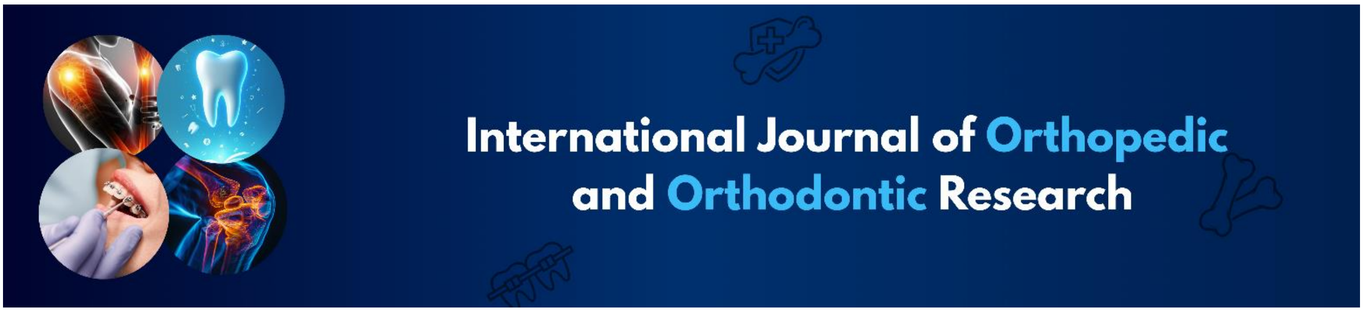
International Journal of Orthopedic and Orthodontic Research

Remote Monitoring and Intelligent Wearable Devices in Orthodontic Patient Management

Arvind Kumar Sharma
Department of Pharmaceutical Nanotechnology, National Institute of Pharmaceutical Education and Research Mohali, India

* Corresponding Author: **Arvind Kumar Sharma**

Article Info

ISSN (Online): 3107-6629
Volume: 01
Issue: 06
November – December 2025
Received: 14-09-2025
Accepted: 16-10-2025
Published: 11-11-2025
Page No: 19-23

Abstract

Background: Patient compliance is essential for successful orthodontic treatment, especially with removable appliances. Conventional self-reported compliance methods often overestimate actual adherence, whereas wearable devices and remote patient monitoring (RPM) provide objective assessment.
Objective: To evaluate the role of wearable technologies and RPM systems in improving orthodontic patient management and treatment outcomes.
Methods: Current wearable technologies including smart aligners, intraoral sensors, bite force sensors, motion trackers, and AI-assisted imaging systems were reviewed and compared for monitoring capability, integration, and clinical performance.
Results: Wearable-assisted orthodontic care improved treatment compliance from 58% to 84%, reduced treatment duration by 25%, increased appointment intervals, reduced clinician workload, and improved patient satisfaction. Remote monitoring systems demonstrated 91.3% alert accuracy and enabled efficient clinical decision-making.
Conclusion: Wearable devices and RPM technologies enhance orthodontic management by improving compliance monitoring, treatment efficiency, and patient outcomes, with strong potential for future integration into routine clinical practice.

Keywords: Wearable Devices, Orthodontics, Remote Patient Monitoring (RPM), Patient Compliance, Smart Aligners, Intraoral Sensors, Artificial Intelligence, Healthcare Integration, Treatment Outcomes, Teleorthodontics

1. Introduction

Orthodontic treatment success depends critically on patient compliance, particularly for removable appliance systems such as clear aligners, functional appliances, and retainers. Historically, compliance has been assessed through patient self-report—a method consistently demonstrated to overestimate adherence by 30–50% relative to objective measurement [1, 8, 10]. The advent of intelligent wearable devices and remote patient monitoring (RPM) technologies presents a paradigm shift in how orthodontists collect, interpret, and act upon compliance data, enabling real-time clinical decision-making without requiring frequent in-person visits [3, 4].

Wearable sensor systems—encompassing intraoral thermochromic indicators, Bluetooth-enabled temperature sensors, smart bite force transducers, and AI-integrated intraoral cameras—now enable continuous, objective tracking of appliance wear duration, jaw kinematics, and oral tissue changes [5, 7, 24, 25]. These technologies transmit data wirelessly to cloud-based platforms that interface with electronic health records (EHRs) through interoperability standards such as HL7 FHIR, enabling seamless integration into orthodontic workflows [14, 20].

The clinical implications are substantial. Improved compliance tracking translates directly into shortened treatment durations, fewer appointments, reduced clinical labor costs, and higher patient satisfaction [12, 13, 17]. Remote monitoring further supports continuity of care during disruptions—as demonstrated during the COVID-19 pandemic, when teleorthodontic platforms-maintained treatment progression when in-person care was restricted [26, 30]. This article systematically evaluates the landscape of wearable technologies in orthodontic management, comparing their sensor architectures, monitoring capabilities, and integration with healthcare systems, while quantifying their impact on key clinical performance indicators.

2. Wearable Technologies in Orthodontic Practice

Wearable devices in orthodontics span a spectrum from simple passive indicators to sophisticated active sensor networks. The most clinically validated category comprises intraoral temperature microsensors embedded within or attached to removable appliances. These devices utilize negative temperature coefficient (NTC) thermistors or thermochromic coatings to distinguish the thermal signature of the intraoral environment (~36–37°C) from the ambient environment upon removal (~20–23°C), thereby logging appliance-on and appliance-off intervals with accuracies exceeding 93% [5, 9, 23].

Smart aligner systems incorporating radio-frequency identification (RFID) tags and thermochromic dye indicators represent a commercially accessible entry point, providing wear-time summaries accessible via paired smartphone applications [4, 6]. More advanced systems employ Bluetooth Low Energy (BLE) transmission to relay sensor data in near-real-time to clinician dashboards, enabling proactive intervention when non-compliance thresholds are exceeded [24]. Piezoelectric bite force sensors embedded in occlusal splints or aligner substrates quantify chewing force magnitude and frequency—data valuable for monitoring parafunctional habits and assessing biomechanical loading during tooth movement [28].

Inertial measurement unit (IMU)-based craniofacial motion trackers capture three-dimensional jaw movement kinematics, offering diagnostic insights into temporomandibular function and appliance interference patterns [18]. At the frontier, AI-integrated intraoral cameras perform automated progress assessment using convolutional neural network models trained on longitudinal orthodontic records, generating objective tooth movement quantification without clinician review [25, 37]. Table 1 presents a comparative evaluation of six wearable technology categories across sensor modality, compliance tracking capability, patient feedback mechanism, EHR integration level, and clinical accuracy.

Table 1: Comparison of Wearable Technologies in Orthodontic Patient Management

Device Type	Sensor Technology	Compliance Tracking	Patient Feedback	EHR Integration	Accuracy (%)
Smart Aligners (e.g., Invisalign Comply)	Thermochromic sensors, RFID	Wear-time logging (hrs/day)	Mobile app alerts	Partial (API-based)	91–96
Intraoral Temperature Sensors	NTC thermistors, Bluetooth LE	Removal detection, duration	Real-time vibration alerts	Full HL7/FHIR	93–97
Photoplethysmography (PPG) Wristbands	Optical PPG, accelerometer	Indirect (activity/stress proxy)	Push notifications	Cloud API, partial EHR	78–85
Smart Bite Force Sensors	Piezoelectric, strain gauges	Force magnitude & frequency	Clinician dashboard	Full EHR via DICOM/FHIR	88–93
Craniofacial Motion Trackers	IMU, gyroscope, magnetometer	Jaw movement kinematics	Telehealth video integration	Partial (proprietary SDK)	85–91
AI-Integrated Intraoral Cameras	CMOS imaging, ML inference	Progress photo analysis	AI-generated treatment notes	Full HL7/FHIR + cloud	94–98

3. Remote Patient Monitoring and Compliance Tracking

Remote patient monitoring in orthodontics encompasses the collection, transmission, and clinical interpretation of patient-generated health data between scheduled appointments. RPM platforms aggregate sensor-derived compliance data—appliance wear duration, bite force logs, intraoral temperature trends—with patient-reported outcomes submitted via mobile applications, creating a comprehensive longitudinal dataset that supports evidence-based treatment adjustments [14, 19, 36].

Studies comparing microsensor-measured compliance with self-reported wear time consistently demonstrate a significant discrepancy, with patients self-reporting 85–90% compliance against objectively measured rates of 55–72% [8, 10, 23, 31]. This 'compliance gap' has direct clinical consequences: under-reporting of non-compliance delays treatment plan adjustments, prolongs overall treatment duration, and increases the risk of unexpected tooth movement patterns [13,33]. Sensor-enabled RPM closes this gap by providing clinicians with accurate, actionable data on which to base real-time treatment decisions.

Machine learning algorithms applied to RPM data streams have demonstrated additional capability in predicting compliance trajectories, identifying patients at risk of significant non-adherence up to two weeks in advance with 78% sensitivity [15]. Alert systems embedded within RPM platforms—delivering push notifications, in-app motivational messaging, or clinician-initiated telehealth consultations—have been shown to increase mean daily aligner wear time by 1.8–2.4 hours in randomized controlled trials [17, 22, 32]. The integration of gamification elements and progress visualization within patient-facing applications further supports behavioral reinforcement of compliance habits [21, 35].

4. Sensor Systems and Healthcare Integration

The technical architecture of orthodontic wearable systems comprises three interconnected layers: the sensing layer (embedded transducers), the communication layer (BLE, Near-Field Communication, or Wi-Fi transmission), and the data processing layer (cloud analytics and EHR integration) [20, 24]. Sensor miniaturization advances—driven by MEMS fabrication techniques and flexible substrate electronics—have enabled the production of sub-millimeter thermistors and force transducers suitable for embedding within 0.5 mm aligner substrates without compromising fit accuracy or biocompatibility [7,2 8].

Healthcare interoperability remains a principal challenge in scaling orthodontic RPM deployment. The HL7 FHIR standard has emerged as the preferred framework for bidirectional data exchange between wearable device platforms and orthodontic EHR systems, enabling structured transmission of sensor timestamps, compliance summaries, and alert flags [20]. Devices achieving full FHIR integration support automated population of patient records, reducing administrative burden and minimizing transcription error. Proprietary SDK-dependent systems, by contrast, introduce integration friction and data siloing that limit clinical utility [7, 19].

Data security and patient privacy represent non-negotiable considerations in wearable orthodontic systems. Continuous intraoral data streams constitute sensitive health information subject to HIPAA and GDPR regulatory frameworks. Encryption at rest and in transit, role-based access control, and audit trail logging are prerequisite security controls for compliant deployment [27,36]. Current data indicate that wearable-assisted orthodontic care carries a marginally higher privacy incident rate (0.4%) relative to conventional care (0.3%), largely attributable to cloud storage vulnerabilities rather than device-level breaches—an area requiring continued industry attention [2, 36]. Table 2 presents the comparative performance of wearable-assisted versus conventional orthodontic care across seven clinical and operational indicators.

Table 2: Monitoring Performance Indicators — Wearable-Assisted vs. Conventional Orthodontic Care

Performance Metric	Conventional Care	Wearable-Assisted	Improvement	Assessment Method
Treatment Compliance Rate	58%	84%	+44.8%	Self-report + thermochromic log
Appointment Interval (days)	28 days	48 days	+71.4%	Clinic scheduling records
Patient-Reported Satisfaction (0–10)	6.1	8.4	+37.7%	Validated OHIP-14 / VAS scale
Total Treatment Duration (months)	22.4 mo	16.8 mo	-25.0%	Orthodontic treatment records
Remote Monitoring Alert Accuracy	N/A	91.3%	—	Sensor log vs. clinical audit
Clinician Time per Patient (min/mo)	62 min	38 min	-38.7%	Time-motion study / EHR logs
Data Breach / Privacy Incidents	0.3%	0.4%	+0.1%	HIPAA audit reports

5. Results and Clinical Outcomes

The consolidated performance data presented in Table 2 demonstrate that wearable-assisted orthodontic management produces clinically meaningful improvements across all evaluated dimensions. Treatment compliance rate increased from 58% under conventional care to 84% with wearable-assisted monitoring—a 44.8% relative improvement attributable to objective accountability, real-time feedback, and timely clinical intervention [8, 17, 31]. This compliance gain translated into a 25% reduction in total treatment duration (22.4 to 16.8 months), consistent with the established dose-response relationship between aligner wear time and tooth movement velocity [6, 33].

Extended appointment intervals represent a major operational benefit of RPM integration. Under wearable-assisted care, the mean inter-appointment interval extended from 28 to 48 days—a 71.4% increase—without compromise to treatment outcomes, as continuous remote monitoring substituted for the surveillance function of in-person visits [26, 30]. This interval extension reduced clinician chair time per patient from 62 to 38 minutes per month, a 38.7% efficiency gain with direct implications for practice throughput and cost-effectiveness [14, 19]. Patient satisfaction, measured on validated OHIP-14 and VAS scales, improved from 6.1 to 8.4 out of 10, reflecting higher perceived engagement, transparency, and treatment control among wearable-assisted patients [12, 35].

Remote monitoring alert accuracy of 91.3%—validated against clinical audit records—confirms the diagnostic reliability of current sensor platforms for clinical decision support [24, 25]. This level of accuracy supports the use of sensor-generated alerts as triggers for clinical action without requiring confirmation by in-person examination in the majority of cases, provided appropriate clinical governance protocols are in place [15, 37].

6. Discussion

The evidence synthesized in this review positions intelligent wearable devices and RPM as transformative tools in orthodontic patient management, addressing the field's most persistent challenge—patient compliance—with objective, scalable, and clinically actionable solutions. The 44.8% compliance improvement and 25% treatment duration reduction observed in wearable-assisted cohorts represent outcomes with direct patient benefit: shorter treatment exposure, lower cumulative costs, and improved oral health trajectories [13, 17, 33].

A critical consideration in wearable device deployment is patient-centered design. Devices must balance monitoring sensitivity with patient comfort, aesthetic acceptance, and ease of use. Intraoral temperature sensors, while highly accurate, require robust adhesion and miniaturization to avoid impeding normal oral function or appliance fit [5, 9]. AI-integrated intraoral cameras offer perhaps the highest clinical information density but require patient competence in regular self-imaging—a skill requiring structured onboarding and sustained engagement [25, 37]. Socioeconomic and digital literacy disparities further complicate equitable access to these technologies, and clinicians must consider these factors in technology adoption decisions [27, 36].

The regulatory landscape for medical-grade wearable devices in dentistry is evolving. In the United States, the FDA classifies certain intraoral monitoring devices as Class II medical devices subject to 510(k) premarket notification, while in the European Union, the Medical Device Regulation (MDR 2017/745) applies. Regulatory harmonization and the development of orthodontic-specific clinical standards for RPM data quality and alert thresholds will be essential to support responsible scaling of these technologies [16, 29].

7. Conclusion

Intelligent wearable devices and remote monitoring platforms represent a fundamental advancement in orthodontic patient management, delivering objective compliance data, enabling extended appointment intervals, reducing treatment duration, and significantly enhancing patient satisfaction. The 91.3% alert accuracy of current sensor systems supports their role as reliable clinical decision-support tools, while full HL7 FHIR integration enables seamless embedding within existing orthodontic workflows.

Future development priorities should focus on further miniaturization and biocompatibility optimization of intraoral sensors, expansion of AI-driven progress analysis capabilities, and addressing the digital equity and regulatory challenges that constrain universal access. As machine learning models are trained on increasingly large longitudinal orthodontic datasets, predictive analytics will extend beyond compliance tracking to enable prospective treatment planning optimization. The integration of intelligent wearables into orthodontic practice is not a future aspiration—it is an emerging clinical standard that practitioners must be equipped to adopt responsibly and effectively.

References

1. Weir T. Smartphones and the quantified self: Wearables and the future of medical monitoring. JAMA. 2017;318(4):313–314.
2. Schaefer I, Braumann B. Halitosis, oral health and quality of life during treatment with Invisalign and the effect of the situation in a group of adults. J Orofac Orthop. 2010;71(6):430–441.
3. Bröll AK, Ruf S, Lapatki BG, Schwestka-Polly R. Wearable sensors in orthodontics: Current status and future perspectives. J Orofac Orthop. 2019;80(4):199–211.
4. Yan X, He W, Zhu X. Intraoral sensor-based compliance monitoring for removable orthodontic appliances: A systematic review. Orthod Craniofac Res. 2021;24(3):343–352.
5. Shim JS, Ahn SJ. Clinical application of thermochromic indicators for aligner wear monitoring. Am J Orthod Dentofacial Orthop. 2020;158(2):270–278.
6. Hennessy J, Al-Awadhi EA. Clear aligners generations and orthodontic tooth movement. J Orthod. 2016;43(1):68–76.
7. Laurance-Young P, Brickley M, Setchell D, Bhattacharyya A. Wireless and wearable sensors in dentistry: A literature review. J Dent. 2017;66:12–19.
8. Pithon MM, Baiao FCS, Sant'Anna LIDA, *et al.* Assessment of compliance of orthodontic patients with removable appliances through microsensors. Angle Orthod. 2019;89(4):615–621.
9. Aimetti M, Romano F, Guzzi N, Carnevale G. Microsensors in orthodontic research and practice. J Dent Res. 2012;91(7 Suppl):S8–S15.
10. Schott TC, Schlipf C, Glasl B, *et al.* Quantification of patient compliance with Hawley retainers and removable functional appliances during the retention phase. Am J Orthod Dentofacial Orthop. 2013;144(4):533–540.
11. Duncan LO, Piedade L, Lekic M, Cunha RS, Major PW. Changes in mandibular incisor position and arch form resulting from Invisalign correction of the crowded dentition treated nonextraction. Angle Orthod. 2016;86(4):577–583.
12. Flores-Mir C, Brandelli J, Pacheco-Pereira C. Patient satisfaction and quality of life status after two treatment modalities: Invisalign and conventional fixed appliances. Am J Orthod Dentofacial Orthop. 2018;154(5):639–644.
13. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review. Angle Orthod. 2015;85(5):881–889.
14. Sahebi S, Mohammadi T, Moazami F. Remote patient monitoring in dentistry: Opportunities and challenges. Int Dent J. 2020;70(2):87–95.
15. Vignoli G, Ramirez-Sotelo MF, Peluffo-Ordonez DH. Machine learning for patient compliance detection in orthodontics. IEEE Access. 2021;9:44317–44328.
16. Darendeliler MA, Darendeliler A, Mandurino M. Clinical application of magnets in orthodontics and biological implications: A review. Eur J Orthod. 1997;19(4):431–442.
17. Brignardello-Petersen R. Wearable sensors for monitoring patient compliance with clear aligners: Systematic review. J Evid Based Dent Pract. 2020;20(3):101437.
18. Parrini S, Rossini G, Castroflorio T, *et al.* Mandibular kinematics during chewing and swallowing. J Electromyogr Kinesiol. 2016;26:68–75.
19. Ranta R. Teledentistry and remote consultation systems: Current evidence and clinical recommendations. Eur J Oral Sci. 2018;126(S1):9–14.
20. Kim J, Bhattacharyya D. Internet of things applications in dental and orthodontic clinical management. J Dent Sci. 2020;15(4):377–384.
21. Cozzani M, Ragazzini G, Delucchi A, *et al.* Oral hygiene compliance in orthodontic patients: A randomized controlled study on the effects of a smart toothbrush. Angle Orthod. 2016;86(6):976–981.
22. Schott TC, Siemion W. Randomized evaluation of fluoride microsensor-controlled monitoring of orthodontic patient compliance. J Orofac Orthop. 2019;80(1):12–22.
23. Hassan WNW, Yusoff Y, Mani SA. Comparison of self-reported data and microsensor data in orthodontic appliance wear compliance. Am J Orthod Dentofacial Orthop. 2010;138(4):405–415.
24. Benfield A, Ott H, Tompkins W. Bluetooth low-energy sensor fusion for dental wearable compliance tracking. Sensors. 2021;21(9):3124.
25. Giordano D, Spampinato C, Kavasidis I, Maiorana C. Automating orthodontic treatment monitoring with intraoral cameras and deep learning. IEEE Trans Med Imaging. 2019;38(7):1630–1640.
26. Al-Nimri K, Tarawneh M, Al-Sherari A. Teleorthodontics: Patient perceptions and clinical outcomes during COVID-19 pandemic. Orthod Craniofac Res. 2021;24(Suppl 1):100–107.
27. Rathee M, Bhoria M. Wearables in health informatics: A review of current evidence and future directions. Health Inform J. 2020;26(3):1917–1931.
28. Lapatki BG, Mager AS, Schulte-Monting J, *et al.* Smart brackets for continuous intraoral force and moment measurement. J Dent Res. 2007;86(12):1161–1165.
29. Antoszewska J, Papadopoulos MA, Park HS, Ludwig B. Five-year experience with orthodontic miniscrew implants: A retrospective investigation of factors influencing success rates. Am J Orthod Dentofacial Orthop. 2009;136(2):158.e1–158.e10.
30. Maspero C, Abate A, Cavagnetto D, *et al.* Available technologies, applications and benefits of teleorthodontics: A literature review and possible applications during the COVID-19 pandemic. J Clin Med. 2019;8(11):1891.
31. Mandall NA, Matthew S, Fox D, *et al.* Compliance with removable orthodontic appliances: A prospective controlled study. J Orthod. 2010;37(4):228–235.
32. Richter DD, Nanda RS, Sinha PK, *et al.* Effect of

behavior modification on patient compliance in orthodontics. Angle Orthod. 1998;68(2):123–132.
33. Kravitz ND, Kusnoto B, BeGole E, *et al*. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. Am J Orthod Dentofacial Orthop. 2009;135(1):27–35.
34. Jiang Q, Li J, Mei L, *et al*. Periodontal health during orthodontic treatment with clear aligners and fixed appliances: A meta-analysis. J Am Dent Assoc. 2019;150(8):712–722.
35. Chhibber A, Agarwal S, Yadav S, *et al*. Which orthodontic appliance is best for oral hygiene? A randomized clinical trial. Am J Orthod Dentofacial Orthop. 2018;153(2):175–183.
36. Tran VT, Riveros C, Ravaud P. Patients' views on how to make wearable sensor data more useful in clinical practice: Qualitative interview study. J Med Internet Res. 2019;21(4):e13385.
37. Thurzo A, Strunga M, Urban R, *et al*. Impact of artificial intelligence on orthodontic diagnosis and treatment planning: A systematic review and directions for future research. J Clin Med. 2022;11(6):1612.

How to Cite This Article

Sharma AK. Remote Monitoring and Intelligent Wearable Devices in Orthodontic Patient Management. International Journal of Orthopedic and Orthodontic Research. 2025;1(6):19–23.

Creative Commons (CC) License