Review Article

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Dentistry Section

Revolutionising Precision and Efficiency of Dental Implant Placement through Digital Planning Software: A Narrative Review

KR SEGIN CHANDRAN[1], NEETI MITTAL[2], MANOJ GOYAL[3]

ABSTRACT

Advancements have transformed dentistry, and digital planning software has emerged as a revolutionary tool in implantology. The present review explores the capabilities, benefits, and limitations of digital planning software in implantology, emphasising its impact on clinical practice and patient outcomes. Traditional implant planning relied on Two-dimensional (2D) radiographs and physical study models, limiting accuracy and predictability. Digital planning software utilises advanced imaging technologies to generate precise Three-dimensional (3D) models of the patient's dentition, enabling comprehensive treatment planning. Key features include 3D visualisation, virtual implant placement, prosthetic-driven planning, and simulations. These features enhance accuracy, enable collaborative decision-making, and streamline the treatment process. Commercially available digital planning software options offer similar advantages but also have unique features. Studies support the clinical efficacy of digital planning in implant placement, showing improved accuracy, patient satisfaction, and reduced complications. However, more randomised controlled trials are needed to evaluate the clinical outcomes of digitally guided implant placement. Considerations include the need for high-quality input data, a learning curve for software proficiency, and cost considerations. Nevertheless, digital planning software has become an indispensable tool in implantology, enhancing treatment outcomes and patient satisfaction. The future of digital planning software in implantology lies in Artificial Intelligence (AI) integration, automation, and personalised recommendations. With ongoing advancements, digital planning software will continue to revolutionise implantology, optimising treatment planning and execution for improved patient care.

Keywords: Computer-aided design, Digital dentistry, Dental implants, Implant planning software, Virtual implant planning

INTRODUCTION

Advancements in technology have revolutionised numerous fields within medicine, and dentistry is no exception [1]. Over the past decade, digital planning software has emerged as a game-changing tool in the field of implantology. These software solutions offer clinicians a precise and efficient approach to dental implant placement, transforming the way oral rehabilitation is conducted. Dental implantology has experienced remarkable growth as a reliable and durable treatment modality for tooth loss [2]. Traditional implant planning involved the use of 2D radiographs and physical study models, which relied heavily on clinician experience and intuition. However, this conventional approach posed limitations in terms of accuracy, visualisation, and predictability [3].

The advent of digital planning software has revolutionised implantology by offering clinicians a 3D virtual platform for comprehensive treatment planning. These software solutions utilise advanced imaging technologies, such as Cone Beam Computed Tomography (CBCT) and intraoral scanning, to generate accurate and detailed 3D models of the patient's dentition [3]. These virtual models serve as a blueprint for precise implant placement, enabling clinicians to evaluate bone quality and quantity, determine optimal implant size, position, and angulation, and anticipate prosthetic outcomes with exceptional accuracy.

The present review aimed to explore the capabilities, benefits, and limitations of digital planning software in implantology, shedding light on its impact on clinical practice and patient outcomes.

Key historical developments in the evolution of digital planning software: Digital planning software has evolved significantly over the years, revolutionising the way individuals and organisations manage their tasks and projects. The historical background of these software solutions can be traced back to the early days of computer technology and the advent of personal computers. In the 1980s, with the rise of personal computing, various rudimentary planning tools began to emerge, primarily as standalone desktop applications. These early software programmes provided basic functionality such as task lists, calendars, and reminders, aimed at helping individuals stay organised and manage their time effectively [4-6].

As computing technology advanced, the capabilities of planning software expanded as well. In the 1990s, with the proliferation of the internet, web-based planning tools emerged, allowing for collaboration and real-time sharing of information across teams and organisations. These web-based solutions brought about a new era in digital planning, enabling seamless communication and coordination among team members, regardless of their physical location. In the early 2000s, the concept of project management gained traction, leading to the development of more robust planning software. As cloud computing gained popularity, online project management platforms emerged, offering anytime, anywhere access to project data and fostering collaboration on a global scale [5-7].

Over the years, digital planning software has continued to evolve and adapt to the needs of users. Modern planning tools now offer a wide range of features, including task assignment, progress tracking, document sharing, communication channels, and analytics, all within a user-friendly interface. Furthermore, integration with other productivity tools, such as email clients, messaging applications, and document management systems, has become commonplace, ensuring a seamless workflow across various applications [7].

Key features and functionality: Digital planning software offers an array of features and tools designed to enhance the accuracy and efficiency of dental implant placement. These platforms enable clinicians to manipulate virtual models, facilitating comprehensive treatment planning from surgical placement to final prosthesis design [3-5]. Key features include:

- **3D visualisation:** Digital planning software provides a clear and detailed visualisation of the patient's anatomy, allowing clinicians to assess critical structures, such as the proximity of nerves, sinuses, and adjacent teeth. This comprehensive visualisation helps in identifying potential anatomical challenges and selecting the most suitable implant sites [3].
- **Virtual implant placement:** Clinicians can virtually position implants within the 3D model, considering bone quality, quantity, and aesthetic considerations. The software aids in selecting the appropriate implant size, angulation, and depth, ensuring optimal support and stability for the final prosthesis [4,5].
- **Prosthetic-driven planning:** Digital planning software facilitates a prosthetic-driven approach, which emphasises the final restoration during implant planning. Clinicians can virtually design the desired prosthesis, ensuring harmonious integration with the patient's dentition and surrounding structures. This approach enhances treatment predictability and enables efficient communication with the dental laboratory [5].
- **Simulations and predictive tools:** These software solutions often incorporate simulation tools that allow clinicians to assess the biomechanical aspects of implant placement. Virtual simulations aid in evaluating stress distribution, occlusal forces, and bone-implant interface dynamics, thereby assisting in treatment optimisation and reducing the risk of complications [3-5,7].

Key Technical Developments

- **Cone beam Computed Tomography (CBCT):** The introduction of CBCT by Mozzo P et al., in 1998 and its subsequent approval by the US Food and Drug Administration (FDA) [4,8] in 2001 has significantly transformed the diagnosis and treatment planning of dental implants. Previously, dentistry, including implant dentistry, heavily relied on conventional 2D periapical and panoramic radiographs, while oral and maxillofacial surgeons were familiar with 3D facial-skeletal evaluations through Computerised Axial Tomography (CT/CAT) scans. CBCT revolutionised dental radiology by providing high-resolution 3D images, reducing radiation exposure, and offering convenience with a quick scan time. However, it has some limitations such as image graininess, limited contrast resolution, and the challenge of integrating CBCT images into dental implant planning software applications [9].
- **Intraoral Optical Scanners (IOS):** Over the past 30 years, the use of IOSs in dentistry has evolved with advancements in Computer-aided Design/Computer-aided Manufacturing (CAD/CAM) technologies [10]. Initially adopted by restorative dentists and prosthodontists, the ergonomics, size, and cost of scanners have improved, making them more accessible to various dental specialties. IOS can generate Standard Triangulation Language (STL) files, which can be imported into treatment planning software applications, allowing their use in orthodontics, periodontal surgery, oral and maxillofacial surgery, and dental implantology. The combination of IOS-generated STL files and CT/CBCT imaging enables accurate treatment planning, virtual tooth placement, and precise dental implant placement [4,10].
- **Surgical implant planning software and guided instrumentation:** For over two decades, dental implant planning software applications have been developed and refined [3,11]. These software applications, either open or closed, allow for treatment planning and surgical guide fabrication using different dental implant systems. Many dental implant manufacturers offer implant-specific guided surgery instrumentation, facilitating accurate implant placement while avoiding anatomical structures. Guided surgery can be fully guided, involving the use of guided instrumentation throughout the drilling sequence, or pilot-guided, with guidance limited to the initial osteotomy. Stereolithographically produced, milled, or printed surgical guides are commonly used in guided surgery workflows.
- **In-office printers:** Most implant planning software applications support the creation of surgical guide STL files, which can be used for guide fabrication through stereolithography, milling, or printing. In-office 3D printers have been developed to enable clinicians to print surgical guides themselves [4,12]. While the cost-effectiveness of providing in-office printing services may be debated, some clinicians opt for this approach. However, concerns have been raised regarding the accuracy and appropriateness of in-office printers compared to manufacturer-produced surgical guides [4].

Static surgical guides and dynamic navigation: Guided surgery using "static" surgical guides has been extensively researched and established for more than 15 years [1,6,13]. Dynamic navigation and robotic surgery have recently emerged as alternative techniques, but the supporting literature is limited, particularly for robotic surgery. While there are ongoing debates among clinicians regarding the advantages, disadvantages, technical considerations, equipment variations, costs, time commitment, ease of use, and supporting evidence of different guided implant placement technologies, it is widely acknowledged that guided implant placement offers superior accuracy and predictability compared to freehand placement [13].

Today, digital planning software has become an indispensable tool for individuals, teams, and organisations across different industries, facilitating efficient project management, optimising resource allocation, and enhancing overall productivity. With the advent of AI and machine learning, the future of planning software holds the promise of advanced automation, predictive analytics, and personalised recommendations, further empowering users to plan, execute, and succeed in their endeavors [3,4].

Clinical benefits and outcomes: The integration of digital planning software in implantology has brought forth numerous clinical benefits, leading to improved patient outcomes [1,2]. Firstly, these platforms enhance accuracy and precision in implant placement, minimising the risk of surgical complications and ensuring predictable results. By virtually visualising the implant site, clinicians can anticipate anatomical challenges and devise appropriate treatment strategies, reducing the incidence of nerve injury, sinus perforation, and damage to adjacent teeth [5].

Secondly, digital planning software facilitates a collaborative approach between the clinician, the dental laboratory, and the patient. The ability to share 3D models and treatment plans enhances communication, enabling a more comprehensive and patient-centered treatment experience. Patients can visualise the proposed treatment outcomes, fostering better understanding and informed decision-making [5,7]. Lastly, the efficiency of digital planning software streamlines the treatment process, saving valuable chairside time and reducing patient discomfort. With accurate preoperative planning, the surgical procedure becomes more efficient, requiring fewer adjustments and reducing the need for additional interventions. This not only improves patient satisfaction but also enhances the overall cost-effectiveness of implant treatment [7].

Limitation(s) and Consideration(s)

While digital planning software offers numerous advantages, it is essential to acknowledge its limitations and consider certain factors when utilising these platforms in clinical practice. Firstly, the accuracy and reliability of the software depend on the quality of the input data, such as CBCT scans and intraoral impressions [3,14]. Clinicians must ensure the acquisition of high-quality images and accurate digital impressions to optimise the accuracy of the virtual models.

Additionally, the learning curve associated with digital planning software should be considered. Clinicians and their teams may require training and practice to fully harness the capabilities of these platforms. Adequate knowledge and proficiency in software manipulation, interpretation of virtual models, and understanding the limitations of the technology are crucial for successful implementation [4,10]. Furthermore, the cost of acquiring and maintaining digital planning software should be taken into account. These platforms often involve significant initial investments, including hardware, software licenses, and staff training. Clinicians must carefully evaluate the cost-benefit ratio based on their practice's specific needs and patient population [10].

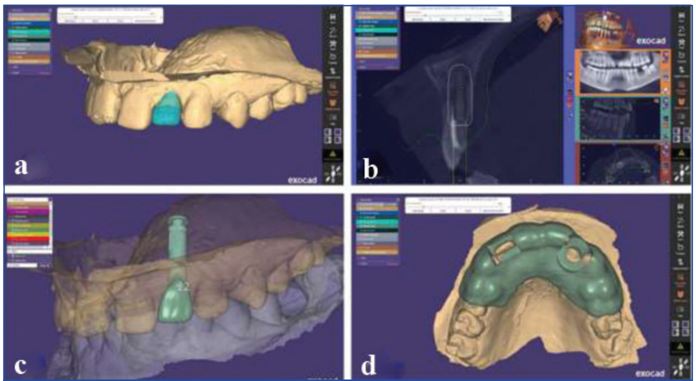
The commercially available digital planning software [Table/Fig-1] [15-25]: A variety of digital planning systems are already available on the market, such as Keystone Dental's 3D Diagnostix [15], OnDemand3D [16], Dental Wings DWOS Implant [17], Exocad Dental CAD [18], Planmeca Romexis® Implant [19], 3Shape Implant Studio [20], Noble Clinician [21], coDiagnostiX [22], Blue Sky Plan [23], Simplant software [24], and R2Gate software [25]. All of these software options provide 3D visualisation, virtual implant placement, prosthetic-driven planning, simulation tools, and collaboration features. They are available at varying costs with excellent customer support. However, they may vary in user interfaces and integration with other implant systems. Some software options that are likely to be available in India include OnDemand3D [16], Dental Wings DWOS Implant [17], Exocad Dental CAD [18], Planmeca Romexis® Implant [19], 3Shape Implant Studio [20], Noble Clinician [21], Blue Sky Plan [23], Simplant software [24], and R2Gate system [25].

Software	Country of origin	User interface preferences	Integrations
Keystone Dental's 3D Diagnostix [15]	United States	Customisable, user-friendly	Integrates with various systems (e.g., intraoral scanners)
OnDemand3D [16]	South Korea	Intuitive, easy to navigate	Integrates with various systems (e.g., CAD/CAM systems)
Dental Wings DWOS Implant [17]	Canada	User-friendly, comprehensive	Integrates with Dental Wings CAD/CAM systems
ExocadDentalCAD [18]	Germany	Customisable, workflow-riented	Integrates with various systems (e.g., CAD/CAM systems)
PlanmecaRomexis® Implant [19]	Finland	Intuitive, streamlined	Integrates with Planmeca CAD/CAM systems
3Shape Implant Studio [20]	Denmark	Modern, intuitive	Integrates with 3Shape CAD/CAM systems
Noble Clinician [21]	United States	User-friendly, comprehensive	Integrates with various systems (e.g., intraoral scanners)
CoDiagnostiX [22]	Germany	Intuitive, comprehensive	Integrates with various systems (e.g., intraoral scanners, CAD/CAM systems)
Blue Sky Plan [23]	United States	User-friendly, simplified	Integrates with various systems (e.g., intraoral scanners)
Simplant software [24]	Belgium	Advanced, feature-rich	Integrates with various systems (e.g., intraoral scanners, CAD/CAM systems)
R2Gate software [25]	Italy	User-friendly, streamlined	Integrates with various systems (e.g., intraoral scanners)

[Table/Fig-1]: Commercially available digital implant planning softwares [15-25].
CAD: Computer-aided design; CAM: Computer-aided manufacturing

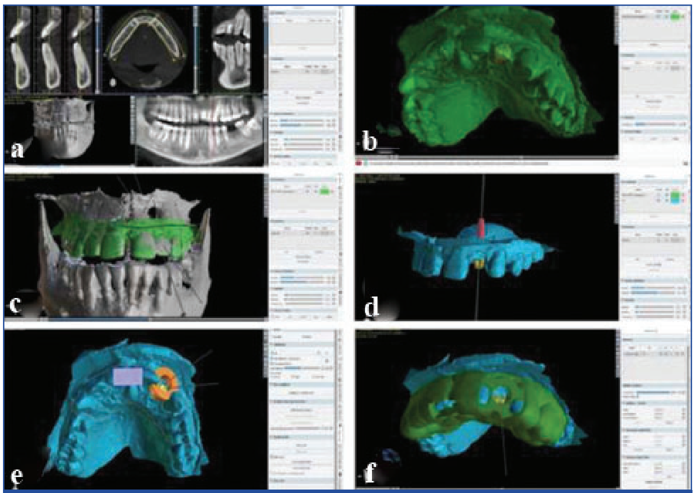
While the advantages of digital planning software are common in most software options, each software also offers unique features and strengths. Let's take a look at some examples:

- **Keystone Dental's 3DDiagnostix [15]:** Keystone Dental's 3D Diagnostix software stands out for its customisable user interface, user-friendly experience, and excellent customer support. It integrates with various systems, such as intraoral scanners, and offers collaboration features for enhanced teamwork.
- **On Demand 3D [16]:** On Demand 3D software is known for its intuitive navigation, easy integration with CAD/CAM systems, and comprehensive customer support. It provides a simplified user interface and streamlined workflow for efficient treatment planning.
- **Dental wings DWOS implant [17]:** Dental Wings DWOS implant software offers a user-friendly interface, seamless integration with Dental Wings CAD/CAM systems, and comprehensive implant planning capabilities. Its focus on comprehensive planning ensures accurate and efficient treatment workflows.
- **Exocad DentalCAD [18]:** Exocad DentalCAD software provides a customisable interface, workflow-oriented design, and seamless integration with various CAD/CAM systems. Its flexibility allows users to adapt the software to their preferences and optimise their workflow [Table/Fig-2a-d].



[Table/Fig-2]: Implant planning and surgical guide designing using Exoplan: (a) Preoperative wax-up tooth in model scan; (b) Implant planning in Exoplan (palatally access planned); (c) Final plan for guide fabrication; (d) Surgical guide design for 3D printing.

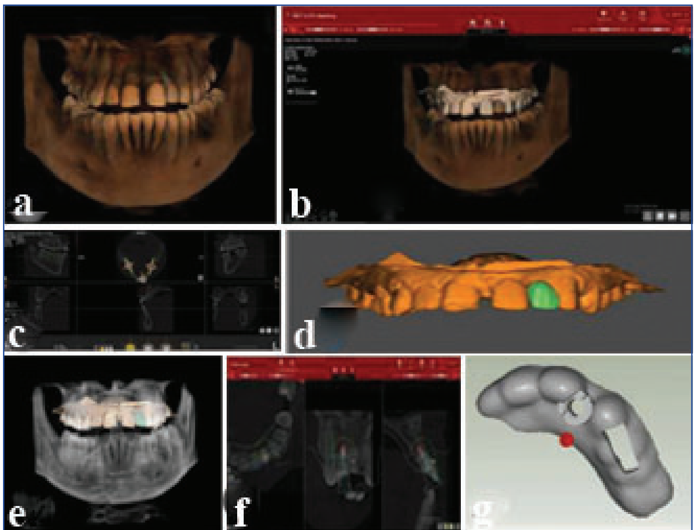
- **PlanmecaRomexis® implant [19]:** PlanmecaRomexis® Implant software offers an intuitive and streamlined user experience, integration with Planmeca CAD/CAM systems, and excellent customer support. Its user-friendly interface simplifies treatment planning and collaboration.
- **3Shape implant studio [20]:** 3Shape Implant Studio software is known for its modern and intuitive user interface, integration with 3Shape CAD/CAM systems, and advanced implant planning capabilities. It provides a comprehensive suite of tools for precise treatment planning.
- **Noble clinician [21]:** Noble Clinician software offers a user-friendly interface, comprehensive implant planning features, and integration with various systems, such as intraoral scanners. Its emphasis on comprehensive treatment planning ensures accurate and efficient implant placement.
- **coDiagnostiX [22]:** coDiagnostiX software offers an intuitive user interface, comprehensive planning capabilities, and extensive integration with systems such as intraoral scanners and CAD/CAM systems. Its user-friendly design promotes efficient treatment planning and collaboration.
- **Blue sky plan [23]:** Blue Sky Plan software is known for its user-friendly and simplified interface, seamless integration with intraoral scanners, and comprehensive implant planning features. Its streamlined design ensures easy treatment planning and intuitive navigation [Table/Fig-3a-f].
- **Simplant software [24]:** Simplant software provides advanced features, rich simulation tools, and seamless integration with various systems. It offers precise implant placement, virtual planning, and surgical guide design capabilities. Simplant's strength lies in its comprehensive implant planning and simulation



[Table/Fig-3]: Implant planning and fabrication of surgical guide using Blue Sky Bio software: (a) Main window of Blue Sky Bio software; (b) STL of the model cast; (c) Model matching; (d) Implant planning in BSB after virtually extracting the tooth (22); (e) Customisation of implant guide; (f) Final guide design using Blue Sky Bio for 3D printed surgical guide.

tools, allowing clinicians to visualise the final outcome and assess anatomical structures for optimal implant placement.

- **R2Gate [25]:** R2Gate software offers an intuitive user interface, comprehensive implant planning features, and advanced integration capabilities. It provides tools for accurate virtual implant placement, bone density analysis, and prosthetic-driven planning. R2Gate's unique feature is its emphasis on bone density analysis, allowing clinicians to assess bone quality and plan implant placement accordingly [Table/Fig-4a-f].



[Table/Fig-4]: Implant planning and surgical guide designing using R2Gate software: (a) CBCT image opened in first window; (b) Sterilisation-converting DICOM file to STL; (c) Model matching; (d) Wax-up of the indicated tooth required for implant planning; (e) Incorporating wax tooth STL file in CBCT imaging; (f) Implant planning done in R2Gate software; g) Designing of surgical guide using R2ware.

Each of the above mentioned software options [15-25] has its own strengths and unique features, catering to the diverse needs of implantologists. These digital planning software solutions provide clinicians with powerful tools to visualise and plan implant treatments accurately, resulting in improved treatment outcomes and patient satisfaction. The common advantages of enhanced visualisation, virtual implant placement, prosthetic-driven planning, and simulation tools, combined with the unique features of each software, make them indispensable in modern implantology practice [10,15].

Clinical efficacy of digital planning in implant placement: The extensive search on the PubMed database provided only nine randomised control trials that offer valuable insights into the accuracy and outcomes of different implant placement techniques in a digitally guided workflow [Table/Fig-5] [13,26-33]. Orban K et al., conducted a prospective, randomised study comparing half-guided implant placement using machine-driven or manual insertion methods [26]. The results indicated that half-guided implant placement with machine-driven insertion demonstrated superior accuracy compared to manual insertion. Franchina A et al., performed a randomised in-vitro study comparing the accuracy of the intraoral scan method versus cone beam computed tomography superimposition in assessing dental implant accuracy [27]. The findings revealed that the intraoral scan method showed comparable accuracy to cone beam computed tomography superimposition, providing a reliable alternative for evaluating implant positions.

In another randomised controlled trial, Sancho-Puchades M et al., compared conventional and computer-assisted implant planning and placement in partially edentulous patients [28]. The study demonstrated that computer-assisted implant planning and placement resulted in improved patient satisfaction and comfort compared to conventional methods. Lou F et al., evaluated the accuracy of partially guided and fully guided templates in implant surgery of anterior teeth through a randomised controlled trial [29]. Their findings showed that fully guided templates achieved higher accuracy and reduced deviation compared to partially guided templates, particularly in anterior tooth implant surgery.

Tallarico M et al., conducted a randomised controlled trial to assess the accuracy of computer-assisted template-based implant placement using conventional impression and scan model or intraoral digital impression [30]. Both methods yielded accurate implant placement with similar outcomes after one year of follow-up.

Wei SM et al., investigated the accuracy of machine-vision-assisted dynamic navigation in digitally planned prosthetically guided immediate implant placement [31]. The study revealed that machine-vision-assisted dynamic navigation improved the accuracy of immediate implant placement compared to conventional methods.

Varga E et al., compared the accuracy of freehand versus guided dental implantation in a randomised clinical trial [13]. The results indicated that guided dental implantation resulted in higher accuracy and reduced deviation compared to freehand implantation.

Author	Year	Place of study	Objectives	Outcomes
Sancho-Puchades M et al., [28]	2019	Zurich, Switzerland	Compare patient-related outcome measures between conventional and computer-assisted implant planning and placement	Computer-assisted implant planning and placement showed improved patient satisfaction and comfort compared to conventional methods
Tallarico M et al., [30]	2019	Tirana, Albania	Assess the accuracy of computer-assisted template-based implant placement using conventional impression and scan model or intraoral digital impression	Both conventional impression and scan model, as well as intraoral digital impression, resulted in accurate implant placement with similar outcomes after one year of follow-up
Smitkarn P et al., [32]	2019	Thailand	Evaluate the accuracy of single-tooth implants placed using fully digital-guided surgery and freehand implant surgery	Fully digital-guided surgery resulted in higher accuracy and reduced deviation compared to freehand implant surgery in single-tooth implant placement
Franchina A et al., [27]	2020	Italy	Compare the accuracy of intraoral scan method versus cone beam computed tomography superimposition in assessing dental implant accuracy between planned and achieved positions	The intraoral scan method showed comparable accuracy to cone beam computed tomography superimposition in evaluating the accuracy of dental implant positions

Varga E et al., [13]	2020	Hungary	Compare the accuracy of freehand versus guided dental implantation	Guided dental implantation resulted in higher accuracy and reduced deviation compared to freehand implantation
Lou F et al., [29]	2021	China	Evaluate the accuracy of partially guided and fully guided templates in implant surgery of anterior teeth	Fully guided templates resulted in higher accuracy and reduced deviation compared to partially guided templates in anterior tooth implant surgery
Orban K et al., [26]	2022	Hungary	Evaluate the accuracy of half-guided implant placement using machine-driven or manual insertion methods	Half-guided implant placement with machine-driven insertion showed superior accuracy compared to manual insertion
Wei SM et al., [31]	2022	China	Evaluate the accuracy of machine-vision-assisted dynamic navigation in digitally planned prosthetically guided immediate implant placement	Machine-vision-assisted dynamic navigation improved the accuracy of digitally planned prosthetically guided immediate implant placement compared to conventional methods
Ngamprasertkit C et al., [33]	2022	Thailand	Compare the implant position accuracy between using only a surgical drill guide and surgical drill guide with implant guide in a fully digital workflow	The use of a surgical drill guide with an implant guide in a fully digital workflow resulted in improved implant position accuracy compared to using only a surgical drill guide

[Table/Fig-5]: Summary of randomised controlled trials on accuracy of digital implant planning software [13,26-33].

Smitkarn P et al., evaluated the accuracy of single-tooth implants placed using fully digital-guided surgery versus freehand implant surgery [32]. Their findings showed that fully digital-guided surgery achieved higher accuracy and reduced deviation compared to freehand implant surgery in single-tooth implant placement.

Finally, Ngamprasertkit C et al., conducted a randomised clinical trial comparing implant position accuracy between using only a surgical drill guide and a surgical drill guide with an implant guide in a fully digital workflow [33]. The study demonstrated that the use of a surgical drill guide with an implant guide in a fully digital workflow improved implant position accuracy compared to using only a surgical drill guide.

Overall, these studies provide valuable evidence supporting the effectiveness and accuracy of various implant placement techniques, highlighting the benefits of incorporating advanced technologies and computer-assisted planning in implant dentistry [15-25]. These findings have important implications for clinical practice and can help guide clinicians in selecting the most appropriate approach for achieving optimal implant placement outcomes.

However, there is a dearth of randomised controlled trials [34-42] on the clinical outcomes of digitally guided implant placement, with some studies being retrospective [34,37,38,41] and others prospective [35,36,39,40,42]. [Table/Fig-6,7] have evaluated the clinical outcomes in terms of implant survival rate, marginal bone loss, and implant-prosthesis failure over variable follow-up periods in healed and/or immediate extraction sockets for single tooth replacement to provision of full arch prosthesis [34-42]. The

Author	Year	Place of study	Study design	Type of dental arch	Condition of implant site	Timing of provision of restoration	Software employed
Meloni SM et al., [34]	2010	Italy	Retrospective analysis	Fully edentulous	Maxilla	Immediate	CBCT scans
Pozzi A et al., [35]	2012	Italy	Proof-of-concept prospective	Atrophic posterior	Not specified	Not specified	NobelGuide™
Marra R et al., [36]	2013	Italy	Multicentre clinical evaluation	Full mouth	Not specified	Immediate	NobelGuide™
Lopes A et al., [37]	2015	Lisbon, Portugal	Prospective report	Edentulous jaws	Not specified	Not specified	The NobelGuide®
Polizzi G and Cantoni T [38]	2015	Italy	5 years follow-up	Maxillary	Fresh extraction and healed sites	Immediate	NobelGuide™
Vogl S et al., [39]	2015	Austria	Randomised clinical pilot study	Not specified	Not specified	Immediate occlusal and non occlusal	Simplant®
Yamada J et al., [40]	2015	Japan	Prospective clinical study	Edentulous maxillae	Flapless guided implant placement	Immediate	NobelGuide™
Ciabattoni G et al., [41]	2017	Italy	3 years follow-up	Full arch	Healed and fresh extraction	Immediate	NobelGuide™
Derksen W et al., [42]	2019	Amsterdam	Prospective cohort study	Not specified	Tooth-supported	Not specified	coDiagnostiX

[Table/Fig-6]: Clinical studies on digital planning in implant placement [34-42].
CBCT: Cone beam computed tomography

Author	Year	Place of study	Implant survival rate	Marginal bone loss	Implant prosthesis complications
Meloni SM et al., [34]	2010	Italy	100% at 1 year	Average 1.6 mm	Not specified
Pozzi A et al., [35]	2012	Italy	96.3% at 3 years	0.6±0.3 mm	Restoration chipping (n=3)
Marra R et al., [36]	2013	Italy	97.9% at 3 years	1.9±1.3 mm	Prosthesis fracture (n=9)
Lopes A et al., [37]	2015	Lisbon, Portugal	96.6% at 5 years	1.9±1.1 mm	Seven patients experienced fracture of the definitive prosthesis (6 patients were heavy bruxers), and abutment screw loosening occurred in 2 patients. Two implants in 2 patients showed peri-implant pathology.
Polizzi G and Cantoni T [38]	2015	Italy	100% at 5 years	0.85±1.28 mm to 1.39±1.29 mm	None
Vogl S et al., [39]	2015	Austria	100% at 1 year	0.4±0.5 mm	Not specified
Yamada J et al., [40]	2015	Japan	98.6% at 1 year	0.32±0.43 mm	Not specified
Ciabattoni G et al., [41]	2017	Italy	97.5% at 3 years	1.32±0.41 mm	Not specified
Derksen W et al., [42]	2019	Amsterdam	99.3% at 1 year	Not specified	Not specified

[Table/Fig-7]: Recent literature studies showing implant survival rates and complications of digital planning software in implant placement [34-42].

findings of these studies [34-42] have depicted excellent implant survival rates and minimal bone loss [34-41], lending weight to the positive impact of digital planning on the clinical outcomes of implants.

Future Perspectives: As digital planning software continues to evolve, the future holds promising advancements in implantology. Integration with AI algorithms may enhance the accuracy and efficiency of treatment planning, offering automated suggestions for implant positioning, bone augmentation, and prosthesis design. Virtual Reality (VR) and Augmented Reality (AR) technologies may further enhance the clinician's visualisation and decision-making processes, providing a more immersive and intuitive planning experience [10,33,40-42]. Furthermore, advancements in additive manufacturing, commonly known as 3D printing, may facilitate the fabrication of patient-specific surgical guides and customised implant restorations. The integration of digital planning software with 3D printing technologies could streamline the treatment workflow, reducing chairside time and improving treatment outcomes [12].

CONCLUSION(S)

Digital planning software has revolutionised implantology by offering clinicians a precise, efficient, and patient-centered approach to dental implant placement. With its 3D visualisation, virtual implant placement, prosthetic-driven planning, and predictive tools, these platforms empower clinicians to optimise treatment outcomes, enhance patient communication, and streamline the treatment process. However, it is crucial to consider the limitations and costs associated with these technologies. As technology continues to advance, the future holds exciting possibilities for further enhancing implant planning and rehabilitation, paving the way for improved patient care in implantology.

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PARTICULARS OF CONTRIBUTORS:

1. PhD Scholar, Department of Integrated Implantology, Santosh Deemed to be University, Ghaziabad, Uttar Pradesh, India.
2. Professor, Department of Paediatric and Preventive Dentistry, Santosh Deemed to be University, Ghaziabad, Uttar Pradesh, India.
3. Professor, Department of Oral and Maxillofacial Surgery, Santosh Deemed to be University, Ghaziabad, Uttar Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Neeti Mittal,
No. 1, Santosh Nagar, Pratap Vihar, Ghaziabad-201009, Uttar Pradesh, India.
E-mail: dr.neetipgi@gmail.com

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