

One-Year Outcomes of 5-0 Prolene Gonioscopy-Assisted Transluminal Trabeculotomy in Juvenile Open-Angle Glaucoma

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Abstract

Purpose

To evaluate the 12 months efficacy and safety of gonioscopy-assisted transluminal trabeculotomy (GATT) in juvenile open-angle glaucoma (JOAG) and to determine whether baseline disease severity influences surgical success.

Methods

Prospective interventional study of 30 eyes undergoing GATT. The present study provides the planned 12-month follow-up of a previously reported 6 month cohort. Outcomes included intraocular pressure (IOP), anti-glaucoma medications (AGMs), visual acuity, success, and complications. Surgical success was defined as IOP ≤ 21 / ≤ 18 / ≤ 15 mmHg with $> 20\%$ / 25% / 30% reduction from baseline (Criteria 1,2,3).

Results

30 eyes (28 patients) were included, of which 11 eyes had mild-to-moderate and 19 eyes had severe JOAG. Mean (SD) IOP (mmHg) decreased from 23.43 ± 9.65 to 13.80 ± 7.09 at 12 months ($p < 0.001$). Mean (SD) AGMs reduced from 2.93 ± 0.87 preoperatively to 0.80 ± 0.99 ($p < 0.001$). Mean IOP reduction was 36.3% in Mild-moderate group and 28.7% in severe JOAG group at 1 year. The overall success in mild to moderate group was 63.6%, 63.6% and 54.6% and in severe group was 73.7%, 68.4% and 47.4% by criteria 1,2 and 3 respectively with no significant difference between the groups ($p = 0.61$, $p = 0.82$ and $p = 0.70$). Hyphema was the most common complication. Microhyphema (< 1 mm) was seen in 6 patients and Macrohyphema (> 1 mm) was seen in two patients, who required anterior chamber wash.

Conclusions

GATT is effective and safe in JOAG, with sustained intraocular pressure control, medication reduction, and good surgical success at the end of 12 months, irrespective of baseline disease severity.

Introduction

Juvenile open-angle glaucoma (JOAG) is a distinct subtype of primary open-angle glaucoma which is associated with markedly elevated intraocular pressure (IOP), rapid disease progression, and a high lifetime risk of visual disability. Unlike adult-onset primary open-angle glaucoma, JOAG often demonstrates a more aggressive clinical course and poorer responsiveness to medical therapy, resulting in an earlier need for surgical intervention¹⁻³. Genetic and histopathological studies suggest that

abnormalities within the trabecular meshwork and conventional aqueous outflow pathways play a key role in disease pathogenesis, making angle-based surgical procedures a suitable option ^{4,5}.

Traditionally, trabeculectomy and glaucoma drainage devices have been the principal surgical strategies for medically uncontrolled JOAG. Although effective in lowering IOP, these procedures are associated with significant short- and long-term complications, including hypotony, conjunctival scarring, cataract formation, bleb-related infections, and failure secondary to an exuberant healing response that is common in younger patients. ^{6,7,8} Given the lifelong nature of glaucoma management in this population, preservation of conjunctival integrity and maintenance of future surgical options are important considerations when selecting an initial surgical procedure ^{9,10}.

Gonioscopy-assisted transluminal trabeculotomy (GATT), first described by Grover et al., is an ab interno circumferential trabeculotomy that achieves 360-degree trabecular meshwork incision while preserving the conjunctiva. It directly addresses the primary site of outflow resistance and enhances access to Schlemm's canal and collector channels. GATT has emerged as an important addition to the spectrum of minimally invasive glaucoma surgery (MIGS), particularly in younger patients. ^{11,12}

Over the past several years, increasing evidence has supported the efficacy of GATT in JOAG. Retrospective studies have demonstrated substantial reductions in IOP and medication burden, during short- and intermediate-term follow-up. Furthermore, GATT has shown promising outcomes in eyes with severe disease, prior glaucoma surgery, and genetically associated forms of JOAG ^{12–18}. Despite these encouraging findings, the current evidence base remains limited by retrospective study designs, heterogeneous patient populations, and variable follow-up durations. GATT has demonstrated favourable short- and intermediate-term outcomes in JOAG, however the sustainability of these effects remains an important consideration in a young population with a lifetime risk of glaucoma progression.

We previously reported the early 6-month outcomes following 5 – 0 Prolene GATT in JOAG, demonstrating significant reductions in IOP and antiglaucoma medication burden ¹⁹. The present study represents the planned longitudinal extension of that cohort to 12 months. The purpose of the current analysis is to determine the durability of IOP and medication reduction through 12 months and to evaluate surgical success using progressively stringent success criteria, with particular emphasis on whether baseline glaucoma severity influenced longer-term outcomes.

Methods

Study design and participants

This was a prospective, interventional, study of patients with juvenile open angle glaucoma who underwent 5 – 0 prolene GATT and were followed for 12 months. Consecutive patients presenting to the glaucoma clinic were screened for eligibility and enrolled after providing written informed consent. The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by

the institutional ethics committee prior to enrolment. This study is a longitudinal extension of a previously reported prospective cohort of eyes undergoing 5 – 0 Prolene GATT for JOAG¹⁹. The earlier report presented postoperative outcomes through 6 months. The present analysis includes follow-up through 12 months and was undertaken to evaluate the treatment effect and longer-term surgical success. Baseline characteristics and outcomes through 6 months were not considered new observations in the present study; these data are presented only where necessary to demonstrate the longitudinal trajectory, with the primary analysis focused on outcomes at 12 months.

Patients were eligible if they (1) had a clinical diagnosis of JOAG, defined as an open anterior chamber angle with identifiable trabecular meshwork on gonioscopy and onset of glaucomatous optic neuropathy between 4 and 40 years of age in the absence of any other identifiable cause of raised IOP; (2) had an IOP that remained uncontrolled, or visual fields that continued to deteriorate, despite maximally tolerated topical medical therapy, or were intolerant of the medications required to control IOP. Eyes were excluded if they had a secondary cause of glaucoma, a history of ocular trauma or of intraocular surgery other than glaucoma surgery, corneal opacity or other media abnormality precluding angle view, or a known bleeding diathesis or anticoagulant therapy.

For the purpose of subgroup analysis, eyes were stratified by baseline visual field severity using the mean deviation (MD) on Humphrey 24 – 2 SITA testing: eyes with MD upto 12 dB were classified as mild-to-moderate JOAG and eyes with MD > 12 dB as severe JOAG.

Surgical technique

All procedures were performed as a stand-alone GATT using a 5 – 0 prolene suture by a single experienced surgeon (DM). The surgery was performed under peribulbar anaesthesia (3-5ml of lignocaine + 50 IU/ml Hyaluronidase and 1:2,00,000 adrenaline). After a standard sterile preparation, a temporal clear corneal incision was made and the anterior chamber was filled with a high molecular weight cohesive viscoelastic (1.6% sodium hyaluronate, Aurogel plus- Aurolab, India). A second, tangentially oriented paracentesis was created in the superonasal or inferonasal quadrant to serve as the working port for suture insertion. The patient's head is turned 30–35 degree away from the surgeon and the operating microscope is tilted towards the surgeon to bring the nasal angle into view through a Swan-Jacob gonioprism (Ocular Instruments, Bellevue, WA, USA). A goniotomy of 1–2 mm was made in the nasal trabecular meshwork using a microvitreoretinal knife (V- Lance Knife, Alcon laboratories Inc, Texas USA), introduced through the temporal incision. The tip of a 5 – 0 prolene suture was thermally blunted by using a low temperature cautery. (Bovie's deluxe low-temperature cautery, Bovie Medical Corporation FL, USA). The suture was gently threaded along the circumference of the Schlemm's canal until the distal tip emerged through the goniotomy site. Then the suture was externalized to complete 360-degree trabeculotomy. When a complete 360-degree pass could not be achieved on the first attempt, the suture was reintroduced in the opposite direction to complete the procedure. At the end of

the procedure, the anterior chamber was filled up to 20–30% with 1.6% sodium hyaluronate (Aurogel, Aurolab, India) to reduce blood reflux and the occurrence of post-operative hyphema.

Postoperative care

Post-operatively, tapering dose of Pred Forte (Prednisolone Acetate Ophthalmic Suspension USP, 1%, India) eye drops for 4 weeks and ofloxacin (Auroflox; Aurolab, India) (0.3%) eye drops four times a day for 10 days. Topical Pilocarpine (2%) was given twice daily for one month.

Outcome measures and definitions

Patients were evaluated on 2 weeks, 1 month, 3, 6 and 12 months postoperatively. At each visit, IOP, AGM, BCVA, complications, and interventions if any were documented. Patients who failed to follow up for more than two consecutive visits or the final visit were considered lost to follow-up. An IOP ≥ 30 mmHg within the first postoperative month was defined as an IOP spike. Hyphema was classified as microhyphema when layered or diffuse blood occupied < 1 mm of the anterior chamber and macrohyphema when it exceeded 1 mm.

Three progressively stringent success criteria were applied in parallel. Complete success included criteria 1 - IOP, > 5 and ≤ 21 mmHg and 20% reduction from baseline, criteria 2 - IOP, > 5 and ≤ 18 mmHg and 25% reduction from baseline and criteria 3 - IOP, > 5 and ≤ 15 mmHg and 30% reduction from baseline, without anti-glaucoma medications in all. Qualified success was defined as achieving success with antiglaucoma medications. Failure was defined as not meeting the relevant criterion on two consecutive visits, or the need for an additional IOP-lowering surgical procedure, or loss of light perception.

Statistical methods:

All statistical analysis was performed using STATA statistical software (version 17.0, StataCorp, USA). The distribution of the continuous variables was assessed for normality using Shapiro-Wilk test and Box-Whisker's plots. Descriptive statistics for continuous variables were reported as mean and standard deviation (SD), while categorical variables were summarized using frequencies (n), and percentages. Snellen's equivalent visual acuity were converted into logarithm of minimum angle of resolution (Log MAR) for the statistical analysis. A mixed-effect regression model was used to compare post-operative measures of IOP, AGM, and BCVA with pre-operative values over the follow-up period. In this model, the follow-up period was considered a fixed effect and each patient's identification number was treated as a random effect. Associations between the success outcome and classification of glaucoma severity were assessed using Chi-square test. Kaplan-Meier survival analysis was performed to visualize the cumulative probability of success, and log-rank test was used to compare the success between the glaucoma severity. A p-value of less than 0.05 considered as statistically significant.

Results

Thirty eyes of 28 patients met the inclusion criteria and completed 12 months of follow-up. Eleven eyes (36.7%) had mild-to-moderate JOAG and 19 eyes (63.3%) had severe JOAG at baseline. The two groups were comparable in age (38.18 ± 9.68 vs 40.53 ± 9.03 years, $p=0.510$), sex distribution (male 63.6% vs 68.4%, $p=0.789$), and laterality. (Table 1).

Mean (SD) IOP (mmHg) decreased from 23.43 ± 9.65 to 13.80 ± 7.09 at 12 months ($p < 0.001$). Mean (SD) AGMs reduced from 2.93 ± 0.87 preoperatively to 0.80 ± 0.99 ($p < 0.001$) (Table 2). The IOP reduction was sustained throughout follow-up, corresponding to a mean IOP reduction of 36.3% and 28.7%, in Mild-moderate and severe JOAG groups respectively. There was no statistically significant change in BCVA in both groups at every follow-up visit (all within-group $p > 0.05$). (Table 3)

Cumulative probability of overall success was estimated separately under each of the three IOP criteria (Table 4) in mild-moderate and severe JOAG groups. By Criteria 1, the cumulative probability of success at 12 months was 63.6% (95% CI 30.0–84.5) in Mild-Moderate and 73.7% (95% CI 47.9–88.1) in Severe Group (log-rank $p=0.609$). Using Criteria 2 it was 63.6% (30.0–84.5) and 68.4% (42.8–84.4) in Mild-moderate and severe groups respectively ($p=0.823$), and by Criteria 3 it was 54.6% (22.9–78.0) and 47.4% (24.4–67.3) ($p=0.697$). There was no statistically significant difference between the success rate of the two groups. Figures. 1, 2, and 3 depict Kaplan-Meier survival curves showing the cumulative probability of overall success of the two groups.

Microhyphema (<1 mm) was the most common postoperative complication, occurring in 6 patients. In all cases it resolved spontaneously by the end of the first postoperative week. Two eyes with macrohyphema required an anterior chamber wash for a persistent and visually significant hyphema. There was no vision threatening complication in the 12 month follow up period.

Discussion

Juvenile open-angle glaucoma is characterized by structural abnormalities of the trabecular meshwork and Schlemm's canal and can be particularly challenging to manage. The disruption of aqueous humor outflow caused by these anatomical variations leads to increased intraocular pressure and subsequent glaucomatous damage²⁰. Schlemm's canal based surgeries like the 360 degree GATT, can be considered as an effective option in the management of JOAG²¹.

In this longitudinal analysis, we found a sustained and clinically meaningful reduction in both IOP (36.3% and 28.7% in the mild-to-moderate and severe groups, respectively) and medication burden at 12 months. Importantly, none of these outcomes differed significantly between eyes with mild-to-moderate versus severe baseline visual field loss. Eyes presenting with advanced functional damage (mean baseline MD of -22.42 dB) achieved pressure-survival curves that matched those of eyes presenting with mild-to-moderate baseline defects. (p value). The physiological basis of these findings underscores the unique therapeutic mechanism of GATT in younger population. Unlike adult-onset

primary open-angle glaucoma (POAG), where multi-factorial outflow resistance may span across both the trabecular meshwork and distal collector channels, the primary anatomical site of resistance in JOAG is localized directly within a dysgenetic or hyper-dense trabecular meshwork. A 360-degree GATT bypasses this localized pathological barrier entirely and restores direct access to physiological aqueous drainage channels. The fact that the severe MD cohort achieved an equally robust drop in mean IOP (p value) highlights the possibility that even in advanced stages of JOAG, the downstream distal collector channels remain structurally viable and patent^{4,12,21}. This is similar to the study by Wang et al ²², who followed 59 JOAG eyes and reported comparable IOP and medication outcomes between mild-to-moderate and severe eyes (MD ≥ -12 dB versus < -12 dB), with a surgical success of 79.1% even in the severe subgroup at 12 months. Their overall cohort achieved a mean IOP of 14.7 ± 3.0 mmHg on 0.7 ± 1.2 medications at 12 months from a preoperative baseline of 26.5 ± 9.0 mmHg on 3.7 ± 0.9 medications – a slightly larger absolute reduction than we observed, which may partly reflect their larger sample size and a marginally higher baseline IOP. Wang et al study evaluated microcatheter assisted GATT, while our study evaluated suture GATT. The overall pattern of sustained, severity-independent benefit seen in the Wang et al study is consistent with our study.

The reported range of surgical success in the limited data available from literature varied from 70–90%^{11–22}. The cumulative probability of overall success in our study in Group 1 and Group 2 was 63.6% and 73.7% by Criteria 1. Hu et al ¹⁴ in their study of 35 eyes for up to three years, reported complete and qualified success rates of 73.7% and 82.6% at 12 months. The modest success rate in our study could be due to the differences in baseline severity and due to different success criteria and our patients was weighted toward severe JOAG, with 63% of eyes falling below -12 dB MD.

Complications were minimal in our study with microhyphema in six patients, all resolving within a week. Macrohyphema and anterior chamber washout was required in two eyes. This is consistent with the safety data reported across the GATT literature in JOAG, in which hyphema is self-limited, and postoperative IOP spikes are usually transient and manageable with medications^{23–25}.

The sample size, while adequate to detect the within-group changes reported, was too small to reliably exclude a modest between-group difference in success. The study included only eyes of Indian patients and all surgeries were performed by a single surgeon, which limits the generalisability of the results. This study represents an extension of a previously published 6-month analysis of the same cohort; therefore, some baseline characteristics and early postoperative observations necessarily overlap with the earlier report. However, our study addresses an important gap in literature by providing long term outcomes of GATT in JOAG.

Conclusion

In Juvenile open angle glaucoma, 5 – 0 Prolene GATT produced sustained IOP reduction, decrease in medication burden, with a good safety profile over 12 months, irrespective of severity of visual field loss.

These findings support GATT as a viable, conjunctiva-sparing surgical option across the severity spectrum of JOAG.

What was known before

- GATT has demonstrated favourable IOP and medication reduction in JOAG ,with good short and intermediate term surgical success.
- Both Microcatheter assisted GATT and suture GATT have been reported as effective surgical approaches for JOAG.
- Evidence on the long-term durability of GATT in JOAG remains limited, especially suture GATT.

What this study adds

- The IOP- and medication-lowering effects were maintained through 12 months.
- Severe JOAG demonstrated outcomes comparable to mild-to-moderate disease.
- Surgical success remained demonstrable even using progressively stringent criteria.
- No new vision-threatening complications emerged during the additional 6 months of follow-up.

Declarations

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Nil

Author contribution

All authors contributed to the study's conception and design.DM: Conception, data interpretation, and revision of the article. MRP: Drafting the article, analysis of data, interpretation, and revision. NN: Data acquisition, analysis and revision. MSU: Data analysis and interpretation.SG, DSG, RR: revising the article critically for important intellectual content. All the authors read and approved the final manuscript.

Conflict of interests

No conflicting relationship exists for any author except DSG.

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Consent to participate: Informed consent was obtained from all individual participants included in the study.

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Tables

Tables 1 to 4 are available in the supplementary files section.

Figures

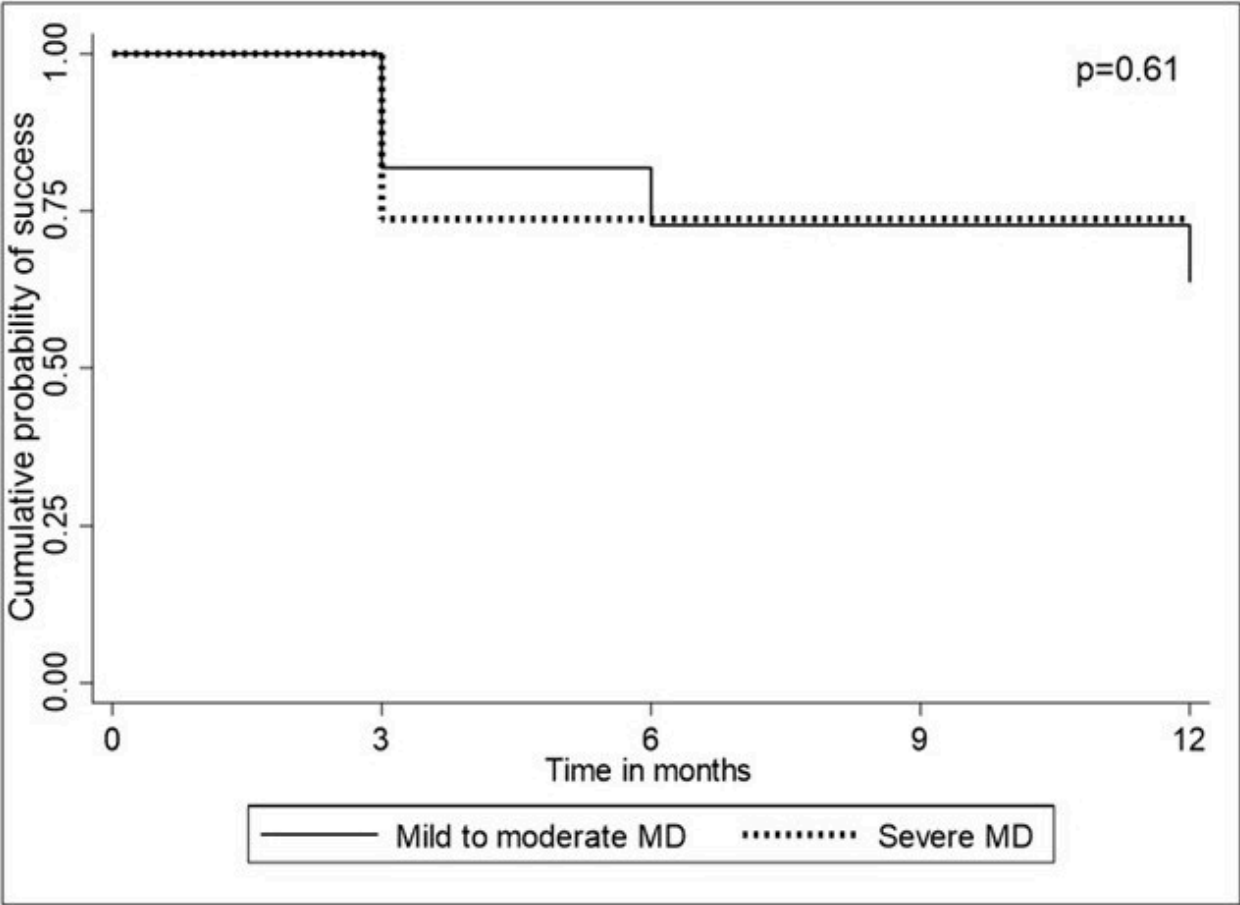


Figure1: Kaplan-Meier survival graph showing the cumulative probability of overall success by success criterion 1

Figure 1

See image above for figure legend.

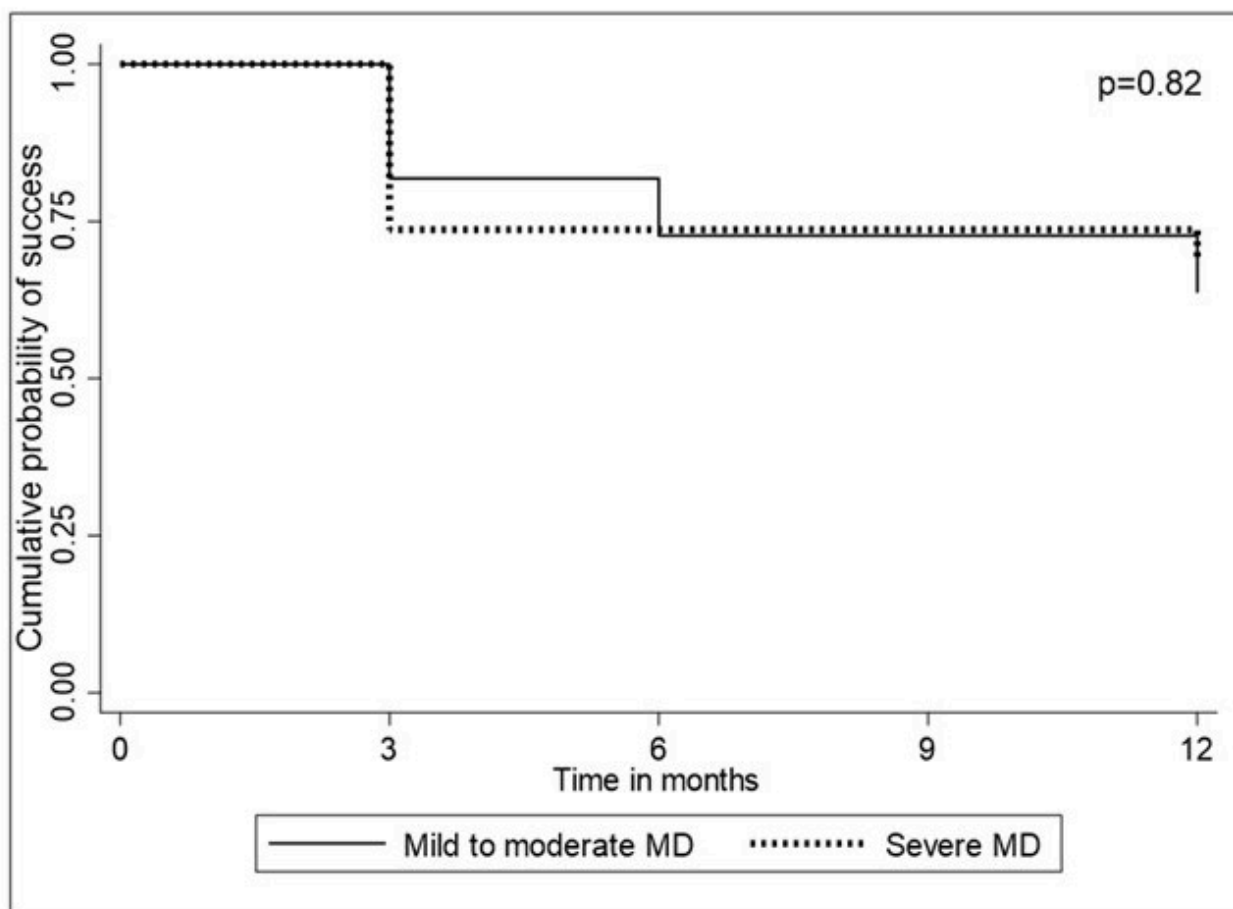


Figure2: Kaplan-Meier survival graph showing the cumulative probability of overall success by success criterion 2

Figure 2

See image above for figure legend.

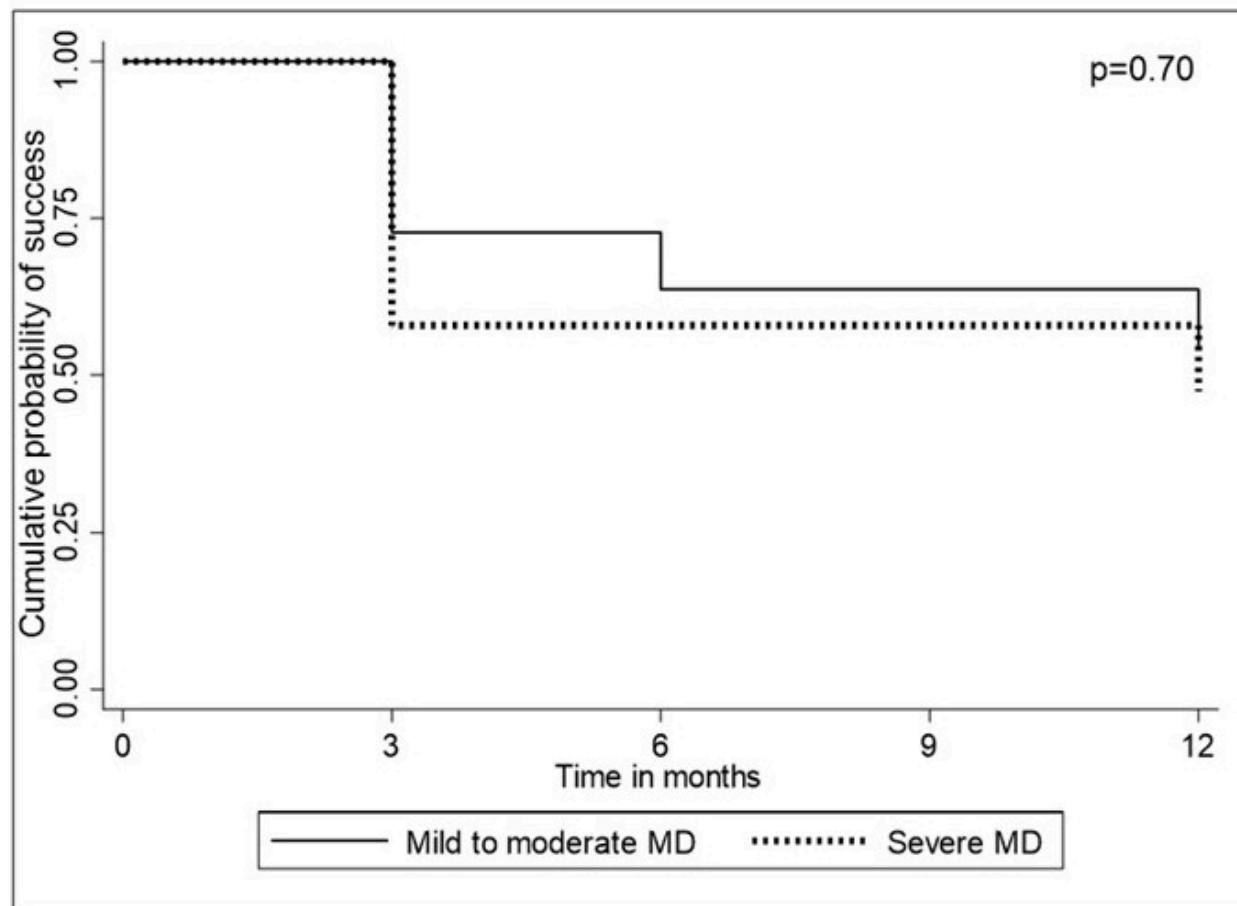


Figure3: Kaplan-Meier survival graph showing the cumulative probability of overall success by success criterion 3

Figure 3

See image above for figure legend.

Supplementary Files

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