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ORIGINAL RESEARCH

Time Savings Using a Digital Workflow versus a Conventional for Intraocular Lens Implantation in a Corporate Chain Hospital Setting

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Purpose: To evaluate and compare the digital cataract workflow with the existing conventional workflow in terms of time savings for overall diagnostic procedures from preoperative measurements, data transfer, intraocular lens (IOL) power calculation, and axis marking for cataract surgery in a corporate hospital chain setting.

Patients and Methods: This prospective non-clinical study assessed the mean procedural times for preoperative assessments, calculation of IOL power, data transfer to operating devices, and total surgery for both digital and existing conventional workflows.

Results: Overall, 430 workflows (digital cataract workflow: 227; existing conventional workflow: 203) were included for time measurements. The digital cataract workflow resulted in shorter mean (± standard deviation [SD]) preoperative assessments with lesser variability among individual assessments than the existing workflow (14.15 ± 1.86 vs 21.41 ± 1.18 min, respectively); with a time saving of 35%. Similarly, the mean (± SD) time required for the subsequent assessment steps such as IOL calculation (2.19 ± 1.23 vs 3.17± 2.29 min; 30%), data transfer (0 vs 1.33 ± 0.25 min; 100%), IOL axis marking and alignment (0 vs 3.07 ± 0.53 min; 100%) were shorter with digital cataract workflow versus existing conventional cataract workflow. Briefly, the overall mean time from preoperative assessments to final surgery was 16.48 min with digital cataract workflow and 30.58 min with existing conventional workflow; resulting in a time saving of 46%.

Conclusion: The Zeiss digital cataract workflow demonstrated greater time savings at each step of the cataract surgery workflow compared to the existing conventional workflow. In addition, digitalization can lead to a more streamlined cataract surgery workflow that is more convenient and cost-effective than the existing conventional practices in a corporate chain hospital setting.

Keywords: biometry, cataract surgery, cataract surgery workflow, digitalization, efficiency

Introduction

Cataract is a common ocular disease with an overall global prevalence of upto 92.6% among older population (>80yrs).[1] Considering an estimated increase in the aging population to 1.5 billion by 2050,[2] age-related cataracts will also become more prevalent.[3] Cataract surgery is one of the most commonly performed interventions globally.[3] Through the years, surgical techniques have evolved from the earliest surgical approaches to the recent phacoemulsification and intraocular lens (IOL) implantation after cataract removal.[4] The IOLs are reported to be effective and associated with reduced corneal astigmatism and spectacle dependence at distance vision.[5]

Considering the technical advancements, the objective of cataract surgery in the current era is not only to remove an opacified crystalline lens but also to reduce postoperative astigmatism and spectacle dependence while ensuring maximum visual quality and patient satisfaction after IOL implantation.[6,7] In this regard, a number of pre- and intraoperative factors such as precise ocular measurements, accurate IOL power calculation, and correct IOL axis alignment and implantation are crucial for achieving desired postoperative outcomes.[1] In turn, IOL power calculation depends on multiple factors such as total keratometry values, IOL specific constant, patient's axial length and so on.[1] The corneal keratometry values and biometric data

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for IOL power calculation can be obtained using optical biometers and the IOL power is calculated using formula available in the literature or online calculators provided by the manufacturers.[8] However, additional calculations are required in patients who need toric IOL correction, had past refractive surgery, or incisional keratotomy.[9] The transfer of biometry data to a surgical planning system requires additional time and resources, resulting in an increased probability of errors and data mismanagement.[9]

Given the global increase in the volume of cataract surgeries, there is a mounting need for a digitally supported surgical workflow that would enable surgeons to handle high patient volumes with automated and efficient IOL power calculation, short operative time, and greater patient satisfaction.[10,11] Recent studies have reported a few advancements, such as cloud-based surgical planning software,[9] computer-assisted toric IOL axis alignment and marking,[12] and digital cataract surgery workflow;[11] however, with a limited number of patients. In this regard, pre- and intraoperative diagnostics integrated into one digital workflow would help deliver quality outcomes in a short duration and save resources required for cataract surgery.

The digital cataract workflow (Carl Zeiss Meditec AG) incorporated with the FORUM® platform is a cataract surgery workflow that follows a complete digital approach with secure data management. The digital cataract workflow allows preoperative measurements, selects IOL, aligns IOL axis, and exports data to intraoperative surgical devices.[11] The present study aimed to evaluate and compare the digital cataract workflow with the existing conventional workflow in terms of time savings for the overall preoperative assessments, data transfer, IOL power calculation, axis marking and alignment, and surgery in a corporate hospital chain setting.

Materials and Methods

Study Design

This prospective non-clinical study included patients who underwent cataract surgery between June and September 2022 at three corporate hospitals in Augsburg, Füssen, and Kaufbeuren, Germany. All study procedures were conducted in accordance with the Declaration of Helsinki and the good clinical practice guidelines. Ethics approval and consent were not applicable in this study, as all procedures performed were part of routine care with de-identified data.

The Augsburg site implemented a digital workflow, whereas the Füssen and Kaufbeuren sites implemented an existing conventional cataract surgery workflow. The patients were randomly assigned to either an existing conventional workflow group or a digital cataract workflow group.

Study Protocol

Preoperative Assessments

All workflows (for all lens types) underwent optical biometry (IOLMaster 700, Carl Zeiss Meditec AG), wherein a high-resolution reference image of the patient's eye was captured to determine the radii and corneal curvature of the axes, limbal position and diameter, iris features, and pupil position and diameter. Other preoperative assessments included optical coherence tomography (OCT) (Spectralis, Heidelberg Engineering/Cirrus 6000, Carl Zeiss Meditec AG), corneal topography (Oculus Pentacam HR, Oculus Optikgeräte GmbH), and endothelial cell count (Nidek CEM 530). OCT and topography were performed only for the aspheric, toric, and multifocal lenses. In the existing conventional workflow, biometry data were entered manually and reference images were exported via a portable memory drive (USB stick) to the patient's electronic medical record (EMR). Whereas, in the digital cataract workflow group, biometry data were auto-populated via FORUM® on the digital cataract workflow.

Surgical Planning and IOL Calculation

In the existing conventional workflow, IOL power was calculated based on keratometry measurements using the appropriate formula available on the IOLMaster 700 (Carl Zeiss Meditec AG). The IOL power was therefore marked on the paper printout, reviewed by the surgeon, and transferred to the operating room via the patient's EMR.

In the digital cataract workflow, preoperative assessment data were exported automatically via FORUM® to Surgical Planner software to determine IOL power. The digital workflow enabled the operating surgeons to choose the preferred

IOL calculation, allowed direct ordering of the IOL, and exported information to the CALLISTO eye in the operating room via a cloud-based network.

Intraoperative Assessments: IOL Axis Marking and Implantation

In the digital group, the biometric data and reference images were matched and the IOL axis was marked digitally. The IOL axis was displayed as an overlay image of the live image for marker-less IOL alignment on the CALLISTO eye. In contrast, in the existing conventional workflow, IOL axis marking and alignment was performed manually using a TOMARK (Gueder GmbH) instrument. An experienced surgeon performed the phacoemulsification and IOL implantation in all patients.

Study Timepoint Measurements

The mean total procedural time for each preoperative measurement, calculation of IOL power, data transfer to operating devices, and total surgery time were recorded second-by-second using a digital time recording system. Each examiner observing/performing the procedure had an assigned chip, and each process was tagged through a RFID (radio-frequency identification) reading device that enabled tracking of the start and end of the process. Data transfer to the operating room was recorded manually using a stopwatch for the existing conventional workflow. However, this was not applicable to the digital cataract workflow (Figure 1).

Statistical Analysis

All data are expressed as means ± standard deviation (SD) and percentages. The Student's *t*-test was performed, and statistical significance was set at $p < 0.05$.

Results

Overall, 430 workflows (digital cataract workflow: 227; existing conventional workflow: 203) were included for time measurements.

Preoperative Assessments

All three study sites performed different preoperative assessments based on the workflow or protocol of each site (Supplementary Table 1).

The overall mean (±SD) process time for the preoperative assessments was reduced in the digital cataract workflow (14.15 [±1.86] min) compared to the existing conventional workflow (21.41 [±1.18] min) with an overall time saving of

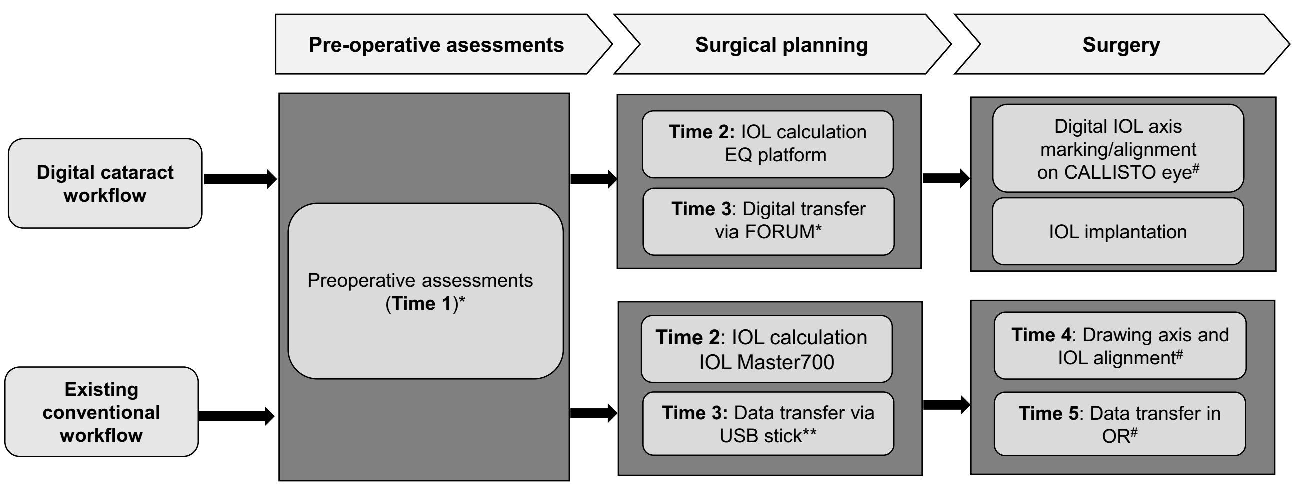

Figure 1 Time assessments for digital cataract workflow and existing conventional workflow. *Time 1 was calculated as the sum of the mean times recorded for each step: (IOL Master) + (Pentacam) + (OCT) + (endothelial cell count). **Time 3: Digital transfer step not applicable in digital cataract workflow as it is automated. #Times 4 and 5: IOL axis marking is not applicable in the digital cataract workflow as it is done via the FORUM® platform/CALLISTO eye.

Abbreviations: IOL, intraocular lens; OR, operating room.

Table 1 Time Measurements at Various Steps in Site's Existing Conventional and Digital Cataract Workflow

Cataract workflow*	Parameters Assessed	Digital Cataract Workflow, Mean± SD (in min.)	Existing Conventional Workflow, Mean ± SD (in min.)	Time Saving (in min.)	Time Saving (%)	p value**
Preoperative assessments[#]	IOL Master/Pentacam/OCT/ Endothelial cell count	14.15 ± 1.86	21.41 ± 1.18	7.33	35%	$p \leq 0.002$
Surgical planning	IOL power calculation	2.19 ± 1.23	3.17 ± 2.29	0.58	30%	–
	Data transfer/export for surgery	NA	1.33 ± 0.25	1.33	100%	–
Surgery	Drawing axis for IOL	NA	3.07 ± 0.53	3.07	100%	–
	Data transfer in operation room	0.20	1.20 ± 0.25	1.00	75%	–
Overall time saving (in min): 14.11 min (Digital vs Existing conventional workflow)						

Note: *Füssen and Kaufbeuren continued with the conventional workflow, whereas Augsburg used the digital cataract workflow. **p value shows significant difference between average process time between the site's existing conventional and digital cataract workflow. [#]Preoperative assessments were calculated as the sum of the mean times recorded for each step: (IOL Master) + (Pentacam) + (OCT) + (endothelial cell count). Overall time= (preoperative measurements) + (surgical planning) + (surgery).
Abbreviations: min, minutes; NA, not applicable; OCT, Optical coherence tomography.

approximately 35% (Table 1). Deviation in the diagnostic process time (owing to inter-examiner differences) was less due to a higher degree of standardization with the digital cataract workflow than with the existing conventional workflow. Except for the endothelial cell count, the other three preoperative assessments were performed at approximately the same time (~4 min) using a digital cataract workflow (Figure 2).

Intraocular Lens Calculation

The mean (± SD) process time for IOL power calculation was lower in the digital cataract workflow (2.19 ± 1.23 min) compared to the existing conventional workflow (3.17± 2.29 min) (Table 1) resulting in a time-saving of 30%. The biometric data were automatically transferred in the digital cataract workflow, while the mean (± SD) time for manual data transfer was 1.33 (± 0.25) min (Table 1), resulting in a time saving of 100%.

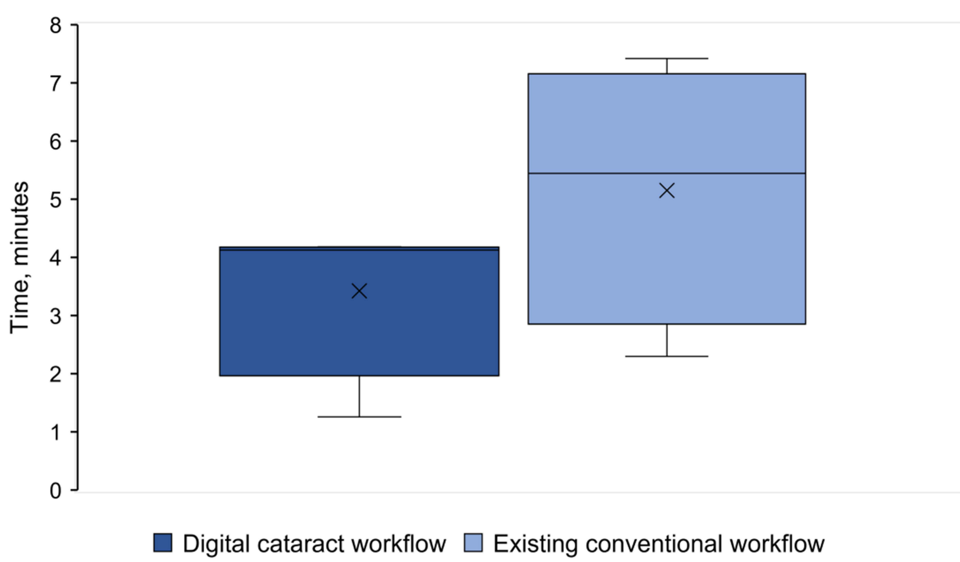

Figure 2 Inter observer variability in the digital cataract workflow versus existing conventional workflow for preoperative assessments.

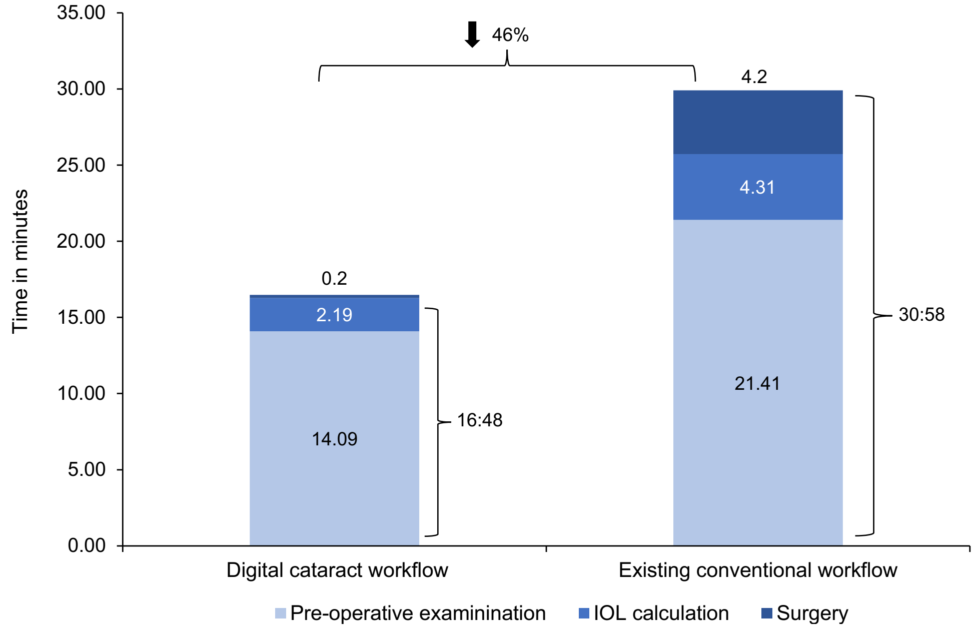

Figure 3 Overall time savings in digital cataract workflow versus existing conventional workflow.
Abbreviation: IOL, intraocular.

Surgery: IOL Axis Marking and IOL Implantation

Intraoperatively, mean (± SD) time to mark IOL axis for toric IOL implantation was 3.07 (± 0.53) min in the existing conventional workflow. As axis marking was performed digitally with a digital cataract workflow, it resulted in a time saving of 100%. Additionally, with the existing conventional workflow mean (± SD) time to transfer the data to the intraoperative device was 1.20 (± 0.25) min, while minimal time was noted with the digital cataract workflow (0.20 min), leading to a time saving of 75% (Table 1).

Overall, the total time required to perform preoperative assessments to the final surgery with the digital cataract workflow was 16.48 min while it was 30.58 min for the existing conventional workflow and approximately two times faster (46% time saving) than the conventional workflow (Figure 3).

Discussion

This prospective non-clinical study evaluated time savings using the Zeiss digital cataract workflow compared with the existing conventional workflow for cataract surgery and IOL implantation in a corporate chain hospital-based setting. In the current study, the time for preoperative assessments, IOL power calculation, IOL axis marking and alignment, and surgery was significantly shorter with the digital cataract workflow as compared to the existing conventional workflow. A global survey on cataract practices reported a significant variation in the time required for pre- and intraoperative diagnostic procedures among eye care practitioners, regardless of the type of institution, surgical volume, and country.[10] Similarly, we also noticed differences in the type of diagnostic assessments performed and overall setup among the three study sites. However, regardless of these variables, digitalization of the cataract workflow saved approximately 14 min compared to the existing conventional workflow.

Thorough preoperative measurements and surgical planning are key to successful postoperative outcomes.[9] Real-time measurements of the preoperative assessments (IOLMaster, Pentacam, OCT, and endothelial cell count) were significantly faster (average saving of 35%) with lesser variability in the digital cataract workflow compared with the existing conventional workflow. The least time saving was noted for Pentacam measurements (12%, data not reported), as at the Augsburg site (where the digital cataract workflow was executed), the pachymetry results were entered manually on a computer situated in the adjacent room. Previous studies have also sought to assess the impact of digitalization or software integration on the cataract surgery workflow.[9,11] A time-and-motion study demonstrated that swept-source OCT integrated with the operating room resulted in quicker measurement times.[13]

Time saving and reducing potential errors during manual transcription are vital for overall productivity and outcomes.[9] In line with earlier observations,[9,11] digital cataract workflow demonstrated significant time savings due to the automatic transfer of biometric data, IOL power calculation, and the reference image import to the intraoperative devices through a cloud-based platform. In contrast, in the conventional method, the biometric data are double-checked, and the reference image is manually transferred to the intraoperative device through a USB stick. This can manifest as errors with a significant increase in the process time.

IOL axis marking and alignment with the corneal cylinder are of utmost importance for effective astigmatic correction. The perils of the commonly used manual marking methods with ink include IOL misalignment due to inaccurate marking, chances of corneal epithelium injury,[12] and fading or complete washout of ink marks during IOL surgery.[14] In recent years, markerless computer-assisted or digital marking and alignment methods have prevented misalignment, decreased surgical duration, and streamlined workflow.[12,14–17] Likewise, in the current study, the FORUM® system combined with Callisto Eye-assisted digital IOL marking and alignment yielded better results than manual marking in terms of reduced surgical duration and workflow. Furthermore, it obviated the need for additional resources and routine preoperative steps (imaging a patient on a slit lamp, use of anesthetic drops, marker ink, and sterilization of the marker tool) involved in the manual method.

Optimizing surgical workflow is of utmost importance owing to the high volume of cataract surgeries, workload on the surgeons, and lack of resources in a hospital setting.[18] Additionally, the IOL implantation in cataract surgery is also associated with significant overall costs and impacts resource utilization.[10] The corporate chain hospitals are no different and are expected to maintain efficacy and consistency to ensure time saving across the procedures. The outcomes of this study provide an opportunity to address these concerns, as the digital cataract workflow facilitates less variability across multiple preoperative assessments and reduces the overall surgical time compared to the existing conventional workflow. The total surgical time was reduced by 50% regardless of the type of IOL implanted, thus saving the surgeon's time and resulting in productive outcomes, better patient scheduling, and surgical slot management, facilitating higher patient throughput with more economic benefits. Moreover, a digital cataract workflow based on a single FORUM® platform can be integrated with other devices across multiple clinics to avoid repetitive measures. Consequently, it has the potential to offer efficient surgical planning regardless of the institutional setup, surgical practices, and type of IOL implanted. Overall, the digital cataract workflow offers a seamless experience for surgeons because the information is available via a one-click touchscreen.

This study had several limitations. Although earlier studies investigated time savings and postoperative or refractive outcomes between fully manual and digital approaches,[12,19] the current study did not compare errors in IOL calculation and axis marking and visual outcomes post cataract surgery. Moreover, the study had an unequal sample size and two workflows were executed at two different sites. Challenges associated with digitalization, such as any delay from technical malfunctions or failures, are likely. Hence, future studies are needed to assess resource costs versus productivity and economic gains to foresee the overall benefits of digital workflow solutions.

Conclusion

In conclusion, significant time savings at each step of cataract surgery planning were observed with the Zeiss digital cataract workflow compared with the existing conventional workflow. Digitalization of the cataract surgery workflow has the potential to improve the efficiency and productivity of the corporate chain of hospitals.

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Author Contributions

All authors have made a significant contribution to the work reported, in the conception, study design, execution, and interpretation; took part in drafting, revising and critically reviewing all versions of the article; gave approval on the final version to be published; have agreed on the journal to which the article has been submitted; and agreed to be accountable for all aspects of the work.

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Disclosure

There is no conflict of interest to declare from all the authors.

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