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Surgical efficiency in femtosecond laser cataract surgery compared with phacoemulsification cataract surgery: a case–control study

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ABSTRACT

Objectives To investigate differences in surgical time, the distance the surgical instrument travelled and number of movements required to complete manual phacoemulsification cataract surgery versus femtosecond laser cataract surgery.

Design Non-randomised comparative case series.

Setting Single surgery site, Moorfields Eye Hospital, UK.

Participants 40 cataract surgeries of 40 patients.

Interventions Laser-assisted and manual phacoemulsification cataract surgery. Laser-assisted surgery cases were performed using the AMO Catalys platform.

Primary and secondary outcome measures Computer vision tracking software PhacoTracking were applied to the recordings to establish the distance the instrument travelled, total number of movements (the number of times an instrument stops and starts moving) and time taken for surgery steps including phacoemulsification, irrigation–aspiration (IA) and overall surgery time. The time taken for laser docking and delivery was not included in the analyses.

Results Data on 19 laser-assisted and 19 manual phacoemulsification surgeries were analysed (two cases were excluded due to insufficient video-recording quality). There were no differences in the number of instrument moves, the distance the instrument travelled or time taken to complete the phacoemulsification stage. However for IA, the number of instrument moves (manual: mean 20 (SD 15) vs laser: mean 38 (SD 22), P=0.008) and time taken (manual: mean 75 s (SD 24) vs laser: mean 108 s (SD 36), P=0.003) were significantly greater for laser cases. For laser versus manual cases overall, there was no difference in number of moves or the distance the instrument travelled, but laser cases took longer (mean 88 s, P=0.049).

Conclusions Laser cataract surgery cases took longer to complete without accounting for the time taken to complete the laser procedure itself. This appears to be in part due to IA requiring more instrument manoeuvres and taking longer to complete. Data from a large randomised series would better elucidate this relationship.

Strengths and limitations of this study

- The PhacoTracking method provides automated, objective measures of the distance the instrument travelled, total number of movements and time taken for the surgical steps.
- All cases were performed by a single surgeon with 18 months previous laser-assisted cataract surgery experience, so there are no confounding effects from intersurgeon or learning curve issues.
- The main limitation of our study is the comparative case series study design whereby patients were not randomised to treatment groups.
- In order to address expected intergroup differences, additional investigation using carefully matched cases or a randomised to treatment group design is required.

INTRODUCTION

Cataract is the leading cause of blindness in the world,[1] and one-third of those in the developed world are estimated to undergo cataract surgery in their lifetime.[2] Femtosecond laser cataract surgery platforms automate many of the steps including corneal incisions, capsulotomy and lens fragmentation. One of the biggest proposed advantages of laser cataract surgery is the reliable and rapid formation of a capsulotomy[3] compared with a capsulorrhexis, the most difficult step of manual phacoemulsification perceived by trainee surgeons.[4] Additionally, it would be anticipated that laser cataract surgery procedures would be quicker due to automation of some surgical steps and that the remaining surgical steps requiring completion by hand may be performed more efficiently. This, however, does not appear to be the case with there being little difference in operation times based on published data[5] and stages such as the aspiration of cortical lens material reported to be more difficult in femtosecond laser-assisted procedures.[6] The postulated mechanisms being laser induced differences in capsulotomy versus capsulorrhexis

Table 1 PhacoTracking parameters by manual phacoemulsification versus laser-assisted cases

	Phacoemulsification	Irrigation–aspiration	Overall
n moves manual, mean (SD)	47 (38)	20 (15)	270 (89)
n moves laser, mean (SD)	52 (24)	38 (22)	305 (104)
P	0.62	0.008	0.32
Distance instrument travels manual, mean (SD)	381 (237)	231 (139)	1753 (1019)
Distance instrument travels laser, mean (SD)	298 (113)	275 (117)	1575 (466)
P	0.17	0.31	0.54
Time manual, mean (SD)	147 (87)	75 (24)	670 (75)
Time laser, mean (SD)	139 (57)	108 (36)	758 (146)
P	0.73	0.003	0.049

size,[7] changes in the lens cortex material near the site of capsulotomy creation or adjustments to the hydrodissection technique required in laser cases to manage the gas within the capsular bag.[8] A previous study investigating differences in irrigation–aspiration (IA) between laser-assisted and manual phacoemulsification reported IA times to be slightly shorter in laser-assisted cases and this met statistical significance.[9]

Quantitative instrument motion analysis ('PhacoTracking')[10] has been successfully used to investigate the number of hand movements, distance the instrument travelled (instrument path lengths) and movements along with the time required to complete surgical steps, having been shown to have construct validity. It has been able to differentiate between expert and novice surgeons based on these and higher-order parameters differentiating more from less efficient phacoemulsification performance.[11 12] The application of motion capture also underpins the technology used in simulators such as the EyesI (VR Magic, Mannheim, Germany).

In this study, we hypothesise that laser cataract operations will have shorter instrument travelled distances and require fewer movements than traditional phacoemulsification, and this may result in more efficient completion of some surgical steps including lens removal. There are no previous studies comparing quantitative instrument motion analysis for laser-assisted and manual phacoemulsification cataract surgery procedures.

METHODS

Video recording was made of cases undergoing manual phacoemulsification or laser-assisted cataract surgery performed by a single surgeon (VM). All cases were private patients of VM and had previously chosen to have either manual phacoemulsification or laser-assisted cataract surgery. All video recordings of the operation were taken through the operating room microscope and were anonymised in accordance with the requirements from the Research Ethics Committee. Informed consent was obtained from all patients. The study adhered to the tenets of the Declaration of Helsinki.

Surgical methodology

All patients underwent preoperative dilation with G cyclopentolate 1% and G phenylephrine 2.5% and topical anaesthesia using G proxymetacaine 0.5%. For manual phacoemulsification cases, a bent needle was used for capsulorrhexis followed by a standard phacoemulsification procedure with phaco-chop technique and bimanual IA. Manual incisions were created using a 2.4 mm keratome, and MVR blades were used for side ports for both laser-assisted and manual phacoemulsification cases. For laser assisted cases, the programmed anterior capsulotomy size was 5.0 mm (default parameters: depth 600 µm, pulse energy 4 mJ, horizontal spot spacing 5 µm, vertical spot spacing 10 µm), and crystalline lens fragmentation was performed using a standardised, surgeon-preferred template (sextants, single pass). Following laser delivery the case was completed using blade created corneal incisions (ie, laser corneal incisions were not performed) and phacoemulsification and bimanual IA by the same methodology as those undergoing non-laser-assisted surgery. All patients underwent surgery by a senior surgeon (VM), who had over 18 months experience of using the Catalys platform at the start of this study. The Alcon Infiniti or Centurion Vision phacoemulsification platforms were used for all cases.

Video analysis methodology

Computer vision tracking software (Speeded-Up Robust Features (SURF) point detection and Kanade-Lucas-Tomasi (KLT) tracking)[10 13] was applied to the recordings to establish the total distance the instrument travelled (path length) and the total number of movements. The total number of movements was defined as the number of times an instrument stops and starts moving. In order to track the tissues, a set of markers are identified within each frame and then tracked over time. In the detection phase (SURF point detection), the robust local feature detector is applied to identify points in the image that contain texture and shape information. These are then tracked over time. In the tracking phase (KLT tracking), the motion of the points is calculated by comparing their position in consecutive frames. This process is iterated over time in order to repeatedly measure the location of the

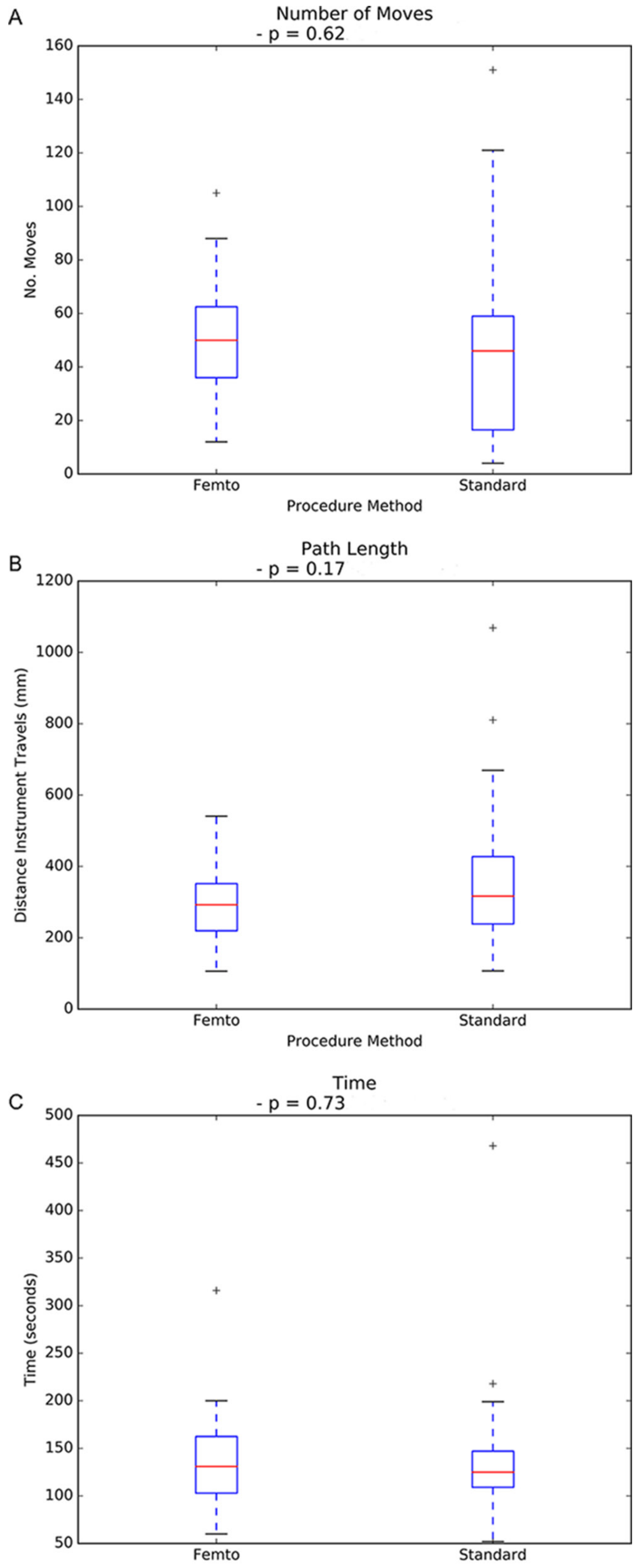

Figure 1 Measured (A) instrument number of moves, (B) path length and (C) time taken for phacoemulsification stage of manual phacoemulsification compared with femtosecond laser-assisted cases.

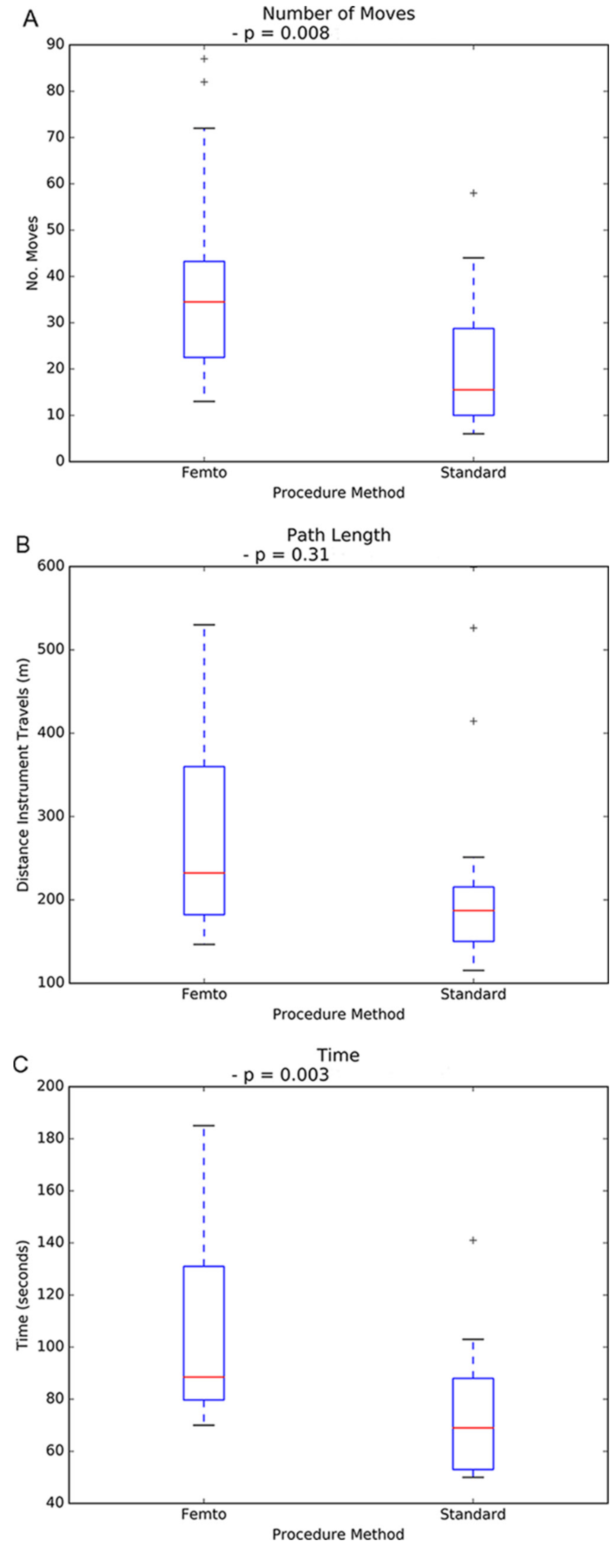

Figure 2 Measured (A) instrument number of moves, (B) path length and (C) time taken for irrigation–aspiration stage of manual phacoemulsification compared with femtosecond laser-assisted cases.

points. The motion of these points is analysed to extract points that are tracking surgical instruments. The total number of pixels these points move through during the operation represents the distance the instrument travelled for the respective surgical instrument. The total number of movements of the surgical instrument is calculated by measuring how many times the direction of motion of these points significantly changes.

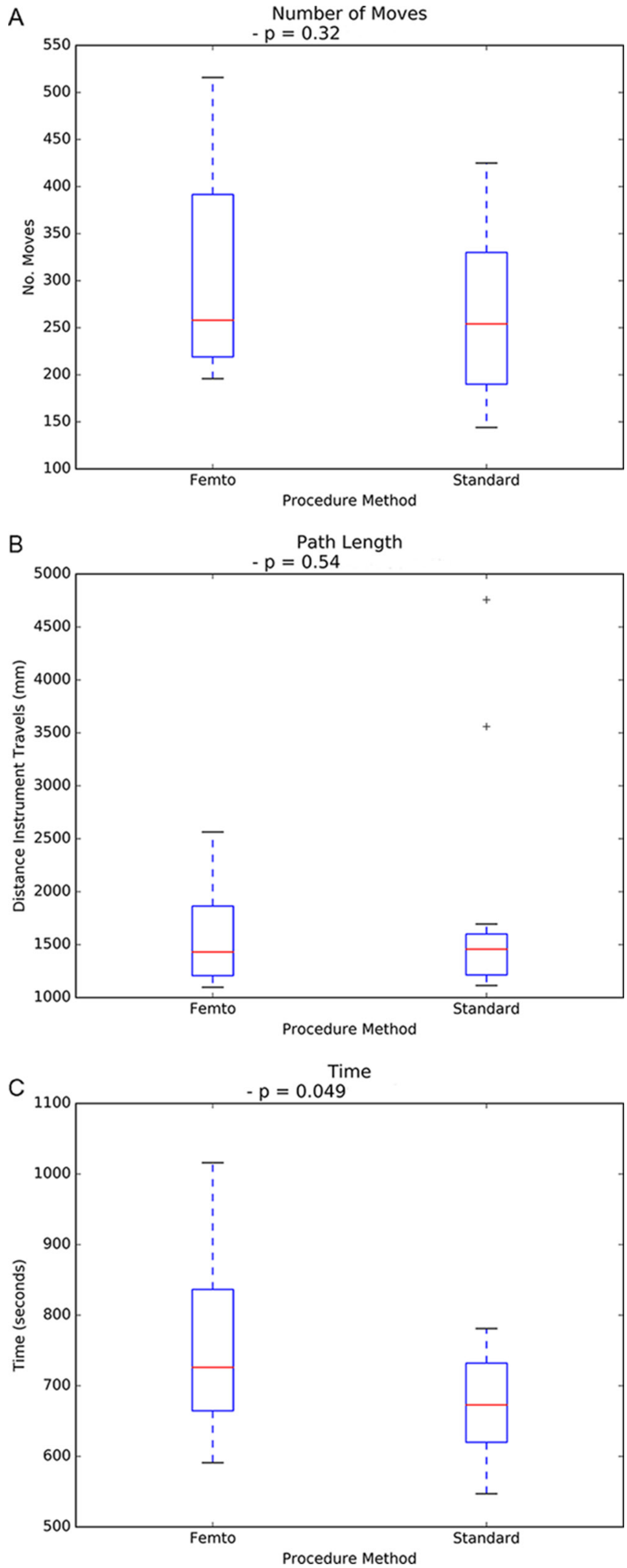

Figure 3 Measured (A) instrument number of moves, (B) path length and (C) time taken overall for manual phacoemulsification compared with femtosecond laser-assisted cases.

Statistical analysis

This was an exploratory study and with planned enrolment of 20 cases per group. The independent t-test was used for statistical analysis of the data using Python programming libraries (Scipy) software to test for a significant difference (P<0.05) between the mean number of movements, the distance the instrument travelled and time taken by procedure type.

RESULTS

Data were available on a total of 40 cataract surgeries, of which 20 were manual phacoemulsification and 20 femtosecond laser-assisted cataract surgeries. Two cases (1 femtosecond and one manual phacoemulsification) were excluded due to insufficient video quality for analysis. Table 1 compares the measured number of instrument moves, distance the instrument travelled and time taken for completion of the operation steps: phacoemulsification (see figure 1A–C), IA (figure 2A–C) and the overall surgery (figure 3A–C).

There were no differences in number of instrument moves, distance the instrument travelled or time taken for the phacoemulsification step (table 1 and figure 1A–C). However, for the IA step, the number of instrument moves and time taken to complete this step were significantly greater for laser cases (table 1 and figure 2A,C). There was no difference in the distance the instrument travelled for laser versus manual cases (table 1 and figure 2B). For the overall procedure, there was no difference in the number of moves or the distance the instrument travelled for laser versus manual cases (figure 3A,B); however, there was a trend for laser cases to take longer that just reached statistical significance (mean 88 s difference, P=0.049, table 1 and figure 3C).

DISCUSSION

We found there to be a trend for laser-assisted cases to take longer than standard manual phacoemulsification cases that just reached statistical significance. This appears to be in part related to the IA stage requiring more instrument moves and so taking longer to complete in laser-assisted cases. While one might expect laser-assisted operations to be shorter due to the capsulotomy already being completed and the crystalline lens being part fragmented, this was not the case. As our analysis did not account for the additional time to perform the laser component of the surgery outside of the operating room, we would expect the total time required for laser-assisted procedures to be an additional 5–10 min per case including transfer times. Locating the femtosecond laser in the operating room would reduce this. Four randomised controlled trials have reported data on the duration of laser cataract surgery cases compared with manual phacoemulsification cases. Three of these are from the same group.[14–16] Conrad-Hengerer *et al* in a study investigating corneal endothelial cell loss following cataract surgery reported a mean duration of 396 s (SD 23) for laser cases versus 390 s (SD 22) for manual phacoemulsification cases.[14] In another study by the same group comparing femtosecond laser cataract surgery (without the use of an ophthalmic viscosurgical device) to manual phacoemulsification, the reported mean operating time for laser-assisted cases was 375s (SD 81) versus 362s (SD 43) for manual phacoemulsification cases.[15] In their study of corneal endothelial cell loss, Conrad-Hengerer *et al* did not report procedure durations, but stated there was no significant difference in surgery times between arms.[16] Yu and coworkers found a non-significant trend towards to shorter surgery time in laser-assisted cases (10.0min (SD 1.4) versus 10.5 min (SD 1.9) manual phacoemulsification cases.[17]

Investigation into where the additional time for laser-assisted procedures occurred appears in part due to two factors. First, although time is saved by the capsulotomy being precompleted, there was the additional step for laser cases of checking the capsulotomy integrity (ie, the absence of any capsulotomy adhesions). Second, IA took longer to complete in laser-assisted cases. A number of possible reasons have been proposed for the differences in IA between manual phacoemulsification and laser cataract surgery including possible difficulty in access due to surgeons selecting to produce a small capsulotomy than capsulorrhexis[7] or laser induced changes in the lens cortex material and/or altered hydrodissection technique.[8] A previous large study of 400 laser-assisted cases and 400 manual phacoemulsification cataract surgeries reported mean IA times to be significantly lower in laser cases (27s (SD 10)) versus manual phacoemulsification cases (30s (SD 13)).[9] They used a biaxial IA technique similar to that used in this study, but their IA times for both laser and manual cases were much lower than those in our study. A previous report of laser-assisted surgery for white hypermature cataracts found a non-significant tendency towards longer aspiration and overall operation times in laser-assisted cases,[6] so in keeping with our study's findings. The authors also reported the removal of cortical material during IA to be 'more difficult' in laser-assisted cases, particularly in the subincisional region.

In our study, we found that the phacoemulsification step was not shorter in laser-assisted cases suggesting that lens fragmentation offered no overall benefit to a senior surgeon using the phaco-chop technique. It is possible that this would be different for a less experienced surgeon. In an analysis of third-year resident and fellow performed manual phacoemulsification and laser-assisted cataract surgery, a non-significant trend was found towards lower surgical complication rates in laser-assisted cases (0/62 laser cases with posterior capsule tears vs 4/128 manual phacoemulsification cases with posterior capsule tears).[18] This was particularly interesting as the residents and fellows had no prior femtosecond laser-assisted cataract surgery experience.

The main limitation of our study is the comparative case series study design whereby patients were not randomised to treatment groups. In order to address expected intergroup differences including adjustment for age, cataract density and axial length or anterior chamber depth differences, additional investigation using carefully matched cases or a randomised to treatment group design would be required. Additionally, 2/40 cases were excluded as video analysis was not possible due to recording quality.

In summary, we found there to be minimal differences in surgical efficiency in femtosecond laser cataract surgery compared with phacoemulsification cataract surgery. IA takes longer to complete in laser-assisted cases, and this appears to be responsible for the slightly longer operation duration for laser cases. Data from large randomised series are required to further investigate our findings.

Contributors ACD, BH, JM and GMS conceptualised and designed the study. FA and VM recruited patients and acquired the data for analyses. ACD drafted the initial manuscript. PRS and HLT were responsible for the analyses and critically reviewed the manuscript. All authors critically reviewed the manuscript and approved the final version to be submitted.

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Patient consent Obtained.

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