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Surgical efficiency in femtosecond laser cataract surgery compared to phacoemulsification cataract surgery.

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Abstract:

Objectives:

To investigate differences in surgical time, instrument path lengths and movements required to complete manual phacoemulsification cataract surgery versus femtosecond laser cataract surgery.

Design:

Non-randomised comparative case series.

Setting:

Single surgery site at Moorfields Eye Hospital, UK.

Participants:

38 cataract surgeries of 38 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 [10] were applied to the recordings to establish total path length, total number of movements 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 were available on 19 laser assisted and 19 manual phacoemulsification surgeries. There were no differences in the number of instrument moves, path length or time taken to complete the phacoemulsification stage. However for IA, the number of instrument moves (manual: 20 (standard deviation, SD 15) vs laser: 38 (SD 22), $p=0.008$) and time taken (manual: 75 sec (SD 24) vs laser: 108 sec (SD 36), $p=0.003$) were significantly greater for laser cases. For laser vs manual cases overall, there were no difference in number of moves, or path length, but laser cases took longer (mean 88 sec, $p<0.05$).

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 maneuvers and taking longer to complete. Data from a large randomized series would better elucidate this relationship.

Strengths and limitations of this study:

- The PhacoTracking method provides automated, objective measures of the instrument path lengths, 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 inter-surgeon or learning curve issues.
- The main limitation of our study is the comparative case series study design whereby patients were not randomized to treatment groups.
- In order to address expected intergroup differences, additional investigation using carefully matched cases or a randomized 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 to 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 vs capsulorrhexis size,[7] changes in the lens cortex material near the site of capsolotomy creation, or adjustments to the hydrodissection technique required in laser cases to manage the gas within the capsular bag or a combination of both.[8] A previous study investigating differences in irrigation-aspiration between laser assisted and manual phacoemulsification reported irrigation/aspiration times to be similar, but significantly shorter in laser assisted cases.[9]

Quantitative instrument motion analysis ("PhacoTracking") [10] has been successfully used to investigate the number of hand movements, 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, Manheim, Germany).

In this study we hypothesise that laser cataract operations will have shorter instrument path lengths and require fewer hand movements than traditional phacoemulsification, and this may result in more efficient completion of some surgical steps including lens removal.

Methods:

Video recording were 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 anonmyised in accordance with the requirements from the Research Ethics Committee. Informed consent was obtained from all patients. The study was approved by the NRES Committee North West – Cheshire (reference 12/NW/0489) and 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.proxymethocaine 0.5%. For manual phacoemulsification cases, a bent needle was used for capsulorrhexis followed by a standard phacoemulsification procedure using an Alcon Infiniti (Alcon, Inc, Fort Worth, Texas, USA) and bimanual irrigation-aspiration stage. Manual incisions were created using a 2.4mm keratome and MVR blades were used for side ports for both laser assisted and manual phacoemulsification cases. The programmed anterior capsulotomy size was 5.0mm and crystalline lens fragmentation was performed using a standardised, surgeon preferred template (sextants). The default parameters for horizontal and vertical spot spacing, laser pulse energy and cut depth were used for all cases. Following laser delivery the case was completed using blade created corneal incisions (ie. laser corneal incisions were not performed), and phacoemulsification and bimanual irrigation aspiration 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. Crystalline lens removal was performed using the phaco-chop technique in all cases. The Alcon Infiniti or Centuron Vision Systems were used for all cases.

Video analysis methodology:

Computer vision tracking software (Speeded-Up Robust Features point detection [SURF] and Kanade-Lucas-Tomasi [KLT] tracking) [10,13] was applied to the recordings to establish total path length and the total number of movements. In order to track the tissues a set of markers are identified within each frame and then tracked over time (see Image 1). 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 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 path length of 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.

Statistical analysis:

This was an exploratory study and with planned enrolment of 20 cases per group. Two cases (1 femtosecond and 1 manual phacoemulsification were excluded due to insufficient video quality). 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, path length, and time taken by procedure type.

Results:

Data were available on a total of 38 cataract surgeries, of which 19 were manual phacoemulsification and were 19 femtosecond laser assisted cataract surgeries. Figure 1, compares the measured number of instrument moves, path length and time taken for completion of the operation steps: phacoemulsification (Figure 2 a-c), irrigation-aspiration (Figure 3 a-c) and the overall surgery (Figure 4 a-c).

There were no differences in number of instrument moves, path length or time taken for the phacoemulsification step (table 1 and figure 1, a-c). However, for the irrigation-aspiration step, the number of instrument moves and time taken to complete this step were significantly greater for laser cases (table 1 and figure 1, d & f). There was no difference in path length for laser vs manual cases (table 1 and figure 1 e). For the overall procedure, there were no difference in the number of moves or path length for laser vs manual cases, however there was a trend for laser cases to take longer that just reached statistical significance (mean 88 seconds, $p<0.05$, table 1 and figure 1i).

Table 1. PhacoTracking parameters by manual phacoemulsification vs 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
Path length manual, mean (SD)	381 (237)	231 (139)	1753 (1019)
Path length laser, mean (SD)	298 (113)	275 (117)	1575 (466)
p=	0.17	0.31	0.55
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**	**<0.05**

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 irrigation-aspiration stage requiring more instrument moves and so taking longer to complete in laser assisted cases. Whilst 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 minutes per case including transfer times. Locating the femtosecond laser in the operating room would reduce this. Four randomized controlled trials have reported data on the duration of laser cataract surgery cases compared to 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 seconds (SD 23) for laser cases vs 390 seconds (SD 22) for manual phacoemulsification cases.[14] In another study by the same group comparing femtosecond laser cataract surgery without the use an ophthalmic viscosurgical device to manual phacoemulsification, reported the mean operating time for laser assisted cases was 375 seconds (SD 81) vs 362 seconds (SD 43) 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 co-workers found a non-significant trend towards to shorter surgery time in laser assisted cases (10.0 minutes (SD 1.4) minutes vs 10.5 (SD 1.9) minutes manual phacoemulsification cases.[17]

Investigation into where the additional time for laser assisted procedures occurred appears in part due to two factors. Firstly, although time is saved by the capsulotomy being pre-completed, there was the additional step for laser cases of checking the capsulotomy integrity (ie. the absence of any capsulotomy adhesions). Secondly irrigation-aspiration took longer to complete in laser-assisted cases. A number of possible reasons have been proposed for the differences in irrigation-aspiration 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 irrigation aspiration times to be significantly lower in laser cases (27 seconds (SD: 10)) vs manual phacoemulsification cases (30 seconds (SD: 13).[9] They used a biaxial irrigation-aspiration technique similar to that used in this study, but interestingly their irrigation aspiration times for both laser and manual cases were much lower than those in our study. Interestingly, 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 irrigation-aspiration to be "more difficult" in laser assisted cases, particularly in the subincisional region.

Interestingly, 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 this would be different for a less experienced surgeon. In an analysis of 3rd 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 randomized to treatment groups. In order to address expected intergroup differences, additional investigation using carefully matched cases or a randomized to treatment group design would be required.

In summary we found there to be minimal differences in surgical efficiency in femtosecond laser cataract surgery compared to phacoemulsification cataract surgery. Irrigation-aspiration 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 randomized series are required to further investigate our findings.

Contributorship statement:

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

Competing interests:

We have read and understood BMJ policy on declaration of interests and declare that we have no competing interests.

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Data sharing statement:

No additional data are available.

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Figure 1: Video still grab showing tracking software overlaid.

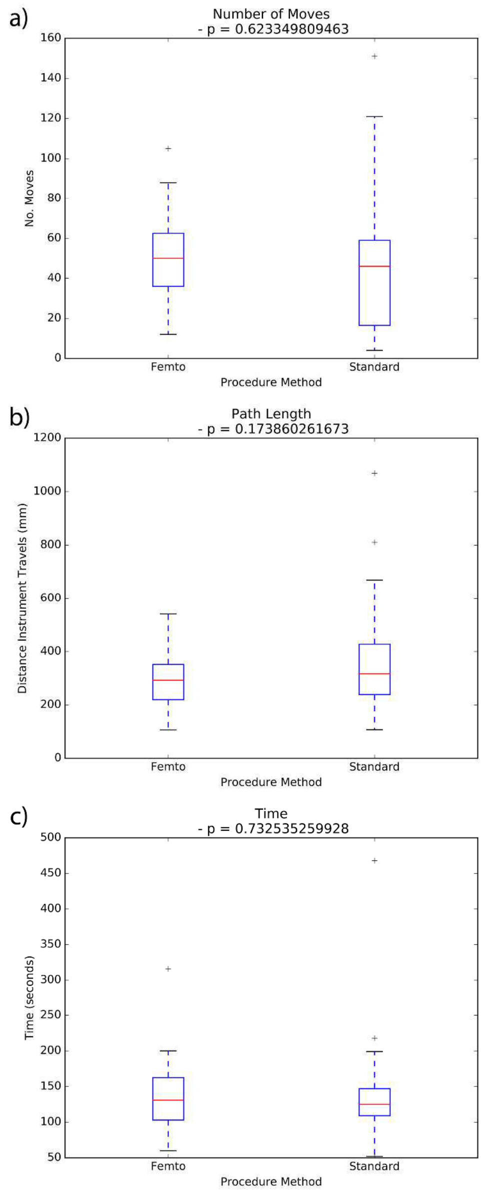

Figure 2. Measured a) instrument number of moves, b) path length and c) time taken for phacoemulsification stage by manual phacoemulsification and femtosecond laser assisted cases.

228x514mm (300 x 300 DPI)

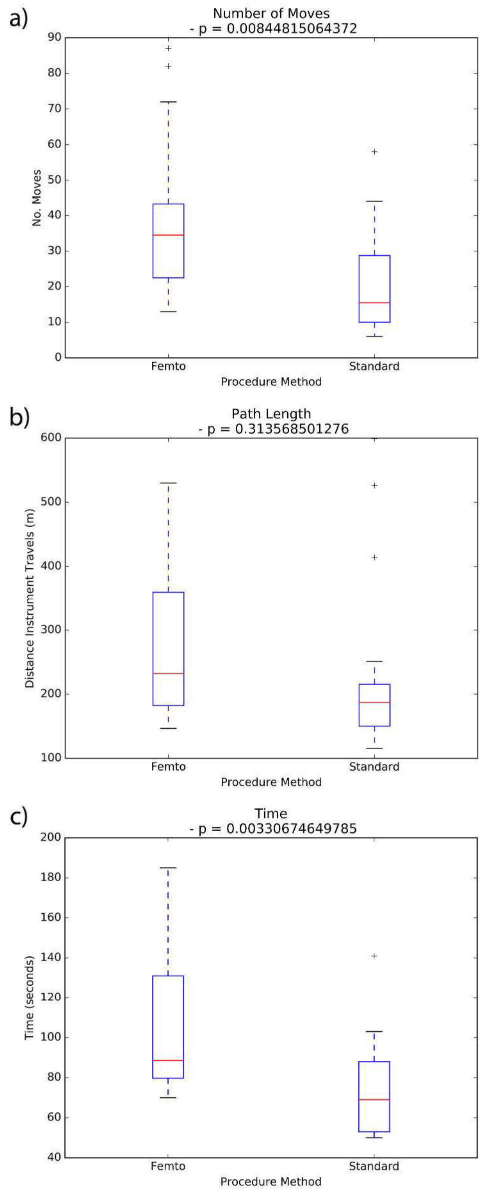

Figure 3. Measured a) instrument number of moves, b) path length and c) time taken for irrigation-aspiration stage by manual phacoemulsification and femtosecond laser assisted cases.

228x514mm (300 x 300 DPI)

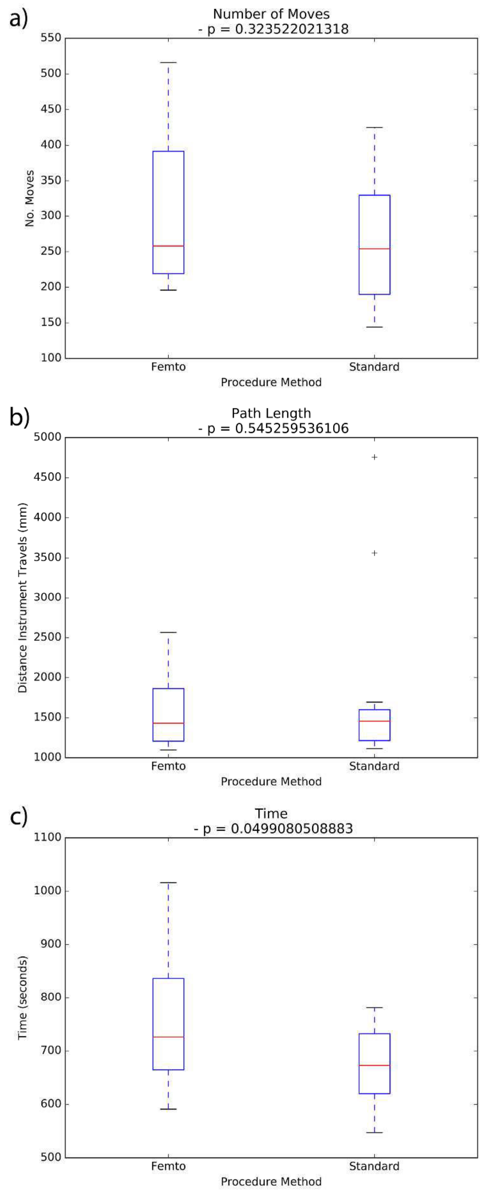

Figure 4. Measured instrument number of a) moves, b) path length and c) time taken for overall surgery by manual phacoemulsification and femtosecond laser assisted cases.

228x514mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
Methods			
Study design	4	Present key elements of study design early in the paper	4-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*4-5*
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	6
		(c) Summarise follow-up time (eg, average and total amount)	6
Outcome data	15*	Report numbers of outcome events or summary measures over time	6-7 and table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	6-7 and table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-9
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-9
Generalisability	21	Discuss the generalisability (external validity) of the study results	9-10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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

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Surgical efficiency in femtosecond laser cataract surgery compared to 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 (2 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 (standard deviation, SD 15) vs laser: 38 (SD 22), $p=0.008$) and time taken (manual: mean 75 sec (SD 24) vs laser: 108 sec (SD 36), $p=0.003$) were significantly greater for laser cases. For laser vs manual cases overall, there were no difference in number of moves, or the distance the instrument travelled, but laser cases took longer (mean 88 sec, $p<0.05$).

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 maneuvers and taking longer to complete. Data from a large randomized 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 inter-surgeon or learning curve issues.
- The main limitation of our study is the comparative case series study design whereby patients were not randomized to treatment groups.
- In order to address expected intergroup differences, additional investigation using carefully matched cases or a randomized 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 to 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 vs capsulorrhexis size,[7] changes in the lens cortex material near the site of capsolotomy 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 between laser assisted and manual phacoemulsification reported irrigation/aspiration times to be similar, but significantly shorter in laser assisted cases.[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, Manheim, 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 were 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 anonmyised in accordance with the requirements from the Research Ethics Committee. Informed consent was obtained from all patients. The study was approved by the NRES Committee North West – Cheshire (reference 12/NW/0489) and 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.proxymethocaine 0.5%. For manual phacoemulsification cases, a bent needle was used for capsulorrhexis followed by a standard phacoemulsification procedure using an Alcon Infiniti (Alcon, Inc, Fort Worth, Texas, USA) and bimanual irrigation-aspiration stage. Manual incisions were created using a 2.4mm keratome and MVR blades were used for side ports for both laser assisted and manual phacoemulsification cases. The programmed anterior capsulotomy size was 5.0mm (default parameters: depth 600µm, pulse energy 4mJ, horizontal spot spacing 5µm, vertical spot spacing 10µm) and crystalline lens fragmentation was performed using a standardised, surgeon preferred template (sextants, single pass). The Following laser delivery the case was completed using blade created corneal incisions (ie. laser corneal incisions were not performed), and phacoemulsification and bimanual irrigation aspiration 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. Crystalline lens removal was performed using the phaco-chop technique in all cases. The Alcon Infiniti or Centuron Vision phacoemulsification platforms were used for all cases.

Video analysis methodology:

Computer vision tracking software (Speeded-Up Robust Features point detection [SURF] 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 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.

Statistical analysis:

This was an exploratory study and with planned enrolment of 20 cases per group. Two cases (1 femtosecond and 1 manual phacoemulsification were excluded due to insufficient video quality). 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 were 20 femtosecond laser assisted cataract surgeries. Two cases (1 femtosecond and 1 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 also Figure 1 a-c), irrigation-aspiration (Figure 2 a-c) and the overall surgery (Figure 3 a-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 1, a-c). However, for the irrigation-aspiration step, the number of instrument moves and time taken to complete this step were significantly greater for laser cases (table 1 and figure 2, a & c). There was no difference in the distance the instrument travelled for laser vs manual cases (table 1 and figure 2 b). For the overall procedure, there were no difference in the number of moves or the distance the instrument travelled for laser vs manual cases (figure 3 a & b), however there was a trend for laser cases to take longer that just reached statistical significance (mean 88 seconds difference, $p<0.05$, table 1 and figure 3 c).

Table 1. PhacoTracking parameters by manual phacoemulsification vs 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	0.55

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**	**<0.05**

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 irrigation-aspiration stage requiring more instrument moves and so taking longer to complete in laser assisted cases. Whilst 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 minutes per case including transfer times. Locating the femtosecond laser in the operating room would reduce this. Four randomized controlled trials have reported data on the duration of laser cataract surgery cases compared to 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 seconds (SD 23) for laser cases vs 390 seconds (SD 22) for manual phacoemulsification cases.[14] In another study by the same group comparing femtosecond laser cataract surgery without the use an ophthalmic viscosurgical device to manual phacoemulsification, reported the mean operating time for laser assisted cases was 375 seconds (SD 81) vs 362 seconds (SD 43) 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 co-workers found a non-significant trend towards to shorter surgery time in laser assisted cases (10.0

minutes (SD 1.4) minutes vs 10.5 (SD 1.9) minutes manual phacoemulsification cases.[17]

Investigation into where the additional time for laser assisted procedures occurred appears in part due to two factors. Firstly, although time is saved by the capsulotomy being pre-completed, there was the additional step for laser cases of checking the capsulotomy integrity (ie. the absence of any capsulotomy adhesions). Secondly irrigation-aspiration took longer to complete in laser-assisted cases. A number of possible reasons have been proposed for the differences in irrigation-aspiration 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 irrigation aspiration times to be significantly lower in laser cases (27 seconds (SD: 10)) vs manual phacoemulsification cases (30 seconds (SD: 13).[9] They used a biaxial irrigation-aspiration technique similar to that used in this study, but their irrigation aspiration 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 irrigation-aspiration to be "more difficult" in laser assisted cases, particularly in the subincisional region.

In our study we found 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 this would be different for a less experienced surgeon. In an analysis of 3rd 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 randomized 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 randomized 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 to phacoemulsification cataract surgery. Irrigation-aspiration 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 randomized series are required to further investigate our findings.

Figure legends:

Figure 1: Measured a) instrument number of moves, b) path length and c) time taken for phacoemulsification stage of manual phacoemulsification compared to 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 to femtosecond laser assisted cases.

Figure 3: Measured a) instrument number of moves, b) path length and c) time taken overall for manual phacoemulsification compared to femtosecond laser assisted cases.

Contributorship statement:

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

Competing interests:

We have read and understood BMJ policy on declaration of interests and declare that we have no competing interests.

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Data sharing statement:

No additional data are available.

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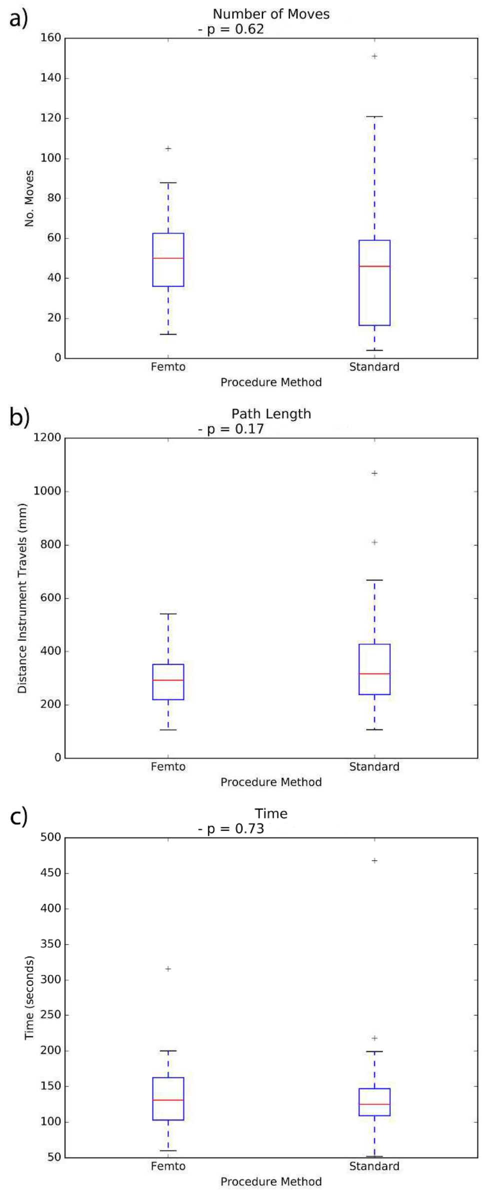

Figure 1. Measured a) instrument number of moves, b) path length and c) time taken for phacoemulsification stage of manual phacoemulsification compared to femtosecond laser assisted cases.

228x514mm (300 x 300 DPI)

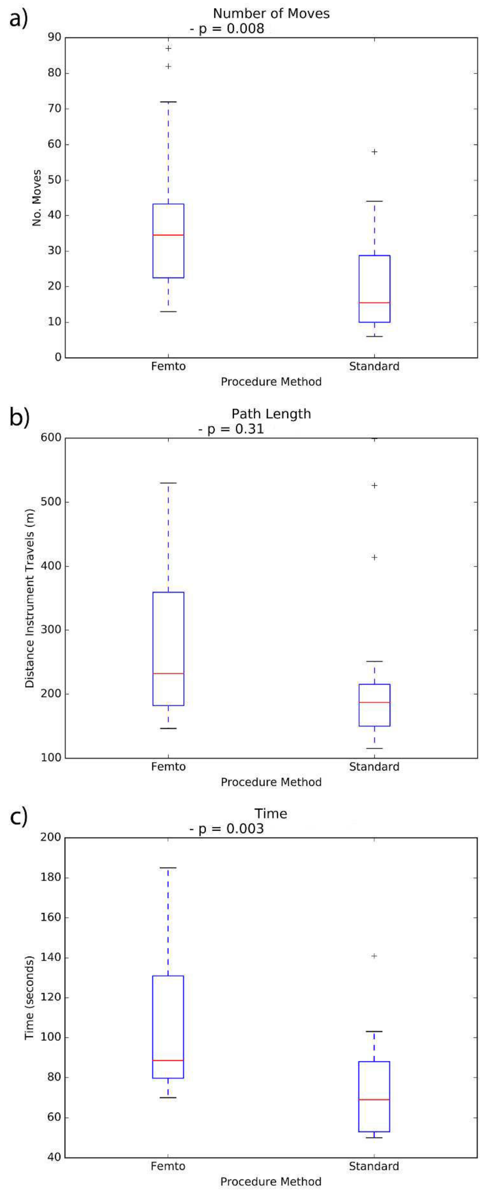

Figure 2. Measured a) instrument number of moves, b) path length and c) time taken for irrigation-aspiration stage of manual phacoemulsification compared to femtosecond laser assisted cases.

228x514mm (300 x 300 DPI)

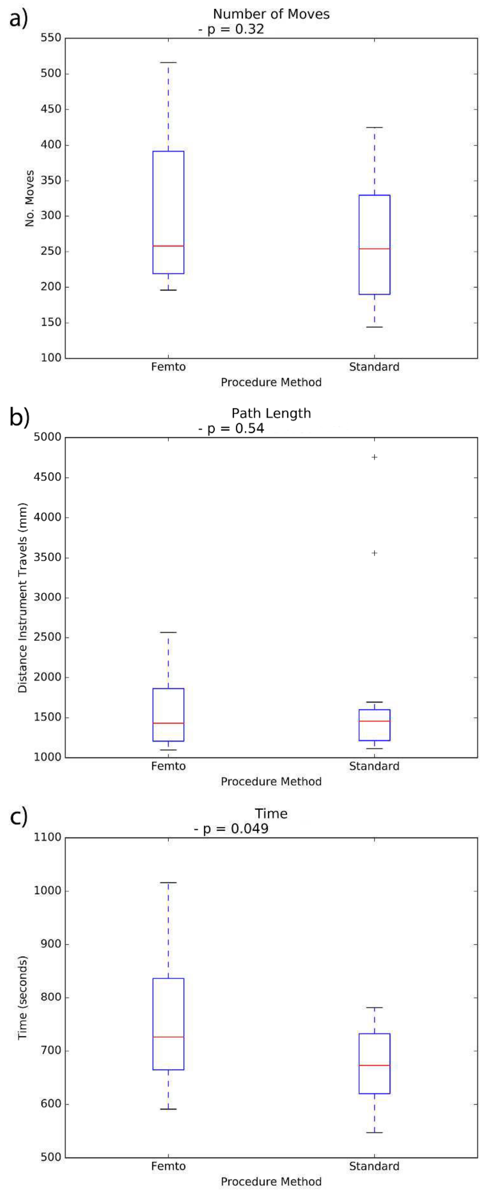

Figure 3. Measured a) instrument number of moves, b) path length and c) time taken overall for manual phacoemulsification compared to femtosecond laser assisted cases.

228x514mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
Methods			
Study design	4	Present key elements of study design early in the paper	4-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*4-5*
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	6
		(c) Summarise follow-up time (eg, average and total amount)	6
Outcome data	15*	Report numbers of outcome events or summary measures over time	6-7 and table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	6-7 and table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-9
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-9
Generalisability	21	Discuss the generalisability (external validity) of the study results	9-10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.