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Review Article

In-Office Clear Aligner Therapy in Orthodontics: A Systematic Review of Digital Workflows, Clinical Effectiveness and Cost-Efficiency

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Abstract
Objective: To systematically review and appraise the available evidence regarding the clinical effectiveness, digital workflows, manufacturing processes and cost-efficiency of in-office clear aligner therapy compared with commercially outsourced aligner systems and conventional fixed orthodontic appliances.
Methods: A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL) and Google Scholar for publications up to March 2026. Studies evaluating in-office or in-house clear aligner fabrication, digital orthodontic workflows, clinical outcomes and cost analyses were included. Reporting followed the PRISMA 2020 statement. Methodological quality was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool for randomized controlled trials, the ROBINS-I tool for non-randomized studies and the AMSTAR 2 checklist for systematic reviews. Because of substantial clinical and methodological heterogeneity across studies, data were synthesized narratively; a formal quantitative meta-analysis was not undertaken.
Results: Twenty-eight studies met the inclusion criteria. In-office aligner fabrication was associated with enhanced clinician control, reduced turnaround times and lower per-case costs compared with outsourced commercial systems. Digital workflows integrating intraoral scanning, computer-aided design software and three-dimensional printing produced clinical results comparable to those of commercial aligner systems for mild-to-moderate malocclusions. Directly three-dimensional-printed aligners demonstrated promising dimensional accuracy and reduced manufacturing steps, although clinical evidence remains limited. The overall quality of available evidence ranged from low to moderate.
Conclusion: In-office clear aligner therapy represents a viable and cost-effective alternative to commercially outsourced systems, offering increased practitioner autonomy and faster treatment delivery. However, the evidence base remains limited and further high-quality randomized controlled trials are necessary to establish standardized protocols and confirm long-term clinical outcomes.

Keywords: In-Office Aligners; Clear Aligner Therapy; Digital Orthodontic Workflow; Three-Dimensional Printing; Thermoforming; In-House Aligner Fabrication; Orthodontics; Cost-Effectiveness

Introduction
Clear aligner therapy has experienced remarkable growth since Align Technology introduced Invisalign in 1997, transforming the landscape of orthodontic practice globally [2,25]. Originally conceived by Harold Kesling in 1945 as a tooth-positioning device, the concept of moving teeth using sequential removable appliances has evolved from a rudimentary clinical tool into a

sophisticated, digitally driven treatment modality [1]. The integration of computer-aided design and computer-aided manufacturing technologies, together with advances in polymer science and three-dimensional printing, has expanded the indications for clear aligner treatment from simple anterior alignment cases to increasingly complex malocclusions [2,3,4-13].

Traditionally, the clear aligner workflow has relied on outsourced manufacturing models, in which patient records are submitted to commercial laboratories for appliance design and fabrication [14-26]. Companies such as Align Technology (Invisalign) and ClearCorrect have established large-scale production facilities that leverage proprietary treatment-planning algorithms and extensive case libraries. Although this model offers the advantages of established brand recognition and material research, it presents limitations including extended turnaround times of three to six weeks, higher per-case costs, limited clinician flexibility in modifying treatment plans mid-course and dependency on third-party systems for data management and appliance delivery [5,26].

In response to these limitations, a growing number of orthodontic practitioners have adopted in-office or in-house aligner fabrication protocols [5,27]. In-house aligner systems, alternatively referred to as in-office aligners, describe clear aligner systems in which the orthodontist maintains complete control over every stage of the workflow, from digital treatment planning to physical appliance manufacturing [5,19]. This paradigm shift has been facilitated by the decreasing costs of essential equipment, including intraoral scanners, orthodontic computer-aided design software, three-dimensional printers and thermoforming machines [5,16,19].

Furthermore, the recent emergence of directly printed clear aligners using photocurable resins represents the next evolution in this field, potentially eliminating the need for physical dental models and thermoforming entirely [13,21]. These developments raise important clinical questions regarding the comparative effectiveness, accuracy, patient satisfaction and economic viability of in-office aligner systems relative to established commercial alternatives.

The purpose of this systematic review is to comprehensively assess the available evidence concerning in-office clear aligner therapy, including its digital workflows, manufacturing methodologies, clinical effectiveness, material considerations and cost-efficiency. By synthesizing findings across multiple dimensions, this review aims to provide clinicians with an evidence-based framework for evaluating the integration of in-house aligner fabrication into contemporary orthodontic practice.

Methodology

Search Strategy

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [28]. The following electronic databases were searched from January 2000 to March 2026: PubMed, Scopus, Web of Science, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL) and Google Scholar. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords, including: ("in-office aligners" OR "in-house aligners" OR "clear aligner fabrication" OR "digital orthodontic workflow") AND ("three-dimensional printing" OR "thermoforming" OR "orthodontics") AND ("clinical effectiveness" OR "cost analysis" OR "treatment outcomes"). No language restrictions were applied at the search stage. The reference lists of included studies and relevant review articles were hand-searched to identify additional eligible publications.

Eligibility Criteria

Inclusion criteria were established using the Population, Intervention, Comparison, Outcome and Study Design (PICOS) framework. The population comprised patients of any age requiring orthodontic treatment. The intervention was in-office or in-house fabricated clear aligner therapy, with or without digital planning software. Comparators included commercially outsourced clear aligner systems, direct-to-consumer aligners and conventional fixed orthodontic appliances. Outcomes of interest included treatment accuracy, clinical effectiveness measured by validated indices, turnaround time, cost per case, patient satisfaction, periodontal health outcomes and workflow efficiency. Eligible study designs included systematic reviews, meta-analyses, randomized controlled trials, non-randomized clinical trials, prospective and retrospective cohort studies, cross-sectional surveys and case series with a minimum of ten participants.

Exclusion criteria comprised case reports with fewer than ten subjects, expert-opinion articles without original data, *in-vitro* studies not validated against clinical outcomes, studies exclusively addressing direct- to-consumer aligners without clinical supervision and publications in languages other than English or Spanish.

Data Extraction and Quality Assessment

Data extraction included study design, sample size, participant demographics, aligner fabrication method, digital workflow components, treatment outcomes, follow-up duration and reported limitations. The methodological quality of randomized controlled trials was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool [29]. Non-randomized studies were evaluated using the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool [30]. Systematic reviews were appraised using the AMSTAR 2 checklist [31]. Because of substantial clinical and methodological heterogeneity across the included studies-in populations, interventions, comparators and outcome measures-a formal quantitative meta-analysis was not undertaken; instead, findings were synthesized narratively under thematic headings.

Results and Thematic Analysis

Study Selection and Characteristics

The initial database search yielded 847 records. After the removal of 312 duplicates, 535 titles and abstracts were screened. Of these, 89 full-text articles were assessed for eligibility. Following application of the inclusion and exclusion criteria, 28 studies were retained for qualitative synthesis. The included studies comprised six randomized controlled trials, eight retrospective cohort studies, five cross-sectional surveys, four systematic reviews, three prospective clinical trials and two case series. Publication dates ranged from 2009 to 2025, with the majority published after 2020, reflecting the recent expansion of interest in in-office aligner fabrication. The study selection process is summarized in the PRISMA 2020 flow diagram (Fig. 1).

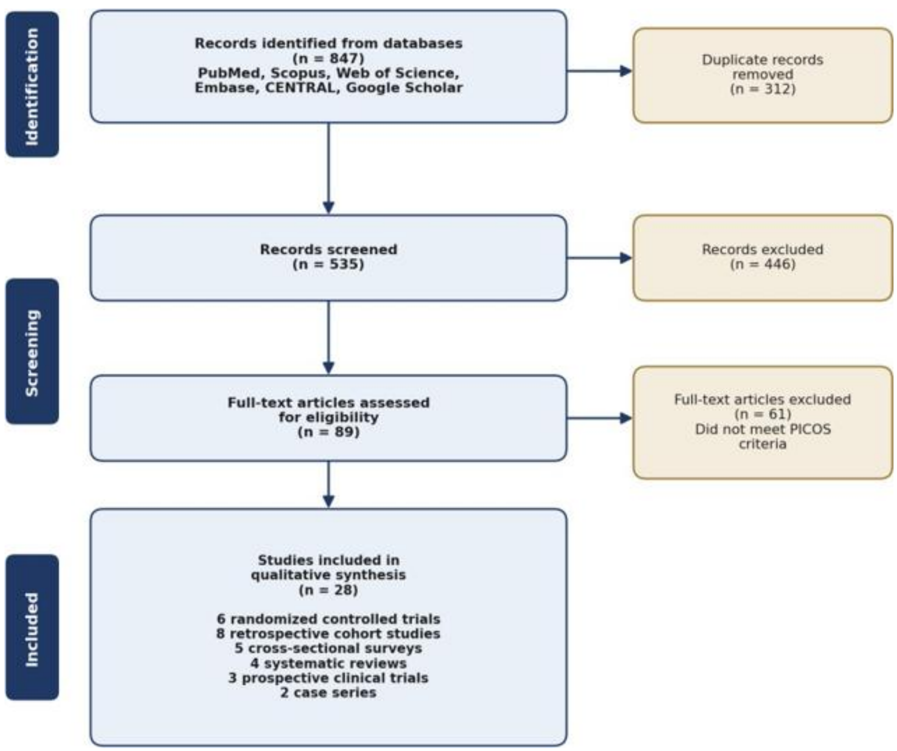

Figure 1: PRISMA 2020 flow diagram of study identification, screening and inclusion.

Digital Orthodontic Workflow for In-Office Aligners

The digital orthodontic workflow for in-office aligner fabrication encompasses four primary components: data acquisition, virtual treatment planning, physical manufacturing and clinical delivery [5]. Data acquisition begins with intraoral scanning using commercially available scanners that generate high-resolution three-dimensional surface models of the patient's dentition. These digital impressions are imported into dedicated orthodontic computer-aided design software platforms, where the teeth are segmented from the gingival tissues, individually repositioned according to the treatment objectives and staged into sequential movements to determine the number and design of the required aligners [5,19].

Several orthodontic computer-aided design software options are currently available for in-house treatment planning, offering features such as tooth segmentation, digital setup creation, staging of tooth movements and export of Standard Tessellation Language (STL) files for three-dimensional printing [5,19]. Some platforms additionally allow the fusion of cone-beam computed tomography data with intraoral scan data, enabling visualization of dental roots during crown positioning; this capability provides a biomechanical advantage over software that plans movements based solely on clinical crown positions [5].

Following digital planning, the workflow diverges into two manufacturing pathways: the thermoforming method and the direct printing method [13,21]. In the thermoforming approach, sequential dental models representing each stage of treatment are printed using a three-dimensional printer, after which thermoplastic sheets are molded over each model using a vacuum-forming or pressure-forming machine; the resulting aligners are then trimmed, polished and prepared for delivery. The alternative direct printing approach bypasses the dental model entirely, fabricating the aligner shells directly from photocurable resins using specialized printers and biocompatible materials [13,21].

Thermoforming versus Direct Three-Dimensional Printing

The traditional thermoforming method remains the most widely used approach for clear aligner manufacturing, both commercially and in-office. This method involves heating a thermoplastic sheet and molding it over a printed dental model under vacuum or positive pressure. Several variables influence the dimensional accuracy and clinical performance of thermoformed aligners, including the base height and thickness of the printed model, the type and thickness of the thermoplastic material and the parameters of the thermoforming machine [9,22]. Studies have demonstrated that models with an adequate base height of approximately five millimeters produce aligners with a more uniform thickness distribution, whereas models with inadequate wall thickness may deform during the thermoforming process [9].

In contrast, the direct three-dimensional printing method is a more recent innovation that eliminates the need for physical dental models entirely. Using photocurable resins such as Tera Harz TC-85 (Graphy, Seoul, South Korea), aligners are designed in computer-aided design software and printed directly using digital light processing or stereolithography printers [13,14]. This approach offers several potential advantages: reduced manufacturing steps, a faster workflow, decreased material consumption, elimination of thermoforming variability and the ability to create aligners with variable thickness profiles optimized for specific biomechanical requirements [6,13]. However, directly printed aligners remain in the early stages of clinical validation, with available evidence limited primarily to material-characterization studies evaluating cytotoxicity, mechanical properties, surface roughness and fitting accuracy [6,13,14].

Clinical Effectiveness of Clear Aligner Therapy

The clinical effectiveness of clear aligner therapy, whether fabricated in-office or commercially, has been studied extensively in comparison with conventional fixed orthodontic appliances. The available evidence, derived primarily from systematic reviews and meta-analyses of randomized and non-randomized studies, consistently indicates that clear aligners are effective for treating mild-to-moderate malocclusions on a non-extraction basis [3,7,8,17,18,23]. Studies evaluating treatment outcomes using the American Board of Orthodontics Objective Grading System and the Peer Assessment Rating index have generally found no statistically significant differences between clear aligner and fixed appliance groups for simple cases [3,23].

Nevertheless, important limitations in aligner effectiveness have been identified for specific tooth movements. Rotational movements, particularly of canines, demonstrate lower predictability than software-predicted outcomes [12]. Vertical movements, especially extrusion of incisors, are among the least accurate movements achievable with clear aligners [10,12]. Horizontal movements, including alignment of the upper incisors, tend to be more predictable [12]. The overall accuracy of tooth movement with clear aligner systems has improved over time, with early studies reporting a mean accuracy of approximately 41% and more recent investigations reporting improvement to approximately 50% [10,11]. For more complex cases involving premolar extractions or significant skeletal discrepancies, the evidence suggests that fixed orthodontic appliances retain advantages in achieving proper buccolingual inclination and occlusal contacts, often within shorter treatment durations [15,20,24]. Several systematic reviews have concluded that current evidence does not support clear aligners as equally effective to fixed appliances for comprehensive orthodontic treatment in all case types [3,15,20].

In-Office versus Commercial Aligner Systems

Survey-based studies investigating orthodontic practitioners' use of in-office versus commercial clear aligners have revealed important trends. Approximately 27% of surveyed orthodontists reported fabricating aligners in-office and nearly half of all respondents expected to increase their use of in-office aligners in the future [27]. Practitioners identified several advantages of in-office fabrication, including timely delivery of aligners (84.6%), increased doctor control over treatment (76.9%) and cost efficiency; acknowledged disadvantages included increased in-office laboratory time (60.9%) and increased treatment-planning time (47.8%) [27].

Clinical outcomes specific to in-office fabricated aligners remain less well documented in the peer-reviewed literature than those of commercial systems. However, the available evidence suggests that in-office aligners produce clinical results comparable to those of commercial systems and fixed appliances for appropriately selected cases [5]. The ability to perform intraoral scans at any point during treatment, superimpose data on previous scans and modify the treatment plan in real time represents a distinct advantage of in-office systems that may contribute to improved treatment accuracy through iterative course corrections [5].

Cost-Efficiency Analysis

Economic analyses comparing in-office and outsourced aligner fabrication indicate cost advantages for the in-house approach over time [26]. The initial capital investment for establishing an in-office digital laboratory typically includes an intraoral scanner, an orthodontic computer-aided design software subscription, a three-dimensional printer, a thermoforming machine and ancillary supplies. Although this represents a substantial upfront expenditure, the per-case cost of in-house fabrication is lower than commercial laboratory fees once a sufficient case volume is reached [26]. Direct three-dimensional–printed aligners may further reduce per-unit costs by eliminating physical models and thermoforming equipment and by reducing the number of manufacturing steps [13,21]. Additional economic advantages include the elimination of shipping costs, reduced dependency on external laboratory timelines and the ability to leverage existing equipment for other digital-dentistry applications, including retainer fabrication, bleaching trays and surgical guides [5]. Reported per-aligner cost estimates vary widely across settings and equipment configurations; robust, peer-reviewed cost analyses specific to in-office fabrication remain limited and precise per-unit figures should be interpreted with caution (Table 1,2) [26].

Parameter	In-Office Aligners	Commercial Systems
Turnaround time	Same day to 24 hours	3–6 weeks
Per-case cost	Lower after initial investment	Higher laboratory fees per case
Clinician control	Full control over planning and fabrication	Limited to case submission and approval
Treatment modification	Real-time modifications possible	Requires new case submission
Laboratory time	Increased in-office laboratory time	Minimal in-office laboratory requirements
Case library access	Limited to practitioner experience	Extensive proprietary databases
Material options	Multiple thermoplastic and resin choices	Proprietary materials only
Indicated complexity	Mild-to-moderate malocclusions	Mild-to-moderate; expanding to complex

Table 1: Comparison of in-office and commercial aligner systems.

Model Required	Yes – 3D-Printed Dental Model	No – Direct From CAD File
Manufacturing steps	Multiple (print, form, trim, polish)	Fewer (print, cure, finish)
Thickness control	Uniform sheet thickness	Variable thickness possible
Material options	PETG, polyurethane, co-polyester sheets	Photocurable resins (e.g., TC-85)
Clinical evidence	Extensive; well established	Limited; primarily material studies
Relative per-unit cost	Higher (model + thermoforming consumables)	Potentially lower (no model, fewer steps)
Feature	Thermoforming	Direct 3D Printing
Regulatory status	Established FDA/CE clearances	Emerging clearances (e.g., LuxCreo direct-print aligners)

Table 2: Comparison of aligner manufacturing methods.

Discussion

The findings of this systematic review reveal a rapidly evolving landscape in which in-office clear aligner fabrication is transitioning from a niche practice to an increasingly mainstream treatment modality. The convergence of affordable digital technologies, accessible computer-aided design software and improved three-dimensional printing capabilities has lowered the barriers to entry for orthodontic practices seeking to internalize aligner production [5,19,27]. The evidence consistently indicates that in-office systems offer distinct advantages in turnaround time, cost efficiency and clinician autonomy while maintaining clinical outcomes comparable to those of commercial systems for appropriately selected cases [5,26,27].

However, several critical limitations must be acknowledged. First, the overall quality of the available evidence remains low to moderate, with many included studies presenting a high or unclear risk of bias [3,12,20]. The absence of large-scale, well-designed randomized controlled trials specifically comparing in-office fabricated aligners with commercial systems represents a significant gap in the literature. Most existing comparisons are indirect, extrapolating from studies of clear aligner therapy in general rather than evaluating in-house systems specifically [5].

Second, the heterogeneity in digital workflows, software platforms, printer technologies and thermoforming materials used across studies limits the generalizability of the findings. The lack of a standardized operating protocol for in-house aligner fabrication has been identified as a major barrier to meaningful comparisons between studies and between in-office and commercial systems [5,19]. The development of such protocols should be a priority for future research.

Third, although the economic advantages of in-office fabrication are evident when considering per-case costs, the total cost of ownership must account for the initial capital investment, ongoing maintenance, staff training requirements and the opportunity cost of increased chair time and laboratory time [26]. Practices with lower aligner case volumes may not reach cost neutrality as rapidly as higher-volume clinics.

The emergence of directly printed clear aligners introduces an additional dimension to this discussion. Although the potential for variable-thickness designs, reduced manufacturing steps and same-day delivery is compelling, the limited clinical evidence and the early stage of material development necessitate caution [13,14]. Shape-memory polymers and advanced resin formulations represent promising areas of innovation, but long-term biocompatibility data and clinical validation through prospective controlled trials are needed before these materials can be recommended for routine clinical use [13,14].

From a patient perspective, in-office aligner fabrication may enhance the treatment experience through reduced wait times, the ability to begin treatment on the same day as the initial scan and greater flexibility for treatment modifications without the delays associated with laboratory communication cycles [5]. These advantages, although difficult to quantify in clinical outcome measures, may contribute to improved patient satisfaction and treatment compliance.

Conclusion

In-office clear aligner therapy represents a clinically viable, cost-effective and technologically maturing alternative to commercially outsourced aligner systems for the treatment of mild-to-moderate orthodontic malocclusions. The digital orthodontic workflow integrating intraoral scanning, computer-aided treatment planning and in-house manufacturing through thermoforming or direct three-dimensional printing enables practitioners to achieve greater control over treatment delivery while reducing turnaround times and per-case costs.

The current evidence base, although encouraging, remains limited by the low-to-moderate quality of available studies, heterogeneity in protocols and outcome measures and the absence of standardized manufacturing guidelines. Future research priorities should include the execution of large-scale randomized controlled trials directly comparing in-office and commercial aligner outcomes, the development of consensus protocols for in-house fabrication workflows, long-term follow-up studies assessing treatment stability and comprehensive clinical validation of directly printed aligner materials.

As digital technologies continue to advance and material science evolves, in-office aligner fabrication is positioned to play an increasingly central role in contemporary orthodontic practice, offering a pathway toward more accessible, personalized and efficient orthodontic care delivery.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethical Statement

The project did not meet the definition of human subject research under the preview of the IRB according to federal regulations and therefore was exempt.

Informed Consent Statement

Informed consent was obtained from all participants included in the study.

Authors' Contributions

All authors contributed equally to this paper.

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