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Research Article

Comparing whole slide digital images versus traditional glass slides in the detection of common microscopic features seen in dermatitis

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Abstract

Background: The quality and limitations of digital slides are not fully known. We aimed to estimate intrapathologist discrepancy in detecting specific microscopic features on glass slides and digital slides created by scanning at ×20. **Methods:** Hematoxylin and eosin and periodic acid–Schiff glass slides were digitized using the Mirax Scan (Carl Zeiss Inc., Germany). Six pathologists assessed 50–71 digital slides. We recorded objective magnification, total time, and detection of the following: Mast cells; eosinophils; plasma cells; pigmented macrophages; melanin in the epidermis; fungal bodies; neutrophils; civatte bodies; parakeratosis; and sebocytes. This process was repeated using the corresponding glass slides after 3 weeks. The diagnosis was not required. **Results:** The mean time to assess digital slides was 176.77 s and 137.61 s for glass slides ($P < 0.001$, 99% confidence interval [CI]). The mean objective magnification used to detect features using digital slides was 18.28 and 14.07 for glass slides ($P < 0.001$, 99.99% CI). Parakeratosis, civatte bodies, pigmented macrophages, melanin in the epidermis, mast cells, eosinophils, plasma cells, and neutrophils, were identified at lower objectives on glass slides ($P = 0.023$–0.001, 95% CI). Average intraobserver concordance ranged from $\kappa = 0.30$ to $\kappa = 0.78$. Features with poor to fair average concordance were: Melanin in the epidermis ($\kappa = 0.15$–0.58); plasma cells ($\kappa = 0.15$–0.49); and neutrophils ($\kappa = 0.12$–0.48). Features with moderate average intrapathologist concordance were: parakeratosis ($\kappa = 0.21$–0.61); civatte bodies ($\kappa = 0.21$–0.71); pigment-laden macrophages ($\kappa = 0.34$–0.66); mast cells ($\kappa = 0.29$–0.78); and eosinophils ($\kappa = 0.31$–0.79). The average intrapathologist concordance was good for sebocytes ($\kappa = 0.51$–1.00) and fungal bodies ($\kappa = 0.47$–0.76). **Conclusions:** Telepathology using digital slides scanned at ×20 is sufficient for detection of histopathologic features routinely encountered in dermatitis cases, though less efficient than glass slides.

Key words: Dermatitis, dermatopathology, digital slides, histologic features, microscopic features

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INTRODUCTION

In the last 10 years, advances in information technology have accelerated its use in the practice of anatomic pathology,[1-4] allowing pathologists to view and diagnose cases digitally.[5] Likewise, the use of digital slides is becoming more common, with its use expanding beyond research applications.[6] It now plays a huge role and is becoming more mainstream in medical education[7-11] and the healthcare system.[4,12-16] Increased availability of digital slide technology has expedited[17-20] secondary consultations,[10,21] and has expanded accessibility of pathology services to include underserved areas in the international community.[22-25] Furthermore, digital pathology facilitates real-time teleconferencing for discussions of a single specimen.[13,26-28] Additional benefits include reduced costs for slide storage, fewer instances of slide misplacement, and easier access to re-review slides once a new biopsy is received.[5]

One of the factors influencing digital slides is the objective lens magnification used by the scanner.[29] Commercially available slide scanning systems scan conventional glass slides at a high magnification (×20 or ×40) and at multiple focal planes in depth. However, image resolution and scanning (digitization) magnification can vary greatly between digital pathology systems.[29] When digital images are compared with viewing images using a microscope, the cellular features can vary in size, ultimately altering what the pathologist can see, and impacting the overall viewing experience.[29]

A drawback with digital microscopy is the requirement for an enormous amount of digital storage space for image data.[30] Image files created by scanning at higher magnification require much more digital storage space. Therefore, many facilities opt to scan slides at a lower magnification power, such as ×20, as opposed to ×40. Furthermore, when selling equipment, some manufacturers claim there is no benefit to scanning slides at magnification power >×20.

We aim to evaluate the relative quality of digital slides scanned at ×20 versus traditional glass slides by estimating intrapathologist discrepancy in detecting specific microscopic features and examining for variation in the objective magnification needed to discern features with either medium. We will also compare the efficiency of workflow with both media by comparing the time needed to recognize the microscopic features of tissues viewed as glass slides versus digital slides.

METHODS

This was a blinded concordance study, adapted from a previous protocol.[5]

Pathologist Selection

Two board-certified dermatopathologists with over 20 years of experience, three board-certified dermatopathologists who had completed fellowship within last 5 years, and one 2nd-year dermatopathology fellow were recruited to participate in this study. If a participant was unaccustomed to digital slides, i.e., did not use them on at least a daily basis, they were encouraged to review at least 100 digital slides training cases with Pannoramic Viewer software (3DHisTech, Budapest, Hungary) before participating. However, all participants felt familiar with digital slides through daily or weekly use in their practice and elected to forgo reviewing the training slides. We chose a diverse group of pathologists with variable degrees of experience to capture the landscape of today's pathology workforce.

Case Selection

The cases were identified by searching the database of a dermatopathology practice within an academic medical facility for common pathological dermatitis diagnoses. Search terms for diagnoses were limited to: "eczema," "seborrheic dermatitis," "lichenoid dermatitis," "lichen planus," and "fungal infection." Seventy-one cases on glass slides (one slide per case) were randomly selected from the search results to avoid allocation bias. Additionally, only glass slides with hematoxylin and eosin (H and E) and periodic acid–Schiff (PAS) stained tissue were included; cases that required the use of imaging oil or magnifications over ×40 were excluded to ensure that the pathologists would be able to evaluate study cases without any need for additional tools or equipment. Diagnoses given to selected cases before the study were not recorded. Cases were not selected based on the provided clinical information by the clinician.

Digitization of Slides

Every case used in the study was de-identified and assigned a unique study number by the study coordinator. Glass slide numbers did not correspond to the digital slide numbers to prevent second look bias (where the pathologist could remember diagnoses from the first media and replicate them during the second session). The glass slide cases were digitized into digital slides image files using the Mirax Scan (Carl Zeiss Inc., Germany) with the following settings: ×20 objective lens, numerical aperture 0.65, pixel resolution 0.23 μ.

Data Collection

The gold standard (set by the principal investigator) was considered to be glass slides reviewed on light microscope by an experienced dermatopathologist with at least 20 years of experience. All cases were reviewed using this gold standard to verify the presence or absence of the following histologic features: Parakeratosis; sebocytes, civatte bodies, pigmented macrophages,

melanin in the epidermis, mast cells, eosinophils, plasma cells, neutrophils, and fungal bodies. Regardless of quantity, a feature was considered to be present if it was clearly distinguishable, even if only a single entity was observed (i.e., if a single sebocytes was clearly observed, that was enough to say that there were sebocytes on the biopsy). This set of features was selected because they are commonly used by dermatopathologists (in addition to identification of the reaction pattern and the pattern of inflammation) to expand and narrow the differential diagnoses of dermatidities. Additionally, the presence or absence of sebocytes is often used to verify anatomic location of biopsy.

The study coordinator met individually with each dermatopathologist at their own workstations 4–5 times, for independent evaluation of 50–71 digital slides that were randomized into smaller batches 15 slides. At each meeting, the study coordinator recorded whether the microscopic features were recognized as well as the objective magnifications used when they were first detected and total time spent evaluating each slide. Three weeks after the last batch of digital slides was reviewed, the process was repeated for the corresponding glass slides at a standardized microscope (8–10 total sessions per pathologists to review all assigned glass slides and digital slides). This 3-week "washout period" fostered objective evaluation and was an additional measure to prevent second-look bias.

At each slide-viewing session, the timer was started at recitation of case number, recorded at time of recognition of each feature (as well as objective magnification on which each feature was seen), then stopped when last feature seen. Therefore, sequence in which the features were identified was variable.

All dermatopathologists reviewed digital slides before the corresponding glass slides to facilitate record keeping, efficiency, and transportation of study equipment by the study coordinator. This study design enabled compliance with the 3-week washout period and permitted the study to be carried out with six dermatopathologists within a 1 year time frame.

All digital slide files were retrieved at the dermatopathologist's workstation from the same external hard drive and viewed with the Pannoramic Viewer software. All workstations where digital slides were reviewed had minimum requirements of liquid crystal display monitors with 100 pixels per inch. In addition, for digital slides the desired objective magnification was selected by the participants using labeled buttons on the Panoramic Viewer interface (×2, ×5, ×10, ×20, and ×40), this selection was recorded for the objective magnification for digital slides. Evaluation of the cases on glass slides was done at a dermatopathology practice within an academic medical facility where all pathologists used the same light microscope (Leica, Germay) with standardized settings (light intensity, focus, condenser, iris, filters, etc.) to ensure consistency. The power of the objective magnification lenses used (×2.5, ×5, ×10, ×20, ×40) defined the objective magnification recorded for glass slides.

Statistical Methods

All statistical analyses were performed using SPSS version 22 (International Business Machines, Armonk, NY, USA). Independent-variables *t*-tests were used to determine significant statistical differences between the objective magnifications used to discern microscopic features on glass slides and digital slides. Cohen's weighted Kappa was used to determine intraobserver variability for detection of microscopic features on glass slides and digital slides (regardless of magnification power used) in addition to calculating concordance of dermatopathologists with the gold standard (for detecting the presence or absence of a feature, regardless of magnification power used).

RESULTS

Characteristics of Cases Undergoing Evaluation

Among these 71 cases [Table 1], parakeratosis was the most frequently occurring feature (n = 65 [92.86%]), followed by plasma cells (n = 35 [50.0%]), civatte bodies (n = 32 [45.71%]); pigmented macrophages (n = 31 [44.29%]); mast cells (n = 29 [41.43%]); neutrophils (n = 29 [41.43%]); and eosinophils (n = 27 [38.57%]). Present in a smaller proportion of cases [Table 2] were sebocytes (n = 18 [25.71%]) and melanin in the epidermis (n = 18 [25.71%]), with fungal elements being present the least often (n = 8 [11.43%]).

The majority of the 71 cases included in this study contained a combination of 5 (n = 17 [23.94%]), 6 (n = 12 [16.90%]) or 7 (n = 14 [19.72%]) of the

Table 1: Proportion of cases with each histologic feature (n=71)

Histologic feature	Number of cases (%)
Parakeratosis	65 (92.86)
Sebocytes	18 (25.71)
Civatte bodies	32 (45.71)
Pigmented macrophages	31 (44.29)
Melanin in the epidermis	18 (25.71)
Mast cells	29 (41.43)
Eosinophils	27 (38.57)
Plasma cells	35 (50.0)
Neutrophils	29 (41.43)
Fungal bodies	8 (11.43)

Parakeratosis was the most frequently occurring feature, followed by plasma cells, civatte bodies; pigmented macrophages; mast cells; neutrophils; and eosinophils. Present less often were sebocytes and melanin in the epidermis. Fungal elements were present the least often

individual histologic features assessed. A combination of 3 features was also fairly common (n = 11 [15.49%]). Only 2 cases (2.82%) contained 9 or 10 features [Table 2].

Proportion of Correctly Identified Features

When compared to glass media, pathologists' average percentage of correctly identified features was higher on digital media (66.64–83.49% vs. 58.43–78.28% on glass media, Tables 3 and 4). Sebocytes (93.24% on digital and 94.78% on glass media) and melanin in the epidermis (92% on digital media and 91.88% on glass) were consistently identified correctly on both media [Tables 3 and 4]. Features accurately identified more frequently on digital compared to glass slides included pigmented macrophages (80.76% vs. 71.50%) and plasma cells (68.05% vs. 61.97%). Features accurately identified more frequently on glass slides compared to digital images included parakeratosis (86.10% vs. 81.56%), neutrophils (84.9% vs. 73.83%), civatte bodies (80.46% vs. 73.83%), and mast cells (70.59% vs. 64.12%) [Tables 3 and 4]. Eosinophils were detected correctly on approximately 77% of cases using either medium. Fungal bodies and plasma cells were correctly identified the least often on both media.

Table 2: Proportion of features in each case (n=71)

Combination of features	Amount of cases (%)
1 feature	4 (5.63)
2 features	2 (2.82)
3 features	11 (15.49)
4 features	6 (8.45)
5 features	17 (23.94)
6 features	12 (16.90)
7 features	14 (19.72)
8 features	3 (4.23)
9 features	1 (1.41)
10 features	1 (1.41)

The majority of cases had a combination of 5, 6, or 7 of the individual histologic features assessed. A combination of 3 features was also fairly common. Only 2 cases contained 9 or 10 features

The average proportion of cases with correctly identified features by pathologist had a wider range on glass media (58.4–100.00%, Table 3) as compared to digital media (65.9–83.49%, Table 4). For glass media, the greatest variability in the proportion of cases correctly identified was observed between the two board-certified dermatopathologists with over 20 years of experience, Pathologists A and B. This variability on glass media was less pronounced between board-certified dermatopathologists who had completed fellowship within the last 5 years (Pathologists C, D, and F) and a 2nd-year dermatopathology fellow (Pathologist E). The majority of pathologists' proportion of correctly identified cases was consistent or improved with the use of digital media [Tables 3 and 4] with the exception of Pathologist A.

Intrapathologist Concordance (Glass versus Digital Media)

By individual histologic features, overall average intraobserver concordance between digital and glass media [Table 5] ranged from κ = 0.30 to κ = 0.78. By pathologist, the overall average intraobserver concordance between the two media was moderate across the board (κ = 0.41–0.55). The individual features with poor to fair average concordance were: Melanin in the epidermis (κ = 0.15–0.58); plasma cells (κ = 0.15–0.49); and neutrophils (κ = 0.12–0.48).

Table 3: Proportion of cases correctly identified for each feature on Glass Media

	Pathologist A (%)	Pathologist B (%)	Pathologist C (%)	Pathologist D (%)	Pathologist E (%)	Pathologist F (%)	Average by feature (%)
Parakeratosis	100	81.81	94.55	73.91	82.22	84.10	86.10
Sebocytes	100	90.90	77.78	100.00	100.00	100	94.78
Civatte bodies	100	80.00	67.86	70.00	80.00	84.89	80.46
Pigmented macrophages	100	57.89	64.29	70.00	63.16	73.68	71.50
Melanin in the epidermis	100	80.00	81.25	90.00	100.00	100	91.88
Mast cells	100	7.14	75.93	100.00	45.24	95.23	70.59
Eosinophils	100	73.68	73.08	75.00	77.78	63	77.09
Plasma cells	100	26.92	63.33	71.43	46.15	64	61.97
Neutrophils	100	77.77	84.62	90.00	73.68	83.33	84.90
Fungal bodies	100	66.67	33.33	100.00	33.33	66.66	66.67
Average by pathologist	100.00	58.43	65.61	76.39	63.78	78.28	

Features accurately identified more frequently on glass slides included parakeratosis, neutrophils, civatte bodies, and mast cells. The average proportion of cases with correctly identified features by pathologist had a wider range on glass media (58.4-100.00%), as compared to digital media [Table 4]. The greatest variability in the proportion of cases correctly identified was observed between the two board-certified dermatopathologists with over 20 years of experience (pathologists A and B). The variability was less pronounced between board-certified dermatopathologists who had completed fellowship within last 5 years (pathologists C, D, and F) and a 2nd-year dermatopathology fellow (pathologist E)

Table 4: Proportion of cases correctly identified for each feature on Digital Slides

	Pathologist A (%)	Pathologist B (%)	Pathologist C (%)	Pathologist D (%)	Pathologist E (%)	Pathologist F (%)	Average by feature (%)
Parakeratosis	90.77	84.09	80.00	73.91	83.33	77.27	81.56
Sebocytes	94.44	100.00	83.33	91.67	100.00	90	93.24
Civatte bodies	75.00	80.00	64.29	60.00	80.00	89.47	74.79
Pigmented macrophages	77.42	78.95	75.00	90.00	78.95	84.21	80.76
Melanin in the epidermis	77.78	100.00	75.00	100.00	100.00	100	92
Mast cells	95.00	2.38	70.37	93.18	23.81	100	64.12
Eosinophils	77.78	78.95	76.92	90.00	72.22	68.42	77.38
Plasma cells	74.29	42.31	83.33	75.00	65.38	68	68.05
Neutrophils	72.41	52.63	65.38	85.00	84.21	83.33	73.83
Fungal bodies	75.00	6.06	66.67	100.00	33.33	100	63.51
Average by pathologist	79.37	66.64	67.82	78.07	65.90	83.49	

Features accurately identified more frequently on digital compared to glass slides included pigmented macrophages and plasma cells. For digital media, the average proportion of correctly identified proportion of cases by pathologist had a narrower range (65.9-83.49%) as compared to glass media [Table 3]

Table 5: Intraobserver kappa binary correlations

	Pathologist A	Pathologist B	Pathologist C	Pathologist D	Pathologist E	Pathologist F	Mean Kappa score for each feature
Parakeratosis	0.21	0.44	0.59	0.61	0.45	0.53	0.47
Sebocytes	0.79	0.73	0.51	0.78	1.00	0.89	0.78
Civatte bodies	0.62	0.21	0.70	0.71	0.65	0.44	0.56
Pigment-laden macrophages	0.39	0.56	0.56	0.66	0.37	0.34	0.48
Melanin in the epidermis	0.15	0.45	0.20	0.58	0.27	0.33	0.33
Mast cells	0.70	NSS	0.78	0.29	0.35	0.78	0.58
Eosinophils	0.43	0.58	0.31	0.79	0.49	0.57	0.53
Plasma cells	0.20	0.15	0.38	0.26	0.49	NSS	0.30
Neutrophils	0.37	0.12	0.41	0.31	0.48	NSS	0.34
Fungal bodies	0.62	NSS	0.76	NSS	0.66	NSS	0.68
Mean Kappa score, by pathologist	0.43	0.41	0.52	0.55	0.52	0.54	0.50

Value of Kappa	Strength of agreement
<0.20	Poor
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Good
0.81-1.00	Very good

By individual histologic features, overall average intraobserver concordance between digital and glass media ranged from fair to good (κ=0.30-0.78). By pathologist, the overall average intraobserver concordance between the two media was moderate across the board (κ=0.41-0.55). Poor to fair average concordance as observed for detection of melanin in the epidermis; plasma cells; and neutrophils. Moderate concordance was observed for parakeratosis; civatte bodies; pigment-laden macrophages; mast cells; and eosinophils. The average intrapathologist concordance was good for sebocytes and fungal bodies. NSS: Not statistically significant

Features with moderate average intrapathologist concordance were: Parakeratosis (κ = 0.21–0.61); civatte bodies (κ = 0.21–0.71); pigment-laden macrophages (κ = 0.34–0.66); mast cells (κ = 0.29–0.78); and eosinophils (κ = 0.31–0.79). The average intrapathologist concordance was good for sebocytes (κ = 0.51–1.00) and fungal bodies (κ = 0.47–0.76).

Assessment of Time and Objective Magnification

The mean time needed to evaluate a case (including glass and digital media) in this study was 157.19 s. The mean time to assess digital slides was 176.77 s and 137.61 s for glass slides ($P < 0.001$, 99% confidence interval [CI]). Overall, glass slides were read in 22.15% less time than digital slides [Table 6].

Table 6: Objective magnifications for feature identification on glass slides and digital slides

Feature	Digital slides		Glass slides		*P*	% CI
	Average OM	*n*	Average OM	*n*		
Parakeratosis	4.93	187	4.23	184	0.004	99
Sebocytes	2.86	56	3.26	56	0.102	NSS
Civatte bodies	15.26	100	11.27	92	<0.001	99
Pigment-laden macrophages	20.51	148	13.75	91	<0.001	99
Melanin in the epidermis	16.31	140	14.24	92	<0.001	99
Mast cells	29.38	136	24.18	141	<0.001	99
Eosinophils	23.92	117	18.97	102	<0.001	99
Plasma cells	29.74	121	20.98	87	<0.001	99
Neutrophils	16.38	115	12.8	134	0.001	99
Fungal bodies	26.41	22	25.53	17	0.016	NSS
Overall (unweighted)	18.75	1181	15.22	1029	<0.001	99
Overall (weighted)*	18.28	1181	14.07	1029	<0.0001	99

*Weighted by number of observations of each feature. The average OM used to detect features was lower using glass slides. Parakeratosis, civatte bodies, pigmented macrophages, melanin in the epidermis, mast cells, eosinophils, plasma cells, and neutrophils, were identified at lower objectives on glass slides than digital slides. NSS: Not statistically significant, OM: Objective magnification, CI: Confidence interval

The average objective magnification used to detect features using digital slides was 18.28 and 14.07 for glass slides ($P < 0.001$, 99.99% CI, Table 6). Parakeratosis, civatte bodies, pigmented macrophages, melanin in the epidermis, mast cells, eosinophils, plasma cells, and neutrophils, were identified at lower objectives on glass slides than digital slides ($P = 0.023$–0.001, 95% CI, Table 6). The difference in objective magnification used between media for detection of sebocytes and fungal bodies was statistically insignificant [Table 6].

CONCLUSIONS

Although many dermatopathologists prefer to use digital microscopy as an adjunct to traditional light microscopy, there is an inevitable trend toward the acceptance of expanding the practice of digital-only slide review.[31] Digital microscopy is commonly used in medical schools to teach histology and pathology, in addition to being used in resident education, in-training examinations, and certification examinations.[32] Potential benefits of digital slides include more efficient workflow, image storage, collaboration, interactive teaching tools, and the possibility of enhancing accuracy and information derived using computer-assisted diagnostic devices similar to those available in radiology.

Our study supports that scanning objective magnification of ×20 is sufficient for discerning the majority of common microscopic features seen in dermatitis. Overall average intrapathologist correlations between both media for each feature were fair to good ($\kappa = 0.30$–0.78), and none of the studied features had poor levels of intrapathologist concordance. The best overall average intraobserver correlations were seen with sebocytes ($\kappa = 0.78$) and fungal bodies ($\kappa = 0.68$), suggesting that cases involving these features (i.e., rosacea, dermatophytosis) can be viewed equivalently on digital slides as compared to glass slides, and there is no loss of detection ability when the glass slides are digitized. Additionally, both sebocytes and fungal bodies had similar average correctly identified proportions between both media as well. Sebocytes, on average, were correctly identified 93.24% of the time using digital slides versus 94.78% using glass slides [Tables 3 and 4]. Fungal bodies, on average were identified correctly 66.67% of the time with glass slides and 63.51% using digital slides.

In particular, digital slides appear to be a superior method for detecting sebocytes. Although the quantity of sebocytes in our sample was relatively less than the other histologic features studied [Table 1], this feature was on average most often correctly identified on both digital and glass media (94.78%, Tables 3 and 4), with the strongest intrapathologist concordance on both media [Table 5]. The average objective magnification used to detect sebocytes was also lower on digital slides [Table 6]. These findings are consistent with a previous study where high correlation rate for dermatopathologists reading sebaceous neoplasms on digital slides was reported.[33]

Moderate intraobserver correlations between both media [Table 5] were seen for parakeratosis ($\kappa = 0.47$); civatte bodies ($\kappa = 0.56$); pigmented macrophages ($\kappa = 0.48$); mast cells ($\kappa = 0.58$); and eosinophils ($\kappa = 0.53$). Of these features, pigmented macrophages were on average identified correctly more often on digital slides. Although the average proportion of cases with parakeratosis, civatte bodies, and mast cells were more often correctly identified using glass slides [Tables 3 and 4], the difference was at best only 15% higher [Tables 3 and 4]. For the studied features with fair levels of intrapathologist concordance (melanin in the epidermis [$\kappa = 0.33$]; plasma cells [$\kappa = 0.30$]; and

neutrophils [κ = 0.34]), the difference of correctly identified cases between both media was at most 12% [Tables 3 and 4]. These findings indicate that there may be limitations in detecting cellular features that could affect diagnostic utility when using telepathology and digital slides. Reasons for a dermatopathologist missing a feature with digital slides when they were able to see that feature on glass could derive from color distortion and inferior resolution by the scanning system, which cannot be corrected by increasing magnification power. In addition, inconsistent digital slide quality by the scanning system, relating to human operator error could occur. In addition, the dermatopathologist's computer processing speed may delay loading of image resolution when scanning across digital microscopic fields. Alternatively, a similar intrapathologist discordance rate might be observed between just glass slides. It is important to consider that the proportion of correctly identified features was similar on both media for all features. Interestingly, the overall proportion of correctly identified features was higher on digital media (66.64–83.49% vs. 58.43–78.28% on glass media, Tables 3 and 4).

Additionally, one should also consider that inflammatory skin lesions present a challenge to pathologists at large; one case series demonstrated that 33% of misinterpretations of dermatopathology specimens were caused by inflammatory skin lesions.[34] Another study showed difficulty among pathologists in recognizing inflammatory cell microscopic features on digital slides, consistent with our study.[35] Difficulties viewing fine details of inflammatory cells by digital slides, such as neutrophilic lobules and eosinophil granules have also been reported by pathologists in a previous study.[35] Despite these difficulties in discerning cellular features on histology with digital slides, previous studies have shown digital slides to be effective reproducing accurate diagnoses that were made on glass slides.[2,5] Perhaps additional steps in the diagnostic process, such as identification of the reaction pattern and the pattern of inflammation present (in cases of dermatitis), may compensate for impaired ability to distinguish cellular features on digital slides. Our data of low intra and inter pathologist concordance for certain histologic features should be applied in context with the knowledge that cellular feature identification is only part of the diagnostic process for inflammatory lesions.

While difficulty discerning histologic features may or may not impact final microscopic diagnosis of inflammatory skin conditions, it certainly impacts workflow efficiency by protracting the length of time required to review a digital slide. In general, we observed efficiency using glass slides was superior to digital slides created by scanning at ×20. Glass slides were read 22.15% faster on average, using 23.00% lower objective magnification on average [Table 6]. This is similar to findings in previous workflow studies.[35] Reasons for faster evaluation with glass slides could include that dermatopathologist were more accustomed to reading conventional glass slides than digital slides. Although there have been a large number of studies to validate the diagnostic utility of digital slides as compared to conventional glass slides,[2-4,36-38] including for the diagnosis of skin tumors,[39] the use of telepathology systems are not preferentially utilized. This occurrence is mainly due to associated costs and time constraints of creating the infrastructure in pathology practices and healthcare systems. Other variables that have prevented the widespread use of teledermatopathology include diagnostic accuracy, licensure requirements, and reimbursement.[40]

The level of training of the dermatopathologist, and prior experience with digital microscopy[41] are important factors to consider when determining whether to use telepathology with an experienced dermatopathologist or whether to sign the case in-house for inflammatory skin lesions. The manner in which fully trained pathologists and pathology residents scan digital slides differs considerably according to one eye movement study.[42] Training pathologists have also reported not favoring the use of digital microscopy for service and board examination testing.[32] Although in this study we observed larger variability in the proportion of cases correctly identified on glass slides between the senior dermatopathologists as compared with more junior board-certified dermatopathologists and a training dermatopathology fellow, the variability did not persist with the use of digital slides [Tables 3 and 4]. Perhaps the large variability seen between the senior dermatopathologists on glass slides was related to the use of use of lower average objective magnification on glass media [Table 6]. Larger studies, which include pathologists with diversified levels of training and experiences, are needed to clarify the relationship between level of training of the dermatopathologist, prior experience, and use of digital microscopy.

Confounders to our study included that the number of tissue profiles (tissue slices) on each slide varied from 1 to 8. While each pathologist in the study was encouraged to view each piece of tissue on the slide, this suggestion was not enforced. The time of day during which our participants volunteered varied based on their schedule; we did not correct for pathologist fatigue based time of day and how many slides they had already viewed during that workday. In addition, one could argue that the standardized light microscope use to read the glass slides for this study decreased efficiency of our participants since it was not their usual microscopes at the workstations to where they were accustomed.

Ideally, our study would have included an arm comparing intra pathologist concordance between glass slides after

a washout period to clarify if the low intrapathologist concordance for certain histologic features seen in this study is truly attributed to digital slides alone. Other limitations of this study include that our case selection is biased toward five diagnoses, which restricts the study's scope to features commonly seen in inflammatory dermatoses. Therefore, we cannot apply our findings to features seen in many other classes of diagnoses (i.e., basement membrane changes, necrosis, and deposits). Similarly, other special stains, which are often used in dermatopathology are not included within the scope of this study (i.e., colloidal iron, alcian blue stains for mucin and Grocott's methenamine silver stain). Finally, the manner in which the slides in this study were deidentified and assigned a study number prevented us from assessing if digital slides are better able to detect fungus with H and E or PAS.

Further studies are needed on alternative digital microscopy interfaces to substantiate our results and observation that a scanning magnification of ×20 for skin biopsies pertaining to dermatidities is sufficient. Furthermore, similar studies which include a wider variety of pathological diagnoses and stains are warranted to further validate the adequacy of using digital slides created by scanning at ×20 in dermatopathology.

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Conflicts of Interest
There are no conflicts of interest.

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