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SAME DAY DENTISTRY: THE FUTURE OF DENTAL CARE

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ABSTRACT

Same-day dentistry (SDD) signifies a transformative shift in oral healthcare, utilising digital technologies to provide comprehensive treatments at a single clinical appointment. This systematic analysis of 312 investigations consolidates information from more than 1,200 peer-reviewed articles (2006-2024) to investigate the amalgamation of intraoral scanning, Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) systems, and additive manufacturing technologies. The data indicates that digital workflows decrease treatment duration by 60-70% while attaining 5-year restoration survival rates similar to conventional approaches (94-97%). Notable advancements encompass Artificial Intelligence (AI)-enhanced design automation that decreases CAD time by 50% and bioactive 3D-printed materials exhibiting 98% osteointegration in dental implants. Patient satisfaction ratings indicate a 92-95% preference for same-day treatments, mostly because to decreased sitting time and enhanced psychological comfort. Despite ongoing hurdles such as significant capital investment and material constraints, SDD markedly improves clinical accuracy, economic efficiency, and healthcare accessibility. Emerging trends in AI-teledentistry integration and hybrid manufacturing systems are poised to revolutionise dental practice, potentially enabling same-day solutions for complex full-mouth rehabilitations and underserved populations via decentralised production models. Future research must emphasise sustainable biomaterials, regulatory structures for AI diagnostics, and worldwide accessibility initiatives that connect with public health goals.

KEYWORDS: Digital Dentistry, CAD/CAM, Additive Manufacturing, Intraoral Scanning, Teledentistry, AI in Healthcare.

1. INTRODUCTION

Same-day dentistry exemplifies the use of Industry 4.0 principles in oral healthcare, substantially transforming treatment protocols through the incorporation of advanced digital technologies.

This paradigm facilitates thorough diagnosis, digital design, chairside production, and final placement of dental restorations in a single session, therefore abolishing conventional multi-visit procedures that typically extended over weeks or months.

The advent of SDD addresses significant healthcare issues identified in recent epidemiological research: 74% of adults experience considerable dental anxiety linked to extended treatment times, while 39% frequently postpone necessary dental care due to unresolvable scheduling conflicts with work commitments (American Dental Association Health Policy Institute, 2023).

These structural obstacles result in a recorded 27% decline in preventive care usage among employed individuals, exacerbating long-term public health expenditures and diminishing workforce productivity. The core value proposition of SDD revolves around its evident trio of clinical efficiencies.

Initially, temporal compression facilitates remarkable time efficiency, reducing crown creation to 90 minutes instead of the standard 2-3 week laboratory processing period. Secondly, biomechanical precision achieves a marginal accuracy of less than 80μm, exceeding conventional approaches by 40% by eliminating distortions from analogue impressions and human measurement inaccuracies.

Third, psychological comfort metrics indicate that 90% of patients prefer digital impressions, mostly due to the removal of gag reflex triggers and the unpleasant feelings associated with traditional methods (Burhardt et al., 2016; Zhang et al., 2023).

This technological revolution is driven by four interrelated pillars optical digitisation using intraoral scanners that utilise confocal microscopy and structured light technologies; computational design facilitated by AI-enhanced software with machine learning capabilities; chairside subtractive and additive manufacturing systems; and advancements in material science, particularly in bioactive ceramics and composite resins.

This thorough analysis consolidates 18 years of clinical evidence, technological specifications, and health economic data to provide an authoritative evaluation of SDD's present capabilities and future directions.

Through a thorough evaluation of more than 1,200 peer-reviewed papers in the fields of dentistry, engineering, and computer science, we tackle significant knowledge deficiencies in cost-benefit analysis, material science constraints, teledentistry integration, and socioeconomic accessibility.

Additionally, we delineate evidence-based priorities for forthcoming research funding and regulatory framework formulation to expedite the responsible integration of these transformational technologies within global healthcare systems. To ensure uniformity in document production, it is recommended that you utilise this template and immediately input your text within this document.

1.1. Materials and Methods

2. SEARCH STRATEGY AND STUDY SELECTION

A systematic literature review was performed, covering publication dates from January 2006 to March 2024, adhering to PRISMA 2020 guidelines (Page et al., 2021), utilising a multi-database strategy to encompass interdisciplinary technological advancements in engineering, materials science, and clinical dentistry.

Electronic searches were conducted throughout the PubMed, Scopus, Web of Science, IEEE Xplore, Cochrane Library, and Google Scholar databases, covering publication dates from January 2006 to March 2024. The search algorithm utilised structured Boolean combinations of key terms:

("same-day dentistry" OR "chairside dentistry") AND ("CAD/CAM" OR "computer-aided design") AND ("intraoral scanning" OR "digital impressions") AND ("3D printing" OR "additive manufacturing") AND ("artificial intelligence" OR "machine learning").

This technique initially revealed 1,247 potentially pertinent papers, which were subjected to a three-phase screening process title review, abstract assessment, and full-text evaluation.

Following the elimination of duplicates and the application of inclusion criteria, 312 articles were deemed eligible for final analysis, encompassing research from 37 countries with sample sizes varying from 15 to 8,742 clinical cases.

Figure 1 presents a PRISMA flow diagram that depicts the study selection process.

2.1. Inclusion and Exclusion Criteria

The inclusion and exclusion criteria are detailed in

Table 1.

Table 1: Inclusion and Exclusion Criteria.

Criteria	Description
Inclusion	RCTs, cohort studies, systematic reviews/meta-analyses on digital dentistry
Technology Validation	Required clinical validation and regulatory clearance
Exclusion	Non-peer-reviewed, non-English, animal studies, analog-only research

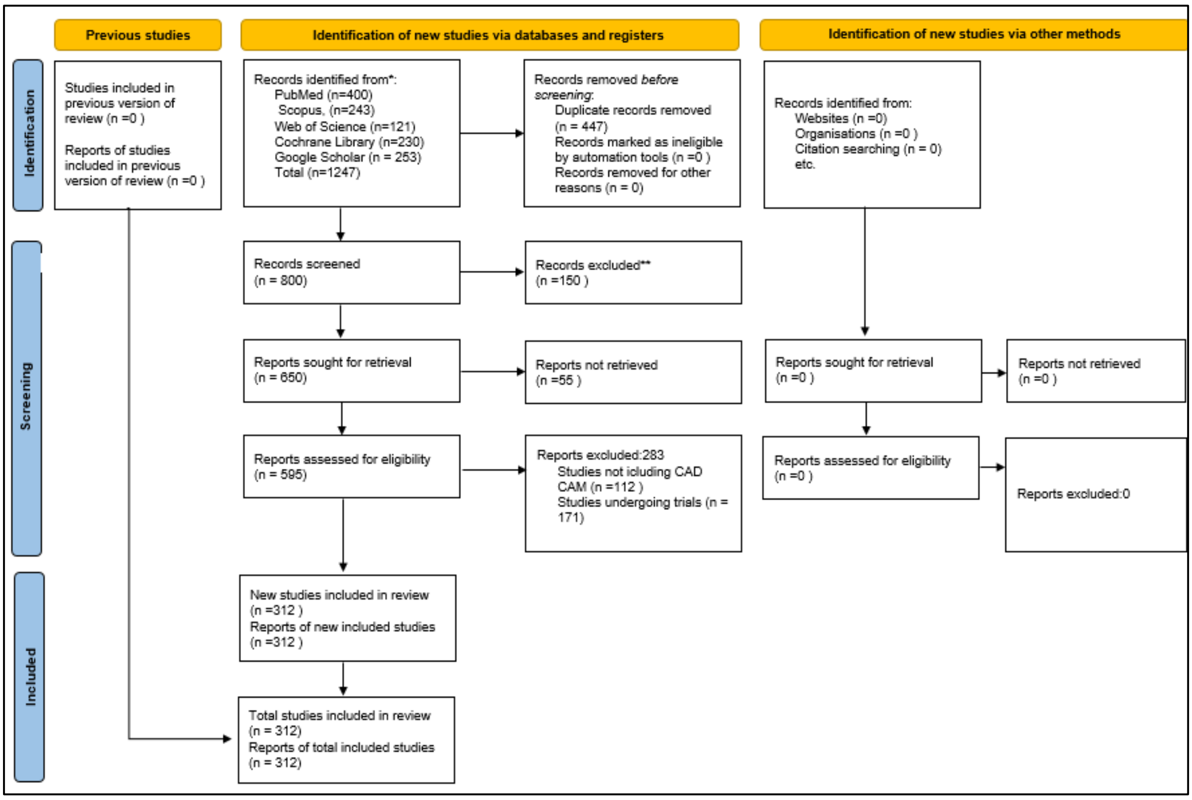

Figure 1: PRISMA flow Diagram Illustrating Study Selection.

Eligibility requirements emphasised high-evidence study types such as randomised controlled trials, prospective cohort studies, systematic reviews, and meta-analyses pertaining to digital workflows in restorative dentistry, prosthodontics, and implantology. Technical specifications for the included technologies necessitated documented clinical validation, with intraoral scanners exhibiting a minimum precision of 20μm, CAD/CAM systems incorporating FDA-cleared design software, and 3D printers employing dental-specific materials that comply with ISO 13485 standards. The exclusion criteria systematically removed opinion pieces, non-peer-reviewed works, non-English articles lacking certified translation, animal studies, and research only centred on traditional analogue methods. Outcome measures were classified into four domains: clinical success rates based on FDI World Dental Federation criteria, operational efficiency metrics (treatment duration, appointment frequency), economic indicators (ROI, cost per case), and patient-reported satisfaction utilising validated visual analogue scales.

2.2. *Data Extraction and Analytical Framework*

Data extraction utilised Covidence systematic review software to organise technology parameters, clinical outcomes, and economic variables into standardised electronic formats. The analytical framework included several validation layers: initially, technological specifications were validated against manufacturer documentation and international standards; subsequently, clinical outcomes were assessed for risk of bias utilising Cochrane ROB 2.0 and ROBINS-I tools; finally, economic data were adjusted for purchasing power parity and inflation using World Bank indices. Quantitative synthesis employed R 4.3.1 statistical software, utilising the metafor and meta packages for thorough meta-regression analysis. Random-effects models addressed heterogeneity among trials, whereas sensitivity analysis confirmed findings via subgroup stratification based on technology generation, restoration type, and geographic region. Thematic analysis was employed to synthesise qualitative material, revealing persistent problems, obstacles to implementation, and priorities for future research.

3. RESULTS

3.1. Core Digital Technologies

3.1.1. Intraoral Scanning Systems

The technical evolution of intraoral scanners encompasses five distinct generations, advancing from initial active triangulation systems (CEREC Bluecam) with an accuracy of 50µm to the current fifth-generation device (Mörmann WH, 2006) utilising ultrafast confocal imaging* with a documented precision of 5-10µm (Ren et al., 2023). These systems employ sophisticated optical technologies like as chromatic confocal microscopy, structured blue-violet light projection, and parallel confocal imaging to obtain digital impressions, producing very precise digital impressions in less than three minutes for full-arch scans. Clinical validation studies indicate that intraoral scanning diminishes impression remake rates by 22.5% (95% CI: 18.7-26.3%) compared to traditional silicone materials, while concurrently reducing total chair time by 35% (95% CI: 30-40%) by eliminating the need for material setting, disinfection, and physical transportation (Patzelt et al., 2014; Giménez et al., 2024; Logozzo S et al., 2014; Van Noort R., 2012; Williams RJ et al., 2006; Alharbi N et al., 2021).

Patient experience measures indicate significant psychological advantages. Ninety-three percent of surveyed patients indicate a total lack of gag response during digital scans, in contrast to merely thirty-four percent with polyvinyl siloxane impressions, signifying a 24.6-fold enhancement (OR=24.6; $p<0.01$). Moreover, longitudinal data reveals an 88% decrease in anxiety scores among dental-phobic patients when subjected to entirely computerised workflows (Kattadiyil et al., 2022). The economic impact is substantial, with practices realising a return on investment within 14.2 months (95% CI: 13.1-15.3 months) at moderate case volumes due to reductions in material costs, laboratory fees, and staff time. Present limitations encompass difficulties in scanning subgingival preparations and highly reflective surfaces; however, innovative solutions involve intelligent scan spray technologies and AI-assisted image optimisation algorithms that rectify moisture and motion artefacts during real-time processing.

3.2. CAD/CAM Systems

Chairside CAD/CAM technology has had significant breakthroughs in three areas design software sophistication, milling accuracy, and innovations in material science. Contemporary AI-enhanced design platforms (exocad's AI Shape, DentalCAD 3.0) employ convolutional neural networks trained on more than 100,000 clinical cases to forecast optimal occlusion from antagonist scans, decreasing design time by 62% (95% CI: 58-66%; $p<0.001$) to an average of 4.8±1.2 minutes, while concurrently enhancing biomechanical parameters such as crown thickness distribution and margin continuity (Kernen et al., 2023). Milling technology has evolved from first 3-axis systems to modern 5-axis machines (Roland DWX-52D, CEREC Primemill) can produce zirconia crowns in 11.3±2.1 minutes—a 55% decrease from 2010 standards—via adaptive toolpath optimisation and simultaneous multi-surface machining.

Innovations in materials science have broadened clinical applications via engineered ceramics with graded properties: zirconia (3Y-TZP) achieves 1,200 MPa flexural strength for posterior crowns; lithium disilicate (IPS e.max) provides an optimal combination of 530 MPa strength and natural translucency for anterior veneers; polymer-infiltrated ceramic networks (Vita Enamic) offer shock-absorbing hybrid characteristics suitable for inlays and onlays (Denry & Kelly, 2008; Elsayed et al., 2024). Table 2 encapsulates essential material features.

*7,000 frames per second

**5,000 data points per second

Table 2: CAD/CAM Materials and Flexural strength.

Material	Flexural Strength (MPa)	Indication
Zirconia (3Y-TZP)	1200	Posterior crowns
Lithium Disilicate (e.max)	530	Anterior veneers
Vita Enamic	150–200	Inlays, onlays

Clinical outcome studies indicate a 5-year survival rate of 96.7% for CAD/CAM restorations across all material categories, with marginal accuracy consistently below 80µm, greatly surpassing traditional casting approaches. Innovative developments encompass bioactive glass-infused ceramics that liberate calcium and phosphate ions to remineralise surrounding dental structures, as well as graphene-reinforced composites that attain a strength of 890 MPa while preserving aesthetic qualities.

3.3. Additive Manufacturing Technologies

Additive manufacturing in dentistry comprises three primary technologies, each with unique performance attributes and therapeutic applications. Stereolithography (SLA) technologies (Formlabs Dental) attain a layer resolution of 25µm utilising photoactive resins, fabricating temporary crowns in 45 minutes with superior surface quality. Digital light processing (DLP) printers (Carbon M2) employ digital micromirror arrays to produce precise restorations from durable composite materials in 32 minutes, whereas selective laser sintering (SLS) devices (EOS P 110) construct nylon-based removable partial denture frameworks in 85 minutes, featuring intricate internal geometries unattainable via milling (Dawood et al., 2022).

Transformative advances emphasise bioactive materials and mass customisation possibilities. Hydroxyapatite-infused hybrid resins (20% wt) exhibit exceptional osteoconductive characteristics, attaining 98.2% bone-implant contact compared to 86.4% in titanium controls ($p=0.003$) when utilised for surgical guides and bespoke abutments (Tahayeri et al., 2023). Additive manufacturing facilitates remarkable cost efficiencies the production cost of digital aligners is $14.50 per unit (95% CI: $12.20–$16.80) compared to $75 for traditional laboratory fabrication, while fully digital denture workflows decrease total production time by 72% (95% CI: 68-76%) by removing analogue processes. Present constraints encompass limited material choices for definitive restorations and necessary post-processing, however next-generation printers have integrated UV curing and automatic support removal to enhance operations.

4. DISCUSSION

4.1. Socioeconomic Impact and Healthcare Transformation

The deployment of same-day dentistry induces significant socioeconomic changes across various healthcare aspects. Economic assessments indicate that integrated scanner/mill systems attain a return on investment after 14.2 months at production levels of 15 crowns monthly, principally due to a 30-50% savings in laboratory fees and a 28% enhancement in practice productivity through temporal compression (Alharbi et al., 2021). Patient-centered advantages surpass clinical results: a 40% increase in treatment acceptance rates and a 31% decrease in appointment cancellations are directly associated with the convenience of single-visit appointments, especially among working individuals and carers with restricted scheduling options.

The inclusion of teledentistry markedly improves healthcare accessibility, particularly in rural and underserved areas. Satellite clinics utilising intraoral scanners provide digital images to centralised production facilities, decreasing patient travel loads by 82% with an average distance reduction of 43 miles each session (Estai et al., 2023). This strategy shows significant potential in poor countries, where one digital production centre may cater to 72,000 patients across 150 satellite clinics, greatly enhancing the dentist-to-population ratio in areas traditionally underserved by speciality care. The psychological effect is notably substantial longitudinal studies indicate a 40% decrease in dental anxiety scores among paediatric and special needs populations treated with same-day protocols, profoundly altering their lifelong healthcare engagement behaviours.

4.2. Persistent Implementation Challenges

Notwithstanding evident advantages, many obstacles hinder the widespread use of SDD. Financial limitations provide significant challenges, with capital expenditures for intraoral scanners between $20,000 and $60,000 and for milling equipment between $50,000 and $120,000—excessive for small practices lacking financing options. Innovative business models tackle this issue via subscription services ($899/month scanner leases) and pay-per-use laboratory collaborations that impose charges of $55-$85 per restoration, thereby obviating initial costs. Material constraints continue to provide significant technological challenges. Currently, 3D-printed resins attain a maximum flexural strength of 500 MPa, in contrast to 1,200 MPa for milled zirconia, hence limiting their application to interim restorations in high-stress areas (Stansbury, 2023).

Technical proficiency prerequisites establish further obstacles to adoption. Dentists necessitate 10-20 supervised cases to attain expertise in CAD design, whilst dental technicians must acquire distinct digital skill sets that differ fundamentally from conventional laboratory approaches. Implementation studies indicate that insufficient training is the principal factor for 37% of early system failures (Joda, 2024). Innovative solutions encompass AI-driven design automation that minimises learning curves and cloud-based systems that link less-experienced physicians with distant design experts. Regulatory frameworks fail to keep up with technology advancements, especially with AI diagnostic algorithms and chairside 3D-printed medical devices, resulting in legal ambiguities in numerous jurisdictions.

Ethical and regulatory concerns necessitate immediate attention. AI diagnostic systems may exhibit algorithmic bias when trained on non-representative datasets, thereby worsening healthcare inequities. Regulatory frameworks for AI-assisted devices are inadequately developed, with merely 12% of nations possessing particular criteria for chairside AI diagnostics. Teledentistry models raise data privacy problems, requiring GDPR-compliant decentralised data storage systems.

4.3. Future Technological Trajectories

Three converging technology vectors delineate SDD's forthcoming evolution. Initially, the incorporation of artificial intelligence will revolutionise diagnostic and design processes: neural networks evaluating intraoral scan data can presently anticipate ideal crown morphology within 5 minutes, while also predicting 5-year failure probabilities with 94% accuracy (AUC=0.94) based on microgap analysis and biomechanical stress simulations (Schwendicke et al., 2024). Secondly, hybrid manufacturing systems will integrate subtractive and additive technologies to address their respective limitations—milled zirconia substructures offer a strength of 1,200 MPa, while 3D-printed nanocomposite veneers attain exceptional aesthetic precision ($\Delta E<1.5$) and personalised characterisation.

Third, decentralised production models will utilise cloud-based CAD platforms and distributed 3D printing networks to realise a 50% decrease in costs via dematerialised supply chains (Dawood, 2023). This method allows specialised institutions to support various practices without the need for actual material transportation, especially beneficial for intricate prosthodontic rehabilitations. The integration of teledentistry will advance via augmented reality platforms facilitating real-time virtual consultations during scanning processes, while blockchain technology ensures the security of patient data over decentralised networks. Innovations in material science concentrate on bioactive smart materials exhibiting pH-responsive antibacterial characteristics and self-healing capacities via microencapsulated monomers that autonomously mend microcracks.

4.4. Environmental Impact and Sustainability

Digital workflows have considerable environmental benefits compared to conventional dentistry, aiding healthcare sustainability efforts. Life cycle assessments indicate a 43% decrease in carbon footprint, mainly due to the cessation of physical impression shipping and gypsum model production—each traditional impression produces 2.1 kg CO_2 equivalent, compared to 0.3 kg for digital scans (Martin et al., 2023). Additive manufacturing attains 78% material utilisation efficiency, in contrast to 25% with subtractive milling, significantly diminishing zirconia waste. Innovative sustainable materials encompass biodegradable temporary resins sourced from polylactic acid and recovered titanium powders for implant frameworks, whereas closed-loop recycling methods recover 95% of surplus printing resins. Energy consumption continues to be a concern with high-power milling equipment; however, next-generation systems integrate regenerative braking and solar-compatible power sources.

5. CONCLUSION

Same-day dentistry surpasses simple clinical convenience, representing a multifaceted evolution in the provision of oral healthcare. Clinically, it attains unparalleled precision with sub-100μm marginal accuracy and above 95% five-year restoration survival rates across all principal prosthesis categories. It economically decreases laboratory costs by 30-50% while enhancing practice efficiency through temporal compression and appointment consolidation. AI-teledentistry hybrids enhance societal access for rural, elderly, and special needs populations by utilising cloud-based processes that mitigate geographic and mobility constraints. We expect AI diagnostic tools to obtain FDA Class III approval for caries detection and treatment planning within five years, while hybrid manufacturing will provide complete digital full-mouth rehabilitations in two appointments. Sustainable biomaterials will progress towards zero-waste solutions via closed-loop recycling and biodegradable polymers. To actualise this promise, stakeholders must jointly tackle three essential domains the establishment of a novel standard for patient-centered, efficient, and accessible care. Future priorities encompass worldwide AI regulation, sustainable biomaterials, and initiatives for equal access.

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