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Key words: experimental ocular inflammation, intravenous endotoxin, altered vascular permeability, $^{125}$I-albumin measurement, prostaglandins, aspirin and indomethacin, platelets, rabbits.

REFERENCES


This report compares the reproducibility of analog and digital photogrammetry for topographical analysis of the optic cup. Ten simultaneous stereophotographs of each of three optic discs were taken with the Zeiss fundus camera plus a twin-prism stereoseparator. Digital processing produced photogrammetric contours of the optic cup and estimates of its geometry. Optic cup contours from the same stereopairs were also drawn with an analog stereoplotter and were analyzed by manual planimetry. The reproducibility of digital photogrammetry and analysis for estimation of cup depth, cup width, cup cross sectional area, and cup volume was concluded to be generally superior to the reproducibility of analog photogrammetry and manual analysis.

Both analog and digital stereophotogrammetry have achieved quantitative analysis of fundus topography. In addition, simultaneous fundus stereography improves the reproducibility potential for optic cup analysis by photogrammetry. Even with simultaneous stereophotography, however, photogrammetric analyses have reproducibility errors. Subtle changes in photographic exposure, retinal illumination, and viewing angle may produce slight changes in the subjective interpretations of the photogrammetrist or in the objective interpretations of the computer.

In addition to reproducibility, other factors such as precision, capacity, cost and convenience will determine which method of photogrammetry is most suited for any given application. For example, large-scale clinical studies might be handled most efficiently by the digital method, whereas individual research cases might be handled as easily by the analog method. Each system offers advantages depending on the user's resources and needs.

This report compares the reproducibility of analog and digital photogrammetry for analysis of optic cup configurations.

Methods. To determine the effect of the optic cup configuration on the reproducibility of topographical analysis, we chose three eyes having cups of different shapes and sizes for study. These eyes were dilated with 10 per cent phenylephrine (Neo-Synephrine) and 1 per cent tropicamide (Mydriacyl). Ten simultaneous stereophotographs (Fig. 1) of each of the three optic discs were then taken with the Zeiss fundus camera using a high-quality twin-prism stereoseparator. Pupil size ranged from 7 to 9 mm. The stereophotographs were taken over a 1 to 2 hour time span.
Digital photogrammetry produced contour maps (Fig. 2, A) for each stereophotograph. Subsequent digital analysis achieved estimates of cup depth, horizontal and vertical cup width, horizontal and vertical profile areas, and cup volume. To achieve our estimates, an elliptical paraboloid was fitted to the cup contours by a chi-square procedure. The top of the cup was similarly defined by fitting a flat plane to the data points falling in a ring centered on the axis of the parabola and having an inner diameter of 1.25 mm and an outer diameter of 1.50 mm. The parameters were defined as follows: (1) cup depth—perpendicular distance between the top of the cup and the deepest point of the cup; (2) cup width—diameter of the cup at half its depth; (3) profile area—that portion of the profile cross section taken through the deepest point of the cup and lying under the top of the cup; and (4) cup volume—space bounded by the top of the cup and the cup surface.

Analog photogrammetry was also applied to the twin-prism photographs. In particular, a trained photogrammetrist, using a Wild A8 stereoplotter, plotted contours (Fig. 2, B) for each of the optic cups studied. The contours were plotted at separate sittings with the order of the discs to be plotted chosen randomly. Appropriate cross sections (Fig. 3) of the contour maps were constructed to obtain estimates for the cup depth, horizontal and
Fig. 2. Contours of the same optic cup. A, By digital photogrammetry. B, By analog photogrammetry.

Fig. 3. Contours of optic cup, and the corresponding horizontal profile drawn through the deepest point of the cup.

vertical cup width, horizontal and vertical profile area, and cup volume from manual planimetric readings. The following additional definitions were used in order to achieve consistent parameter estimates (Fig. 3): (1) top of cup—straight line connecting the disc edges as perceived by the photogrammetrist; (2) cup depth—distance between the top of the cup and the deepest point of the cup, averaged from the estimates taken from the horizontal and the vertical cross sections; (3) cup edge—the point, when going from the center of the cup toward the disc margin, where the absolute value of the slope of the cup last begins to decrease; and (4) cup volume—sum of the increment volumes as determined from horizontal sections selected at intervals from the superior to the inferior margins of the cup.

Results. Since the two methods of photogrammetry used different scaling factors to achieve their results, a direct comparison of the optic cup parameters is not meaningful. Accordingly, the results are reported in Table I as per cent error (i.e., standard deviation/mean). The depth sensitivities of the two methods of photogrammetry were similar, ranging from approximately 50 to 200 μ, depending on the geometric charac-
teristics of the patient's eye. In general, digital photogrammetry and planimetry achieved more reproducible results than did analog photogrammetry and manual planimetry.

**Discussion.** The present study demonstrates that the photogrammetric reproducibility of the digital method is somewhat superior to that of the analog method. One might have anticipated this result as a function of the superior ability of programmable machines over human beings to perform arduous tasks in a similar fashion time after time.

Analog photogrammetry involves the services of a trained photogrammetrist for approximately 1 hour per eye at a cost of about $25. He is limited to approximately 40 eyes per week. In addition, planimetry of contour maps is required. In this study, a trained technician spent approximately 1 hour per eye for manual planimetry. It is anticipated that this portion of the analysis will be automated. Hence the dollar cost and the technician time could be reduced, and the reproducibility improved. Thus, analog photogrammetry appears to be limited primarily by available photogrammetric time and funds. Instamatic photogrammetry as described by Schirmer may improve the practicality and speed of photogrammetric analysis for many applications.

Digital photogrammetry and planimetry involve the services of a computer technician and time on a general purpose digital computer. The system used in the present study required approximately 300 seconds of CDC 6400 computer time per eye at a total cost of about $50 per eye. In principle, digital photogrammetry and analysis could be accomplished with a minicomputer system, with a reduction in processing costs to approximately $15 per eye.

The logistical factors and economic constraints of each photogrammetric system for clinical and research applications must be considered. In particular, the requirements of the photogrammetric methods used in this study might necessitate a laboratory service, perhaps independent of the ophthalmologist or of his institution, to be cost-effective. Capital expenditures, such as for the computer or the stereoplotter, and the programming costs could then be shared by all users of the service. On the other hand, analog photogrammetry with a table-top stereoplotter, such as described by Schirmer, might be accomplished by an ophthalmologist's assistant. Thus, a wide range of photogrammetric capability is available. In order to achieve efficient resource utilization, comparisons of photogrammetric systems must be done with respect to their anticipated use.

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**Key words:** optic disc, optic cup, stereophotogrammetry.

**REFERENCES**


**Morphological fiber types of retractor bulbi muscle in mouse and rat.** BRUCE R. PACHTER, JACOB DAVIDOWITZ, AND GOODWIN M. BREININ.

Retractor bulbi muscles of mouse and rat were examined by light and electron microscopy. Two morphological fiber types were observed, analogous to Type I and Type II cells of skeletal musculature and comparable to fibers observed in the global region of the rectus extraocular muscles of these species.

In addition to the four recti, two oblique, and levator palpebrae muscles, the extraocular muscles of some species also include the retractor bulbi (RB); assorted specialized functions have been