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CLINICAL ARTICLE

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Dental software classification and dento-facial interdisciplinary planning platform

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Abstract

Objective: Despite all advantages provided by the digital workflow, its application in clinical practice is still more focused on device manufacturing and clinical execution than on treatment planning and communication. The most challenging phases of treatment, comprehensive planning, diagnosis, risk assessment, and decision-making, are still performed without significant assistance from digital technologies. This article proposes a new dental software classification based on the digital workflow timeline, considering the moment of patient's case acceptance as key in this classification, and presents the ideal software tools for each phase.

Clinical Considerations: The proposed classification will help clinicians and dental laboratories to choose the most appropriate software during the treatment planning phase and integrate virtual plans with other software platforms for digitally guided execution. A dento-facial interdisciplinary planning platform virtually simulates interdisciplinary clinical procedures and assists in the decision-making process.

Conclusions: The suggested classification assists professionals in different phases of the digital workflow and provides guidelines for improvement and development of digital technologies before treatment plan acceptance by the patient.

Clinical Significance: Three-dimensional interdisciplinary simulations allow clinicians to visualize how each dental procedure influences further treatments. With this treatment planning approach, predictability of different procedures in restorative dentistry, orthodontics, implant dentistry, periodontal, and oral maxillofacial surgery is improved.

KEYWORDS

CAD-CAM, dental software, digital workflow, interdisciplinary simulations, treatment planning

1 | INTRODUCTION

The complete digital workflow has been widely studied and reported in several areas of dentistry.[1-13] Recently, a conceptual digital workflow that changes and improves the process of treating a comprehensive case from planning to execution has been presented with six key steps (Figure 1).[14] The process begins with the patient digitalization (Step 1), obtained by the scanning of hard and soft tissues. Facial and intra-oral scanners, cone-beam computed tomography, and additional digital resources, such as digital smile design,

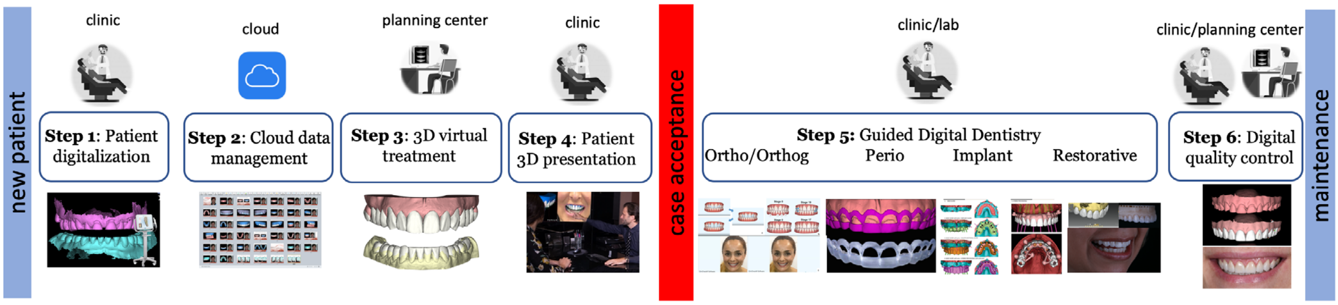

FIGURE 1 The six steps of the complete digital workflow

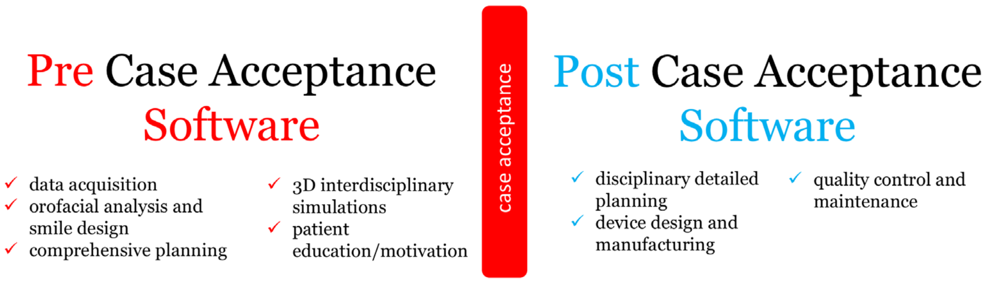

FIGURE 2 Digital timeline divided by the case acceptance moment into pre case acceptance and post case acceptance. Pre software and post software and their respective goals

virtual articulators, and jaw tracking devices, are used for this purpose.[9-11,15-18] All these files can be immediately stored in a dental cloud platform and shared with the professional team.[17] Interdisciplinary treatments can be proposed based on a digital brainstorm among clinicians, on which an asynchronous communication facilitates diagnosis and treatment planning (Step 2). In sequence, 3D treatments simulations[1] can be performed assisted by an interdisciplinary software (Step 3). The next step consists of presenting these treatment options and the desired outcome to the patient (Step 4). These simulations not only help the clinician to make better clinical decisions, but also serve as a tool for patient education, motivation, and case acceptance. The process is then completed by so-called guided dentistry, which implies that digital guides, appliances, and restorations can be printed or milled to transfer the digital plan to the patient's mouth (Step 5).[19,20] After every single clinical procedure, quality control can be performed by comparing the scans of clinical results to the initial 3D simulations. Thus, treatment maintenance is ensured by comparing treatment outcomes at different follow-up times (Step 6).[21]

Several digital workflows combining intraoral scanning, additive, and subtractive manufacturing methods and CAD-CAM technology, have been published recently.[22-27] These articles described protocols focused on comprehensive patient diagnosis and treatment plan for esthetic restorations,[22,23] complex occlusal rehabilitation,[24,25] and rehabilitation of severely worn dentitions.[26,28]

It is the purpose of this article to propose a dental software classification based on the digital workflow timeline, considering the moment of patient's case acceptance as key in this classification, and present the ideal characteristics/tools of software for each phase. The generated guidelines may help clinicians and dental laboratories to choose the most appropriate software for the planning phase before the patient's case acceptance and also integrate these virtual plans with the other software tools used after the case acceptance, digitally guiding the execution phase.

2 | CLINICAL CONSIDERATIONS

2.1 | Dental software classification

The key moment for any dental treatment to be ultimately executed is the patient's case acceptance. Therefore, the digital workflow timeline can be divided into a pre-case-acceptance phase (planning) and a post case acceptance phase (execution). In the same way, dental software platforms can be divided into pre-case-acceptance software (pre software) and post case acceptance software (post software) and present the ideal features according to the phase in which they will be used (Figure 2).

2.2 | Pre case acceptance software

The pre software needs to have two main characteristics: treatment planning guided by the face and interdisciplinary integration. A facially driven smile design project is the starting point for the entire treatment plan. Modern dentistry is interdisciplinary and the impact of one possible procedure over the others must be well understood. For these reasons, the software should be used for diagnosing, designing the initial ideal smile, and simulating different solutions. It should allow facial analysis and ideal smile design features and be capable of performing all interdisciplinary simulations in the same software, so one can judge the best combination of procedures for each patient.

Main goals of a pre case acceptance software: (a) data acquisition; (b) improve the process of identifying the patient's issues and diagnoses; (c) simulate, compare the options, and promote a team brainstorm of the solutions; (c) improve the decision-making process and risk assessment; (d) present and explain treatment options to the patient, having the patient participate in the decision-making process with pre software as a 3D visual communication tool.

2.3 | Post case acceptance software

Once treatment is planned and patient accepted the plan, the team can export the files from the pre software and import them into different post software. The post software are the specialized software in each area, and their main goal is to plan a specific disciplinary procedure precisely while designing any device needed to perform the clinical procedure (Figure 3).

Main goals of a post case acceptance software: (a) import files from pre software: import the ideal design and initial specialty simulation suggestion; (b) precisely merge files from pre software with working files to perform disciplinary tasks; (c) design the devices needed to perform specific procedures; (d) connect to manufacturing systems as milling and 3D printing machines.

2.4 | Ideal solutions

Following the complete digital workflow (Figure 1), technologies that help to achieve the goals reported in Figure 2 are needed. Therefore, an ideal digital dental platform would be one that could manage all patient information and data in a cloud, which would aid diagnostics powered by artificial intelligence (AI). AI would permit asynchronous access and facilitate interdisciplinary communication by allowing the specialists to express their ideas through 3D simulation, which improves the decision-making process and risk assessment through collective intelligence. AI solutions are still under development, but a couple of things are already in use: (i) Smile Design: solutions like the DSDApp are using A.I. to suggest initial smiles but still human hands are needed to fine tune it. It is speeding up the process though. (ii) Ortho movements: solutions like Invisalign are very advanced in biomechanics and are helping technicians and doctors by suggesting the best way to move teeth, (iii) Radiographic interpretation: several solutions are under development and some already in use and helping doctors to see better and not miss important details.

An ideal dental platform should also translate the treatment plan presentation speech into images and simulations, improving patient education and motivation. Finally, it would carry out integrated plans by pre case acceptance software with post software for guided execution of clinical procedures and digital quality control. The ideal features of a pre software are presented in Table 1.

2.5 | Current technologies

Decades ago, Dawson[27] pointed out that the professionals dedicated almost 90% of their time to the execution of the treatments and only 10% to the planning. However, most of the failures happened not due to incorrect technical execution but due to incorrect diagnoses and treatment planning. Currently, professionals

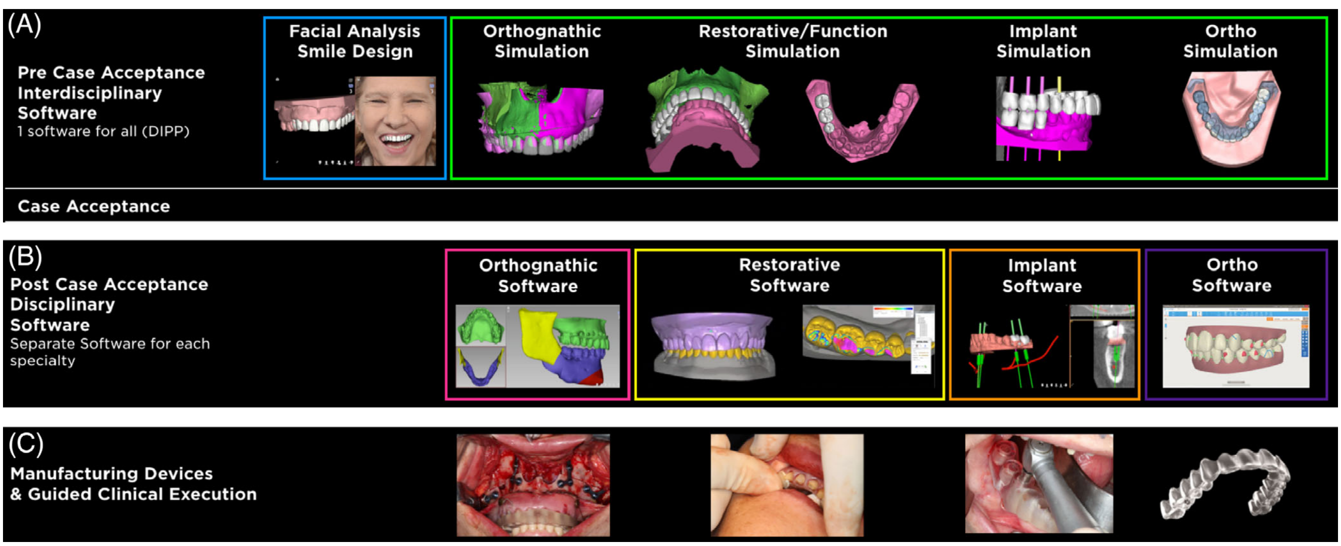

FIGURE 3 (A) pre case acceptance software: "digital wax-up" software for facially driven smile designs (blue box), dento-facial interdisciplinary planning platform for interdisciplinary simulations (green box). Blue and green can be one software or separate ones; (B) post case acceptance software for disciplinary planning and design (pink, yellow, orange and purple, respectively for orthognathic, restorative, implant and orthodontic); (C) Manufacturing devices for guided clinical execution

have numerous digital tools, software and technologies available. The most challenging phases of treatment: diagnosis, team communication, planning, decision making, and patient communication/education are still mostly done without assistance from technologies. This means that dental software companies are not focusing on developing solutions to assist dentists during the most important phases.

When only post software is used, all major decisions related to treatment planning are done without the help of digital technologies. Software is only used to plan fragmented discipline-specific procedures and to manufacture devices that are probably not ideally integrated into a comprehensive facially driven treatment plan.

2.6 | Limitations

Not all dental software use initial ideal facially driven smile design to guide patient-specific treatment planning, nor can simulate different specialties since discipline-specific software tools are not connected to one another. Today, additional tools have been incorporated to these post software such as orofacial analysis, smile design, and 3D interdisciplinary simulations. A dentist who only works with a post software (disciplinary software) may miss all the benefits of digitally assisted comprehensive treatment planning.

Merging various digital data sets has been recognized as a significant break-through in digital diagnosis and treatment planning.[29-32] However some authors still pointed out limitations in the alignment of scans of edentulous arches,[29,30] difficulties to accurate merging of facial and intraoral scan information as facial soft tissue changes with every scan,[31] and adverse effects of high amount of scatter on cone beam computed tomography scans.[32] Further studies are needed to validate the multidisciplinary protocols mentioned in this manuscript.

2.7 | Dento-facial interdisciplinary planning platform

While an ideal software with all necessary tools and features is still not available, the DIPP comes close. DIPP is a virtual environment that connects professionals to a Planning Center through a chair side software (DSDapp, Digital Smile Design, Madrid, Spain) or a lab/chair side software (NemoStudio, Nemotec, Madrid, Spain), which allows organizing the complete patient data, facilitating team communication, performing facial analyses, creating the initial ideal smile design, and enabling treatment simulations. The DIPP software can be divided into two aspects: facial analysis/smile design and 3D interdisciplinary simulations (Figure 3).

The facial analysis and smile design can be performed on a separate, specific software. Similar to a "digital wax-up" software, it can export a 3D file of the ideal design into the planning software to perform all the interdisciplinary simulations (Figure 3). This will become more common when that easy-to-use software assisted by artificial intelligence will be used only for smile design, without the ability to perform treatment simulations. It will also become more popular because many good interdisciplinary software platforms do not feature adequate smile simulation tools. Another advantage of a "digital

TABLE 1 Main features of a pre software

Tools/functions	Ideal features
Orofacial analysis	Frontal and lateral analysis with tools as cephalometric, denture parameters and esthetic guidelines.
Digital smile design	Facially driven 3D digital smile design
Link 2D-3D	2D-3D link to bring facial reference lines from 2D to 3D
Functional wax-up	3D virtual upper and lower wax-up with natural teeth libraries
Occlusal analysis	Tool for digital occlusal analysis
Virtual articulator	Virtual articulator and vertical dimension modifications integrated with jaw movements
Calibration	Automated calibration between intraoral scan and facial 2D photographs and/or 3D facial scans
Merging	Merging the ideal design with orthodontic simulations, with periodontal surgery planning, with the virtual articulator, with implant planning
Interdisciplinary 3D simulations	Tool to do interdisciplinary simulations together to analyze the impact of one over the other
Orthodontic simulation	Simulation of tooth movement
Orthognathic simulation	Simulation of maxillary and mandibular corrections and extra oral soft tissue simulation
Perio simulation	Virtual gingivectomy on the digital model, design of hard and soft tissue grafting and 3D assessment of the volume of the grafts
Implant simulation	Superimposition of ideal design with CBCT file and implant placement
measurements	Tool for measurements
Translucency	Partial translucency to visualize ideal design and treatment simulations

Abbreviation: CBCT, cone beam computed tomography.

wax up" software is the low cost and user-friendliness, providing restorative dentists with an easy-to-use communication tool with their dental laboratory, which designs the restorations. The dentist can open the project in the "wax up" software to review, modify, and approve the design for the laboratory to continue the work.

The 3D interdisciplinary simulations provide clinicians the opportunity to visualize each dental procedure and their impact on further treatment. For example, it can visualize pre-restorative orthodontic alignment to keep the restorative treatment minimally invasive.[17] Likewise, crown lengthening on neighboring teeth can improve a dental implant esthetic outcome in the anterior zone.[18] Therefore, this treatment planning approach improves the predictability of different procedures in restorative dentistry, orthodontics, implant dentistry, periodontal, and oral maxillofacial surgery.[19]

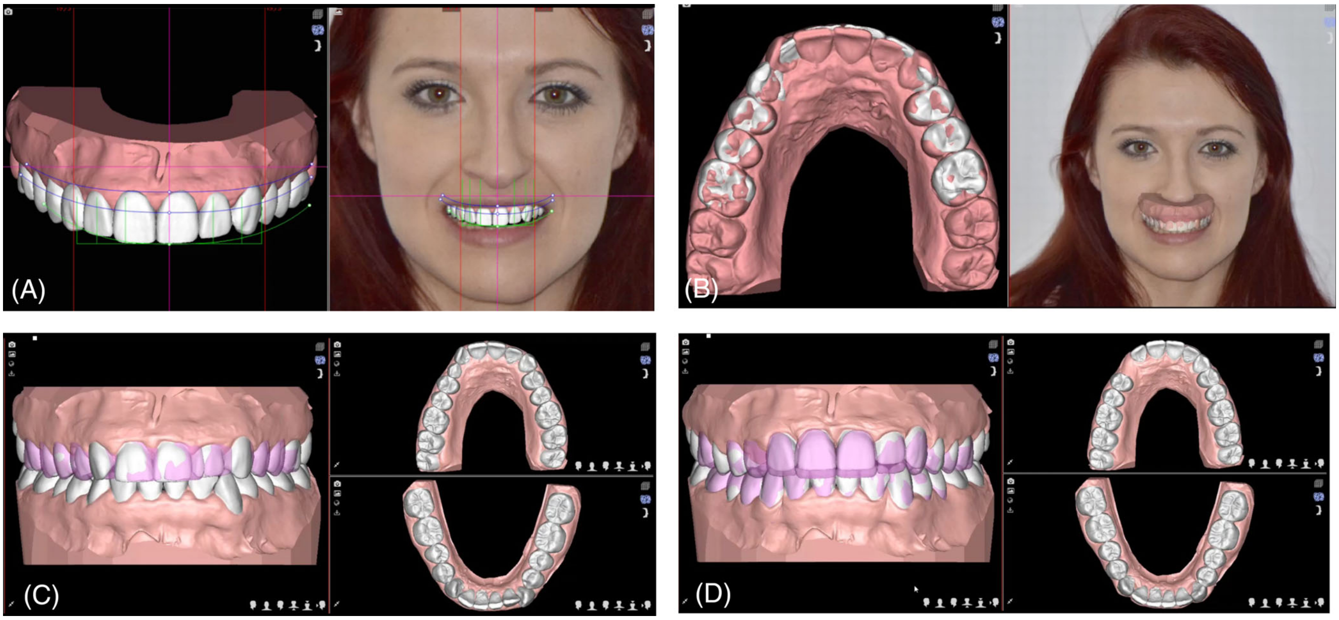

FIGURE 4 (A) facially driven smile design respecting dental midline not coincident with facial midline; (B) smile design correcting the midline; (C) merging one design to another; (D) simulation of orthodontic movements defining ideal position for dental implant

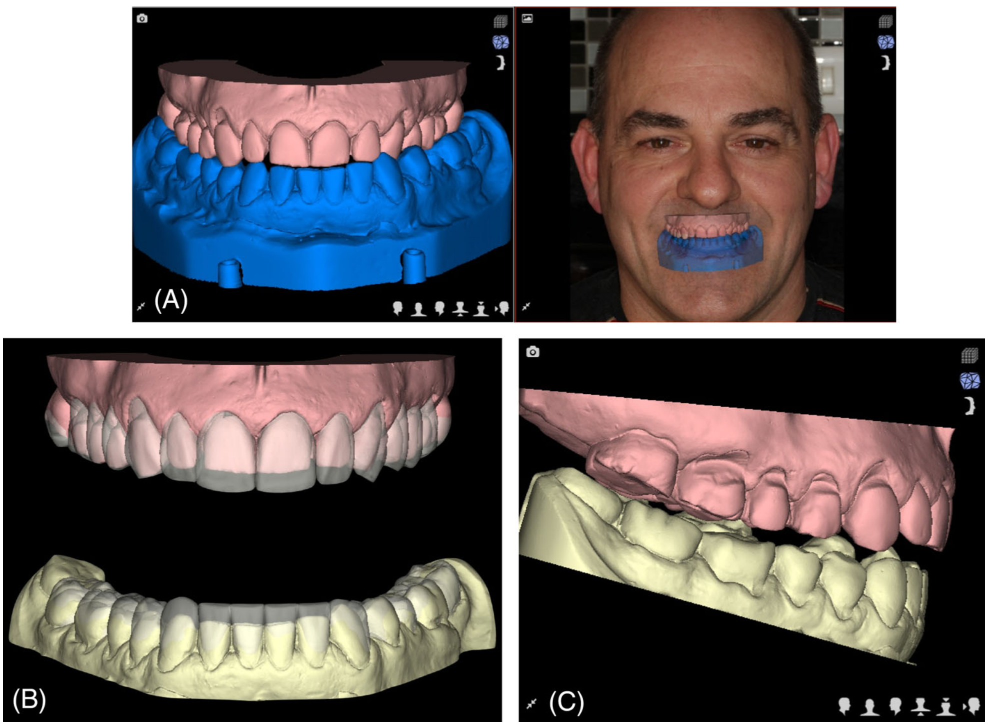

FIGURE 5 (A) initial occlusion; (B) simulation of the increase of occlusal vertical dimension and assessment of new intermaxillary relationship to define the need for orthodontics and/or orthognathic; (C) virtual wax-up

2.8 | Interdisciplinary treatment simulations

The interdisciplinary communication and collaboration start after the patient is completely digitized and files are uploaded to the planning platform.[14] As the team of specialists suggests treatment options, a 3D software expert team at the Planning Center will translate these ideas into simulations to visualize prospective outcomes and their impact. A software system (NemoStudio, Nemotec) that allows for all types of simulations on the same platform and at the same time is used to enable this.

Clinical examples where DIPP software facilitated the ideal facially driven smile design as a reference for interdisciplinary simulations are illustrated in Figures 4–7. Figure 4 shows a patient with non-coinciding facial and dental midlines and a deciduous right canine, which could possibly require implant and orthodontic treatment. 3D software simulation assisted the team to understand and visualize the combination of

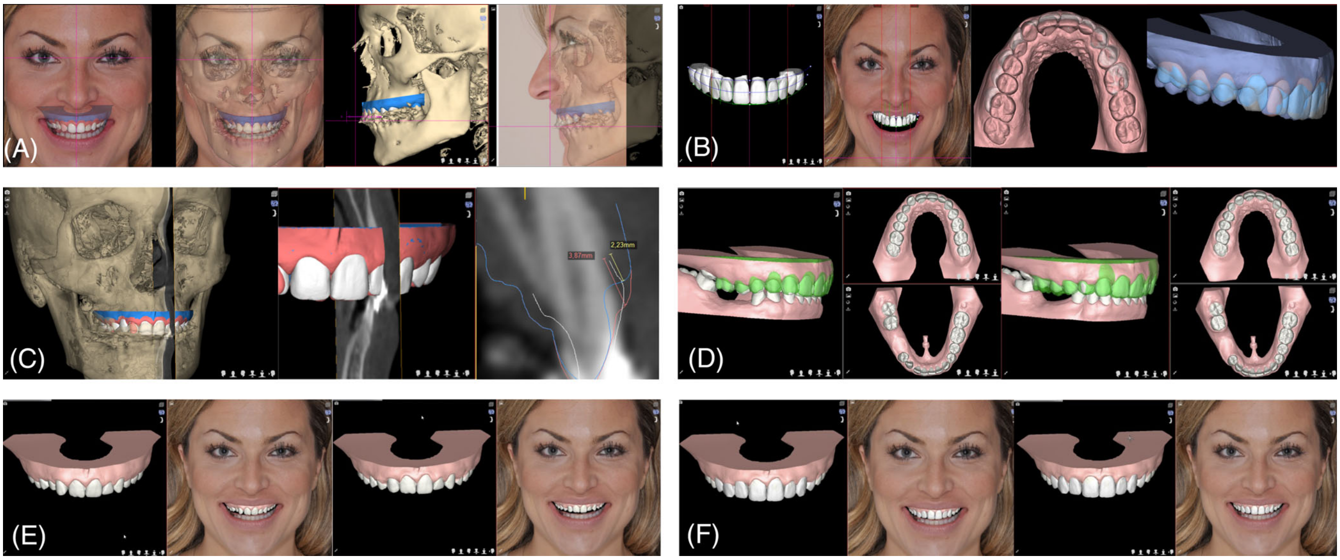

FIGURE 6 (A) 3D virtual patient; (B) Facially driven smile design indicating the need for perio, ortho and restorative treatment; (C) virtual Perio-analysis; (D) simulation of tooth movement to position teeth for minimally invasive preparations; (E) analysis on the face before ortho simulation (on the left side) and after ortho simulation (on the right side); (F) analysis on the face after anterior restorations simulation (on the left side) and after gingivectomy (on the right side)

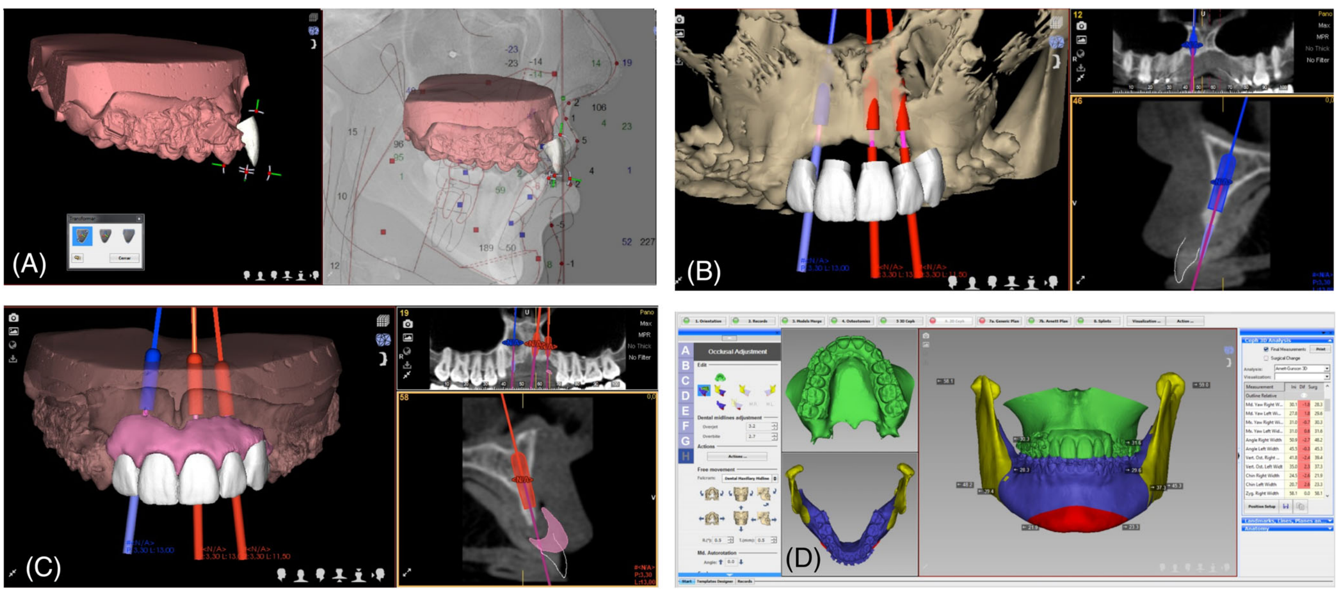

FIGURE 7 (A) ideal position of the maxillary anterior teeth according to facial references and cephalometric analysis; (B) ideal position of dental implants according to future prosthetic tooth position; (C) ideal volume of soft and hard tissues; (D) 3D cephalometric analysis and relationship between orthognathic/ortho/implants and restorations

both procedures, and to decide on the ideal tooth movement to facilitate proper implant placement and soft tissue outcomes, on the ideal implant position after orthodontic treatment, and the treatment sequence while considering the possibility of anchorage.

The patient in Figure 5 presented with worn dentition and a posterior cross bite, probably requiring orthodontic treatment and increase of occlusal vertical dimension (OVD). The treatment plan question here was how to uncross his bite. Ortho or restoratively. But, testing on the software different amounts of opening and develop the digital wax-up we could see how much to open to uncross with crowns. The more we open the easier to uncross. Virtual simulations provided and understanding if opening of the OVD could eliminate the need for orthodontics or facilitate it. It also allowed to compare gaining space with orthodontic intrusion versus vertical augmentation and to visualize how the combination of both can generate the most convenient and minimally invasive restorative outcome. So, we first design the upper esthetically with the face and then we test different OVD on the software and check the lower design to suggest the best treatment plan. If opening the bite plus crowns can uncross the bite, this means we can eliminate the need of ortho to achieve the same. After define which is the most convenient opening to allow the integration of function and esthetics, then we can digitally design an anterior jig with this exact dimension and, in the mouth, find the centric relation (CR) and scan it, go back to the software and fine tune the design in the patients CR and on the most convenient vertical. The software cannot find the CR, it just has a vertical articulator that can do exactly what an analogue articulator can do: open the bit on the incisal pin of the articulator.

Another patient presented with a missing right lateral incisor, a deciduous canine, and a malpositioned permanent right canine, probably needing orthodontic, periodontic, and restorative treatment (Figure 6). Software simulations facilitated detailed evaluation and assessment of the proposed procedures and allowed the interdisciplinary team to visualize the ideal tooth position in harmony with the face, simulating the ideal treatment sequence and timing to position the teeth for minimally invasive restorative intervention.

The patient in Figure 7 likely needed orthognathic surgery, bone grafting, and dental implants. Interdisciplinary virtual treatment planning with merged files and simulations helped to understand the relationship between orthognathic surgery, orthodontic treatment, restorative dentistry, and dental implants.

While the treatments suggested for these cases in the beginning was based on sole assumptions and without any projection of the possible outcomes, the DIPP software has proven to be an invaluable tool to simulate and visualize the suggested treatment and interventions, ultimately providing guidance for a patient-specific, individualized, interdisciplinary, and minimally invasive treatment plan.

3 | CONCLUSIONS

The proposed classification and software can assist clinicians during the different phases of the digital workflow and generate guidelines for the improvement and development of technologies for the pre case acceptance phase.

CONFLICT OF INTEREST

Christian Coachman is DSD founder and CEO. The other authors do not have any financial interest in the companies whose materials are included in the article.

DATA AVAILABILITY STATEMENT

Data sharing not applicable - no new data generated.

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