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Original Contribution

The utility of digital pathology in improving the diagnostic skills of pathology trainees in commonly encountered pigmented cutaneous lesions during the COVID-19 pandemic: A single academic institution experience

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ABSTRACT

Digital pathology has become an integral part of pathology education in recent years, particularly during the COVID-19 pandemic, for its potential utility as a teaching tool that augments the traditional 1-to-1 sign-out experience. Herein, we evaluate the utility of whole slide imaging (WSI) in reducing diagnostic errors in pigmented cutaneous lesions by pathology fellows without subspecialty training in dermatopathology. Ten cases of 4 pigmented cutaneous lesions commonly encountered by general pathologists were selected. Corresponding whole slide images were distributed to our fellows, along with two sets of online surveys, each composed of 10 multiple-choice questions with 4 answers. Identical cases were used for both surveys to minimize variability in trainees' scores depending on the perceived level of difficulty, with the second set being distributed after random shuffling. Brief image-based teaching slides as self-assessment tool were provided to trainees between each survey. Pre- and post-self-assessment scores were analyzed. 61% (17/28) and 39% (11/28) of fellows completed the first and second surveys, respectively. The mean score in the first survey was 5.2/10. The mean score in the second survey following self-assessment increased to 7.2/10. 64% (7/11) of trainees showed an improvement in their scores, with 1 trainee improving his/her score by 8 points. No fellow scored less post-self-assessment than on the initial assessment. The difference in individual scores between two surveys was statistically significant ($p = 0.003$). Our study demonstrates the utility of WSI-based self-assessment learning as a source of improving diagnostic skills of pathology trainees in a short period of time.

1. Introduction

The COVID-19 pandemic has brought unprecedented challenges for educational programs across North America, including pathology residency and fellowship training programs, forcing them to adapt to a new educational environment that mandates appropriate social distancing while maintaining effective delivery of educational materials to learners and/or trainees. Most pathology training programs have either eliminated the traditional double/multiheaded-scoping or 1-to-1 sign-out (at least during the initial phase of the pandemic) or reduced its frequency to minimize the spread of the coronavirus among faculty, trainees, and other laboratory staff members. In response to the crisis with loss of conventional sign-out opportunities for pathology trainees, many training programs, including our own, have adapted alternative teaching methods, primarily through various virtual platforms and online resources, or created innovative training curricula that allow trainees to continue their education in a physically distanced and safe environment [1-4]. Digital pathology with whole slide imaging (WSI) has been increasingly utilized in many institutions since its first approval by the U.S. Food and Drug Administration for primary diagnosis in 2017 [5,6]. Having been gradually incorporated as an essential component in pathology education in recent years, it has emerged as one of the most logical alternative teaching modalities, if available, in this pandemic era, for its ability to simulate an actual 1-to-1 or even group sign-out experience, when used in conjunction with other virtual videoconference platforms. Currently, WSI is routinely being used in the Section of Dermatopathology in our Department of Pathology not only for primary diagnosis and case previewing by faculty and trainees, respectively, but

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also for other intra- and interdepartmental educational activities. However, our trainees, except for those subspecializing in dermatopathology, have had limited exposure to digital pathology or virtual sign-outs throughout the pandemic due to a relatively lower frequency of WSI usage in other subspecialty sections in the Department.

Most studies published to date have largely focused on practicing pathologists' or trainees' perception on the usage of WSI as a diagnostic or learning tool, compared to traditional microscopic glass slides, or their willingness to adapt digital pathology sign-outs post-pandemic [7-11]. To the best of our knowledge, few studies, if any, have previously evaluated the utility of WSI as an educational tool capable of not only replacing 1-to-1 sign-out during the COVID-19 pandemic but also enhancing pathology trainees' diagnostic skills in commonly encountered pigmented cutaneous lesions (PCLs). In the Section of Dermatopathology at our institution, misclassification of PCLs is among the most common sources of diagnostic discrepancies identified in outside referral cases received here for internal review. Although the underlying cause of such discrepancies is likely multifactorial, a significant component may be attributed to their morphologic similarities. Furthermore, PCLs are commonly encountered in general practice, and in many pathology laboratories, these skin biopsies are interpreted by general surgical pathologists without subspecialty training in dermatopathology [12,13]. Thus, greater awareness and experience with these lesions is needed among surgical pathologists, as misclassification or inaccurate diagnosis can have significant clinical implications.

Herein, we evaluate the utility of WSI and histomorphology-based teaching slides as a supplemental self-assessment (SA) tool in reducing diagnostic errors in 4 commonly encountered PCLs: seborrheic keratosis (SK), actinic keratosis (AK), melanoma in situ (MIS) lentigo maligna (LM) type, and LM melanoma, by pathology fellows without subspecialty training in dermatopathology at a large academic institution.

2. Materials and methods

2.1. Case selection and review of whole slide imaging

After obtaining Institutional Review Board approval, we searched our pathology database and selected a total of 10 cases of 4 commonly misdiagnosed PCLs, including SK, AK, MIS LM type, and LM melanoma, diagnosed at our institution between 2019 and 2020. The selected cases were all confirmed to be pigmented clinically and had WSIs of corresponding hematoxylin and eosin (H&E)-stained slides available through Aperio ImageScope (Leica Biosystems, Buffalo Grove, Illinois) (scanned at 20× magnification) (Fig. 1). The scanned WSIs were reviewed by 3 pathologists (W.C.C., P.G., C.A.T.) to ensure the quality of the scanned images and to determine the suitability of the chosen cases for an appropriate level of difficulty; cases whose WSIs showed artifacts (e.g., paraffin on top of the glass slide obscuring the underlying histomorphology, lack of focus with blurriness of scanned images, overstained original H&E-stained slides, particularly with hematoxylin, etc.) or cases deemed unsuitable for testing for general surgical pathologists without dermatopathology fellowship training, including those that necessitate acquisition of additional immunohistochemical studies due to inconspicuous or overlapping histomorphology, were excluded.

2.2. Distribution of surveys and self-assessment tool and statistical analysis

The selected WSIs from 10 cases of PCL were deidentified (Fig. 1) and subsequently distributed to all fellows in the Department of Anatomic Pathology (12 surgical pathology fellows, 6 cytopathology fellows, 2 breast pathology fellows, 2 genitourinary pathology fellows, 2 gynecological pathology fellows, 1 bone and soft tissue pathology fellow, 1 head and neck pathology fellow, 1 gastrointestinal pathology fellow, and 1 thoracic pathology fellow) at our institution, along with 2 sets of

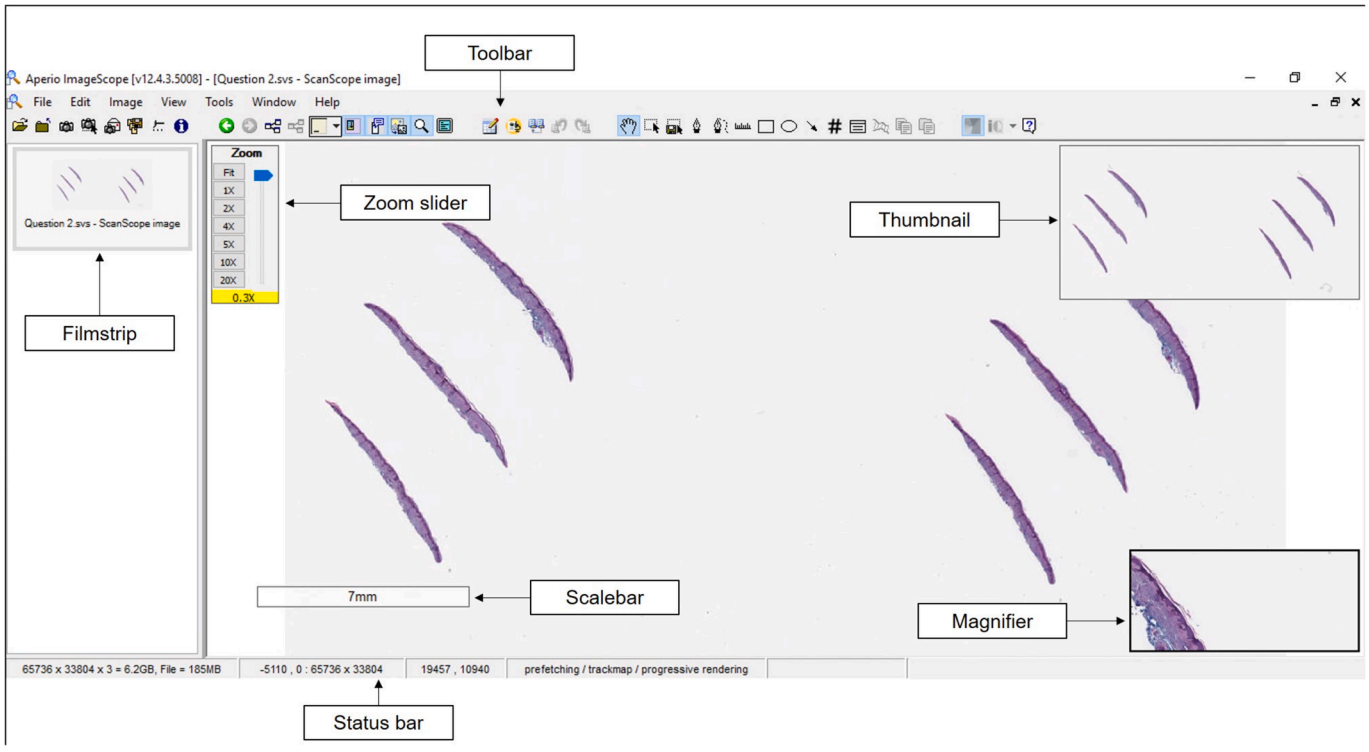

Fig. 1. Representative example of whole slide imaging of a pigmented cutaneous lesion viewed via Aperio ImageScope. The main elements of the ImageScope include the toolbar, filmstrip, zoom slider, thumbnail, scale bar, magnifier, status bar, and label (not shown), all of which can be removed from the viewer's screen by unchecking the corresponding options available under the View menu. The cases included in our study were all scanned at 20× magnification and appropriately deidentified prior to distribution to the participants.

online surveys through Google Forms (Google, Mountain View, California), each composed of 10 multiple-choice questions with 4 answers (SK, pigmented AK, MIS LM type, LM melanoma). All fellows had varying levels of background training in dermatopathology depending on their prior residency programs in the United States and Canada and other training or academic experience. Two dermatopathology fellows were excluded from these surveys. Two weeks were given to the fellows to complete each survey, with a 2-week interval between the assessments. Identical WSIs were used for both online surveys to minimize variability in subjects' scores depending on the perceived difficulty of provided PCLs, with the second set of WSIs being distributed to the participants after shuffling (i.e., the same cases of PCL as in the first set but presented in a different order). All participants were blinded and thus made unaware of the usage of the same test sets. Following the first survey, short image-based teaching slides in Microsoft PowerPoint (Microsoft Corporation, Redmond, Washington) primarily focusing on histomorphology as a supplemental SA tool (estimated review time of approximately 10 min or less) were provided to the participants. The teaching slides encompassed both a brief overview (Fig. 2) and key histological features of 4 PCLs identifiable on H&E-stained sections (Figs. 3, 4, 5 and 6). The images used for the SA were snapshot representations of each PCL's WSI directly taken from an additional pool of cases found in our database, all of which were ensured to demonstrate a similar, if not identical, resolution to those of the cases incorporated in our surveys. Participants were required to utilize the SA tool prior to completing the second survey. Following the completion of the second survey, pre- and post-SA scores were analyzed. Fischer's exact test was used to assess the difference in individual scores between the two online surveys.

3. Results

3.1. Trainees' online survey participation rates

The participation rates among our fellows in the Department of Anatomic Pathology for both surveys are summarized in Table 1. Overall, the fellows' participation rate in the first online survey (i.e., pre-SA) was 61% (17 of 28), with surgical pathology fellows demonstrating the highest participation rate of 75% (9 of 12). The overall participation rate dropped from 61% to 39% (11 of 28) in the second online survey (i.e., post-SA); 65% (11 of 17) of those who did the first survey successfully completed the second survey following SA. There were 2 surgical pathology fellows who only completed the second survey, skipping the first test set; thus, their scores were excluded from our analysis.

3.2. Trainees' pre- and post-self-assessment scores and survey question analysis

The individual scores obtained by our fellows in the Department of Anatomic Pathology who participated in at least one survey are summarized in Table 2. The mean score in the first survey was calculated to be 5.2 out of 10, with a median score of 5 out of 10 (range, 0–9). The fellows' mean score in the second survey following the completion of SA increased to 7.2 out of 10, with a median score of 8 out of 10 (range, 3–9). 64% (7 of 11) of participants who had completed both assessments improved their scores, with 1 trainee improving his/her score by 8 points. No fellow scored less post-SA than on the initial assessment.

The participants' diagnostic accuracy rates in each survey by lesion type are summarized in Table 3. Our test set was composed of 4 cases of MIS, LM type, 3 cases of SK, 2 cases of AK, and 1 case of LM melanoma, respectively. The lesion types with the highest and lowest diagnostic accuracy rates on the initial assessment were LM melanoma (Question 10 in the first survey) and SK (Question 8 in the first survey), respectively. The fellows' scores improved in most questions, with 100% correction on 3 questions post-SA, which correspond to SK (Question 6 of the first survey), MIS, LM type (Question 7 of the first survey), and LM melanoma (Question 10 of the first survey), respectively. Overall, a statistically significant difference ($p = 0.003$) was observed between the two survey individual scores (Table 2).

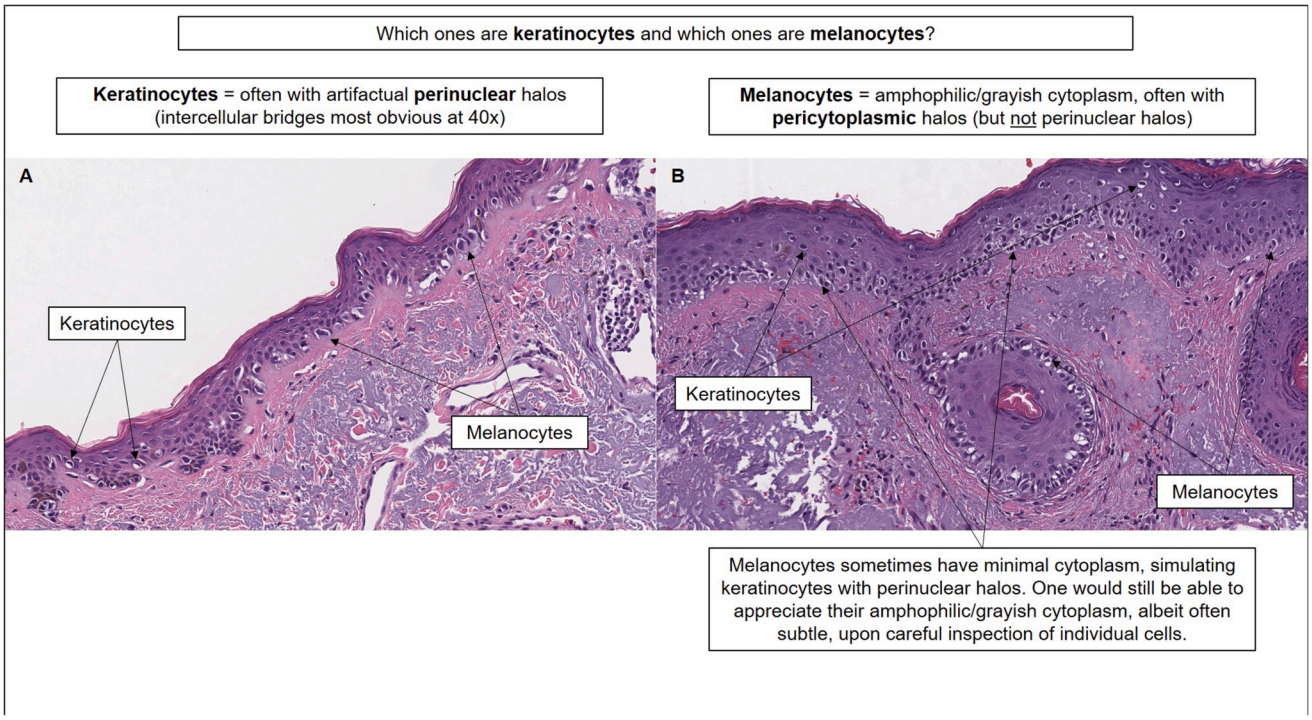

Fig. 2. Overview section of image-based teaching slides. A brief overview highlighting key morphologic differences between keratinocytes and melanocytes on hematoxylin and eosin-stained sections was provided as part of the self-assessment following the completion of the first survey. These images were taken from cases of melanoma in situ, lentigo maligna type (A and B, hematoxylin and eosin, original magnification ×20), one of which showed an area of adnexal extension (B).

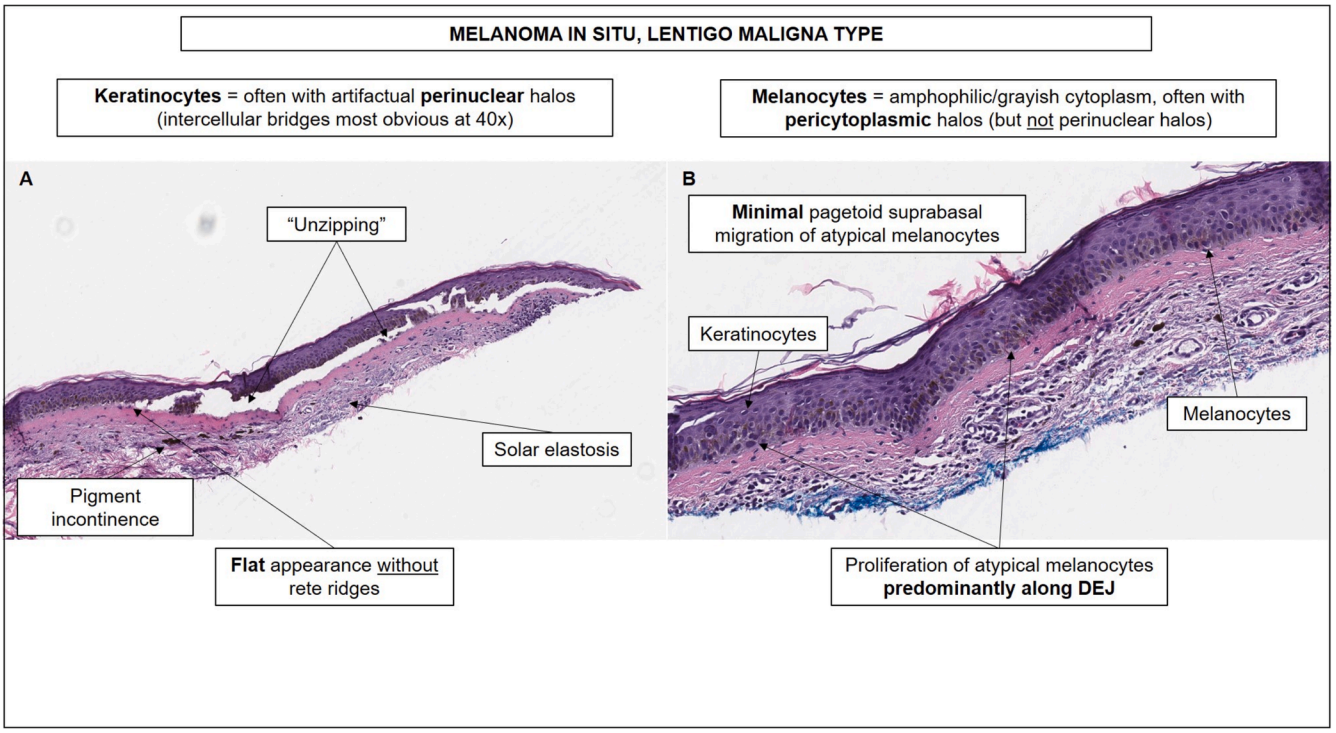

Fig. 3. Image-based teaching slides highlighting key histological features of melanoma in situ, lentigo maligna type (A and B, hematoxylin and eosin, original magnification ×10 and ×20, respectively). Abbreviation: DEJ = dermal-epidermal junction.

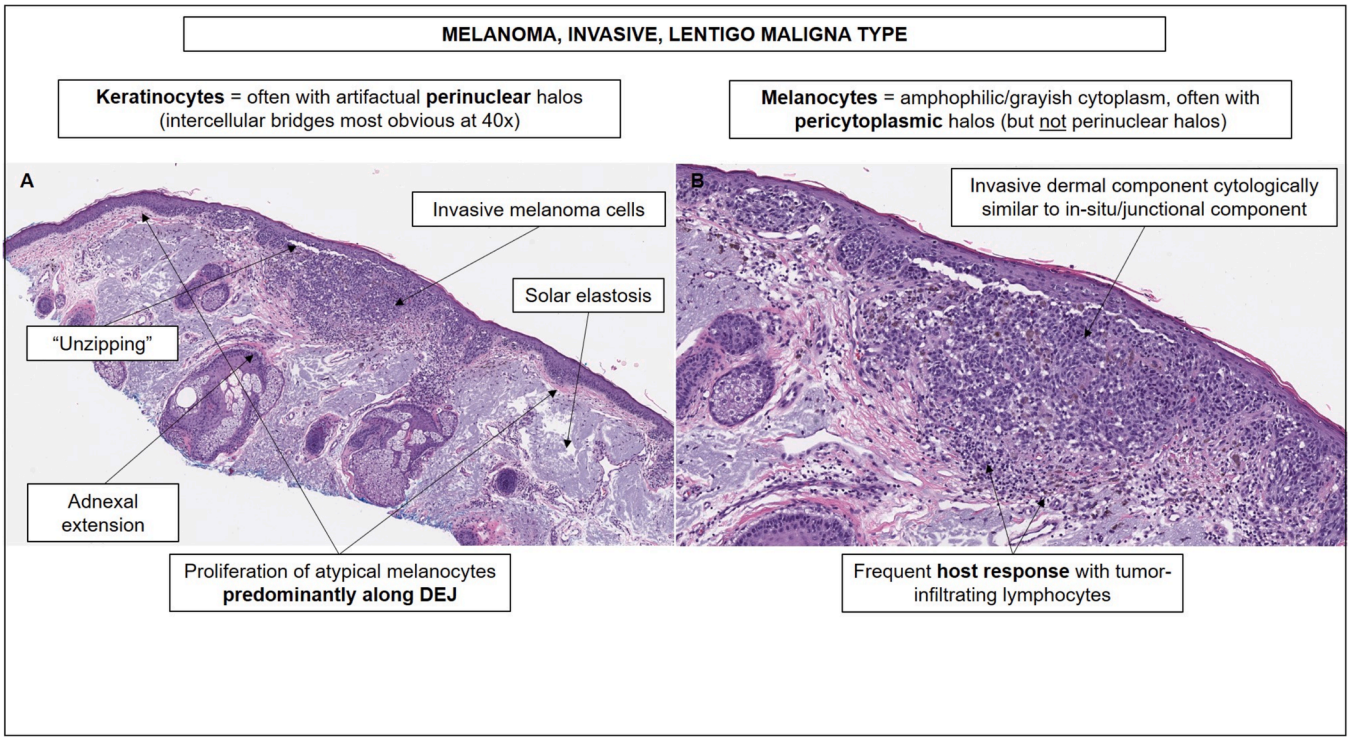

Fig. 4. Image-based teaching slides highlighting key histological features of lentigo maligna melanoma (A and B, hematoxylin and eosin, original magnification ×10 and ×20, respectively). Abbreviation: DEJ = dermal-epidermal junction.

4. Discussion

WSI technology provides a virtual environment in which one can view and control digitally captured, high-resolution images representing tissue sections from glass slides on a computer screen. It simulates the operation of conventional light microscopy—except that one uses a computer mouse to navigate the field of tissue sections and adjust magnification instead of a stage and fine/coarse adjustment knobs as in a microscope. The usage of WSI has been gradually gaining popularity in pathology practice in recent years, particularly in the field of

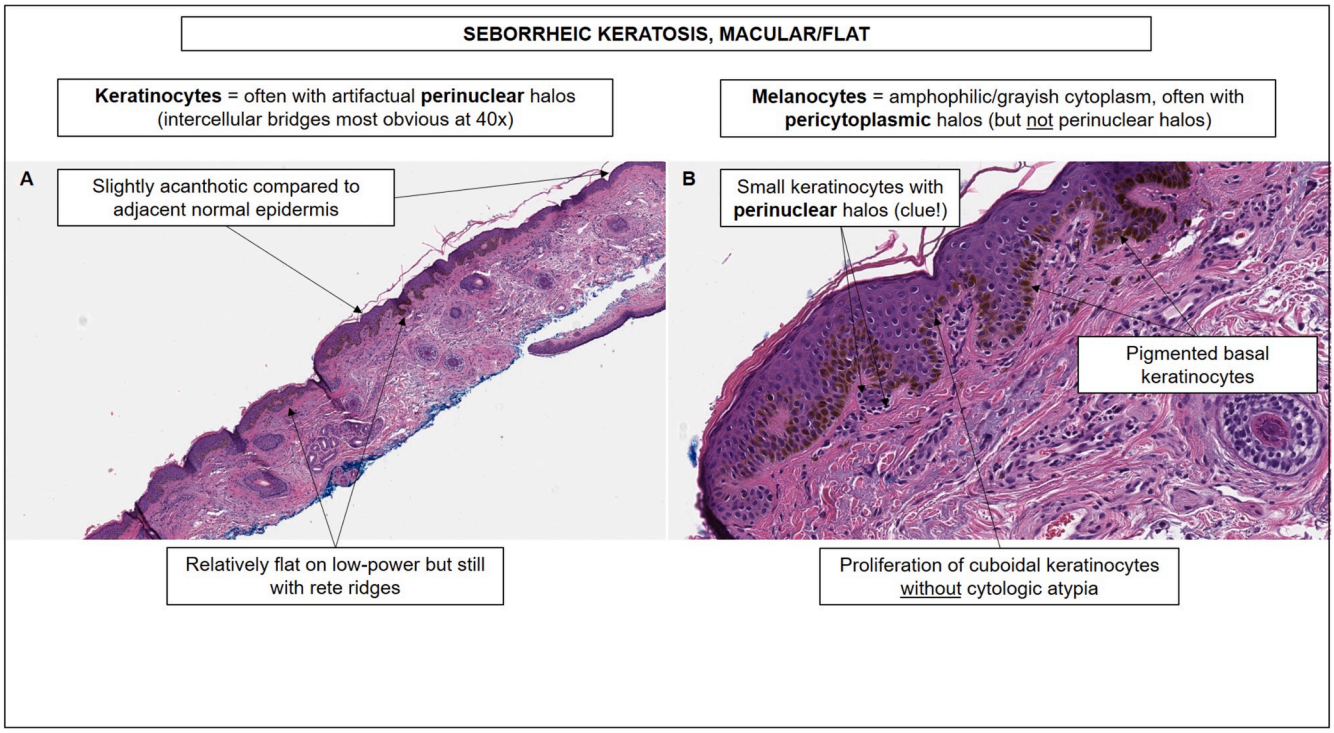

Fig. 5. Image-based teaching slides highlighting key histological features of macular seborrheic keratosis (A and B, hematoxylin and eosin, original magnification ×10 and ×20, respectively).

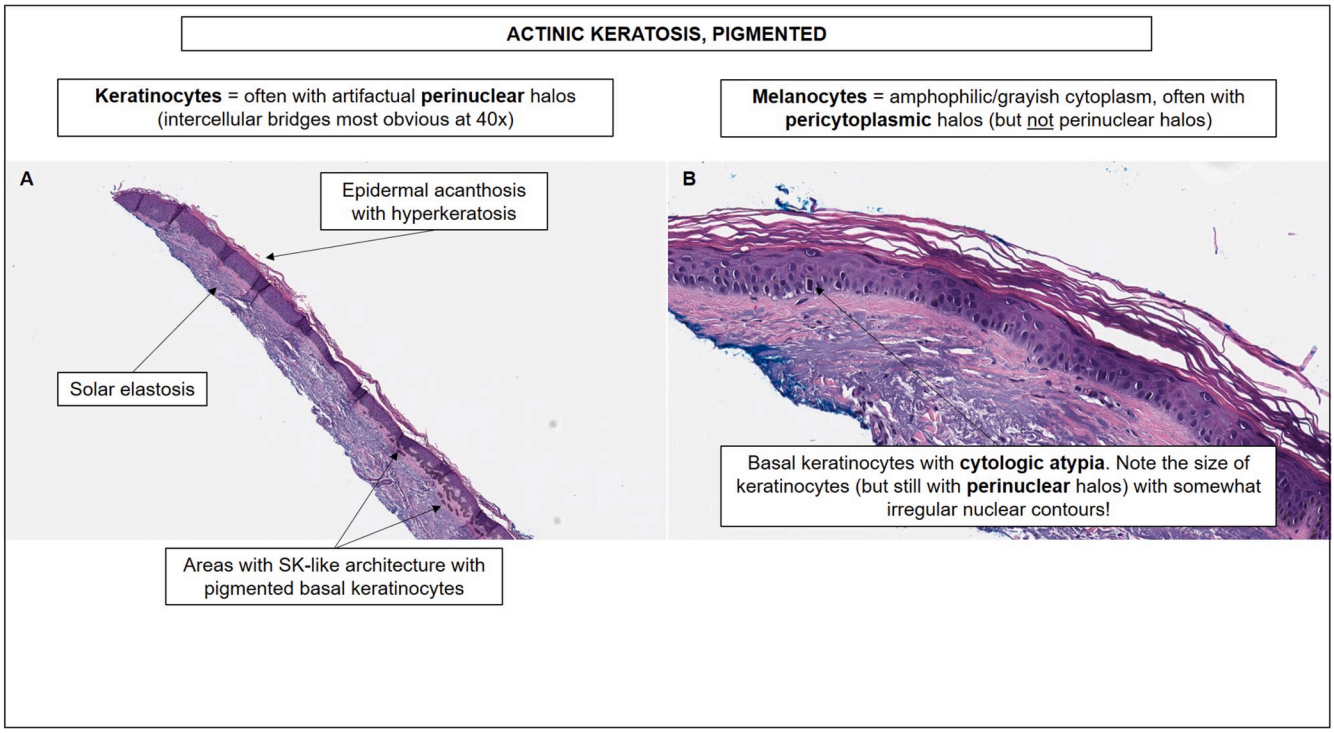

Fig. 6. Image-based teaching slides highlighting key histological features of pigmented actinic keratosis (A and B, hematoxylin and eosin, original magnification ×10 and ×20, respectively). Abbreviation: SK = seborrheic keratosis.

dermatopathology, for the many benefits it provides, including a high diagnostic concordance rate between WSI and traditional light microscopy, enhanced workflow, easier accessibility of archived glass slides, ability to annotate slides, and improved quality assurance activities [8,14-16]. It has also become an integral part of pathology education due to its utility as a teaching tool that further supplements 1-to-1 sign-out or in-person didactics at a dual- or multiheaded microscope, a feature that is most desired in a difficult time like this with the current global pandemic.

In our study, we successfully demonstrated the utility of WSI-based,

Table 1
Pathology fellows' online survey participation rates.

	First survey	Second survey
Group type (n)	Participation rate (n)	Participation rate[b] (n)
Overall (28)	61% (17)	39% (11)
SP fellow (12)	75% (9)	42% (5)
Subspecialty fellow[a] (10)	60% (6)	40% (4)
Cytopathology fellow (6)	33% (2)	33% (2)

Abbreviation: SP, surgical pathology.
[a] Subspecialty fellows included 2 breast pathology fellows, 2 genitourinary pathology fellows, 2 gynecological pathology fellows, 1 bone and soft tissue pathology fellow, 1 head and neck pathology fellow, 1 gastrointestinal pathology fellow, and 1 thoracic pathology fellow.
[b] There were 2 additional SP fellows who only completed the second survey; thus, their scores were not included in the study.

trainee-oriented SA learning as a source of improving diagnostic skills of pathology trainees in a relatively short period of time. The entire study period was approximately 6 weeks. The teaching slides (Figs. 2, 3, 4, 5 and 6) provided to the participants between each survey as a SA tool played an important role in improving the trainees' visual recognition of cytomorphologic changes seen in PCLs tested in our study. They were primarily image-based with minimal texts; key histological features that help distinguish one entity from another were highlighted by arrows to draw trainees' attention and to simulate an environment wherein an attending pathologist would normally point such features out for trainees at in-person sign-out had there been no COVID-19 pandemic. Furthermore, knowing our fellows' busy schedules with a high daily caseload, we also took the amount of time it would take for them to review the SA into consideration; we limited the number of PowerPoint slides of the SA to 15 and estimated the whole review time to be 10 min or less. As a result, most of our fellows (7 of 11) who had completed all 3 components demonstrated an improved diagnostic accuracy in 4 types of PCLs tested herein (Table 2). Four fellows showed no improvement in their scores; however, 2 of these participants had already scored greater than or equal to 8 on their initial assessment, with relatively little room for further improvement (Table 2). Nonetheless, it was remarkable to see a striking improvement in 1 fellow whose score jumped 8 points following SA, which further supports the utility of a combination of digital pathology and supplemental image-based teaching slides as an effective trainee-oriented learning tool. This is particularly important in the era of the COVID-19 pandemic when the return to fully normalized traditional in-person sign-out and teaching continues to remain uncertain in the foreseeable future. As of this writing, despite the gradual increase in COVID-19 vaccination rates in both our institution and nearby communities, all lecture courses and didactics are still being delivered virtually through various commercially available platforms, such as Zoom (Zoom Video Communications, San Jose, California) or WebEx (Cisco, Milpitas, California), and double-scoping or groups sign-outs to the capacity similar to that of the pre-COVID-19 era have not been fully restored in our Department.

It is noteworthy that, intriguingly, our trainees appeared to have struggled more on benign lesions, such as SK and AK, than on malignant lesions (Table 3). There were 2 questions in our test set whose post-SA scores by the participants declined compared to their pre-SA counterparts: Questions 1 and 3 in the first survey, which correspond to SK and AK, respectively. There was another question of SK (Question 8 in the first survey) that showed the lowest diagnostic accuracy rate in both surveys. Coincidently, these 2 questions of SK were macular/flat type SKs, like the example provided in the SA (Fig. 5). Although it is hard to draw definitive conclusions from this study with a small number of participants, it is possible that these types of cutaneous lesions, macular SK and pigmented AK, are perceived to be challenging by general surgical pathologists, especially when the classical morphological features that they might have anticipated (e.g., pseudo-horn cysts in SK, basal keratinocytic atypia without pigment in AK) are absent. Perhaps, this may be one of the areas where further subspecialty training in dermatopathology is necessary to solidify pattern recognition of the subtle changes in various cutaneous lesions and thus to avoid diagnostic discrepancies. In one study that investigated the diagnostic discrepancy rate for skin biopsies reported by general surgical pathologists, 6.5% (38 of 589) of them were found to have discrepancies, 21% of which (8 of 38) were of potential clinical significance [13]. More recently, 22% (91 of 405) of skin biopsies were found to show major diagnostic discrepancies, 92% (84 of 91) of which were diagnosed by general surgical pathologists without further subspecialty training in dermatopathology [17]. Nonetheless, pigmented cutaneous lesions, as those tested herein, are frequently encountered in general practice, and given these lesions are one of the most common sources of medicolegal issues for pathologists in general [18-20], it is crucial for general surgical pathologists to get accustomed to and be proficient in the diagnosis of these lesions.

Table 3
Pre- and post-self-assessment survey question diagnostic accuracy rate by lesion type.

First survey question[a]	Second survey question[a]	Lesion type	Participants' pre-SA diagnostic accuracy rate	Participants' post-SA diagnostic accuracy rate
1	3	SK	64% (7/11)	55% (6/11)
2	5	AK	45% (5/11)	82% (9/11)
3	2	AK	55% (6/11)	36% (4/11)
4	10	MIS, LM type	55% (6/11)	64% (7/11)
5	9	MIS, LM type	45% (5/11)	64% (7/11)
6	1	SK	64% (7/11)	100% (11/11)
7	4	MIS, LM type	73% (8/11)	100% (11/11)
8	6	SK	9% (1/11)	36% (4/11)
9	7	MIS, LM type	18% (2/11)	82% (9/11)
10	8	LM melanoma	91% (10/11)	100% (11/11)

Abbreviation: SA, self-assessment; SK, seborrheic keratosis; AK, actinic keratosis; MIS, melanoma in situ; LM, lentigo maligna; WSI, whole slide image.
[a] Identical WSIs were used for both online surveys and the second set was distributed to the participants after shuffling as shown above.

Table 2
Pre- and post-self-assessment scores by fellows who participated in at least one survey.

Participant[a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Pre-SA score	5	3	8	7	1	5	6	7	4	4	0	9	8	4	7	1	5	–	–
Post-SA score	5	6	9	7	9	–	–	9	–	6	3	9	8	–	–	–	8	4	10
Δ in score[b]	0	+3	+1	0	+8	–	–	+2	–	+2	+3	0	0	–	–	–	+3	–	–

Abbreviation and symbol: SA, self-assessment; Δ, difference.
[a] Fellows who completed at least one survey were arbitrarily numbered 1 through 19 and their corresponding score results from either one or both surveys were listed.
[b] Only 11 participants who completed both surveys were included in statistical analysis. The mean pre- and post-SA scores were 5.2 and 7.2, respectively, with a mean difference in score of 2.0. Overall, the difference between the two survey individual scores were statistically significant ($p = 0.003$).

In conclusion, our experience has demonstrated that digital pathology in conjunction with supplemental image-based teaching slides helps reduce diagnostic errors in commonly encountered PCLs by pathology trainees and may serve as an effective, trainee-centered learning tool throughout the COVID-19 pandemic and even beyond. Its utility is not limited to dermatopathology, in our opinion, and this teaching method can certainly be applied to other subspecialties or organ systems and other training programs provided appropriate infrastructures and resources for WSI are available.

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