Optical coherence tomography: beware of optical illusions

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Standardised disturbance of the optical coherence tomography signal has varying effects on the scan quality assessment when comparing four devices.

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ABSTRACT

Purpose. Assess the change in subjective image quality and image quality parameter (IQP) provided by four different spectral-domain optical coherence tomography (SD-OCT) devices using artificial filters simulating optical eye media disturbances.

Methods. In four healthy subjects, single non-averaged B-scans of the macula were acquired using four commercially available SD-OCT systems; 3D OCT-1000 MarkII (Topcon Medical Systems, Inc, Oakland, New Jersey, USA); Cirrus HD-OCT (Carl Zeiss Meditec, Dublin, California, USA); RTVue OCT (Optovue, Inc, Fremont, California, USA); and Spectralis OCT (Heidelberg Engineering, GmbH, Heidelberg, Germany). Four series of artificial filters, with known optical density (OD), were placed in front of the eye while scanning.

Results. A rather precise linear relationship was found between the OD of the filters and the change in the IQP of the device but with different slopes. This indicates that light attenuation is the main factor determining the IQP provided, but also that the IQPs are not directly comparable. Images made through the same filter demonstrated differences in visualisation of the preretinal, intraretinal and subretinal structures, and background noise. OD values of the selected images with identical, barely distinguishable intraretinal structures varied between instruments from OD 0.54 to OD 0.75.

Conclusion. Equal disturbances of the OCT signal have different effects on subjective scan quality and the IQP provided by the instrument in the four SD-OCT devices investigated. Standardisation of the IQP, which would be desirable in order to compare different devices and study results, seems to be impossible.
INTRODUCTION

Optical coherence tomography (OCT) has become a successful application in ophthalmology. Time-domain OCT (Stratus, Carl Zeiss Meditec) has been overtaken by spectral-domain OCT (SD-OCT) which has major advances in imaging speed, sensitivity and image resolution. Several SD-OCT devices are commercially available. In this small study, we assessed the change in subjective image quality and image quality parameter (IQP) provided by four different SD-OCT devices using artificial filters simulating optical eye media disturbances.

MATERIALS AND METHODS

In four healthy subjects, single non-averaged B-scans of the macula were acquired using four commercially available SD-OCT systems:

1. 3D OCT-1000 MarkII (Topcon Medical Systems, Inc, Oakland, New Jersey, USA): Software V.3.21, 27,000 A-scans per second, superluminescent diode 840 nm light source, 5–6 micron axial resolution, ‘Q-factor’ IQP scale 0–100.
2. Cirrus HD-OCT (Carl Zeiss Meditec, Dublin, California, USA): Software V.2.0, 27,000 A-scans per second, super-luminescent diode 840 nm light source, 5 micron axial resolution, ‘Signal Strength’ IQP scale 0–10.
3. RTVue OCT (Optovue, Inc, Fremont, California, USA): Software V.2.0.4.0, 26,000 A-scans per second, superluminescent diode 840 nm light source, 5 micron axial resolution, ‘Signal Strength Index’ IQP scale 0–100.

Four series of artificial filters, with a reflective, an absorbing (both attenuating), a scattering (straylight), and refractive (defocusing) property, respectively, were placed in front of the eye while scanning 20 filters in total. The effective optical density (OD) of the filters, ranging from low to high, was calculated as described previously and compared with the IQP of the OCT images as supplied by the different devices.

RESULTS

For each SD-OCT device, a rather precise linear relationship was found between the optical density of the filters and the change in the IQP of the device (Q-factor, signal strength, signal strength index and quality), but with different slopes (see Figure 1, p<0.0001). This indicates that light attenuation is the main factor determining the IQP provided, but also that the IQPs are not directly comparable. Moreover, figure 1 shows that differences between filter types are small.
Figure 2 shows OCT images made with the four devices, without filter, through an identical filter and through a filter selected to result in an image with identical, barely distinguishable intraretinal structures. Images made through the same filter (OD=0.54) demonstrated differences in visualisation of the preretinal, intraretinal and subretinal structures, and background noise. OD values of the selected images with identical, barely distinguishable intraretinal structures varied between instruments from OD 0.54 to OD 0.75.

DISCUSSION

As expected, there was a rather precise linear relationship between the optical density of the filters and the IQPs, confirming that attenuation of the OCT signal is the main determinant of the IQP calculation. The observed differences in the effect of a series of filters with different OD on the subjective quality of images and on the IQPs are probably caused by differences in hardware, acquisition methods and postacquisition processing of the signal. The range of quality measures and the basis for image quality assessment are not comparable across instruments. Note that we used single non-averaged B-scans, whereas averaging processes and eye tracking improves image quality, which is for example used in standard Spectralis OCT volume scanning.

In conclusion, equal disturbances of the OCT signal have different effects on subjective scan quality and the IQP provided by the instrument in the four SD-OCT devices investigated. Standardisation of the IQP, which would be desirable in order to compare different devices and study results, seems to be impossible.

![Figure 1](image.png)

**FIGURE 1.** Correlation between the percentage change in image quality parameter and the optical density of the filters used. Pearson correlation 3D optical coherence tomography (OCT)-1000 MarkII $R^2=0.98$, $p<0.0001$; Cirrus $R^2=0.93$, $p<0.0001$; RTVue $R^2=0.93$, $p<0.0001$; Spectralis, $R^2=0.82$, $p<0.0001$. 

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Comparison of OCT scan quality among four devices
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FIGURE 2. Optical coherence tomography (OCT) images made with the four devices, without filter, through an identical filter (optical density (OD)=0.54) and through a filter resulting in an image where intraretinal structures can be just distinguished.

REFERENCES