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Medication Adherence and Visual Field Progression in Glaucoma: A Thirty Six Month Prospective Cohort: Adherence Stratified Outcomes, Predictors of Non-Adherence and Intervention Opportunities

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Abstract — Glaucoma is a leading cause of irreversible blindness globally, with effective treatment available but adherence to chronic topical medication regimens emerging as a major determinant of long-term outcomes. We undertook a prospective cohort study of 276 patients with primary or secondary glaucoma followed for 36 months at a tertiary glaucoma service, with structured adherence assessment using the Morisky Medication Adherence Scale (MMAS-8), electronic pharmacy refill data, and clinical outcomes including intraocular pressure trajectory and visual field progression. High adherence (MMAS-8 ≥7) was achieved by 112 patients (40.6%), moderate (5-6.75) by 102 (37.0%), and low (<5) by 62 (22.5%). Mean intraocular pressure across visits was 15.2 mmHg in the high-adherence group, 18.4 mmHg in moderate, and 22.8 mmHg in low adherence patients. Confirmed visual field progression at 36 months occurred in 25.0% of high adherence patients, 48.0% of moderate, and 72.6% of low. Strongest independent predictors of poor adherence included high out-of-pocket cost, complex multi-drop regimens, adverse effects, cognitive impairment, living alone, and asymptomatic disease perception. Caregiver-supported drop administration and engagement with structured patient education were strongly protective. The findings support comprehensive adherence interventions including regimen simplification, cost reduction, structured education, and caregiver engagement to preserve vision in glaucoma.

Keywords — *Glaucoma; Primary Open-Angle Glaucoma; Medication Adherence; Intraocular Pressure; Visual Field Progression; Topical Antiglaucoma Medications; Chronic Disease.*

1. Introduction

Glaucoma is the leading cause of irreversible blindness globally, with the World Health Organization estimating approximately 80 million people affected worldwide. The disease is characterised by progressive optic neuropathy with corresponding visual field loss, with intraocular pressure (IOP) the principal modifiable risk factor. Effective treatment exists topical pressure-lowering medications, laser interventions including selective laser trabeculoplasty (SLT), and incisional surgery but the natural history of treated disease depends critically on sustained IOP control which in turn depends on medication adherence in patients managed pharmacologically (Jha, Kumar, & Neha, 2026; Yatish, Khatoon, & Kumar, 2026; Kumar, Sharma, & Gupta, 2026). Adherence to chronic glaucoma medication is challenging for multiple reasons. The disease is typically asymptomatic until advanced stages, providing little behavioural reinforcement for daily compliance. Many regimens require two or three drops with different scheduling, often from different bottles with potentially identical appearance. Topical agents produce common adverse effects including ocular irritation, hyperaemia, periocular pigmentation, and systemic effects (β-blocker-induced bradycardia, fatigue). Cost is substantial particularly for newer prostaglandin analogues. Bottle-handling becomes difficult with age-related cognitive and motor decline (Jha, Kumar, & Neha, 2026; Kumar, Gautam, & Maitiy, 2026; Bhatnagar, Kumar, & Shivam, 2026). Understanding the determinants of adherence and the impact on long-term outcomes is essential for clinical and operational programme design. We undertook a prospective cohort study at our tertiary glaucoma service to characterise adherence patterns, IOP trajectories, and visual field progression over 36 months, and to identify modifiable predictors of poor adherence amenable to intervention (Yatish, Khatoon, & Kumar, 2026; Devi et al., 2025; Shanthi et al., 2025).

2. Methods

We conducted a prospective cohort study at the glaucoma service of a tertiary ophthalmology centre between January 2022 and December 2024. Inclusion required (a) diagnosis of primary or secondary glaucoma confirmed by experienced glaucoma specialists; (b) age 18 years or older; (c) treatment with topical antiglaucoma medications (monotherapy or combination); (d) reliable visual field tests available at baseline; and (e) capacity to complete 36-month follow-up. Exclusion criteria included media opacities precluding adequate optic disc evaluation,

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advanced visual field loss precluding meaningful progression analysis, and ongoing eligibility for surgical management not yet undertaken. The final cohort comprised 276 patients. Medication adherence was assessed using three complementary approaches. First, the Morisky Medication Adherence Scale (MMAS-8), an 8-item validated patient-reported instrument with scores from 0 to 8 (high adherence ≥7, moderate 5-6.75, low <5). Second, electronic pharmacy refill data captured prescription fill patterns with proportion-of-days-covered (PDC) calculated for the previous 6 months at each follow-up visit. Third, structured patient interview captured specific reasons for any missed doses including cost, forgetting, adverse effects, regimen complexity, and perceived lack of benefit. The three measures were aggregated for primary classification. All patients underwent comprehensive clinical assessment at baseline and at 6-monthly intervals including best-corrected visual acuity, slit-lamp examination, intraocular pressure measurement (Goldmann applanation tonometry, with at least two measurements averaged), gonioscopy, dilated fundus examination with stereo optic disc photography, and Humphrey 24-2 SITA-Standard visual field testing. Optical coherence tomography of the retinal nerve fibre layer and macular ganglion cell complex was performed at baseline and at 12-monthly intervals. Glaucoma subtype, severity at baseline, and treatment regimen complexity were documented systematically. Primary outcomes were intraocular pressure trajectory (mean across visits, target achievement) and visual field progression (confirmed by Guided Progression Analysis or by ≥2 dB decline in mean deviation on consecutive reliable tests). Secondary outcomes included OCT retinal nerve fibre layer change, requirement for treatment escalation (additional topical agents, laser, or surgery), visual acuity change, NEI-VFQ-25 quality of life, and adverse events. Time-to-event analyses used Kaplan-Meier estimation with log-rank testing. Multivariable logistic regression identified independent predictors of poor adherence (MMAS-8 <5).

3. Results

3.1 Cohort Characteristics

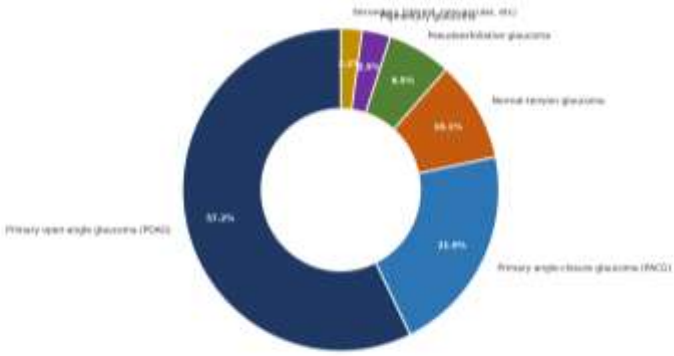

Fig.1: Glaucoma subtype distribution

Glaucoma subtype distribution is shown in Figure 1. Primary open-angle glaucoma accounted for the majority (57.2%), followed by primary angle-closure glaucoma (21.0%), normal-tension glaucoma (10.1%), and pseudoexfoliative glaucoma (6.5%). Less common subtypes included pigmentary, neovascular, and steroid-induced glaucoma.

Table 1. Baseline characteristics by adherence stratum

Characteristic	High (n=112)	Moderate (n=102)	Low (n=62)
Age, mean (SD), years	58.4 (12.6)	62.4 (13.2)	68.4 (14.8)
Female sex, n (%)	48 (42.9)	52 (51.0)	32 (51.6)
Lives alone, n (%)	12 (10.7)	22 (21.6)	28 (45.2)
Has caregiver support for drops, n (%)	42 (37.5)	32 (31.4)	12 (19.4)
Education ≥12 years, n (%)	68 (60.7)	48 (47.1)	18 (29.0)
Currently employed, n (%)	58 (51.8)	42 (41.2)	18 (29.0)
Out-of-pocket cost >₹400/month, n (%)	32 (28.6)	58 (56.9)	42 (67.7)
Has medical insurance, n (%)	48 (42.9)	32 (31.4)	12 (19.4)
Symptomatic at diagnosis, n (%)	52 (46.4)	42 (41.2)	12 (19.4)
Bottle-handling difficulty reported, n (%)	12 (10.7)	32 (31.4)	32 (51.6)
Cognitive impairment documented, n (%)	8 (7.1)	12 (11.8)	18 (29.0)
Number of topical agents (mean)	1.6	2.4	2.8
Single agent, n (%)	58 (51.8)	32 (31.4)	12 (19.4)
Two agents, n (%)	42 (37.5)	48 (47.1)	18 (29.0)
Three or more agents, n (%)	12 (10.7)	22 (21.6)	32 (51.6)
Currently on prostaglandin analogue, n (%)	98 (87.5)	78 (76.5)	48 (77.4)
Currently on β-blocker, n (%)	42 (37.5)	48 (47.1)	32 (51.6)
Adverse effect reported (any), n (%)	32 (28.6)	52 (51.0)	42 (67.7)
Baseline IOP, mean, mmHg	21.8	23.2	25.4
Baseline mean deviation, mean, dB	-4.2	-6.2	-8.4

3.2 IOP Outcomes by Adherence

Intraocular pressure across visits by adherence stratum is shown in Figure 2. High-adherence patients achieved and maintained substantially lower mean IOP (15.2 mmHg) than moderate (18.4 mmHg) or low (22.8 mmHg) adherence patients. The pattern was consistent across

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baseline IOP subgroups and across glaucoma subtypes, indicating that adherence rather than initial disease characteristics drove the IOP differential. Target IOP achievement (at least 20% reduction from baseline or absolute IOP ≤18 mmHg) was achieved by 88% of high adherence patients compared with 56% moderate and 22% low adherence patients (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

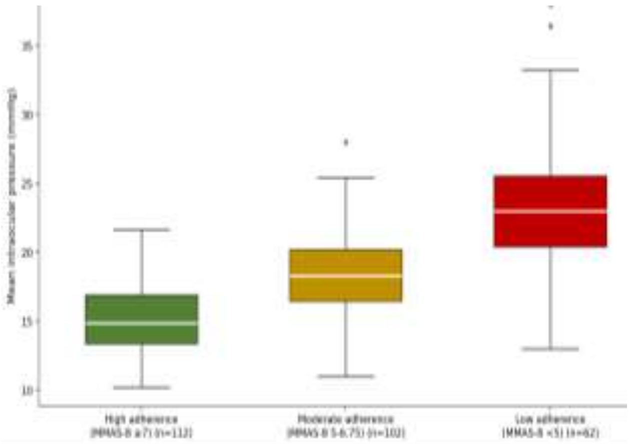

Fig.2: Intraocular pressure by medication adherence stratum

3.3 Visual Field Progression

Visual field progression-free survival over 36 months differed substantially by adherence stratum (Figure 3). High-adherence patients showed approximately 75% progression-free survival at 36 months, moderate-adherence 52%, and low-adherence 28%. The hazard ratio for VF progression in low-versus-high adherence patients was approximately 4.2, supporting adherence as a dominant outcome modifier. Annual rate of mean deviation decline averaged -0.4 dB/year in high adherence patients, -0.8 dB/year in moderate, and -1.6 dB/year in low adherence patients.

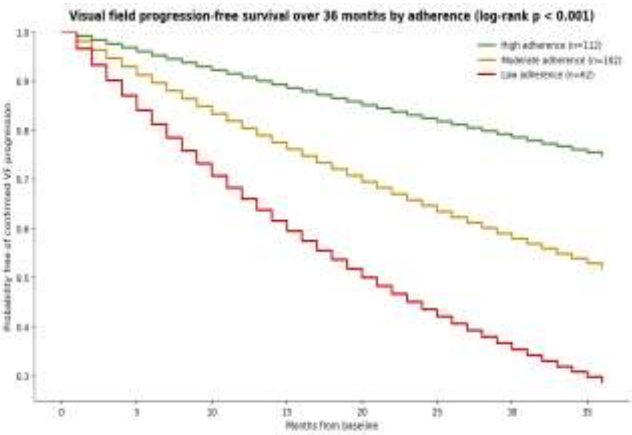

Fig.3: Visual field progression-free survival by adherence stratum

Table 2. Outcomes at 36 months by adherence stratum

Outcome	High (n=112)	Moderate (n=102)	Low (n=62)
Mean IOP across visits, mmHg	15.2	18.4	22.8
Target IOP achieved, n (%)	98 (87.5)	58 (56.9)	14 (22.6)
Confirmed VF progression at 36 mo, n (%)	28 (25.0)	48 (47.1)	45 (72.6)
Mean deviation change, dB	-1.4	-2.6	-4.8
RNFL thinning ≥4 μm at 36 mo, n (%)	32 (28.6)	52 (51.0)	48 (77.4)
Required additional topical agent, n (%)	22 (19.6)	42 (41.2)	42 (67.7)
Required SLT during follow-up, n (%)	12 (10.7)	22 (21.6)	18 (29.0)
Required incisional surgery, n (%)	6 (5.4)	14 (13.7)	18 (29.0)
BCVA loss ≥3 lines at 36 mo, n (%)	2 (1.8)	8 (7.8)	18 (29.0)
Legal blindness in study eye, n (%)	2 (1.8)	4 (3.9)	12 (19.4)
NEI-VFQ-25 score at 36 mo, mean	82	68	48
Switched from PRN to fixed combination, n (%)	42 (37.5)	32 (31.4)	12 (19.4)
Discontinued therapy during follow-up, n	2	8	22

3.4 Predictors of Poor Adherence

Multivariable logistic regression identified ten independent predictors of poor adherence. Out-of-pocket cost above ₹400/month carried strong association (OR 3.42), reflecting the substantial cost burden of chronic glaucoma medication particularly with prostaglandin analogues and fixed-combination agents. Regimen complexity (≥3 agents), adverse effects, cognitive impairment, living alone, asymptomatic disease perception, lower education, and bottle-handling difficulty each predicted poor adherence.

Caregiver-supported drop administration and engagement with structured patient education were strongly protective. The modifiable factors cost, regimen, education, caregiver support identify principal levers for adherence intervention (Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026; Vettriselvan, Ramya, et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025).

Table 3. Adverse effects, treatment escalation and intervention

Domain	Value
Any topical adverse effect reported, n (%)	126 (45.7)
Ocular surface disease symptoms, n (%)	98 (35.5)
Allergic conjunctivitis attributed to drops, n (%)	42 (15.2)
Periocular pigmentation (prostaglandin), n (%)	58 (21.0)

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Lash hypertrichosis, n (%)	32 (11.6)
Systemic adverse effects (any), n (%)	38 (13.8)
β-blocker-related bradycardia or hypotension, n	18
Switched agent due to adverse effects, n	42
Required treatment escalation during 36 mo, n (%)	106 (38.4)
SLT performed, n	52
Trabeculectomy or MIGS performed, n	38
Tube-shunt surgery performed, n	8
Engaged with structured patient education, n (%)	158 (57.2)
Used pill organiser or drop schedule reminder, n (%)	102 (37.0)
Tele-glaucoma follow-up used, n (%)	82 (29.7)
Caregiver-administered drops where eligible, n (%)	68 (24.6)
Engaged in glaucoma support group, n (%)	32 (11.6)
Patient satisfaction (1-10), mean	7.6

Table 4. Cost, resource, and operational outcomes

Metric	Value
Mean topical medication cost per month, INR	620
Patients with cost <₹400/month, n (%)	118 (42.8)
Patients with cost ₹400-1000/month, n (%)	112 (40.6)
Patients with cost >₹1000/month, n (%)	46 (16.7)
Mean clinic visits per year	3.2
Out-of-pocket cost per year (medication + visits), INR	9,200
Insurance coverage for glaucoma medications, n (%)	78 (28.3)
Government scheme coverage, n (%)	38 (13.8)
Generic substitution used, n (%)	148 (53.6)
Patients who would benefit from SLT first-line, n	98
Patients who would benefit from cataract+MIGS, n	52
Tele-glaucoma diagnostic accuracy concordance with in-person, %	91
Mean training hours for caregivers, hours	2.8
Caregiver competence in drop administration verified, n	82
Annual cost-saving from generics, mean, INR	2,400
Cost per visual-field-progression-free year (high adh), INR	18,400

4. Discussion

4.1 Principal Findings

Across 276 glaucoma patients followed for 36 months, three observations dominate. First, adherence to topical glaucoma medication is the dominant modifier of long-term outcomes, with high-adherence patients achieving lower IOP, slower visual field progression, and substantially less vision loss than low-adherence patients. Second, the determinants of adherence are largely modifiable cost, regimen complexity, education, caregiver support providing clear operational levers. Third, the magnitude of effect (4-fold higher rate of VF progression in low vs high adherence patients) approaches the magnitude of biological severity factors, supporting adherence intervention as a core component of glaucoma care (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.2 Surgical and Procedural Alternatives

For patients with substantial adherence challenges or those failing medical therapy despite adequate adherence, surgical and procedural interventions offer alternative pathways. Selective laser trabeculoplasty (SLT) as first-line therapy has shown non-inferiority to medication in pivotal trials and may be particularly valuable in patients with anticipated adherence challenges. Minimally invasive glaucoma surgery (MIGS) performed at the time of cataract surgery provides incremental IOP reduction with favourable safety profile (Kumar, Kumar,, & Tomer, 2026; Gautam, Samyal,, & Chaudhary, 2026). Trabeculectomy and tube-shunt procedures remain options for more advanced or refractory disease. Each surgical intervention requires structured perioperative planning including preoperative risk stratification, anaesthesia considerations particularly for elderly comorbid patients, infection prevention, wound healing, and enhanced recovery (Lal, Vaibhav,, & Khursheed, 2026; Bhatnagar, Tyagi,, & John, 2026; Agarwal, Kumar,, & S, 2026; Singhal, Kumar,, & Kataria, 2026; Mishra, Choudhary,, & Kumar, 2026; Gautam, Samyal,, & Chaudhary, 2026). Post-operative critical care follows structured protocols (Kumar, Kumar,, & Dhabhai, 2026; Ahluwalia, Gupta,, & Chaudhary, 2026). Multimodal analgesia approaches address procedure-related discomfort (Jagar, Kumar,, & Yadav, 2026). For patients with concurrent musculoskeletal comorbidities affecting positioning, structured assessment is warranted (Singh, Chauhan,, & Kumar, 2026; Durgia, Kumar,, & Neha, 2026). Bone health considerations apply to elderly patients (Sahu, Sharma,, & Gupta, 2026; Gupta, Gautam,, & Maitiy, 2026; Rani, & Tyagi, 2026). Quality improvement methodology applied to glaucoma surgical pathways supports outcome enhancement (Bhatnagar, Kumar,, & Shivam, 2026). Sports-injury rehabilitation principles inform return-to-activity guidance (Sehgal, Jayapriya,, & Kumar, 2026).

4.3 Vision Rehabilitation and Multimodal Care

For patients with established visual field loss affecting function, structured vision rehabilitation supports adaptation. Multidisciplinary rehabilitation including low-vision specialists, occupational therapy, and orientation-

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mobility training produces measurable functional benefits (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026). Adaptive devices including reading aids, audio interfaces, and home modifications support independence (Natarajan et al., 2026). Advanced prosthetic and motion-control technologies inform broader rehabilitation philosophy (Pavithra et al., 2026; Suresh et al., 2026).

Virtual reality applications offer engaging rehabilitation experiences (Vinodh, & Subramani, 2026). Psychosocial impact of progressive vision loss warrants structured support (Sharma, Sharma,, & Tyagi, 2026; Aumose, & Raj, 2026). Self-leadership and emotional intelligence approaches support adaptation (Mustafa et al., 2026; Zahoor et al., 2025). For elderly patients facing vision loss, community programmes and social support structures are essential (Ashifa, 2022; Rasi, & Ashifa, 2019; Natarajan et al., 2026). Multimorbidity-aware management addresses concurrent conditions (Kumar, Sharma,, & Gupta, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.4 Patient Education and Behavioural Intervention

Structured patient education emerged as one of the strongest protective factors against poor adherence. Effective education programmes address disease understanding (the asymptomatic nature of early disease, the progressive nature of vision loss, the irreversibility of damage), drop administration technique (with caregiver involvement where appropriate), management of adverse effects, and behavioural strategies for medication routines (Vettriselvan, Ramya, et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025; Yatish, Khatoon,, & Kumar, 2026). Mindful technology use considerations are relevant for using digital reminders without over-reliance (Vettriselvan, Velmurugan, et al., 2025). Strategic healthcare partnerships and SME engagement extend education reach (Vettriselvan, 2025; Vijayalakshmi et al., 2025; Jenifer et al., 2025).

4.5 Digital Health and AI Integration

Digital health tools offer substantial promise for glaucoma care. Patient-facing apps for medication reminders, symptom tracking, and educational content support engagement (Deepa et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025). Wearable monitoring of cardiovascular parameters and blood pressure (relevant for glaucoma progression particularly normal-tension subtype) provides valuable data (Deepa et al., 2026). Tele-glaucoma consultation reduces travel burden and supports follow-up of stable patients (Vijayalakshmi et al., 2025; Vinodh, Subramani,, & Vettriselvan, 2026). AI-supported decision tools assist with optic disc evaluation, visual field interpretation, and progression detection (Devi et al., 2025; Shanthi et al., 2025; Jha, Kumar,, & Neha, 2026). Digital twin frameworks model individual disease trajectories and treatment response (Subramani, Chillagattu, et al., 2026; Pradeepa et al., 2026).

Cyber-physical infrastructure supports cold-chain logistics for ophthalmic medications (Catherine, Nasrin Sulthana, et al., 2026). Educational infrastructure for training ophthalmologists, optometrists, and pharmacy personnel in glaucoma management is essential (Vinodh, Subramani,, & Vettriselvan, 2026; Bhatnagar, Tyagi,, & John, 2026). AI ethics and governance frameworks address algorithmic fairness particularly for elderly patients with limited digital literacy (Selvi et al., 2026). Biomarker-based progression assessment informs individualised management (Kumar, Gautam,, & Maitiy, 2026).

4.6 Limitations

Limitations include the single-centre tertiary setting which over-represents complex cases; the reliance on self-reported adherence measures with potential response bias; the 36-month follow-up which captures most early progression but does not address very-long-term trajectories; the inability to fully control for biological factors that may correlate with both adherence and progression; and the limited sample for some glaucoma subtypes. Selection bias toward patients engaging with tertiary care may under-represent the broader glaucoma population including those who never engage with specialist services.

5. Conclusion

Glaucoma medication adherence in this real-world tertiary cohort was the dominant modifier of long-term outcomes, with high-adherence patients showing 75% progression-free survival at 36 months compared with 28% in low-adherence patients. Strongest predictors of poor adherence included cost, regimen complexity, adverse effects, cognitive impairment, living alone, asymptomatic disease, and bottle-handling difficulty. Caregiver support and structured education were strongly protective. The findings support comprehensive adherence intervention programmes addressing cost (generic substitution, government scheme inclusion), regimen complexity (fixed combinations, SLT first-line consideration), education (structured programmes with behavioural change components), and caregiver engagement to preserve vision in glaucoma.

References

[1] Agarwal, A., Kumar, D., & S, P. M. (2026). Optimizing clinical effectiveness of enhanced recovery after surgery (ERAS):

DOI: 10.30726/esij/v13.i3.2026.1330047

Multidisciplinary pathways, patient-centered outcomes, and data-driven performance analytics. International Innovations & Scholarly Trends Journal, 2(2).

[2] Agarwal, P., Khatoon, N., & Kumar, A. (2026). Infection control and implant survival in orthopaedic surgery: Evidence-based strategies, antimicrobial innovation, and digital surveillance. International Journal of Scientific Research in Engineering and Management, 10(03).

[3] Ahluwalia, M. G. C. S., Gupta, S. K., & Chaudhary, A. (2026). Precision-oriented hemodynamic monitoring in critical care practice: Evidence-based strategies, clinical integration, and outcome optimization. International Journal of Scientific Research and Technology.

[4] Ashifa, K. M. (2022). A situation analysis of the social well-being of elderly during the COVID-19 pandemic. International Journal of Health Sciences, 6(3), 10156–10163.

[5] Aumose, L., & Raj, M. A. (2026). Applications of intelligent motion control systems in promoting mental health and human-centered support for higher secondary students. In Intelligent motion control for human-centered systems (pp. 127–152). IGI Global.

[6] Bhatia, R., Shivakumar, R. M., & Kumar, N. (2026). Determinants of functional recovery and health-related quality of life following total hip and knee arthroplasty. International Journal of Recent Development in Engineering and Technology, 15(3).

[7] Bhatnagar, M., Kumar, N., & Shivam. (2026). Quality improvement frameworks in modern surgical practice: Evidence-based models, implementation science, and outcome-oriented performance evaluation. International Journal of Scientific Research and Engineering Development, 9(2).

[8] Bhatnagar, V., Tyagi, N., & John, L. (2026). Simulation-based competency development in anesthesia training: Educational theory, assessment validity, and clinical impact. International Journal of Versatile Research and Analysis, 4(2).

[9] Catherine, S., Gupta, N., Gopi, E., & Swadhi, R. (2025). Enhancing patient engagement and outcomes through digital transformation: Machine learning in medical marketing. In Impact of digital transformation on business growth and performance (pp. 285–312). IGI Global.

[10] Catherine, S., Nasrin Sulthana, M., Manimaran, M., Praba Devi, P., & Akila, R. (2026). Cyber-physical systems and cloud robotics for global supply chain resilience. In Methodologies and applications of intelligent motion control systems (pp. 133–158). IGI Global.

[11] Deepa, R., Swadhi, R., Udayavani, V., Lakshmi, R., & Rafiq, S. (2026). Motion-controlled wearables for physiological monitoring and predictive diagnostics. In R. Vettriselvan & N. Suresh (Eds.), Intelligent motion control for human-centered systems (pp. 1–28). IGI Global.

[12] Devi, M., Manokaran, D., Sehgal, R. K., Shariff, S. A., & Vettriselvan, R. (2025). Precision medicine, personalized treatment, and network-driven innovations: Transforming healthcare with AI. In AI for large scale communication networks (pp. 303–322). IGI Global.

[13] Durgia, B., Kumar, P., & Neha. (2026). Comparative clinical effectiveness and long-term functional outcomes of conservative versus surgical management in degenerative and compressive spinal disorders. International Journal of Scientific Research in Engineering and Management, 10(03).

[14] Gautam, M., Samyal, M., & Chaudhary, S. (2026). Preoperative risk stratification and surgical outcome prediction: Integrating clinical scoring systems, data-driven models, and patient-centered optimization. International Innovations & Scholarly Trends Journal, 2(3).

[15] Gupta, O. P., Gautam, S., & Maitiy, S. (2026). Management strategies for degenerative musculoskeletal disorders: An integrated clinical and technological framework. International Journal of Recent Development in Engineering and Technology, 15(3).

[16] Jagar, K. D., Kumar, A., & Yadav, A. (2026). Multimodal analgesia in acute and chronic pain management: Mechanistic rationale, clinical applications, and outcome-focused strategies. Journal of Advanced Academic Research and Findings, 4(2).

[17] Jenifer, R. D., Vettriselvan, R., Saxena, D., Velmurugan, P. R., & Balakrishnan, A. (2025). Green marketing in healthcare advertising: A global perspective. In AI impacts on branded entertainment and advertising (pp. 303–326). IGI Global.

[18] Jha, S. C., Kumar, P., & Neha. (2026). Artificial intelligence-assisted decision support in internal medicine: Enhancing clinical judgment, precision care, and health system performance. International Journal of Scientific Development and Research, 11(2).

[19] Kumar, A., Kumar, N., & Dhabhai, M. (2026). Optimizing outcomes through evidence-based protocols in postoperative intensive care: Clinical standards, implementation strategies, and quality improvement. International Journal of Scientific Research and Technology.

[20] Kumar, P., Gautam, S., & Maitiy, S. (2026). Diagnostic utility of biomarkers in early disease stratification: Clinical applications, predictive value, and emerging innovations. Journal of Emerging Technologies and Innovative Research, 13(2).

[21] Kumar, R., Sharma, K., & Gupta, S. K. (2026). Multimorbidity patterns and therapeutic complexity in adult medical practice: Implications for polypharmacy and patient-centred care. International Journal of Creative Research Thoughts, 14(2).

[22] Kumar, S., Kumar, V., & Tomer, H. (2026). Evolution of minimally invasive surgical techniques and clinical outcomes: Technological progress, specialty-specific adoption, and outcome-oriented evidence. Asian Journal of Multidimensional Research.

[23] Lal, S. K., Vaibhav, & Khursheed, M. (2026). Anesthetic management in geriatric and comorbid patients: Clinical challenges, risk stratification, and outcome-oriented strategies. International Innovations & Scholarly Trends Journal, 2(2).

[24] Lodha, V., Sharma, K., & Saraswat, P. (2026). Role of structured multidisciplinary rehabilitation in optimizing functional recovery and long-term outcomes in musculoskeletal disorders. International Journal of Scientific Research in Engineering and Management, 10(03).

[25] Mishra, A., Choudhary, A., & Kumar, S. (2026). Infection prevention strategies in operative care: Evidence-based interventions, systems integration, and outcome-oriented practice. Asian Journal of Multidimensional Research.

[26] Mustafa, N., Zahoor, H., Gamil, R. E., Ashifa, K. M., & Safaei, M. (2026). Empowering future caregivers: The role of self-leadership in reducing stress among nursing students. International Journal of Innovation and Learning, 39(1), 74–103.

[27] Natarajan, P., Saravanan, A., Krishnakumar, B., Chandralekha, V., & Suresh Kumar, A. (2026). Motion control strategies in assistive devices for elderly and differently-abled patients. In Intelligent motion control for human-centered systems (pp. 103–126). IGI Global.

[28] Pavithra, M. R., Chitra, V., Subhashini, V., Hemalatha, D., & Kiran, S. R. (2026). Intelligent prosthetics motion learning and neuro-muscular feedback integration. In Intelligent motion control for human-centered systems (pp. 77–102). IGI Global.

[29] Pradeepa, S. V., Gokilavani, R., Deepan, A., Sridevi, J., & Selvi, K. (2026). Predictive maintenance and asset management using motion analytics. In Methodologies and applications of intelligent motion control systems (pp. 75–104). IGI Global.

[30] Rani, A., & Tyagi, N. (2026). Osteoporosis risk assessment and preventive interventions: Evidence-based screening, predictive modelling, and community-level strategies. International Journal of Recent Development in Engineering and Technology, 15(3).

[31] Rasi, R. A., & Ashifa, K. M. (2019). Role of community-based programmes for active ageing: Elders self-help group in Kerala. Indian Journal of Public Health Research & Development, 10(12).

[32] Sahu, R. L., Sharma, K., & Gupta, S. K. (2026). Biological and mechanical determinants of fracture healing: An integrated mechano-biological, systemic, and translational framework. International Journal of Recent Development in Engineering and Technology, 15(3).

[33] Sehgal, A., Jayapriya, R., & Kumar, A. (2026). Evidence-based rehabilitation in sports-related injuries: Clinical effectiveness,

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ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

multidisciplinary integration, and technological advancements. International Journal of Recent Development in Engineering and Technology, 15(3).

[34] Selvi, K., Anbarasan, P., Madhumita, G., Janaki, L., & Devi, K. K. (2026). Governance, security, and ethical considerations in AI-driven motion control systems. In Methodologies and applications of intelligent motion control systems (pp. 217–242). IGI Global.

[35] Shanthi, H. J., Gokulakrishnan, A., Sharma, S., Deepika, R., & Swadhi, R. (2025). Leveraging artificial intelligence for enhancing urban health: Applications, challenges, and innovations. In Nexus of AI, climatology, and urbanism for smart cities (pp. 275–306). IGI Global.

[36] Sharma, S., Sharma, K., & Tyagi, N. (2026). Geriatric psychiatry and cognitive decline: Clinical evaluation, neuropsychological determinants and evidence-based management. International Journal of Management Research and Social Science, 13(2).

[37] Singh, S., Chauhan, Y., & Kumar, D. (2026). Biomechanical innovations in orthopaedic implant design: Materials science, AI-assisted customization, and smart integration. International Journal of Scientific Research in Engineering and Management, 10(03).

[38] Singhal, A., Kumar, A., & Kataria, N. (2026). Advances in wound healing and tissue regeneration: Biomaterials, regenerative strategies, and translational challenges. International Innovations & Scholarly Trends Journal, 2(2).

[39] Subramani, M., Chillagattu, V., Gayathri, K., Rastogi, V., & Ranganathan, S. (2026). Digital twin integration for predictive and real-time motion control in infrastructure engineering. In Methodologies and applications of intelligent motion control systems (pp. 189–216). IGI Global.

[40] Suresh, N. V., Hemalatha, S., Lakshmi, S. J., Mounica, C., & Kalaivani, M. (2026). AI-enabled motion control in surgical robotics: Precision, dexterity, and real-time adaptation. In Intelligent motion control for human-centered systems (pp. 29–50). IGI Global.

[41] Swadhi, R., Gayathri, K., Suresh, N. V., Catherine, S., & Velmurugan, P. R. (2025). Leveraging machine learning for enhanced patient engagement and outcomes: Revolutionizing healthcare marketing. In Impact of digital transformation on business growth and performance (pp. 313–340). IGI Global.

[42] Venice, A., Swadhi, R., Gayathri, K., Chandra, P., & Sajana, K. P. (2026). Rehabilitation robotics and adaptive motion planning for patient-centric care. In R. Vettriselvan & N. Suresh (Eds.), Intelligent motion control for human-centered systems (pp. 51–76).

[43] Vettriselvan, R., Ramya, R., Selvalakshmi, V., Jyothi, P., & Velmurugan, P. R. (2026). Empowering patients through knowledge: Educational strategies in rehabilitation. In Holistic approaches to health recovery (pp. 263–290). IGI Global.

[44] Vettriselvan, R. (2025). Harnessing innovation and digital marketing in the era of industry 5.0: Resilient healthcare SMEs. In The future of small business in industry 5.0 (pp. 163–186). IGI Global.

[45] Vettriselvan, R., Velmurugan, P. R., Varshney, K. R., EP, J., & Deepika, R. (2025). Health impacts of smartphone and internet addictions across age groups: Physical and mental health across generations. In Impacts of digital technologies across generations (pp. 187–210). IGI Global.

[46] Vijayalakshmi, M., Subramani, A. K., Vettriselvan, R., Velmurugan, P. R., & Hasine, J. (2025). Strategic collaborations in medical innovation and AI-driven globalization: Advancing healthcare startups. In Navigating strategic partnerships for sustainable startup growth (pp. 85–110). IGI Global.

[47] Vinodh, N., & Subramani, A. K. (2026). Augmented and virtual reality for training and operations in motion-control environments. In Intelligent motion control for human-centered systems (pp. 153–178). IGI Global.

[48] Vinodh, N., Subramani, A. K., & Vettriselvan, R. (2026). Transforming the future of management and medical education: AI-driven innovations in curriculum design. In AI education strategies for future-proofing curriculum design (pp. 459–476). IGI Global.

[49] Yatish, Khatoon, N., & Kumar, A. (2026). Advancing preventive strategies for chronic disease management: Clinical, behavioral, and population-level perspectives. International Journal of Novel Trends and Innovation, 4(2).

[50] Zahoor, H., Mustafa, N., Ashifa, K. M., Safaei, M., & El Gamil, R. (2025). Unlocking resilience: Emotional intelligence and self-leadership shape stress perception among health students. International Journal of Innovation and Learning, 38(4), 395–419.

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