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Visual and refractive outcomes of laser cataract surgery

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Abstract

Purpose of review—Femtosecond laser is a promising new technology for the field of cataract surgery. Early studies have investigated many factors including visual outcomes, complication rates, and financial overhead costs. This review analyzes the most recent clinical studies of visual and refractive outcomes in laser cataract surgery, including those that make comparisons to outcomes found in conventional phacoemulsification cataract surgery.

Recent findings—As femtosecond laser cataract surgery has only emerged recently, there is limited literature available regarding visual outcomes. Most but not all existing studies showed no statistically significant difference in visual acuity and mean absolute refractive error between laser and conventional cataract surgery cases.

Summary—The majority of studies examined found visual acuity or refractive outcomes of femtosecond laser to be statistically equivalent to those of conventional phacoemulsification cataract surgery. However, the learning curve involved with laser use may account for these early results, which could potentially improve as better technology and surgical techniques are developed. Further long-term outcomes studies are necessary to more accurately evaluate the benefits and drawbacks of femtosecond laser cataract surgery.

Keywords

cataract; femtosecond laser; laser cataract surgery; phacoemulsification; visual outcomes

INTRODUCTION

Cataract removal is the most common surgical procedure worldwide, with an estimated 19 million surgeries performed annually [1]. Cataract surgery has evolved dramatically in the past few decades with new technologies and surgical techniques bringing improvements in visual outcomes and patient safety. Femtosecond laser cataract surgery (FLCS) is the newest technology to emerge in the field, bringing with it potential benefits and barriers that surgeons should be aware of when considering whether or not to integrate the laser technology into their practice.

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Conflicts of interest
No author has any conflicts of interests relating to the content of the study.

Mechanism of femtosecond laser

Femtosecond laser works by photodisruption: light energy absorbed by tissue induces optical breakdown, in which tissue is transformed into plasma [2]. The plasma rapidly expands, creating microcavitation bubbles and acoustic shock waves that cause morphological tissue changes [3]. The near infrared wavelength of commercial femtosecond lasers (1053 nm) is not absorbed by transparent or limited thickness translucent tissues, affecting only the tissue at the focus point of the beam [4]. Thus, these lasers can travel freely though the cornea and work on targeted areas in the anterior chamber. The name 'femtosecond' arises from the rapid pulse time utilized – 10^{-15} s, which allows for far less collateral tissue damage compared with Nd:YAG and other laser systems [5].

Femtosecond lasers have been FDA approved for the following three steps in cataract surgery: corneal incision construction, anterior capsulotomy, and lens fragmentation. The laser can also be used to create limbal relaxing incisions for astigmatic correction. Currently, four commercial FLCS platforms are available: LenSx (Alcon, Aliso Viejo, California, USA); Catalys (Optimedica, Santa Clara, California, USA); LensAR (LensAR, Orlando, Florida, USA); and VICTUS (Technolas GMBH Munich, Germany). The platforms vary slightly in their docking system and imaging modality, but the overall procedure performed is similar [5].

Potential benefits

The use of femtosecond laser offers many potential benefits, including more accurate capsulotomy, decreased phacoemulsification time, and an improved safety profile [6■,7–9]. Nagy *et al*. and several other studies have shown femtosecond laser-guided anterior capsulotomies performed with various commercial platforms were significantly more accurate and reproducible in terms of circularity, centration, and size versus manual capsulorhexis [8,10–12,13■]. Kránitz *et al*. [7] found that the risk of IOL decentration was six times higher in manual capsulorhexis compared with femtosecond laser-assisted capsulotomy [7]. Laser fragmentation of cataracts decreases the required phacoemulsification energy and time [6■]. Complication rates have remained low in most FLCS studies: Bali *et al*. [14] reported no significant difference in anterior radial and posterior capsular tear rates between their first 200 FLCS patients and 1000 routine phacoemulsification patients. Complication rates have been reported to drop as surgeons perform more FLCS cases [14].

Cost considerations

Incorporating femtosecond lasers into a surgery practice requires considerable investments in terms of equipment, workflow adjustments, and appropriate education of staff and patients [15]. A survey of 1047 ophthalmologists' opinions on FLCS revealed that the most common concern was financial costs (72%), then reduced workflow efficiency (13%), followed by patient dissatisfaction or increased expectations (6%) [16]. Although costs are predicted to eventually drop with time, a 2011 estimate placed the cost of a commercial femtosecond laser platform between $400 000 and $500 000 USD [17]. In addition, currently there is an extra usage fee of $150 to $400 per case, as well as maintenance, insurance, and upgrade costs of $40 000 to $50 000 per year [17]. This estimate does not

take into account additional time needed to train surgeons, technicians, and other employees to familiarize themselves with the new technology and processes it entails. Medicare and commercial insurance companies currently only reimburse femtosecond laser procedures involving limbal relaxing incisions for astigmatism correction or for use in conjunction with premium lens technology (toric and accommodating IOLs). Physicians interested in investing in the technology will need to determine how to integrate these costs successfully into their practice [15].

Is it worth it?

The debate over the benefits and costs of FLCS has led us to perform a review of the current literature to determine whether there are significant differences in visual and refractive outcomes between conventional phacoemulsification and FLCS. Many studies have measured visual outcomes in FLCS cases alone and found promising results. In an early clinical evaluation in 2009, Nagy *et al*. [10] reported laser capsulorhexis and/or lens fragmentation on nine patients, all of which reached a best corrected visual acuity of 20/20 one month postoperatively with no complications. Szigeti *et al*. [18] performed laser capsulorhexis with accommodating IOLs on 17 eyes, and reported promising results of 11 eyes with uncorrected distance visual acuity of 20/25 or better after 1 year. In the first 200 eyes undergoing FLCS surgery with six surgeons, Bali *et al*. [14] found corrected distance visual acuity to be 20/30 or better in 84.5% of eyes 2 weeks postoperatively.

However, few studies have been published comparing the visual outcomes of FLCS to a controlled cohort of conventional phacoemulsification cataract surgery cases (performed by the same surgeon, during a similar time period, similar patient demographics). To best answer the question of whether or not there is a significant difference in visual and refractive outcomes, we chose to focus specifically on current literature that compares visual outcomes between two groups, laser and conventional.

EVIDENCE FOR A SIGNIFICANT IMPROVEMENT IN VISUAL OUTCOMES

Few published studies note significantly better refractive results with FLCS compared with conventional surgery. Kránitz *et al*. [7] used the femtosecond laser for anterior capsulorrhexis on 20 eyes and compared the results to manual capsulorrhexis performed on 25 eyes. They found a statistically significant difference in corrected distance visual acuity between the two groups, one month 0.94±0.11 vs. 0.84±0.16 (decimal form), $P = 0.031$) and 1 year (0.97±0.06 vs. 0.92±0.09, $P=0.038$) after surgery. Using a Scheimpflug camera (Pentacam), authors correlated the significantly better corrected distance visual acuity in the capsulorrhexis cases with less vertical tilt and total IOL decentration. There was no significant difference in uncorrected distance visual acuity between the two groups at any time point postoperatively.

Filkorn *et al*. [13■] also found improved refractive results using the femtosecond laser compared to conventional phacoemulsification. Rather than capsulorhexis alone, their prospective study used the laser for the additional steps of corneal wound construction and lens fragmentation. Seventy-seven eyes underwent FLCS and 57 received conventional phacoemulsification. The authors measured the mean absolute error, which was defined as

the absolute difference between predicted and achieved postoperative spherical equivalent refraction. A smaller mean absolute error is associated with better predictability of IOL power calculation. Six weeks after surgery, the mean absolute error was significantly lower in the laser group [0.38±0.28 D] than in the conventional group (0.50±0.38 D) (*P*=0.04). However, the authors did not find a significant difference between the groups in terms of other measures of visual outcomes, including manifest refraction spherical equivalent, corrected distance visual acuity, and mean error (nonabsolute difference between predicted and achieved postoperative spherical equivalent).

EVIDENCE FOR NO SIGNIFICANT DIFFERENCE IN VISUAL OUTCOMES

Although most studies agree that femtosecond lasers increase the accuracy and reproducibility of the steps involved in cataract surgery, several have found that FLCS does not offer significantly superior visual outcomes compared with standard surgery. Mihältz *et al*. [19■] performed laser capsulorhexis in 48 eyes and compared the results to conventional manual capsulorhexis in 51 eyes. Six months postoperatively, they found no significant difference in uncorrected and corrected distance visual acuity between the two groups. The authors did find that the laser group had lower values of internal vertical tilt and higher Strehl ratios (both measures of the internal aberrations of the eye), which suggest a better image quality for these patients. However, the authors noted that the source of these internal aberrations could not be isolated to the lens, but could also come from the posterior surface of the cornea. Distinguishing the source of the internal aberrations could not be performed with the OPD-Scan. Whether the decrease in internal aberrations ultimately brings improvements in clinically significant visual outcomes remains to be proven.

An Australian study of 61 FLCS eyes and 29 standard cases found no significant difference in several visual and refractive outcomes, including uncorrected and corrected distance visual acuity, uncorrected near visual acuity, mean postoperative spherical equivalent refraction, and mean absolute and arithmetic refractive prediction error [20■]. In this study, femtosecond laser was used for the three steps of capsulorhexis, fragmentation, and corneal incisions. Patients were evaluated 3 months after surgery.

Roberts *et al*., [21] also from the same institute, found no significant difference in visual outcomes in a prospective study of 113 FLCS procedures versus 105 conventional cases. The absolute mean difference from intended correction in diopters was 0.29±0.25 D for the FLCS group and 0.31±0.24 D for the standard group (*P*=0.512). More than 90% of patients in both groups achieved 20/40 uncorrected distance visual acuity 3 months, postoperatively.

Most recently, Abell *et al*. [6■] found no significant difference in best-corrected visual acuity and mean absolute error in 150 FLCS eye versus 51 conventional eyes. Femtosecond laser was used for capsulorhexis and lens fragmentation, not for the corneal incisions. Three weeks after surgery, both groups had a mean BCVA of 20/30. Unlike the other studies, this one did not exclude patients with other ocular comorbidities such as age-related macular degeneration, which explains the rather low visual acuities found compared with cases without comorbidities. Mean absolute error was −0.51±0.50 D the FLCS group in and −0.45±0.71 D in the group, an insignificant standard difference. The authors did note a

significant decrease in phacoemulsification time in the FLCS group, which previous studies have shown leads to decreased endothelial cell loss [22]. However, in this study, there was no significant difference in postoperative mean endothelial cell count between the two study groups. The reduction in phacoemulsification time validates the femtosecond laser's safety and efficacy, although it did not lead to any significant improvement in visual outcomes.

CONCLUSION

Although most studies to date have found no significant difference in visual outcomes between FLCS and conventional surgery, there are many factors that must be considered when evaluating these results. Most of these studies evaluate the early experiences with the laser. For example, in the 2012 study by Lawless *et al*., [20■] the authors did not find a significant difference in visual acuity or mean absolute error between the two groups, but noted that the laser cases in the study were the surgeons' initial consecutive FLCS experiences. As they also found a significant initial learning curve associated with the procedure, they believe FLCS results will improve over time as surgeons gain more experience and improve their techniques [5].

Furthermore, as femtosecond technology has emerged only within the past few years, many of the published studies were not randomized or blinded, introducing the risk of bias. Most early studies published were performed by consultants for laser companies. Yet, it is interesting that given these circumstances, many studies to date have not found FLCS to be superior to phacoemulsification in terms of visual outcomes.

Given the potential financial benefit of integrating FCLS into clinical practice, it is likely that FCLS will only continue to grow in popularity. Many authors have drawn an analogy of the emergence of FLCS with the previous rise and eventual adaptation of phacoemulsification, when similar debates arose in terms of phacoemulsification's efficacy and benefits over standard extracapsular surgery. Sutton *et al*. [23,24] noted that proper long-term, randomized controlled studies that demonstrated phacoemulsification's superiority over extracapsular cataract surgery were not published until 2001, well after phacoemulsification had been adopted as the preferred surgery in developed countries. Today, much more extensive literature on phacoemulsification has established it as a benchmark of safety and efficacy. Ultimately, more long-term outcomes studies on FLCS need to be performed to determine the impact of femtosecond lasers on patient outcomes and quality of cataract surgery.

The rise of new technology and techniques in cataract surgery has greatly transformed the field of ophthalmology over the past few decades. We anticipate that in the next few years, a surge in femtosecond laser cataract surgeries performed will yield more helpful data to broaden our understanding of the efficacy and benefits of this procedure.

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KEY POINTS

- Femtosecond laser is a promising new technology emerging in the field of cataract surgery. Due to its young age, few studies have been performed on long-term outcomes.
- Overall, current studies that compare femtosecond laser cases with conventional cases have shown visual and refractive outcomes to be statistically equivalent.
- More randomized, blinded studies with long-term visual outcomes need to be performed to properly evaluate the efficacy of femtosecond laser cataract surgery compared to traditional phacoemulsification.