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## Original Research Article

# Anterior capsulorhexis opening reduction after cataract surgery with subluxated lenses

Juris Vanags<sup>a,b,\*</sup>, Renārs Erts<sup>c</sup>, Guna Laganovska<sup>a,b</sup>

<sup>a</sup> Department of Ophthalmology, Riga Stradins University, Riga, Latvia

<sup>b</sup> Clinic of Ophthalmology, P. Stradins Clinical University Hospital, Riga, Latvia

<sup>c</sup> Department of Physics, Riga Stradins University, Riga, Latvia

## ARTICLE INFO

## Article history:

Received 5 December 2015

Received in revised form

13 February 2017

Accepted 19 October 2017

Available online 14 December 2017

## Keywords:

Anterior capsulorhexis opening

Subluxated lens

Capsular tension ring

Pseudoexfoliation

## ABSTRACT

**Background and objective:** This study sought to evaluate anterior capsulorhexis opening (ACO) reductions after surgery for a subluxated lens. Significant reduction of an ACO supports direct zonular involvement (capsular factors excluded by use of capsular tension rings [CTRs] and modern intraocular lens [IOLs]), and these findings question the long-term efficacy of subluxated lens surgery by means of cataract surgery. A small ACO due to lens mobility, non-enlargement of the ACO, and no lens epithelial cell washing due to an additional risk of further zonular damage were left as additional features to evaluate the possible outcomes of this simplified but still complicated surgery.

**Materials and methods:** Data from 30 patients were used in the final analysis of this prospective study. Phacoemulsifications of subluxated lenses were performed in all patients, and iris/capsule hooks and CTRs or Cionni rings were used as stabilisers of the lens. Photography of the anterior parts (performed at 1 day, 1 week, 1 month, 3 months and 6 months after surgery) was used to evaluate the anterior capsulorhexis openings.

**Results:** Small initial anterior capsulorhexis openings (13.54 mm<sup>2</sup>) were achieved, and the area reduction at 6 months was 16.70% (mean area at month 6: 11.28 mm<sup>2</sup>,  $P < 0.001$ ). The reduction of the ACO area in the pseudoexfoliation (PEX) syndrome patients was 20% relative to the initial size (13.49 mm<sup>2</sup> vs. 10.92 mm<sup>2</sup>,  $P < 0.001$ ). Two patients exhibited marked ACO reductions, and both were referred for anterior laser capsulotomy treatment.

**Conclusions:** A weak or partially absent zonule does not markedly affect the reduction of the anterior capsule opening if appropriate surgical techniques, support materials and IOLs are used, even in the presence of a small initial capsulorhexis opening area. Therefore, a cataract surgery approach on the subluxated lens should be used. Ocular comorbidities, particularly PEX syndrome, play more significant roles in ACO reduction, and appropriate ACO size reducing inhibitors (e.g., anterior laser capsulotomy) or other types of surgery should be used.

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\* Corresponding author at: Clinic of Ophthalmology, P. Stradins Clinical University Hospital Pilsonu 13, LV-1002 Riga, Latvia.

E-mail address: [jurisvanags@inbox.lv](mailto:jurisvanags@inbox.lv) (J. Vanags).

<https://doi.org/10.1016/j.medici.2017.10.003>

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## 1. Introduction

The cause of lens subluxation can be congenital (e.g., Marfan syndrome, homocystinuria, Ehlers–Danlos syndrome, hyperlysinemia, sulphite oxidase deficiency, primary ectopia lentis, and congenital aniridia syndrome) or acquired (e.g., blunt trauma, iatrogenic [following ocular surgery], pseudoexfoliation [PEX] syndrome, and retinitis pigmentosa) [1–4]. Lens subluxation is characterised by a weakness or absence of zonular support [3,5,6], which is also one of the causes of increased anterior capsulorhexis opening reductions [7–9]. Reduction of the equatorial capsular bag diameter, malpositioning of the anterior capsule opening, anterior capsule opacification, hyperopic shifts, intraocular lens (IOL) displacement or encapsulation, zonular traction, ciliary body detachment with resultant hypotony, and retinal detachment can be secondarily caused by marked anterior capsule contraction [10,11], and the visualisation of the peripheral retina during retinal surgery or laserphotocoagulation might also be compromised [12]. Various techniques and devices have been developed for cataract surgeries involving subluxated lenses [4,13–15]. These techniques and devices also decrease the anterior capsular area reduction after surgery [16,17] and allow for the implantation of various IOLs of improved material and design [12,18,19]. The aim of this study was to evaluate the rate of anterior capsulorhexis area reduction following cataract surgeries on subluxated lenses. Significant reduction of anterior capsulorhexis opening (ACO) supports direct zonular involvement (capsular factors excluded by use of capsular tension rings [CTRs] and modern IOLs), and these findings question the long-term efficacy of subluxated lens surgery by means of cataract surgery. A small ACO due to lens mobility, non-enlargement of the ACO, and no lens epithelial cell washing due to an additional risk of further zonular damage were left as additional features to evaluate the possible outcomes of this simplified but still complicated surgery.

## 2. Materials and methods

A prospective study was performed from 2011 to 2013 in the P. Stradins Clinical University Hospital, Riga, Latvia. A total of 44 patients suffering different grades of lens subluxation and cataracts were included. Grade 1 lens subluxation was defined as iridodonesis and/or phacodonesis and the lack of a visible lens margin in a fully medically dilated pupil (grade 1). Grade 2 lens subluxation was defined by the presence of the above-mentioned signs and a lens margin that was visible over no more than one-third of the pupillary area. Grade 3 was defined similarly for cases in which the lens margin was visible in one-half of the pupillary area. The exclusion criteria were the failure to create a continuous capsulorhexis, rupture of the anterior capsule during surgery, failure to implant the capsular tension ring (CTR), loss of capsules and inability of the patient to return for a follow-up visit within 1 month.

### 2.1. Surgery

In the majority of the patients (30), local sub-tenon anaesthesia was administered. A few patients underwent

surgery under general anaesthesia (14). All surgeries were performed by a single surgeon (JV). During the surgeries, the main temporal tunnel incision (2.75 mm) and nasal paracentesis (1.2 mm) were performed at the 3 o'clock and 9 o'clock positions, and the anterior chamber was subsequently filled with viscoelastic material. Following continuous capsulorhexis, additional paracenteses at 1.30, 4.30, 7.30 and 10.30 were performed, and iris hooks or capsular hooks were implanted at the margin of the capsulorhexis to provide lens/capsular bag stability during surgery. A CTR or modified CTR (Cionni) was implanted immediately after the hooks if a Cionni ring-sulcus fixation through the scleral flap and a sclerotomy with polypropylene 10/0 were performed. Phacoemulsification of the cataractous lens was performed, subcapsular material was removed via manual irrigation-aspiration without additional anterior capsule polishing to remove the lens epithelial cells, and the IOL bag was then implanted (bags from 3 manufacturers were used: Alcon [Acrysof SN60AT, MN60 MA, IQ SN60 WF; Alcon Surgical, Inc., Fort Worth, TX, USA], AMO [Tecnis ZCB00; Abbott Medical Optics Inc, Santa Ana, CA, USA], and Medicontur [877FABY; Medicontur Medical Engineering Ltd., Zsámbék, Hungary]). Next, the hooks were explanted, the viscoelastic material was removed, and the wound was closed. The IOLs were selected randomly (in terms of the manufacturer). If a Cionni ring was implanted, it was selected to provide the closest fit to the calculated IOL power. If a CTR was implanted, a Medicontour IOL was used based on the surgeon's preference; this preference was formed based on the presence of double haptics, which increased the number of possible IOL resuturing points in the case of late IOL dislocation. Small capsulorhexes were not enlarged because this procedure is complicated and may result in additional zonular damage. After surgery, eye drops (antibiotic + dexamethasone) were prescribed for 1 month.

### 2.2. Examination

All patients were routinely examined before cataract surgery (i.e., visual acuity [VA], intraocular pressure [IOP], and slit lamp examinations). IOL calculations were performed with an IOL Master (Carl Zeiss Meditec AG, Jena, Germany). If the lens was too cataractous, the axial length was measured via an A-scan and then manually entered in the IOL master data sheet. Photography of the anterior parts (Carl Zeiss Fundus camera FF450plus, Visupac 4.3 software [Carl Zeiss Meditec AG, Jena, Germany]) with full medical pupil dilatation was performed at all visits. Video recordings of the surgeries were made. The follow-up visits included the preoperative examination (visit 0), day 1 postoperative visit (visit 1), 1st week visit (visit 2), and 1- (visit 3), 3- (visit 4) and 6- month (visit 5) visits.

The relative anterior capsulorhexis area was measured with the Visupac software that was available with the fundus camera and then calculated manually using the standard IOL diameter (6 mm) as a reference. If the IOL edges were not visible due to poor pupil dilatation, and the horizontal interlimbal distance was used as reference to measure the anterior capsulorhexis opening.

### 2.3. Statistical analysis

The demographic data and changes in the eyes were compared between the groups using the t test for continuous variables and the Pearson chi-square test for discrete variables. The data are presented as means and standard deviations unless otherwise noted. Spearman correlation coefficients were used to indicate the magnitudes and directions of the relations between variables. Paired and unpaired t tests were applied when appropriate. Three groups were compared with ANOVA.

The statistical effect size was calculated using a receiver operating characteristic (ROC) curve. Effect sizes ranging from 0.60 to 0.70 were deemed negligible to poor, 0.70 to 0.80 were deemed to be fair, 0.80 to 0.90 were deemed to be good, and  $>0.90$  were deemed excellent. All of the calculated probability values were 2-tailed, and  $P < 0.05$  was taken to indicate statistically significant differences.

Statistical analyses were performed using MedCalc for Windows, version 14.0 (MedCalc Software, Ostend, Belgium).

## 3. Results

For the final data analysis, 30 of the 44 patients were included. Of the 14 excluded patients, 1 was excluded due to the failure of creating a continuous capsulorhexis, 4 were excluded due to rupture of the anterior capsulorhexis, 2 were excluded due to the failure of implanting the CTR, 1 was excluded due to the loss of the capsule during surgery, and 6 patients did not return for follow-up visits. The mean age of the patients was 67.40 (10.55) years.

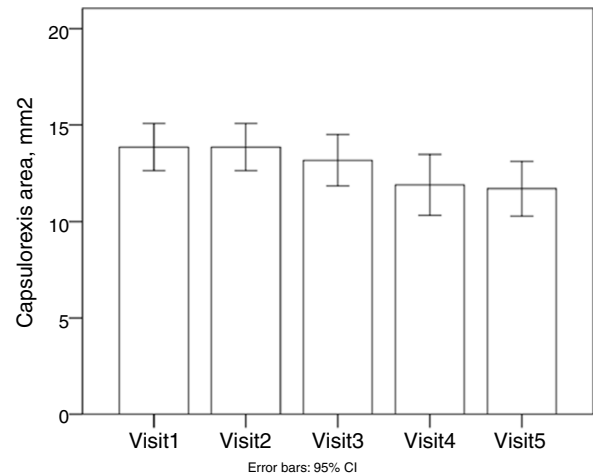
Fourteen patients (46.67%) had an Abbot ZCB00 IOL implanted, 7 patients (23.33%) had an Alcon IOL (Alcon IQ SN60 WF, Alcon Acrysof SN60AT, Alcon Acrysof MN60 MA) implanted, and 9 (30%) patients had a Medicontur 877FABY IOL implanted. Capsular Tension Rings were implanted in 19 (63.33%) patients, and Cionni rings were implanted in 11 (36.67%) patients. A total of 17 of all CTR cases (both CTR and Cionni rings) had a diameter of 11 mm (56.67%) and 13 CTRs, a diameter of 12 mm (43.33%).

Fig. 1 illustrates the changes in the patients' capsulorhexis areas over time. The Mauchly's test of sphericity indicated that the assumption of sphericity was violated ( $\chi^2[9] = 216.11$ ,  $P < 0.001$ ); therefore, a Greenhouse–Geisser correction was used. There was a significant effect of time on the change in the capsulorhexis area ( $F[1,30] = 15.82$ ,  $P < 0.001$ ).

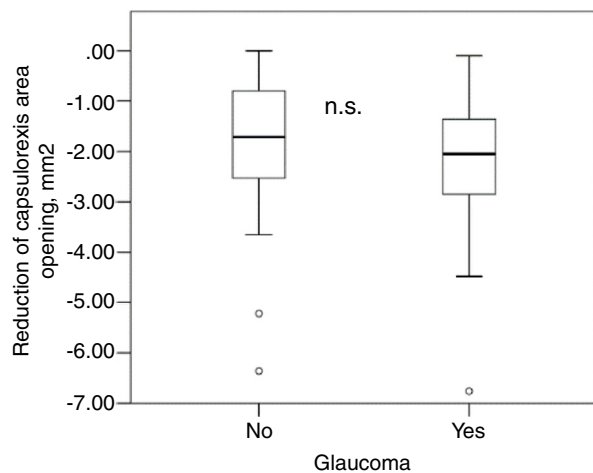
Statistical analysis revealed significant differences in the capsulorhexis sizes between visits 1 and 5 ( $P = 0.01$ ) and between visits 2 and 5 ( $P = 0.01$ ). No significant differences between the other follow-up visits were found ( $P > 0.05$ ).

It was found that the mean capsulorhexis opening area decreased from the initial size ( $M = 13.54$ ;  $SD = 3.07$ ) until visit 5 ( $M = 11.28$ ;  $SD = 3.71$ ; area reduction: 16.70%), and this difference was significant ( $P < 0.001$ ). ROC curve analysis revealed that the statistical effect size was poor ( $AUC = 0.66$ ;  $P < 0.05$ ).

At visit 4 (month 3), two patients (No. 21 and No. 26) exhibited marked anterior capsulorhexis constriction. Both of these patients were referred for anterior laser capsulotomy, and enlargements of the anterior capsulorhexes were observed in both patients at visit 5.



**Fig. 1 – Changes in the capsulorhexis area over time. Error bars indicate 95% confidence interval.**



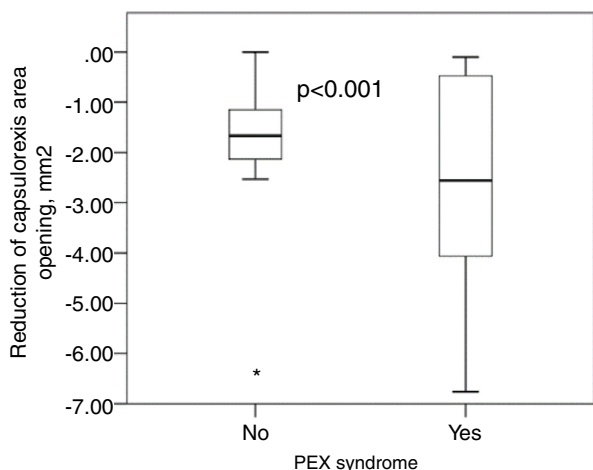
**Fig. 2 – Reduction of the capsulorhexis area opening in patients with glaucoma.**

It was found that glaucoma did not influence the capsulorhexis openings from visits 1 to 5 ( $P = 0.65$ ) (Fig. 2).

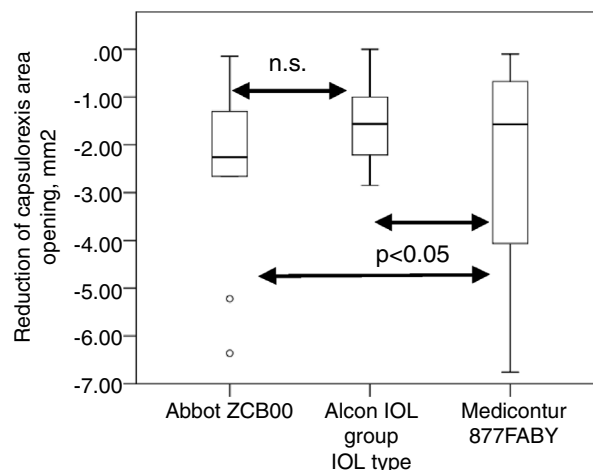
The ACO area reductions in patients with PEX syndrome were statistically significant ( $P < 0.001$ ) and reached 20% of the initial size (Visit 1 mean = 13.49;  $SD = 3.84$ ; Visit 5 mean = 10.92;  $SD = 4.71$ , mean reduction 2.57 mm<sup>2</sup>) (Fig. 3).

The changes in the capsulorhexis opening areas across all visits and IOL types revealed no significant difference ( $P > 0.05$ ) between the Alcon IOL group and the Abbot ZCB00 group, but repeated-measures ANOVA with post hoc analysis revealed significant ( $P < 0.05$ ) differences between both of these groups and the Medicontour 877FABY group (Figs. 4 and 5).

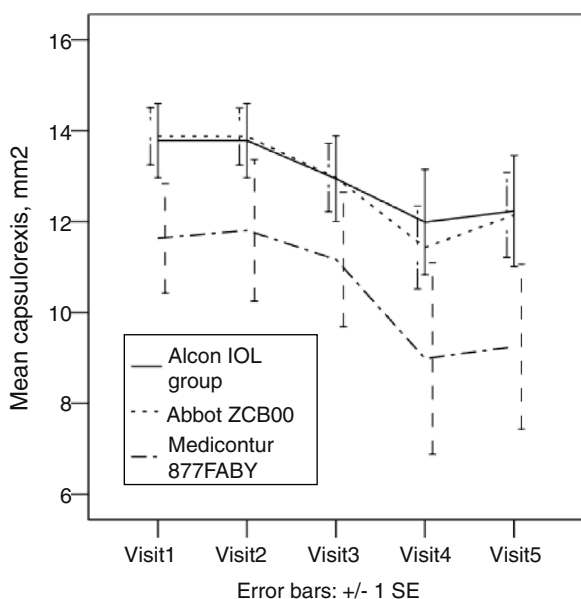
It was found that Cionni ring-implanted eyes exhibited less capsulorhexis opening reduction than the CTR-implanted eyes ( $P = 0.04$ ), and ROC curve analysis of this result indicated that the statistical effect size was average ( $AUC = 0.70$ ,  $P = 0.04$ ).



**Fig. 3 – Reduction in the capsulorhexis area opening and PEX syndrome.**



**Fig. 5 – Reduction in the capsulorhexis area openings.**



**Fig. 4 – Mean capsulorhexis changes during 5 visits according to IOL type.**

**Table 1 – Ocular comorbidities.**

Comorbidity	No	Yes
Myopia	26 (86.67)	4 (13.33)
Glaucoma	16 (53.33)	14 (46.67)
Marfan syndrome	28 (93.33)	2 (6.67)
PEX syndrome	11 (36.67)	19 (63.33)
Trauma	23 (76.67)	7 (23.33)

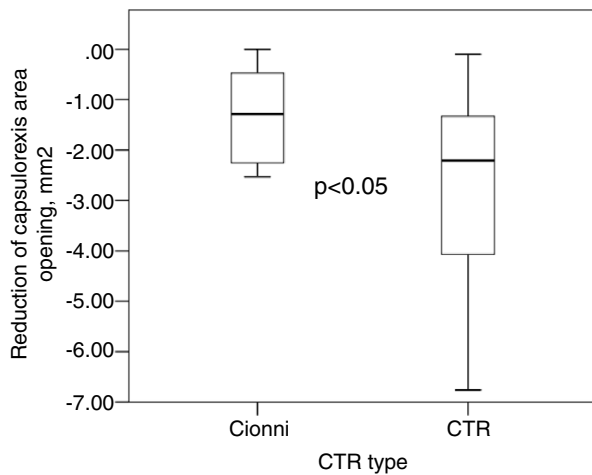
Values are n (percentage).

(3.07) mm<sup>2</sup>. The area achieved in our study was far smaller than the area that has been shown to be optimal for cataract surgery (i.e., a capsulorhexis diameter of 5.0 mm or an area size of 19.6 mm<sup>2</sup>) [8,10,12,19,20]. Vasavada et al. reported a small capsulorhexis size in cases of seriously subluxated lenses, but they were enlarged during surgery [23]. The reductions in the capsulorhexis areas from visit 1 to visit 5 were statistically significant (Visit 1 13.54 [3.07] and visit 5 11.28 [3.71] mm<sup>2</sup>) (Fig. 2). The rate of capsulorhexis opening reduction (16.70%) was similar to the values reported by Hayashi et al. for a group of eyes that were at high risk for capsular contraction (i.e., due to pseudoexfoliation, diabetes, or angle closure) after cataract surgery and did not undergo Nd:YAG anterior capsulotomy (size reduction 17–30%) [20] despite the initially smaller capsulorhexis opening areas.

The reductions in the anterior capsule areas were more pronounced for those with implanted CTRs than those with implanted Cienni rings (Fig. 6). It has been reported that no reductions in the anterior capsule openings of healthy eyes are observed if CTRs are inserted [24], while zonular weakness/absence affected eyes suffer only slight ACO area reductions [17,25], for which 2.5% is defined as a severe contraction [25]. PES, glaucoma and older patients were more likely to receive CTRs, but only the PEX syndrome eyes exhibited a significantly greater decrease in the capsulorhexis area (Fig. 3). Pseudoexfoliation syndrome has been reported to be one of the main risk factors for anterior capsule contraction syndrome in multiple publications [3,7,8,20] and to cause area reductions as great as 22–24% of the initial capsulorhexis size. PEX syndrome

#### 4. Discussion

Publications related to anterior capsule contraction have elucidated the contraction process in normal, noncomplicated eyes undergoing surgery for cataracts and the best IOL materials and designs for use in such surgeries [10–12,18,19]. Additionally, other studies have described capsular contraction and its treatment in high-risk eyes [8,20], and there are case reports about severe capsular contraction in high-risk/complicated eyes [7,9,21,22]. Our study group included zonular weakness/absence patients with lens subluxations caused by various factors and comorbidities (Table 1). Small capsulorhexis sizes due to increased lens mobility were created in the majority of the patients; the mean area at visit 1 was 13.54



**Fig. 6 – Capsulorhexis opening area changes from visit 1 to visit 5 depending on the CTR type.**

may lead to severe contraction that affects visual acuity and IOL centration, but these effects can be corrected with Nd:YAG laser anterior capsulotomy. The two patients in our study group who exhibited marked anterior capsule contraction and were referred for Nd:YAG anterior capsulotomy also suffered from PEX syndrome. The anterior capsulorhexis opening and its relationships with patient age and the presence of glaucoma might have been related to the fact that the same patients suffered from PEX syndrome (Figs. 2 and 3). Kato et al. reported an increase in the reduction of the ACO with age due to increased permeability of the blood aqueous barrier [26], but the same mechanism caused ACO reductions in PEX syndrome due to low-grade inflammation in the affected intraocular tissues [27]. The strong association between PEX syndrome and glaucoma has been confirmed [27]. The majority of our study group patients who suffered from glaucoma also had PEX syndrome, but no statistically significant decrease in ACO was observed for these subgroups.

All of the patients received IOLs of similar material and design, i.e., foldable, hydrophobic, acrylic and sharp-edged. IOLs made of these materials can reduce the anterior capsule contraction compared to other materials (i.e., hydrogel and silicone) in healthy eyes [10,12]. High-risk eyes (due to angle closure, pseudoexfoliations, or diabetes) that are implanted with IOLs of similar material (Abbot ZA 9003) exhibit significant anterior capsule contraction [20]. Greater incidences of anterior capsulorhexis phimosis and opacification have been reported for the Alcon IOL compared with the Tecnis IOL, but this difference did not reach statistical significance [19]. There was no difference in the ACO reductions in the eyes implanted with Alcon IOLs and Tecnis IOLs in our study group (Fig. 5). The eyes implanted with Medicontur 877FABY exhibited the greatest reductions in capsulorhexis openings. One difference in the design of the 877FABY IOL is that it has a double haptic instead of the single haptics of the ZCB00 and Alcon IOLs; however, a number of haptics and their designs and materials have been reported to have no significant influence on ACO [11,12].

## 5. Conclusions

Weak or partially absent zonules do not markedly affect the reduction of the anterior capsule opening if appropriate surgical techniques, support materials and IOLs are used, even in the presence of a small initial capsulorhexis opening area, therefore a cataract surgery approach for a subluxated lens would be used. Ocular comorbidities, particularly PEX syndrome, play more significant roles in ACO reduction and appropriate ACO size reducing inhibitors (e.g., anterior laser capsulotomy) or other types of surgery would be used.

## Conflict of interest

The authors state no conflict of interest.

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