EDITORIAL

It has been more than 15 years since the editorial "The cornea is not a piece of plastic" was published. It appears that since the late 1990's, an entire new field of research and development in Ophthalmology has evolved in clinical corneal biomechanical assessment. The topic of corneal biomechanics has gained in importance and popularity, and nowadays fills large conference rooms with researchers, clinicians and people from the industry at huge international conferences.

Biomechanical properties of the human cornea have been extensively investigated through experiments in research labs, incorporated into numerical simulation models, and the biomechanical impact on refractive surgical outcomes has been analyzed carefully and quantified. Innovative, biomechanically motivated interventions, such as SMILE by Carl Zeiss Meditec, have emerged and become available for daily clinical use.

Novel measurement methods and technologies, such as Brillouin Microscopy, shear-wave elastography, and dynamic Scheimpflug imaging for in-vivo assessment of individual corneal biomechanics are being investigated and developed by academic and industrial representatives. Devices such as the Corvis ST by Oculus bring these interesting technologies into the market and into clinics and allow us to gain a better understanding of the biomechanics of our patients' corneas, and offer improved preoperative assessments.

Individual biomechanical measurements, in combination with anterior segment tomography will help us to improve preoperative surgical planning with sophisticated software tools, such as Optimeyes™ by Optimo Medical AG. Moreover, the understanding of biomechanical properties helps to improve patient selection and planning, as well as diversifies the different technologies of intervention. With these diversifications, the needs of the patients can be tended to more specifically and more precisely.

The Essentials of Corneal Biomechanics, CBEssentials by Optimo Medical AG, brings you an update of recent literature in the field of corneal biomechanics. The future of this field seems bright, and we will see many more applications, technologies, devices, and surgical procedures brought forward to improve vision and save eyesight.

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Biomechanical impact of femto-second laser arcuate keratotomy

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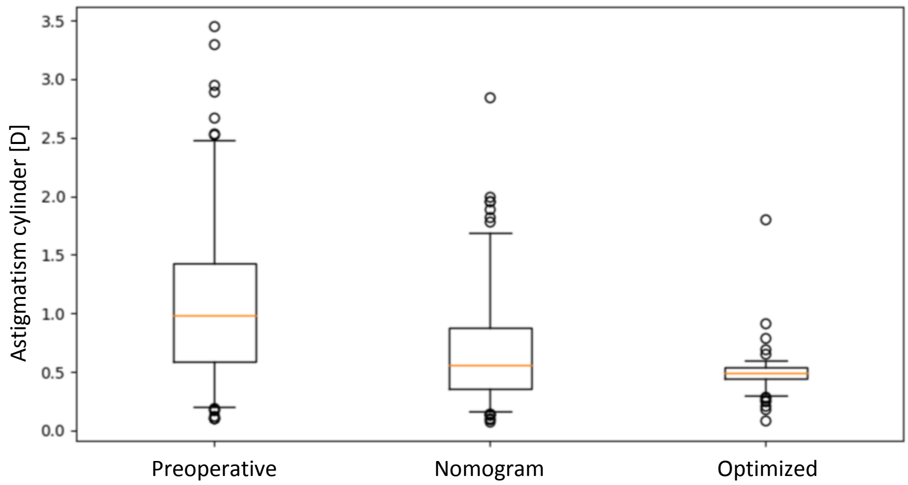
It has long been assumed, and since some years is known that refractive surgical treatments have an impact on the biomechanics of the cornea. Therefore, it is even more important to understand the underlying biomechanical mechanism of such procedures. One such surgical technique, exploiting biomechanical effects to treat corneal astigmatism, is femto-second laser arcuate keratotomy (AK). Manual AK incisions were being used for years in clinical practice, but were abandoned by many because of too poor outcome predictability. Now with the femto-second (FS) laser getting more and more popular, the technique has seen a comeback in clinics. FS Laser manufacturers such as Alcon, Bausch+Lomb, AMO, and Ziemer are already providing the ability to cut arcuates into corneal tissue. With the Optimeyes™ 1.0 software, Optimo Medical is providing an entirely novel approach to optimize arcuate parameters for the individual eye.

Based on realistic biomechanical simulations, the software evaluates the best possible incision configuration for the patient. The underlying algorithms include a sophisticated optimization approach that allows finding the best possible surgery for the individual patient. The following diagram presents simulation results and compares the outcome of nomogram based planning to patient-individual surgery parameters. For the optimization, we set a target postoperative astigmatism of 0.5D. Interestingly, the diagram highlights that optimized parameters reduce preoperative astigmatism much more effectively than nomograms do. Hence, Optimeyes 1.0 will likely allow much more precise planning of post-surgical astigmatism than has been possible up until now:



In this context, it is interesting to note, that two recent (2016) consecutive publications by the same authors of the Moorfields Eye Hospital in London focused on efficacy, predictability, sensitivity, and the effect of multiple parameters in the femto-second laser intrastromal arcuate keratotomy. Printed one after another, in the same volume of the Journal of Cataract and Refractive Surgery (Volume 42, 2016), the first study by Alexander C. Day et al. (2016) describes the effects and results of intrastromal femto-second astigmatic keratotomy (AK). Due to the minimal data about the efficacy of intrastromal AK, it aims to determine the astigmatic changes happening in this intervention.

Alex Day et al (2016), Nonpenetrating femtosecond laser intrastromal astigmatic keratotomy in eyes having cataract surgery; Journal of Cataract and Refractive Surgery 42(1):102-10

196 eyes were used, and the operation was planned with nomograms. The corneas all underwent an astigmatic correction additionally to a cataract surgery. They then were analyzed with three vectors of the Alpins method: the target induced astigmatism (set at 0, to facilitate calculations), surgically induced astigmatism, and the difference vector. Additional parameters were the correction index, the coefficient of adjustment, the magnitude and angle of error, and the index of success. The results are summarized in the Table 1 on the right hand side.

Essentials of Corneal Biomechanics

As can be seen in the graph below, this method can indeed reduce astigmatism. A closer look at the results, however, shows that most cases were under-corrected. This was expected by the authors, as the nomogram targets an outcome of 0.7D, to avoid over-correction. Still, there were some cases with over-correction, but no correlation with age, sex or arc length was noticed. The coupling ratio between steep and flat axis was 0.56, showing that the opposite (flat) meridian underwent a change in corneal power of 56%. Overall, the authors found that intrastromal femto-second laser AK can reduce astigmatism, and that the between-eye variance in the astigmatism vector must be further analyzed (see Figure 1).

Table 1 Vector analysis parameter values (N = 196 eyes).

Parameter	Mean (SD)	Range
Target induced astigmatism (D)	1.21 ± 0.42	0.75, 2.64
Surgically induced astigmatism (D)	0.74 ± 0.40	0.00, 2.86
Difference vector (D)	0.74 ± 0.38	0.00, 2.25
Correction index	0.63 ± 0.32	0.00, 1.93
% astigmatism corrected	63 ± 32	0, 193
Coefficient of adjustment	2.07 ± 1.35	0.00, 9.33
Magnitude of error	−0.47 ± 0.43	−2.02, 1.24
Angle of error	3 ± 70	−175, 176
Index of success	0.63 ± 0.30	0.00, 1.99

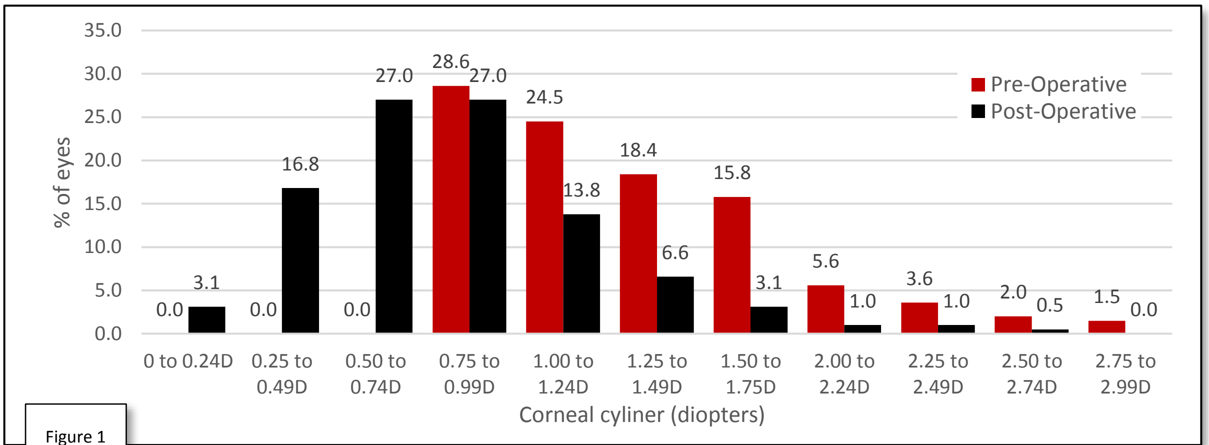


Figure 1

Referencing their first findings, the authors state in their second study that it is known that intrastromal keratotomy reduces astigmatism. However, the exact correlation between the arc length of the AK and the astigmatic correction is not clear. With their second study, Alexander C. Day et al (2016) intend to change this, and additionally want to analyze the effects of corneal biomechanical parameters on the efficacy of the operation. The selected preoperative parameters were axial length, anterior chamber depth, central corneal thickness, corneal hysteresis, corneal resistance factor and some more (see Table 2).

Alex Day et al (2016), Predictors of femtosecond laser intrastromal astigmatic keratotomy efficacy for astigmatism management in cataract surgery; Journal of Cataract and Refractive Surgery 2016; 42(2):251-257

The study included 319 eyes which underwent an astigmatism reduction in addition to the normal cataract surgery. Results primarily showed that long and deep incisions as well as high preoperative cylinder correlate with higher astigmatic correction. Regression analysis indicated that increasing patient age was associated with the SIA magnitude. In a second step, the authors considered biomechanical parameters, and correlated them to astigmatic effects. Results showed that surgically induced astigmatism is meridian-dependent and its magnitude is greater when corneal hysteresis (CH) is lower, but its corneal resistance factor (CRF) is higher. It also appeared that WTR (with the rule) astigmatism induces a 0.13 higher SIA than ATR (against the rule). Finally, the authors state that out of all parameters they looked at, only preoperative corneal cylinder magnitude, AK depth, and the steep astigmatism meridian were independent predictors for surgically induced astigmatism. Moreover, the correlation between incision length and the induced astigmatic correction was found to be poor.

Table 2 Multiple variable regression models of dependent variable SIA induced by femtosecond laser intrastromal AK.

Variable	B value	B 95% CI	*P* Value
Model 1 ($R^2 = 0.27$)			
Femtosecond arc length (degrees)	0.005	0.001, 0.008	.006
Femtosecond start depth (%)	−0.019	−0.028, −0.009	<.001
Preoperative corneal cylinder (D)	0.347	0.220, 0.474	<.001
Age (y)	0.005	0.000, 0.009	.044
Astigmatism type (oblique/WTR/ATR)*	−0.067	−0.131, −0.004	.038
Model 2 ($R^2 = 0.38$)			
Femtosecond arc length (degrees)	0.008	0.005, 0.012	<.001
Femtosecond start depth (%)	−0.019	−0.029, −0.009	<.001
Preoperative corneal cylinder (D)	0.250	0.105, 0.396	.001
Corneal hysteresis	−0.063	−0.099, −0.027	.001
Corneal resistance factor	0.044	0.08, 0.80	.018
Astigmatism type*	−0.133	−0.203, −0.064	<.001

ATR = against the rule; CI = confidence interval; WTR = with the rule
*Oblique astigmatism meridian was coded as 0, with-the-rule as 1, and against-the-rule as 2.