Journal of Dentistry 175 (2026) 106857

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

A practical, descriptive comparison of seven guided implant surgery planning software using clinical scenarios

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ARTICLE INFO

Keywords:
Guided implant surgery
Implant planning software
Digital workflow
Prosthetic planning
Surgical guide

ABSTRACT

Objectives: To provide a practical and descriptive comparison of contemporary clinical planning software for guided implant surgery, focusing on digital workflow feasibility, user experience, system requirements, cost models, and the availability of prosthetic component libraries, based on real-world expert use.
Methods: Seven implant planning software platforms (DentiqGuide, BlueSkyPlan, CoDiagnostix, Implant Studio, R2Gate, ExoPlan, and RealGuide) were evaluated by experienced clinicians using two predefined clinical scenarios representing moderate and high planning complexity. User interface (UI) friendliness was assessed using a Likert scale, and planning time was recorded according to standardized task definitions. Hardware requirements, pricing models, available functionalities, and workflow completeness were compared. All quantitative outcomes were analysed descriptively.
Results: Descriptive values of UI scores ranged from 5.3 to 10, while planning times ranged from 10 to 67 minutes depending on workflow completeness and task availability. Based on a predefined complete workflow (CW), only DentiqGuide and BlueSkyPlan enabled completion of all planning steps within a single clinical software environment, whereas other platforms required additional modules or external tools. System requirements and cost structures differed substantially, including license-based and pay-per-use models. Semi-automated functions, such as wax-up–guided implant positioning, were available in several platforms. However, none provided fully automated planning. A consistent limitation across all evaluated software was restricted availability of prosthetic components within integrated libraries.
Conclusions: Within the limits of this descriptive, expert-based evaluation, the findings should be interpreted as exploratory and hypothesis-generating rather than as comparative performance rankings. However, current clinical implant planning software may demonstrate substantial variability in workflow integration, usability and cost structure, and a common limitation in the availability of prosthetic component libraries. These findings highlight a persistent gap in achieving fully prosthetically driven digital workflows in clinical planning environments. The present findings reflect expert-dependent interaction with individual software platforms and were not validated using inter-rater reliability assessment. Therefore, the reported outcomes should not be interpreted as standardized or directly comparable measures of usability or workflow performance.
Clinical Significance: Understanding practical digital workflow limitations, particularly restricted prosthetic component libraries, may support clinicians in selecting implant planning software that aligns with their experience level, case complexity, and clinical setting, while emphasizing the need for careful verification of prosthetic feasibility during digital treatment planning.

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https://doi.org/10.1016/j.jdent.2026.106857
Received 28 October 2025; Received in revised form 22 June 2026; Accepted 24 June 2026
Available online 27 June 2026
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1. Introduction

Cone beam computed tomography (CBCT) enables precise assessment of bone dimensions, the intraosseous structures, neighboring teeth, and soft tissue dimensions [1]. For dental implant planning, CBCT can be integrated into modern implant planning software to allow clinicians to choose an ideal implant and plan for correct three dimensional (3D) positioning. By examining cross sections of the proposed implant site in horizontal and vertical planes, clinicians can select the appropriate implant size and plan its ideal 3D position [2]. However, it remains challenging to transfer the planned ideal implant position to the patient's mouth accurately [3].

Surgical guides are used by the surgeon to control implant placement and can be made from various materials. Modern guides are commonly fabricated using computer aided design and computer-aided manufacturing (CAD/CAM) technologies, which improve transfer of the virtual plan to the patient's mouth during surgery. CAD/CAM guides can be static devices in the form of surgical guides used for static computer-assisted implant surgery (sCAIS). Alternatively, the CAD/CAM guides may support real-time navigation of dynamic computer-assisted implant surgery (dCAIS) [4], or robotic computer-assisted implant surgeries (rCAIS) [5]. A recent meta-analysis concluded that sCAIS currently demonstrates the most predictable accuracy outcomes [6]. Today, the static implant guides are designed in a number of different implant planning software packages that share similar capabilities. Previous software analyses by Kernen et al. and Flügge et al. have provided comprehensive assessments of implant planning software, focusing on data handling, virtual implant planning, prosthetic set-up, and guide design capabilities [7,8]. These studies established an important framework for understanding software functionalities and limitations. Nevertheless, rapid evolution of implant planning software, changes in modular software architectures, and growing clinical demand for fully integrated digital workflows highlight the need for continued evaluation under real-world conditions. The present study complements the earlier studies by providing a practical, expert-based descriptive evaluation of contemporary clinical software versions, emphasizing Complete Workflow (CW) feasibility, availability of prosthetic component libraries, and usability during routine expert use, rather than formal performance validation or feature-based benchmarking. The existing literature on implant planning software and workflows does not consistently integrate current evidence on prosthetically driven 3D implant positioning. Virtual implant planning is often described as positioning the implant at the center of the prosthetic set-up (wax-up), which represents the future restoration [2,4,7,8]. However, several studies indicate that ideal implant positioning also requires maintaining appropriate vertical distance from implant platform to the restorations' cervical margin to achieve correct size, emergence angle and profile, including a minimum abutment height of 3–4 mm and an emergence angle not exceeding 30–40° [9–11]. To provide sufficient space for the supracrestal implant complex (SIC) [9], the implant must be restored with a prosthesis on an abutment that has the correct size, emergence angle and profile (Fig. 1A and 1B). If abutment specifications are not defined during planning, the implant may ultimately be restored with an abutment that has unfavorable gingival height [12], emergence angles [13] and profile [14]. Gaps therefore remain in the functionalities of available implant-planning software, particularly regarding virtual libraries for prosthetic components.

Thus, the aim of this study is to analyze contemporary implant planning software with respect to available virtual libraries, capabilities, system requirements, costs, user interface (UI) friendliness and completeness of the ideal workflow. The present study defines an ideal CW as a sequence of planning steps that enables a clinician to independently complete guided implant surgery planning within a single clinical software package, without reliance on external laboratory software or additional design modules. This CW workflow involves data import, virtual wax-up and implant positioning through the prosthetic component, surgical guide design, and temporary prosthesis design. The complete CW workflow is described in detail and illustrated in Fig. 2.

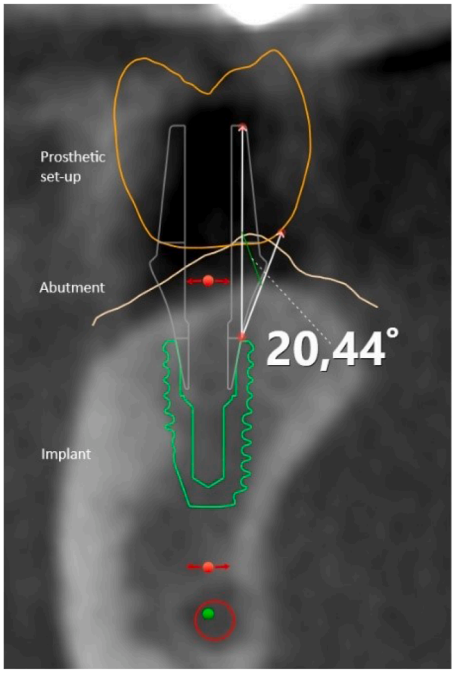

Fig. 1A. Crown down implant planning including prosthetic set-up, prosthetic abutment with appropriate gingival height (4 mm) and narrow emergence angle (<40 degrees) and implant. In such protocol implant is positioned in the tissues through the prosthetic abutment, securing appropriate space for the temporary or permanent restoration.

2. Materials and methods

The study was conducted between December 2022 and December 2023 in five centers in Australia, Egypt, Italy, Lithuania and Poland. Five experienced implant clinicians with long-term experience using digital implant planning software performed the evaluation of seven implant planning platforms. To ensure evaluator anonymity, individual identifiers were replaced with coded labels (E1–E5) in Table 1. The evaluated software platforms were: DentiqGuide v. 1.3.052023011 (DG) (3DII, Seoul, South Korea), BlueSkyPlan v. 4.9.4 (BSP) (BlueSkyBio, Libertyville, United States), CoDiagnostix v. 10.7 (CD) (DentalWings, Canada), Implant Studio v. 2023.1.6 (IS) (3Shape, Copenhagen, Denmark), R2Gate v. 2.2.0 (R2G) (MegaGEN IMPLANT Co.,Ltd., Seoul, South Korea), ExoPlan v. 3.1 (EP) (Exocad GmbH, Darmstadt, Germany) and RealGuide v. 5.1 (RG) (3DIEMME srl, Figino Serenza, Italy).

Evaluators were not blinded to software identity, as each platform features a distinct and readily recognizable interface and was assessed by an expert user with routine experience using that specific software. This approach was deliberately chosen to enable a real-world expert evaluation and to avoid confounding results with learning-curve effects. Each software platform was assessed by a single expert user familiar with that system. Therefore, inter-rater agreement analysis was not performed. The study was not designed to evaluate cross-observer variability, but rather to capture expert interaction under routine clinical conditions. Accordingly, the present study was not intended to provide standardized cross-platform usability benchmarking, but rather descriptive expert-based observations reflecting interaction with individual software environments.

The study consisted of two parts, A and B. Part A - user perception - was an evaluation of functions available in different software and included computer system requirements for effective software operation, software functionalities, price, virtual libraries and completeness of

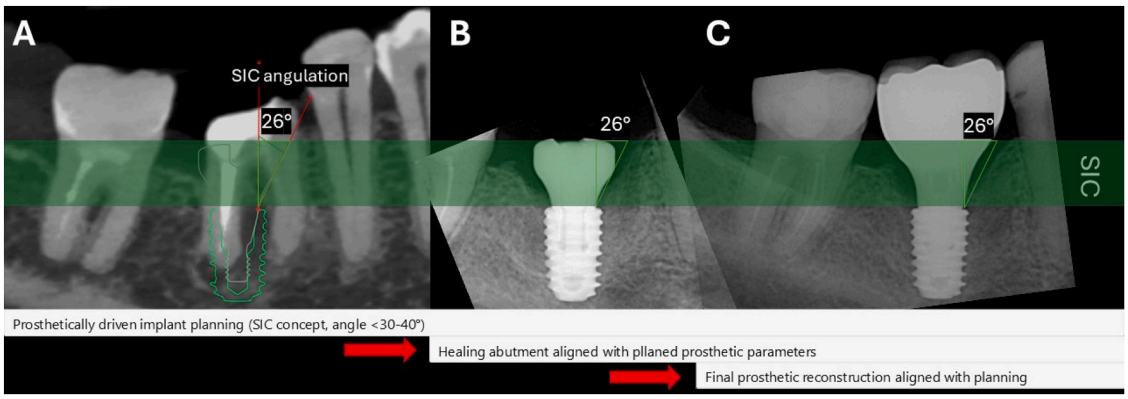

Fig. 1B. Prosthetically driven implant planning based on healing abutment selection and its clinical and radiographic validation. (A) Virtual implant planning incorporating a healing abutment to define implant position according to prosthetic requirements. The implant is positioned to achieve a controlled emergence profile and appropriate angulation for the supra crestal implant complex (SIC), with angulation maintained below 30–40° based on the specification of the healing abutment. (B) Postoperative radiographic view demonstrating implant placement consistent with the prosthetic-driven plan and planned healing abutment alignment. (C) Radiographic projection illustrating consistency with the original implant position and prosthetic design. Green zone indicates reference levels used to assess implant depth, emergence profile, and SIC alignment across imaging modalities. This figure is provided as a conceptual clinical illustration and does not represent measured outcomes of the present study.



Fig. 2. Complete Workflow (CW) expected from the planning software. The diagram illustrates the sequence of steps required to complete implant therapy planning, from data import and virtual wax-up through implant positioning with prosthetic libraries, surgical guide design and temporary prosthesis design.

Table 1
Software name, version, evaluator and computer system requirements.

Software name, version and the evaluator	Implant Studio v. 2023.1.6 (IS) E1	Exoplan v. 3.1 (EP) E2	Dentiq Guide v. 1.3.0520230111 (DG) E3	Blue Sky Plan v. 4.9.4 (BSP) E4	CoDiagnostix v. 10.7 (CD) E4	R2Gate v. 2.2.0 (R2G) E5	RealGuide v. 5.1 (RG) E2
CPU	Intel i7	Intel Quad Core-i7 9700k	Intel i5	Quad Core Intel i7	Intel Core 2 Duo P8600	Intel 7th Gen Core i7	Intel i7
RAM (GB)	32	8	16	4	8	4	8
GPU- Dedicated Graphic Card memory (GB)	4	4	0	1	0	2	3
Screen resolution	1920 × 1080	1920 × 1080	1920 × 1080	1440 × 900	1920 × 1080	1920 × 1080	1920 × 1080
Windows OS	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mac OS	No	No	No	Yes	No	No	Yes
Hard disc (GB)	512	2	2	0.5	15	1	0.5
Network	Yes	Yes	Yes	Yes	Yes	Yes	Yes

the planning workflow from importing data to designing the temporary prosthesis. The cost comparison between pay-per-use (PPU) and license-based software models represents an illustrative scenario based on standardized assumptions and should be interpreted as descriptive

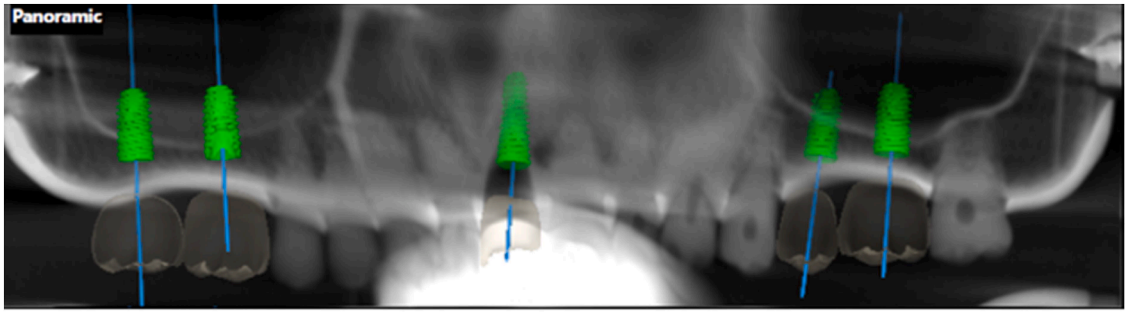

Fig. 3. Case 1, upper arch with 5 implants planned for 17, 16, 11, 25 & 26.

guidance rather than a formal economic analysis. Part B - practical experience - was conducted using each software to plan two clinical scenarios. Digital Imaging and Communication in Medicine (DICOM) and Standard Tessellation Language (STL) files of dental implant training models SUMGU5-maxillary and SUMGL3-mandibular (Osstem Implants, Seoul, South Korea) were prepared and sent with an instructional message to all the evaluators prior to the evaluation process.

Maxillary partially edentulous model was used to plan 5 implants including immediate placement of central incisor with design of an immediate temporary restoration and a tooth-supported surgical guide (Fig. 3). This task was simulated to receive implant rehabilitation of partially edentulous arch and represents a frequently encountered clinical scenario in daily practice. This case requires precise DICOM/STL merging, virtual extraction, single-tooth wax-up, implant positioning in relation to a prosthetic setup, design of a tooth-supported surgical guide, and fabrication of an immediate temporary restoration (single unit). It allowed evaluation of software performance in tasks commonly used by a broad range of clinicians and served as a baseline assessment of workflow organization and expert-perceived usability.

The mandibular edentulous model was used to plan 6 implants for restoration of the full arch. This case requires full-arch planning, prosthetically driven implant positioning, multi-unit abutment (MUA) selection, design of a tissue-supported surgical guide with 3 fixation pins, and planning of a provisional full-arch restoration (Fig. 4). Case 2, chosen as a high-complexity scenario reflecting advanced implant rehabilitation, was included to evaluate more advanced workflow capabilities of the evaluated software in handling advanced workflows, prosthetic libraries, and integration of multiple planning steps. These two scenarios were intentionally selected to represent moderate (single-unit immediate implant placement) and complex (full-arch implant-supported rehabilitation) clinical workflows, allowing evaluation of software performance across different levels of planning complexity and CW integration.

In the present study, CW refers specifically to the ability to perform all planning steps within a single clinical software environment without requiring external laboratory software or additional modules. Software that required integration with laboratory tools or external modules was classified as supporting a partial or extended workflow rather than a standalone CW.

All practical evaluations were performed on high-performance Windows-based workstations with comparable specifications (Intel i7-class CPUs, 64 GB RAM, dedicated GPUs), exceeding manufacturer-recommended requirements. Machines were not identical but were comparable in performance. The times required to perform both cases were measured using a stopwatch under standardized task definitions (sent before testing) and subsequently reviewed by the main authors for consistency. Additional evaluation of the user interface (UI) friendliness was done with the Likert scale [15] from 1 to 10, where 1 is the worst user experience and 10 is the best user experience with the software and its functionalities. However, UI evaluations are subjective expert assessments aimed to critically review the software and use the predefined scale anchors, which were operationally defined and provided to all evaluators prior to testing as follows:

1 – Definitively unfriendly and difficult to use; workflow is non-intuitive and clinically impractical
3–4 – Poor usability; significant obstacles to practical clinical use
5–6 – Acceptable usability; workflow achievable but with notable limitations or inefficiencies
7–8 – Good usability; intuitive workflow with minor limitations
9–10 – Excellent usability; highly intuitive, clinically logical, and well-organized workflow

A standardized spreadsheet (Excel, Microsoft, Redmond, USA) divided into parts A and B was prepared by LZ and JA and completed by the evaluators for their respective software platforms (Table 1). Data for each software were subsequently reviewed and comparatively assessed by an additional expert clinician (ID). Mean values were calculated for planning time and UI scores. These values represent descriptive indicators intended to illustrate practical differences observed by expert users rather than statistically generalizable comparisons.

This study design prioritized ecological validity by capturing expert-level interaction with familiar software environments. However, it was not intended to provide inter-system statistical comparability or standardized usability benchmarking across platforms.

This study did not involve human participants, patient-specific data, or biological material. All analyses were performed exclusively on commercially available training models and their corresponding CBCT-derived DICOM and STL files. Therefore, ethical approval or review by an institutional ethics committee was not required.

3. Results

Part A

3.1. System requirements

The computer system requirements for each evaluated software platform are summarized in Table 1. All software packages are available for Windows-based personal computers. RG and BSP are available for macOS systems. Most platforms required an Intel i7-class CPU as a minimum specification with the exception of DG and CD, which support Intel i5 and Intel Core 2 Duo processors, respectively.

IS had the highest hardware demands, requiring 32 GB of RAM and the largest hard-disk capacity (512 GB). IS and EP required a dedicated graphics processing unit (GPU) with at least 4 GB of dedicated video memory. DG and CD did not formally require a dedicated GPU, however, manufacturers recommend one for optimal performance. All software

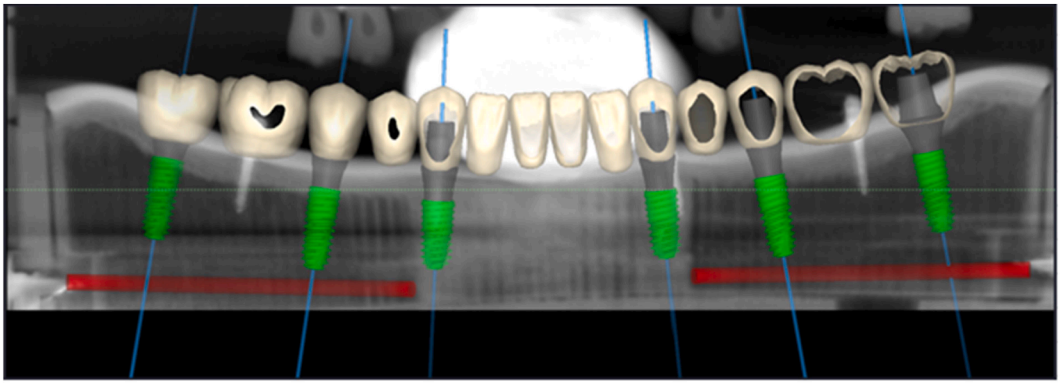

Fig. 4. Case 2, lower arch with implants in the 37, 35, 33, 43, 45, 47 positions.

platforms required a minimum screen resolution of 1920 × 1080 pixels, except BSP, which supports a lower resolution (1440 × 900 pixels).

BSP and RG required the smallest hard-disk storage capacity (0.5 GB). Internet access was required by all software platforms for license verification, updates, and installation of new features. However, continuous network connectivity was not required for offline treatment planning.

3.2. Price comparison

Direct price comparison was challenging because the evaluated software platforms operate under different pricing models. Five software packages (IS, EP, DG, CD and RG) require purchase of an initial license. IS represented the highest initial cost (6500 EUR), whereas RG had the lowest base license price (1140 EUR). However, RG provides planning functionality only, while surgical guide and temporary prosthesis design require an additional RealGuide Design license, resulting in a total annual cost of 3534 EUR.

CD offered the lowest initial license cost among fully licensed systems (2000 EUR). IS, EP, CD and RG licenses covered an unlimited number of cases for planning and export during the license period. With the exception of DG, all licensed platforms required annual renewal fees, ranging from 200 EUR (CD) to 1620 EUR (IS). DG offers a lifetime base license.

BSP and R2G are free to download and do not require an initial license; however, both operate under a pay-per-use (PPU) export model, as does DG for case export. Under the PPU model, planning is unrestricted until export of STL files for surgical guide or provisional restoration fabrication. Case export requires purchase of credits, which are available in bundled packages. For this study, single-export costs were calculated based on 10-credit packages, resulting in per-case costs of 27 EUR (DG), 17.2 EUR (BSP), and 15.2 EUR (R2G). A summary of pricing models is provided in Table 2.

Based on pricing structure, two groups were identified:

Group A – license-based software with unlimited exports but recurring annual costs (IS EP, CD RG),
Group B – PPU-based software with free or low-cost entry (BSP, R2G and DG).

Estimated break-even calculations (Table 3) illustrate the number of cases required for PPU-based software to reach the cost of license-based platforms. IS required the largest number of PPU cases to reach license equivalence, whereas CD required the fewest.

3.3. Functions

A summary of software functionalities is presented in Supplementary Table 1. Substantial differences were observed across software platforms.

3.3.1. Data importing options

All software platforms support multi-file DICOM import. Single-file DICOM import was supported by all platforms except R2G. Import of STL files from intraoral and laboratory scanners was universally supported.

Table 2
Summary of costs to operate the software.

	IS	EP	DG	BSP	CD	R2G	RG + RG Design
License price (EUR)	6500	3230	324	0	2000	0	1140+ 2394= 3534
Case export price (EUR)	0	0	27	17.2	0	15.2	0
Each next year license (EUR)	1620	790	0	0	200	0	1140+ 2394= 3534

Table 3
Estimated break-even calculations presenting the number of cases required for PPU-based software to reach the initial cost of license-based platforms.

	RG + RG Design	CD	EP	IS
DG	115	62	108	229
BSP	200	116	188	378
R2G	226	132	213	428

3.3.2. DICOM-STL merging

Automatic DICOM–STL merging is available in DG and IS, provided that CBCT data quality is adequate and free of artifacts. All software platforms supported manual DICOM–STL merging using three-point registration.

3.3.3. AI-supported functions

None of the evaluated platforms offered fully automated inferior alveolar nerve detection. All platforms required multi-point manual nerve tracing. Automatic panoramic curve detection was available only in IS and EP. DG, R2G and EP offer semi-automated implant positioning guided by virtual wax-up, enabling axial implant alignment relative to prosthetic crowns.

3.3.4. Prosthetic set-up (Virtual wax-up)

All platforms supported virtual extraction and virtual wax-up. EP demonstrated the broadest wax-up functionality

(UI score = 10), particularly regarding tooth morphology, anatomical detail, and size customization. RG demonstrated more limited wax-up functionality (UI score = 3).

3.3.5. Implant measurements and safe zone adjustment

Safety zone adjustment and comprehensive distance measurements were available in all platforms except R2G and BSP. Implant angulation measurements were supported by DG, IS, BSP, CD and RG. R2G did not support angulation measurement. Implant grouping and parallelization were not available in BSP.

3.3.6. Guide design process and user friendliness

DG and EP achieved the highest descriptively recorded guide-design user-friendliness scores (both = 10). RG does not support guide design within the clinical software and requires an additional RG Design module. Therefore, guide-design usability was not evaluated for RG. Most platforms allow modification of guide offset values, except IS and RG, which provide fixed offsets.

3.3.7. Completion of planning and digital model generation

DG, IS and BSP supported planning workflows up to provisional prosthesis design. DG supported planning with straight abutment only, and IS supported single-unit but not bridge temporization. Digital model generation for 3D printing was supported by DG, BSP, CD and EP.

3.3.8. Provisional crown and bridge design

Provisional crown design was supported by DG, IS, and BSP. Additionally, BSP supported both straight and angled abutments. Provisional full-arch bridge design was supported only by DG and BSP.

3.3.9. Additional functions

Post-operative scan comparison was supported by all platforms; however, DG and R2G required STL import of implant positions for comparison. Post-operative CBCT-based comparison was available in DG, CD, RG and EP. All platforms supported DICOM cropping. Preset implant selection was available in DG, IS, BSP, CD and EP. Multi-piece

guide design was supported by DG, IS, R2G, CD and EP. (Supplementary Table 2).

3.3.10. Planning report

Most platforms provide comprehensive planning reports. All supported note annotation except R2G, which permits notes only via the mobile R2GATE Lite application. All platforms supported cross-section adjustment. User-selected screenshots could be added in all software except RG. Planning reports were exportable in PDF format and generally provide sufficient information to execute a single implant surgery without reopening the planning file. The summary of planning report function is presented in Supplementary Table 2.

3.3.11. Libraries available during implant positioning

It is important to note that the number of components provided by the manufacturers of software refer primarily to the implant libraries (surgical parts) rather than prosthetic components, indicating limitations in the prosthetic libraries. According to manufacturer data on implant libraries, EP had the largest number of available implant brands (520), followed by RG (118), IS (114), CD (75), BSP (73), DG (61), and R2G (10). However, these values do not directly reflect the availability of prosthetic components within the software, as some software platforms were linked to laboratory extensions with a broader range of prosthetic components. Therefore, considering differences between the software it was not possible to determine the exact number of each prosthetic component for each company. For stock abutments, both straight and angled options were supported by DG, BSP, CD, and RG, but not IS and EP. Titanium base abutments were universally supported across most software options, as are Multi-Unit Abutments (MUA) in both straight and angled configurations, which were offered by all except IS.

Regarding healing abutments, DG, R2G and CD supported only 1 manufacturer (Osstem, Megagen and Straumann respectively). IS, BSP, RG and EP do not provide healing abutments libraries. Temporary abutments were supported by DG, BSP, CD, EP, and RG, while IS did not provide this component.

Locators were available only in BSP and RG. Ball attachments were uniquely supported by RG, while scan abutments were available in DG, R2G (only for Megagen), and BSP. R2G and RG also supported other prosthetic components, but they were not specified by the evaluators.

Lastly, a bone anchor pins library was present in all software except BSP. Anchor pins could be virtually designed by creating a custom implant providing the length and diameter. The summary of the available components is presented in supplementary Table 3. Despite the wide availability of implant libraries across all evaluated platforms, a marked and consistent limitation was observed in prosthetic component libraries, with missing or highly restricted options for healing abutments, stock abutments, temporary abutments, and multi-unit abutments in several software systems.

For improved readability, a schematic comparison of key workflow and functional characteristics of the evaluated platforms is presented in Table 4.

Part B

3.4. Complete workflow (CW) and user interface (UI) friendliness

Not all evaluated software platforms supported every step of the predefined CW (Figure 2) in their standard clinical versions. In several cases, completion of specific tasks required additional laboratory software modules. These limitations directly impacted workflow completeness, usability, and overall cost.

Based on the two study cases, only DG and BSP completed the entire predefined CW within a standalone clinical software environment, whereas other platforms required additional modules or laboratory software integration to achieve comparable workflow steps (Table 4). RG required additional modules for guide and temporization design. EP, CD and R2G did not support provisional restorations, whereas IS lacked full-arch provisional bridge design.

UI friendliness scores were highest descriptively recorded for EP (10.0), followed by CD (9.5), R2G (9.0), DG (8.0), IS (7.4), BSP (7.3) and RG (5.3) (Fig. 5). The assessment of the functions available up to the wax-up stage yielded the following scores: EP (10.0), CD (9.3), R2G and DG (9.0), BSP (8.7), IS (7.7), RG (5.3). (Table 5)

3.5. Time required for planning of study cases

Planning times were measured for the full set of assigned tasks. Software packages capable of completing all workflow steps independently were identified and analyzed separately. These measurements were labeled as CW to distinguish full workflow timing from partial task completion. This approach was adopted to ensure transparency and to avoid artificial normalization of non-equivalent workflows, while allowing clinically meaningful interpretation of workflow completeness and task organization. A summary of planning times is presented in

Table 4
Schematic comparison of key workflow and functional characteristics of evaluated implant planning software platforms. Standalone workflow (CW) refers to the ability to complete the predefined clinical workflow within a single software environment, whereas partial workflow (No) indicates the need for integration with laboratory software or additional modules. Prosthetic library availability reflects the range of prosthetic components implemented within the planning software (e.g. healing abutments, temporary abutments, and multi-unit abutments) under the evaluated conditions. Automation features describe semi-automated tools supporting implant planning, such as wax-up–guided implant placement. AI-assisted functions are limited to specific image-processing tasks (e.g. panoramic curve detection) and do not represent fully automated planning. Implant presets refer to predefined implant parameters, including implant type, diameter, and length, implemented within the software. These presets support workflow standardization including implant size selection, but they do not constitute automated decision-making and require clinician verification.

Software	Standalone CW	Prosthetic Library Availability	Automation features	AI-assisted functions	Implant Presets	Prosthetic Design Capability
DG	Yes	Moderate-extended	Wax-up guided implant placement DICOM–STL merging	No	Yes	Advanced (crowns, bridges)
BSP	Yes	Limited	Wax-up guided implant placement	No	Yes	Advanced (crowns, bridges)
CD	No	Moderate	No	No	Yes	Moderate-extended
IS	No	Moderate	DICOM–STL merging	Panoramic curve detection	Yes	Moderate-extended
R2G	No	Moderate	Wax-up guided implant placement	No	No	Basic-moderate
EP	No	Moderate	Wax-up guided implant placement	Panoramic curve detection	Yes	Moderate
RG	No	Limited	No	No	No	Moderate-extended

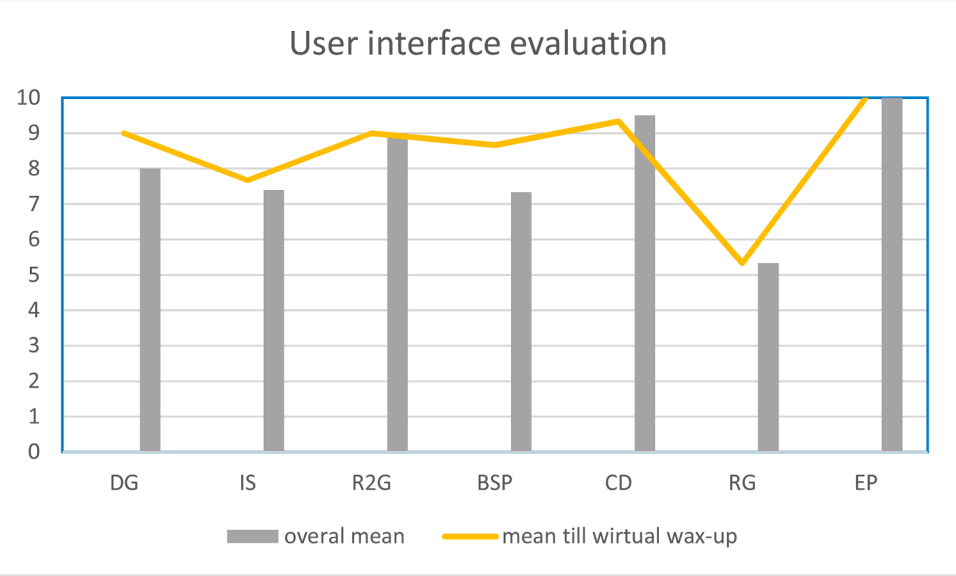

Fig. 5. Descriptive mean scores of the UI evaluation. The figure is presented for illustrative purposes only and does not represent inferential statistical comparison.

Table 5
User Interface (UI) friendliness, evaluated using a 1–10 Likert scale, where:
1 Definitively unfriendly and difficult to use
3–4 Poor usability
5–6 Acceptable usability
7–8 Good usability
9–10 Highly intuitive and clinically practical
NA = not available in the tested package.

Task/Evaluation	DG	IS	R2G	BSP	CD	RG	EP
General UI	9	9	8	8	8	8	10
Logic and clinically oriented planning workflow	10	10	10	10	10	8	10
Virtual wax-up single tooth	10	10	9	10	10	6	10
Virtual wax-up full arch	7	3	8	6	8	2	10
Temporary single crown design	7	6	NA	7	NA	NA	NA
Temporary full arch bridge design	4	NA	NA	3	NA	NA	NA
Guide design	10	8	9	8	10	NA	10

Table 6. The times marked with an asterisk (*) indicate that the corresponding planning task was not fully completed within the tested clinical software package because one or more workflow steps (e.g., surgical guide design or provisional prosthesis design) were unavailable and would have required additional software modules. These time values therefore reflect partial task completion only and were excluded from the analysis of CW planning times. Descriptive timing observations were therefore limited to Case 1 across IS, DG, BSP, and to Case 2 across DG and BSP only.

Among software completing the predefined workflow for Case 1, the shortest observed planning time was recorded for DG (10 min) followed by IS (23 min). The longest observed planning time was observed for BSP (56 min). The more complex Case 2 required longer planning time in each software. The shortest observed planning time was recorded with DG (16 min) and the longest observed with BSP (67 min). Cases 1 and 2 in EP took 11 and 14 min respectively, however, no provisional prostheses were designed within that time. Thus, descriptive mean (CW) time for Case 1 was 30 min and for Case 2 was 42 min.

4. Discussion

Importantly, the applied study design does not aim to establish comparative performance rankings between software platforms. Instead, it provides expert-based observations of workflow architecture, integration limitations, and practical constraints encountered during real-world use. Observed differences should therefore be interpreted descriptively rather than as statistically validated or generalizable performance measures.

Accordingly, differences between software platforms should be interpreted as reflecting expert-user interaction rather than intrinsic usability characteristics. The applied study design intentionally prioritizes ecological validity and interaction with familiar software environments and is therefore not intended to provide standardized or directly comparable performance measures between systems.

This descriptive expert-based comparison of seven contemporary implant planning software platforms highlights key differences in system requirements, functionality, workflow completeness, UI friendliness, and cost structures. These factors may inform software selection based on clinical requirements, workflow needs, user experience, and budget. Digital workflows in implant dentistry are expanding, with recent studies emphasizing fully digital treatment pathways integrating prosthetic planning, guided surgery, and immediate restoration protocols [16–25]. Implant planning software is increasingly incorporated

Table 6
Descriptive planning time metrics (minutes) for Case 1 and Case 2 across evaluated clinical software platforms. Reported values represent descriptive workflow indicators rather than inferential statistical measures. An asterisk (*) indicates incomplete task performance requiring additional software modules. CW values reflect calculations only for software completing the full predefined workflow. Time values reflect descriptive measurements under non-equivalent workflow conditions and are not intended as direct indicators of software efficiency. Standard deviation (SD) values are presented as descriptive indicators of variability and should not be interpreted as inferential statistical measures.

	IS	EP	DG	BSP	CD	R2G	RG	Min	Max	Mean	Min CW	Max CW	Mean CW	SD CW
Time required to plan Case 1	23	11*	**10**	**56**	32*	11*	15*	10	56	23	10	56	30	24
Time required to plan Case 2	51*	14*	**16**	**67**	30*	21*	12*	12	67	30	16	67	42	36

into undergraduate and postgraduate education [26,27]. Contemporary platforms accommodate a broad range of clinical complexities and facilitate interdisciplinary planning [28]. However, selecting appropriate software remains challenging, as no single platform offers universally optimal solutions across all clinical, technical, and economic parameters.

Cost may remain a major barrier, particularly for clinicians with limited implant case volume or reduced digital experience. Findings from the present study indicate that pay-per-use (PPU) platforms can be a pragmatic entry option when planning frequency is low. Hardware requirements also varied substantially across platforms. Only RG and BSP supported macOS, whereas all other evaluated software were limited to Windows environments. Requirements for CPU performance, RAM, GPU capability, and storage may therefore influence accessibility, particularly in practices with limited technological infrastructure.

An additional practical consideration concerns licensing architecture. Several platforms (IS, DG, EP, and CD) require physical license dongles, typically connected via USB-A ports. As many modern laptops increasingly rely on USB-C-only configurations, this requirement may introduce additional limitations. Despite these constraints, IS—while demonstrating the highest hardware demands and licensing costs—showed favourable descriptively recorded UI scores and shorter observed planning time in the first clinical scenario. IS and CD also benefit from integration with advanced laboratory software ecosystems, facilitating collaboration with digitally equipped dental laboratories [8,29,30].

All evaluated platforms operate on standard data formats (DICOM and STL). Only DG and IS support automatic DICOM–STL merging, which may influence workflow execution and reduce planning time depending on the task structure, whereas other platforms require manual landmark selection. Automatic panoramic curve detection was available only in IS and EP, while automatic inferior alveolar nerve detection was absent across all evaluated systems, in contrast to earlier reports describing semi-automated approaches [8]. These differences may reflect variations between software versions and indicate areas for future development.

Current automation in implant planning software can be conceptually divided into three levels:

(1) Currently available semi-automated functions, including preset-based planning and wax-up–guided implant positioning,
(2) AI-assisted tools, primarily used for image segmentation and anatomical structure identification,
(3) Hypothetical future fully automated workflows, in which artificial intelligence may support or perform comprehensive implant planning.

At present, all evaluated platforms operate within the first two categories and require active clinician input and verification. Although AI-assisted planning has been reported to offer advantages such as reduced planning time and comparable accuracy under certain conditions [31–34], these approaches may not consistently incorporate essential prosthetic considerations. For example, SIC-related spatial requirements or prosthetic component selection. However, recent studies have further highlighted the growing role of AI-supported workflows in digital implant planning while emphasizing their current limitations in prosthetically driven decision-making [33–37].

Therefore, current automation should be regarded as workflow support rather than autonomous decision-making, and future developments should be interpreted as potential directions rather than established clinical capabilities.

Virtual wax-up capabilities were available across all platforms, though their complexity varied. While single-unit workflows were generally perceived as easier to manage, full-arch planning and provisional prosthesis design were more demanding. DG and BSP enabled completion of the predefined workflow within a standalone clinical environment, whereas other platforms required integration with additional modules or laboratory software. It is important to emphasize that CW in this study refers to workflow implementation within a single clinical environment and does not imply functional equivalence between broader software ecosystems.

A distinction should therefore be made between standalone clinical workflows and workflows requiring integration with laboratory software ecosystems, which may support similar clinical objectives through different operational pathways.

Prosthetic component libraries represent a clinically relevant limitation across all evaluated platforms. Despite extensive implant libraries, prosthetic components—including healing abutments, temporary abutments, and angulated multi-unit abutments—remain inconsistently available. This discrepancy may be explained by the separation between clinical and CAD laboratory environments, as well as regulatory and logistical constraints. As previously reported [8], this limitation creates a gap between system-level offerings and practical clinical usability.

In routine clinical practice, incomplete prosthetic libraries may directly influence implant positioning decisions. For example, the absence of angled multi-unit abutments with appropriate vertical height may lead to suboptimal implant angulation in full-arch cases, potentially resulting in compromised screw access positioning. Similarly, limited availability of healing or temporary abutments may hinder accurate visualization of the implant–abutment–crown complex.

This limitation may also affect interdisciplinary communication between the clinician and the dental technician, as discrepancies between planned and available prosthetic components can lead to inconsistencies in treatment planning and restorative execution.

The following considerations provide a literature-based clinical interpretation of potential implications. They are intended as hypothesis-generating reflections rather than outcomes of the present study. Previous studies suggest that emergence profile geometry and abutment characteristics may influence peri-implant tissue stability [9–11,38]. However, these relationships were not evaluated in the present analysis and should be interpreted cautiously.

Planning times differed across platforms, however, because workflows were not equivalent, such differences should be interpreted cautiously. Variations in planning duration likely reflect workflow structure, module integration, and task availability rather than intrinsic software efficiency.

The findings of this study reflect the evaluated software versions at the time of testing. Rapid technological development, particularly in AI-supported functions, may alter capabilities over time. The study is limited by evaluator-dependent design, absence of inter-rater validation, and descriptive analytical framework. Results should therefore be interpreted as expert-dependent observations rather than standardized usability comparisons.

Clinicians may consider selecting software according to clinical objectives, experience level, and workflow requirements. Lower-cost or PPU platforms may be suitable for simple cases, whereas modular systems may offer greater flexibility in complex scenarios, albeit with higher costs and increased workflow complexity.

Cost comparisons should be interpreted in the context of pricing models. PPU systems provide flexibility for low-frequency users, while license-based systems become more economical with higher utilization. Therefore, cost-effectiveness is context-dependent rather than inherent to a specific model.

5. Conclusions

Within the limitations of this descriptive expert-based evaluation, the present study provides practical observations on workflow structure, integration, usability, and prosthetic component availability in contemporary implant planning software.

The findings indicate variability in workflow integration, user

interaction, cost structure, and availability of prosthetic component libraries across evaluated platforms. These differences likely reflect variations in software architecture and implementation rather than standardized performance outcomes.

Importantly, the presented results represent expert-dependent interaction with individual software systems and predefined clinical workflows, without inter-rater reliability assessment. Therefore, the findings should be interpreted as descriptive and hypothesis-generating observations rather than comparative or directly comparable measures of usability or workflow performance.

The observations reported in this study are limited to the evaluated software versions and may change with ongoing technological developments, particularly in AI-supported functions.

Within this context, the findings may inform clinicians about practical aspects of software use, including workflow organization, prosthetic planning capabilities, and system integration. However, they should not be interpreted as direct recommendations or rankings, but rather as guidance for consideration in specific clinical and workflow settings.

Future research integrating software-based analysis with clinical and biological outcome measures is required to further clarify the clinical implications of software-related planning limitations.

CRediT authorship contribution statement

Łukasz Zadrożny: Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Jaafar Abduo:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Conceptualization. **Vygandas Rutkunas:** Writing – review & editing, Software, Investigation, Data curation. **Marco Tallarico:** Writing – review & editing, Software, Investigation, Data curation. **Sam Omar:** Writing – review & editing, Software, Investigation, Data curation. **Ivan Darby:** Writing – review & editing, Validation, Supervision, Software, Investigation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Lukasz Zadrozny reports travels related to perform this study was provided by Polish National Agency for Academic Exchange (NAWA), Warsaw, Poland. Manuscript preparation was supported during Harvard Medical School's Polish Clinical Scholars Research Training Program, organized by the Agencja Badan Medycznych (ABM, English: Medical Research Agency, Warsaw, Poland). Marco Tallarico, Sam Omar and Łukasz Zadrożny declare being key opinion leaders (KOLs) for companies producing software evaluated in this study. All authors declare the concept, design, data collection, analysis, interpretation of results, and manuscript preparation were carried out independently within an academic framework. No software manufacturer, commercial entity, or third party had any influence on the study design, execution, results, or conclusions. No software licenses, discounts, credits, or other material support were provided by software manufacturers specifically for the purposes of this study. All software was used under standard personal or institutional licenses routinely available to the evaluators. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The project was initiated during the Research Fellowship at the Melbourne Dental School, The University of Melbourne, Australia, under PROM Program, founded by the Polish National Agency for Academic Exchange (NAWA), Warsaw, Poland.

Manuscript preparation was supported during Harvard Medical School's Polish Clinical Scholars Research Training Program, organised by the Medical Research Agency (ABM), Warsaw, Poland.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jdent.2026.106857.

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