An application of virtual microscopy in the teaching of an oral and maxillofacial pathology laboratory course

Yuk-Kwan Chen, DDS, MS,[a] Shue-Shang Hsue, DDS, MS,[b] Dai-Chung Lin, DDS, MS,[b] Wen-Chen Wang, DDS, MS,[c] Jing-Yi Chen, DDS,[d] Cheng-Chung Lin, DDS,[e] and Li-Min Lin, DDS, MS, PhD,[e] Kaohsiung, Taiwan
KAOHSIUNG MEDICAL UNIVERSITY

Objective. The aim of this study is to share the experience of establishing a virtual microscope and telepathology system for the oral and maxillofacial pathology laboratory course in a dental school.
Study design. A dot-slide system has been used to generate digitized microscopic slides, which are placed on an image server that is available online.
Results. Using software that is available as a free download (OlyVIA), students are able to select a teaching slide record, view at magnifications comparable with those of a conventional microscope, and navigate to any area on the matching virtual slide image that is stored on the image server database. Before class, the students can review the findings of the virtual teaching slides at any time or any place via broadband internet by using the instructions available on DVD. During class, students report and discuss the histological findings of the virtual teaching slides with tutors who evaluate, test, and make constructive comments on the presentations in a Web-based computer classroom. After class, students can revise the histological findings of the microscopic virtual slides available on the server.
Conclusions. Virtual microscopy has many advantages over real microscopy in oral and maxillofacial pathology education. Furthermore, telepathology could also be applied in other pathological services, such as intraoperative frozen sections, routine surgical pathology, and subspecialty consultation. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:342-7)**

Oral and maxillofacial pathology (lecture and laboratory) is one of the basic science courses in dental school curricula worldwide. In our school, the oral and maxillofacial pathology laboratory course is scheduled for the first semester of the third year of undergraduate students for 4 hours per week; the class size is 80 students. For almost 20 years, standard classroom teaching of this subject in our school employed the optical microscope to observe prepared tissue sections on glass slides. If demonstration and viewing of the microscopic teaching slide was necessary, an optical microscope with a projector operated by an instructor was required, as well as the simultaneous presence of the students. Then, 5 years ago, a DVD version of the instructions for our pathology course was developed to enable all students to access the pathology course even if they did not have a conventional optical microscope.

With recent advances in the technology of virtual microscopy and the development of broadband internet connection, it is now feasible for microscope slides to be digitized, placed on an image server, and made available online by means of a Web site.[1] In this article, we share our experience of establishing a virtual microscopy and telepathology system for the oral and maxillofacial pathology laboratory course in our school.

MATERIAL AND METHODS

To produce digitized microscopic slides, a *dot-slide system* developed by Soft Imaging System GmbH (Olympus Deutschland GmbH, Hamburg, Germany) was employed. The hardware used in this system is shown in Fig. 1 and chiefly includes the following 5 components: (1) a light microscope (BX51, Olympus) equipped with a motorized nosepiece (BX-REMCB, Olympus). The revolver is fitted with several objectives and can be remotely manipulated using the image anal-

The first three authors have contributed equally to this article.
[a]Associate Professor and Head, Department of Oral Pathology, School of Dentistry, Kaohsiung Medical University, Kaohsiung Medical University Hospital.
[b]Graduate Student, Department of Oral Pathology, School of Dentistry, Kaohsiung Medical University, Kaohsiung Medical University Hospital.
[c]Visiting Staff, Department of Oral Pathology, School of Dentistry, Kaohsiung Medical University, Kaohsiung Medical University Hospital.
[d]Resident, Department of Oral Pathology, School of Dentistry, Kaohsiung Medical University, Kaohsiung Medical University Hospital.
[e]Professor, Department of Oral Pathology, School of Dentistry, Kaohsiung Medical University, Kaohsiung Medical University Hospital.
Received for publication Feb 4, 2007; returned for revision Mar 10, 2007; accepted for publication Mar 14, 2007.
1079-2104/$ - see front matter

doi:10.1016/j.tripleo.2007.03.020

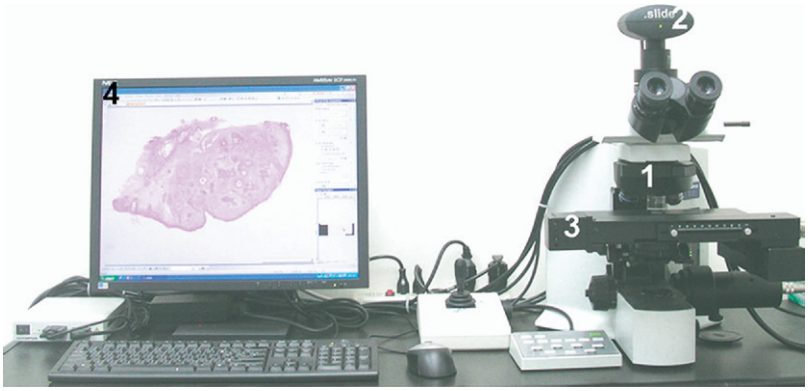

Fig. 1. The hardware used in the dot-slide system is chiefly composed of *1,* a light microscope equipped with a motorized nosepiece; *2,* a high-resolution digital color camera (1376 × 1032 pixels); *3,* a stage that is motorized in all 3 directions and can be moved with both the joystick and the software; and *4,* a PC installed with the image acquisition software, with a monitor of standard resolution of 1600 × 1200 dpi. The server computer is not shown.

ysis system; (2) a high-resolution digital color camera (1376 × 1032 pixels), pixel size of 6.45 μm; (3) a stage, which is motorized in all 3 directions and can be moved using both the joystick and the software; (4) a PC, installed with the image acquisition software, with a monitor of standard resolution of 1600 × 1200 dpi; and (5) a server computer (IBM, Microsoft Window server 2003R2; IBM, Armonk, NY) with a 200-gigabyte hard disk. To protect against server drive failure, a backup 200-gigabyte hard disk is also available.

The total cost of this system is approximately US $100 000 with no recurring annual fee. Our 4 teaching assistants helped to generate the electronic files for the pathology course under the supervision of a faculty member (Y.-K. C.), without additional personnel expenditure.

The conventional glass teaching slide is placed on the microscope stage, and the digital camera captures high-quality field of view single images (usually at ×40 objective) as the motorized stage moves the glass slide from left to right and up and down. Eventually, a collection of field of view images is obtained, representing the entire glass slide. These images are subsequently stored to the PC connected to the digital camera, and the image acquisition software installed on the PC will "stitch" together these field of view images to create an entire virtual slide image of between 300 and 600 megabytes in file size). This virtual slide image can then be transmitted to the image file server and the server file address can be stored in a database record. Consequently, a database of virtual slides encompassing various fields of oral and maxillofacial pathology is established. A client viewer software (Olympia OlyVIA; Olympus; free download available) is installed on the Web server so that when students log on to the Web site, they can download this software to their PC. Our Web site has been placed on the main server of our institution. Prior to implementing the course via the internet, trials were performed to ensure that all students can link to our Web site by using a broadband connection and experience no bandwidth problems. Using the free software, the student can select a teaching slide record (either during the class or at home) and view the slide at magnifications comparable to those of a conventional microscope, navigating to any area on the matching virtual slide image that is stored on our image server database (Fig. 2, *A-D*).

Before class, the students can study by themselves and review the findings of the virtual teaching slides at any time or any place—via broadband internet—by using the instructions available on DVD. Then, during class, the students, divided into 6 groups, report and discuss with the tutors (1 professor, 1 assistant professor, and 4 teaching assistants) the histological findings of the virtual teaching slides. In a Web-based computer classroom, the tutors evaluate, test, and make constructive comments on the students' presentations. After class, the students can easily revise the histological findings of the microscopic virtual slides available on the server.

RESULTS

The effectiveness of the virtual microscope system and DVD-based instruction of the oral and maxillofacial pathology laboratory course has been evaluated using a questionnaire, which was administered after the students had completed the laboratory sessions. The assessment contained 2 categories of questions. The first category acquired students' opinions on the usefulness of the virtual laboratory course, rated on a scale of 1 to 5 (1,

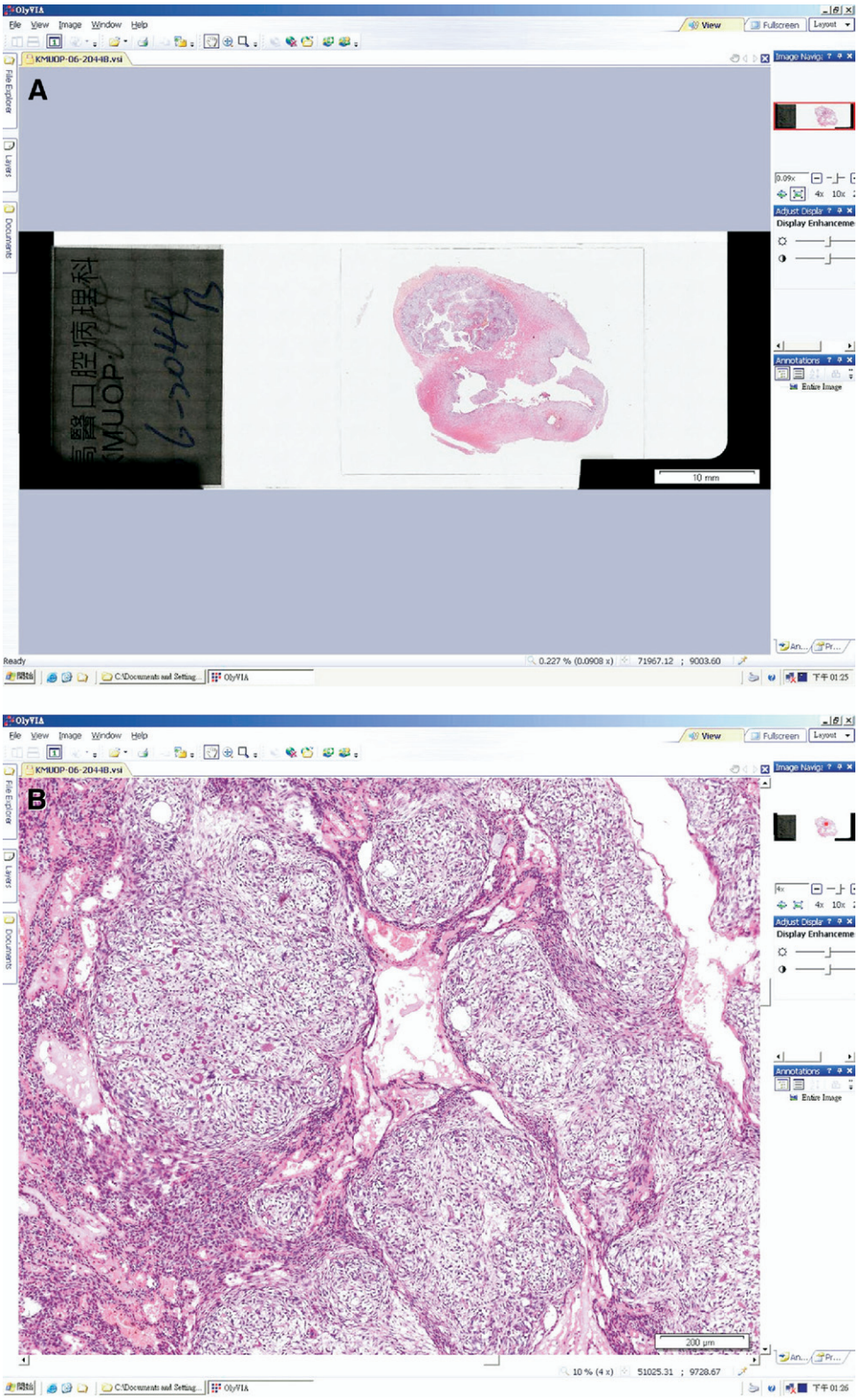

Fig. 2. Using OlyVIA software, a teaching slide record can be selected and viewed at different magnifications and is comparable with that of a conventional microscope. Any areas on the matching virtual slide image that is stored on the server database can be navigated to. **A,** Naked eye. **B,** Low. **C,** Medium. **D,** High.

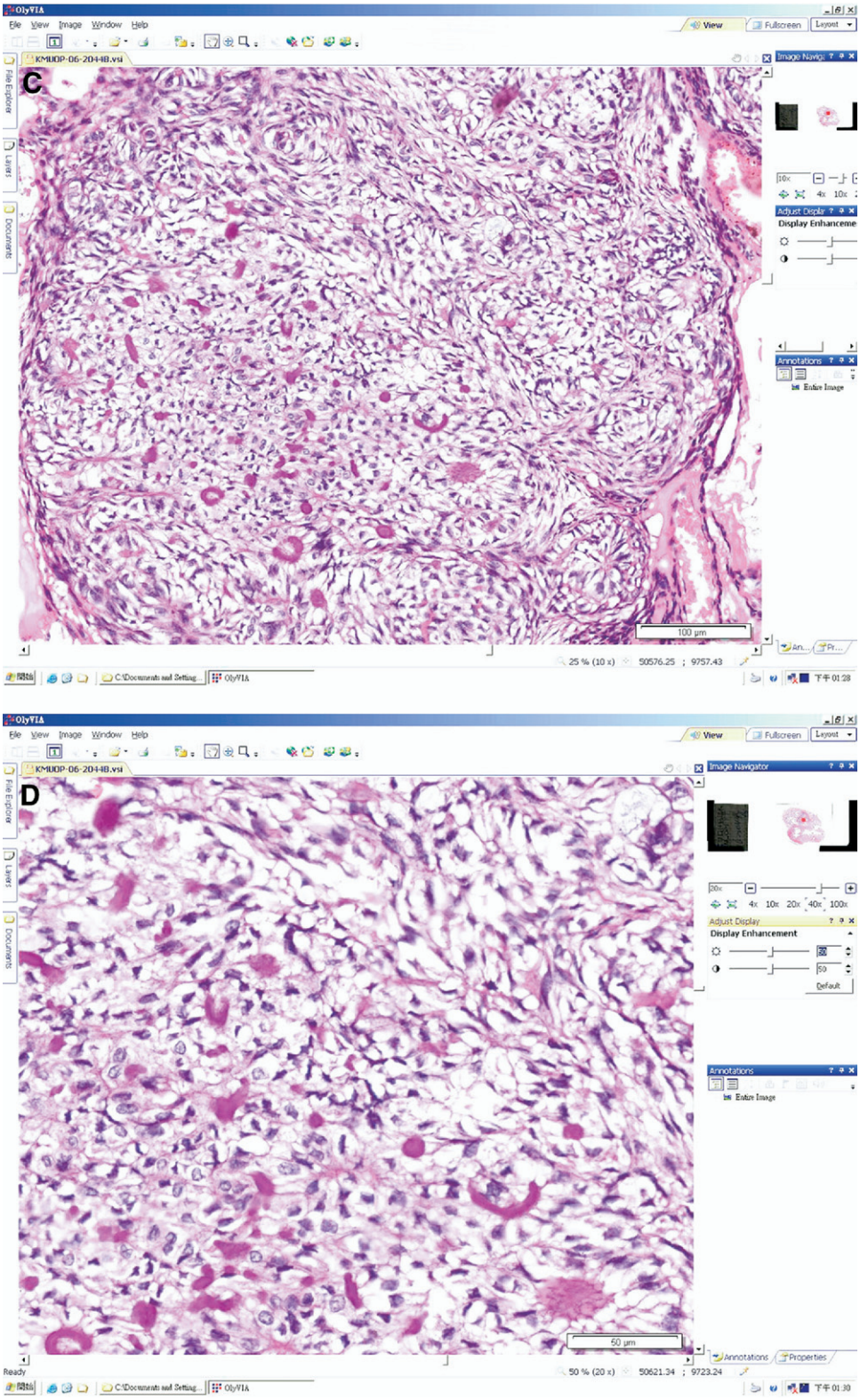

Fig. 2. Continued

Table I. Ratings of attributes of virtual microscopy (N = 80)*

Attributes of virtual microscopy	*Mean*	*SD*
Quality of the digital microscopic images	4.4	0.69
Ease of navigation of the system	4.1	0.87
Image histological description by DVD	4.1	0.88
Overall satisfaction with the course	4.0	0.81

*Based on a scale of 1 to 5: 1, not at all useful; 5, very useful.

Table II. Ratings of student perceptions of virtual microscopy (N = 80)*

Criteria for student perceptions	*Mean*	*SD*
I enjoyed learning via the online virtual microscope system	3.4	0.79
This system was effective in teaching the given content	3.3	0.77
I prefer the virtual microscope to a real microscope	3.1	0.68

*Based on a scale of 1 to 4: 1, strongly disagree; 4, strongly agree.

not useful at all; 5, very useful); the results are shown in Table I. The second category contained questions related to students' perceptions of the overall cognitive effectiveness of the virtual laboratory course, by using a scale of 1 to 4 (1, strongly disagree; 4, strongly agree); the results are given in Table II. Table I shows that students rated all aspects of Web-based study to be highly useful; Table II indicates that student satisfaction with the virtual laboratory was also high, showing the students favored virtual microscopy more than traditional optical microscopy. Therefore, it was found that students appeared to enjoy Web-based study, and virtual microscopy has significant advantages over real microscopy in oral and maxillofacial pathological education; it enables learning and has been favorably received by the students.

DISCUSSION

Telepathology is the use of a telecommunications technique to transmit pathological images between remote sites for various purposes, such as diagnosis and teaching.[2,3] There are 3 types of telepathology systems: static image systems, real-time systems, and virtual microscopy systems. The static image system has the obvious drawback of only being able to provide selected microscopic pictures at selected magnification, whereas the latter 2 systems can evaluate the entire microscopic slide and navigate to any field of view at magnifications comparable to those of a conventional microscope. With a real-time system, the user can actively maneuver a robotic microscope located at a distant site, whereas the virtual microscope system employs an automated scanner to take virtual images of the entire tissue sections, which can then be transferred to another location such as a Web site, as described in the aforementioned Material and Methods section.[4] As we are more familiar with virtual microscopy systems, we chose to develop a digital oral and maxillofacial pathology laboratory by using a virtual microscopy system and telepathology.

To our knowledge, the application of telepathology has seldom been described in the teaching of oral and maxillofacial pathology in dental schools (only in an abstract published in this journal),[5] as we discovered after reviewing existing English language medical literature. It has, though, already been applied in histological teaching in some medical schools.[6-8] Evaluation by questionnaire of all these studies[6-8] indicated that virtual slides enhanced student interest in learning microscopic histology/pathology over the traditional optic microscope. Our results also showed that students rated all aspects of Web-based study as highly useful. In addition, student satisfaction with the virtual laboratory was high, showing that the students liked virtual microscopy more than optical microscopy. Consequently, we can conclude that the students appeared to enjoy Web-based study, and virtual microscopy has significant advantages over real microscopy in oral and maxillofacial pathological education; it enables learning and has been favorably received by the students. Furthermore, in 2004 Kumar et al.[8] reported on the use of virtual microscopy for learning and assessment in medical pathology. They found that student examination scores for questions on the case for which a virtual slide was used were indistinguishable from those for the comparable case for which a traditional glass slide was used.[8] Surely, further studies will be required to evaluate whether the use of virtual microscopy will improve student test scores and clinical performance in oral and maxillofacial pathology.

A number of merits have been noticed after implementing the concept of virtual microscopy in the teaching of our oral and maxillofacial pathology laboratory course 2 years ago. The students do not need to rent or buy expensive optical microscopes because the virtual pathology system, incorporating image processing software tools, mimics the use of a conventional microscope in both the stepwise increase in magnification and in the lateral motion in the directions of the x- and y-axes. The students can now view, manipulate, and position the high-quality microscopic image on a monitor as if they were using a regular microscope to observe the original glass slide. Furthermore, we prefer the students to view the microscopic images without supplementary text or annotations marked on the slides in order to assess the their histopathology skills—although, with the use of the image processing software

tools, the virtual slides can be supplemented with textual descriptions or other annotations if desired. Importantly, the glass slides are now available in digital format on a Web site, overcoming time and physical constraints and enabling viewing of the image at any time and any place with broadband internet available.

Although there are a number of merits to using the virtual microscopy system, some drawbacks have also been noted. The scanning of virtual slides can be a time-consuming procedure, ranging from approximately 30 minutes to 2 hours to accurately scan a single glass slide, depending on the area of the tissue section to be scanned. Moreover, the large data size of the virtual slides indicates that a large data storage space is needed, as well as adequate archival and backup systems. However, recent developments in virtual slide systems have resulted in a large decrease in the time needed for scanning a single slide, and also an automated slide feeding facility has been developed in conjunction with these systems to allow batch slide scanning of a number of slides without the user having to manually feed a single slide at a time onto the stage (www.soft-imaging.net; www.dotslide.net). In the future, it is expected that technological advances will result in smaller file sizes, and thus, smaller data storage space will be required.

As described in this article, virtual microscopy has noteworthy advantages over real microscopy in pathology education, and has been noted by other authors.[9] Indeed, this telepathology system would also apply to other areas of pathological service, for instance, intraoperative frozen sections, routine surgical pathology, and subspecialty consultation.[10-15] As the production of virtual microscopic slides remains a time-consuming task and the cost of archiving the images digitally is still considerably higher than archiving on glass slides, the use of virtual microscopy for routine diagnostics is not yet routinely implemented. With the next generation of more rapid and easy-use virtual slide systems, a dramatic alteration in potential usage of telepathology is promised. Consequently, one could imagine that, in the future, glass slides will be archived directly following digitization, and the work of diagnosis, teaching, and research will be performed using the virtual microscopy system. Then, perhaps, microscopic virtual images may one day be incorporated into digital databases for clinical diagnosis, adding the histological images as part of medical digital charts of patients, as is currently the case for images of computerized tomography, magnetic resonance imaging, or sonography acquired from other existing imaging modalities.[16]

REFERENCES

1. Leong FJW-M, Graham AK, Gahm G, McGee JOD. Telepathology clinical utility and methodology. In: Lowe DG, Underwoord JCE, editors. Recent advances in histopathology. 18th ed. London: Churchill Livingstone; 1999. p. 217-40.
2. Wenstein RS. Prospects for telepathology. Hum Pathol 1986;17:433-4.
3. Wenstein RS, Bloom KJ, Rozek LS. Telepathology. Longdistance diagnosis. Am J Clin Pathol 1989;91:S39-42.
4. Weinberg DS, Allaert FA, Dusserre P. Telepathology diagnosis by means of still digital imagines: an international validation study. Hum Pathol 1996;27:111-8.
5. D Silva NJ, Hanks CT, Andrews B. Internet- and DVD-based instruction in oral pathology for dental students. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;98:195.
6. Marchevsky AM, Relan A, Baillie S. Self-instructional "virtual pathology" laboratories using web-based technology enhance medical school teaching of pathology. Hum Pathol 2003;34:423-9.
7. Blake CA, Lavoie HA, Millette CF. Teaching medical histology at the University of South Carolina School of Medicine: transition to virtual slides an virtual microscopes. Anat Rec B New Anat 2003;275:196-206.
8. Kumar RK, Velan GM, Korell SO, Kandara M, Dee FR, Wakefield D. Virtual microscopy for learning and assessment in pathology. J Pathol 2004;204:613-8.
9. Lundin M, Lundin J, Helin H, Isola J. A digital atlas of breast histopathology: an application of web based virtual microscopy. J Clin Pathol 2004;57:1288-91.
10. Petersen I, Wolf G, Roth K, Schluns K. Telepathology by the Internet. J Pathol 2000;191:8-14.
11. Brauchli K, Christen H, Haroske G, Meyer W, Kunze KD, Oberholzer M. Telemicroscopy by the Internet revisited. J Pathol 2002;196:238-43.
12. Wells CA, Sowter C. Telepathology: a diagnostic tool for the millennium? J Pathol 2002;196:351-5.
13. Taylor RN, Gagnon M, Lange J, Lee T, Draut R, Kujawski E. CytoView. A prototype computer image-based Papanicolaou smear proficiency test. Acta Cytol 1999;43:1045-51.
14. Barbareschi M, Demichelis F, Forti S, Dalla Palma P. Digital pathology: science fiction. Int J Surg Pathol 2000;8:261-3.
15. Teodorovic I, Isabelle M, Carboneb A, Passioukov A, Lejeune S, Jamine D, et al. TuBaFrost 6: virtual microscopy in virtual tumor banking. Eur J Cancer 2006;42:3110-6.
16. Kayser K, Kayser G, Radziszowski D, Oehmann A. New developments in digital pathology: from telepathology to virtual pathology laboratory. Stud Health Technol Inform 2004;105:61-9.

Reprint requests:

Li-Min Lin, DDS, MS, PhD
Department of Oral Pathology
School of Dentistry
Kaohsiung Medical University
100, Shih-Chuan 1st Road
Kaohsiung, Taiwan
k0285@ms22.hinet.net