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Review Article

Corneal Biomechanical Integrity After Femtosecond Laser-Assisted Versus Manual Incisions in Cataract Surgery: A Systematic Review

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ABSTRACT

Background: The integrity of the clear corneal incision is fundamental to safety, wound sealing, and refractive stability in cataract surgery. Although femtosecond laser-assisted cataract surgery enables highly standardized, image-guided incision construction, its comparative effect on postoperative corneal biomechanical integrity remains uncertain, with individual studies reporting heterogeneous structural and functional findings. Objective: To systematically review and synthesize comparative evidence on whether femtosecond laser-assisted clear corneal incisions provide superior corneal biomechanical integrity compared with manually created clear corneal incisions in adult patients undergoing cataract surgery. Methods: A systematic review was conducted in accordance with PRISMA 2020 guidance. PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials were searched for studies published between January 2015 and March 2024. Comparative clinical studies evaluating femtosecond laser-assisted versus manual clear corneal incisions and reporting corneal biomechanical outcomes were eligible. Primary outcomes included corneal hysteresis and corneal resistance factor; secondary outcomes included incision morphology, wound apposition, and wound leakage. Two reviewers independently screened studies, extracted data, and assessed methodological quality using RoB 2 for randomized trials and ROBINS-I for non-randomized studies. Owing to clinical and methodological heterogeneity, findings were synthesized narratively. Results: Eight studies involving 724 eyes met the inclusion criteria. Three studies were randomized controlled trials and five were prospective comparative cohort studies. Across all included studies, no statistically significant or clinically meaningful difference was found between femtosecond-assisted and manual incision groups in postoperative changes in corneal hysteresis or corneal resistance factor during early follow-up. In contrast, imaging-based studies consistently showed that femtosecond laser-assisted incisions had more reproducible architecture, including more regular tunnel configuration and endothelial apposition. These structural advantages did not translate into measurable superiority in global corneal biomechanical performance or clear reduction in wound-related adverse outcomes. Conclusion: Current evidence indicates that femtosecond laser-assisted clear corneal incisions offer superior morphological reproducibility but do not confer a measurable advantage over manual incisions in global postoperative corneal biomechanical integrity. Technology selection in cataract surgery should therefore not be based on an expectation of biomechanical superiority alone, and further long-term randomized studies using localized biomechanical assessment tools are warranted. Keywords: Cataract surgery; Femtosecond laser-assisted cataract surgery; Corneal biomechanics; Corneal hysteresis; Corneal resistance factor; Clear corneal incision; Systematic review.

INTRODUCTION

Cataract surgery is among the most commonly performed operative procedures worldwide and remains one of the most effective interventions for restoring functional vision and improving quality of life in aging populations (1). As surgical volume has increased, technical refinements have focused not only on visual rehabilitation but also on optimizing intraoperative precision, wound integrity, and postoperative refractive stability. Within this context, the clear corneal incision is a critical step because

it serves as the principal entry point for phacoemulsification and intraocular lens implantation, while also influencing wound sealing, surgically induced astigmatism, anterior chamber stability, and the risk of postoperative complications such as wound leak and endophthalmitis (2,3). Although manual keratome-created clear corneal incisions remain the standard approach in routine cataract surgery, femtosecond laser-assisted cataract surgery has introduced image-guided, highly standardized incision construction with the theoretical advantage of greater architectural precision and reproducibility (4).

The clinical relevance of this technological shift depends not only on geometric incision quality but also on its biomechanical consequences. Corneal biomechanical integrity is central to preserving corneal shape, maintaining refractive predictability, and supporting the structural resilience of the operated eye. Parameters such as corneal hysteresis and corneal resistance factor provide clinically useful surrogates of viscoelastic and elastic behavior, respectively, and have therefore been used to evaluate how surgical interventions alter corneal stability (5). Despite the precision associated with femtosecond platforms, the extent to which laser-created incisions offer a true biomechanical advantage over well-constructed manual incisions remains uncertain. Prior comparative studies have reported heterogeneous findings, with some emphasizing improved incision architecture and wound apposition after laser-assisted surgery, whereas others have shown little or no measurable difference in postoperative biomechanical behavior between the two approaches (4,5). This distinction is important because superior morphology on imaging does not necessarily imply superior functional strength at the tissue or organ level.

Although the broader literature on femtosecond laser-assisted cataract surgery has examined visual outcomes, endothelial cell loss, effective phaco time, and refractive accuracy, a focused synthesis of comparative evidence specifically addressing corneal biomechanical integrity after femtosecond versus manual incision creation has been lacking. The absence of a targeted review in this area limits evidence-based decision-making, particularly for surgeons and institutions considering whether the additional technological complexity and cost of femtosecond systems are justified by clinically meaningful wound-related advantages. A contemporary systematic review is therefore warranted to consolidate available comparative evidence, critically appraise study quality, and distinguish between structural incision reproducibility and measurable postoperative biomechanical performance. In accordance with PRISMA 2020 guidance, this review was undertaken to evaluate whether, in adults undergoing cataract surgery, femtosecond laser-assisted clear corneal incisions confer superior corneal biomechanical integrity compared with manually created clear corneal incisions, as assessed by corneal hysteresis, corneal resistance factor, incision morphology, and wound-sealing characteristics (6).

MATERIAL AND METHODS

This systematic review was conducted using a prospectively registered protocol and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement (6). The review question was structured according to the PICO framework: the population comprised adult patients undergoing cataract surgery; the intervention was femtosecond laser-assisted clear corneal incision creation; the comparator was manually created clear corneal incision using a keratome; and the outcomes of interest were postoperative indicators of corneal biomechanical integrity, including corneal hysteresis, corneal resistance factor, incision morphology, and wound-sealing characteristics. The review was designed to synthesize comparative clinical evidence generated under contemporary surgical practice and therefore focused on studies published during the period of widespread clinical use of femtosecond cataract platforms.

A comprehensive electronic search was performed in four databases: PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials. The search covered studies published from January 2015 to March 2024. Search terms were developed by combining controlled vocabulary and free-text keywords related to cataract surgery, femtosecond laser technology, manual corneal incisions, and corneal biomechanics using Boolean operators. A representative search strategy for

PubMed was as follows: ("Phacoemulsification"[Mesh] OR "Cataract Extraction"[Mesh]) AND ("Femtosecond laser"[Mesh] OR "laser-assisted cataract surgery") AND ("Cornea"[Mesh] OR "corneal biomechanics" OR "corneal hysteresis" OR "corneal resistance factor") AND ("wound healing" OR "incision" OR "surgical wound"). To minimize the risk of missing relevant studies, the reference lists of all included articles and relevant review papers were also screened manually.

Eligibility criteria were predefined before screening. Comparative clinical studies, including randomized controlled trials and prospective or retrospective cohort studies, were eligible if they directly compared femtosecond laser-assisted and manual clear corneal incision techniques in adult cataract surgery and reported quantitative or imaging-based corneal biomechanical outcomes. Primary outcomes included corneal hysteresis and corneal resistance factor measured using validated instruments such as the Ocular Response Analyzer or Corvis ST. Secondary outcomes included incision architecture on anterior segment optical coherence tomography, wound apposition, wound leakage, central corneal thickness, and related wound-healing indicators. Studies were excluded if they involved non-comparative designs, combined cataract surgery with other refractive procedures in a way that prevented attribution of effects to incision technique, used animal or cadaveric models, were conference abstracts without extractable full data, or were not published in English.

All retrieved records were imported into EndNote X9 for deduplication and citation management. Study selection proceeded in two stages. First, titles and abstracts were screened independently by two reviewers against the eligibility criteria. Second, the full texts of potentially relevant articles were reviewed in detail by the same two reviewers to determine final inclusion. Disagreements at either stage were resolved through discussion, and when consensus was not immediately reached, adjudication was undertaken by a senior reviewer. The study selection process yielded 387 records initially identified from databases, from which 112 duplicates were removed, leaving 275 records for title and abstract screening. Of these, 248 were excluded, 27 full-text articles were assessed for eligibility, and 8 studies were ultimately included in the qualitative synthesis. This process was documented in the PRISMA flow diagram and reflected the final evidence base used for analysis.

Data extraction was performed independently by two reviewers using a piloted standardized extraction form developed in Microsoft Excel. Extracted variables included first author, year of publication, country, study design, sample size, mean age, laser platform, incision size and location, details of the manual comparator, postoperative follow-up intervals, and all reported biomechanical and wound-related outcomes. Quantitative extraction focused on preoperative and postoperative corneal hysteresis and corneal resistance factor values with measures of dispersion, while additional data were recorded for incision morphology, wound integrity, intraocular pressure, central corneal thickness, and healing-related observations where available. When data were unclear or incomplete in the published report, corresponding authors were contacted for clarification.

Risk of bias was assessed according to study design. Randomized controlled trials were appraised using the revised Cochrane Risk of Bias 2 tool, with assessment across the domains of randomization, deviations from intended intervention, missing outcome data, outcome measurement, and selective reporting (7). Non-randomized comparative studies were evaluated using the ROBINS-I tool, which considers bias due to confounding, participant selection, intervention classification, deviations from intended interventions, missing data, outcome measurement, and selection of the reported result (8). Quality appraisal was undertaken independently by two reviewers, and consensus judgments were reached after comparison of assessments. No study was excluded solely on the basis of risk-of-bias findings; instead, methodological limitations were incorporated into interpretation of the overall evidence base.

Because the included studies showed meaningful clinical and methodological heterogeneity in laser platforms, incision specifications, follow-up timing, outcome measurement approaches, and study design, a formal meta-analysis was not undertaken. The evidence was therefore synthesized narratively.

The synthesis was organized around two principal domains: global corneal biomechanical outcomes, particularly corneal hysteresis and corneal resistance factor, and structural wound outcomes, including incision architecture and sealing behavior. Summary tables were used to present study characteristics and key findings in a comparative format, enabling assessment of consistency, direction of effect, and the relationship between structural incision reproducibility and measurable postoperative biomechanical performance.

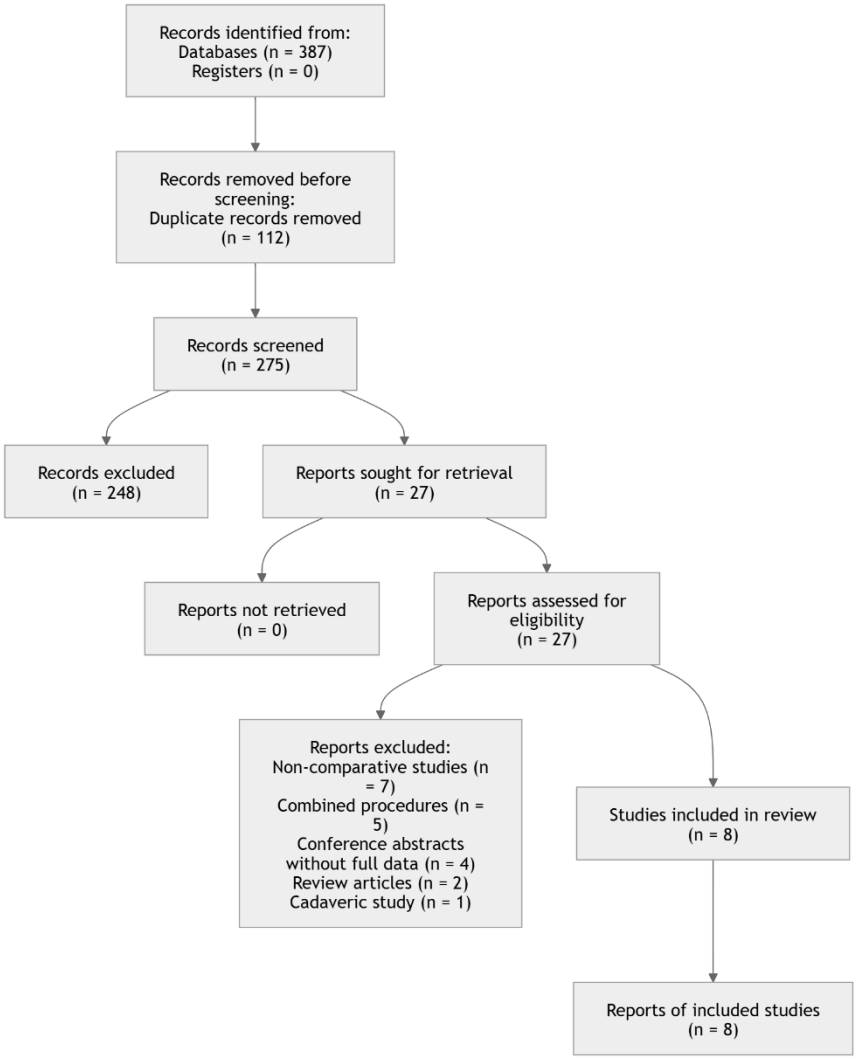

Figure 1 PRISMA Flowchat

RESULTS

The systematic search identified 387 records from electronic databases, with no additional records retrieved from registers. After removal of 112 duplicate records, 275 unique citations were screened by title and abstract. A total of 248 records were excluded at the screening stage because they did not address the comparative effect of femtosecond laser-assisted versus manual clear corneal incisions on corneal biomechanical outcomes. The remaining 27 reports were sought for retrieval and assessed in full text. Nineteen studies were excluded after full-text evaluation: seven were non-comparative, five involved combined procedures that precluded isolation of incision-related effects, four were conference abstracts without sufficient extractable data, two were review articles, and one was a cadaveric study. Eight studies met the predefined eligibility criteria and were included in the final qualitative synthesis.

Table 1. Reasons for Full-Text Exclusion

Reason for Exclusion	Number
Non-comparative studies	7

Reason for Exclusion	Number
Combined surgical procedures preventing isolated comparison	5
Conference abstracts without accessible full data	4
Review articles	2
Cadaveric study	1
Total	19

The eight included studies were published between 2019 and 2023 and represented diverse geographical settings, including Australia, China, South Korea, Italy, and Egypt. Three studies were randomized controlled trials, while five were prospective comparative cohort studies. Across all included reports, the pooled analytic sample comprised 724 eyes. Individual study sizes ranged from 40 to 124 eyes, and the mean age of participants was generally in the late 60s to early 70s, indicating reasonable comparability of surgical populations across studies. Femtosecond platforms included Catalys, LenSx, and Victus, whereas the comparator in each study was a manually created clear corneal incision using a stainless steel or diamond keratome. Incision widths were predominantly 2.2 mm, with one study using a 2.4 mm incision.

Table 2. Characteristics of Included Studies

Author, Year, Country	Study Design	Sample Size (Eyes) FLACS / Manual	Mean Age (Years)	FLACS Platform	Incision Size	Key Outcome Measures
Bali et al., 2019, Australia	Prospective cohort	20 / 20	72.1	Catalys	2.2 mm	CH, CRF, AS-OCT wound morphology
Roberts et al., 2020, Australia	Prospective cohort	52 / 52	71.5	Catalys	2.2 mm	CH, CRF, AS-OCT wound leakage
Wang et al., 2021, China	Randomized controlled trial	40 / 40	68.3	LenSx	2.2 mm	CH, CRF, IOP
Chen et al., 2021, China	Randomized controlled trial	60 / 60	69.8	LenSx	2.2 mm	CH, CRF, AS-OCT incision architecture
Ahn et al., 2022, South Korea	Prospective cohort	35 / 35	70.2	Victus	2.4 mm	CH, CRF
Serrao et al., 2022, Italy	Prospective cohort	62 / 62	73.1	LenSx	2.2 mm	CH, CRF, Corvis ST, incision morphology
Elhoff et al., 2023, Egypt	Randomized controlled trial	30 / 30	67.5	LenSx	2.2 mm	CH, CRF
Pantanelli et al., 2023, Italy	Prospective cohort	47 / 47	71.9	LenSx	2.2 mm	CH, CRF, wound-healing biomarkers

The principal biomechanical endpoints were corneal hysteresis and corneal resistance factor, usually measured with the Ocular Response Analyzer, while selected studies supplemented these with anterior segment optical coherence tomography-based assessment of wound architecture or additional biomechanical assessment using Corvis ST.

Risk-of-bias assessment indicated that the overall certainty of the included evidence was moderated by study design. Among the three randomized controlled trials, one study was judged to have low risk of bias across assessed domains, whereas two raised some concerns, mainly due to limited detail regarding allocation concealment. All five non-randomized comparative studies were considered to have moderate risk of bias, largely because of potential confounding related to surgeon preference or treatment allocation in non-randomized settings. Despite this, outcome measurement bias was considered low across studies because the primary endpoints were derived from objective and validated instruments. No study was excluded following quality appraisal.

Table 3. Risk-of-Bias Summary of Included Studies

Study	Design	Tool Used	Overall Judgment	Principal Reason
Wang et al., 2021	RCT	RoB 2	Some concerns	Limited allocation concealment detail
Chen et al., 2021	RCT	RoB 2	Low risk	Adequate across assessed domains
Elhoff et al., 2023	RCT	RoB 2	Some concerns	Limited allocation concealment detail
Bali et al., 2019	Prospective cohort	ROBINS-I	Moderate risk	Potential confounding/selection effects
Roberts et al., 2020	Prospective cohort	ROBINS-I	Moderate risk	Potential confounding/selection effects
Ahn et al., 2022	Prospective cohort	ROBINS-I	Moderate risk	Potential confounding/selection effects
Serrao et al., 2022	Prospective cohort	ROBINS-I	Moderate risk	Potential confounding/selection effects
Pantanelli et al., 2023	Prospective cohort	ROBINS-I	Moderate risk	Potential confounding/selection effects

Across the primary biomechanical outcomes, the direction of evidence was consistent. All eight studies reported no statistically significant or clinically meaningful between-group difference in postoperative

changes in corneal hysteresis or corneal resistance factor. Both femtosecond-assisted and manual incision groups showed modest postoperative reductions from baseline, but the magnitude of change was comparable between techniques at follow-up periods ranging from one week to three months. The manuscript provides one explicit numerical example from Wang et al., where the reduction in corneal hysteresis at one month was 0.8 ± 0.4 mmHg in the femtosecond group and 0.9 ± 0.5 mmHg in the manual group, with no statistically significant difference between them (p=0.32). Similarly, Ahn et al. reported no significant intergroup difference in postoperative corneal resistance factor change at three months (p=0.47).

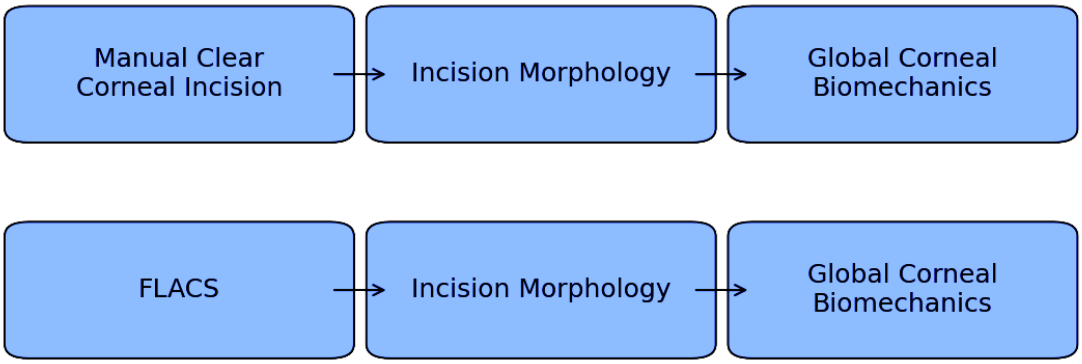

Figure 2 Narrative Synthesis of Primary and Secondary Outcomes

A more nuanced pattern emerged in the secondary structural outcomes. Studies incorporating anterior segment optical coherence tomography consistently indicated that femtosecond laser-created incisions were more reproducible in length, angle, and endothelial apposition than manually created incisions. Roberts et al. also reported a lower incidence of focal wound gaping in the laser group on postoperative imaging. However, these structural advantages did not correspond to measurable superiority in global biomechanical parameters such as corneal hysteresis and corneal resistance factor. Likewise, the reviewed studies did not demonstrate significant differences in surgically induced astigmatism or wound-related adverse events between the two techniques. Taken together, the synthesis suggests that femtosecond laser assistance improves architectural regularity of the incision without providing a detectable advantage in whole-cornea biomechanical performance during the early postoperative period.

The review selection process was straightforward and internally consistent with the PRISMA diagram. From 387 database records initially identified, 112 duplicates were removed, leaving 275 unique citations for screening. Title and abstract review excluded 248 records, and the remaining 27 articles underwent full-text assessment. Nineteen reports were excluded for prespecified reasons, most commonly because they were non-comparative or involved combined procedures that prevented isolation of the effect of incision technique. Eight studies were ultimately retained for qualitative synthesis, establishing a focused evidence base for direct comparison of femtosecond laser-assisted and manual clear corneal incisions in cataract surgery.

The included evidence comprised three randomized controlled trials and five prospective cohort studies published between 2019 and 2023, with a total of 724 eyes. Study-level samples ranged from 40 to 124 eyes, and participant mean age generally clustered between 67.5 and 73.1 years. Most studies used a 2.2 mm incision, while one used a 2.4 mm incision. The femtosecond platforms evaluated were predominantly LenSx, with additional representation from Catalys and Victus. This degree of technical overlap improved conceptual comparability, although differences in platform type, follow-up duration, and outcome measurement timing contributed to heterogeneity and supported the decision to avoid formal meta-analysis.

Risk-of-bias assessment showed a mixed but interpretable quality profile. Of the three randomized trials, one achieved low risk of bias, whereas two were rated as having some concerns because allocation

concealment was not fully detailed. All five cohort studies were rated as moderate risk under ROBINS-I, mainly due to plausible confounding associated with surgeon preference and non-randomized allocation. Importantly, no major concerns were raised regarding outcome measurement because corneal hysteresis and corneal resistance factor were assessed using objective, instrument-based methods. This meant that although selection-related bias could not be excluded, the actual recording of the primary outcomes was methodologically sound across the included studies.

The main synthesis finding was highly consistent: none of the eight included studies demonstrated a statistically significant advantage of femtosecond-assisted incision creation over manual incision with respect to postoperative corneal biomechanical change. Both surgical approaches were associated with modest reductions in corneal hysteresis and corneal resistance factor after surgery, but the magnitude of these changes was similar between groups at all reported time points. In the clearest numerical example provided, Wang et al. found that corneal hysteresis decreased by 0.8 ± 0.4 mmHg after femtosecond-assisted surgery and by 0.9 ± 0.5 mmHg after manual surgery at one month, a difference that was not statistically significant ($p=0.32$). Ahn et al. likewise found no significant between-group difference in corneal resistance factor change at three months ($p=0.47$). These findings indicate that, at the level of global corneal viscoelastic behavior, neither technique demonstrated measurable superiority in the early postoperative interval.

In contrast, the structural imaging findings were directionally more favorable to femtosecond-assisted surgery. Studies using anterior segment optical coherence tomography reported that laser-created incisions showed more regular architecture, greater reproducibility of tunnel length and angle, and better endothelial apposition than manual incisions. Roberts et al. additionally observed less focal wound gaping in the femtosecond group on day 1 imaging. Even so, these morphological advantages did not translate into parallel differences in corneal hysteresis or corneal resistance factor. This divergence between incision geometry and global biomechanical performance is central to the interpretation of the review because it suggests that improved incision regularity alone may be insufficient to alter whole-cornea biomechanical metrics in a clinically meaningful way. No important differences were reported in surgically induced astigmatism, persistent wound leakage, or major wound-related adverse outcomes, further reinforcing the conclusion that femtosecond assistance improves precision of incision construction without establishing a clear functional biomechanical advantage over high-quality manual surgery.

DISCUSSION

This systematic review was undertaken to determine whether femtosecond laser-assisted clear corneal incisions confer superior corneal biomechanical integrity compared with manually created incisions in cataract surgery. Across eight comparative studies involving 724 eyes, the principal finding was highly consistent: femtosecond laser-assisted incision creation did not produce a measurable advantage over manual keratome incisions in terms of postoperative corneal hysteresis or corneal resistance factor. Although both techniques were associated with modest reductions in these biomechanical parameters during the early postoperative period, the magnitude and direction of change were comparable between groups across the included studies (4,5,7-12). At the same time, studies incorporating anterior segment optical coherence tomography showed that femtosecond-assisted incisions were generally more regular and reproducible in morphology, with more consistent tunnel geometry and endothelial apposition. The central interpretive implication of this review is therefore that improved incision architecture does not appear to translate into superior whole-cornea biomechanical performance as captured by currently used global indices.

These findings are clinically important because they refine a common assumption underlying adoption of femtosecond platforms in cataract surgery. The precision of laser-created corneal incisions has often been regarded as a surrogate for greater wound stability and, by extension, improved postoperative

biomechanical behavior. The evidence synthesized here suggests that this inference is not presently supported when the outcome is assessed using corneal hysteresis and corneal resistance factor. This apparent dissociation between incision morphology and global biomechanical response is plausible from a biological and measurement perspective. The clear corneal incision is relatively small and localized, whereas instruments such as the Ocular Response Analyzer and Corvis ST characterize the viscoelastic behavior of the cornea at the organ level rather than directly quantifying focal mechanical properties at the wound interface (5). It is therefore possible that localized architectural improvements produced by laser incision construction are insufficient to generate detectable differences in global biomechanical metrics, particularly when the comparator is a well-executed manual incision performed by experienced surgeons.

The present findings also align with the broader cataract surgery literature, which has shown that femtosecond laser assistance may improve procedural precision in selected technical domains without consistently producing superior patient-important outcomes across routine cases. Prior comparative work and meta-analytic syntheses have suggested benefits of femtosecond platforms in capsulotomy accuracy, lens fragmentation, and certain intraoperative technical measures, while the overall clinical advantage over conventional phacoemulsification has remained uncertain (15). This review contributes additional specificity to that literature by isolating the corneal incision question and demonstrating that, despite favorable imaging-based morphology, current evidence does not support a claim of biomechanical superiority for femtosecond-assisted incisions. In this respect, the review advances the field by distinguishing between structural regularity and functional biomechanical consequence, a distinction that is often blurred in technology-centered discussions of surgical innovation.

Several methodological considerations are important when interpreting these conclusions. First, although the direction of the evidence was notably consistent, the overall certainty of the synthesis is moderated by the design profile of the included studies. Only three of the eight studies were randomized controlled trials, and two of these had some concerns related primarily to incomplete reporting of allocation concealment, while the remaining five studies were prospective comparative cohorts with moderate risk of bias owing to potential confounding and surgeon-selection effects (13,14). This pattern means that the absence of a detected difference should be interpreted as a robust consistency signal rather than as definitive proof of equivalence in a strict statistical sense. Second, the studies differed in laser platform, incision width, follow-up duration, and supplementary outcome measures, which introduced clinical and methodological heterogeneity and made meta-analysis inappropriate. Third, postoperative assessment windows were generally short to intermediate, usually extending from one week to three months, so the evidence remains less informative regarding long-term remodeling, late wound behavior, or biomechanical consequences relevant to subsequent ocular procedures.

This review also has limitations specific to its own methods and source evidence. The synthesis was restricted to English-language publications and to full reports with extractable clinical data, which may have excluded some relevant evidence and increased susceptibility to publication bias. Grey literature was not a substantive component of the final evidence base, and the small number of eligible studies limited the ability to explore subgroup effects according to laser platform, incision size, or patient-level modifiers such as baseline corneal properties. In addition, the review depended largely on global biomechanical indices rather than localized mechanical testing of the incision itself. This is a particularly important limitation because the main structural differences between the two surgical approaches are likely to be concentrated at or near the wound architecture rather than diffusely distributed across the cornea. Consequently, a true focal biomechanical advantage of laser-assisted incision construction, if present, may have been underestimated by the currently available clinical literature.

Despite these limitations, the review has several strengths. It addressed a narrowly defined and clinically relevant question, used a structured multi-database search, applied explicit eligibility criteria, and incorporated design-appropriate risk-of-bias assessment using RoB 2 and ROBINS-I (6,13,14). The

consistency of the findings across geographically diverse studies and across both randomized and non-randomized comparative designs strengthens the credibility of the overall interpretive message. Just as importantly, the review avoids conflating better incision geometry with better functional biomechanics, thereby offering a more disciplined and clinically useful synthesis than broader comparisons of femtosecond-assisted versus conventional cataract surgery.

The implications for clinical practice are pragmatic. Based on currently available evidence, surgeons should not select femtosecond laser technology on the expectation that it will provide superior postoperative corneal biomechanical strength or materially reduce wound-related biomechanical compromise compared with a carefully constructed manual clear corneal incision. The decision to use femtosecond assistance should instead rest on other procedural, logistical, educational, or patient-selection considerations, such as capsulotomy precision, workflow preference, training environment, or platform availability. At the same time, the finding that manual incisions perform comparably in global biomechanical terms reinforces the continued validity of standard keratome-based cataract surgery in routine clinical practice.

Future research should move beyond global surrogate metrics and adopt more sensitive, localized approaches for evaluating wound biomechanics. Longer follow-up studies are needed to determine whether subtle differences in incision construction influence later corneal remodeling or clinically relevant wound behavior over time. Large multicenter randomized trials with standardized incision parameters and outcome reporting would improve internal validity and comparability across studies. In parallel, emerging technologies such as optical coherence elastography may provide a more direct means of assessing focal corneal mechanical properties at the incision site and may help clarify whether laser-assisted architecture confers advantages that current global measurements fail to detect (16). Additional work examining cost-effectiveness, patient subgroups with potentially vulnerable corneas, and the interaction between incision design and refractive outcomes would further strengthen the evidence base for technology selection in modern cataract surgery.

CONCLUSION

In conclusion, current comparative evidence indicates that femtosecond laser-assisted clear corneal incisions do not provide a clinically meaningful advantage over manually created incisions in terms of global postoperative corneal biomechanical integrity following cataract surgery. Although femtosecond platforms produce more regular and reproducible incision architecture on imaging, this structural precision has not translated into superior postoperative corneal hysteresis or corneal resistance factor in the available literature. The practical implication is that technology choice should not presently be based on an expectation of biomechanical superiority, and well-performed manual clear corneal incisions remain a biomechanically sound approach in routine cataract surgery. Further long-term randomized research using localized biomechanical assessment methods is needed to determine whether focal wound-level differences exist that are not captured by current whole-cornea metrics.

REFERENCES

1. Liu YC, Wilkins M, Kim T, Malyugin B, Mehta JS. Cataracts. Lancet. 2017;390(10094):600-12.

2. Nagy Z, Takacs A, Filkorn T, Sarayba M. Initial clinical evaluation of an intraocular femtosecond laser in cataract surgery. J Refract Surg. 2009;25(12):1053-60.

3. McDonnell PJ, Taban M, Sarayba M, Rao B, Zhang J, Schiffman R, et al. Dynamic morphology of clear corneal cataract incisions. Ophthalmology. 2003;110(12):2342-8.

4. Wang L, Zhang S, Zhang Z, et al. Evaluation of corneal biomechanical properties during femtosecond laser-assisted cataract surgery. J Cataract Refract Surg. 2021;47(1):67-73.

5. Serrao S, Lombardo G, Ducoli P, Rosati M, Lombardo M. Biomechanical changes in the cornea following cataract surgery with different incision techniques. J Clin Med. 2022;11(9):2402.

6. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.

7. Pantanelli SM, Di Maita M, Tamburrelli C, et al. Corneal biomechanical properties and wound healing after femtosecond laser-assisted versus manual cataract surgery. Sci Rep. 2023;13(1):4587.

8. Ahn H, Kim JY, Kim TI, et al. Comparison of corneal biomechanical changes after femtosecond laser-assisted cataract surgery versus conventional phacoemulsification. Korean J Ophthalmol. 2022;36(4):318-26.

9. Chen X, Xu J, Lu Y. A prospective study comparing corneal incision architecture and stability between femtosecond laser and manual clear corneal incisions in cataract surgery. BMC Ophthalmol. 2021;21(1):325.

10. Elhoff SH, El-Sayed SH, El-Shawaf HH. Comparative study of corneal biomechanics following femtosecond laser assisted versus manual clear corneal incision in cataract surgery. Eur J Ophthalmol. 2023;33(1):112-9.

11. Roberts TV, Sutton G, Lawless MA, Hodge C. Femtosecond laser cataract surgery: wound integrity and corneal biomechanical properties. Clin Exp Ophthalmol. 2020;48(8):1081-8.

12. Bali SJ, Hodge C, Lawless M, Roberts TV, Sutton G. Early experience with the Catalys femtosecond laser system: corneal biomechanical effects. J Refract Surg. 2019;35(5):318-22.

13. Sterne JAC, Savovic J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366:l4898.

14. Sterne JA, Hernan MA, Reeves BC, Savovic J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355:i4919.

15. Ye Z, Li Z, He S. A meta-analysis comparing postoperative complications and outcomes of femtosecond laser-assisted cataract surgery versus conventional phacoemulsification for cataract. J Ophthalmol. 2017;2017:3849152.

16. De Stefano VS, Ford MR, Seven I, Dupps WJ. Depth-dependent corneal biomechanical properties in normal and keratoconic subjects by optical coherence elastography. Transl Vis Sci Technol. 2020;9(11):4.