

Methodology for Corneal Compensated IOP and Corneal Resistance Factor for An Ocular Response Analyzer

David Luce - Reichert, Inc., Buffalo, New York

Background

Many recent studies of corneal interference with Goldmann applanation tonometry GAT IOP readings have suggested the use of CCT as the basis for a correction algorithm.¹ Weak correlation of CCT and GAT limits the efficacy of this process. Reichert's Ocular Response Analyzer measures viscoelastic properties of the cornea by determining two applanation pressures in response to an air puff stimulus. The analyzer displays four parameters derived from these two pressures - IOPg, a Goldmann equivalent IOP, CH, corneal hysteresis related the difference of the two pressures, IOPcc, a corneal compensated IOP and CRF, an optimized corneal biomechanical parameter.

Purpose

Descriptions of the methods employed in the derivation of IOPcc and CRF are presented..

Method for IOPcc

Figure 1 gives a time plot of the air puff pressure function and the applanation signal (curvature measure). Figure 2 shows a typical set of pre and post LASIK corneal hysteresis and IOPg measurements for a single subject (2 measurements per eye). Note that both the hysteresis and IOPg show reductions after surgery. The decrease in IOPg is due to the same corneal interference observed in GAT IOP measurements.

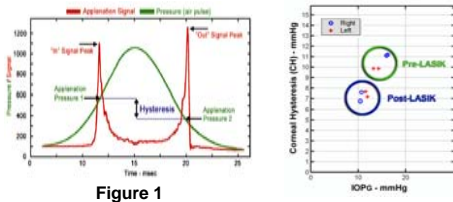


Figure 1

Figure 2

A functional diagram of the IOPcc derivation process is shown in Figure 3.

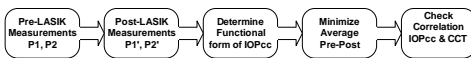


Figure 3

The functional form for IOPcc was determined by examining the behavior of the changes of the P1 and P2 applanation pressures.

Figure 4 demonstrates that the P2 pressures are significantly less affected than P1 pressures by LASIK. Less corneal effect on P2 suggests that P2 be used as the starting point for IOPcc and that corneal correction be based on P1.

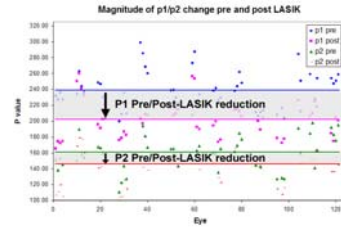


Figure 4

Consequently the functional form chosen for IOPcc was:

$$IOPcc = m1*(P2 + k*P1) + b1, \text{ for } -1 < k < +1$$

where m1 is a calibration constant, b1 is a calibration offset and s is a free parameter adjusted to minimize the function:

$$IOPc(\text{pre}) - IOPcc(\text{post})$$

Results - IOPcc

Figure 5 shows a plot of the function D (N = 45 pre-post LASIK eyes) defined by:

$$IOPcc(\text{pre}) - IOPcc(\text{post}) \propto \sum(P2 + k*P1) - \sum(P2' + k*P1')$$

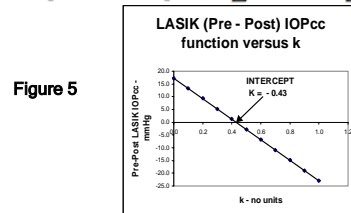


Figure 5

Figure 6 shows IOPg post-LASIK versus IOPg pre-LASIK. Figure 7 shows IOPcc post-LASIK versus IOPg pre-LASIK. The red line in both cases is the ideal slope of 1.0. The orthogonal regression lines for IOPg and IOPcc are 0.61 and 0.95 respectively. Orthogonal regression was used because both axis variables have similar variability.

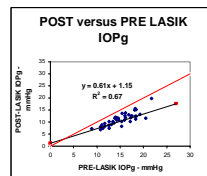


Figure 6

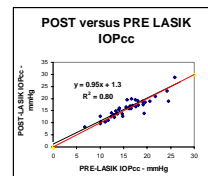


Figure 7

Figures 8 and 9 show clearly that the **expected correlation of CCT with IOPg is eliminated for IOPcc.**

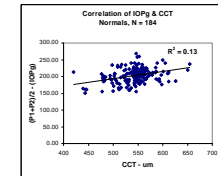


Figure 8

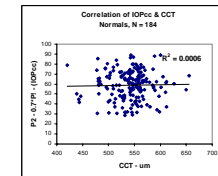


Figure 9

Method for CRF

Two independent methods for deriving CRF were used. A functional diagram for the first method, based on CCT, is shown in Figure 10.



Figure 10

CCT measurements were made with a DGH 20 mHz ultrasonic pachometer.

A functional diagram for the second method, based on correlation with IOPcc, is shown in Figure 11.



Figure 11

As indicated by Figure 4, P1 values demonstrate the largest change post-LASIK.

Therefore, the functional form chosen for CRF is:

$$CRF = m2*(P1 - k*P2) + b2, \text{ for } 0 < k < +1$$

Results - CRF

Figure 12 shows that **minimum (zero) correlation of CRF and IOPcc** occurs at **k = 0.7**. We consider IOPcc and CRF to be "orthogonal" or independent if their correlation $r(\text{iopcc}, \text{crf})$ in a normal population is insignificant.

Figure 13 shows that the **maximum correlation of CRF and CCT** as a function of k also occurs at **k = 0.7** for three different populations, normals, glaucomatous and normals/OHT.

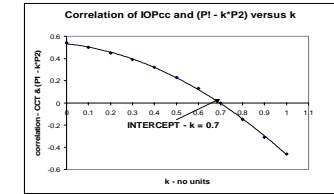


Figure 12

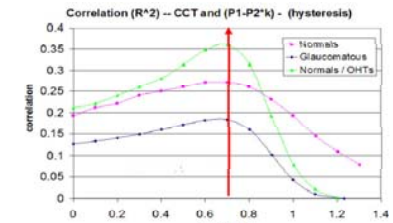


Figure 13

Discussion/Conclusions

With regard to IOPcc, elimination of pre/post LASIK IOPcc pressure change with simultaneous elimination of IOPcc-CCT and IOPcc-CRF correlation gives a high level of confidence that IOPcc is a "cornea free" measurement.

With regard to CRF, elimination of IOPcc & CRF correlation with independent simultaneous maximization of CRF and CCT correlation indicates that CRF is a strong corneal factor. The relationships between IOPcc, CRF and CCT may indeed change for different populations as the correlation plot of Figure 12 suggests. Although the direct use of CCT for pressure correction is of limited value, it provides a powerful tool for methodology verification.

Acknowledgements

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References

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