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CLINICAL ARTICLE

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Interdisciplinary guided dentistry, digital quality control, and the "copy-paste" concepts

Christian Coachman DDS, CDT[1,2] | Lauren Bohner DDS, PhD[3] | Camila Sales Jreige DDS[4] | Newton Sesma DDS, PhD[4] | Marcelo Calamita DDS, PhD[5]

[1]Department of Preventive and Restorative Sciences, University of Pennsylvania, Philadelphia, Pennsylvania
[2]DSD Founder, Madrid, Spain
[3]Department of Oral and Maxillofacial Surgery, University Hospital Muenster, Muenster, Germany
[4]Department of Prosthodontics, University of São Paulo School of Dentistry, São Paulo, Brazil
[5]Private Practice, São Paulo, Brazil

Correspondence
Camila Sales Jreige, Department of Prosthodontics, University of São Paulo School of Dentistry, 2227 Professor Lineu Prestes Avenue, São Paulo, Brazil.
Email: camilajreige@usp.br

Abstract

Objective: The aim of this report is to present an interdisciplinary approach with novel concepts to virtually plan and achieve esthetics and function.

Clinical Considerations: Despite the advancements in the digital workflow applied to restorative dentistry, the final outcomes are commonly not similar to initial planning. To overcome this major limitation, three concepts are proposed: guided dentistry, digital quality control and "copy-paste" dentistry. Guided dentistry consists of simulations in 3D software and also includes the manufacture of guides/appliances to assist dentists in all clinical steps. Digital quality control involves the use of intraoral scanners and 3D software to compare the real outcomes with the pre-operative simulations after every procedure. "Copy-paste" dentistry is a consequence of the previous two concepts. Using the capacity of the software to overlap files, the original project can be maintained and adapted to achieve results more comparable with the initial design. The proposed method associates facially driven treatment planning and periodontal and restorative procedures to perform the patient's dental rehabilitation.

Conclusion: Through a guided workflow and digital control of clinical steps, the final outcomes obtained were equivalent and closer to the initial design.

Clinical Significance: In interdisciplinary cases, the treatment plan needs to address individual requirements and to coordinate sequential clinical stages. It is challenging to meet these demands in a conventional process. The proposed concepts engage technological resources to orientate the procedures and to provide assessment in each step. This approach enables the development of a complete and accurate functional-esthetic rehabilitation. Ultimately, the technique presented is reproducible and the results reflect the established plan.

KEYWORDS
CAD-CAM, dental technology, digital workflow, periodontics, prosthodontics

1 | INTRODUCTION

The modern restorative dentistry represents the interdisciplinary use of technology from the initial project to treatment execution. A contemporary clinician is expected not only to successfully perform the clinical procedures but also to generate outcomes more similar to the preliminary simulations. Accordingly, dentistry is moving into less free hand and more into guided techniques because of the increase in efficiency and predictability.[1-3]

The complete digital workflow can be divided into six steps: patient digitalization, cloud data management, 3D virtual planning, patient treatment presentation/education, guided execution, and digital quality control.[4] The first step is to create a virtual patient through the superimposition of the data acquired from different devices, such as cone beam computed tomography (CBCT), intraoral scanners (IOS), and extraoral scanners.[5,6] With the use of these tools, it is possible to visualize the relations among orofacial structures. In this sense, diagnosis and planning are performed considering the patients' expression and functional movements.[7-9] After acquisition, the entire dataset of digital information can be shared with the team members using a cloud management system. For treatment planning, the specialists can simultaneously study and discuss the clinical case by means of an asynchronous communication and collaboration. The expected outcome can be virtually simulated and presented to the patient using a dento-facial interdisciplinary planning platform (DIPP). In compliance with patient expectations, the project can be modified at any time before the final restorations are manufactured.[10-12] After treatment planning approval, the clinical stages are orientated by the guided dentistry concept. Any simulation can be transformed into a guide, appliance or restoration to increase the scope of guided procedures and to reduce the number of free hand steps (Figure 1).

Guided dentistry consists of three phases: (a) planning procedures by operating 3D software (using DIPP) before executing them to improve decision making, (b) translating the treatment simulations into the manufacture of guides/appliances/restorations using 3D technology, and (c) performing all clinical steps with the guides/appliances/restorations to increase the chances of achieving outcomes as those envisaged in the virtual plan.

The final step in the complete digital workflow is quality control. This concept comes hand-in-hand with guided dentistry and consists of using IOS and 3D software to compare real outcomes with the initial pre-operative simulations. This should be performed after every clinical procedure. Most of 3D software programs enable the superimposition of the virtual plan and the real outcome files, which generates a visual comprehension and allows the professional to control quality, fine tune, redo or proceed with the next treatment stage.

As a consequence of the previous two concepts, "copy-paste" dentistry can be performed. Using the principles of guided dentistry, implementing digital quality control and exploiting the capacity of software to overlap files in between each step, the original project can be kept alive to produce final outcomes comparable to ideal design. Therefore, the mock-up will look like the initial design, as well as the provisional and final restorations. This is possible because we can import and export files from the machines and software and superimpose them, so the process is literally a copy-paste of a previous step onto the next one.

These three concepts are presented in this article in a clinical case report and aim to make the restorative results more similar to those conceived in the initial design and diagnostic wax-ups.

2 | CASE REPORT

A 57-year-old female patient was referred to the private dental office due to the need of an esthetic and functional rehabilitation. After a detailed anamnesis, the clinical examination revealed a gummy smile and worn teeth with loss of occlusal vertical dimension (OVD). An interdisciplinary treatment plan was elaborated after taking photographs, acquiring intraoral scans of both arches and registering the bite (TRIOS 3, 3Shape, Copenhagen, Denmark) (Figure 2(A)). A facially-driven smile was designed using the NemoStudio software (Nemotec, Madrid, Spain) (Figure 2(B)). For this purpose, a smile frame was created based on reference lines of facial and smile proportions, which served as guidance for the virtual wax-up. The ideal smile design was established in accordance with the natural shape and texture imported from the digital library of natural teeth (Figure 2(C)). After obtaining patient's approval, a collaborative digital approach was chosen to fulfill the multiple requirements of the case. Thus, periodontal crown lengthening and prosthetic rehabilitation were planned to restore esthetics and function.

2.1 | Guided crown lengthening procedure

A CBCT was acquired with a lip retractor[13] to capture accurate images of tissues, especially of the buccal bone.[14] Also, an IOS

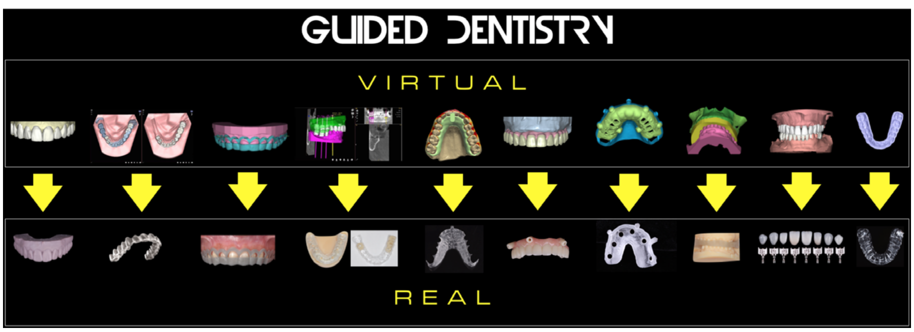

FIGURE 1 Guided dentistry: virtual simulation and real devices

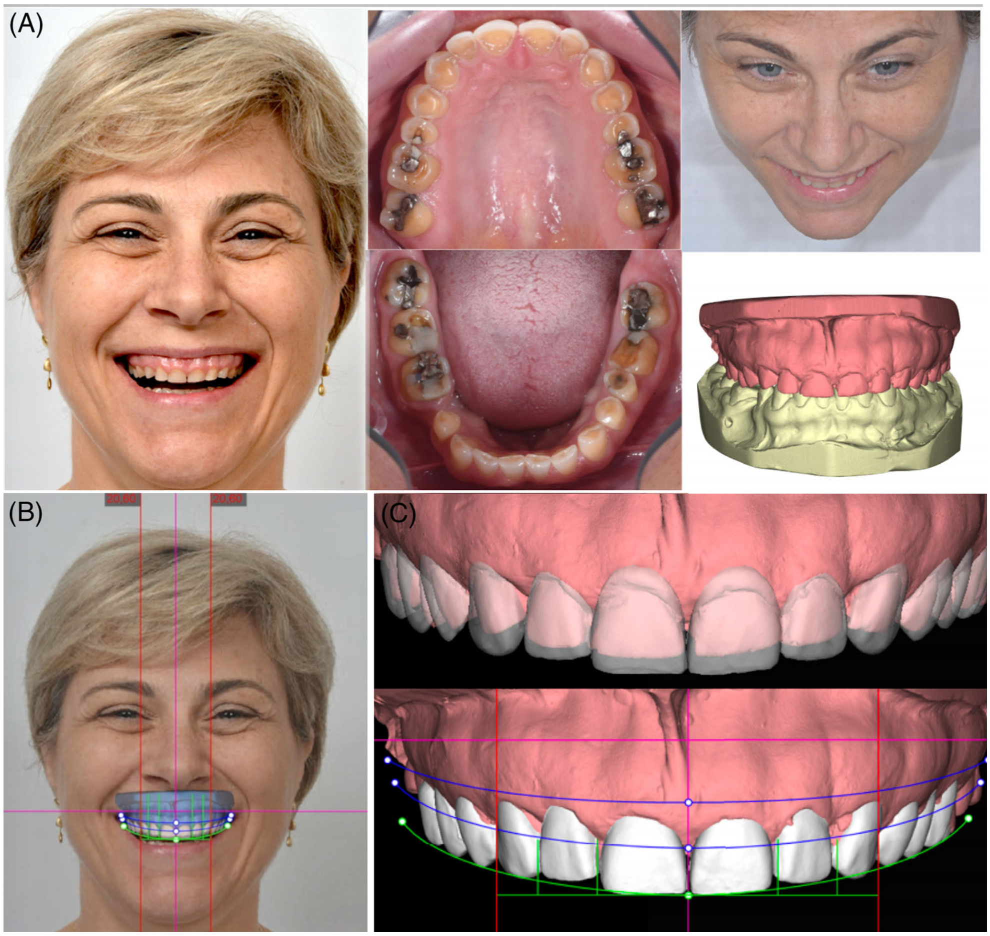

FIGURE 2 Patient initial condition and DSD: (A), photographic documentation and digital models; (B), facially driven smile frame and smile design exhibiting the need for crown lengthening; (C), ideal smile design with natural shape and texture imported from a digital library of natural teeth

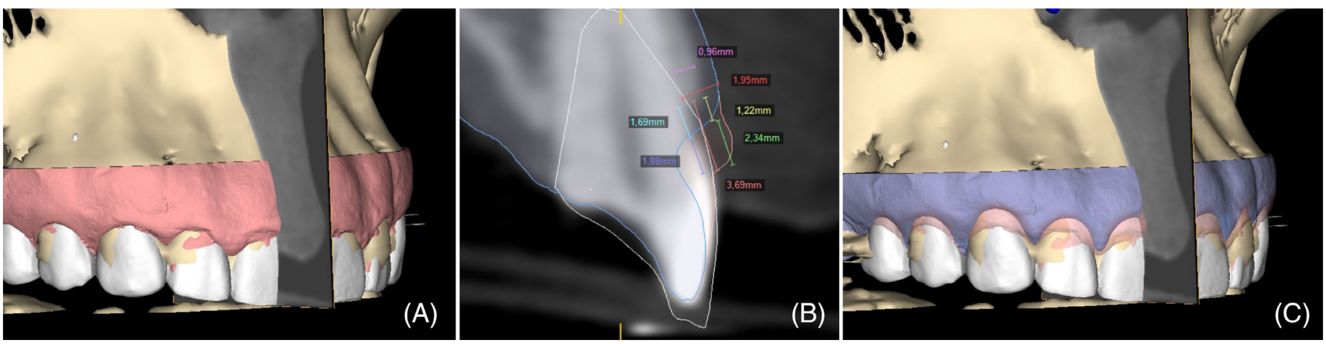

FIGURE 3 3D Perio analysis and crown lengthening planning (NemoStudio, Nemotec, Madrid, Spain): (A) Intraoral scan superimposed on CBCT; (B) Seven measurements of bone and gingiva established to orientate the design of the guide: actual gingival level to bone level (existing biological width) = 3.69 mm (light red); ideal gingival level to bone level = 1.22 mm (yellow); actual gingival level to ideal gingival level = 2.34 mm (green); CEJ to bone level = 1.69 mm (blue); actual gingival level to CEJ = 1.88 mm (purple); bone thickness = 0.96 mm (pink); gingival thickness = 1.95 mm (red); (C), virtual simulation of the gingivectomy on the digital model

(TRIOS 3, 3Shape, Copenhagen, Denmark) was obtained for surgical planning. The virtual model was merged with the CBCT scan, and seven measurements were digitally made by using the 3D Perio Analysis tool of NemoStudio software (Nemotec, Madrid, Spain). These measurements allowed professionals to establish the quantity of bone and soft tissue to be surgically removed, increasing accuracy, respecting the cement-enamel junction (CEJ), determining the amount and type of bone reduction, verifying the need for flap or flapless surgery and favoring the accomplishment of a harmonious esthetic result (Figure 3(A–C)). In order to orientate the

FIGURE 4 Guided crown lengthening: (A) Pre-operative intraoral condition; (B) Pre-operative digital model; (C) CAD of the dual guide (gingivectomy/osteotomy); (D) Printed guide in the mouth prior to gingivectomy; (E) Guided gingivectomy; (F) Guided osteotomy; (G) Post-operative appearance; (H) Post-operative digital model for quality control

surgeon for both gingival and bone resection, a surgical guide was virtually planned and printed (Form 2, Formlabs, Somerville, Massachusetts). The dual technique guide was chosen to provide references for the gingival level in its inner contour and for the bone level in its apical external contour, which is an essential information after the flap is open (Figure 4(A–H)).[15]

2.2 | Perio quality control

Before proceeding to the prosthetic phase, a digital quality control was performed overlapping pre- and post-operative virtual models (Figure 5(A,B)). This allowed the team to understand whether the case needed retouches or if it was sufficiently adequate to advance to the next stage. The ideal design was then copy-pasted onto the post-procedure model to be refined and adapted, aiming to respect the real outcome of the periodontal procedure (Figure 5(C,D)).

2.3 | Guided vertical dimension augmentation

In this particular case, according to treatment plan, the next step was to open the vertical dimension (digital bite lift) to obtain adequate posterior clearance and anterior overbite/overjet. This strategy was first conducted in the virtual articulator and then was clinically implemented (Figure 6(A,B)). To achieve this aim, a digital anterior deprogrammer (Kois deprogrammer)[16,17] was designed (NemoStudio, Nemotec, Madrid, Spain) and printed (Form 2, Formlabs, Somerville, Massachusetts) (Figure 6(C,D)). When the mandible was stable and in centric relation (CR), this position was scanned (TRIOS 3, 3Shape, Copenhagen, Denmark) (Figure 6(E,F)).

2.4 | Vertical dimension quality control

The new file was imported into the software (NemoStudio, Nemotec, Madrid, Spain) to be overlapped on the initial digital bite opening. A quality control assessment was done, and the condition achieved in the mouth was checked to verify if it was similar to the position previously planned. After team approval, the same present model was superimposed again on the previous model containing the ideal design, to copy-paste this design into the current situation and to continue with the next step in the appropriate maxillomandibular position.

2.5 | Functional design on the new OVD

With the new maxillomandibular/CR position in the digital articulator, the mandibular design was adjusted to the maxillary design. Thus, optimal function was incorporated into the ideal smile layout (Figure 7(A,B)). The functional-esthetic project was then imported into a restorative software (NemoStudio, Nemotec, Madrid, Spain) to translate the designs into maxillary and mandibular transitional restorations (Figure 7(C,D)).

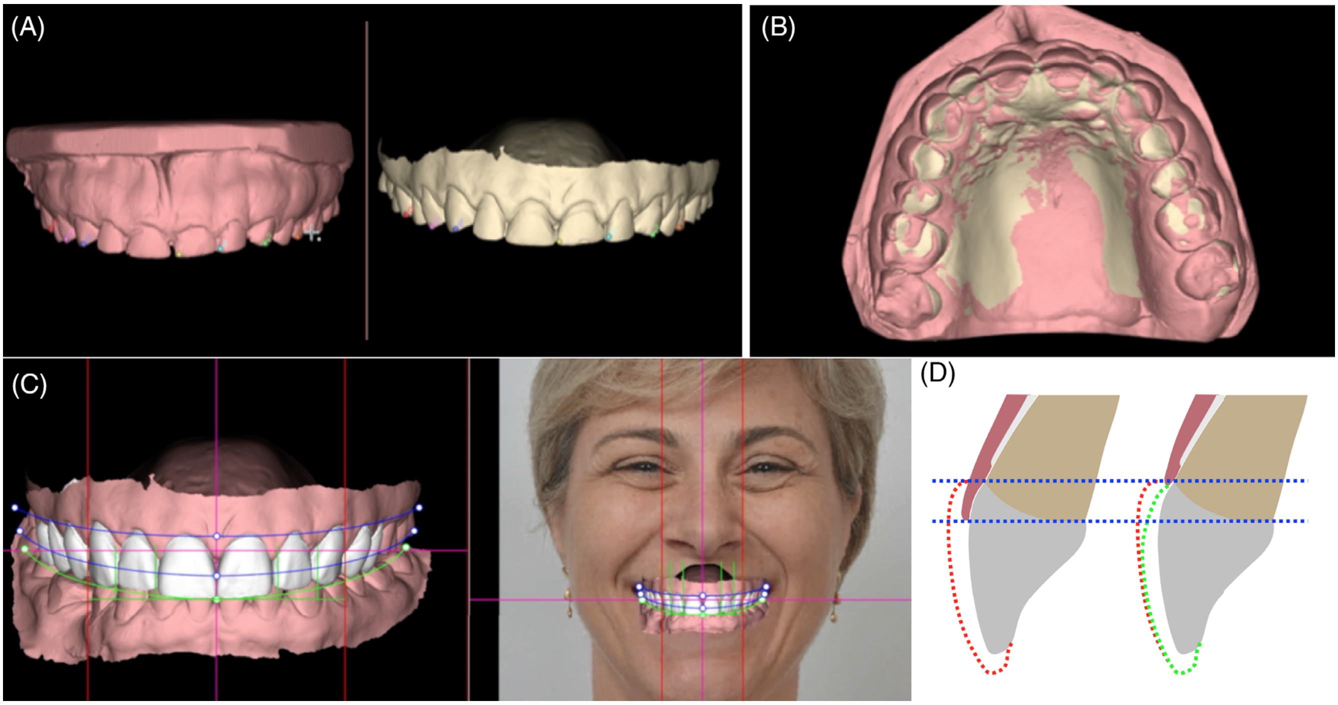

FIGURE 5 Crown lengthening digital quality control: (A) Pre-operative and post-operative virtual models; (B) Pre-op and post-op digital models superimposed in NemoStudio software (Nemotec, Madrid, Spain); (C) Ideal design that was attached to pre-op file is fine tuned to the post-op real outcome, considering orofacial harmony; (D) Red dotted line represents the ideal design over the gingiva before crown lengthening surgery and green dotted line shows the design adaptation to respect the new gingival position

2.6 | Transitional restorations

The option for this case was to perform prepless transitional restorations to test drive function and esthetics before advancing to the final restorations. Thin posterior overlays (table tops), mandibular anterior buccal veneers and maxillary anterior palatal veneers were designed (NemoStudio, Nemotec, Madrid, Spain) and manufactured (Lava, 3M ESPE, St. Paul, Minnesota). At this phase, nothing was programmed for the buccal surface of maxillary teeth since the plan was to proceed with definitive buccal ceramic veneers after a few weeks of test drive. In one appointment, all transitional prepless restorations were bonded, providing the patient with a new bite, vertical dimension, and smile curve (Figure 7(E,H)). These interim restorations are a significant diagnostic tool. The quality material selected to mill the overlays and veneers is durable, and the time of replacement will depend on patient's function and financial resources.

2.7 | Transitional restorations quality control

As executed in all previous steps, an intraoral scan (TRIOS 3, 3Shape, Copenhagen, Denmark) was acquired after bonding the restorations for quality control purposes, in order to compare the final bite/OVD with the one initially planned. Secondly, the process continued with this model being superimposed on the previous files, which included the ideal smile design.

2.8 | Guided tooth preparation

The technical mock-up is represented in Figure 8. The ideal design was adapted to the current model after crown lengthening, bite lift and bonding the transitional restorations. This new design became the reference to produce the prep guides, and both provisional and final restorations (Figure 8(A)). To function as a prep guide, the design was printed (Form 2, Formlabs, Somerville, Massachusetts) and a silicone matrix was manufactured (Figure 8(B)). Then, a bis-acryl technical mock-up was performed, and the teeth were prepared on the mock-up (Figure 8(C,D)).[18,19] Minimally invasive final preparations of the buccal surfaces of maxillary teeth were guided by the ideal restorative design (Figure 8(E,F)). The interface between the remaining enamel and the palatal composites was visible from the buccal surface of the preps. A "sandwich approach"[20] was used on the maxillary teeth, with composite on the palatal/occlusal surfaces and ceramics on the buccal side. The combination of this method with the bite opening allowed for an ultra-conservative practice with maximum tooth structure preservation. The milled composite restorations in the mandibular arch were not replaced by ceramic and were maintained with clinical monitoring.

2.9 | Tooth preparation quality control

One more quality control evaluation was done by overlapping the actual model on the ideal design file to analyze whether the preparations were

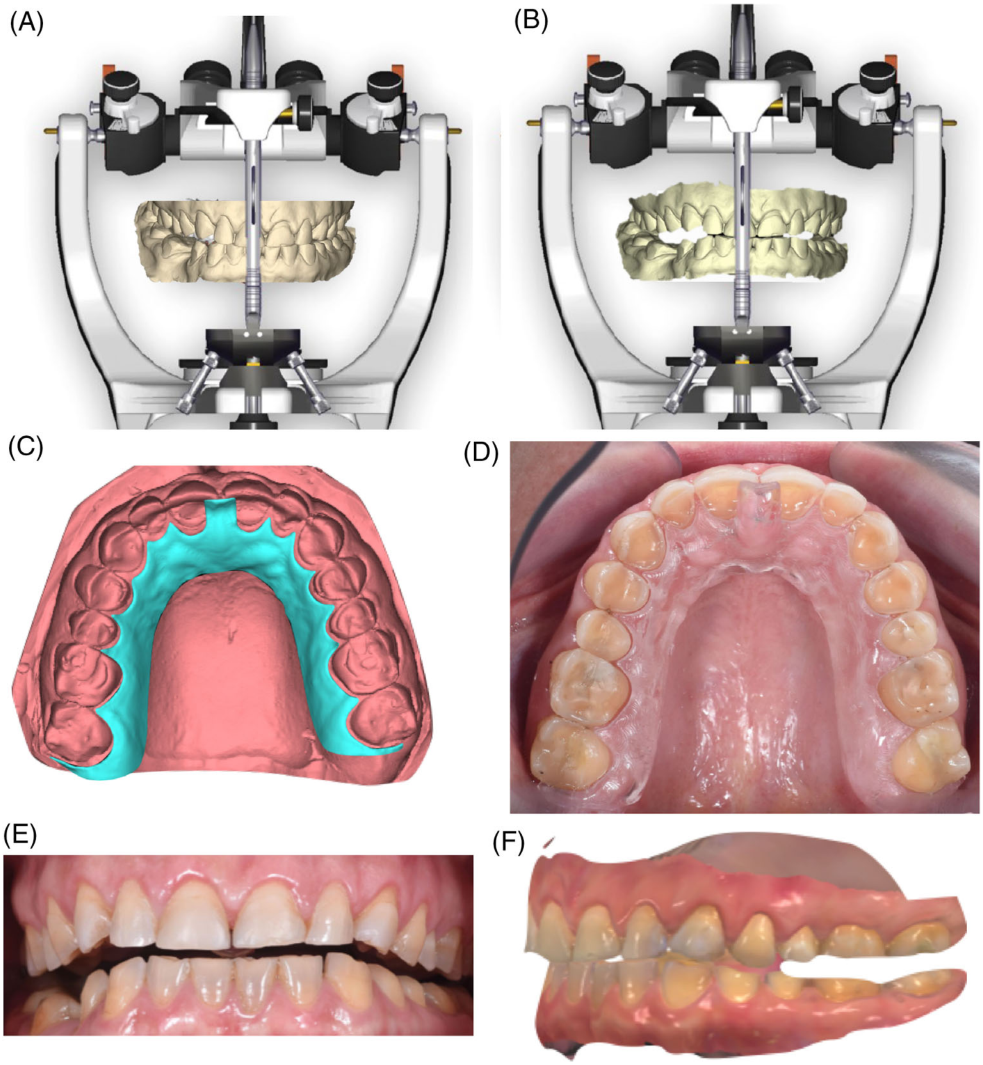

FIGURE 6 Digital bite lift: (A) Pre-operative models mounted in virtual articulator; (B) Occlusal vertical dimension (OVD) virtually increased; (C) Anterior deprogrammer (Kois deprogrammer) digitally designed (NemoStudio, Nemotec, Madrid, Spain); (D) Printed deprogrammer in occlusal view; (E) Bite lift in frontal view; (F) Intraoral scan of the new maxillomandibular relationship (OVD and CR position) to perform digital quality control

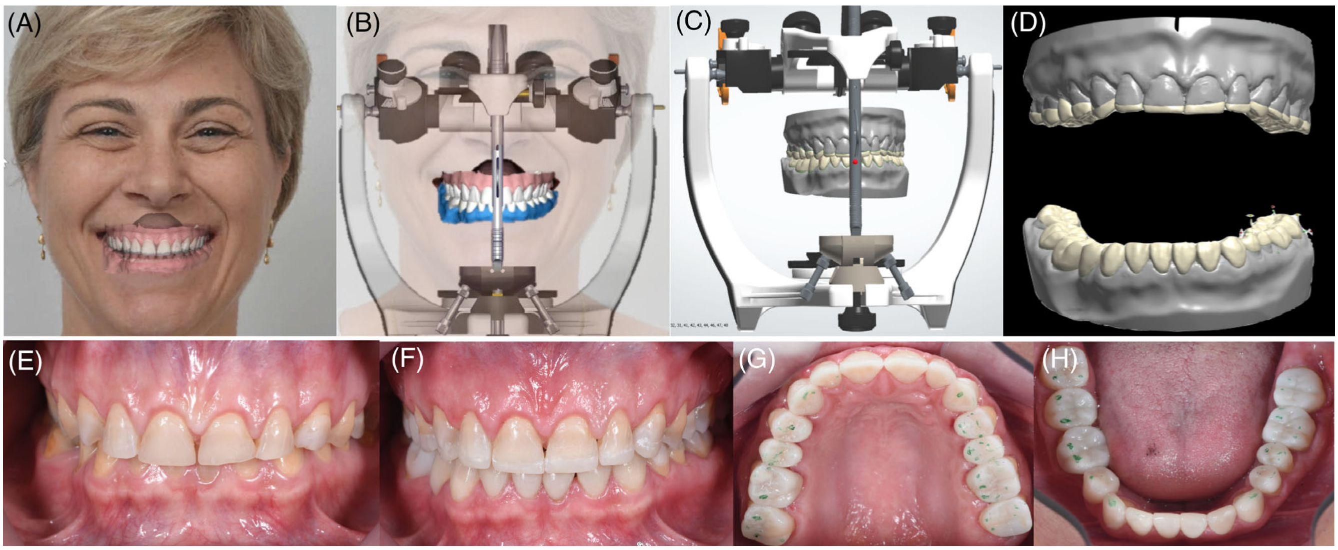

FIGURE 7 Transitional phase: (A) Facially driven maxillary esthetic design approved in the beginning of the treatment; (B) Mandibular design adjusted to the maxillary project in the new maxillomandibular relationship, integrating esthetics and function; (C) Functional-esthetic design exported to CAD restorative software (NemoStudio, Nemotec, Madrid, Spain); (D) CAD of prepless transitional restorations (additive case): posterior overlays, mandibular anterior buccal veneers and maxillary anterior palatal veneers; (E) Before transitional restorations; (F) Bonded transitional restorations in frontal view; (G) Maxillary occlusal view; (H) Mandibular occlusal view

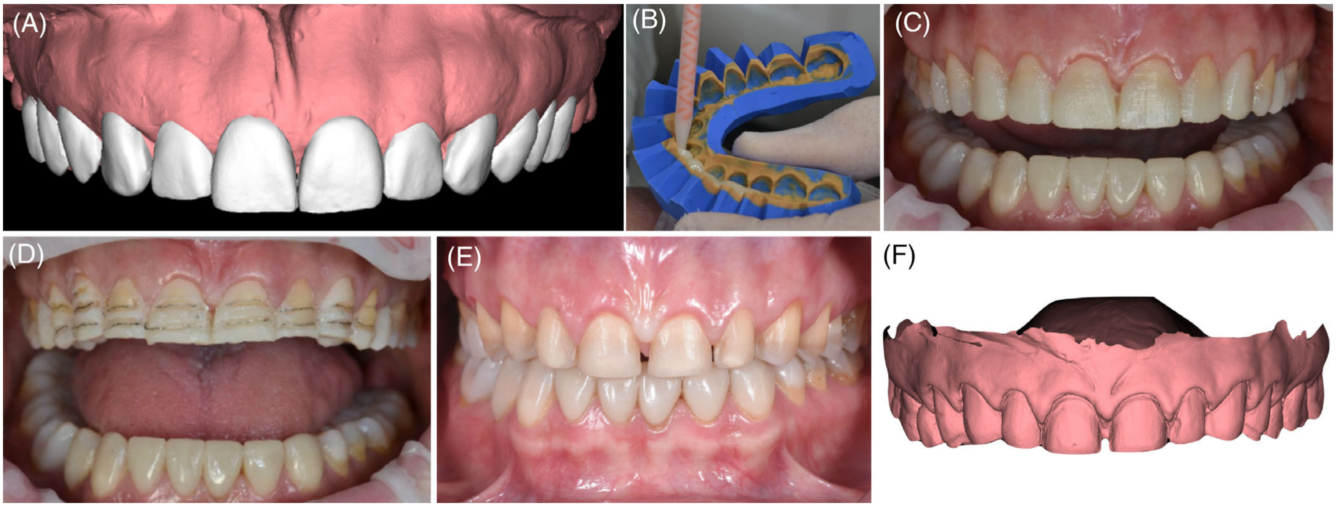

FIGURE 8 Technical mock-up to guide tooth preparation: (A) Ideal design adapted to current digital model (after crown lengthening and bite lift); (B) Silicone matrix manufactured on the printed model; (C) Bis-acryl mock-up; (D) Incisal and buccal grooves made by depth cutter burs on the mock-up; (E) Minimally invasive preparations for maxillary buccal laminate veneers; (F) Post-preparation digital model to be overlapped with the pre-operative model for quality control of tooth preps

satisfactory and to adapt the design to the preps, respecting the new finishing lines.

2.10 | Over the prep restoration design and manufacturing (CAD/CAM)

The "copy-paste"/overlapping workflow is presented in Figure 9. Post-preparation maxillary working model (yellow) was superimposed on the pre-operative model containing the ideal design (salmon color) (Figure 9(A–C)). Subsequently, the mandibular model (with transitional restorations) was related to the maxillary working model in the increased OVD and CR position (Figure 9(D,E)). Pre-operative models (salmon) were removed but the ideal design remained on the maxillary working model (Figure 9(F)). The design was adjusted tooth by tooth to the preparations and finishing lines and checked with the face and smile frame guidelines (Figure 9(G,H)). After approval, the concept of "copy-milling" was applied in order to clone the virtual design to fabricate restorations.[21,22] Hence, the file with natural shape and texture (Figure 9(I)) was exported to a software (Ceramill Mind, Amman Girrbach/Straumann, Koblach, Austria) to enable the manufacture of individual restorations.

The monolithic lithium disilicate veneers IPS e.max CAD HT BL3 (Ivoclar Vivadent AG, Schaan, Liechtenstein) were milled and hand polished to preserve natural texture.

2.11 | Bonding and final quality control

Prior to definitive cementation of final restorations, a veneer try-in was performed, and considering the achievement of a favorable esthetic result, the procedure was completed (Figure 10(A–F)). After cementation and bite adjustment, one more intraoral scan (TRIOS 3, 3Shape, Copenhagen, Denmark) was acquired to serve as a back-up file, to register the final status of the smile and to allow the last quality control assessment, with the intention of comparing the initial condition with the final outcome of the case.

3 | DISCUSSION

This case report aimed to present an interdisciplinary approach, in which esthetics and function could be virtually planned and implemented by means of a guided workflow. The quality of every clinical step was digitally controlled to guarantee final outcomes similar to those predicted in the initial planning.

To date, dental procedures may benefit from a facially-driven treatment plan and from the subsequent creation of a smile design harmonized with the facial appearance.[6,23,24] This concept represents a new proposal, which establishes that dentists should focus not only on the mouth, but also on the face.

With regard specifically to periodontal surgery, the conventional crown lengthening techniques have some limitations concerning the clinical definition of the final gingival and bone margins. In the digital workflow, the relations between hard and soft tissues can be evaluated by merging CBCT and intraoral scans. In this case report, a crown lengthening double guide was designed based on virtual measurements, and it was used as a template to ensure the optimal removal of bone and soft tissue.[10,15]

As demonstrated throughout the steps, to perform interdisciplinary guided dentistry and digital quality control, the following resources are required: IOS (mandatory to start the process and to

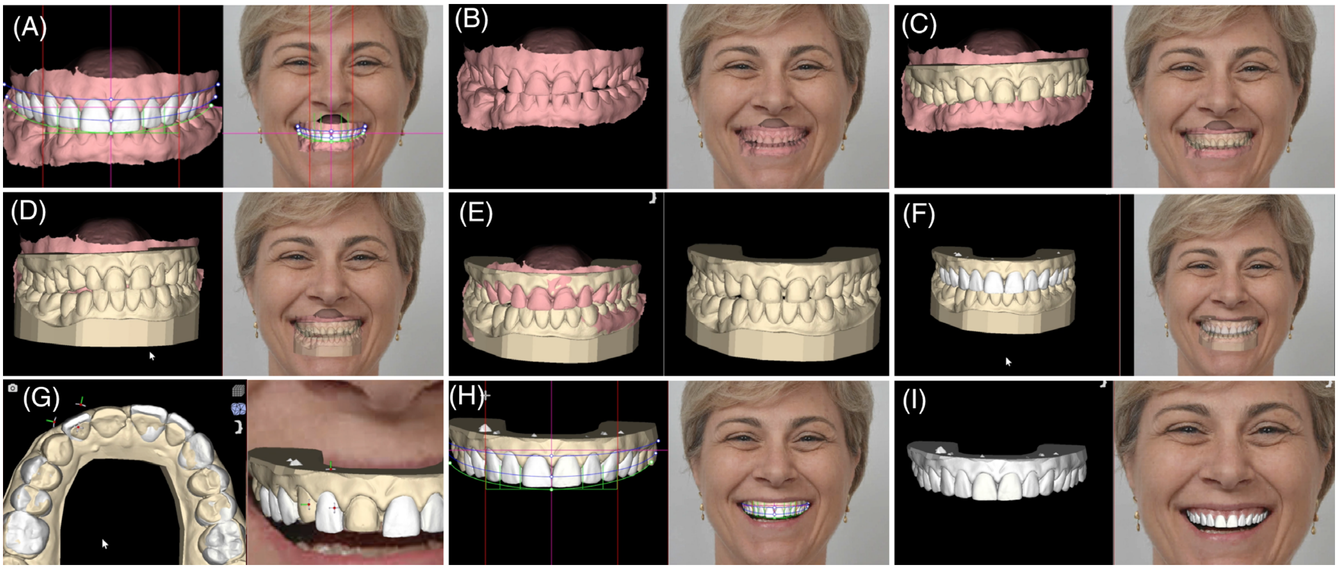

FIGURE 9 "Copy-paste"/overlapping workflow: (A) Pre-operative models with ideal design (salmon color); (B) Pre-operative models with the design in 100% transparency to facilitate overlapping; (C) Post-preparation maxillary working model (yellow) overlapped with pre-operative model; (D) Mandibular model (with transitional restorations) related to the maxillary working model in the increased OVD and CR position; (E) Pre-operative models (salmon) overlapped with working models (yellow) on the left and pre-operative models removed on the right; (F) Ideal design on the maxillary working model; (G) Design adjusted tooth by tooth to the preparations and finishing lines; (H) Design checked with the face and smile frame guidelines; (I) After approval, files with natural shape and texture ready to be exported to a software (Ceramill Mind, Amman Girrbach/Straumann, Koblach, Austria) to fabricate individual restorations

FIGURE 10 Final monolithic CAD/CAM ceramic veneers from tooth 14 to 24: (A) adaptation to the physical model; (B) Intraoral frontal view; (C) Right side clinical view; (D) Left side clinical view; (E) Facial outlook; (F) Smile outcome

digitalize the patient, but also key for the purpose of quality control), interdisciplinary software (to develop all initial 3D simulations), any 3D software to enable superimposition and the quality control practice, printing technology to produce models and guides, a vacuum tray for some appliances such as aligners, and a milling machine to fabricate final restorations.

Even when using guided dentistry, the initial simulation and the actual result of the procedure are not identical. Consequently, the ideal design needs to be calibrated considering the realistic outcome after each step of the treatment, before designing the appliances for the next stage. Since the ideal design is attached to the pre-operative model, this method always requires overlapping pre and post-procedure files.

After every clinical phase, an intraoral scan should be performed for two reasons. First, for quality control, to compare the outcome with the virtual plan. Second, to overlap the current situation with the previous files containing the ideal smile design. Thereby, the design can be "copy-pasted" onto the new digital model in order to be revised and adapted to the overall project.

Based on the reported considerations and digital trends, further advancements may include the 4D digital analysis of patient's movements, leading to a complete true to life treatment plan.

4 | CONCLUSION

Interdisciplinary guided dentistry, digital quality control and "copy-paste" are concepts related to the development of a comprehensive treatment plan, which integrates esthetics and function with accuracy and predictability. In the proposed workflow, technological resources and the assessment of clinical steps provided smile outcomes in accordance with the initial design.

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DISCLOSURE

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 to this article as no datasets were generated or analysed during the current study.

ORCID

Camila Sales Jreige https://orcid.org/0000-0002-0783-6551
Newton Sesma https://orcid.org/0000-0001-5044-1742

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