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Research Article

Virtual Microscopy versus Conventional Light Microscopy (Glass Slides) In Undergraduate Pathology Teaching: Technology Taking the Lead

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ABSTRACT
Background: Virtual microscopy has emerged as an important educational technology in pathology, offering standardized digital slides, improved accessibility, and opportunities for self-directed learning. With competency-based medical education (CBME) emphasizing active and technology-enabled learning, evaluating the effectiveness of virtual microscopy compared with conventional light microscopy has become increasingly relevant.
Objectives: To compare virtual microscopy with conventional light microscopy in teaching pathology to undergraduate medical students and to assess students' perceptions regarding the usefulness of virtual microscopy.
Materials and Methods: A descriptive observational study was conducted among Phase II MBBS students over four months (September–December 2024). Sixty consenting students were randomly allocated into two groups of 30. Ten histopathology slides were used for teaching in both conventional light microscopy and virtual microscopy formats. Student performance was assessed using diagnostic scores (maximum score: 10). Perceptions regarding virtual microscopy were evaluated using a validated 10-item questionnaire based on a five-point Likert scale. Data were analyzed using SPSS software. Mann–Whitney U test, Chi-square test, and Student's t-test were applied, with $p<0.05$ considered statistically significant.
Results: Virtual microscopy produced significantly higher performance scores than conventional light microscopy (mean±SD: 7.95±1.36 vs. 4.82±1.92; $p<0.001$). Students demonstrated greater consistency in performance with virtual microscopy. Questionnaire responses showed positive perceptions toward virtual microscopy, particularly for interpretation and diagnosis (mean 4.10), preference over conventional microscopy (4.13), and enhancement of learning (4.03). Lower ratings were observed for image viewing (3.22), magnification adequacy (3.14), and accessibility outside scheduled class hours (3.30), indicating areas requiring technical improvement.
Conclusion: Virtual microscopy significantly enhances academic performance and is well accepted by undergraduate medical students. It provides advantages in accessibility, standardization, learner engagement, and self-directed learning. A blended approach combining virtual microscopy with conventional light microscopy is recommended to optimize pathology teaching while preserving essential microscope handling skills.

Keywords: Virtual Microscopy, Digital Pathology, Light Microscopy, Undergraduate Medical Education, Pathology Teaching, Competency-Based Medical Education (CBME).

BACKGROUND

Change from traditional, didactic teaching methods to more innovative and effective ways of instruction have been the current need of medical education. In order to train medical/ professional course students to equip with the right knowledge and skills, teachers need to update with current technology and their utilisation in medical education. Advances in medicine have increased demands on academic faculty and to incorporate newer teaching technologies in the curriculum for better learning by future health care professionals.[1] Use of technology in medical education like virtual reality, simulation, and online learning

are being increasingly used to improve quality of education provided[2].

Recent advances and innovations in the information technology field have revolutionized the use of hard- and software in medical education[2].

Virtual microscopy is defined as "a method of posting microscope images on, and transmitting them over, computer networks".[3]

Digitization of glass slides enhance the teaching and learning of microscopic aspects of disease.[4]

The usage of whole-slide images (virtual slides or digital slides) has recently been gaining a foothold in medical education, training, and diagnosis. [5]

"Light microscopy" the traditional modality of teaching undergraduate pathology subject was the main tool in practical sessions before the availability of computers and portable electronic devices[6].

The use of high resolution digital images, whic h can be stored in local or distant servers, has resulted in enabling e-learning including both class room and distance learning[5]. Virtual slides become an integral part of telepathology practice, both for consultation and educational purposes, including the potential usage of whole-mount slides in Pathology[6]. Advantages of digital slides/ virtual microscopy are many[7]. There is no longer a need for individual student microscopes, for technical staff for microscope maintenance or repair or worries about the loss of valuable specimens. There is no longer a need for individual slide sets or to prepare new slides. Virtual microscopy is a valuable teaching tool that enhances student educational experiences. [4]

This study was taken up to know usefulness of virtual microscopy compared to conventional light microscopy in teaching Pathology to medical students.

Objectives

To compare virtual microscopy versus conventional light microscopy in teaching Pathology to undergraduate medical students

MATERIALS & METHODS

Study Design: Descriptive observational study

Study Participants: Phase II MBBS CBME batch students

Study Duration: 4 months [September to December 2024]

Sample Size: 60 students

Inclusion Criteria: MBBS phase II students willing to participate with due consent

Exclusion Criteria: Students not giving consent and other course/ postgraduate students.

Study Design: A total of 60 second year MBBS students who attended (CBME curriculum Pathology practical/ DOAP classes and voluntarily willing to take part in the study were included for the study. Later these students were randomly assigned two group of 30 each virtual microscopy group and light microscopy group). A set of 10 histopathology slides were selected for the study. Same slides were scanned at 10x, 40x magnifications and converted to high quality digital images using camera mounted on microscope. Virtual slides /images were chosen from DOAP histopathology section of CBME based phase II MBBS curriculum. A tutorial was conducted on the slide viewing and identification points with final diagnosis was discussed.

Both groups were given general instructions regarding identification and diagnosis histopathology glass slide and digital slide viewing. Digital images of slides were displayed (virtual slide images taken from corresponding glass slides) on a projector using power point presentation.

First traditional glass slides and microscope were provided for identifying diagnosis and scores taken for each correct diagnosis. Then for the same group digital images of slides were displayed on a projector using power point presentation. Again, scored for each correct diagnosis. The individual scores for the virtual and light microscopies were also calculated with a maximum possible score of 10 and a minimum score of 0.

The evaluation method of the study was done by questionnaire survey. Each group was separately assessed using questionnaire on usefulness of digital microscopy and ratings of the above questions were scored with a five-point Likert scale where a higher score indicated greater preference.

he ratings of the questionnaire were scored with a five-point Likert scale for both microscopy as follows: 1- Strongly disagree; 2-Disagree; 3-Neutral; 4-Agree; and 5-Strongly agree.

The total score for each item was summed accordingly. The individual scores for the virtual and light microscopies were also calculated with a maximum possible score of 45 and a minimum score of 9, where a higher score indicated greater preference. After collecting data, it was entered in excel spread sheet and analysis was done using SPSS software. Results

were compared using chi square and students T test. P value of 0.05 was regarded as significant.

RESULTS

A total of 60 phase II MBBS students participated in this study. Table 1 presents a critical comparison between two teaching methods through performance scores. The conventional light microscopy method (HP SCORE) showed a mean score of 4.82 with a median of 5, indicating a relatively symmetric distribution around the middle value. The standard deviation of 1.92 suggests considerable variation in student performance, with scores ranging from a minimum of 1 to a maximum of 9.

In contrast, the virtual microscopy method (SCORE V M) demonstrated notably superior performance metrics. The mean score of 7.95 with a median of 8 indicates consistently higher achievement. The smaller standard deviation of 1.36 suggests more consistent performance across students. Importantly, the minimum score of 5 for virtual microscopy was equal to the median score of conventional microscopy, while the maximum reached 10.

Table: 1 Comparison between Two Teaching Methods through Performance Scores

Method	Mean	Median	Std. Deviation	Minimum	Maximum	P -value Mann-Whitney U test
HP SCORE	482	5	1.92	1	9	<0.001 Significant
SCORE V M	7.95	8	1.36	5	10	

The Mann-Whitney U test, which compares the distribution of scores between two independent groups, yielded a p-value < 0.001. This indicates that the difference between the two methods is highly statistically significant

Students responded to questionnaire survey (Table 2) positively and preferred virtual microscopy over traditional methods and they found virtual microscopy helpful for to identify and understand pathological features on slides. Most students found it convenient, found it very helpful for managing their study time and learning effectiveness in making the virtual microscopy experience more engaging.

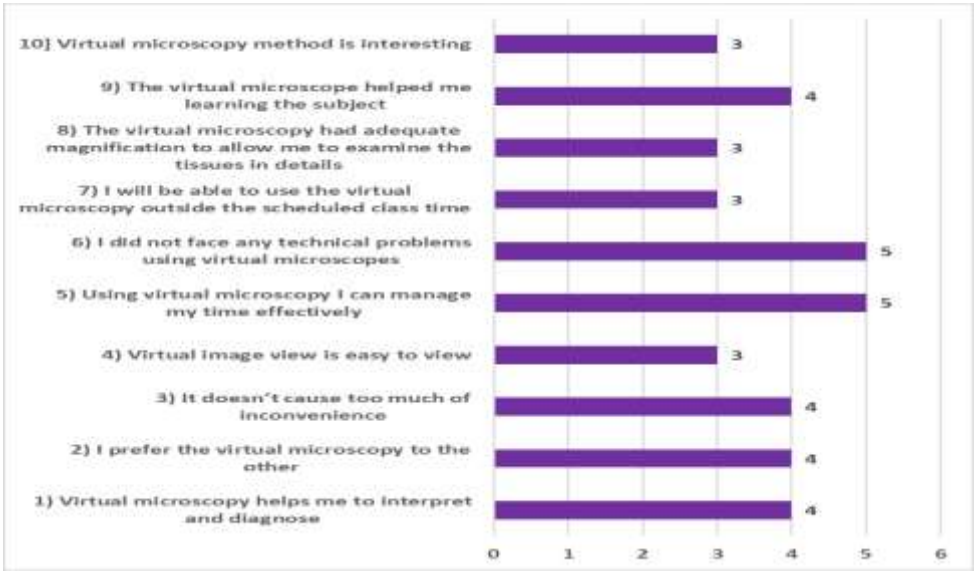
Magnification adequacy received lower ratings suggesting this technical aspect might need enhancement for better tissue examination indicating room for improvement in making the virtual microscopy experience more engaging.

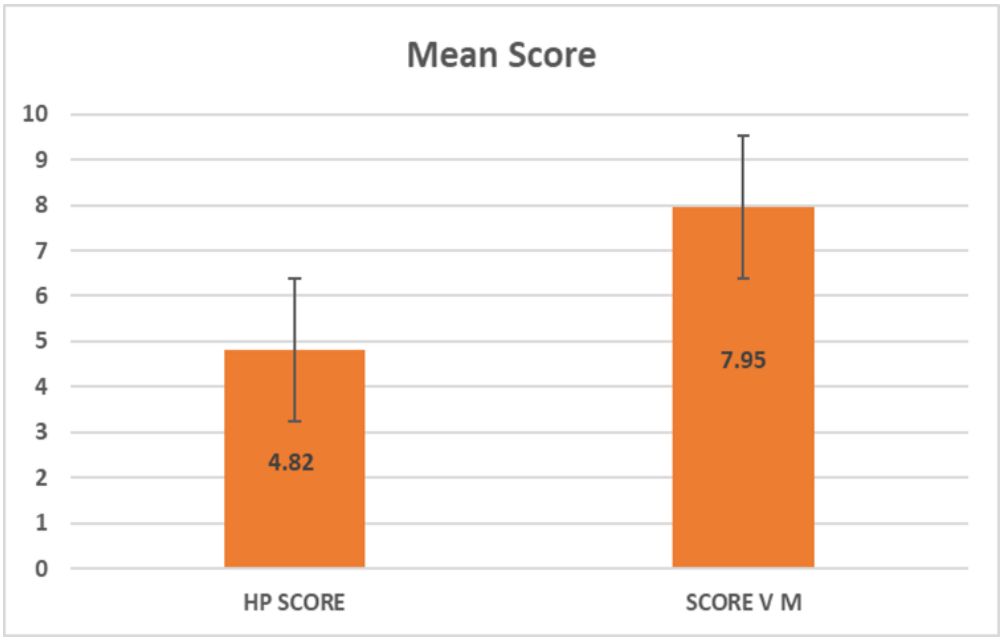
Table: 2 Questionnaire Survey

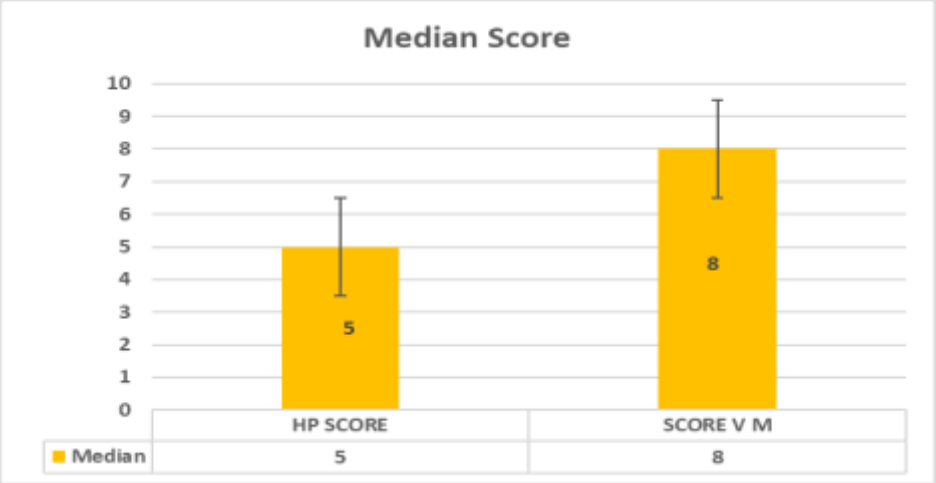
Questions	Mean	Median	Std. Deviation	Minimum	Maximum
1) Virtual microscopy helps me to interpret and diagnose	4.1	4	0.86	2	5
2) I prefer the virtual microscopy to the other	4.13	4	1.05	1	5
3) It doesn't cause too much of inconvenience	3.76	4	1.38	1	5
4) Virtual image view is easy to view	3.22	3	1.73	1	5
5) Using virtual microscopy I can manage my time effectively	3.51	5	1.83	1	5
6) I did not face any technical problems using virtual microscopes	3.6	5	1.83	1	5
7) I will be able to use the virtual microscopy outside the scheduled class time	3.3	3	1.77	1	5
8) The virtual microscopy had adequate magnification to allow me to examine the tissues in details	3.14	3	1.7	1	5

9) The virtual microscope helped me learning the subject	4.03	4	0.98	2	5
10] Virtual microscopy method is interesting	3.22	3	1.72	1	5

These results indicate that while virtual microscopy effectively supports learning and is generally preferred by students, there are technical aspects that could be improved to enhance the overall educational experience.







DISCUSSION

The present study compared virtual microscopy with conventional light microscopy in undergraduate pathology teaching and demonstrated that students using virtual microscopy achieved significantly higher performance scores than those using conventional microscopy (mean score 7.95 vs. 4.82, $p<0.001$). Students also expressed positive perceptions regarding learning, diagnosis, convenience, and preference for virtual microscopy. These findings support the growing evidence that digital pathology is an effective educational tool in undergraduate medical education.

The significantly better performance observed among students using virtual microscopy is consistent with findings reported in several systematic reviews and comparative studies. Rodrigues-Fernandes et al. systematically reviewed the use of digital microscopy in pathology education and concluded that virtual microscopy improves learning outcomes, promotes active participation, and provides educational experiences equivalent or superior to conventional microscopy.[8] Similarly, the systematic review by Kuo and Leo found that virtual microscopy enhances students' understanding of microscopic pathology while improving learning efficiency and accessibility.[9] More recently, the meta-analysis by Maity S et al. Demonstrated that virtual microscopy significantly improves students' academic performance and learner satisfaction compared with light microscopy, supporting the findings of the present study.[10]

The higher mean score and lower variability in student performance observed in our study may be explained by the inherent advantages of virtual microscopy. Unlike conventional microscopy, digital slides provide standardized images, uniform quality, and easy navigation across the specimen. Students are able to repeatedly examine identical microscopic fields without the difficulties associated with microscope focusing, illumination, or poor-quality glass slides. These characteristics reduce technical barriers and allow learners to concentrate on identifying histopathological features and arriving at correct diagnoses.

Our findings are comparable with those reported by Nauhria and Ramdass, who conducted a randomized crossover study among undergraduate medical students and demonstrated significantly better learning experiences with virtual microscopy.[11] the authors concluded that students appreciated the ability to repeatedly review slides, better visualization of tissue architecture, and improved confidence during practical sessions. Likewise, study by Foad AFA reported that students exposed to virtual microscopy performed significantly better than those using conventional microscopes and expressed greater satisfaction with the learning process.[12] The present study also demonstrated a strong preference for virtual microscopy among undergraduate students. Questionnaire responses showed high agreement regarding its usefulness in interpretation and diagnosis (mean 4.10), preference over conventional microscopy (mean 4.13), and its contribution to learning pathology (mean 4.03). Similar observations have been reported by Francis et al. who found that virtual microscopy effectively supports competency-based medical education by promoting active participation, self-directed learning, and repeated practice.[13] Their study emphasized that digital pathology enables learners to revisit slides multiple times outside classroom sessions, thereby strengthening concept retention and diagnostic skills.

Student satisfaction observed in the present study is also supported by Blesile and Tecson who reported significantly higher satisfaction scores among medical students using virtual microscopy compared with traditional light microscopy.[14] Likewise, Angelovska et al. found that undergraduate medical students preferred virtual microscopy because of better image quality, easier accessibility, and improved learning flexibility.[15] These studies suggest that digital microscopy enhances learner engagement and motivation, both of which are essential components of effective competency-based education.

Although students generally preferred virtual microscopy, certain questionnaire items received relatively lower scores, particularly regarding image viewing (3.22), adequate magnification (3.14), and availability outside scheduled class hours (3.30). These findings indicate that technical factors continue to influence learner experience. Similar limitations have been described by Liu and Pantanowitz , who highlighted challenges including image resolution, storage requirements, internet connectivity, and software infrastructure during implementation of digital pathology.[16] Amer and Nemenqani also observed that while virtual microscopy was highly accepted during the COVID-19 pandemic, technical issues such as internet speed and hardware limitations affected the learning experience of some students.[17]

The educational advantages of virtual microscopy observed in our study are further supported by technological advances in digital pathology. Hamilton et al. described virtual microscopy as a transformative educational technology that enables standardized teaching, remote learning, and collaborative pathology education.[18] Similarly, Bashshur et al. emphasized that digital pathology has become an essential component of telepathology, allowing both education and diagnostic consultation irrespective of geographical location.[1] Zwönitzer et al. further highlighted that standardization of digital pathology using DICOM technology facilitates integration into educational and clinical practice.[5]

The present findings also align with recent evidence published after the COVID-19 era. Harizanova et al. demonstrated that medical and dental students preferred virtual microscopy because of its ease of navigation, improved visualization, and enhanced understanding of histological structures.[19] Similarly, Rabha et al. reported that virtual microscopy significantly improved students' learning of histology while promoting greater interaction and independent learning compared with conventional microscopy.[20] Başer and Büyük also concluded that virtual microscopy bridges the gap between conventional microscopy and modern digital medical education by providing superior learning experiences and supporting competency development.[21]

One notable finding in the present study was the smaller standard deviation observed with virtual microscopy (1.36) compared with conventional microscopy (1.92), suggesting greater consistency in student performance. This likely reflects the uniformity of digital slides, where every student observes identical microscopic images without variation in slide quality, staining, or microscope adjustment. Such standardization enhances fairness in teaching and assessment while minimizing technical variability.

The findings of the present study have important implications for competency-based undergraduate medical education. Digital pathology facilitates blended learning, self-directed learning, flipped classrooms, and remote education. Virtual microscopy also supports repeated practice and independent revision, which are essential components of lifelong learning expected from Indian Medical Graduates. Rather than replacing conventional microscopy completely, virtual microscopy should be viewed as an effective complementary teaching strategy that combines technological innovation with traditional practical skills.

Overall, the present study provides strong evidence that virtual microscopy significantly improves undergraduate pathology learning outcomes while being well accepted by students. Although conventional light microscopy remains valuable for understanding microscope handling and basic laboratory skills, virtual microscopy offers substantial educational advantages in terms of accessibility, standardization, flexibility, and learner engagement. A blended teaching approach combining conventional microscopy with virtual microscopy is therefore recommended to optimize pathology education in modern medical curricula.

CONCLUSION

In conclusion, the present study supports virtual microscopy as an effective educational tool in undergraduate pathology and effectively

supports learning and is generally preferred by students. The findings are consistent with previous studies demonstrating improved academic performance, higher student satisfaction, enhanced accessibility, and greater learner engagement. It has less maintenance and more student friendly. Virtual microscopy can supplement traditional age old glass slides and light microscopy in all practical sessions of Pathology and other disciplines. A blended approach combining virtual microscopy with conventional light microscopy is likely to provide the most comprehensive educational experience while preparing medical students for the increasing adoption of digital pathology in clinical practice.

Limitations of the study

The present study has certain limitations. It was conducted in a single institution with a relatively small sample size and evaluated only undergraduate students. Whole-slide imaging scanners were not used, and digital images were generated using microscope-mounted cameras, which may not provide the same level of image manipulation as dedicated virtual slide systems. Long-term retention of knowledge and diagnostic competency were also not evaluated.

Future recommendations

Future research should include metacentric studies with larger sample sizes, incorporation of whole-slide imaging platforms, evaluation of long-term learning outcomes, and assessment of faculty perceptions and cost-effectiveness. Integration of artificial intelligence-assisted digital pathology and learning analytics may further strengthen undergraduate pathology education.

Conflict of interest

Nil

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