

Color Calibration for Digital Cytology Scanner

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Abstract

Color calibration is complex. The method by which whole slide imager (WSI) systems observe color is different from the way the human eye does, thus images need to be processed to interpret these differences. The standard method of determining the difference between color truth and the WSI image is by imaging a calibrated color slide and comparing spectral variations via CIE ΔE standards. Further complexity is added to this process when the WSI manufacturer must determine what colors the scanner requires for adequate calibration. The next issue is to determine how much variation is acceptable for the human eye and computer algorithms. The construction of the calibration slide must also be considered.

Objectives

- Measure the color accuracy (ΔE) of uncalibrated Hologic WSI system
- Select a calibration slide with suitable color palette for digital cytology
- Generate a color calibration (ICC) profile and apply to Hologic WSI system
- Discuss importance of color calibration on WSI system

Sierra Calibration Slide

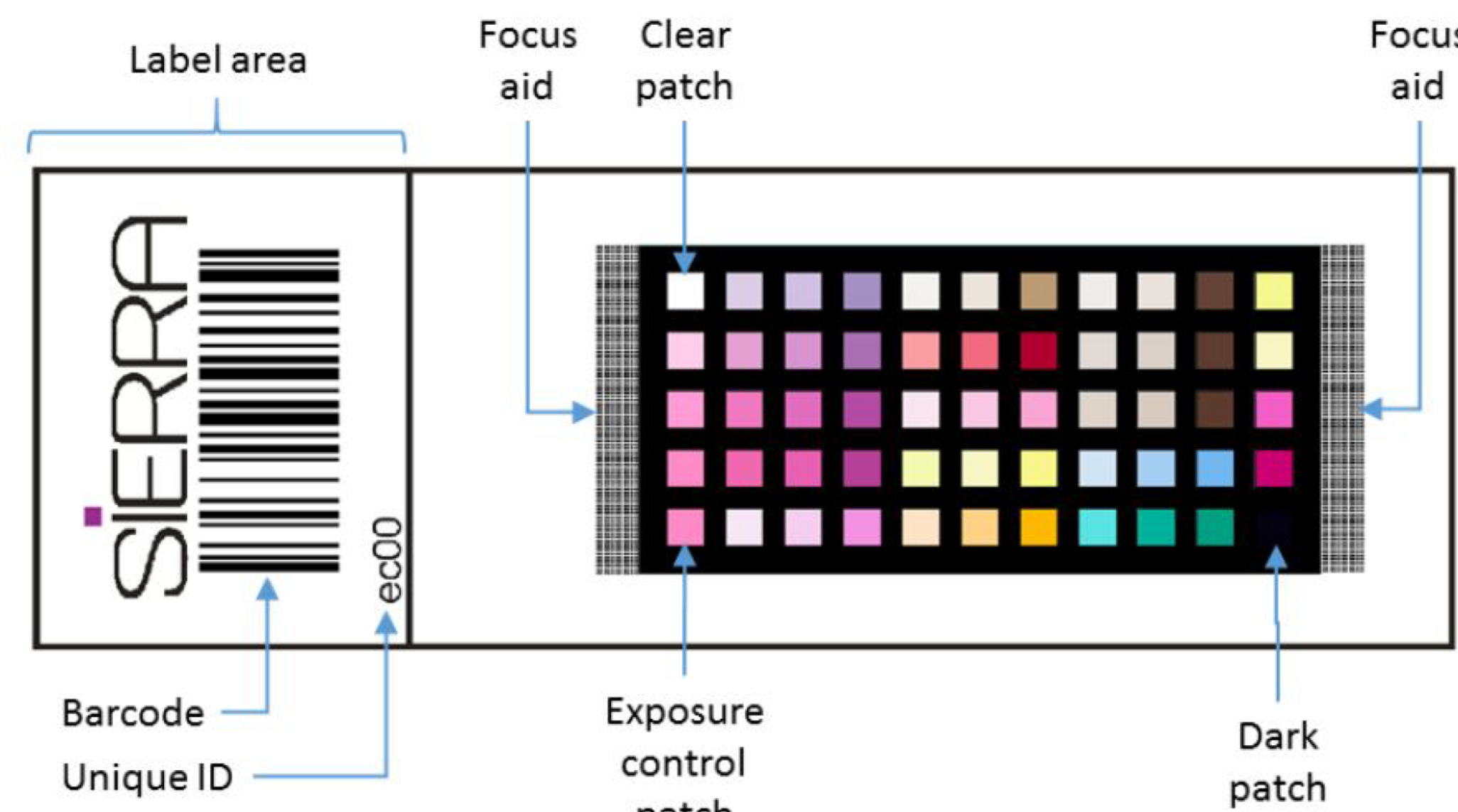
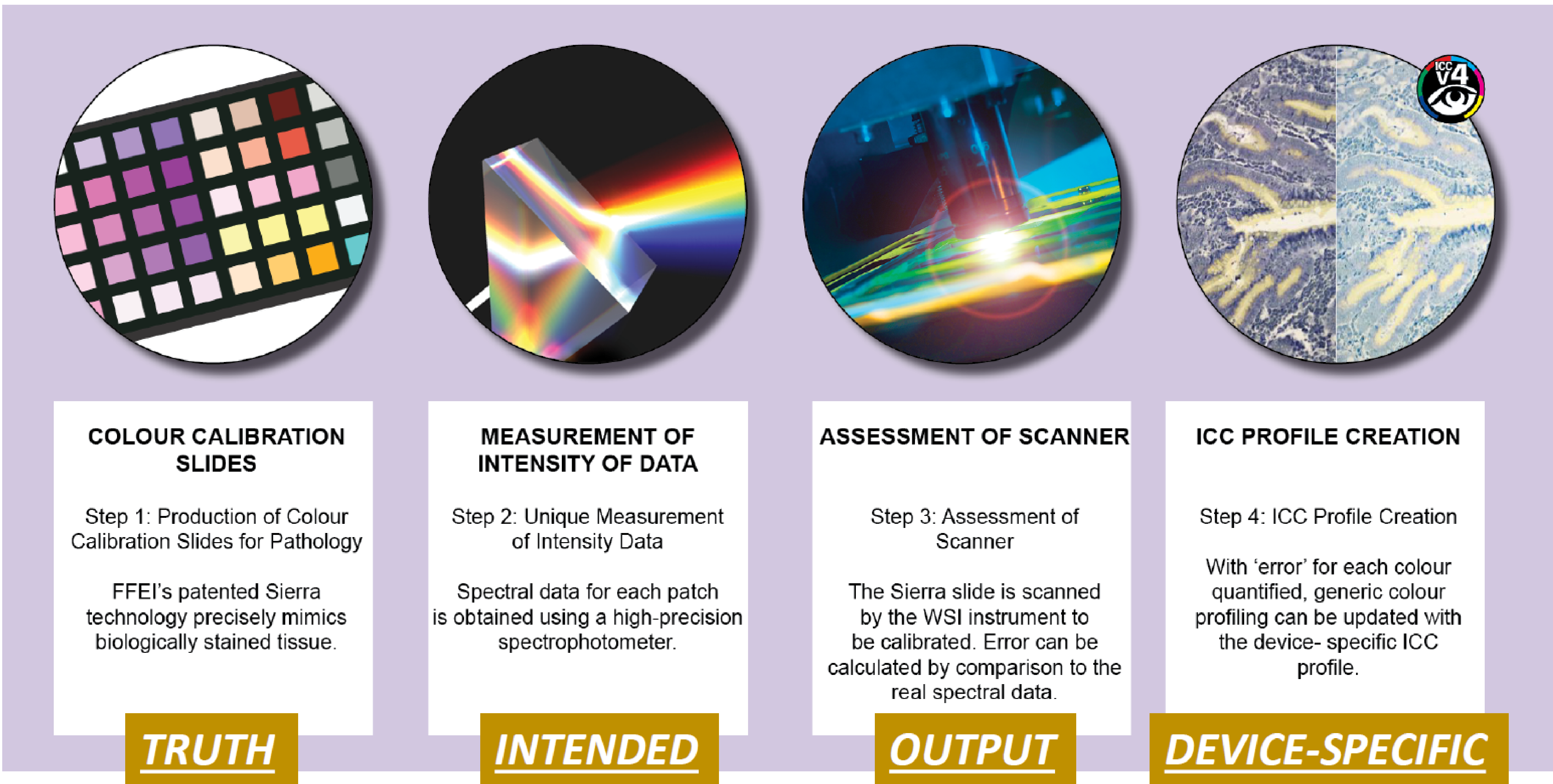


Figure 1 - Sierra Slide

The FFEI Sierra slide shown in Figure 1 incorporates 55 patches of a material that mimics the way stains bind to tissue, which when stained using common histology and cytology stains from across the color gamut of pathology creates an accurate measure of ground truth color as found in histological and cytological samples. With this color truth captured, the Sierra slide can be scanned on the WSI device to be calibrated with the resultant image containing the color errors introduced by digitization.

WSI Calibration Process

Biological 'Ground-Truth' Method for Solving a Digital Problem



SCAN ME

References

1. Revie C. Development of a novel tissue-mimicking color calibration slide for digital microscopy. Color Research and Application. 2017 Oct 09 <https://onlinelibrary.wiley.com/doi/abs/10.1002/col.22187>
2. Anderson N. Technical Performance Assessment of Digital Pathology Whole Slide Imaging Devices. FDA, Division of Molecular Genetics and Pathology 2016 Apr 16 <https://doi.org/10.3109/10520295.2015.1044566>
3. International Commission on Illumination (CIE), Colorimetry - Part 6: CIEDE2000 Colour-Difference Formula, ISO 11664-6:2014 <https://www.iso.org/standard/63731.html>

ICC Profile Creation

Using the ground truth slide measurements and the scanned color with errors, the color difference introduced by WSI can be calculated, represented as Delta E values using the CIEDE2000 formula accredited by ISO11664-6. From this data, a corrective ICC profile is computed through multi variant interpolation, resulting in a set of correction factors for which each displayed color is adjusted to achieve color reality. Complete accuracy and standardization across a scanner portfolio is achieved by each individual scanner deploying a unique ICC profile with unique corrective ratios. ICC profiles produced by FFEI's Sierra technology are DICOM and ISO 15076-1 compliant and meet the FDA Guidance of 2016 as shown in Figure 2.

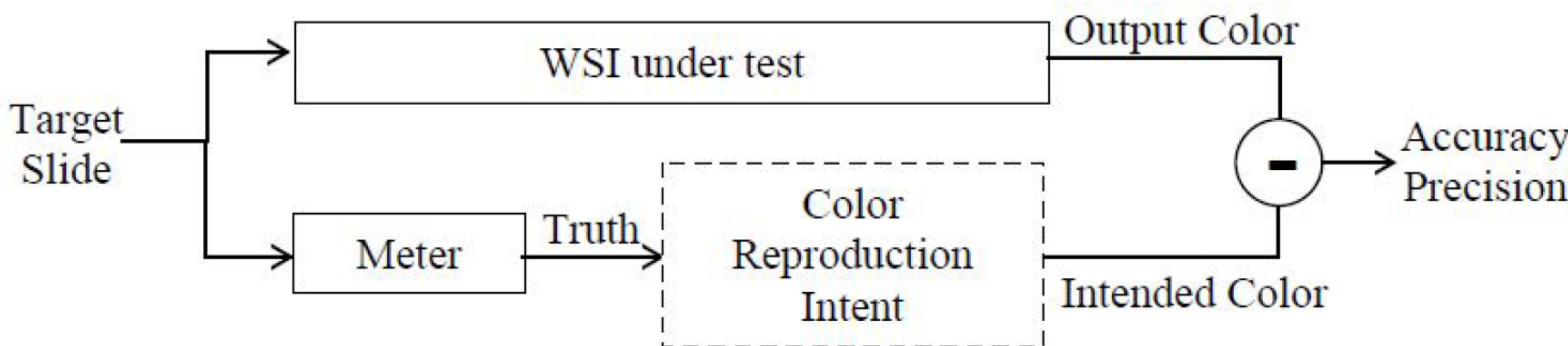


Figure 2 - FDA Guideline for Color Accuracy Measurement

Results: Color Accuracy Measurements

The data below shows the Hologic WSI system before and after color calibration. Figure 3 shows the error of the Hologic WSI without color correction. Figure 4 shows the color accuracy of the Hologic WSI with the Sierra ICC profile applied. Figure 5 and 6 show actual cytology specimen with and without the Sierra ICC profile applied. The Hologic Digital Imager (WSI) when using Sierra reduces color variation to less than 2 ΔE for intended color range. When the digital image is passed on to a review station or an algorithm platform, the color fidelity is maintained.

Figure 3 - Raw Scanner Variation (ΔE)

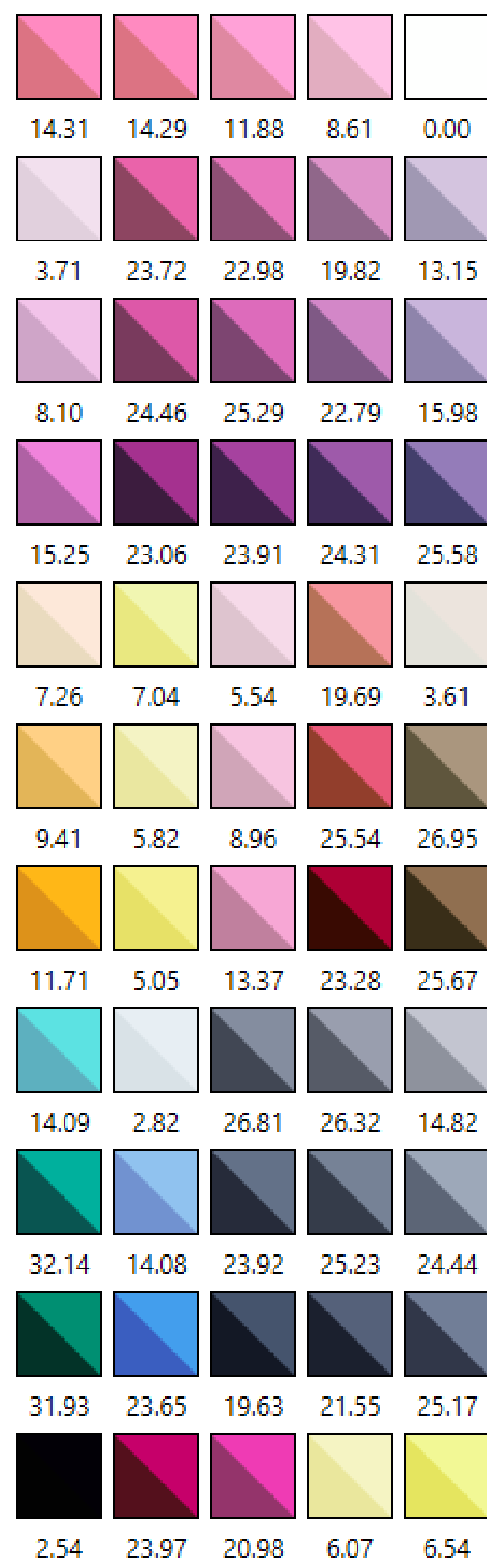


Figure 4 - Scanner Variation (ΔE) after ICC Profile Applied

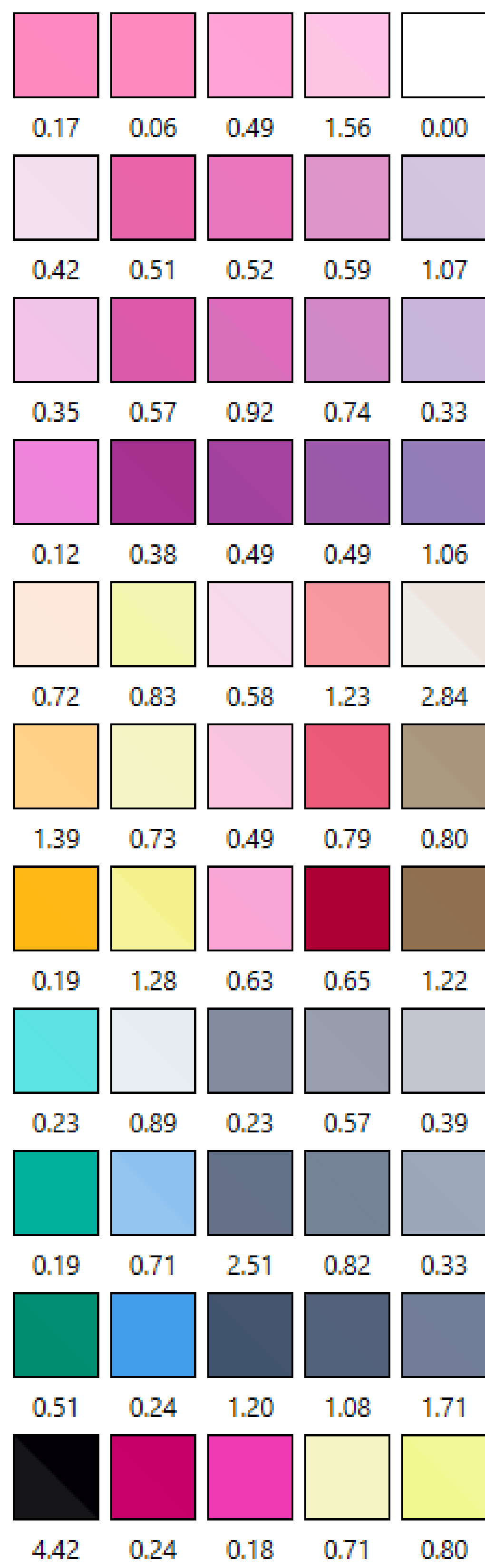


Figure 5 - Raw Scanner Variation (ΔE)

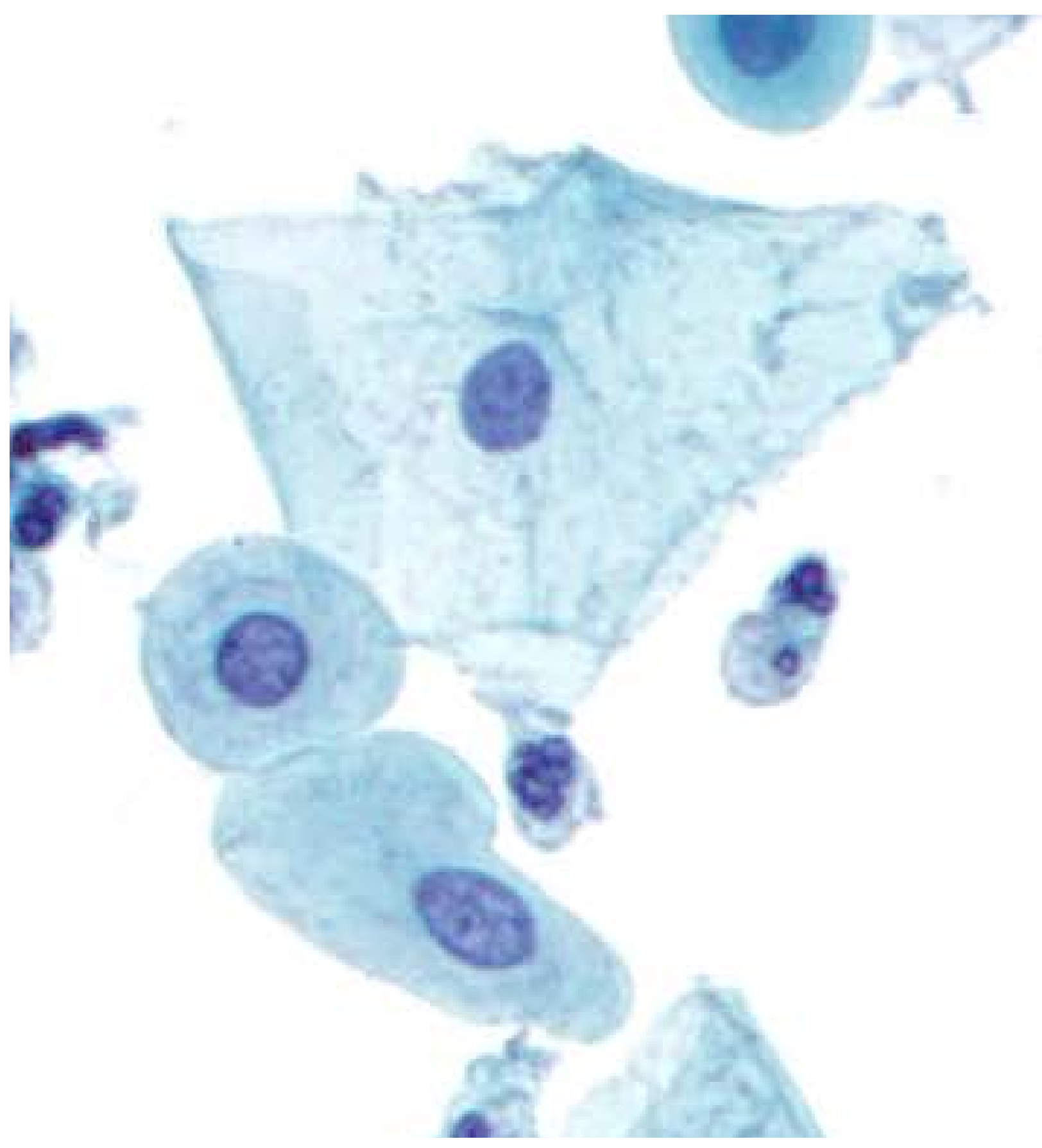


Figure 6 - Scanner Variation (ΔE) after ICC Profile Applied

Conclusions

WSI systems seeking usage for primary diagnosis require color calibration. The Sierra slide provides acceptable color calibration for the Hologic cytology WSI system. The amount of spectral variation (ΔE) acceptable for WSI is subjective based on many factors, with most literature citing ΔE of 5 or less. Color calibration minimizes system to system WSI variability, producing repeatable color output regardless of system age or optical component variation.