

Digital Transformation in Orthopedics: Can India Leapfrog with Artificial Intelligence, Augmented Reality, and Robotics?

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Learning Point of the Article:

Strategic integration of AI, AR, and robotics, supported by indigenous innovation and context-specific implementation, can enable India to leapfrog toward precise, personalized, and accessible orthopedic care.

Abstract

Digital technologies are transforming orthopedic practice by improving diagnostic accuracy, surgical precision, and personalized patient care. Artificial intelligence, augmented reality, and robotics are increasingly integrated across the orthopedic continuum, enabling data-driven decision-making and reproducible surgical execution. India presents a unique opportunity to accelerate this transformation due to its high clinical volumes, expanding digital infrastructure, and growing ecosystem of indigenous innovation. However, challenges related to cost, infrastructure, workforce training, and governance remain significant. This editorial explores the opportunities, barriers, and strategic priorities for adopting digital technologies in orthopedics and discusses whether India can leapfrog conventional developmental pathways to establish an integrated, affordable, and patient-centered digital orthopedic ecosystem.

Keywords: Diagnostic accuracy, artificial intelligence, augmented reality, indigenous innovation, digital orthopedic ecosystem, digital infrastructure.

Introduction

Orthopedics is entering a phase of rapid digital transformation driven by artificial intelligence (AI), augmented reality (AR), and robotic-assisted (RA) technologies. These innovations are reshaping how surgeons diagnose disease, plan procedures, execute surgery, and monitor recovery. Beyond improving technical precision, digital technologies are shifting orthopedics toward a more data-informed, patient-specific model of care [1]. While technologically advanced healthcare systems have adopted these tools over decades, emerging economies such as India may have an opportunity to accelerate this transition by selectively adopting scalable digital solutions. India faces a high burden of musculoskeletal disease, rapidly increasing

arthroplasty demand, and significant disparities in access to specialist care. Yet, the country also possesses unique strengths, including high clinical volumes, rapidly expanding digital infrastructure, and a strong culture of frugal innovation [2,3]. This convergence of need and opportunity raises an important question: can India leapfrog conventional developmental pathways and transition directly toward integrated, digitally enabled orthopedic care?

AI: From Data to Clinical Decision-Making

AI represents the cognitive foundation of digital orthopedics. Machine learning and deep learning models are increasingly being applied to imaging interpretation, fracture detection,

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osteoarthritis grading, outcome prediction, and surgical planning. AI has demonstrated potential across the orthopedic continuum, from supporting diagnosis to identifying patient-specific risk factors and improving clinical decision-making [4]. Recent literature suggests that AI may improve efficiency, reduce diagnostic variability, and facilitate personalized treatment strategies, particularly when large datasets are available for algorithm training and validation [4,5]. Postoperatively, predictive analytics may facilitate individualized rehabilitation pathways and early identification of complications.

In arthroplasty, AI is increasingly being integrated with robotic platforms to improve implant positioning and support personalized alignment strategies. Furthermore, AI-driven analysis of large datasets may enable the development of patient-specific treatment algorithms, an area of particular relevance for the Indian population, where substantial anatomical and demographic diversity exists [6]. However, challenges persist, including data heterogeneity, algorithmic bias, and the need for robust clinical validation. Establishing robust data governance frameworks and developing region-specific datasets will therefore be essential.

AR: Enhancing Visualization, Navigation, and Education

AR and mixed reality technologies add a visualization layer to orthopedic workflows by projecting digital anatomical information onto the operative environment. By providing surgeons with real-time visualization of anatomy and implant positioning, AR can improve spatial orientation and reduce dependence on repeated fluoroscopy. Applications of AR are expanding rapidly in spine surgery, trauma, and arthroplasty [7]. Navigation platforms such as Knee + AR navigation system (Pixee Medical Company, Besancon, France) have demonstrated promising results in total knee arthroplasty

(TKA) by providing real-time guidance without the need for conventional navigation consoles and assist with intraoperative navigation, while Intellijoint (Intellijoint Surgical Inc., Ontario, Canada) assists total hip arthroplasty by enabling accurate intraoperative assessment of leg length, offset, and component positioning [8,9]. Beyond surgery, AR and mixed-reality technologies are transforming orthopedic education through immersive simulation-based training. The educational implications are particularly important in India. Variability in surgical exposure and training opportunities exists across institutions, especially between urban tertiary centers and peripheral hospitals. AR-based simulation may help bridge this gap by democratizing access to advanced surgical education and standardized training [7].

Although still early in routine clinical integration, AR may become particularly relevant in resource-sensitive settings where precision guidance could improve procedural reproducibility without requiring high-cost infrastructure.

Robotics: Precision, Personalization, and Reproducibility

RA surgery represents the executional arm of digital transformation, translating meticulous pre-operative planning into precise intraoperative action. Robotic platforms are now increasingly used in knee and hip arthroplasty to improve implant positioning, alignment accuracy, and reproducibility. Systems such as MAKO, ROSA, VELYS, CUVIS, and MISSO Joint Robot have expanded access to precision-assisted surgery in India [2]. Importantly, indigenous innovations such as the MISSO Surgical Robot (Meril Healthcare Pvt. Ltd., Vapi, India) reflect a growing commitment toward cost-effective and locally adaptable technological solutions [10]. These technologies enhance precision and consistency, potentially improving outcomes and implant longevity. AI integration further supports intraoperative decision-making and

Table 1: Role of artificial intelligence, augmented reality, and robotics in digital transformation of orthopedics

Technology	Core function	Key orthopedic applications	Clinical impact	Limitations
Artificial intelligence (AI)	Data analysis and predictive modeling	Fracture detection, osteoarthritis grading, risk stratification, pre-operative planning, limb alignment restoration and component positioning in arthroplasty	Supports diagnosis and decision-making, may improve accuracy, enables more personalized care	Dependent on data quality, risk of algorithmic bias, requires validation and integration
Augmented reality (AR)	Real-time visualization and navigation	Surgical guidance in spine and arthroplasty, anatomical mapping, training and simulation	Improves spatial orientation, reduces intraoperative errors, decreases radiation exposure	Limited availability, hardware and usability constraints, still early in routine clinical adoption
Robotics	Precision-assisted surgical execution	Total knee and hip arthroplasty, implant positioning, bone preparation	Improves accuracy and reproducibility, especially in alignment and implant placement	High cost, steep learning curve, limited accessibility in low-resource settings

adaptability, strengthening the role of robotics in precision-based orthopedic care. Nevertheless, barriers remain substantial, particularly related to acquisition costs, maintenance expenses, learning curves, and uncertainty regarding long-term cost-effectiveness in healthcare systems with constrained resources [11].

Robotics should also be viewed as an enabling platform through which AI-derived planning can be translated into precise surgical execution. In arthroplasty, AI can support pre-operative assessment of patient anatomy, deformity patterns, ligament balance, and outcome risk, while robotic systems can execute component positioning according to the selected alignment philosophy [12]. This integration is particularly relevant in TKA, where mechanical alignment, kinematic alignment, restricted kinematic alignment, functional alignment, and phenotype-based strategies require reproducible control over femoral and tibial resections, joint-line orientation, and gap balance. By linking AI-based planning with robotic execution, surgeons may be able to individualize alignment targets while maintaining intraoperative precision and reducing variability between the planned and achieved component position [12, 13].

Integration of Technologies: The Digital Orthopedic Ecosystem

The true transformative potential of digital orthopedics lies not in isolated technologies but in their convergence [14]. AI contributes predictive analytics and decision support, AR enhances visualization and navigation, and robotics enables reproducible surgical execution. Together, these technologies may create a connected workflow extending from diagnosis and planning to surgery, rehabilitation, and longitudinal monitoring. Emerging concepts such as digital twins, smart implants, and wearable sensor integration further support the transition toward continuous, data-driven patient care [1,15]. In a country like India, where access to follow-up care may be limited in rural and remote regions, digital health technologies offer a scalable solution for improving post-operative outcomes and patient engagement. The complementary roles of these technologies in orthopedic practice are summarized in Table 1. India's high surgical volumes, expanding digital infrastructure, and increasing collaboration between clinicians, academia, and industry provide a fertile environment for developing such integrated ecosystems.

India's Leapfrogging Potential: Opportunities and Constraints

India may be uniquely positioned to benefit from this integrated

model. Large patient volumes generate substantial clinical datasets that can support AI development. Increasing penetration of electronic health records and telemedicine platforms is improving digital infrastructure. Furthermore, Indian healthcare innovation frequently emphasizes affordability and scalability, encouraging the development of locally adaptable technologies rather than dependence on imported systems [3,16]. Indigenous robotic platforms and lower-cost digital solutions may therefore allow selective adoption of advanced orthopedic technologies without replicating the prolonged implementation pathways seen in high-income countries.

Despite this opportunity, significant barriers remain. Robotic systems and advanced imaging technologies continue to require high capital investment, restricting access largely to urban tertiary centers. Fragmented data ecosystems, inconsistent documentation standards, and limited interoperability remain major obstacles to AI deployment. Digital literacy and training gaps among healthcare professionals further complicate adoption. Ethical concerns regarding algorithmic bias, data privacy, and regulatory oversight also require structured governance frameworks [7,16]. Without addressing these limitations, digital orthopedics risks widening disparities between technologically advanced institutions and resource-constrained healthcare settings.

Strategic Priorities

For India to successfully leapfrog into the era of digital orthopedics, technological adoption must be guided by practicality, scalability, and clinical value rather than novelty alone. Priority should be given to AI-driven solutions, which offer the greatest potential for widespread implementation due to their scalability, relatively low cost, and applicability across the continuum of care. Simultaneously, selective deployment of robotic systems in high-volume procedures, supported by AR-assisted surgical guidance, may provide a balanced pathway between innovation and affordability [17,18].

Sustained investment in indigenous technology development will be crucial to reducing reliance on costly imported platforms and to creating solutions tailored to local clinical needs. Equally important are the strengthening of digital infrastructure, establishment of robust data governance frameworks, and development of training programs that equip surgeons to effectively utilize emerging technologies [19]. By adopting context-specific strategies that prioritize accessibility, affordability, and patient outcomes, India has the opportunity to bypass intermediate stages of technological evolution and build a digitally integrated orthopedic ecosystem.

Conclusion

Digital transformation in orthopedics is not about replacing conventional practice but about enhancing precision, expanding access to expertise, and delivering more personalized patient care. India possesses many of the prerequisites for technological leapfrogging, including high clinical volumes, a rapidly evolving digital ecosystem, engineering expertise, and a growing culture of indigenous innovation. Ultimately, the question is not whether India can leapfrog, but how effectively it can integrate AI, AR, and robotics into routine practice while ensuring affordability, accessibility, and equitable care. If achieved, digital transformation will not replace the orthopedic surgeon but will

augment clinical expertise, positioning India to emerge as a global leader in next-generation orthopedic care.

Clinical Message

AI, AR, and robotics should be viewed as complementary technologies that augment surgical expertise rather than as a surrogate to surgeons. Their thoughtful integration into routine orthopedic practice can enhance diagnostic accuracy, improve surgical precision, support personalized decision-making, and ultimately lead to better patient outcomes. For resource-constrained healthcare systems such as India, context-specific and affordable adoption of these technologies is essential for achieving equitable and sustainable orthopedic care.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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References

1. Youssef Y, De Wet D, Back DA, Scherer J. Digitalization in orthopaedics: A narrative review. *Front Surg* 2024;10:1325423.
2. Mulpur P, Jayakumar T, Kikkuri RR, Annareddy A, Hippalgaonkar K, Reddy AV. Trends in adoption of robotics in arthroplasty: An analysis of the Indian landscape. *J Robot Surg* 2025;19:62.
3. Yadav AK, Joshi P, Tiwari A, Watarkar S, Paul I, Bhandari G. From data to precision: The transformative role of AI and machine learning in modern orthopaedic practice. *J Clin Orthop Trauma* 2025;69:103101.
4. Geda MW, Tang YM, Lee CK. Applications of artificial intelligence in orthopaedic surgery: A systematic review and meta-analysis. *Eng Applic Artif Intellig* 2024;133:108326.
5. Regmi A, Jain V, Baral S, Niraula BB. Global research landscape of artificial intelligence in orthopaedics: A decade of trends from a scopus-based bibliometric analysis (2015-2025). *J Clin Orthop Trauma* 2026;73:103342.
6. Elkohail A, Soffar A, Khalifa AM, Omar I, Mosaad M, Abdulaziz M, et al. AI-enhanced surgical decision-making in orthopedics: From preoperative planning to intraoperative guidance and real-time adaptation. *Cureus* 2025;17:e92762.
7. Goh GS, Lohre R, Parvizi J, Goel DP. Virtual and augmented reality for surgical training and simulation in knee arthroplasty. *Arch Orthop Trauma Surg* 2021;141:2303-12.
8. Sakellariou E, Alevrogiannis P, Alevrogianni F, Galanis A, Vavourakis M, Karampinas P, et al. Single-center experience with Knee+TM augmented reality navigation system in primary total knee arthroplasty. *World J Orthop* 2024;15:247-56.
9. Paprosky WG, Muir JM. Intellijoint HIP®: A 3D mini-optical navigation tool for improving intraoperative accuracy during total hip arthroplasty. *Med Devices (Auckl)* 2016;9:401-8.
10. Aneja K, Rudraraju RT, Shyam A. Personalized alignment strategies and the need for customization in total knee arthroplasty: The role of MISSO joint robotic system. *J Orthop Case Rep* 2025;15:1-5.
11. Andriollo L, Picchi A, Iademaro G, Fidanza A, Perticarini L, Rossi SM, et al. The role of artificial intelligence and emerging technologies in advancing total hip arthroplasty. *J Pers Med* 2025;15:21.
12. Kim KB, Kim GB, Kim JH, Lee SM. Artificial intelligence in total knee arthroplasty: Clinical applications and implications. *Knee Surg Relat Res* 2025;37:44.
13. Vaishya R, Sibal A, Kar S, Reddy S. Integrating artificial intelligence into orthopedics: Opportunities, challenges, and future directions. *J Hand Microsurg* 2025;17:100257.
14. Tafat W, Budka M, McDonald D, Wainwright TW. Artificial intelligence in orthopaedic surgery: A comprehensive review of current innovations and future directions. *Comput Struct Biotechnol Rep* 2024;1:100006.
15. Dean MC, Oeding JF, Diniz P, Seil R, Samuelsson K,

ESSKA Artificial Intelligence Working Group. Leveraging digital twins for improved orthopaedic evaluation and treatment. *J Exp Orthop* 2024;11:e70084.

16. Han F, Huang X, Wang X, Chen YF, Lu C, Li S, et al. Artificial intelligence in orthopedic surgery: Current applications, challenges, and future directions. *MedComm (2020)* 2025;6:e70260.

17. Desai KB, Mulpur P, Jayakumar T, Suhas Masilamani AB, Ranjan A, Gurava Reddy AV. Adoption of robotics in arthroplasty- a survey of perceptions, utilization and challenges with technology amongst Indian surgeons. *J*

Orthop 2023;46:51-7.

18. Mickley JP, Kaji ES, Khosravi B, Mulford KL, Taunton MJ, Wyles CC. Overview of artificial intelligence research within hip and knee arthroplasty. *Arthroplasty Today* 2024;27:101396.

19. Aneja K, Machaiah PK, Shyam A. Indigenous innovation in orthopedic robotics: Making joint replacement affordable in India. *J Orthop Case Rep* 2026;16:431-6.

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