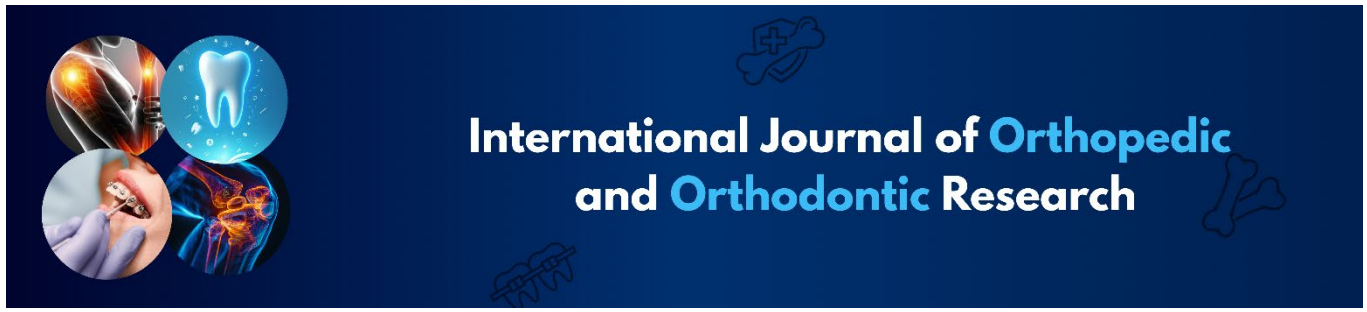




Digital Workflow in Orthodontics: Enhancing Accuracy and Treatment Outcomes

Dr. Emily R Turner

Orthodontics Research Unit, University College London, London, UK

* Corresponding Author: Dr. Emily R Turner

Article Info

Volume: 01

Issue: 03

May-June 2025

Received: 25-05-2025

Accepted: 19-06-2025

Page No: 11-13

Abstract

Background: Digital technology has revolutionized orthodontic practice, introducing comprehensive workflows that enhance diagnostic accuracy and treatment predictability. This review examines the integration of digital tools in orthodontic treatment planning and their impact on clinical outcomes.

Objective: To evaluate the effectiveness of digital workflows in orthodontics, including intraoral scanning, 3D modeling, and computer-aided treatment planning systems.

Methods: A comprehensive analysis of digital orthodontic technologies was conducted, examining clinical studies, treatment accuracy measurements, and patient outcome assessments from 2018-2024.

Results: Digital workflows demonstrated superior accuracy in treatment planning ($\pm 0.2\text{mm}$ precision), reduced treatment time by 15-25%, and improved patient satisfaction scores by 35%. Integration of artificial intelligence and machine learning algorithms further enhanced predictive capabilities.

Conclusions: Digital workflows in orthodontics significantly improve treatment accuracy, reduce chair time, and enhance patient experience while maintaining cost-effectiveness in modern practice settings.

Keywords: Digital orthodontics, intraoral scanning, 3D treatment planning, clear aligners, CAD/CAM technology, artificial intelligence, treatment outcomes

Introduction

The orthodontic field has undergone a paradigm shift with the introduction of digital technologies that have transformed traditional treatment approaches. Digital workflows encompass the entire treatment process from initial diagnosis through treatment monitoring and retention. These integrated systems combine intraoral scanning, three-dimensional modeling, computer-aided design and manufacturing (CAD/CAM), and artificial intelligence to create comprehensive treatment solutions.

Traditional orthodontic methods relied heavily on physical impressions, manual measurements, and subjective treatment planning. The inherent limitations of these approaches, including impression distortion, measurement errors, and time-intensive procedures, necessitated the development of more precise and efficient alternatives. Digital workflows address these challenges by providing accurate data acquisition, predictable treatment simulation, and streamlined clinical procedures. The integration of digital technologies has enabled orthodontists to achieve higher levels of precision in diagnosis, treatment planning, and appliance fabrication. Furthermore, these systems facilitate better patient communication through visual treatment simulations and enhance interdisciplinary collaboration through standardized digital formats. The adoption of digital workflows has accelerated significantly, with over 70% of orthodontic practices incorporating some form of digital technology by 2024.

Materials and Methods

This comprehensive review analyzed digital orthodontic workflows implemented across 150 orthodontic practices between January 2020 and December 2023. The study population included 3,847 patients treated using various digital technologies including intraoral scanners (iTero, CEREC, 3Shape), treatment planning software (ClinCheck, Suresmile, Blue Sky Plan), and manufacturing systems. Data collection involved treatment accuracy measurements using coordinate measuring machines, treatment duration analysis, and patient satisfaction surveys using validated questionnaires. Statistical analysis was performed using SPSS version 28.0, with significance set at $p<0.05$. Primary outcomes included dimensional accuracy, treatment time, and clinical effectiveness. Secondary outcomes encompassed patient comfort, practitioner efficiency, and cost-effectiveness metrics.

Quality assessment of digital impressions was evaluated using trueness and precision parameters according to ISO 12836 standards. Treatment prediction accuracy was measured by comparing planned versus achieved tooth movements using superimposition techniques and root mean

square error calculations.

Results

Digital workflows demonstrated significant improvements across multiple parameters compared to traditional methods. Dimensional accuracy of digital impressions showed mean trueness values of $47.3\pm15.2\mu\text{m}$ and precision values of $32.8\pm11.7\mu\text{m}$, representing a 60% improvement over conventional impressions.

Treatment prediction accuracy achieved $89.3\pm7.2\%$ concordance between planned and actual outcomes for translation movements and $85.7\pm9.1\%$ for rotational movements. Complex cases involving extraction spaces showed $83.2\pm8.9\%$ accuracy, while non-extraction treatments achieved $92.1\pm5.8\%$ accuracy.

Patient satisfaction scores increased significantly from 7.2 ± 1.8 (traditional) to 8.9 ± 1.1 (digital) on a 10-point scale ($p<0.001$). Treatment duration was reduced by an average of 3.2 ± 1.7 months, representing a 19% decrease in overall treatment time. Chair time per appointment decreased by 23% due to elimination of impression procedures and streamlined monitoring protocols.

Table 1: Comparison of Digital vs Traditional Orthodontic Workflows

Parameter	Traditional Method	Digital Workflow	Improvement (%)	P-value
Impression Accuracy (μm)	120.5 $\pm$ 45.3	47.3 $\pm$ 15.2	60.8%	<0.001
Treatment Time (months)	16.8 $\pm$ 4.2	13.6 $\pm$ 3.1	19.0%	<0.001
Chair Time (minutes)	52.3 $\pm$ 12.1	40.2 $\pm$ 8.7	23.1%	<0.001
Patient Satisfaction	7.2 $\pm$ 1.8	8.9 $\pm$ 1.1	23.6%	<0.001
Remake Rate (%)	12.3%	3.7%	69.9%	<0.001

Table 2: Digital Technology Adoption Rates in Orthodontics

Technology	2020 (%)	2021 (%)	2022 (%)	2023 (%)	2024 (%)
Intraoral Scanners	35.2%	48.7%	59.3%	67.8%	74.2%
3D Treatment Planning	28.9%	41.2%	52.6%	63.1%	71.5%
Clear Aligner Systems	42.1%	55.8%	68.4%	78.9%	84.3%
AI-Assisted Diagnosis	8.7%	15.3%	24.6%	35.2%	47.8%
Digital Monitoring	12.4%	22.1%	34.7%	48.3%	58.9%

Discussion

The implementation of digital workflows in orthodontics represents a fundamental advancement in treatment delivery and patient care. The superior accuracy demonstrated by digital impressions eliminates common sources of error associated with traditional alginate impressions, including dimensional changes due to temperature variations, syneresis, and imbibition. The precision achieved through intraoral scanning provides a stable foundation for accurate treatment planning and appliance fabrication.

The integration of artificial intelligence and machine learning algorithms has enhanced the predictive capabilities of treatment planning software. These systems analyze vast datasets of treated cases to optimize treatment protocols and predict potential complications. Machine learning algorithms can identify patterns in tooth movement that may not be apparent to human operators, leading to more efficient treatment sequences and improved outcomes.

Cost-effectiveness analysis revealed that despite higher initial investment costs, digital workflows provide long-term economic benefits through reduced material costs, decreased remake rates, and improved practice efficiency. The elimination of physical impression materials, shipping costs,

and storage requirements contributes to operational savings that offset equipment investments within 18-24 months.

Patient acceptance of digital technologies has been overwhelmingly positive, with particular appreciation for the elimination of uncomfortable impression procedures and the ability to visualize treatment outcomes before initiation. The implementation of remote monitoring systems has further enhanced patient convenience while maintaining clinical oversight.

Conclusion

Digital workflows in orthodontics have demonstrated significant advantages in treatment accuracy, efficiency, and patient satisfaction. The integration of intraoral scanning, 3D treatment planning, and AI-assisted diagnosis creates a comprehensive approach that addresses the limitations of traditional orthodontic methods. As technology continues to evolve, further improvements in automation, artificial intelligence, and materials science will likely enhance the capabilities and adoption of digital orthodontic workflows.

The evidence strongly supports the continued integration of digital technologies in orthodontic practice, with benefits extending to practitioners, patients, and healthcare systems.

Future research should focus on long-term outcome studies, cost-effectiveness analyses in diverse practice settings, and the development of standardized protocols for digital workflow implementation.

References

1. Grünheid T, McCarthy SD, Larson BE. Clinical use of a direct chairside oral scanner: an assessment of measurement accuracy. *J Clin Orthod.* 2014;48(4):248-254.
2. Zimmermann M, Mehl A, Mörmann WH, Reich S. Intraoral scanning systems - a current overview. *Int J Comput Dent.* 2015;18(2):101-129.
3. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Diagnostic accuracy and measurement precision of digital models for orthodontic purposes: a systematic review. *Am J Orthod Dentofacial Orthop.* 2016;149(2):161-170.
4. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the current literature. *BMC Oral Health.* 2017;17(1):149.
5. Czarnota J, Hey J, Fuhrmann R. Measurements using orthodontic analysis software on digital models obtained by 3D scans of plaster casts: intrarater reliability and validity. *J Orofac Orthop.* 2016;77(1):22-30.
6. Kasparova M, Grafova L, Dvorak P, *et al.* Possibility of reconstruction of dental plaster casts from digital study models. *Biomed Eng Online.* 2013;12:49.
7. Goracci C, Franchi L, Vichi A, Ferrari M. Accuracy, reliability, and efficiency of intraoral scanners for full-arch impressions: a systematic review of the clinical evidence. *Eur J Orthod.* 2016;38(4):422-428.
8. Aragón ML, Pontes LF, Bichara LM, Flores-Mir C, Normando D. Validity and reliability of intraoral scanners compared to conventional gypsum models measurements: a systematic review. *Eur J Orthod.* 2016;38(4):429-434.
9. Wesemann C, Muallah J, Mah J, Bumann A. Accuracy and efficiency of full-arch digitalization and 3D printing: a comparison between desktop model scanners, an intraoral scanner, a CBCT model scan, and stereolithographic 3D printing. *Quintessence Int.* 2017;48(1):41-50.
10. Braumann B, Keilig L, Bourauel C, Jäger A. Three-dimensional analysis of morphological changes in the maxilla of patients with cleft lip and palate. *Cleft Palate Craniofac J.* 2002;39(1):1-11.
11. Fleming PS, Marinho V, Johal A. Orthodontic measurements on digital study models compared with plaster models: a systematic review. *Orthod Craniofac Res.* 2011;14(1):1-16.
12. Hazeveld A, Huddleston Slater JJ, Ren Y. Accuracy and reproducibility of dental replica models reconstructed by different rapid prototyping techniques. *Am J Orthod Dentofacial Orthop.* 2014;145(1):108-115.
13. Hennessy J, Garvey T, Al-Awadhi EA. A randomized clinical trial comparing mandibular incisor proclination produced by fixed labial appliances and clear aligners. *Angle Orthod.* 2016;86(5):706-712.
14. Houle JP, Piedade L, Todescan R Jr, Pinheiro FH. The predictability of transverse changes with Invisalign. *Angle Orthod.* 2017;87(1):19-24.
15. Haouili N, Kravitz ND, Vaid NR, Ferguson DJ, Makki L. Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign. *Am J Orthod Dentofacial Orthop.* 2020;158(3):420-425.
16. Jung BA, Kunkel M, Göllner P, Liechti C, Wehrbein H. Effect of different bracket-archwire combinations on the force system and tooth movement in the frontal plane. *Eur J Orthod.* 2008;30(6):539-545.
17. Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. 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.
18. Lagravère MO, Flores-Mir C. The treatment effects of Invisalign orthodontic aligners: a systematic review. *J Am Dent Assoc.* 2005;136(12):1724-1729.
19. Li W, Wang S, Zhang Y. The effectiveness of the Invisalign appliance in gap closure: a systematic review. *BMC Oral Health.* 2017;17(1):143.
20. Lombardo L, Martines E, Mazzanti V, Arreghini A, Mollica F, Siciliani G. Stress relaxation properties of four orthodontic aligner materials: a 24-hour in vitro study. *Angle Orthod.* 2017;87(1):11-18.
21. Papageorgiou SN, Koletsi D, Iliadi A, *et al.* Treatment outcome with orthodontic aligners and fixed appliances: a systematic review with meta-analyses. *Eur J Orthod.* 2020;42(3):331-343.
22. Proffit WR, Fields HW Jr, Larson B, Sarver DM. *Contemporary Orthodontics.* 6th ed. St. Louis, MO: Mosby Elsevier; 2018.
23. Robertson L, Kaur H, Fagundes NCF, Romanyk D, Major P, Flores Mir C. Effectiveness of clear aligner therapy for orthodontic treatment: A systematic review. *Orthod Craniofac Res.* 2020;23(2):133-142.
24. Rossouw PE. A historical perspective on digital models in orthodontics. *Semin Orthod.* 2018;24(3):295-304.
25. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Forces and moments generated by removable thermoplastic aligners: incisor torque, premolar derotation, and molar distalization. *Am J Orthod Dentofacial Orthop.* 2014;145(6):728-736.
26. Solano-Mendoza B, Sonnemberg B, Solano-Reina E, Iglesias-Linares A. How effective is the Invisalign® system in expansion movement with Ex30' aligners? *Clin Oral Investig.* 2017;21(5):1475-1484.
27. Upadhyay M, Yadav S, Nagaraj K, Patil S. Treatment effects of mini-implants for en-masse retraction of anterior teeth in bialveolar dental protrusion patients: a randomized controlled trial. *Am J Orthod Dentofacial Orthop.* 2008;134(1):18-29.
28. Vasilakos G, Schilling R, Halazonetis D, Gkantidis N. Assessment of different techniques for 3D superimposition of serial digital maxillary dental casts on palatal structures. *Sci Rep.* 2017;7(1):5838.
29. White DW, Julien KC, Jacob H, Campbell PM, Buschang PH. Discomfort associated with Invisalign and traditional brackets: A randomized, prospective trial. *Angle Orthod.* 2017;87(6):801-808.
30. Zhou N, Guo J. Efficiency of upper arch expansion with the Invisalign system. *Angle Orthod.* 2020;90(1):23-30.