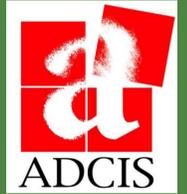




Repeatability and Validation of Scheimpflug Scleral Data

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PURPOSE

The purpose of this project is to assess the repeatability and validate the elevation data of the scleral profile using Scheimpflug corneo-scleral profiling (CSP).

METHODS

The Scheimpflug technology normally captures up to 12 mm of central corneal surface. With enhanced software, the coverage can be extended up to 17 mm vertically and 18 mm horizontally (acquired through 5 scans). This is accomplished by:

- Using lower light for measuring the peripheral scleral area.
- The 4 peripheral exams (nasal, temporal, superior, inferior) are captured in primary gaze by displacing the machine 1.65 mm, rather than adjusting fixation.
- The 5 exams (4 peripheral and one central) are stitched together to create one 3D shape file with 18 mm of corneal and scleral data. As there is no fixation displacement during image capture, tilt reconstruction is not necessary. Each sub-exam uses 50 segmental images, so a total of 250 images are captured during the acquisition phase.

14 eyes were scanned at 2 different time points (T1 and T2) using CSP. These scans were imported into a modified version of the EyePrint™ Designer Software. Additionally, a digitized impression (DI) was generated as an STL file for the 14 eyes at T1.

The DI and CSP datasets are defined with two different coordinate systems; therefore, an automatic registration step is necessary. Similarly, the 2 CSP files captured at T1 and T2 were automatically registered, one on top of the other to assess the difference between them.

METHODS (CONTINUED)

The registration algorithm uses the following steps to register a CSP over a Reference Surface (RS), which is either a DI or a CSP:

1. Using manually positioned limbus points on the RS, determine the visual axis and compute the initial RS highest point (apex);
2. Translate the CSP to be registered so that its Vertex Normal (VN) matches the RS apex;
3. Rotate the CSP up to 5° around its X axis to minimize its distance to the RS. As it is rotated, update the RS apex according to the CSP Z axis (visual axis), and reposition the CSP accordingly;
4. Similarly, rotate the CSP up to 5° around its Y axis to minimize its distance to the RS;
5. Iterate steps 3 and 4 three times ;
6. Finally, rotate the CSP up to 2° around its Z axis until its squared distance to the RS is minimized.

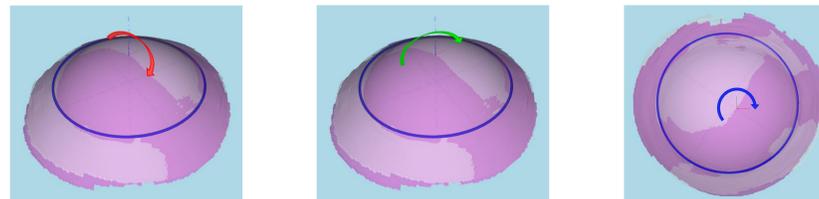


Figure 1: Rotations along the CSP X, Y, and Z axes

The following results were generated after running the algorithm:

- Root Mean Square (RMS) of distance between CSP datasets at T1 and T2;
- RMS distances between CSP at T1 and DI, and CSP at T2 to DI;
- RMS distance between each CSP and itself, to assess the algorithm intrinsic inaccuracy.

A comparison was also performed on the maximum (i.e. ellipse major axis) limbal diameter between CSP at T1, T2, and DI.

RESULTS

	RMS CSP T 1 vs DI	RMS CSP T 2 vs DI	RMS CSP T1 vs T2	Limbal diameter max CSP auto (mm)	Limbal diameter max CSP manual (mm)	Limbal diameter max EP(mm)
Eye #1	0.064447	0.064703	0.082619	11.68	12.09	12.33
Eye #2	0.094008	0.098795	0.105413	11.79	12.10	12.53
Eye #3	0.094255	0.090186	0.051320	11.42	11.72	11.95
Eye #4	0.072263	0.088035	0.072934	11.41	11.74	11.83
Eye #5	0.068831	0.086754	0.079106	12.45	12.87	13.56
Eye #6	0.062159	0.070276	0.037865	12.16	12.41	13.14
Eye #7	0.078770	0.084152	0.075070	12.30	12.38	12.85
Eye #8	0.105042	0.103524	0.041144	12.63	12.99	13.39
Eye #9	0.132996	0.126536	0.080783	12.55	12.63	12.76
Eye #10	0.189965	0.189253	0.059661	11.92	12.14	12.84
Eye #11	0.058301	0.062743	0.103244	12.10	12.17	12.84
Eye #12	0.084826	0.069242	0.042852	11.72	11.97	13.05
Eye #13	0.055523	0.056843	0.030539	11.98	12.05	12.76
Eye #14	0.083371	0.089727	0.028619	12.09	12.17	13.28
Average	0.088911	0.091484	0.063655	12.01	12.25	12.79
STD Dev	0.035805687	0.033702753	0.025594599	0.387193338	0.377333764	0.503810208

Figure 2: RMS distances, max limbal diameter for CSP and DI

- Not all CSP scans were able to reach 4 mm past the limbus. The average CSP scan yielded 2.5 mm of usable scleral elevations.
- The average RMS difference between the 2 CSP scans is 0.064 mm with a SD of 0.026 mm.
- The average RMS difference between CSP T1 and DI is 0.089 mm with a SD of 0.036 mm.
- The average RMS difference between CSP T2 and DI is 0.091 mm with a SD of 0.034 mm.

CONCLUSIONS

- Scheimpflug scanning data provides reasonable elevation measurements up to 18 mm, which are consistent over multiple scans and corresponds to impression elevations.
- The greatest deviation between the CSP scans and the digitized impression was the limbal diameter. This may arise from discrepancies in how to identify the limbus. The CSP software consistently chooses a maximum limbal diameter almost 0.25 ± 0.132 mm smaller than manual detection on the same scans. Manual detection of the limbal diameter of the DI was about 0.75 ± 0.308 mm larger than the automatic detection in the CSP software.