching medical although not dental students. For instance, the Leeds 'Powerwall' is an interactive, wall-size visualisation system, created from an array of 28 × 20 inch monitors that provides an overall image size of 3.0 × 1.2 metres and resolution of 54 million pixels. This version of VM has also been successful, with feedback responses from medical students reporting that the Powerwall made histopathology 'more interesting' and 'engaging'.[13]

Following the introduction of the successful pilot, VM has now been fully integrated into

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the undergraduate curriculum in Sheffield for both the teaching of histology and oral histopathology. The course now consists of 20 VM practical classes in years 1, 2 and 4 of the curriculum similar in format to that described above. This totals around 60 hours of teaching, supplemented in all years by traditional lectures and for final year students, case seminars, where they work in small groups of six to eight. Here, each student studies a case that consists of either a clinical photograph or radiograph and a virtual image. The student is required to describe the clinical or radiographic image, suggest a differential diagnosis, describe the histopathological image and attempt to determine a final diagnosis and treatment plan. The student indicates how they would manage such a patient in general dental practice and then if appropriate how the patient would be managed in secondary care. Each student presents their case to the group and answers questions from the tutor and the group. Thus all students learn from each case and in total 32 cases are discussed over four sessions. Our student feedback reflects how valuable these case seminars are to students, as they help to consolidate lectures and earlier histopathology class practicals. They encourage students to be independent and describe and manage a case from presenting symptoms through to the delivery of a sound management plan or appropriate referral strategy; skills which are required of dental practitioners in primary care.

In order to determine whether the views of VM in the initial cohort of students was maintained in subsequent years, students in 2012 who had used virtual microscopy in years 2, 4 and 5 of the course but who had studied histology in the first year using microscopes, were asked about their views of virtual microscopy compared to conventional microscopy using an anonymous, voluntary questionnaire. This questionnaire had a response rate of 44/70 (63%). This showed that 95% (42/44) of students agreed that VM was better than a traditional light microscope for learning histopathological features (Fig. 3); 93% (41/44) said they would use the VM resource as a revision tool when revising for oral pathology exams (Fig. 4); and 97% (43/44) said VM was better than still photographic images for understanding histopathological features (Fig. 5).

When the technology was first introduced in 2007, we experienced more technical difficulties due to the large image files, which was resolved in 2008 when we acquired a new, more

Fig. 3 Virtual microscopy is better than traditional microscopy for understanding histopathological features

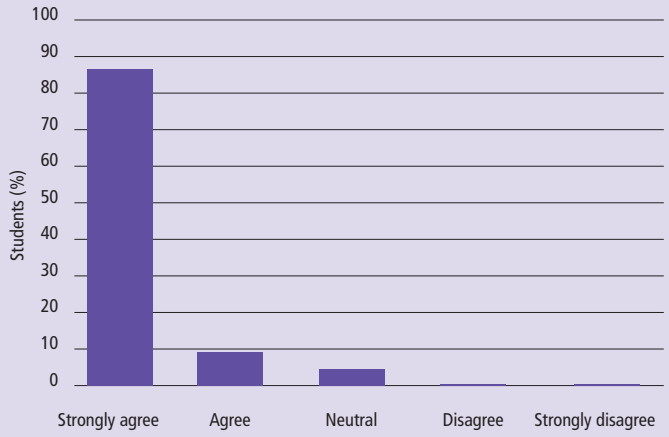


Fig. 4 I will use the virtual microscopy resource as a revision tool

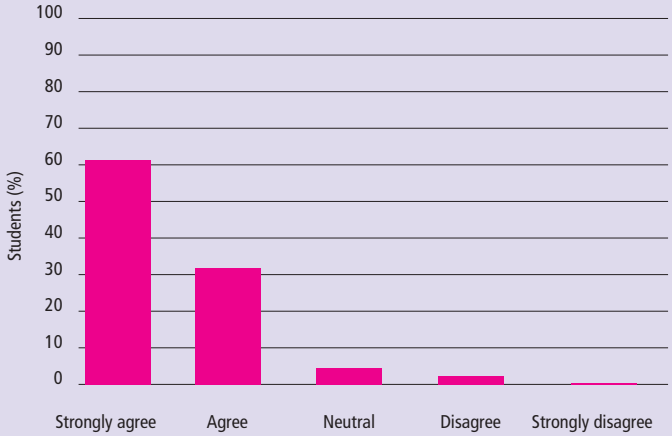
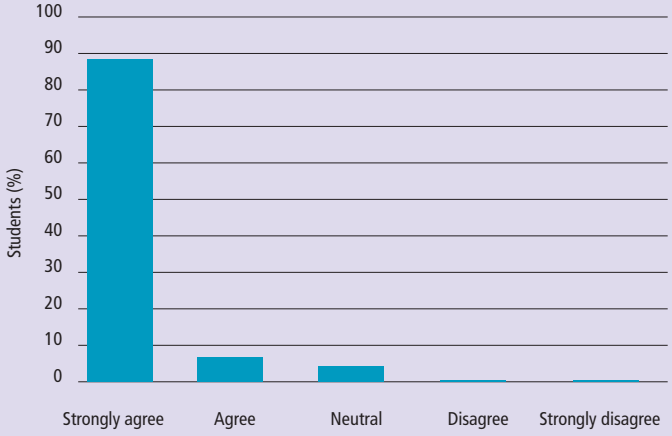


Fig. 5 Virtual microscopy is better than still photographic images for understanding histopathological features



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powerful server to store and access the images. Some of the original histopathology cases have also been amended following student feedback. VM has proven to be very popular with our undergraduate students and has also made teaching more enjoyable and rewarding for staff. We now use VM in oral pathology postgraduate courses and have implemented it at several conferences and online symposia. Due to the widespread use of VM throughout our teaching in Sheffield it is not possible to accurately determine whether there has been a financial cost saving but the advantages in terms of efficiency and quality of teaching as well as the breadth of courses we are able to offer are immeasurable.

Conclusion

Student feedback on their learning experience with VM has been overwhelmingly positive since its introduction in 2007. This was particularly reflected in their ability to view identical microscopic images simultaneously with their peers, tutors and the class leader, facilitating productive discussion, reinforcement and confidence in their learning. For VM to be successful, ICT infrastructure and support alongside appropriate learning spaces are required. We have found many outlets for VM and believe it has enhanced our ability to teach oral pathology to both our undergraduate and postgraduate students. We believe that the successful integration of oral pathology into clinical scenarios has enriched student learning and made histopathology more meaningful to students.

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