Original Research Article

Digital Microscopy Using Online Mapping Technology: A Solution for Oral Pathology Education in Virtual Learning

ABSTRACT

Objective: Our study aimed to develop a database containing high-quality digital oral and maxillofacial pathology (OMFP) slides without the high cost of whole slide imaging (WSI) for students and educators in low-income countries.

Methods and materials: First, general expectations and criteria of the software were determined by asking the OMFP specialists and students during focus group meetings. Then, we generated a digital OMFP slides database available in different angles and magnifications. Next, with assistance from programmers, the offline software was linked to the database and piloted to evaluate the software faults. Users were also asked to assess the software and the evaluation continued until reaching the desired outcome. Finally, the updated version was presented to 27 dental students (third- and fourth-year) during their clinical pathology course. Students' opinion toward the database was then evaluated using a standard questionnaire. Students' scores were also compared to that of the last semester.

Results: Our findings showed that most students found the digital pathology software helpful, easy to use, reliable, well-organized, consistent, inclusive, and helpful. Overall, the participants regarded the experience as satisfactory. There was no significant difference between the students' exam scores compared with the population average.

Conclusion: According to our results, digital pathology slides can improve oral pathology education and help dental students and professors in clinical and practical learning.

Keywords: digital microscopy; telepathology; virtual slides; oral pathology; dental education;

INTRODUCTION

As technology is growing every day, it becomes more integrated into different fields of science and oral pathology is not an exception. Accurate diagnosis is crucial in pathology and the "gold standard" device of diagnosis has been the light microscope since the 19th century. Diagnostic radiology has gone digital for a decade or so, yet pathology is still dependent on glass slides. It is about time for pathology to join the multitude of scientific disciplines transformed by technology.[1-3]

The emergence of virtual/digital slides has not only affected the diagnostic procedure but also made an impact on international conferences, research, and education.[4] The use of digital images for remote pathological diagnosis, consultation, and education is called "telepathology".[5] Furthermore, whole slide imaging (WSI) facilitates sharing, recording, and viewing high-resolution digital slides for researchers, clinicians, educators, and students. Simply put, WSI prepared the ground for the shift from glass slides to digital ones in pathology.[2]

In modern dentistry, digital and virtual techniques have been utilized for different purposes, from digital records to real situations. Almost every field of dentistry has been influenced by digitization such as digital models in orthodontics and maxillofacial surgery, 3D constructions using CBCT (Cone Beam Computed Tomography) in endodontics, CAD-CAM (computer-aided design and computer-aided manufacturing) in prosthodontics or for other dental devices, oral radiography, and pathology.[6-10]

Although different dental fields have embraced the value of digitization, oral pathology has experienced digital blending rather recently and only to a limit.[11]

Application of digital slides and WSI in oral pathology can diminish the disadvantages of challenges that come with glass slides, such as geographical barriers, storage, transport issues, and reliance on a physical microscope. Digital slides are more time-efficient compared to traditional ones and they do not require multiple tissue recuts. They also keep a permanent record that can be shared anytime and anywhere.[11] In addition, AI (artificial intelligence) can be used in the digital imaging system for different tasks, e.g., cancer screening.[12]

On the other hand, WSI and digital slides are faced with some challenges, e.g., the cost of high-quality imaging, ergonomics and occupational health (musculoskeletal and visual), and image quality issues. [11-13]

In education, digital pathology can also facilitate learning and affect the learning experience. Students can use digital slides for self-evaluation without the limitations of time and place, which can come in handy now due to the rising importance of e-learning and virtual education during the COVID-19 pandemic. Nevertheless, it is essential to consider the challenges along the way to digitization, i.e., technological infrastructure and its costs, the novelty of the technique, unfamiliarity and adaptation problems, format differences, and limited research, especially in the field of oral pathology.[11,12,14-16] Last but not least, digital slides are in great need of proper regulations.[17]

The resources for WSI implementation are not available to everyone in low-income countries. Therefore, many students are denied access to these laboratories and virtual experiences. Using a virtual microscope database may solve this problem to some extent.

Therefore, our goal was to develop a free digital database of oral and maxillofacial slides for students and educators.

METHODS

Study sample

This study was performed among dental students of Mashhad University of Medical Sciences (MUMS) during the academic year 2016-2017.

Study design

1) Planning (feasibility)

In the beginning, specialists and students of oral and maxillofacial pathology (OMFP) were asked for general requirements and their expectations of the software. Data were collected during focus group meetings, and the scope of software development and production was then identified and analyzed.

2) Creating the database

A database of digital OMFP slides was created from all angles and with different magnifications. The data obtained in the previous stage was also taken into consideration.

3) Initial implementation and software testing

In this phase, with the help of programming experts, the offline map was coded and linked to the database. The software was then piloted to identify existing defects and determine users' expectations. The process continued until the desired result was achieved.

4) Final application

After eliminating the defects and meeting the users' expectations, the software was approved for final use and presented to 27 dental students (third- and fourth-year) who had a clinical pathology course.

Software development

In this study, we aimed to establish a digital database of OMFP slides. To do so, we used proper tools and coding to design the *MegaNama* software where digital images of oral and maxillofacial lesions are provided in the form of an interactive map with features such as multiple filters, different magnifications, and an image comparison option for studying cell morphology and diagnosis. These features can facilitate tissue examination and reduce training costs. The software can be used as a suitable alternative to histopathology examination by light microscopy when needed.

This platform allows users to share (upload and download) histological images free of charge and available to educators and students. Figure 1 shows the software environment.

Data collection

To evaluate the students' opinions toward the software, we used a valid and reliable questionnaire (Likert scale). The survey was done after each participant viewed 17 magnified images.

Statistical evaluation

The data collected from the questionnaires and students' test scores were analyzed using the software IBM SPSS Statistics V23.0. and with the help of the appropriate statistical tests (chi-squared test and one-sample t-test). The significance level was considered 0.05.

RESULTS

In this study, an 18-item questionnaire was given to 30 dental students in the third and fourth year of dental school. A total of 27 students, including 13 females and 14 males with a mean age of 22 years, participated in this study. The chi-squared test results showed no statistically significant relationship between gender and student response (P> 0.05).

To assess the performance quality of the platform, we asked the students to fill out a questionnaire after viewing 17 magnified images. The results are demonstrated in Figure 2.

The results showed that 51% of students rated the overall performance of the software very good. Also, none of the respondents reported this item as bad or very bad. Overall, 58% of students rated the software as easy and very easy to use. Regarding the software user experience (UX), 82% of students rated the software as satisfactory and very satisfactory, while none of the participants reported unsatisfactory or very unsatisfactory results.

According to the results, 75% of students described the software as motivating and very motivating to learn, and 72% of students viewed the software as flexible and very flexible. Concerning character readability, 86% of students rated the software characters as easy and very easy to read.

Only 3.4% of students deemed the software information organization confusing, whereas other participants (96.6%) considered it to be clear on some level. Of all the respondents, 82% rated the page sequence as clear and very clear, and 3% reported it as difficult. The results depicted that 82% of the students evaluated the status of the software terminology as consistent and very consistent and no one stated any inconsistency.

Among users, 96% found the software terminology relevant and tangible with no report of it to be intangible and 86% evaluated the placement of the messages as consistent, and only 7% of respondents reported some inconsistency. As for the clarity of the input prompts, 86% of students rated the software as clear and very clear with no confusion report.

Overall, 66% of the users rated the software warnings as helpful and very helpful and none of them reported that the software warnings were unhelpful. In general, 86% of students found the software instructions easy and very easy. The results also revealed that 75% of the participants evaluated the software task performance as straightforward.

According to the findings, 72% of students found the system's loading speed good and very good, and only 6% reported that sometimes the execution was slow. While 75% considered the software reliable and very reliable, no one rated it as unreliable. Finally, 82% of participants regarded the software as inclusive and very inclusive, designed for different user levels.

At the end of the practical pathology course, students' exam scores were obtained and compared with the known average of the population (dental students of previous years – historical control group) using the one-sample t-test ($P > 0.05$).

In this study, the mean age of the students was not significantly different from the population (dental school students in the same degree and semester) ($P > 0.05$).

According to the study results, the gender ratio of students was not significantly different from the population ($P > 0.05$).

DISCUSSION

As mentioned above, whole-slide images are widely used in microscope-dependent fields for educational and diagnostic purposes.[15] Meanwhile, the production and presentation of these images require appropriate systems and infrastructure. In this project, inspired by Google Maps, we decided to find a way to produce high-quality, digital pathology slides for educational use.

Digital microscopy and pathology are considered a recent revelation; thus, there is not enough research around the subject, especially with regard to oral pathology.

In 2015, Fonseca et al. [18] assessed students' compliance with the new digital pathology laboratory in a Brazilian dental school. They asked students' opinions on digital vs. conventional slides and digital laboratory software as well. According to their findings, dental students found the software easier to use, more motivating, and more efficient compared to conventional microscopy. Mainly, we focused on the platform itself rather than a comparison of the techniques, which was. However, our results also showed that students considered our platform reliable, consistent, motivating, and easy to use.

We also obtained students' exam results and compared them with previous years. The results were not statistically significant, which can be translated into the efficiency of the platform without the disadvantages of physical slides and microscope such as storage, transportation, and maintenance, which is not in compliance with the results of [18], where students claimed that the software had improved their learning.

In another study in 2011, Szymas et al. [19] evaluated a web-based virtual pathology software, WebMicroscope, over a period of 5 years. Both systemic and oral pathology

microscopy were analyzed during the course of their study. The students generally had a positive attitude toward the software, which further improved after five years. Although the study was long-term, they did not evaluate the quantitative results of the software (students' test scores).

Vosough Hosseini et al. [20] compared students' practical pathology test results between two groups (one group using conventional microscopy and another using an additional digital image software as an educational aid) in a 2014 study. Their results were not statistically significant, which complies with our findings.

Another virtual pathology laboratory was developed by Chen et al. [21] in 2007 for teaching OMFP. They assessed students' perceptions and overall opinions about the software with the help of a questionnaire. Overall, students found the software highly satisfactory and effective, which is in compliance with our results. Additionally, research shows that students prefer virtual microscopy and find it more interesting than physical laboratories.[18,22-24] Although our findings did not show any difference in the exam scores, digital pathology may make the experience more fun.

Furthermore, dental students stated that digital microscopy is easy to use for oral pathology and histology learning.[21-23,25-27] However, in some studies, students claimed that digital microscopy might not be able to replace the conventional methods,[18,28] whereas, in others, they encouraged the expansion of virtual pathology to take the place of physical microscopy.[24] Students also deemed the digital pathology platforms to be more dynamic and flexible. [22-24,29]

In our study, participants found the digital pathology software motivating, dynamic, relevant, inclusive of different levels, and consistent, with simple instructions and annotations. They also perceived the overall experience as satisfactory without any negative ratings.

The students were the most satisfied with the consistency of the system's terminology and readability of characters on screen, whereas the inclusivity for all levels of users was found the least satisfactory feature of all (with 11% finding it not designed for all levels). This can be explained by the platform being focused on higher education. Previous studies mentioned earlier mostly confirm our results; however, further research is still required.

Overall, digital pathology can be as practical as conventional microscopy in OMFP education without the limitations of physical slides and light microscopes. Digital microscopy helps break the barriers of location and time, and offers better access for students and educators worldwide. It does not need colossal storage units or transport costs. Without the need for multiple recuts, tissue is preserved, and high-quality images can be shared repeatedly without losing any quality. It can facilitate research, education, diagnosis, consultation, and general workflow.[11] In addition, it is important to consider that students found it more enjoyable and fun to work with digital microscopy. [22,25] This technique can help students test and master the skill of microscopic examination repeatedly in the comfort of their own home, which is particularly valuable in the current COVID-19 pandemic.[16] However, the method is relatively new, expensive, and still progressing. In the present study, our goal was to find a more cost-efficient technique to provide dental students with high quality digital slides free of cost. Therefore, it seems crucial to further evaluate and develop this technique in a more economical way.

CONCLUSION

This study demonstrated that digital microscopy and virtual slides in pathology are a significant improvement in education, leading to better satisfaction and learning of students. Therefore, it is an appropriate development in clinical and practical education in dentistry.

LIMITATIONS

In this project, we faced a number of challenges, such as collecting images and software design. Considering that there was no access to whole-slide scanners, we had to connect more than 40 small images to produce a high-quality image of a complete slide. This was very difficult and time-consuming.

Also, the shortage of budget was another obstacle. Students were least satisfied with the guides and notifications on the platform. Due to the current software's funding limitations, we hope to improve this feature in the next upgrades.

Furthermore, high magnification at a sufficient rate was challenging due to the bandwidth and internet access limitations. To solve this issue, we divided each image into multiple small images. Learners were then able to access high-quality images quickly and efficiently.

FURTHER RESEARCH

It is suggested that this software be used in various disciplines such as microbiology, mycology, parasitology, histology, and other microscope-dependent fields along with pathology to educate students globally.

Surely, appropriate software development for sharing, producing, and manipulating digital slides is deemed necessary and needs additional research.

Ethical Approval and Consent

In this study, all information was considered confidential and all sensitive and personal data has been kept private. All participants received a thorough explanation of the study design

beforehand and signed the informed consent form. The research protocol was approved by the Ethics Committee of Mashhad University of Medical Sciences with the registry code: IR.MUMS.REC.1397.004.

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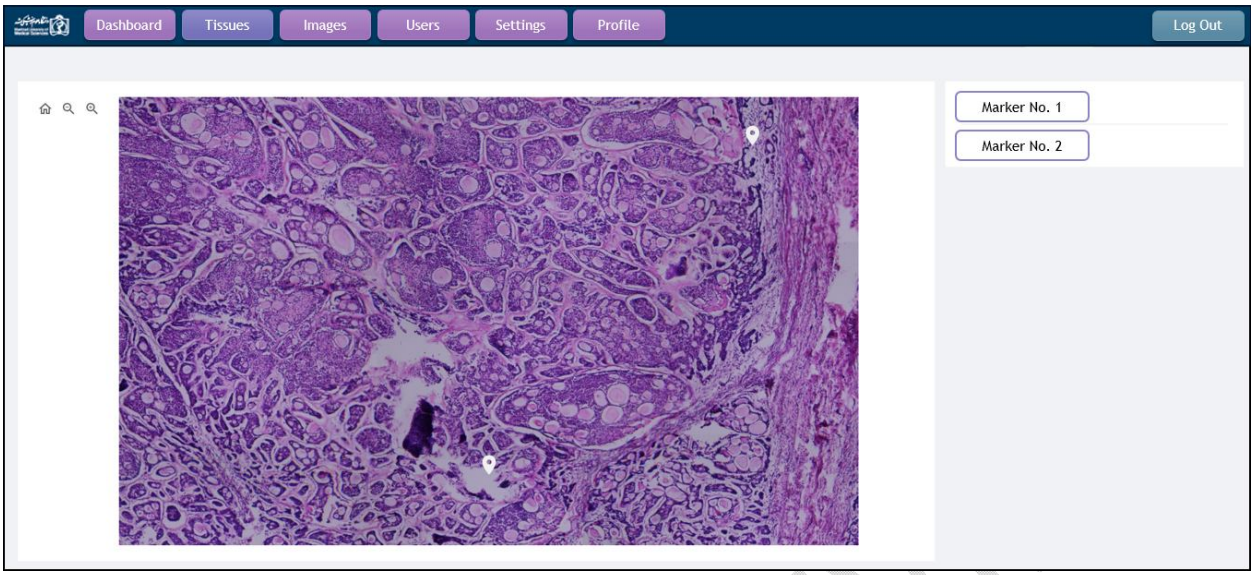

Figure 1 MegaNama Software Environment.

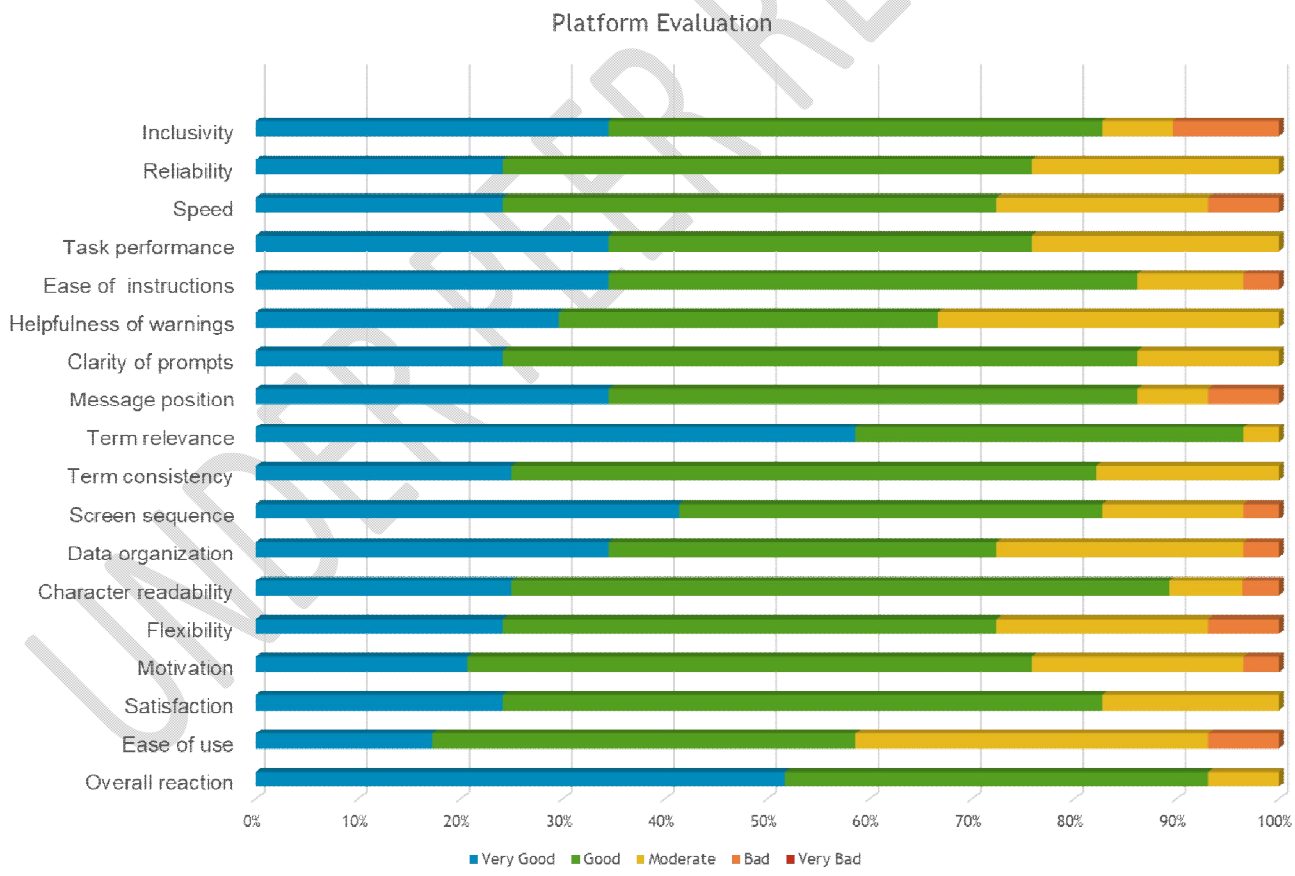

Figure 2 The bar chart shows the overall results of the Questionnaire for User Interface Satisfaction (QUIS) evaluating the digital pathology platform.