Role of Lens Extraction In Glaucoma – A Review

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Abstract
Primary angle closure glaucoma (PACG) is a multifactorial disease with ethnicity, gender, ocular anatomy, iris configuration, lens volume and angle pathology all contributing to its genesis. The frequency of this disease is maximal in Asia where 85% of patients with PACG reside. The magnitude of this disease, primarily asymptomatic coupled with late presentation, where merely laser iridotomy does not suffice to arrest its progression makes surgical treatment by trabeculectomy a necessity to control glaucoma related blindness. However since trabeculectomy in the best of scenarios and best of hands is a surgery with limited functional longevity, more viable and robust surgical treatments for blinding glaucoma have long been explored. Of these new strategies, lens removal is one such modality which has been in the forefront of many recent debates.

Laser lens extraction surgery has always been known to be been associated with reduction of intraocular pressure in patients with nonmotive states as well as ocular hypertensive states and performing lens extraction as primary treatment modality to control PACG has been advocated in the past. The soaring popularity of more elegant, less tissue destructive phacoemulsification procedure over manual extracapsular cataract surgery (ECCE) over the last two decades has led to a phenomenal increase in reports confirming increased utility of lens extraction as a viable method for treatment of PACG. Past phacoemulsification, there is a notable increase in the angle opening distance (AOD500), as seen on various angle imaging modalities, which corresponds positively with improvement in other anterior chamber biometric parameters. But can this anatomical widening of crowded angle and reduction in IOP be extrapolated to the entire spectrum of glaucoma cases? Can primary phacoemulsification be promoted as the first treatment for PACG in the current scenario? Does documented widening of angle by imaging translate into persistent IOP control leading to reduced requirement of other means of glaucoma treatment? This article attempts to answer these questions by literature review of articles and studies pertaining to role of lens extraction in open angle as well as angle closure glaucoma eyes, in those with acute angle closure attack and the new buzzword ‘clear lens extraction’.

Keywords: glaucoma, phacoemulsification, angle closure, open angle, intraocular pressure control, primary lens extraction, clear lens extraction

Introduction
Treatment in glaucoma aims to prevent future visual loss keeping in mind the natural course of disease. In addition to time tested medical, laser and surgical treatment, current evidence is veering towards lens extraction as the new treatment modality especially for glaucoma of anatomical origin namely angle closure. Keeping in mind the position of lens in anatomy of anterior chamber angle configuration, lens extraction seems a reasonable option for widening the narrow angle. This has been amply documented with imaging studies confirming increased angle opening distance at 500um (AOD500) post phacoemulsification, which correlates with improved anterior chamber dynamics. The magnitude of this intraocular pressure (IOP) drop varies from 1.5-6.5mmHg with lower range being applicable for normotensive eyes and higher for ocular hypertensive eyes. For primary open angle glaucoma (POAG), IOP decrease has been documented at 13% but for primary angle closure glaucoma (PACG), it is more significant and ranges from 13-37%. However despite the plethora of articles in recent literature clear cut guidelines for lens extraction have not yet emerged with appropriateness of lens extraction being still questioned. The following article aims to clarify the concepts regarding this aspect and summarize the recent and past literature on this treatment of glaucoma.

Anatomical Considerations by Imaging Studies
Etiopathogenesis of angle closure glaucoma is presence of relative resistance to aqueous flow from posterior chamber to anterior chamber, which generates a pressure gradient and determines iris contour. Greater the pressure differential, more convex is iris contour resulting in iridocorneal angle closure. The ‘pinch region’ or iris-lens channel between posterior iris surface and anterior lens surface in turn is determined by iris configuration, lens size and lens vault. Does documented widening of angle by imaging translate into persistent IOP control leading to reduced requirement of other means of glaucoma treatment? This article attempts to answer these questions by literature review of articles and studies pertaining to role of lens extraction in open angle as well as angle closure glaucoma eyes, in those with acute angle closure attack and the new buzzword ‘clear lens extraction’.

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Older studies

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Intraocular Pressure Reduction
Effect of Cataract Surgery on
Intraocular Pressure Reduction

Even in normotensive eyes, a beneficial effect on IOP has been noted after uneventful lens extraction with reduction of 1.5-3.5mmHg over a 1 month to a 3 year period.5-8 For eyes with POAG, this reduction is significantly more and varies from 1.8-4.5mmHg.5-9 The reduction of IOP has a linear correlation with pre-operative pressures and a study by Matsumura et al documented a 5.5 mmHg decrease in eyes with high pre-op IOP (≥21mmHg), a 2.5mmHg reduction in cases with IOP <20mmHg and 1.5mmHg for normotensive eyes over a long term follow up of 3 years.5 In ocular hypertensive eyes, a similar trend has been observed with a 6.5mmHg reduction

By combined trabeculectomy and cataract operation rather than by cataract operation alone; with average IOP being 3-4mmHg lower in combined group along with need for fewer medications.24 Advanced surgical trends of current era with enhanced imaging modalities leading to better insight, mandate a more recent update to resolve this dilemma.
A. Role in Open Angle Glaucoma
Most studies confirm beneficial effect of lens extraction with average IOP reduction of 2.3mmHg with a 12% reduction in medications.20

What are the mechanisms for IOP lowering in POAG after lens extraction?
The mechanism is obscure with few researchers giving the answers. A hypothesis proposed by Poley et al noted that thickening of crystalline lens with age narrows the anterior chamber angle and contributes to onset of pressure elevation and that lens removal causes angle widening, even in open angle cases, and hence control of IOP.26 They based this on the theory of ‘intrinsic pumping mechanism in canal’ by Johnstone et al, which states that apposition of Schlemm’s canal wall and trabecular tissue stiffening in glaucomatous eyes causes failure of circumferentially positioned aqueous valves in Schlemm’s canal.25 Phacoemulsification by targeting scleral spur and its ciliary body attachment enlarges lumen of Schlemm’s canal and reverse this pump failure.20 Another factor i.e. lens position, as computed by the AC depth and lens thickness (LT), has been found to be of predictive value for amount of IOP reduction among non-glaucomatous eyes as well. Based on the ‘pinch region’ theory, the more anteriorly positioned the lens is, the more likely it is to result in a ‘partial pupillary block’ like condition; which is relieved with lens extraction.27 Another proposed mechanism states that ultrasound energy used in phacoemulsification causes an abrupt rise in anterior chamber pressure, producing inflammatory cytokines (mostly IL-1) which in turn stimulate metalloproteinase production and trabecular meshwork remodelling thereby facilitating aqueous humour drainage and IOP reduction.28 For glaucoma secondary to pseudoexfoliation, a greater IOP reduction has been noted than in fellow eyes after a bilateral cataract surgery with a 3.5mmHg reduction being documented compared to 0.48 mmHg in control eyes.29,30 Despite this beneficial effect on IOP, eyes with pseudoexfoliation glaucoma could still present with higher pressure spikes in early postoperative period.31

So where do we stand? Recent literature does document mild glaucoma cases, well controlled on few medications with a visually significant cataract benefit by phacoemulsification and for this subset lens extraction alone may suffice.23 For those cases with poor control of pressure, IOP reduction after cataract surgery depends on height of pre-op values with a linear correlation irrespective of glaucomatous optic nerve changes.23,25,29,31 Thus a decision to undertake a lens extraction alone needs to be individually tailored depending on target pressure, patient profile, adherence to medication and accessibility to medical care. Long term control of IOP is possible and two recent multicentre study groups (iStent study group and OHTS) have documented IOP reduction of 8.5 and 4mmHg post-phacoemulsification in the control arm over a follow up of 1-3 years.20,22 A word of caution however as upto 26% patients may require additional medications, laser treatment or glaucoma surgery within a year of lens extraction.10 Though additional benefit of lens removal is improvement in visual acuity and clearing of media thereby permitting better visualization of optic nerve details and enhanced reliability in visual fields.

B. Role in Primary Angle Closure Glaucoma (Chronic)
Older studies in late 20th century prior to popularity of phacoemulsification have reported on the beneficial effects of conventional extra-capsular cataract surgery with posterior chamber intraocular lens implantation as a first procedure in angle closure cases compared to combined cataract and filtering surgery.33-35 This aspect is based on intrinsic role of lens in anterior chamber anatomy in patients of PACG. Since angle closure is a disease of ocular anatomy related to pupillary-block and angle-crowding mechanisms which lead to closure of filtration angle, treatment that addresses this causal mechanism by lens extraction is logical. Lens as the culprit has been documented, since in PACG patients it is thicker and more anteriorly placed.36 Lens vault (LV) is another aspect which determines the extent of villainy of lens. It is defined as the amount of lens situated anterior to a plane between the scleral spurs.37 The presence of a large lens vault or a thick lens tilts the clinical decision towards lens extraction for controlling the glaucoma.2 Studies comparing phacoemulsification and trabeculectomy alone in eyes with PACG have reported comparable glaucoma control with reduction in number of glaucoma medications being more in trabeculectomy and improvement in visual acuity better in phacoemulsification group.30,39 Gunning & Greve in addition noted need for additional incisional surgery in 80% of trabeculectomy group and requirement of subsequent cataract surgery in 75% versus only 27% further surgeries in phacoemulsification group.38 Other studies have compared phacoemulsification alone with combined phaco-trabecelectomy.19,31 Tham et al in 72 medically controlled PACG eyes with coexisting cataract noted no statistically significant differences in mean IOP between the two treatment arms over a 2 year follow-up with combined surgery being associated with lesser number of post-op medication use and marginally better IOP control and phacoemulsification to reduced postoperative complications.31 In another study on 52 medically uncontrolled PACG eyes with cataract, they noted better IOP control with combined surgery but again with greater post-operative complications.20 They opined that further study is required to determine whether this marginally better IOP control with combined surgery justifies potential additional risks of complications. In order to quantify these complications, the same group went on to study these 123 eyes subjected to phacoemulsification or combined surgery and noted a complication rate of 8.1% vs 26.2% respectively.40 Despite no significant differences in final visual acuity or glaucomatous progression between two treatment groups over a 2-year follow-up, UBM imaged angles documented significantly greater postoperative AOD 500 and reduction in extent of synchial angle closure in phacoemulsification alone arm.41 Recent AAO guidelines (2015) have also favoured lens extraction and state that for patients with chronic PACG (controlled with >1 medications), phacoemulsification alone is beneficial by reducing IOP up to 30%, with a 58% reduction in medication use and a 4-9% risk of deterioration in IOP control with very few requiring glaucoma filtration surgery over a 2
year follow up. Recent studies have validated this and linked pressure reduction with angle widening and not extent of PAS, nor presence or absence of patent peripheral laser iridotomy. Summarizing the choice between lens extraction or trabeculectomy, Trikhaa et al based the decision on extent of glaucomatous damage, extent of PAS and residual angle closure, magnitude of IOP, dimensions of lens vault or lens thickness and refractive error especially hyperopia, with presence of latter influencing in favour of lens extraction. However a Cochrane Database Systematic Review in 2006 opined that no evidence exists for effectiveness of lens extraction for chronic PACG based on non-existence of data from randomised control studies and presence of only two non-randomised comparative studies. Another comprehensive literature review in 2009 by Tarongoy et al concluded that although favourable clinical reports about role of lens extraction for treatment of PACG exist, its appropriateness remains unproven both after and in lieu of laser peripheral iridotomy. More recently, a meta-analysis of 5 RCTs and 11 case-control studies by Deng et al evaluated 1495 eyes in 2011 and concluded that phaco-trabeculectomy scored in IOP control, over 2 year follow up with no differences in terms of visual acuity. The jury is still out but broad guidelines for PACG scenario should be lens extraction for cases with mild disease with additional goniosynechiolysis being attempted for those with extensive PAS. For advanced damage trabeculectomy is to be favoured and combined surgery for those with additional cataract especially those with limited resources or access to medical care.

C. Role in Acute ACG

Laser peripheral iridotomy (LPI) has been the standard treatment for acute angle closure attack once control of IOP elevation has been achieved medically. Post LPI, anterior chamber angle widens but residual irido-trabecular contact may remain despite a patent PI. Keeping in mind the anatomical considerations of ‘pinch region’, many advocate primary cataract surgery instead of LPI as lens removal would eliminate further chances of ‘pupil block’. Few randomised control trials and case studies support the above with most patients not showing requirement of additional long term medications. Gunning & Greve in their study noted 45-55% IOP drop in patients with acute ACG and uncontrolled IOP subjected to lens extraction. Lam et al in their study of 62 eyes, evaluated primary phacoemulsification versus LPI and documented an IOP increase from 16% at 3 month follow-up, to 47% at 18 month follow-up in LPI group compared to only 3.2% (one patient) in phacoemulsification group at all follow-up visits. In their study, the LPI group fared significantly worse than phacoemulsification group in terms of mean IOP, mean number of medications needed and angle opening. These authors found high presenting IOP >55 mmHg to be an additional risk factor for subsequent pressure rise and recommended that early phacoemulsification be considered as a definitive treatment in such eyes. Husain et al in their study of 37 eyes of medically controlled acute ACG, also documented favourable response to phacoemulsification with a cumulative 2-year survival of 89.5% versus 61.1% for LPI. Although encouraging, the limited data makes it difficult to advocate radical change in standard line of care. Also performance of phacoemulsification is challenging in these smaller eyes with shallow anterior chamber and should only be considered after the inflammation and corneal edema have subsided.

D. Indian Context

Existence of both morbidities of cataract and glaucoma in patients is reflected in statistics from US Medicare which confirm concomitant glaucoma in 30% patients undergoing cataract surgery. Knowing that the burden of glaucoma in Indian population aged 40 or more reaches approximately 11.2 million and in a scenario where both cataract and glaucoma increase with increasing age, role of cataract surgery in glaucoma patients could assume more significance due to following aspects. Firstly, cataract induced visual loss is reversible and visual restoration by lens extraction significantly improves patients’ quality of life. Secondly, as cataract would progress more rapidly post a successful trabeculectomy many patients would require surgical intervention for it at a later date, especially the older patients. Since cataract surgery performed following trabeculectomy is technically more difficult and entails increased risk for bleb failure, presence of even minor cataract at the time of operating for glaucoma should favour performance of combined procedure, especially in a country like India where limited resources and even more limited access to ophthalmological care is common.

E. Role of Clear Lens Extraction

The decision to perform clear lens extraction for glaucoma is still unresolved. Studies advocating extraction of incipient cataracts and clear lenses in patients with subacute or chronic angle-closure glaucoma date from 1998 to 2013. Tham et al in the 2013 study by Tham et al noted that for medically uncontrolled PACG eyes without cataract, trabeculectomy is more effective in reducing dependence on glaucoma drugs but is associated with more complications. The authors believe that phacoemulsification alone may be a possible alternative to trabeculectomy as an initial surgical option in such eyes especially for those prone to complications but the decision needs to be individualised. Extent of pre-operative synechial angle closure needs to be assessed to determine beneficial effect of lens extraction, requirement of future filtration surgery and the extent of IOP reduction. Walland & Thomas in a recent review have however questioned the practice of clear lens extraction and advocate, stepped up approach of LPI as the first resort followed by lens extraction, after a month only for eyes with uncontrolled IOP. For fellow eyes with cataract, phacoemulsification seems a reasonable option but for eyes without cataract, no justification exists for clear lens extraction instead of LPI despite non opening of angle fully after a LPI, since natural course of disease progression and risk-benefit evaluation do not justify clear lens phacoemulsification. The same holds true for primary angle closure suspects (PACS). Despite popular belief, utility of even LPI is being questioned in such eyes with normal IOP by an ongoing study, the ZAP trial, which is looking at the natural course of the disease.
The scenario is a little different in eyes with the presence of synechial closure and PACG wherein clear lens extraction alone may be attempted in eyes with uncontrolled pressures expecting opening up of appositional closure, but with little effect on diurnal variation which is more likely to be controlled by filtration surgery.\(^5\) For eyes with minimal visual acuity or visual field loss and none/minimal optic nerve damage, surgical intervention for a mere restoration of normal angle anatomy does not justify rendering the patient a pseudophakic. In an attempt to answer these questions, the EAGLE trial (Effectiveness of Early Lens Extraction with Intraocular Lens Implantation for the Treatment of Primary Angle-Closure Glaucoma) is currently under way.\(^7\)

Initiated in 2011, this multi-centric prospective randomized clinical trial compares clear-lens extraction with current standard care in angle-closure glaucoma, in terms of primary outcomes like IOP, patient’s quality of life and cost-effectiveness at 3 years follow-up.

### Conclusion

Whether phacoemulsification or ‘lens based glaucoma surgery’ becomes the primary standard of care in near future is debatable but the emerging fact is that this procedure definitely has the potential to reduce need for IOP lowering drugs and glaucoma filtration surgery at the same time maintaining good visual acuity, all of which would improve quality of life in glaucoma patients.

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**References**

1. Huang G, Gonzalez E, Lee R, Leungurasatien T, He M, et al. Anterior chamber depth, iridocorneal angle width, and intraocular pressure changes after phacoemulsification: narrow vs open iridocorneal angles. *Arch Ophthalmol* 2011; 129:1283–90.

2. Huang G, Gonzalez E, Lee R, Chen YC, He M, Lin SC. Association of biometric factors with anterior chamber angle widening and intraocular pressure reduction after uneventful phacoemulsification for cataract. *J Cataract Refract Surg* 2012; 38:108–16.

3. Hayashi K, Hayashi H, Nakao F, Hayashi F. Changes in anterior chamber angle width and depth after intraocular lens implantation in eyes with glaucoma. *Ophthalmology* 2000; 107:698–703.

4. Kurimoto Y, Park M, Sakaue H, Kondo T. Changes in the anterior chamber configuration after small-incision cataract surgery with posterior chamber intraocular lens implantation. *Am J Ophthalmol* 1997; 124:775-80.

5. Matsunura M, Mizooguchi T, Kuroda S. Intraocular pressure decrease after phacoemulsification-aspiration and intraocular lens implantation in primary open-angle glaucoma eyes. *Nippon Ganka Gakkai Zaashi* 1996; 100:885-9.

6. Shingleton BJ, Pasternack JJ, Hung JW, O’Donoghue MW. Three and five year changes in intraocular pressure after clear cornea phacoemulsification in open-angle glaucoma patients, glaucoma suspects, and normal patients. *J Glaucoma* 2006; 15:494–8.

7. Kim DD. Intraocular pressure reduction following phacoemulsification cataract extraction with posterior chamber lens implantation in glaucoma patients. *Ophthalmic Surg Lasers* 1999; 30:37-40.

8. Mathalonne N, Hyams M, Neiman S. Long-term intraocular pressure control after clear cornea phacoemulsification in glaucoma patients. *J Cataract Refract Surg* 2005; 31:479–83.

9. Poley BJ, Lindstrom RL, Samuelson TW. Long-term effects of phacoemulsification with intraocular lens implantation in normotensive and ocular hypertensive eyes. *J Cataract Refract Surg* 2008; 34:75-9.

10. Chen PP, Lin SC, Junk AK, Radhakrishnan S, Singh K, Chen TC. The Effect of Phacoemulsification on Intraocular Pressure in Glaucoma Patients - A Report by the American Academy of Ophthalmology. *Ophthalmology* 2015; 122:1294-307.

11. Tarongoy P, Ho CL, Walton DS. Angle-closure Glaucoma: The Role of the Lens in the Pathogenesis, Prevention, and Treatment. *Surv Ophthalmol* 2009; 54:211-25.

12. Silver DM, Quigley HA. Aqueous Flow through the Iris—Lens Channel: Estimates of Differential Pressure between the Anterior and Posterior Chambers. *J Glaucoma* 2004;13:100-7.

13. Issa SA, Pacheco J, Mahmood L. A novel index for predicting intraocular pressure reduction following cataract surgery. *Br J Ophthalmol* 2005; 89:543-6.

14. Liu CJ, Cheng CY, Ko YC, Lai LL. Determinants of long-term intraocular pressure after phacoemulsification in primary angle-closure glaucoma. *J Glaucoma* 2011; 20:566-70.

15. Mansberger SL, Gordon MO, Jampel H, Bhorade A, Brandt JD, Wilson Bet al; for the Ocular Hypertension Treatment Study Group. Reduction in intraocular pressure after cataract extraction: the Ocular Hypertension Treatment Study. *Ophthalmology* 2012; 119:1826–31.

16. Hayashi K, Hayashi H, Nakao F, Hayashi F. Effect of cataract surgery on intraocular pressure control in glaucoma patients. *J Cataract Refract Surg* 2001; 27:1779-86.

17. Sham JS, Foster PJ. Clinical outcomes after lens extraction for visually significant cataract in eyes with primary angle closure. *J Glaucoma* 2012; 21:545-50.

18. Lai J, Tham C, Chan J. The clinical outcome of cataract extraction by phacoemulsification in eyes with primary angle-closure glaucoma and co-existing cataract: a prospective series. *J Glaucoma* 2006; 15:47-52.

19. Tham CC, Kwong YY, Leung DY, Lam SW, Li FC, Chiu TY, et al. Phacoemulsification versus combined phacotrabeculectomy in medically controlled chronic angle closure glaucoma with cataract. *Ophthalmology* 2008; 115:2167-73.

20. Tham CC, Kwong YY, Leung DY, Lam SW, Li FC, Chiu TY, et al. Phacoemulsification versus combined phacotrabeculectomy in medically uncontrolled chronic angle closure glaucoma with cataracts. *Ophthalmology* 2009; 116:725–31.

21. Chang RT, Shingleton BJ, Singh K. Timely cataract surgery for improved glaucoma treatment [guest editorial]. *J Cataract Refract Surg* 2012; 38:1709–10.

22. Lai J, Choy BN, Shum JW. Management of Primary Angle-Closure Glaucoma. *Asia Pac J* *Ophthalmol (Phil) (Phil)* 2016; 5:59-62.

23. Velez G, Pinto LA, Marques-Neves C. Cataract surgery and Intraocular Pressure. *Ophthalmic Res* 2015; 53:141-8.

24. Friedman DS, Jampel HD, Lubomski LH, Kempen JH, Quigley H, Congdon N, et al. Surgical strategies for coexisting glaucoma and cataract: an evidence-based update. *Ophthalmology* 2002; 109:1902–13.

25. Poley BJ, Lindstrom RL, Samuelson TW, Schulze R Jr. Intraocular pressure reduction after phacoemulsification with intraocular lens implantation in glaucomatous and nonglaucomatous eyes; evaluation of a causal relationship between the natural lens and open-angle glaucoma. *J Cataract Refract Surg* 2009; 35:193-5.

26. Johnstone MA. The aqueous outflow system as a mechanical pump; evidence from examination of tissue and aqueous movement in human and non-human primates. *J Glaucoma* 2004; 13:421-38.
27. Hsu C-H, Kakigi CL, Lin S-C, Wang Y-H, Porco T, Lin SC. Lens position parameters as predictors of intraocular pressure reduction after cataract surgery in non-glaucomatous patients with open angles. *Invest Ophthalmol Vis Sci* 2015; 56:7807-13.

28. Wang N, Chintala SK, Fini ME, Schuman JS. Ultrasound activates the TM ELAM-1/IL-1/NF-κB response: a potential mechanism for intraocular pressure reduction after phacoemulsification. *Invest Ophthalmol Vis Sci* 2003; 44:1977-81.

29. Shingleton BJ, Nguyen BK, Eagan EF, Nagao K, O’Donoghue MW. Outcomes of phacoemulsification in fellow eyes of patients with unilateral pseudoxefoliation: single-surgeon series. *J Cataract Refract Surg* 2008; 34:274-9.

30. Cimetta DJ, Cimetta AC. Intraocular pressure changes after clear corneal phacoemulsification in non-glaucomatous pseudoxefoliation syndrome. *Eur J Ophthalmol* 2008; 18:77-81.

31. Levkovitch-Verbin H, Habot-Wilner Z, Burla N, Melamed S, Goldenfeld M, Bar-Sela SM, et al. Intraocular pressure elevation within the first 24 hours after cataract surgery in patients with glaucoma or exfoliation syndrome. *Ophthalmology* 2008; 115:104-8.

32. Samuelson TW, Katz LJ, Wells JM, Duh Y-J, Giamporcaro JE; for the US iStent Study Group. Randomized evaluation of the trabecular micro-bypass stent with phacoemulsification in patients with glaucoma and cataract. *Ophthalmology* 2011; 118:459-67.

33. Wishart PK, Atkinson PL. Extracapsular cataract extraction and posterior chamber lens implantation in patients chronic with primary angle-closure glaucoma: Effect on intraocular pressure control. *Eye* 1989; 3:706-12.

34. Gunning FP, Greve EL. Uncontrolled primary angle-closure glaucoma: results of early extracapsular cataract extraction and posterior chamber lens implantation. *Int Ophthalmol* 1991; 15:237-47.

35. Greve EL. Primary angle-closure glaucoma: extracapsular cataract extraction or filtering procedure. *Int Ophthalmol* 1988; 12:157-62.

36. Lowe RF. Aetiology of the anatomical basis for primary angle-closure glaucoma: biomeirical comparisons between normal eyes and eyes with primary angle-closure glaucoma. *Br J Ophthalmol* 1970; 54:161-9.

37. Nongpiur ME, He MG, Amerasinghe N, Friedman DS, Tay WT, Baskaran M, et al. Lens vault, thickness and position in Chinese subjects with angle closure. *Ophthalmology* 2011; 118:474-9.

38. Gunning F.P., Greve E.L. Lens extraction for uncontrolled angle-closure glaucoma: long-term follow-up. *J Cataract Refract Surg* 1998; 24:1347-56.

39. Tham CC, Kwong YY, Baig N, Leung DY, Li FC, Lam DS. Phacoemulsification versus Trabeculectomy in Medically Uncontrolled Chronic Angle-Closure Glaucoma without Cataract. *Ophthalmology* 2013; 120:62-7.

40. Tham CC, Kwong YY, Leung DY, Lam SW, Li FC, Chiu TY, et al. Phacoemulsification vs phacotrabeculectomy in chronic angle closure glaucoma with cataract: complications. *Arch Ophthalmol* 2010; 128:303-11.

41. Tham CC, Leung DY, Kwong YY, Li FC, Lai JS, Lam DS. Effects of phacoemulsification versus combined phacotrabeculectomy on drainage angle status in primary angle closure glaucoma. *J Glaucoma* 2010; 19:119-23.

42. Imaizumi M, Takaki Y, Yamashita H. Phacoemulsification and intraocular lens implantation for acute angle closure glaucoma not treated or previously treated by laser iridotomy. *J Cataract Refract Surg* 2006; 32:85-90.

43. Trikhaa S, Pereraa SA, Husaina R, Aung T. The role of lens extraction in the current management of primary angle-closure glaucoma. *Curr Opin Ophthalmol* 2015; 26:129-34.

44. Friedman DS, Vedula SS. Lens extraction for chronic angle-closure glaucoma. *Cochrane Database Syst Rev* 2006; 19:CD005555.

45. Deng BL, Jiang C, Ma B, Zhang WF, Lu P, Du YY, et al. Surgical treatment for primary angle-closure glaucoma: a meta-analysis. *Int Ophthalmol* 2011; 4:223-7.

46. He M, Friedman DS, Ge J, Huang W, Jin C, Cai X, et al. Laser peripheral iridotomies in eyes with narrow drainage angles: ultrasound biomicroscopy outcomes. The Liwan Eye Study. *Ophthalmology* 2007; 114:1513-9.

47. Lam DS, Leung DY, Tham CC, Li FC, Kwong YY, Chiu TY, et al. Randomized trial of early phacoemulsification versus laser peripheral iridotomy for acute primary angle closure. *Ophthalmology* 2008; 115:1134-40.

48. Hsusain R, Gazzard G, Aung T, Chen Y, Padmanabhan V, Oen FT, et al. Initial management of acute primary angle closure: a randomized trial comparing phacoemulsification with laser peripheral iridotomy. *Ophthalmology* 2012; 119:2274-81.

49. Zha MZ, Lim AS, Yin W, T. A pilot study of lens extraction in the management of acute primary angle closure glaucoma. *Am J Ophthalmol* 2003; 135:554-6.