Revista Española
De Educación Médica

UNIVERSIDAD DE MURCIA

Use of Virtual Microscopy in the Teaching-Learning of Oral Pathology. Levels of Learning Achieved in Postgraduate Courses.

Uso de Microscopía Virtual en la Enseñanza- Aprendizaje de Anatomía Patológica Bucal. Niveles de Aprendizajes Logrados en Cursos de Posgrado.

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Submitted: 10/29/24; Accepted: 11/19/24; Published: 11/21/24

Abstract: Virtual Microscopy (VM) is a technological tool that uses the digitalization of microscopic preparations to produce high-quality virtual images and videos, emulating a conventional microscope (CM). The objective of the present study was to evaluate the ability to recognize normal histological structures, basic histopathological lesions, microscopic descriptions configuring an entity and the diagnosis of entities. Using VM in 2 postgraduate courses with b-learning modality, using the Moodle platform as a virtual learning environment (VLE). The learning levels achieved in two postgraduate courses on "Oral Mucosal Pathology and Jaw Pathology" taught to 30 general dentists were evaluated. VM was incorporated live and in videos obtained from virtual preparations. The students received clinical-pathological information on all cases during the course. The final evaluation was carried out on two cases, the following items were observed and categorized: A) Recognition of Normal Histological Structures (NHS). B) Recognition of Basic Histopathological Lesions (BHL). C) Description of Microscopic Pictures (DCM) and D) Diagnosis of Entities (Dx E). 80% (n=24) of the participants were able to recognize BHL and 20 % (n=6) with a Level of 3. Regarding the DCM, 76.6% (n=23) described correctly; (n=25) with a Level 4. Conclusion: The implementation of the MV improves learning in the recognition of BHL, BHL, DCM and Dx E. The detailed evaluation allows to infer that the most complex skill: Dx E, achieved a high percentage of students with the highest Level. It reinforces the concept that teaching from less to greater complexity is effective. The MV is an ideal tool for the teaching-learning process of topics in Oral Pathology, as occurred in our educational experience.

Keywords: Virtual microscopy, virtual environments, pathological anatomy.

Resumen: La Microscopía Virtual (MV) es una herramienta tecnológica que utiliza la digitalización de preparados microscópicos para producir imágenes y videos virtuales de alta calidad, emulando un microscopio convencional (MC). El objetivo del presente estudio fue evaluar la capacidad de reconocimiento de estructuras histológicas normales, lesiones histopatológicas básicas, descripciones microscópicas configurando una entidad y el diagnóstico de entidades. Utilizando la MV en 2 cursos de posgrado con modalidad b-learning, utilizando la plataforma Moodle como entorno virtual de aprendizaje (EVA). Se evaluaron los niveles de aprendizaje alcanzados en dos cursos de posgrado de "Patología de la mucosa bucal y Patología de los Maxilares" dictado a 30 Odontólogos generalistas. Se incorporó la MV en vivo y en videos obtenidos a partir de preparados virtuales. Los alumnos recibieron la información clínico-patológica de todos los casos durante el cursado. La evaluación final se realizó sobre dos casos, se observaron y categorizaron los siguientes ítems: A) Reconocimiento de Estructuras Histológicas Normales (EHN). B) Reconocimiento de Lesiones Histopatológicas Básicas (LHB). C) Descripción de Cuadros Microscópicos (DCM) y D)

Diagnóstico de Entidades (Dx E). El 80% (n=24) de los participantes fueron capaces de reconocer EHB y 20 % (n=6) con Nivel de 3. En relación a la DCM el 76,6% (n=23) describió correctamente; (n=25) con un Nivel 4. Conclusión: La implementación de la MV mejora el aprendizaje en el reconocimiento de EHN, LHB. DCM y Dx E. La evaluación pormenorizada permite inferir que la habilidad más compleja: Dx E, logró un alto porcentaje de cursantes con el máximo Nivel. Refuerza el concepto de que la enseñanza de menor a mayor complejidad es efectiva. La MV es una herramienta ideal para el proceso de enseñanza aprendizaje de temas de Anatomía Patológica Bucal, como lo ocurrido en nuestra experiencia educativa.

Palabras clave: Microscopía virtual, entornos virtuales, anatomía patológica.

1. Introduction

Education in Pathological Anatomy (PA) plays an important role in the training of health professionals, allowing a deep understanding of diseases and their manifestations at macroscopic and microscopic levels. Traditionally, the teaching of this discipline has depended on the use of specimens macroscopic and the use of histological preparations observed in transmitted light optical microscopes. However, with technological advances, virtual microscopy (VM) has emerged as an innovative alternative.

The digitalization of complete histopathological preparations, also known as Digital Pathology (DP) or Whole Slide Imaging (WSI), has represented a significant advance in the specialty of Pathological Anatomy at undergraduate and postgraduate level, allowing not only to transfer the histopathological image to the computer screen, but also to share it with remote users and analyze it from a new perspective. According to Sagun, 2018, the application of PD in the educational field has opened new and wide possibilities for the transmission of knowledge between pathologists and students (1). The development of software that emulates the operation of a microscope promoted the emergence of VM, putting technology not only at the service of PD, but also in a valuable teaching application tool for the teaching and evaluation of practical content at a distance (2).

Foster considers WSI as a powerful teaching and learning tool for both histology and pathology (3). With recent advances in VM and broadband Internet connectivity, it is now feasible to digitize images from the microscope and place them on a server available online through a website (4) or upload them to a virtual classroom. VM is a technological tool that uses the digitization of microscope slides through a computer to produce high-quality virtual images and videos, emulating a conventional microscope (CM). VM presents advantages over conventional microscopy (5-6). Blake et al (2003) consider that image digitization promotes self-learning and is more cost-effective compared to the maintenance of optical microscopes and collections of histological slides (7). The rapid advance in educational computing, added to the use of high-resolution photographic or video cameras coupled to the microscope, together with the development and improvement of programs for the capture, editing and analysis of images, have allowed the digitization of histological slides (8). However, experience with this technology is still limited and there is little evidence of its effectiveness in these contexts. In postgraduate pathology courses, where students already have a knowledge base, the use of VM can further enhance the teaching and learning process by facilitating detailed exploration of complex and varied clinical cases.

When addressing the effectiveness of using VM in teaching pathological anatomy, it is essential to consider the different levels of learning that can be achieved by students. Establish a hierarchy of cognitive levels ranging from the recognition of normal histological structures, followed by the recognition of basic histopathological lesions (BHL), then the elaboration of a description of BHL by configuring a microscopic picture, until achieving greater complexity by elaborating a diagnosis of an entity. That is, learning from less to greater complexity.

In this study, we present the experience of postgraduate dental students attending a theoretical-practical course on Oral Mucosal Pathology and Jaw Pathology using b-learning modality. The objective was to evaluate the students' ability to recognize Normal Histological Structures (NHS) and Basic Histopathological Lesions (BHL), integrate knowledge at a descriptive level in microscopic pictures (DCM), and reach the maximum level of competence through the diagnosis of entities (DxE), using virtual microscopy (VM) in a virtual learning environment (VLE). The implementation of virtual microscopy (VM) in a virtual learning environment (VLE) in postgraduate courses is an effective tool for the teaching-learning process in Oral Pathological Anatomy, contributing to the development of descriptive and diagnostic skills in pathology through the analysis of virtual microscopic preparations.

2. Methods

The learning levels achieved in two theoretical-practical postgraduate courses with b-learning modality were evaluated, in which 30 dentists participated. The courses, designed on Pathology of the Oral Mucosa and Pathology of the Jaws, were held at the Círculo Odontológico Santiagueño and at the Faculty of Dentistry of the National University of Tucumán (UNT), respectively. The course on Pathology of the Oral Mucosa was attended by 13 dentists, while the course on Pathology of the Jaws (Odontogenic Cysts and Tumors) was attended by 17 dentists belonging to the Surgery Degree of the Faculty of Dentistry of the UNT.

Both courses were designed using the Moodle educational platform, implemented by the National University of Tucumán. The platform provides access to all relevant course information and course activities. Virtual resources were incorporated through videos, created from virtual preparations and in vivo MV. The course was developed with theoretical classes, case seminars and with live MV, with MV videos available in the platform's classroom . In all case seminars used in the course sessions, students received relevant clinical information.

The practical final assessment was carried out using virtual microscopy (VM). Each student was assigned two randomly selected cases on specific topics, extracted from the digital repository English : https://www.virtualpathology.leeds.ac.uk/ . An approximate time of 20 minutes was established for the assessment of each case, considering it sufficient for students to be able to recognize normal structures, identify alterations, describe the lesions and reach a diagnosis. The selected cases included lesions and tumors representative of the topics covered in each course. In the Oral Mucosa Pathology course, the following entities were considered representative for evaluation: Localized fibrous hyperplasia, Lichen planus, Pemphigus, Mild and moderate dysplasias, Carcinoma in situ, Squamous cell carcinoma grade I, II and III, and Ackerman verrucous carcinoma . In the Maxillary Pathology course, the following were considered: Radicular cysts, Dentigerous cyst, Bone fibrous dysplasia, Compound and complex odontoma, Ameloblastoma, Keratocystic odontogenic tumor, Adenomatoid odontogenic tumor and Myxoma.

The following questions were asked in both cases selected for each student: 1. Mention the normal histological structures that you recognize. 2. Mention the alterations that you observe in the histological preparation. 3. Describe the lesions that you observe. 4. Make a diagnosis based on what you observed. The evaluator (SC) performed the review of the histological preparation with different magnifications, as requested by the student and entered the answers to the aforementioned questions in an ad hoc form. The following recognition items were recorded in the form: A) Normal Histological Structures (EHN): Levels from 1 to 4 according to the number of structures recognized in the case. B) Basic Histopathological Lesions (LHB): Levels from 1 to 4, according to the number of structures recognized in the case. C) Description of Microscopic Pictures (DCM): Levels of 0, 2 or 4, 0 does not describe or insufficient description, 2 describes incompletely (50%) and 4 describes all the structures sufficient to configure an entity (100%) D) Diagnosis of Entities (Dx E): Level 0: does not diagnose, Level 4: diagnoses correctly. In case of diagnostic errors, diagnostic discrepancies could be analyzed, which would be minor discrepancies, such as not distinguishing a histopathological subtype and major discrepancies benign vs malignant tumors.

Discrepancy analysis was not performed in this study, because no discrepancies were found to justify it. As an example of the evaluation method used, the items evaluated are attached: EHN figure 1; LHB figure 2; DCM, figure 3 and Dx E, figure 4, using the repository of Slide Pathology of University of Leeds (9). The evaluation was carried out using the rubrics detailed in tables 1 and 2.

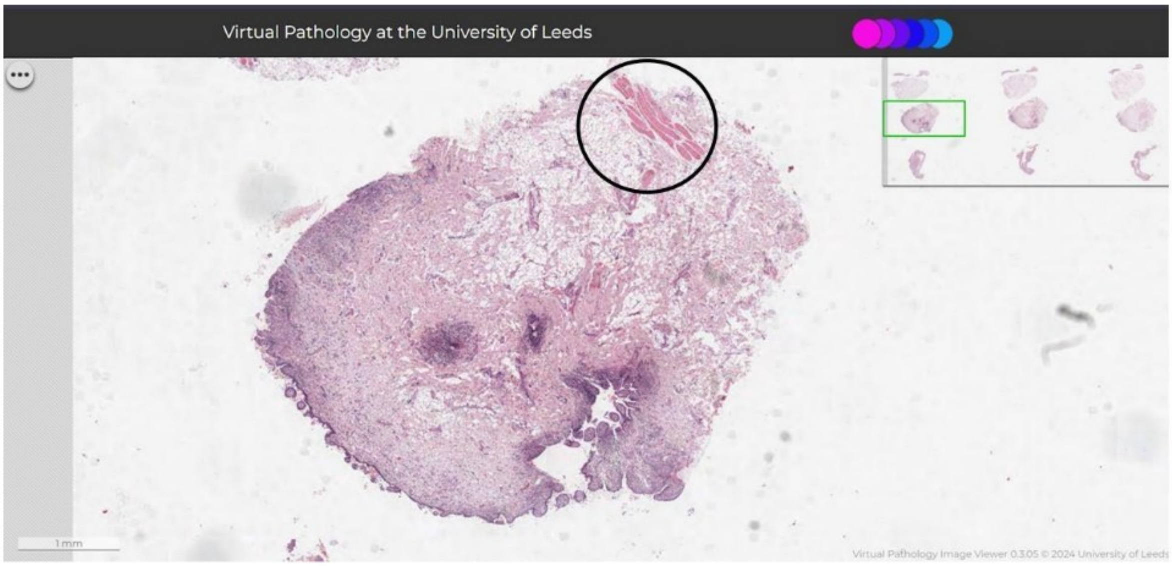

Figure 1a. EHN Recognition to lower magnification. Recognition of striated muscle tissue in the skin sample. (Source: Virtual Pathology at the University of Leeds).

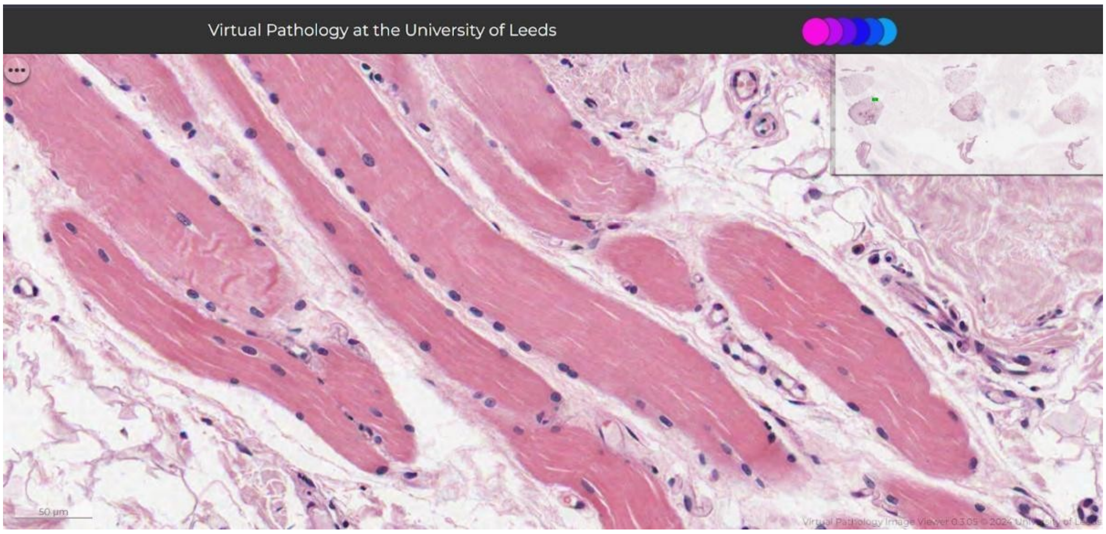

Figure 1b. Recognition of EHN at higher magnification (circle in Figure 1a); peripheral nuclei and transverse striations of skeletal muscle are observed. (Source: Virtual Pathology at the University of Leeds).

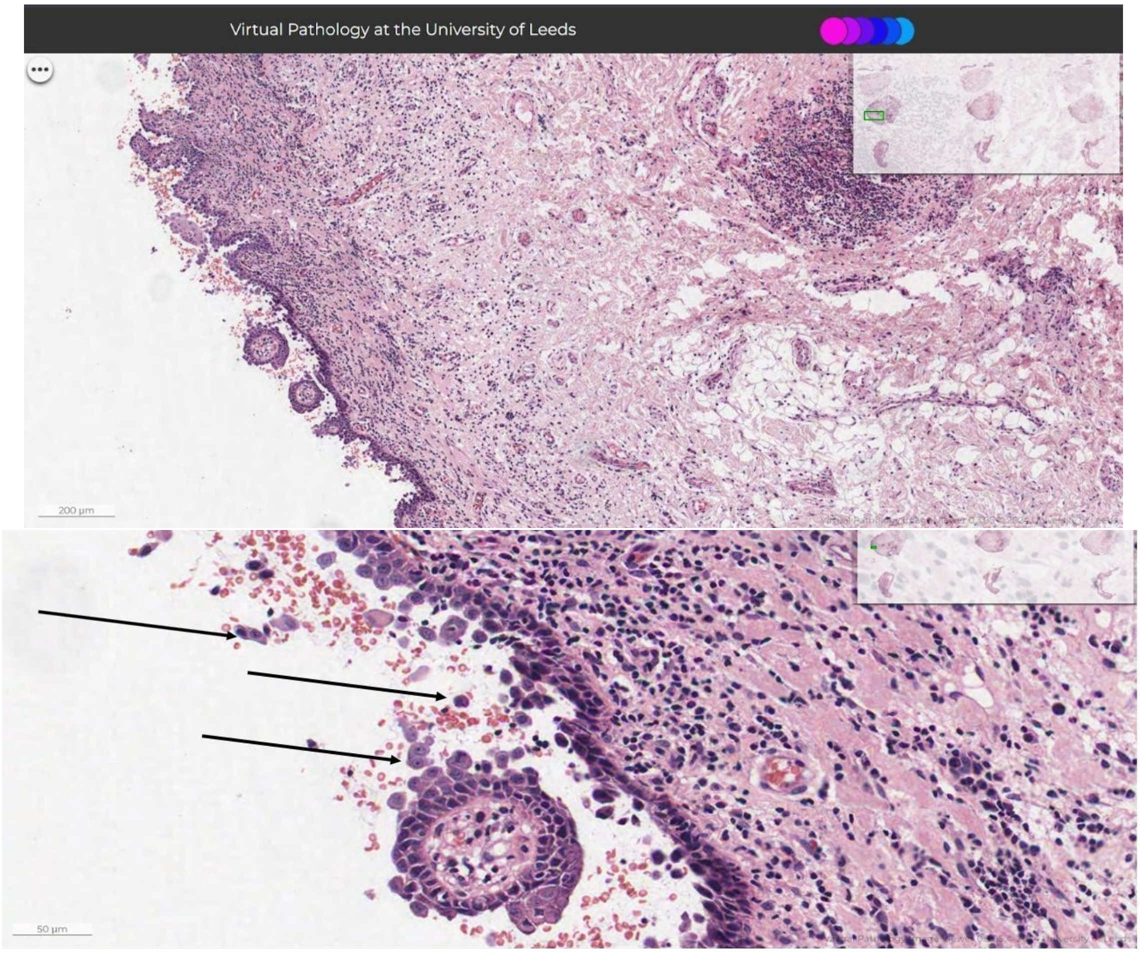

Figure 2. LHB recognition **:** At lower magnification (top) the persistence of the basal layer can be seen and at higher magnification (bottom) an LHB Acantholysis is observed, presence of loose cells detached from the epithelium, due to loss of intercellular junctions (black arrows). Source. Virtual Pathology at the University of Leeds.

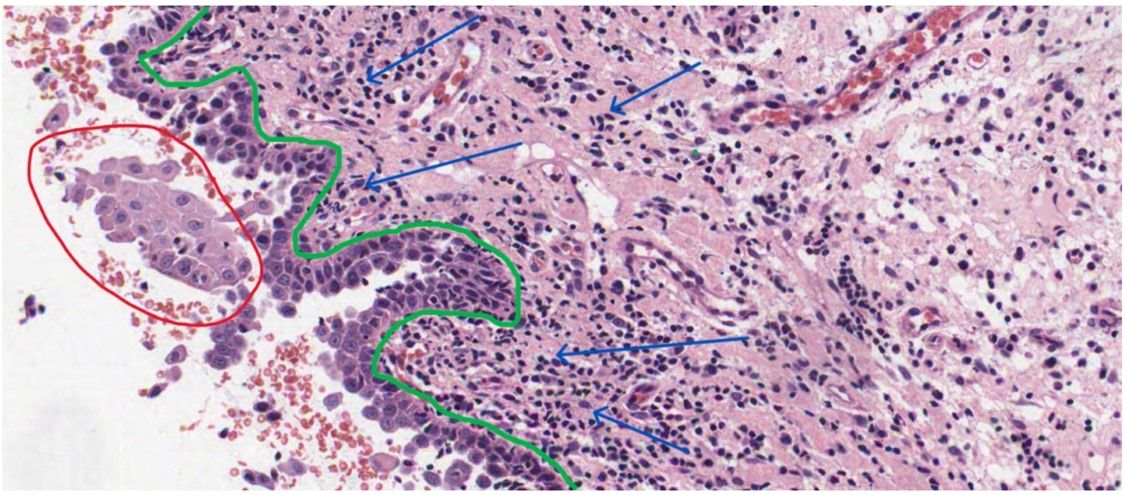

Figure 3. Microscopic picture description: Persistence of the basal layer attached to the lamina propria (green line). Acantholytic cells with intraepithelial blister formation (red circle). Chronic subepithelial inflammatory infiltrate (blue arrows). Source. Virtual Pathology at the University of Leeds.

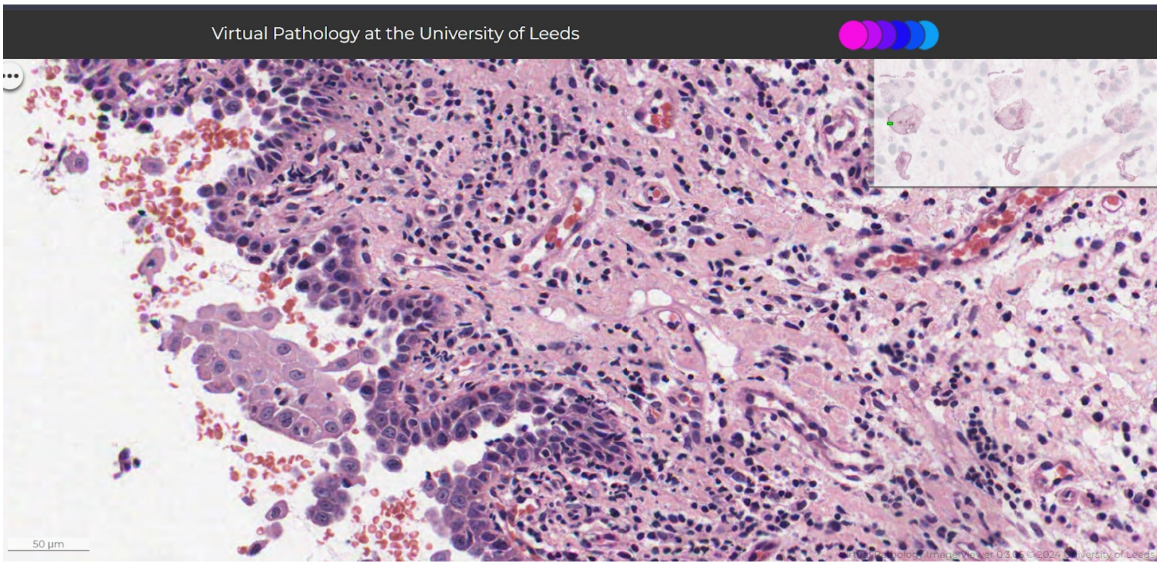

Figure 4. DxE: Pemphigus. Presence of intraepithelial acantholytic blisters with subepithelial lymphocytic infiltrate. Basal layer attached to the lamina propria. Source: http://bit.ly/3YYjJ6V

Table 1. Rubric for Evaluation of Recognition and Description of Histological Structures in Virtual Microscopy.

Virtual Microscopy	
Does not recognize Normal Histological Structures (EHN)	0
Recognizes Normal Histological Structures. Recognition of histological structures: Epithelium. Salivary glands: Type of secretion Ductal and acinar structures; Connective tissue, bone, muscle, cartilage. Adipose tissue, vessels, nerves; dental structures, dentin, cementum, pulp and periodontium.	1 2 3 4 (Level 1-4, according to the number of structures recognized in each case)
Recognizes Basic Histopathological Lesions (BHL) Epithelium: Elementary histological alterations: Hyperkeratosis, acanthosis, hyperplasia, metaplasia, etc. Connective tissue: Inflammatory infiltrate. Types. Exudate. Types. Hemorrhage. Pigments. Etc.	1 2 3 4 (Level 1-4, according to the number of LHBs in each case)
Description of microscopic pictures, configuring entity. (DCM) Eg. Inflammatory cyst: Non-keratinized stratified squamous epithelial lining. Connective tissue: inflammatory infiltrate, lymphoplasmacytic. multinucleated giant cells of foreign body type, cholesterol crystals. All components: 4 The essential components: 2 Does not describe the microscopic picture: 0	0 2 4 (Level 0/2/4) 0 does not describe, 2 (50%) and 4 (100%)
Diagnose entities. Eg: Inflammatory epithelial cyst.	0 4 (Level 0/4 non-diagnostic, diagnostic) in turn the Diagnostic Discrepancy can be analyzed, it was not analyzed in this sample (major discrepancy and minor discrepancy).

Table 2. Evaluation Rubric.

Virtual Microscopy (VM)	Learning Levels
It does not recognize normal histological structures.	0
Only recognizes normal histological structures. (Level 1 to 4) normal tissues)	1 2 3 4
Recognizes basic histopathological lesions (Level 1-4 lesions)	1 2 3 4
Describe a microscopic picture (Level 0, 2, /4).	0 (does not describe), 2(50%), 4 (100%)
Diagnose entities (Level 0, 4)	0 (not diagnostic) , 4 (diagnostic)

3. Results

80% of participants were able to recognize EHN with a Level of 4 (n=24) and 20% with Level 3 (n=6). Regarding the recognition of LHB, 50% recognized 4 or more LHB, (n=15), 13.3% recognized 3 LHB (n=4) and 36.7% only 2 (n=11). Regarding the DCM, 76.6% (n=23) with Level 4, correctly described the sufficient and essential quantity of microscopic components to configure the entity; and 23.3% (n=7) made incomplete descriptions with a level of 2. Regarding Dx E, 83.3% (n=25) obtained Level 4, with correct Dx of entities and 16.7% (n=5) at Level 2. No students were observed at Levels 1 and 0, in any of the evaluated categories (Table 3).

Table 3. Distribution of Scores by Competence in Microscopic Recognition, Description and Diagnosis.

Levels	EHN Recognition	LHB Recognition	Microscopic Frame Description (DCM)	Diagnosis of entities (Dx E)
Level 4	80 % (n=24)	50 % (n=15)	76.6% (n=23)	83.3 % (n=25)
Level 3	20 % (n=6)	13.3% (n=4)	---	---
Level 2	---	36.7 % (n=11)	23.3% (n=7)	16.7 % (n=5)
Level 1	---	---	---	---

4. Discussion

The students showed an Excellent performance at level 4 in all categories, demonstrating a high ability to recognize EHN (80%); LHB (50%); DCM (76.6%) and Dx E (83.3%). The Very Good performance at Level 3 was lower, with only 20% recognizing EHN and 13.3% recognizing LHB. These data show that, in a low percentage of students, it is necessary to increase the practice of seeing more cases to acquire the skills of recognizing EHN and LHB, in order to reach Level 4.

Students with a Regular performance at Level 2 showed a low LHB recognition, less than 50%, which indicates the need for more practice with problem cases, to increase LHB recognition; students who achieved knowledge integration at Level two were 23%, these students together with the 16.7% who did not manage to make a microscopic diagnosis, must reinforce the mainly theoretical content in order to reach the Higher Level.

Students who reach Level 4 appear to have more theoretical background and information, more integration of knowledge, and more practical experience, while students who reach Level 3 may indicate that they are in intermediate stages of learning and need to increase their practice to reach the higher level.

Regarding the cases selected for assessment, these cover a spectrum of relevant lesions and tumors commonly encountered in clinical practice and represent the most significant pathological entities for each course. The two randomly selected cases in the practical assessment allowed to assess the path from the recognition of EHN, LHB, DCM to the Diagnosis of the entity (DX E). Although each case represented only a part of oral pathology, students were exposed throughout the course to a wide variety of pathologies in case seminars and in theoretical classes. This allowed them to apply knowledge acquired from pathologies not included in the assessment.

The sample size (n=30) is justified given that postgraduate courses in Oral Pathology usually attract a limited number of professionals due to the specialization of the subject. This sample allowed us to implement innovative teaching methods, such as virtual microscopy (VM), and to perform individualized and in-depth assessments. Furthermore, the use of VM requires providing detailed attention to each student to ensure an accurate and personalized assessment of their diagnostic and descriptive skills.

Our results show that the integration of VM in a VLE is a successful tool in the learning of AP. VM improves teaching and learning in the recognition of EHN, LHB, DCM and Dx E. VM is a versatile and easy-to-use adopted tool, but requires operators trained in histopathological diagnosis. On the other hand, it can digitally solve the lack of equipment for teaching AP.

The MV incorporated into the EVA Moodle showed the development of capabilities in the recognition of EHN, EHB, DCM and Dx E. and the ease of access to the video material uploaded to the platform to reinforce what is taught in face-to-face classes. There are numerous tools today that use video tutorials and streaming connections using WSI for teaching purposes, both with a similar success rate. The results in our study with the MV are consistent with Al-Janabi et al., 2011, who produced complete images of WSI histological preparations, for educational and diagnostic purposes in pathology, observing the advantage of detailed exploration of the preparations at different magnifications, instant availability for multiple online students and excellent image quality (10).

The use of this type of model requires greater participation of the student in his or her own learning, compared to the traditional model, since the challenge of reaching a diagnosis falls on his or her own capacity for reasoning, data integration and interpretation. At the same time, this model is more adaptable to the needs of each student, the student can choose the number of times he or she watches each video and has unlimited access to the images, unlike the actual teaching sessions with only the MC, which are carried out during limited hours (11-1). Ayman & Foad, in a pilot study carried out on 40 students, compared the use of MV vs. MC, and showed that the performance of the MV group was superior (12). while Deniz, et al evaluated the impact of MC vs MV on the learning of pathology among third-year medical students, and showed that both methods produce similar results in the exams. Ordi et al, compared the use of MV vs MC in undergraduate students, and confirmed that MV can effectively replace CM for teaching pathology in undergraduate courses in medical schools and demonstrated that microscopic skills acquired with MV are comparable to those acquired with CM, the classic tool for teaching pathology.(14) The ability of MV to simulate a light microscope by offering different magnification levels and to walk through an entire slide in a flexible learning context has had a positive impact on the development of diagnostic skills.

Compared to conventional microscopy (CM), virtual microscopy (VM) offers significant benefits, especially in terms of accessibility and flexibility in pathology learning. According to Ordi et al., VM allows unlimited access to high-quality digital images, enabling students to review study materials at any time, resulting in increased knowledge retention and a more personalized learning experience. Studies such as that of Al-Janabi et al. (2011) suggest that VM not only facilitates detailed review at different magnifications but is also positively perceived by students in terms of satisfaction and self-confidence. These findings are consistent with the results of our study, where VM facilitated the development of advanced diagnostic skills in oral pathology.

In future work, a follow-up evaluation is planned after a significant period of time using clinical-pathological case seminars. This follow-up would allow a better understanding of whether VM contributes to long-lasting and effective learning in Oral Pathology.

5. Conclusions

- The implementation of MV improves learning in the recognition of EHN, LHB, DCM and Dx E. The detailed evaluation allows us to infer that the most complex skill: Dx E, achieved the highest level of the total number of participants (83%). It reinforces the concept that teaching from less to greater complexity is effective.
- The assessment at levels using a rubric allowed us to identify specific areas of acquired skills and weaknesses, which allows us to reorient students in Levels 2 and 3 and reinforce those areas to achieve Level 4 performance.
- VM in a Moodle environment in medical education is a valuable tool that provides practical and accessible educational resources in an unlimited way without time restrictions.
- MV offers significant advantages such as image quality, the possibility of multiple views, accessibility for multiple online users and the personalized tour of the histological preparation according to the needs of each user.
- It is a very accessible resource and there are numerous repositories of virtual microscopy images, many of them freely accessible. However, its use requires, without exception, an operator (histologist or pathologist) trained in histological and histopathological microscopic diagnosis, since most of the repositories do not have descriptions of the images, nor marks or labels identifying structures and often contain cases of unknown diagnosis (unknown cases).
- It is an ideal tool for the teaching-learning process of Pathological Anatomy topics, which allows in the best of cases to achieve the complexity of the diagnosis of entities.

Funding: No funding was available.
Declaration of conflict of interest: The authors declare that they have no conflict of interest.
Author contributions: All authors have contributed to the completion of the work.

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