

Changes of intraocular lens position induced by Nd:YAG capsulotomy

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Aims. The aim of this study was to evaluate the changes in IOL position (axial shift, tilt and decentration) in the capsular bag after Nd:YAG laser capsulotomy and to create a user-friendly software that is optimized for the output of available imaging technology, then verify the relationship between the biometric parameters of the eye and the extent of changes in the IOL position.

Patients and Methods. The study included 35 ardephakic eyes that underwent laser capsulotomy. Before and at least one hour after capsulotomy, all patients underwent the following assessments: optical biometry (Lenstar LS900), OCT with anterior segment module (Optovue Avanti) and IOL photography in infrared mode using reference unit (Verion). The original software solution was designed for the graphical evaluation of the differences between centering, axial displacement and tilt of IOL. Changes in IOL position were evaluated as simple differences before and after the laser procedure and as differences in absolute values (abs).

Results. The following results show the average differences in IOL position: ACD=0.02±0.23 mm (abs=0.11±0.20 mm), IOL decentration in x-axis = -0.001±0.091 mm (abs=0.065±0.063 mm), IOL decentration in y-axis =0.012±0.119 mm (abs=0.048±0.53 mm), tilt in horizontal plane TILT-H=0.11±0.83° (abs=0.51±0.66°) and tilt in vertical plane TILT-V = -0.14±0.49° (abs=0.26±0.44°). All changes were insignificant ($P>>0.05$). In total, 74.29% of IOLs showed a hypermetropic shift. A moderate positive correlation was found between the absolute differences in horizontal tilt and keratometry ($r=0.45$). Relationship with other changes and parameters were weak.

Conclusion. In conclusion, the use of the original software solution developed by the authors showed that changes in IOL centering, axial displacement and tilt occur after Nd:YAG capsulotomy, but average differences were insignificant. In almost 3/4 cases, there was a hypermetropic axial displacement of the IOL.

Key words: NdYAG laser, capsulotomy, IOL position, IOL tilt, IOL centration, IOL axial shift, posterior capsule opacification

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INTRODUCTION

Posterior capsular opacification (PCO), also secondary cataract or after-cataract, is one of the most common postoperative complication following cataract surgery. Opacification reduces transparency of the capsular bag, worsens visual acuity after cataract surgery and causes whole postoperative visual discomfort. It can be stated that PCO is a multifactorial physiological consequence of cataract surgery, when the cloudy cortex together with the core of the lens is emulsified and aspirated from the eye commonly using a technique called phacoemulsification. A small opening (capsulorhexis - diameter about 5 mm) creates an entrance for the phacoemulsification process, but the rest of the capsular bag is left intact to serve as a resting place for the intraocular artificial lens (IOL). PCO are consequences of lens epithelial cell migration and proliferation whose cause is not fully clarified. The incidence shows a relationship to the material (hydrophilic/hydrophobic) and design (round/sharp edge) of

the implanted intraocular lens (IOL). In approximately up to 5% (ref.¹⁻⁶) of operated eyes for cataract there is PCO.

Removal of secondary cataract is commonly performed using Nd:YAG laser capsulotomy, which is the most effective and safe procedure in the management of PCO (ref.⁷). The laser interaction with the tissue of the capsular bag results in photodisruption and the formation of a posterior capsule opening, which restores the previous visual acuity. The average level of one laser hit varies according to the laser device, but on average it is at an energy level about 1 mJ, and a successful capsulotomy is usually obtained by up to 30 hits^{2,5,8,9}.

The capsule opening can cause the shape and tension of the capsular bag to change and this can cause changes in the position of the artificial lenses, especially in tilting, centering and axial displacement. This study aimed to analyze and determine the extent of these induced IOL position changes, then determine the relationships of these changes to the biometric parameters of the eye, to predict them before laser surgery. For this purpose, a spe-

cific methodology and software are needed for the ability to analyze the necessary data from images.

PATIENTS AND METHODS

This retrospective study included a total of 35 arthropathic eyes with diagnosed posterior capsule opacities. Eyes

with other diseases were excluded. All patients included in this study provided written information on participation and the study protocol was in line with the principles set out in the Declaration of Helsinki. All data used were anonymized. The following models were among the evaluated eyes: MA50BM (in 68.57% of eyes), SN60WF (8.57%), MI60 (5.71%), SA60AT (5.71%), SN6ATx (2.86%), AcriTec (2.86%), enVista (2.86%) and Aspira (2.86%).

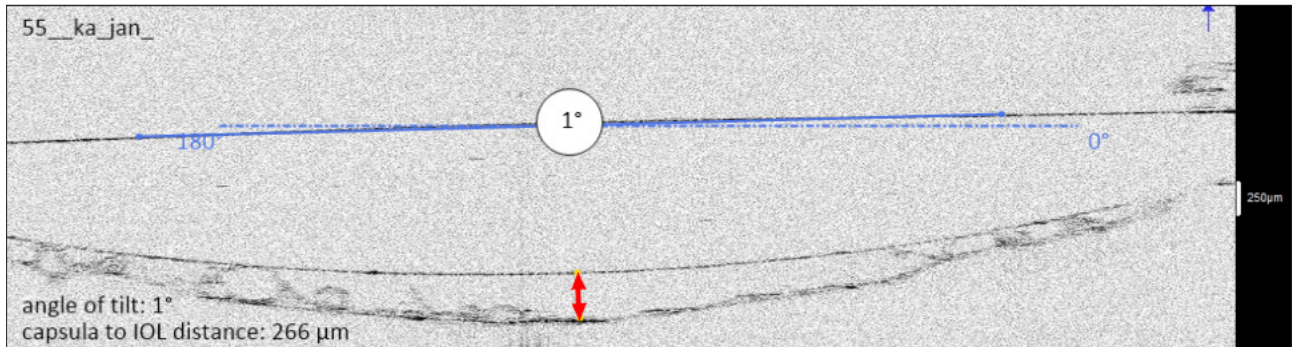


Fig. 1. OCT image of IOL in the eye with posterior capsule opacification. The angle of tilt is equal to 1° from horizontal plane, red arrow present distance from posterior plane of IOL to posterior capsule (LCD) which is equal to $266 \mu\text{m}$.

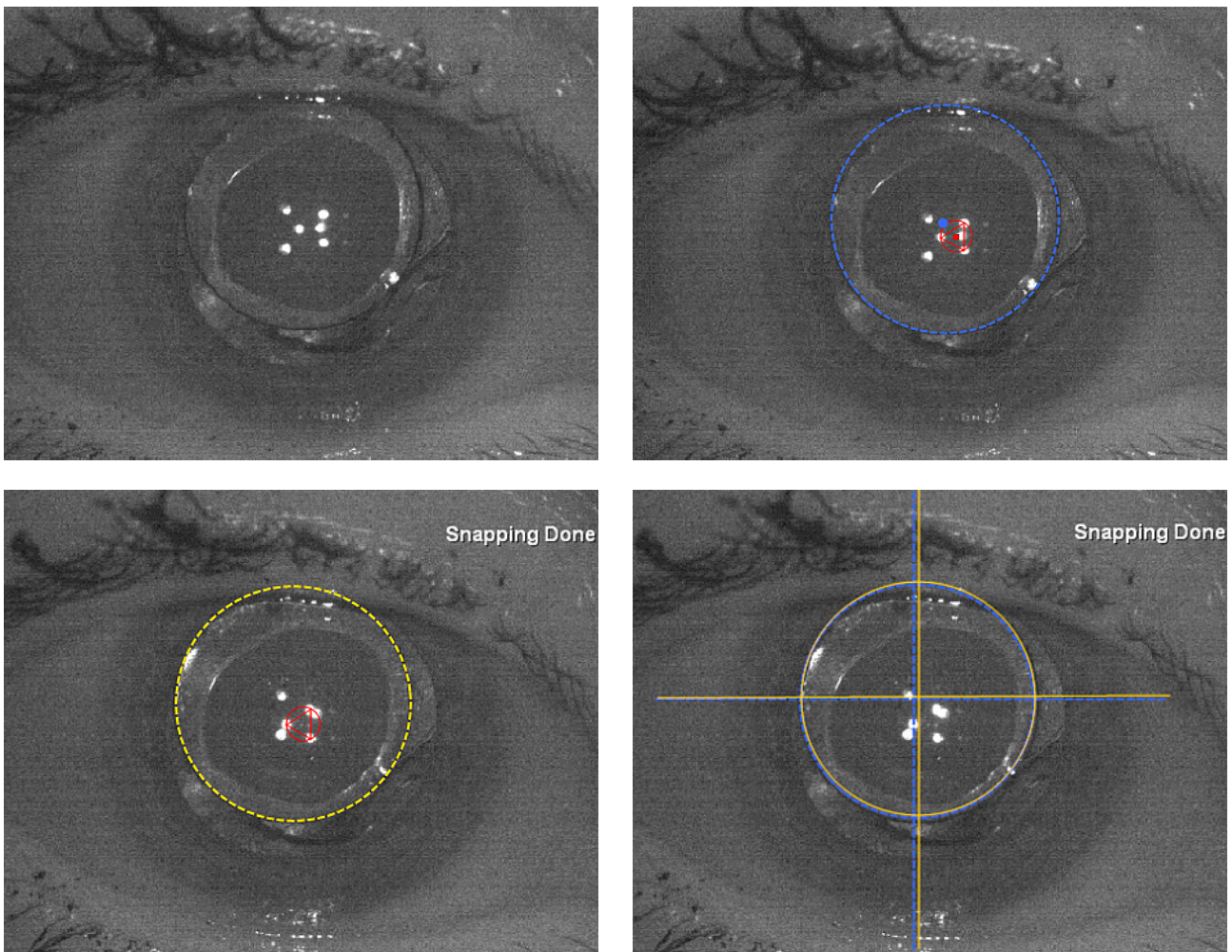


Fig. 2. Infrared images for evaluation of IOL decentration: a) default image, b) reference point (red) and contours of the optical part of IOL with center point (blue) before capsulotomy, c) contour of the optical part of IOL with center point (yellow) after capsulotomy, d) blending of both contours and visualization of change in centration.

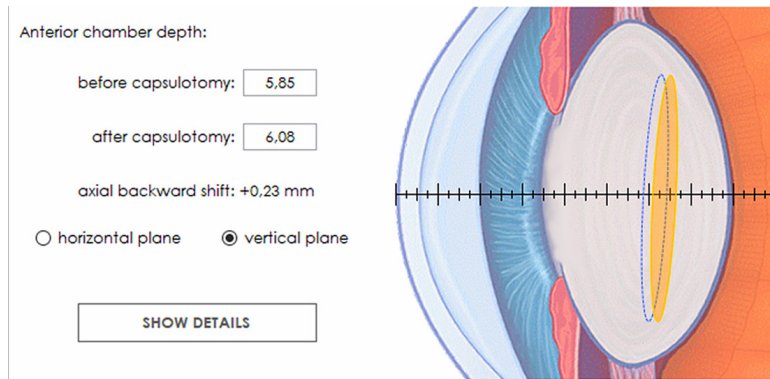


Fig. 3. Graphical visualization of the eye with IOL position and tilt before (blue dashed) and after capsulotomy (filled in yellow).

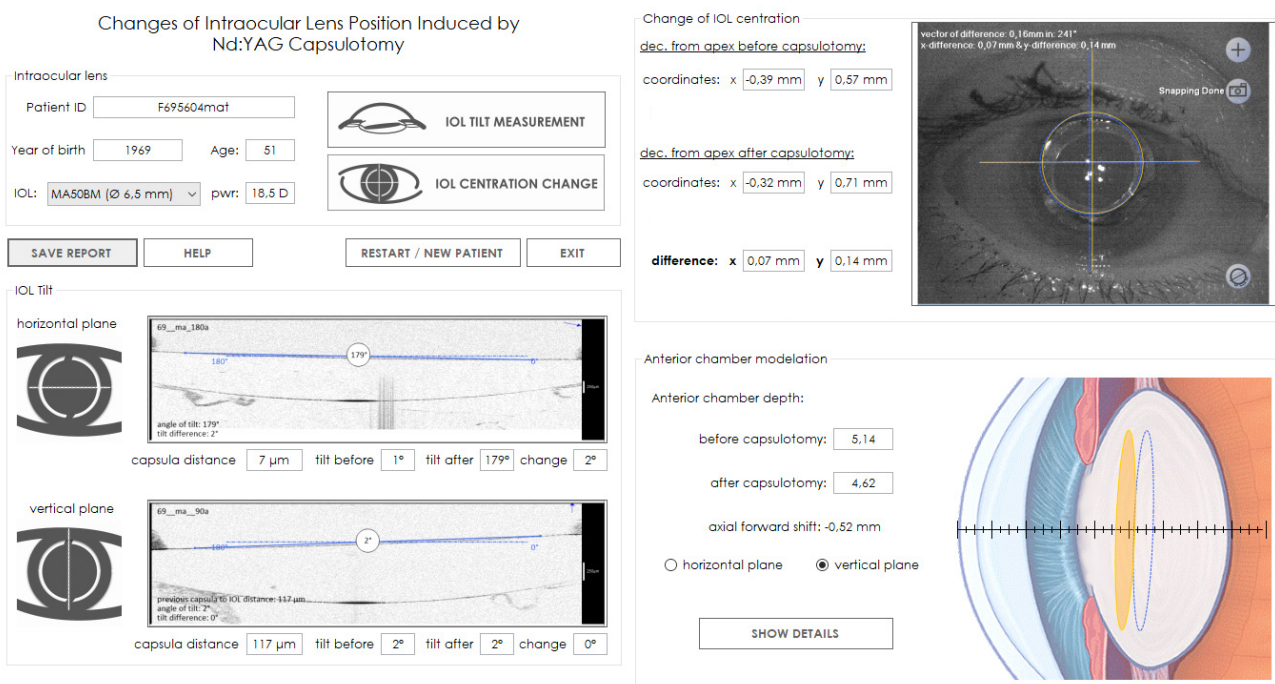


Fig. 4. Final report and graphical visualization of all changes in IOL position.

Laser capsulotomy was realized using Nd:YAG Ultra Q Reflex and was always performed by the same doctor and the same technique: a series of circularly placed laser pulses of 1 mJ, the number of pulses and the total energy depend on the level of opacity. Eyes in which the position of the lens may have changed after being struck by the laser beam were also excluded. All patients received the same preoperative and postoperative medication treatment. None of the patients included in the study had significantly increased intraocular pressure affecting the position of the lens.

Graphical analysis of the images described below to identify IOL position changes was performed using an original software solution developed by the authors (using MS Visual Studio) specifically for this research.

All patients underwent all following examinations twice – before and after (at least one and at most two hours) laser capsulotomy. IOL tilt in the horizontal

(TILT-H) and vertical plane (TILT-V) was measured using images from the anterior segment module of OCT Optovue Avanti. A total of 4 tomographic images were used. Tilt values were used for evaluation as deviations at the intersections of the horizontal plane perpendicular to the axis of view of the eye and the constant position of the fixation point. In addition to tilt, tomography images were used for measurement of distance from posterior plane of IOL to posterior capsule (lens to capsula distance – LCD, farthest space and perpendicular to the front surface of the IOL) in an area called Berger space, see for example Fig. 1.

Infrared images from the VERION reference unit were used to evaluate the IOL centering (see Fig. 2). The center of gravity of the triangle formed by the three reflections of the firsts Purkinje images was used as a reference point. The center of the optical part of IOL was used as a point of decentration to the reference point, and decentration

vectors can be created from their coordinates. Analysis of images before and after capsulotomy provides changes in x-axis (decX) and y-axis (decY) coordinates decentration (from the reference point), respecting the markings and rules of the Cartesian coordinate system. Knowledge of the diameter of the optical part of the IOL was used for the conversion to values in millimeters.

All patients underwent optical biometry to measure keratometry (K), axial length (AL), anterior chamber depth (ACD), and limbus diameter (WtW) using a Lenstar LS900. The displacement and tilt of the IOL before and after the capsulotomy is graphically processed in Fig. 3.

After the step-by-step analysis, the software compiles a final report as a summary with graphical visualization (Fig. 4).

Pearson's correlation coefficient was used to measure the strength of the association between eye parameters and the change of IOL position, *P*-value of differences before and after treatment was determined by a t-test.

RESULTS

Results in IOL position changes of monitored parameters are shown in Table 1. Averages of biometry values showed that monitored group has normal physiological layout (average=24.28±1.8 mm; average K=44.13±1.95 D; CCT=548.81±28.7 µm; WtW=12.09±0.42 mm). Average lens to capsule distance was in the horizontal plane equal to 95.14±146.81 µm and in the vertical plane 79.46±135.9 µm. At the first sight are the values of average changes of parameters are very low. Average difference of ACD was 0.02±0.23 mm (0.11±0.20 mm in absolute values), but in 74.29% of cases, a hypermetropic (towards the retina) shift of the IOL was noted. Changes of IOL decentration to the corneal apex in *x* and *y* values

Table 1. Average values and differences or differences in absolute value of parameters before (index b) and after (index a) laser capsulotomy.

Parameter	Average values	ave Δ	ave Δ
ACD _b [mm]	4.78±0.44	0.02±0.23*	0.11±0.20*
ACD _a [mm]	4.80±0.50		
decX _b [mm]	0.21±0.19	-0.001±0.091*	0.065±0.063*
decX _a [mm]	0.21±0.21		
decY _b [mm]	0.14±0.13	0.012±0.119*	0.048±0.53*
decY _a [mm]	0.15±0.16		
TILT-H _b [°]	3.09±1.58	0.11±0.83*	0.51±0.66*
TILT-H _a [°]	2.91±1.38		
TILT-V _b [°]	1.14±0.91	-0.14±0.49*	0.26±0.44*
TILT-V _a [°]	1.29±0.99		

ave Δ - average of differences, ave |Δ| - average of differences in absolute values. **P* value *P*>0.05

were negligible. The change in tilt did not exceed 2° and in 57.14% of the eyes no change in tilt was recorded in both planes. The significance of the differences (also in the differences of the absolute values) using the t-test was *P*>0.05 and was thus insignificant.

The results of the Pearson correlation coefficients (*r*) between the eye or IOL parameters and the differences in IOL position change are shown in Table 2. ACD changes correlate weakly with AL and PWR (IOL power) and in absolute values with WtW. The change of IOL decentration in the x-axis is weakly dependent on WtW, in the y-axis there is a weak correlation with AL. LCD in both planes had no significant effect on changes. The largest number of dependences of eye parameters on changes in IOL position was found in tilt in the horizontal plane, in addition to a weak correlation with AL, PWR, WtW, a moderate relationship of the absolute value of change with average keratometry (K) was found.

The results of the correlation of differences in absolute values are shaded light blue. The values over *r*≥0.25 are highlighted in bold.

DISCUSSION

The designed user-friendly software solution has simplified the demanding analysis of the position of the lens in the eye. Limitation of methods and software was optimization only for images from specific devices acquired by the given methodology, lower resolution of images, especially in the evaluation of decentration and the largest limitation was the pupil diameter in artificial mydriasis. Large number of eyes in mydriasis with a pupil under 6 mm in diameter had to be excluded because of unable to evaluate of decentration in the x-axis and y-axis using the edges of the optical part of the IOL. The observed trend of the IOL shift towards the retina indicates mild postoperative hypermetropization, probably due to capsule release tension. The role of this shift is probably also determined by the design and material or position of the haptics. The number of patients in our study was too low for this type of analysis and given the variability of IOL models. By far the largest changes were observed in horizontal tilt, with weak relationship to axial length, corneal diameter, IOL power and moderate with average keratometry. This means that a flatter cornea and larger corneal diameter with greater IOL power led to larger changes of horizontal tilt.

Changes in tilt and decentration of the IOL after capsulotomy have been analyzed in several studies. We discuss the following investigations studied using a Scheimpflug camera for imaging the position of the IOL or optical biometry for evaluation change in ACD. Study published by Uzel¹⁰. In 29 patients (except the control group) were used a Scheimpflug camera imaging system within one month apart from using Nd:YAG laser. Results are similar to ours: the consequences of laser capsulotomy are changes in IOL position, but the values of decentra-

Table 2. Results of Pearson's correlation coefficients between eye or IOL parameters and differences in IOL position change (correlation of absolute values are in the second line of each parameter).

	AL	WTW	K	CCT	PWR	LCD-V	LCD-H
Δ ACD	-0.25	0.08	0.07	-0.06	0.27	0.04	-0.03
	0.09	0.31	0.07	0.15	-0.02	-0.05	-0.15
Δ decX	-0.06	-0.28	-0.08	-0.03	-0.02	-0.13	-0.17
	-0.15	-0.05	-0.04	0.13	0.17	0.00	-0.01
Δ decY	-0.31	0.01	0.17	-0.16	0.02	0.04	0.20
	0.30	0.07	-0.14	0.22	-0.03	0.19	0.00
Δ TILT-H	-0.21	0.35	-0.29	-0.04	0.30	0.20	0.15
	-0.27	0.01	0.45	0.21	0.22	0.11	0.07
Δ TILT-V	0.03	0.01	-0.02	-0.06	0.23	0.03	0.23
	-0.06	0.09	0.01	0.15	0.17	0.14	-0.01

tion changes were very low and not significant (horizontal plane $P=0.35$, vertical plane $P=0.107$).

Parajuli¹¹ evaluated the effect of laser capsulotomy on intraocular pressure, refraction, ACD and macular thickness 1 h and 1 month postoperatively, 96 eyes were divided in two groups according to the total laser energy used. Mean ACD change 1 hour after surgery was in both groups equal 0.01 ± 0.02 mm and 0.01 ± 0.04 mm, but these changes were not significant ($P=0.948$). These values are ten times lower than in our study, probably due to different instruments (Lenstar LS900 vs. IOL Master 500). An interesting result of this study is an increase in macular thickness (but not significant) after surgery, but also significant ($P=0.003$) increase of intraocular pressure in the group which received laser energy level above 50 mJ and which had not returned to preoperative levels at 1-month follow-up.

Original study designed to compare changes in IOL decentration and tilt in a group of patients with manual capsulorhexis and femtosecond laser capsulorhexis during cataract surgery showed interesting results. The femtosecond laser capsulorhexis group resulted in better mechanical stability of the IOL, due to better maintenance of the correct position of the IOL. Although the differences in groups were statistically significant, the tilt and decentration values were small and not clinically significant, as in our study¹².

Zafer Oztas¹³ reported significantly increased ACD after Nd:YAG surgery. Mean ACD was 4.26 ± 0.63 mm before the procedure, 3.73 ± 0.56 mm at one week and 3.75 ± 0.56 mm at one month. Thus, the mean significant ($P<0.001$) shift of approximately 0.5 mm toward the retina was several times greater than our results.

With one exception, with a slightly higher change in ACD, all studies discussed above confirmed our results that changes in IOL position after capsulotomy due to PCO occur but at very low levels.

CONCLUSION

In conclusion, the use of the original software solution developed by the authors showed that changes in IOL centering, axial displacement and tilt occur after Nd:YAG capsulotomy. However, the differences in parameters were

on average very low (also in absolute values) and not significant. Increased ACD (shift of the IOL position in the axial axis towards the retina) occurred in 74.29% of cases. In identifying the relationship between changes and biometric parameters of the eye, we found a moderate positive correlation of the absolute change in lens tilt in the horizontal plane (TILT-H) with average keratometry (K). The other parameters were weakly correlated.

The design of the software is adapted to images from specific imaging devices, and its optimization for universal or wider use is the following challenge. As well as an online version available to the ophthalmological public.

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