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ORIGINAL ARTICLE

Clinical Evaluation of a Modified Scleral Tunnel Technique for Manual Small-Incision Cataract Surgery in Low-Resource Settings

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ABSTRACT
Background: Manual small-incision cataract surgery (MSICS) is an effective and affordable option for cataract management in low-resource settings.
Objective: To evaluate the clinical outcomes of a modified scleral tunnel technique for manual small-incision cataract surgery in low-resource settings, with assessment of visual recovery, surgically induced astigmatism, wound stability, and surgical complications.
Material and Methods: This prospective interventional study was conducted at Department of Opthalmology Nishtar Hospital Multan from June 2022 to January 2023, included 85 patients with visually significant age-related cataract who underwent MSICS using a modified scleral tunnel technique. Preoperative and postoperative visual acuity, corneal astigmatism, wound stability, and intraoperative and postoperative complications were recorded.
Results: The mean age of the patients was 62.7 ± 8.9 years, and 46 (54.1%) were male. Mean best-corrected visual acuity improved from 1.18 ± 0.42 logMAR preoperatively to 0.19 ± 0.14 logMAR at 6 weeks ($p<0.001$). At final follow-up, 76 (89.4%) patients achieved BCVA of 6/18 or better. Mean surgically induced astigmatism was 0.74 ± 0.39 D. A self-sealing wound was achieved in 81 (95.3%) patients, while 4 (4.7%) required suturing. The most common postoperative complication was corneal edema in 7 (8.2%) patients, followed by anterior chamber inflammation in 5 (5.9%).
Conclusion: The modified scleral tunnel technique for MSICS showed favorable short-term outcomes, including significant improvement in visual acuity, low surgically induced astigmatism, a high rate of self-sealing wounds, and a low frequency of complications.
Keywords: cataract, manual small-incision cataract surgery, scleral tunnel, visual acuity, surgically induced astigmatism

INTRODUCTION
Despite being one of the most preventable causes of vision loss and blindness, cataract continues to be one of the major causes of visual impairment and blindness in low- and middle-income countries[1]. Access to ophthalmic services remains poor in many low-resource settings, which is due to limited availability of trained personnel, high surgical costs and limited availability of advanced ophthalmic equipment[2]. The surgery for cataract must thus be safe, effective, affordable, reproducible, and practical in hospitals where high technology is not on a regular basis. Phacoemulsification cataract surgery is very popular due to the ability to remove the lens via a small incision and typically offers very quick visual rehabilitation. But the method is costly, demanding a significant amount of surgical training, and the use of disposable materials and regular upkeep[3]. It might not be used routinely in resource-limited areas. Manual small-incision cataract surgery (MSICS) is an important alternative for the good visual outcomes it can offer without the use of a phacoemulsification machine. It can be especially beneficial in dense and mature cataracts, often seen in populations where patients come to the clinic late for surgery[4].

The size, shape, location, and architecture of the scleral tunnel are crucial in the MSICS procedure as they affect the wound stability, ease of nucleus delivery, surgically induced astigmatism and postoperative recovery[5]. A good self-sealing tunnel reduces the need for sutures and helps to preserve anterior chamber stability during and after surgery. Contrastingly, a tunnel that is too big, too short, or has been poorly positioned can lead to leakage of the tunnel, prolapse of the iris, damage to the iris, postoperative astigmatism, or the inability to fully restore vision after the surgery[6]. Several variations of the classic tunnel design have been created to facilitate the surgical procedure and provide better post-operative results. The modified scleral tunnel technique would have the following potential benefits: Wound architecture, delivery of the nucleus, less manipulation of tissue, and maintaining self-sealing properties. These changes might be particularly useful in developing countries where the surgical technique should be simple, affordable, and flexible to different cataract density and surgeon experience[7]. A further issue in cataract surgery is the growing burden of surgery in groups of people who have limited access to ophthalmic services. Many patients present with advanced cataracts in most low-resource areas, due to financial constraints, travel difficulties, poor awareness or lack of specialist services, and because the patients have been unable to obtain timely care for their visual impairment[8]. These patients may have dense nuclei which are technically more difficult to be operated on and may need a larger incision which is safe for the delivery of the lens during the surgery[9]. In these circumstances, manual small-incision cataract surgery is especially appropriate as it allows flexibility in handling a variety of cataract densities, and at relatively low procedural costs. Scleral tunnel also has a significant influence on the postoperative refractive outcome[10]. Good incision architecture is crucial during IOLent implantation even after successful extraction of the cataract and can help prevent surgically induced astigmatism and changes in corneal curvature. This may result in delayed functional visual recovery and enhanced dependency on postoperative spectacles[11]. These changes can be minimized by altering the dimensions, shape, location and/or interior of the tunnel to assure sufficient access for nucleus delivery. A method that allows a balance between adequate surgical exposure and minimal distortion of corneal shape might, therefore, result in better anatomical and visual results[12].

Objective: To assess visual and other clinical outcomes of modified scleral tunnel technique (MST) for manual small incision cataract surgery (MSCS) in low resource settings and compare it to the stability of the wound, surgically induced astigmatism and intra and postoperative complications.

METHODOLOGY
This prospective interventional study was conducted at Department of Opthalmology Nishtar Hospital Multan from June 2022 to January 2023. In total 85 patients with manual small

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incision cataract surgery (MSCS) were selected for study. The patients who met the inclusion criteria were selected by non-probability consecutive sampling. The inclusion criteria were: age 40 years or older, suitable for manual small-incision cataract surgery and gave informed written consent for inclusion. All patients with varying grades of senile cataract were included as long as they were suitable to be assessed in the postoperative period. Patients with traumatic or complicated cataract, previous intraocular surgery, corneal opacity or significant corneal disease, active infection or inflammation, glaucoma with significant damage to the optic nerve, retinal disease affecting postoperative visual acuity, zonular weakness, lens subluxation or any other ocular condition that was likely to interfere with postoperative visual assessment were excluded. Pre-operative ocular evaluation was done.

Data collection: Demographic data, presenting visual acuity and best-corrected visual acuity, intraocular pressure, slit-lamp findings, cataract morphology and fundus findings (when visible) were documented. Preoperative keratometry was used to record the corneal astigmatism. The standard biometry method was used to determine axial length and intraocular lens power. Patients were evaluated for general and ocular systems prior to surgery. All procedures were carried out under proper local anaesthesia under standard aseptic precautions. Peritomy of the conjunctiva was carried out, and cauterization was done if necessary. Then a modified scleral tunnel was constructed as per the predesigned surgical procedure. The tunnel was designed to allow for sufficient access for the delivery of the nucleus, yet still have a self-sealing wound architecture. The internal opening of the tunnel presented the way into the anterior chamber. Capsulotomy or capsulorhexis was performed and hydrodissection and removal of the cataractous nucleus through the scleral tunnel was done. Whenever possible, the capsular bag was used for posterior chamber intraocular lens (PCIOL) insertion, and the residual cortical matter was removed. The anterior chamber was rebuilt at the end of surgery and the wound was evaluated for leakage and stability. There were no sutures used unless a satisfactory self-sealing of the wound was obtained. All intraoperative complications such as premature entry, buttonholing of the tunnel, iris prolapse, posterior capsular rupture, zonular dialysis, problem with delivery of the nucleus, or problem with the wound was recorded. Patients were assessed on the first postoperative day and at approximately 1, 4 and 6 weeks after surgery. The visual acuity, clarity of the cornea, reaction of the anterior chamber, the integrity of the wound, intraocular pressure, and postoperative complications were evaluated at each of the follow-up visits. Best-corrected visual acuity and keratometry were rechecked at the end of the follow-up period. These were the primary results measured: postoperative VA, surgically-induced astigmatism, wound stability and the incidence of intraoperative and postoperative complications. Surgically induced astigmatism was calculated by subtracting the preoperative keratometric value from the postoperative keratometric value. Data regarding post-operative complications (corneal edema, wound leakage, inflammation of the anterior chamber, hyphema, intraocular infection, raised intraocular pressure, and other procedure-related adverse events) were collected.

Data Analysis: Data were analyzed and inputted into SPSS v21. Continuous variables like age, VAS, keratometric values, and S.I.A. were expressed as mean ± SD or median (IQR), as relevant. Data relating to the categorical variables (gender, type of cataract, wound stability and complications during the surgery) were expressed as frequencies and percentages. The paired-samples t-test or Wilcoxon signed-rank test was used to compare continuous outcomes before and after surgery, based on the distribution of the data. A p-value of 0.05 or less was deemed as statistically significant.

RESULTS

The mean age of the patients was 62.7 ± 8.9 years. Males were slightly more common, accounting for 46 (54.1%) patients, while 39 (45.9%) were females. The right eye was operated in 44 (51.8%) patients and the left eye in 41 (48.2%). Nuclear sclerosis was the most common type of cataract, observed in 36 (42.4%) patients, followed by mature cataract in 29 (34.1%), posterior subcapsular cataract in 12 (14.1%), and cortical cataract in 8 (9.4%) patients.

Mean BCVA improved from 1.18 ± 0.42 logMAR preoperatively to 0.39 ± 0.21 at 1 week, 0.25 ± 0.16 at 4 weeks, and 0.19 ± 0.14 at 6 weeks, with a statistically significant difference ($p<0.001$). The proportion of patients achieving BCVA ≥6/18 increased from 7 (8.2%) preoperatively to 57 (67.1%) at 1 week, 70 (82.4%) at 4 weeks, and 76 (89.4%) at 6 weeks ($p<0.001$). In contrast, patients with BCVA <6/60 decreased from 49 (57.6%) preoperatively to only 1 (1.2%) at 6 weeks.

Mean preoperative corneal astigmatism was 1.10 ± 0.56 D, while postoperative corneal astigmatism at 6 weeks was 1.39 ± 0.63 D. The mean surgically induced astigmatism was 0.74 ± 0.39 D. A self-sealing wound was successfully achieved in 81 (95.3%) patients, while suturing was required in only 4 (4.7%).

Table 1: Demographic and Clinical Characteristics of Patients

Variable	Frequency (%) / Mean ± SD
Age, years	62.7 ± 8.9
Male	46 (54.1%)
Female	39 (45.9%)
Right eye operated	44 (51.8%)
Left eye operated	41 (48.2%)
Nuclear sclerosis	36 (42.4%)
Mature cataract	29 (34.1%)
Posterior subcapsular cataract	12 (14.1%)
Cortical cataract	8 (9.4%)

Table 2: Comparison of Preoperative and Postoperative Visual Outcomes

Visual Outcome	Preoperative	1 Week	4 Weeks	6 Weeks	p-value
BCVA, logMAR, Mean ± SD	1.18 ± 0.42	0.39 ± 0.21	0.25 ± 0.16	0.19 ± 0.14	<0.001
BCVA ≥6/18, n (%)	7 (8.2%)	57 (67.1%)	70 (82.4%)	76 (89.4%)	<0.001
BCVA 6/24–6/60, n (%)	29 (34.1%)	24 (28.2%)	13 (15.3%)	8 (9.4%)	—
BCVA <6/60, n (%)	49 (57.6%)	4 (4.7%)	2 (2.4%)	1 (1.2%)	—

Table 3: Keratometric Changes, Surgically Induced Astigmatism, and Wound Stability

Outcome	Result
Preoperative corneal astigmatism, D, Mean ± SD	1.10 ± 0.56
Postoperative corneal astigmatism at 6 weeks, D, Mean ± SD	1.39 ± 0.63
Surgically induced astigmatism, D, Mean ± SD	0.74 ± 0.39
Self-sealing wound achieved, n (%)	81 (95.3%)
Suturing required, n (%)	4 (4.7%)
Wound leakage, n (%)	1 (1.2%)

Table 4: Intraoperative and Postoperative Complications

Intraoperative Complications	n (%)
Premature entry into anterior chamber	2 (2.4%)
Tunnel buttonhole	1 (1.2%)
Iris prolapse	2 (2.4%)
Posterior capsular rupture	1 (1.2%)
Difficult nucleus delivery	3 (3.5%)
Postoperative Complications	
Corneal edema	7 (8.2%)
Anterior chamber inflammation	5 (5.9%)
Raised intraocular pressure	4 (4.7%)
Hyphema	2 (2.4%)
Wound leakage	1 (1.2%)
Endophthalmitis	0 (0.0%)

Difficult nucleus delivery was the most common intraoperative complication, occurring in 3 (3.5%) patients. Premature entry into the anterior chamber and iris prolapse were each observed in 2 (2.4%), while tunnel buttonhole and posterior capsular rupture each occurred in 1 (1.2%) patient. Among postoperative complications, corneal edema was the most frequent, affecting 7 (8.2%) patients, followed by anterior chamber inflammation in 5 (5.9%), raised intraocular pressure in 4 (4.7%), hyphema in 2 (2.4%), and wound leakage in 1 (1.2%). No case of endophthalmitis was observed.

DISCUSSION

In this study, the clinical results of a modified scleral tunnel procedure for small-incision cataract surgery (SICS) performed manually were analyzed in 85 patients. The study demonstrated significant postoperative visual acuity improvement, high wound self sealing rate, low surgically induced astigmatism and low intraoperative and postoperative complication rate. The present results indicate that the modified scleral tunnel technique may be an effective and feasible alternative surgical method for cataract surgery in those areas where there is limited access to cataract phacoemulsification machines. The age of the studied population was 62.7 ± 8.9 years, with slightly more men patients. The most common type of cataract was nuclear sclerosis and mature cataract. This is clinically important in low-resource areas where patients may come in with more advanced lens opacities and present later. In such cases, the manual small-incision cataract surgery is useful because it can remove the dense nucleus and doesn't require expensive phacoemulsification equipment[13].

There was a significant increase in BCVA following surgery. Preoperatively, mean BCVA was 1.18 ± 0.42 logMAR, but it was 0.19 ± 0.14 logMAR at 6 weeks. The final follow-up BCVA was 6/18 or better in 76 patients (89.4%), with only one patient with BCVA < 6/60. This improvement has shown that the modified tunnel technique gave good access for the removal of the cataract and adequate postoperative visual rehabilitation. The relatively low surgically induced astigmatism was another important finding[14]. The mean corneal astigmatism was 1.10 D ± 0.56 D preoperatively and 1.39 D ± 0.63 D at 6 weeks postoperatively. The mean surgically induced astigmatism was 0.74 ± 0.39 D. The scleral tunnel architecture is one of the crucial factors relating to postoperative corneal curvature; an ideal incision will limit postoperative distortion due to the wound itself. Little induced astigmatism was seen in this study, indicating that the modified tunnel was not associated with excessive corneal shape change and was still stable enough to achieve good wound healing[15].

The modified tunnel also exhibited good wound-related outcomes. A self-sealing wound was accomplished in 81 (95.3%) patients, and only 4 (4.7%) had to be sutured. Only one patient had wound leakage. A high rate of self-sealing wounds, especially in resource-limited areas, is beneficial as it decreases the need for sutures, quickens the procedure and can potentially decrease suture-induced post-operative complications[16]. This feature also could render the technique applicable to high-volume cataract surgery programs. There was a low incidence of intra-operative complications. The delivery of the nucleus was difficult in 3 (3.5%) patients and in 2 (2.4%) patients, the nucleus was delivered too early, and in 2 (2.4%) cases, there was prolapse of the iris. One patient each was found to have posterior capsular rupture and "tunnel buttonholing[17]. The results show that it was generally possible to use the modified tunnel technique and that it could be performed with the required space for the delivery of the nucleus and without compromising the integrity of the wound. There are still some complications associated with the tunnel construction, however, which may be cataract density, scleral thickness, depth of incision, and surgeon experience[18-20].

Limitations: There were several limitations in this study. It was carried out in a reasonably small sample of 85 patients and in a single clinical setting, thus questioning the extensibility of the results. A control group who underwent conventional scleral tunnel MSICS or phacoemulsification was not included in the study, so the relative benefit of the modified tunnel technique could not be directly determined. No long-term follow-up was performed and late astigmatic changes, posterior capsular opacification and late complications were not evaluated. Furthermore, no assessment was done on endothelial cell loss, patient satisfaction, cost-effectiveness, or surgeon's learning curve. A larger, multicenter study with longer follow-up is suggested to validate the safety, effectiveness and repeatability of the modified scleral tunnel technique.

CONCLUSION

The manual small-incision cataract surgery using the modified scleral tunnel had satisfactory short-term clinical results, with significant improvement in postoperative visual acuity, a high percentage of self-sealing incisions, and low surgically induced astigmatism and few complications during the surgery and in the immediate postoperative period. The technique seems to be a safe, effective and practical one for cataract surgery in the low income countries where phacoemulsification facilities may not be readily available. Further larger studies with longer follow-up are suggested to validate its long-term benefits and effectiveness when compared to traditional methods.

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