Since the first reports of femtosecond laser assisted cataract surgery (FLACS) in 2009, the scientific literature has provided over 250 peer-reviewed articles, ranging from randomised controlled trials to cohort studies, case reports and editorials. Over this time there has been a rapid evolution in technology, surgical techniques and surgeon experience.

SAFETY

In 2012 our group described the safety and outcomes of patients undergoing FLACS,[1] highlighting the technology in its infancy and a clear learning curve for ophthalmologists. Early cohort papers with other laser units described similar findings.[2, 3] Subsequent articles confirmed training and technique adaptations and the rapid evolution of both software and hardware leading to improved outcomes. [4-7]

The safety of the FLACS procedure has been confirmed with a controlled, comparative cohort of manual phacoemulsification patients.[8] Our follow-up paper of 1300 eyes provided results equal or surpassing the best safety outcomes for manual procedures.[9] These excellent safety outcomes have since been replicated in more recent articles.[10, 11] Table 1 outlines the best
published safety outcomes for femtosecond versus manual procedures. [3, 9-17] Differences in safety outcomes have been variously explained by study design, selection bias and variation across individual laser units and surgeons. FLACS offers some significant safety advantages, as seen in numerous case reports and series in complex cases. (Table 2)

**PHACOEMULSIFICATION TIME AND ENERGY**

Evidence is overwhelming in describing how FLACS decreases effective phacoemulsification time and energy.[18-20] Further studies confirm this may lead to less early inflammation, endothelial cell loss and potential post-operative retinal health advantages.[21-25] A reduction in macular thickness following FLACS and the possibility of a reduced post-operative cystoid macular oedema (CME) has been suggested.[26] Subsequent studies however have not shown a difference in the incidence of clinical CME.[13,27]

**ANTERIOR CAPSULOTOMY**

Anterior capsule integrity has also been a source of considerable discussion. As described in early studies, anterior capsular tears were observed during the initial learning curve.[1] This has variously been ascribed to incomplete capsulotomies, capsulotomy tags or perforations and an inherent reduction in capsulotomy strength following FLACS.[28] Studies have shown morphological differences in capsulotomy edge characteristics between FLACS and manual specimens with scanning electron microscopy imaging.[29,30] One group raised safety concerns and suggested the high complication rate in their series was due to an intrinsic weakness in laser-cut capsulotomies.[11]. However subsequent large prospective studies from other centres using different laser
systems have found the anterior capsule tear rate to be extremely low,\textsuperscript{[10,11,31]} indicating the high tear rate previously reported would be due to laser energy settings and individual surgical technique.

**REFRACTIVE OUTCOMES**

Early reports confirmed greater circularity, centration and consistency of laser capsulotomies.\textsuperscript{[51-53]} Combined with less cumulative dissipated energy and phacoemulsification time it was expected that the FLACS patient would not only recover faster but have better, more stable refractive outcomes.\textsuperscript{[24, 54]} The first paper to show a statistically significant refractive difference in outcomes between FLACS and manual cohorts found the mean absolute error (MAE) to be $0.38 \pm 0.28$D and $0.50 \pm 0.38$D for FLACS and manual cohorts respectively.\textsuperscript{[55]} Differences were greater in patients with short and long axial lengths.

Other authors similarly found mean residual spherical equivalent and MAE to be smaller in their FLACS comparison study. This difference further increased with time.\textsuperscript{[53]} Interestingly, the same group later found lower variability in post-operative anterior chamber depth and post-operative refraction which did not translate to a significantly lower MAE in this series.\textsuperscript{[55]} Other studies have shown a statistically greater percentage of patients achieving post-operative refraction $\pm 0.5$D within intended targets for the FLACS group compared to the manual cohort, \textsuperscript{[24]} and a considerable difference between mean difference from target for FLACS and manual cohorts ($0.16 \pm 0.16$D vs. $0.74 \pm 0.65$D, $p < 0.01$).\textsuperscript{[56]} Other studies have not reached statistical or clinical significance across refractive parameters.\textsuperscript{[30,57-59]} These latter papers had excellent
refractive results in the comparative manual surgery groups, and very large sample sizes would therefore be required to demonstrate statistically significant improved outcomes.

**CONCLUSION**

The evidence-based literature suggest that the first 5 years of published outcomes have been supportive of the long-term future of FLACS. Additional controlled trials and practical experience is required to further assess both safety and refractive outcomes. Published refractive results to date across laser and manual cataract surgery suggest that outcomes may be approaching the upper limits of intraocular lens technology and IOL calculations and further refractive benefits of FLACS may only become evident with improvements in these areas.

**Further information:**

Tim Roberts, MD

tim.roberts@visioneyeinstitute.com.au

Chris Hodge, PhD

christopher.hodge@visioneyeinstitute.com.au
Table 1: Published rates of complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>Lowest Published Rate</th>
<th>FLACS</th>
<th>MANUAL SURGERY</th>
</tr>
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<tbody>
<tr>
<td>AC TEAR</td>
<td>0.10%</td>
<td>Day et al 2015 (10) (n=1000) Roberts et al. 2015 (9) (n= 3355)</td>
<td>0.22% Abell et al. 2015 (14) (n= 2228)</td>
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<tr>
<td></td>
<td>0.21%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC TEAR without vitreous</td>
<td>0.08%</td>
<td>Roberts et al 2013 (9) (n=1300)</td>
<td>0.16% Misra et al. 2005[15] (n = 1883) Ewe et al 2016 [12] (n=888)</td>
</tr>
<tr>
<td>Tear with vitreous</td>
<td>0.23%</td>
<td>Roberts et al. 2013 [9] (n=1300)</td>
<td>0.20% Gimbel 2001[16] (n=18,470)</td>
</tr>
<tr>
<td>Posterior Lens Dislocation</td>
<td>0.00%</td>
<td>Roberts et al. 2015[11] (n=3355) Chee at al. 2015[3] (n=1105)</td>
<td>0.00% Gimbel 2001 [16] (n=18,470)</td>
</tr>
<tr>
<td>Clinical CME</td>
<td>0.80%</td>
<td>Ewe et al 2016[12] (n=883) Levitz et al. 2015[13] (n=677)</td>
<td>0.2% Ewe et al 2015 [17] (n= 458)</td>
</tr>
<tr>
<td></td>
<td>1.18%</td>
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</table>
Table 2: Proposed benefits of FLACS in complex cases

<table>
<thead>
<tr>
<th>Condition</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Capsular Contraction</td>
<td>Schweitzer JRS 2015 [35]</td>
</tr>
<tr>
<td>Bag in Lens Technique</td>
<td>Dick JCRS 2013 [36]</td>
</tr>
<tr>
<td>Floppy Iris Syndrome</td>
<td>Martin Curr Opin 2014 [37]</td>
</tr>
<tr>
<td>Fuchs Dystrophy</td>
<td>Martin Curr Opin 2014 [37]</td>
</tr>
<tr>
<td>Nanophthalmia</td>
<td>Martin Clin Exp Ophthalmol 2014 [38]</td>
</tr>
<tr>
<td>Paediatric Cataract</td>
<td>Dick JCRS 2013 [39]</td>
</tr>
<tr>
<td>Phacomorphic Glaucoma</td>
<td>Kranitz JRS 2013 [40]</td>
</tr>
<tr>
<td>Post Penetrating Keratoplasty</td>
<td>Martin Curr Opin 2014 [37]</td>
</tr>
<tr>
<td>Post Trabeculectomy</td>
<td>Roberts Clin Exp ophthalmol 2013 [28]</td>
</tr>
<tr>
<td>Primary Posterior Capsulotomy</td>
<td>Dicks JRS 2014 [43]</td>
</tr>
<tr>
<td>Rescue for Capsulorrhexis Enlargement</td>
<td>Dicks JCRS 2014 [44]</td>
</tr>
<tr>
<td>Traumatic Cataract</td>
<td>Grewal JCRS 2015 [45, 46]</td>
</tr>
<tr>
<td>Subluxed Lens</td>
<td>Crema JRS 2015 [47], Schultz JRS 2013 [48]</td>
</tr>
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References: