Assessing the Effectiveness of Keychain 'Make-roscope' as an Alternative Modality to Light Microscopy for Selected Medical Diagnostic Applications

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ABSTRACT

Microscopy is a fundamental tool in diagnosing pathogenic diseases but faces significant accessibility challenges in resource-limited settings due to the high costs and maintenance requirements of traditional microscopes. This study evaluates the effectiveness of the Keychain Make-roscope, a portable 3D-printed microscope, as an alternative to traditional light microscopes for specific medical diagnostic applications. The research focuses on parameters such as specimen clarity, contrast, shape, color, and ease of use, aiming to present a viable alternative to conventional diagnostic equipment, particularly in underserved rural areas with limited healthcare resources. Using a comparative research design, this study involves Medical Technologists assessing the Keychain Make-roscope alongside traditional light microscopes. Data analysis includes descriptive statistics like frequency, percentage, and weighted mean to provide insights into the performance of the Make-roscope. The Mann-Whitney U test is employed for inferential statistics to determine significant differences in diagnostic parameters.The results indicate that the Keychain Make-roscope excels in examining parasites and urine sediments, offering superior clarity and color compared to traditional microscopes. However, its limitations in magnification and advanced imaging capabilities affect its performance with bacteria, tissues, and blood smears. Despite these limitations, the Make-roscope is a practical and portable alternative in areas with limited access to conventional microscopes. Future research should prioritize the Keychain Make-roscope for examining parasites and urine sediments and explore its use in direct fecal smear techniques. Proper preservation techniques and maintenance are essential to ensure quality observations. Comparative analyses with other portable microscopy devices are recommended to refine the Make-roscope and enhance its utility in clinical settings. Local government units (LGUs) should consider adopting the Make-roscope in primary healthcare to improve diagnostic capabilities and health outcomes in resource-constrained areas. Training programs for healthcare workers in rural areas can further optimize the device's impact, empowering them to conduct essential diagnostics without relying on centralized facilities.

Key words: accessibility, comparative research design, healthcare, Mann-Whitney U test, resource-constrained

Microscopy stands as a cornerstone in the diagnosis of diverse pathogenic diseases, enhancing physician's ability to identify and understand various health conditions. With the aid of microscopy, the quality of patient and health care has been elevated. Standard bright field microscopes, commonly utilized in clinical settings, provide the capability to visualize a variety of specimens, including living cells and microscopic organisms, owing to their resolution limit of 0.2 µm or 200 nm, which allows for the observation of numerous cellular organelles

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(Instruments of Microscopy | Microbiology, 2015). These microscopes often require meticulous setup, adjustments, and can be relatively large and expensive, making them less accessible in resource-constrained healthcare environments. According to clinical laboratory licensing requirements in the Philippines, the utilization of diagnostic microscopy for essential tests, including Tuberculosis (TB) sputum microscopy, urinalysis, pap smears, wet smears, optional complete blood count, stool exams, and malaria thick and thin smears, is mandated to be accessible and available in primary care centers. However, the realization of this accessibility faces challenges due to the scarcity of trained personnel and the high costs associated with supplies and diagnostic equipment, particularly in rural and underserved areas.[1] In an article by Elizeus Rutebemberwa, et al.[2] rural areas in Uganda which had a general lack of qualified personnel to handle microscopes resulted in poor public health as microscopic techniques were not optimal to be employed in communities.

In a cross-sectional study conducted among 127 microscopists in Palawan that identified the impact of factors associated with the number of community malaria awareness-raising activities implemented by microscopists, service quality, knowledge on malaria, and ability in malaria microscopy were one of the few factors that were assessed. Based on this study, results show that microscopists' skills including preparation and documentation, slide preparation and observation, safe handling and disposal, and knowledge on the morphology of infected red blood cells play a significant factor in malaria prevention.[3] Meanwhile, in a study conducted assessing the conditions of the public health sector in the Island Municipality of Jomalig, Quezon Province in Luzon, Philippines, results suggest that challenges in the island's sector include electric supply, better budgetary allocation for their facilities, and equipment and additional training for the barangay (village) health workers that affect the health status of the population.[4]

These laboratory challenges motivated the invention of 3D printed portable microscopes. One of the most recent inventions is the 'Make-roscope' invented by a Filipino engineer, Jeremy De Leon, can simplify the microscopy process by attaching directly to smartphones, completely eliminating the need for complex setups. It provides 400x magnification with a compact design for portability, attaching directly to smartphones for user-friendly operation. Additionally, it features a push-to-focus function for optimal image adjustment. While the keychain 'makeroscope' has been utilized with educational specimens such as onion skin, there is a notable gap in its examination capabilities for diagnostic and medical specimens.

Figure 1. Keychain Make-roscope

Further research and investigation in this specific domain are imperative to enhance the device's utility and applicability in medical settings. Portable microscopes such as the Keychain 'Make-roscope' have the potential to significantly improve impact the turnaround time, ease of disease detection, and public health in rural areas with these features (Make-Roscope Keychain Microscope for Phone/Tablet | Portable Microscope, 2022). Difficulties, such as laboratory cost often requiring time-consuming fine-tuning, can be streamlined with portable microscopes, allowing for quicker and more efficient examinations. Additionally, the simplified operation of portable microscopes makes disease detection more accessible to a broader range of healthcare professionals, further contributing to the early and accurate identification of diseases.

MATERIALS AND METHODS

Research Design

The study aimed to assess the effectiveness of keychain 'Make-roscope' as an alternative modality to light microscopy for selected medical purposes. To achieve this goal, the study utilized a comparative research design to systematically compare the diagnostic performance of the 'Make-roscope' keychain microscope and traditional light microscopy for selected medical diagnostic applications. Comparative research design involves comparing two or more groups, conditions, or variables to assess their differences or similarities. This broadly focuses on comparing existing groups without the requirement of experimental manipulation. The comparative research design allows for a comprehensive evaluation of specific parameters, including clarity of specimen, contrast, shape, color, and ease of use. By using this method, the researchers aim to discern nuanced distinctions in performance across various diagnostic applications such as examining parasites, bacteria, tissues, urine sediments, and blood smears. Data collected from both groups undergo thorough analysis using descriptive statistics, including frequency, percentage, and weighted mean, providing insights into the overall performance of each tool. Additionally, inferential statistics, specifically the Mann-Whitney U test, is employed to identify significant differences in the examined parameters.

Study Population and Study Site

In this study, the focus population consists of the specimens that was examined to evaluate the efficacy of the Make-roscope. The study focused on validating the efficacy of Make-roscope using sample specimens of various bacteria, parasites, tissue samples, urine sediments, and blood smears, which are commonly tested in laboratory diagnostics. To determine the efficacy of the Make-roscope to be an alternative for traditional light microscopes, a set of criteria such as clarity of specimen, contrast, shape, color and ease of use, were evaluated. This study conducted within the FEU-NRMF community as Registered Medical Technologists come from the Staff of the institution itself.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria are essential in laboratory studies to ensure the validity and reliability of research results by selecting appropriate and relevant specimens. Inclusions specify the necessary characteristics that make a specimen eligible for the study, such as safety, proper collection, preparation and adequate preservation to avoid infection or biohazard. To reduce potential biases that may affect the reliability of the findings, it is necessary to collect specimens only from the official laboratory sections of FEU Medical Laboratory Science that are designated for research purposes. On the other hand, exclusions indicate the characteristics that disqualify a specimen from the study, such as high risk for harming medical technologists, easy degradability, and expiration or invalidity. WHO Public Health guidelines on risk groups were followed to guide the researchers in properly selecting specimens employed in conducting the research. Risk groups 3 and 4 which are high risk and lethal to laboratory workers were not employed in the study.

Materials

Table 1. Materials and function

Materials	Function
Light Microscope	Control Microscope
Keychain'Make-roscope'	Assessed Microscope
Laboratory Slides a. Parasitic Slides (5) b. Bacterial Slides (3) c. Tissue Slides (5) d. Urine Sedimen Slides (5) e. BloodSmears(4)	Slides to be evaluated under the 'make-roscope' and microscope
8MP Mobile Device With Third-party application: XZoomPro To utilize the front cam zoom, a third party application will be used'	Device used to visualize the specimen using the keychain 'make-roscope
DeskLamp	Illuminator
Personal Protective Equipment	Prevent risk of any infection

Data Collection

Phase 1 Selection of Specimens

The researchers selected specimens that were easily available, accessible, and frequently used in the laboratory at FEU-NRMF. The specimens and artifacts selected were common indicators neccessary for diagnosing specific clinical conditions, thus, hold clinical significance in the diagnostic process. The selection was driven by both practicality and clinical relevance, ensuring the alignment of the authors' research objectives with the common diagnostic practices in the field. Preserved specimens were borrowed from the different departments in the Institute of Medical Medicine which include the Department of Microbiology- Parasitology, Department of Hematology, Department of Clinical Microscopy and the Department of Pathology.

Under the Parasitology section, different parasites such as *Trichuris trichiura* male, *Necator americanus* adult female, *Taenia solium scolex*, *Dipylidium* *caninum scolex*, and *Ancylostoma caninum* female. The following are parasites commonly found in tropical areas such as the Philippines and are parasites that have been already documented in the country. For Microbiology, gram positive cocci, gram negative bacilli and spores were utilized. The following are organisms commonly examined in the microbiology laboratory. On the other hand, under the hematology section, 2 normal blood smears and 2 abnormal blood smears were prepared. Unfortunately for microbiologic and hematologic slides, resource limitations were challenged in obtaining the desired quantity of bacterial slides. Nonetheless, due to the limited visibility of these microscopic structures, bacterial slides and blood smears may not always yield distinct and diverse results under a portable microscope compared to other groups of specimens that are more visible under the 'Make-roscope'. Under Pathology, the slides utilized contain abnormal tissues such as Invasive Ductal Carcinoma (Breast), Amyloidosis (Thyroid), Squamous Cell Carcinoma (Skin), Prostate Adenocarcinoma, and Clear Cell Renal Cell Carcinoma (Kidney). The following are abnormal tissues associated with a specific organ or tissue, and they represent different histological and clinical entities. Lastly, for urine sediments, sample slides were analyzed using freshly collected urine samples. These samples have not undergone pre-visualization under the portable microscope, and no predetermined artifacts or cells have been established in advance. The decision to utilize freshly collected urine underscores the unpredictable nature of urinary sediments, as the aim was to capture a comprehensive and unbiased representation of any potential cellular elements or artifacts present in the samples. This approach ensured that observations were not influenced by prior knowledge or expectations, allowing for a more genuine and exploratory analysis of the urinary sediment composition. As part of the research approach, the same set of 22 specimens were to all three participating medical technologists. By standardizing the specimens across all participants, the authors aimed to minimize the potential influence of specimen variability on the study results, thereby facilitating a more precise evaluation for the said parameters.

Phase 2 Obtaining Samples and Approval

The researchers derived specimens from various sections within the FEU-NRMF laboratories. To secure the necessary specimens, the researchers requested permission to borrow the properly preserved slides and specimens housed at the laboratory. The specimens used for the study were preserved sample slides from the Laboratories of the Medical Laboratory Sciences of FEU-NRMF.

The researchers sought permission to use and utilize the specimen slides, Microbiology-Parasitology Laboratory Facility and 2 sets of Olympus CX23 Microscope as a control microscope needed for the study. The Olympus CX23 is a durable and reliable light microscope that is ergonomic and lightweight. The microscope features an outstanding optical performance as it provides a uniform LED illumination ensuring that there is uniformity of color when observing specimens. It also includes a wide field view of 20 where it allows a wide range of viewing of specimens. The objectives are specially designed that allows observation of specimens to stay flat when around the field (Evident, n.d.). This microscope also includes the standard 4 objective lenses and their specific magnifications. These are the Scanner with 4x, Low Power with 10x, High Power with 40x, and Oil Immersion with 100x.

Phase 2.1 Participation of Medical Technologist

In this study, Registered Medical Technologists (RMTs) were provided with an Informed Consent Form served as a transparent communication of the study's objectives, methodologies, and potential implications, allowing RMTs to make informed decisions about their participation. Upon the voluntary agreement of the RMTs to participate in the study, the Registered Medical Technologist were asked to submit their curriculum vitae that would ensure that the study was conducted with a skilled and experienced workforce, upholding the integrity and credibility of the research outcomes.

Phase 3 Experimentation and Data Collection

Prior to initiating the experiment, the Medical Technologists received a comprehensive briefing on the procedural guidelines and instructions. In performing the experiment, materials were prepared for both the Olympus CX23 light microscope setup and Keychain 'Make-roscope' setup. The specimen slides were then prepared in front of the Registered

Medical technologists. The Registered Medical Technologists were then given an evaluation checklist for them to input the necessary data. The evaluation checklist included their findings on the clarity, contrast, color, shape and ease of use for both keychain 'Make-roscope' and Olympus CX23 light microscope. Specimens were initially examined under the light microscope that served the control microscope, then transferred and observed on to Make-roscope using a mobile device. In the course of this experiment, the researchers employed an Apple iPad 8th Generation, equipped with an 8MP camera featuring an $f/2.4$ aperture. To facilitate zooming capabilities, particularly when utilizing the front camera of the device, the researchers opted for the xZoom Camera Booster application. Any application with front camera zooming capabilities can be utilized in performing this experiment as long as it has front camera zooming capabilities. Any application equipped with front camera zooming capabilities may be utilized for this experiment, provided it offers the necessary functionality for optimal zooming during data acquisition. The Medical Technologists examined specimens in each section, recorded findings on provided checklists. Completed checklists are submitted to the researchers, who compiled and analyzed the data.

DISCUSSION

The findings encompassed multiple variables that were considered when comparing the keychain make-roscope and light microscope. These variables included criteria such as clarity, contrast, shape, color, and ease of use. Each of these variables was individually graded by the three (3) Registered Medical Technologists. Thus, the researchers calculated the importance of each variable by taking the mean of all gradings. For instance, the grading of parasites based on the clarity of specimens was categorized into three (3): High Resolution, Moderate Resolution, and Low Resolution when comparing the keychain make-roscope and light microscope. Based on the findings, the obtained p-values provided the statistical significance of the differences observed between the make-roscope and microscope regarding various parameters in parasite, bacteria, tissue, urine sediment, and blood smear examination.

Difference Between Make-roscope and Microscope in Examining Parasites

Table 2. Difference between make-roscope and microscope in examining parasites

Variable Tested	Test Statistic	p-value	Interpretation
Clarity	67.50	0.024	Significant
Contrast	103.5	0.632	Non-significant
Ease of Use	97.5	0.433	Non-significant
Shape	97.5	0.386	Non-significant
Color	75.0	0.017	Significant

Note: Test at 0.05

In examining parasites, significant differences were observed in "Clarity" and "Color," with p-values of 0.024 and 0.017, respectively, indicating a notable distinction between the instruments in evaluating parasites based on these criteria. Parameters such as "Contrast," "Ease of Use," and "Shape" yielded p-values exceeding 0.05, suggesting that there are observed differences between make-roscope and light microscope. Consequently, while the null hypothesis was rejected for clarity and color, it was retained for contrast, ease of use, and shape, indicating no significant difference between the make-roscope and microscope in these regards.

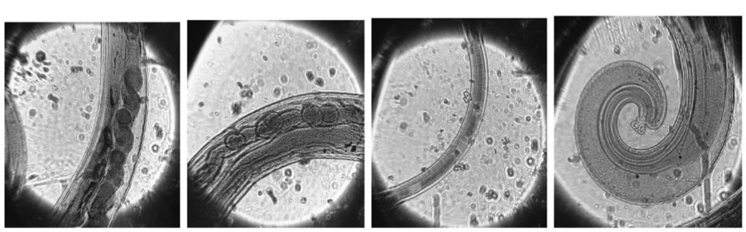

Figure 2. Trichuris trichiura male under the keychain Make-roscope

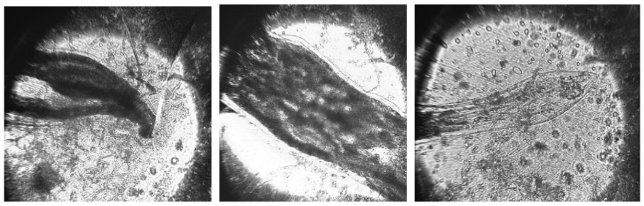

Figure 3. Necator Americanus under keychain Make-roscope

Figure 4. Taenia solium scolex under the keychain Make-roscope

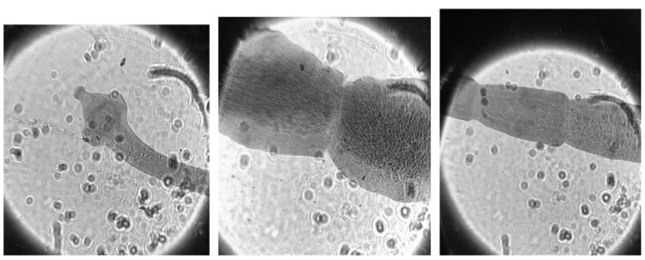

Figure 5. Dipylidium caninum under keychain Make-roscope

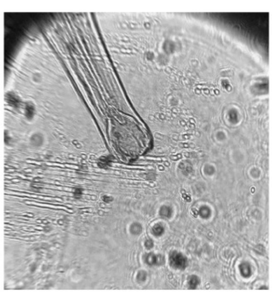

Figure 6. Ancylostoma caninum female under keychain Make-roscope

Based on the gathered data, a significant difference was found between make-roscope and microscope in examining parasites. In terms of clarity and color, keychain make-roscope was deemed more superior than the light microscope. However, in terms of contrast, ease of use, and shape, both the light microscope and the keychain make-roscope performed similarly.

Difference Between Make-roscope and Microscope in Examining Bacteria

Table 3. Difference between make-roscope and microscope in examining bacteria

Variable Tested	Test Statistic	p-value	Interpretation
Clarity	1.50	0.000	Significant
Contrast	0.00	0.000	Significant
Ease of Use	40.50	1.000	Non-significant
Shape	0.00	0.000	Significant
Color	13.50	0.005	Significant

Note: Test at 0.05

In examining bacteria, significant differences were observed in "Clarity," "Contrast," "Shape," and "Color," with p-values of 0.000 for each parameter, leading to the rejection of the null hypothesis. This indicates a clear disparity between the make-roscope and microscope in their ability to assess bacteria in terms of these aspects. However, for "Ease of Use," the obtained p-value of 1.000 exceeded the significance threshold of 0.05, resulting in the retention of the null hypothesis. Consequently, there was no significant difference between the make-roscope and microscope in examining bacteria regarding ease of use. These findings underscore the nuanced performance of the two instruments in bacterial examination.

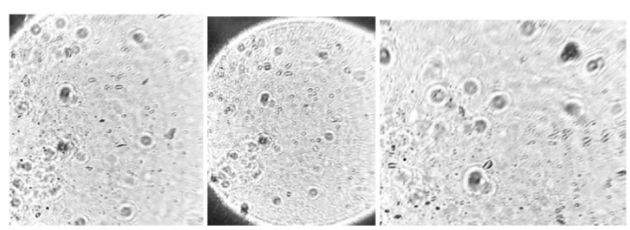

Figure 7. Bacterial slides under the keychain Make-roscope

According to the data presented, a significant difference was observed between the keychain make-roscope and light microscope terms of clarity, contrast, shape, and color.

It was observed that only artifacts were visualized under the keychain make-roscope. Due to its limited capacity for magnification, small samples such as the bacteria, failed to be observed under the keychain make-roscope. However, in terms of ease of use, the keychain make-roscope and the light microscope performed similarly.

Difference Between Make-roscope and Microscope in Examining Tissue Samples

Table 4. Difference between make-roscope and microscope in examining tissue samples

Variable Tested	Test Statistic	p-value	Interpretation
Clarity	22.50	0.000	Significant
Contrast	60.00	0.003	Non-significant
Ease of Use	112.50	1.000	Non-significant
Shape	45.00	0.000	Significant
Color	45.00	0.000	Significant

Note: Test at 0.05

In the examination of tissue samples, significant differences were noted in “Clarity,” “Contrast,” “Shape,” and “Color,” with p-values of 0.000, 0.003, 0.000, and 0.000, respectively. Consequently, the null hypothesis was rejected, indicating a significant difference between the make-roscope and microscope regarding these parameters. However, for “Ease of Use,” the obtained p-value of 1.000 surpassed the significance threshold of 0.05, leading to the retention of the null hypothesis. Thus, there was no significant difference between the make-roscope and microscope in terms of ease of use when examining tissue samples.

Based on the gathered data, a significant difference was evident between the make-roscope and the microscope in examining tissue, particularly regarding clarity, contrast, shape, and color. The light microscope demonstrated superiority over the keychain

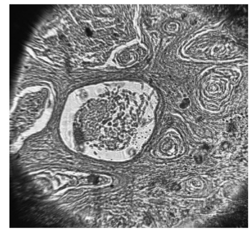

Figure 8. Invasive ductal carcinoma metastatic to the lymph node breast tissue under the keychain make-roscope

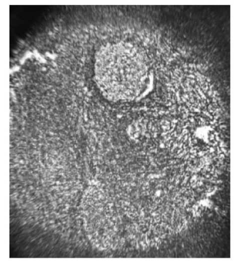

Figure 9. Amyloidosis (thyroid) under the keychain make-roscope

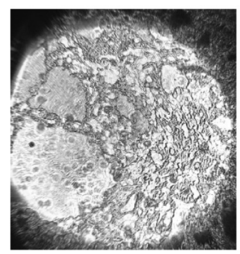

Figure 10. Clear cell carcinoma under the keychain make-roscope

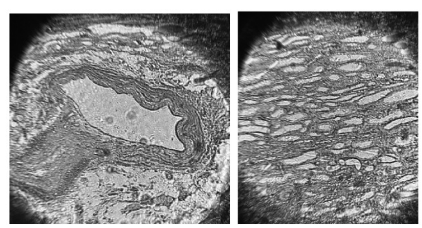

Figure 11. Prostate adenocarcinoma under the keychain make-roscope

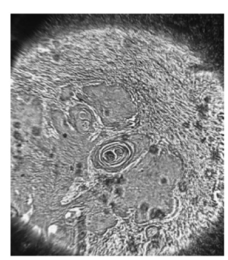

Figure 12. Squamous cell carcinoma under the keychain make-roscope

make-roscope across all four parameters. While the tissue was observable under the keychain make-roscope, its limited magnification capacity impeded the identification of specific tissue abnormalities. On the other hand, in terms of ease of use, both the microscope and make-roscope met the optimal criteria that resulted to no significant difference between the two microscopes.

Difference Between Make-roscope and Microscope in Examining Urine Sediments

Table 5. Difference between make-roscope and microscope in examining urine sediments

Variable Tested	Test Statistic	p-value	Interpretation
Clarity	105.00	0.752	Significant
Contrast	80.00	0.149	Non-significant
Ease of Use	100.00	0.586	Significant
Shape	102.50	0.669	Non-significant
Color	95.00	0.435	Non-significant

Note: Test at 0.05

In the examination of urine sediments, the obtained p-values for “Clarity,” “Contrast,” “Ease of Use,” “Shape,” and “Color” were 0.752, 0.149, 0.586, 0.669, and 0.435, respectively, all surpassing the significance threshold of 0.05. Consequently, the null hypothesis was upheld, signifying no significant difference between the make-roscope and microscope in terms of clarity, contrast, ease of use, shape, and color when examining urine sediments. These findings indicated a comparable performance between the two instruments in this particular aspect of examination, suggesting their interchangeable utility in clinical settings.

According to the data presented, there was no significant difference between make-roscope and microscope in examining tissue in terms of clarity, contrast, ease of use, shape, and color. The keychain make-roscope and the microscope performed similarly in analyzing all five (5) parameters. Both

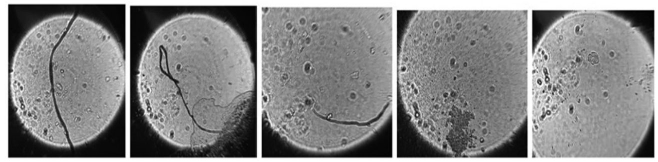

Figure 13. Urine Sediments under the Keychain Make-roscope

the keychain make-roscope and the microscope demonstrated comparable performance in analyzing all five parameters. Specimens observed under the light microscope exhibited similar characteristics when viewed under the microscope.

Difference Between Make-roscope and Microscope in Examining Blood Smears

Table 6. Difference between make-roscope and microscope in examining blood smears

Variable Tested	Test Statistic	p-value	Interpretation
Clarity	2.000	0.000	Significant
Contrast	0.000	0.000	Significant
Ease of Use	64.000	0.604	Non-significant
Shape	0.000	0.000	Significant
Color	0.000	0.000	Significant

Note: Test at 0.05

In examining blood smears, the obtained p-values for “Clarity,” “Contrast,” and “Color” were all 0.000, falling below the significance threshold of 0.05. Consequently, the null hypothesis was rejected, indicating a significant difference between the make-roscope and microscope in terms of clarity, contrast, and color when examining blood smears. However, for “Ease of Use,” the obtained p-value was 0.604, exceeding the significance threshold, leading to the retention of the null hypothesis. Thus, no significant difference was found in ease of use between the make-roscope and microscope in blood smear examination.

Based on the gathered data, a significant difference was evident between the make-roscope and the microscope in examining blood smears, particularly

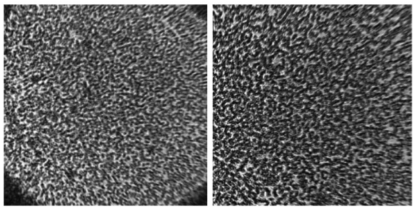

Figure 14. Abnormal blood smear under the keychain make-roscope

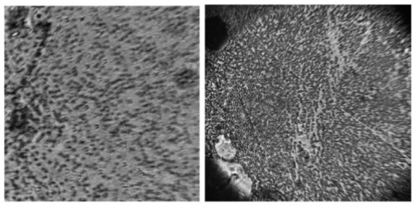

Figure 15. Normal blood smears under the keychain make-roscope

regarding clarity, contrast, shape, and color. The light microscope demonstrated superiority over the keychain make-roscope across all four parameters. While the red blood cells were observable under the keychain make-roscope, its limited magnification capacity impeded the identification and distinction between abnormal and normal cells under the make-roscope. However, in terms of ease of use, both the microscope and make-roscope met the optimal criteria that resulted to no significant difference between the two microscopes.

The keychain make-roscope emerges as a notable instrument despite its inherent limitations relative to traditional light microscopes. Its significance manifests in its adaptability to specific research contexts and scenarios. The keychain make-roscope can be judiciously employed in research endeavors where the exhaustive examination is not deemed imperative. This deliberate utilization ensures the optimal allocation of resources, thereby maximizing the utility of the keychain microscope in targeted research applications. Moreover, its compact design and user-friendly interface enhance its appeal by offering convenience and accessibility, particularly in research environments that prioritize portability and ease of use. Consequently, while the keychain make-roscope may lack the comprehensive functionalities of its larger counterparts, its consistent delivery of reliable results in focused research settings underscores its significance as a valuable scientific instrument.

CONCLUSION AND RECOMMENDATION

Based on the gathered results, the keychain microscope shows potential as an alternative to the standard microscope, especially for pre-examining easily distinguishable specimens that do not require higher magnification. The Make-roscope proves advantageous in studying parasites, exhibiting superior clarity and color compared to the traditional microscope. While both microscopes are comparable in terms of ease of use, the keychain microscope falls short in performance when dealing with bacteria, tissues, and blood smears due to limitations in magnification and advanced imaging capabilities. Despite this, the Make-roscope is deemed a practical and portable alternative in areas where access to conventional light microscopes is limited.

Prioritizing the keychain Make-roscope for specific clinical applications, such as examining parasites and urine sediments, is advised for future researchers. Mounting bacteria with a cover slip and ensuring proper preservation techniques are crucial for achieving optimal results. Researchers should tailor their focus on specimen characteristics, considering the advantages of the Make-roscope over traditional light microscopes. Given its potential as a practical solution in resource-constrained environments and rural areas where conventional microscopes are scarce, exploring the utilization of direct fecal smear techniques is recommended due to its versatility. However, it’s essential to establish regular cleaning and maintenance routines to mitigate the presence of artifacts, ensuring the quality and accuracy of observations. Furthermore, future studies should include comparative analyses against other portable microscopy devices to discern the keychain Make-roscope’s strengths and weaknesses in various contexts. This will spur further development and refinement of the device, enhancing its utility in clinical settings.

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