

CLINICAL ARTICLE

Contemporary Digital Dentistry for Complex Cases in the Anterior Maxilla

Ignacio Pedrinaci^{1,2} | Javier Calatrava^{1,3}  | Manuel Toledano-Osorio¹ | Na Zhao² | Alejandro Lanis^{2,4} | Mariano Sanz¹

¹Section of Graduate Periodontology (Department of Dental Clinical Specialties), Complutense University of Madrid, Madrid, Spain | ²Division of Regenerative and Implant Sciences, Department of Restorative Dentistry and Biomaterials Sciences, Harvard School of Dental Medicine, Boston, Massachusetts, USA | ³Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, Michigan, USA | ⁴Section of Oral & Maxillofacial Implantology, University of Chile School of Dentistry, Santiago, Chile

Correspondence: Ignacio Pedrinaci (ignpedri@ucm.es)

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ABSTRACT

Objectives: To demonstrate how contemporary digitally driven workflow can enhance outcomes for complex esthetic dental cases, focusing on three distinct clinical scenarios involving implant placement, esthetic crown lengthening, and tooth auto-transplantation (ATT).

Overview: Three multidisciplinary clinical cases demonstrate our contemporary digital workflows, integrating diagnosis, treatment planning, patient communication, and guided execution. The first case involves replacing two anterior central incisors using digital planning, guided surgery, prefabricated customized healing abutments, and a digitally driven restorative process. The second case showcases an esthetic crown-lengthening procedure, where Multifunctional Anatomical Prototypes (MAPs) serve as both mock-up and surgical guides, enhancing patient communication on expected outcomes and ensuring precise tissue management to prevent soft tissue rebound. The final case features a tooth ATT, where virtual surgical planning and 3D-printed tooth replica and guides ensure predictability in the therapeutic outcome. These digitally enabled strategies underscore the predictability and customization achievable with contemporary dental technology.

Conclusions: Dental treatments in the esthetic zone require meticulous planning and precise execution to achieve controlled results that ensure patient satisfaction and long-term stability. Contemporary Digital Dentistry enhances predictability, creating a pathway that leads to success.

1 | Introduction

Oral Care has quickly evolved from the traditional methods in Dentistry to the full integration of digital technologies at every stage of the care pathway: diagnosis, treatment planning, patient communication, and treatment execution. This integration represents the best way to define “Contemporary Digital Dentistry (CDD)”, since today’s advancements in digital tools have upshifted clinical practice and have converted the clinical workflows into more comprehensive, streamlined, and

multidisciplinary therapies [1–3]. The use of digital tools should no longer be considered optional add-ons; but essential components to enhance the accuracy and predictability of patient-centered care. A clear example of this current paradigm is the treatment of esthetically compromised cases, where the use of contemporary digital strategies becomes essential.

CDD integrates 2D and 3D radiographic data with surface scanner data (i.e., intraoral and facial scanners), simultaneously assessing hard and soft tissue anatomical structures [4, 5].

Combined with the planned restorative outcome, this creates a virtual environment that enables a comprehensive diagnosis [6, 7]. Additionally, the use of artificial intelligence-(AI)-driven virtual segmentation tools, together with digital occlusal tracking devices, allows for the development of hyper-realistic virtual smile scenarios, providing highly individualized treatment plans to optimize both esthetic and functional outcomes. Furthermore, these virtual simulations improve the professional-patient communication since they provide clear visualizations of the treatment goals, and allow for the active involvement of the patients in the treatment decision-making, which will potentially increase their satisfaction with the proposed treatments [8, 9]. Finally, the use of digital tools has been shown to improve accuracy during treatment, reducing the importance of the provider's technical ability and experience, thus enhancing treatment predictability and improved outcomes and the success rate of clinicians that employ these workflows.

This concept will be further developed throughout the manuscript. It will be exemplified in three clinical cases that followed a structured and streamlined digital workflow with four clearly defined steps: diagnosis, treatment planning, patient communication, and guided execution. These clinical cases aim to demonstrate how the use of these digital strategies may have a direct impact on the resolution and outcome of complex esthetic challenges.

2 | Contemporary Digital Workflow for the Replacement of Two Upper Central Incisors With Dental Implants

2.1 | Diagnosis

A 41-year-old healthy female patient was referred by her endodontist to evaluate teeth #11 and #21 since she presented diffuse apical symptomatology in tooth #21. In the anamnesis, the patient referred that both central incisors had undergone

root canal treatment (RCT) about 9 years prior due to trauma and had been restored with cemented metal posts/cores. Then, 2 years post-RCTs, an acute infection around the apical area of #21 occurred, which was treated by apicoectomy and retrograde amalgam filling. The clinical examination revealed moderate pain upon percussion of #21 and discoloration of both incisors with defective class III restorations, which created an esthetic concern for the patient. Periapical radiographs, a Cone Beam Computed Tomography (CBCT), and Digital Intraoral Scan (IOs) were obtained during the first visit. Periodontal assessment indicated that #11 and #21 had a favorable periodontal prognosis. However, both teeth were restoratively compromised since #11 exhibited root resorption at the facial cervical area and secondary decay at the tooth-core interface. At the same time, #21 had an apical lesion with a chronic buccal fistula. Functionally, the patient presented an Angle's Class III molar occlusion with a diminished overjet and overbite. Anterior guidance was provided by #11, #21, and the mandibular incisors, with strong protrusive contacts due to minimal overjet. Based on the clinical evaluation and digital data registers, both upper central incisors were deemed irrational to treat (Figure 1).

2.2 | Treatment Planning

Digital Imaging and Communication in Medicine (DICOM) files from the CBCT were merged with the Polygon File Format (PLY) file obtained from IOS in an implant planning software (Codiagnostix, Straumann, Basel, Switzerland). Due to the patient's reduced overjet, Computer-Assisted Design (CAD) software was used to create a new digital tooth arrangement (DTA) with a corrected overbite and overjet (Cares Visual, Straumann, Basel, Switzerland). DTA was imported into CodiagnostiX for accurate bio-restorative implant planning [10]. CodiagnostiX was then integrated with the CARES (Synergy protocol) to simultaneously modify the DTA based on the foreseen implant 3D position and strategy (i.e., immediate placement (Type 1) and immediate or

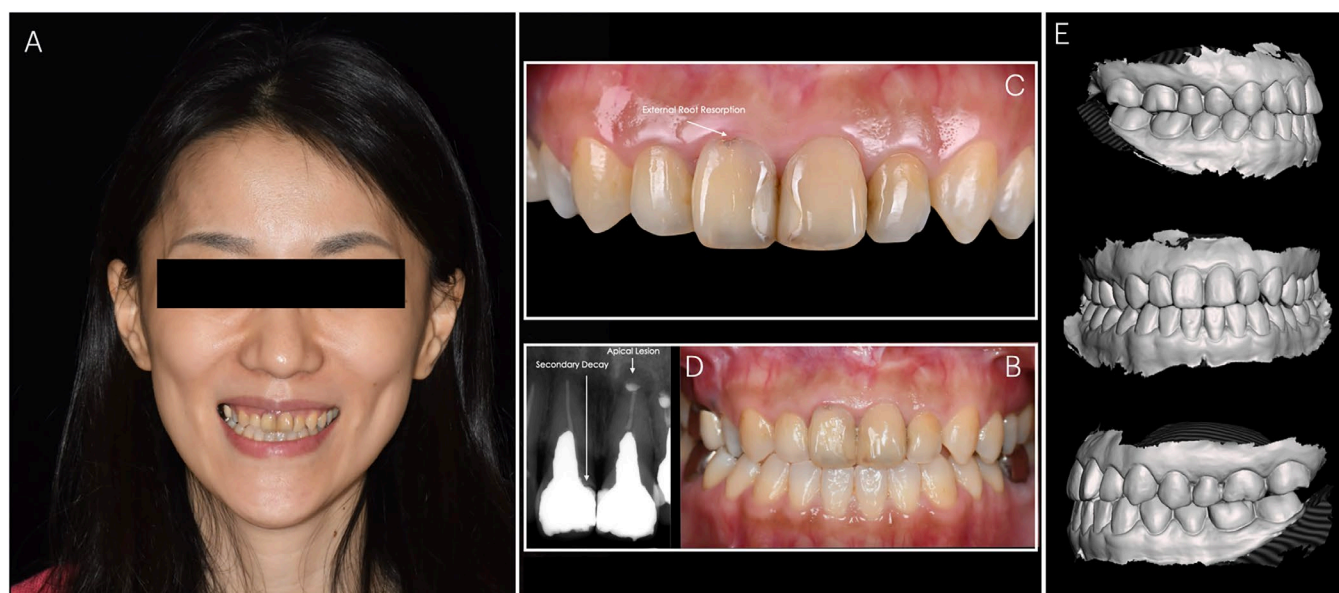


FIGURE 1 | (A) Baseline extraoral patient smile; (B) Intraoral photography. Patient in maximal intercuspation. (C) Detailed image of the maxilla. (D) Periapical X-rays and CBCT sagittal slices of #11 and #21. (E) Lateral and frontal view of baseline IOs.

conventional loading (A/C) depending on the interpretation of the functional loading applied to a SSA) [11] (Figure 2A).

Following the Synergy protocol, interim restorations were planned for their delivery immediately after implant placement, hence eliminating the need for abutment pickup. For this purpose, prosthetic abutments were digitally selected, and two sets of provisional restorations were designed, exported, milled in PMMA, and bonded to these selected abutments. These two sets of interim restorations created: (A) Digitally Sealing Socket Abutment (SSA) [12, 13] for the osseointegration phase and (B) full tooth structure interim restorations maintaining the same designed emergence profile as SSA (Figure 2B). Surgical sleeve configurations were digitally positioned, and a surgical

guide was designed and exported as a Standard Tessellation Language (STL) file for 3D printing (Figure 2C).

2.3 | Patient Communication

Digital implant planning software enabled the simulation of the complete surgical and restorative treatment, facilitating effective communication between the clinical team and the patient. The treatment plan was presented to the patient using images from the digital planning software (Figure 3) (Codiagnostix, Straumann, Basel, Switzerland) to ensure her complete understanding of the clinical proposal. Also, the visual scale resulting from the SAC classification in Implant

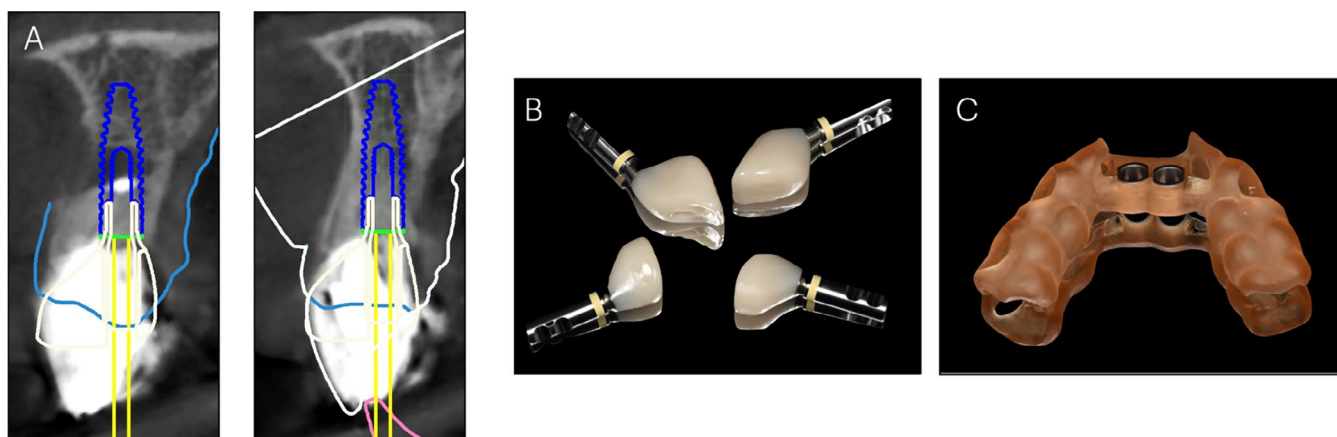


FIGURE 2 | (A) Bio-restorative implant planning. (B) Prefabricated customized PMMA sealing socket abutments (SSA) and provisional restorations. (C) 3D-Printed Surgical.

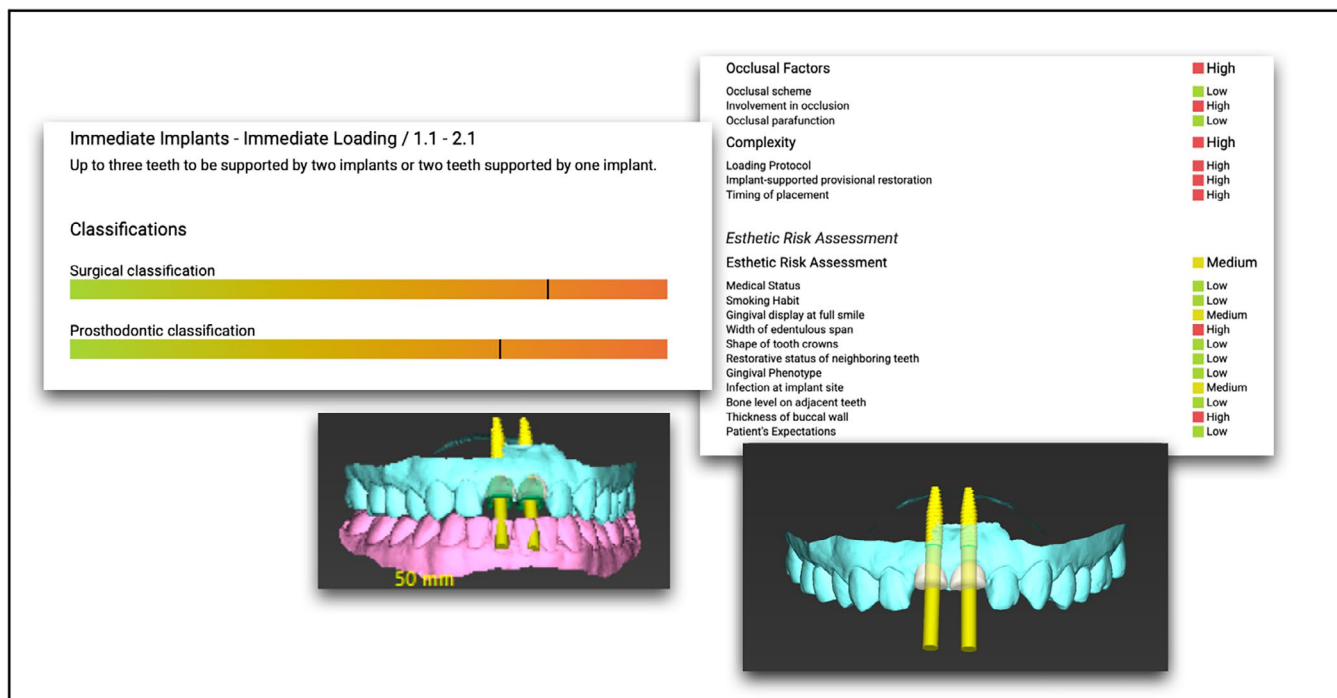


FIGURE 3 | Digital planning software showed to the patient explaining the length, diameter, and 3D position of the planned implants and SSA. Visual analysis scale from SAC classification was used to explain to the patient objectively the complexity of this surgery, not the recommendation for immediate loading, and highlight patient collaboration in the post-operative measurement.

Dentistry (Figure 3) [14] was used to explain the complexity of the treatment to her, which required her cooperation during postoperative care.

2.4 | Execution: Static Computer-Aided Surgery

A prophylactic antibiotic dose of 2 g of Amoxicillin was administered 1 h prior to the procedure [15]. After local anesthesia of the area, minimally invasive extractions were carried out followed by a thorough socket debridement using curettes and copious irrigation with saline solution. Other intra-surgical requirements, such as bone availability, were checked with a periodontal probe in both extraction sites [16]. The tooth-supported surgical guide was then positioned, and the surgical protocol was followed using fully guided osteotomies. Special attention was paid to ensuring the implant connection's correct depth and rotational alignment according to the digital plan. A marked guide ensured that one flat surface of the prosthetic connection faced the appropriate direction for accurately positioning the provisional restorations. Two narrow-diameter implants (Straumann BLT SLActive 3.3×12 NC, Straumann, Basel, Switzerland) were placed using sCAIS. The insertion torque of the implants exceeded 50 Ncm, and implant stability was assessed with resonance frequency, resulting in ISQ values of 71 and 68 for #11 and #21, respectively (Ostell, Gothenburg, Sweden). Conventional healing abutments were initially placed. The buccal gap between the implant and the inner surface of the buccal bone wall and the labial fenestration on #21 was grafted with a deproteinized bovine bone mineral (DBBM) substitute (Bio-Oss, Geistlich Pharma AG, Wolhusen Switzerland) [17, 18]. Given the patient's thick phenotype [19], no connective tissue graft was added. Then, the custom SSA were placed [11, 20, 21]. An essix retainer was provided for esthetic purposes over the following weeks (Figure 4).

2.5 | Execution: Digitally-Driven Restorative Process

8–12 weeks post-implant placement, the SSAs were removed, and ISQ values were reassessed, yielding readings of 74 and 70 for #11 and #21, respectively. SSAs were replaced with prefabricated provisional crowns (Figure 5A). Over the next 6 months, the provisional restorations were carefully modified to achieve the ideal emergence profile (Figure 5B). After achieving the desired emergence profile, an IOS of the provisional restorations, emergence profiles, scan bodies, and antagonists was performed (Figure 5C). The resulting digital files were transferred to the lab technician (Figure 5C). The abutment designs selected during the initial planning were maintained to avoid disrupting the peri-implant tissues, and to minimize the risk of bone remodeling [22]. Both critical and subcritical contours [23] were preserved to promote stable peri-implant soft tissues over time. Two CAD/CAM monolithic zirconia implant-supported crowns were designed and milled. A staining technique was applied to enhance characterization (Figure 5D). The crowns were then delivered and torqued to 35 Ncm. The patient was scheduled for follow-up appointments at 14, 30 days, 3, 6 months, and 1-year post-delivery (Figure 6).

2.6 | Treatment Outcomes: Predictability

The surgical protocol of immediate implant placement and immediate loading in the esthetic zone has been extensively studied over the years, demonstrating a high predictability of outcomes [16, 24]. However, this treatment protocol is still highly technique-sensitive, mainly depending on two key factors: (1) The thorough evaluation of the receptor site anatomy and (2) the clinical execution. The main goal of this treatment

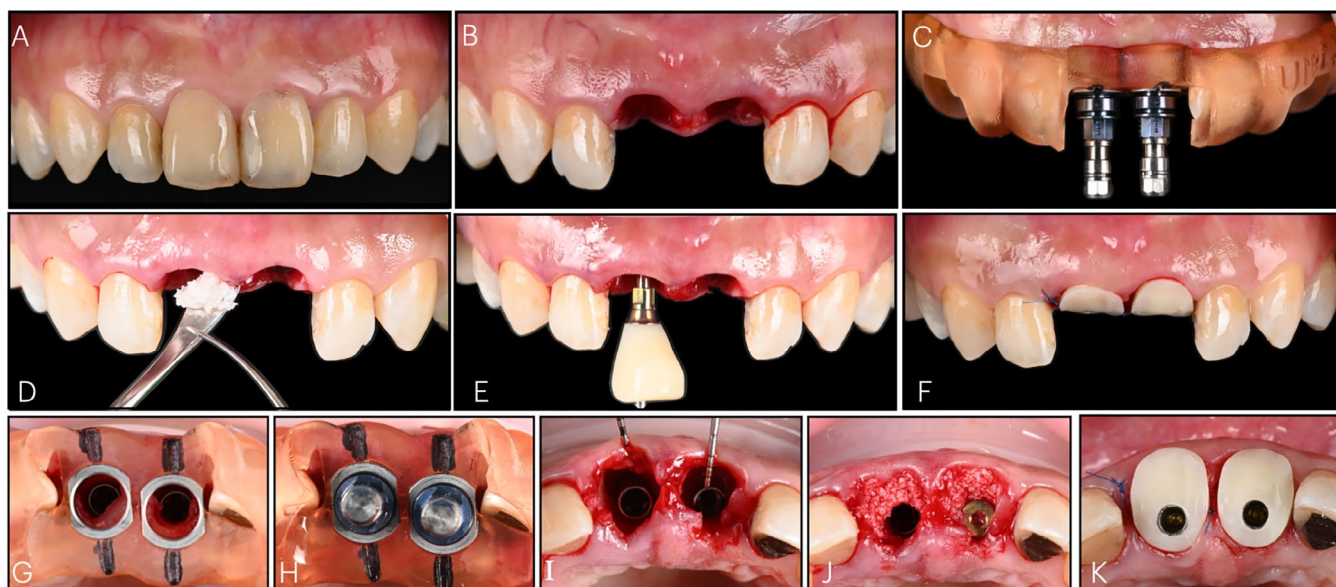


FIGURE 4 | Frontal view of the clinical sequence of guided surgery: (A) Initial situation. (B) Minimally invasive extractions, (C) sCAIS implant placement. (D) Buccal gap filling with xenograft. (E) and (F) Customized healing abutment. Occlusal view of the clinical sequence for sCAIS implant placement. (G) Surgical bed preparation. (H) Guided implant placement. (I) Buccal gap assessment. (J) Gap grafting technique with stock abutments. (K) Customized healing abutments positioning.

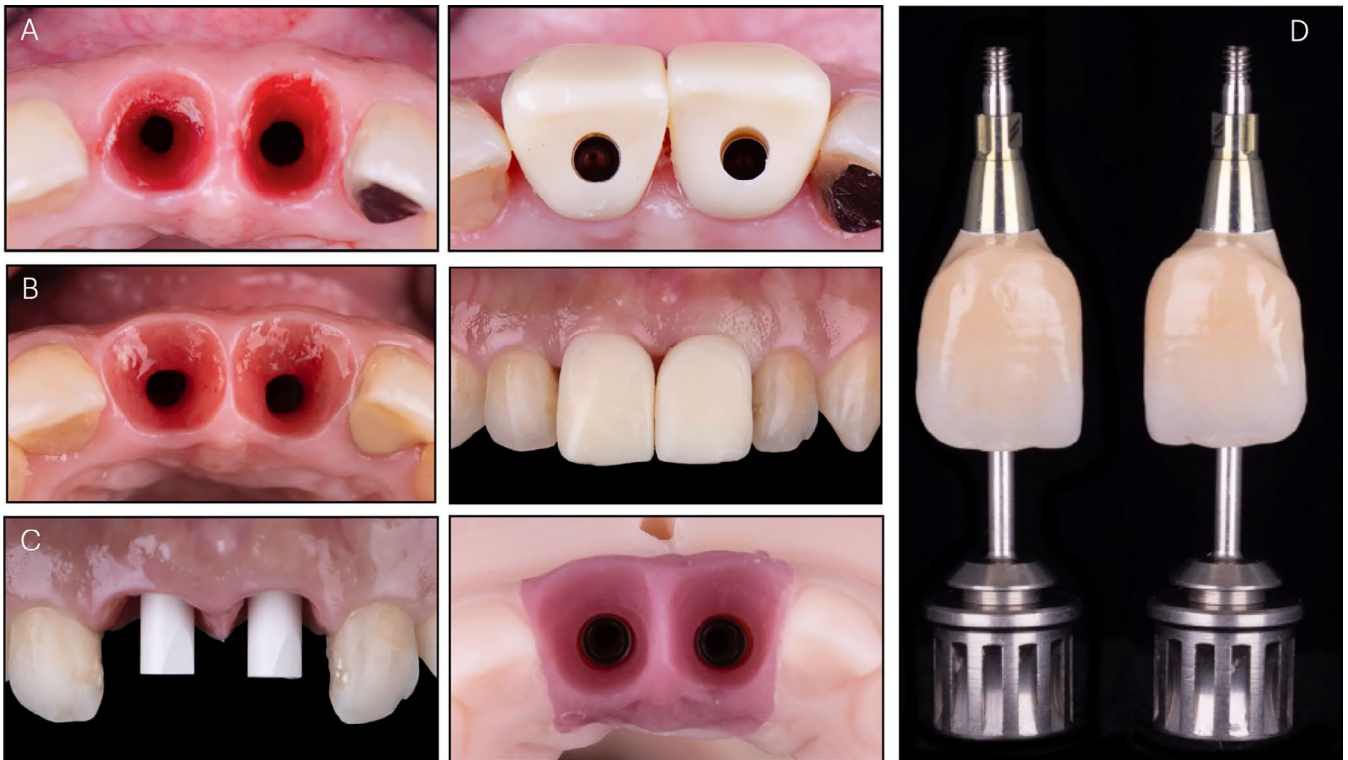


FIGURE 5 | (A) Occlusal view of the SSA and its soft tissue emergence profile after removal. (B) Customized provisional restorations frontal view and occlusal view of the emergence profile at 9 months after implant placement. Notice how the prosthetically driven soft tissue conditioning has favorably modified the emergence profile. (C) Scanbodies screwed in the implant for final digital impressions and 3D printed model.

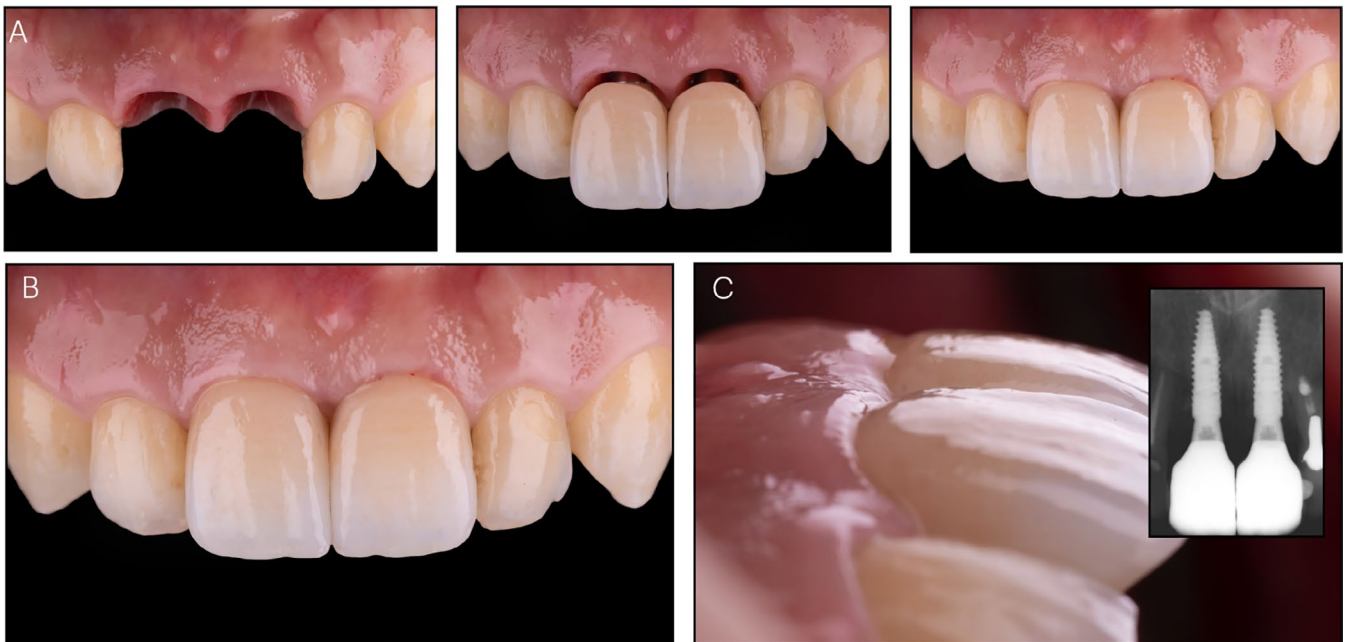


FIGURE 6 | (A) Definitive restoration delivery process. (B) Frontal and (C) Lateral view at 1 year follow up. Periapical X-Rays follow-up.

is to preserve the pre-existing tooth's soft tissue profile to obtain a natural result. In this sense, digital technologies and virtual implant planning allow clinicians to pre-simulate the procedure and to analyze every single factor and its interactions. In this sense, appropriate implant digital planning involves the

selection and placement strategy of the implant (macro-design, diameter, and 3D position), surgical technique, planning, and manufacturing of the supra-platform restoration [10]. All of these digital steps play a key role in achieving successful long-term implant predictable outcomes (Figure 7).

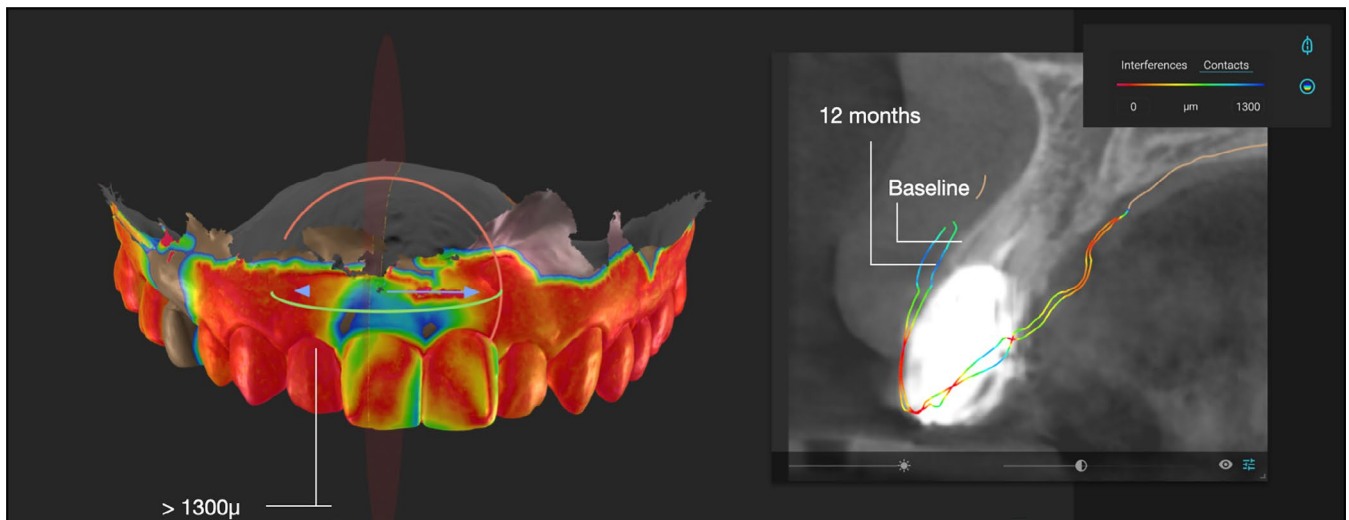


FIGURE 7 | Quality-check of the outcome. IOs comparison before and 12month follow-up. A heat map chart was used to note changes over 1300um in blue color. Preservation and augmentation of buccal tissues at #11 and #21 can be emphasized.

3 | Multifunctional Anatomical Prototypes for Smile Esthetic Improvement due to Altered Passive Eruption

3.1 | Diagnosis

A 25-year-old female was referred to improve her smile esthetics. In a first appointment, a thorough examination of the patient, including CBCT, IOs and photographs, was performed to comprehensively diagnose altered passive eruption (APE) [25, 26] combined with a short lip [27]. In short, DICOM, STL, and JPEG files were aligned using Smilecloud ([Smilecloud.com](https://www.smilecloud.com), Smilecloud SRL, Timisoara, Romania) (Figure 8A) as previously described by Pedrinaci et al. [9] and with the use of AI, this software automatically aligns the DICOM and STL files and performs the virtual segmentation of the teeth, bone and soft tissues that allows to individually and precisely analyze each tooth, using sagittal sections. Measuring the distances between the alveolar crest (ABC), cemento enamel junction (CEJ), and gingival margins (GM) (Figure 8B), confirmed the diagnosis of type 1B APE [25].

3.2 | Planning

The design of the MAPs requires the identification of the following anatomic landmarks: the GM, the CEJ, the ABC, and the supracrestal tissue attachment space (STA). The MAPs were designed from teeth 1.5 to 2.5, extending from the incisal edge of each tooth to the CEJ, since the patient showed up to the second premolars in the dynamic and static smile analyses. The MAPs were designed preserving the clinical crown morphology, with the unique objective of bringing the GM to the CEJ and, thus, changing the proportion of central incisors from 96% to an ideal one of 78% [28] (Figure 9). The CEJ was identified by analyzing the curvature change between the anatomical crown and the root of each tooth. It is known that CBCTs are not always able to detect mineralized structures thinner than 1 mm [29], and since in anterior teeth, the enamel thickness at the CEJ is only 0.3–0.4 mm [30] it is important to

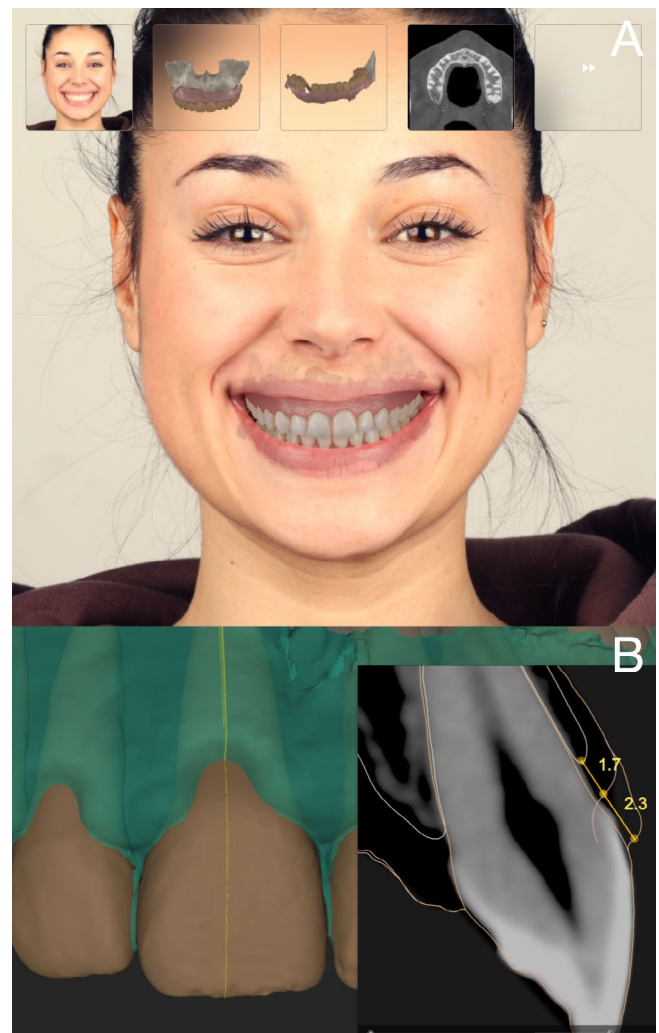


FIGURE 8 | (A) Superimposition of the CBCT, STL and digital photos aligned by the AI of Smilecloud. (B) Sagittal slide of tooth 1.1 in which different landmarks can be identified: alveolar bone (white line), baseline gingival profile (orange line), ideal gingival profile (pink). The distances AB-CEJ and CEJ-GM can also be measure, being 1.7 and 2.7, respectively.

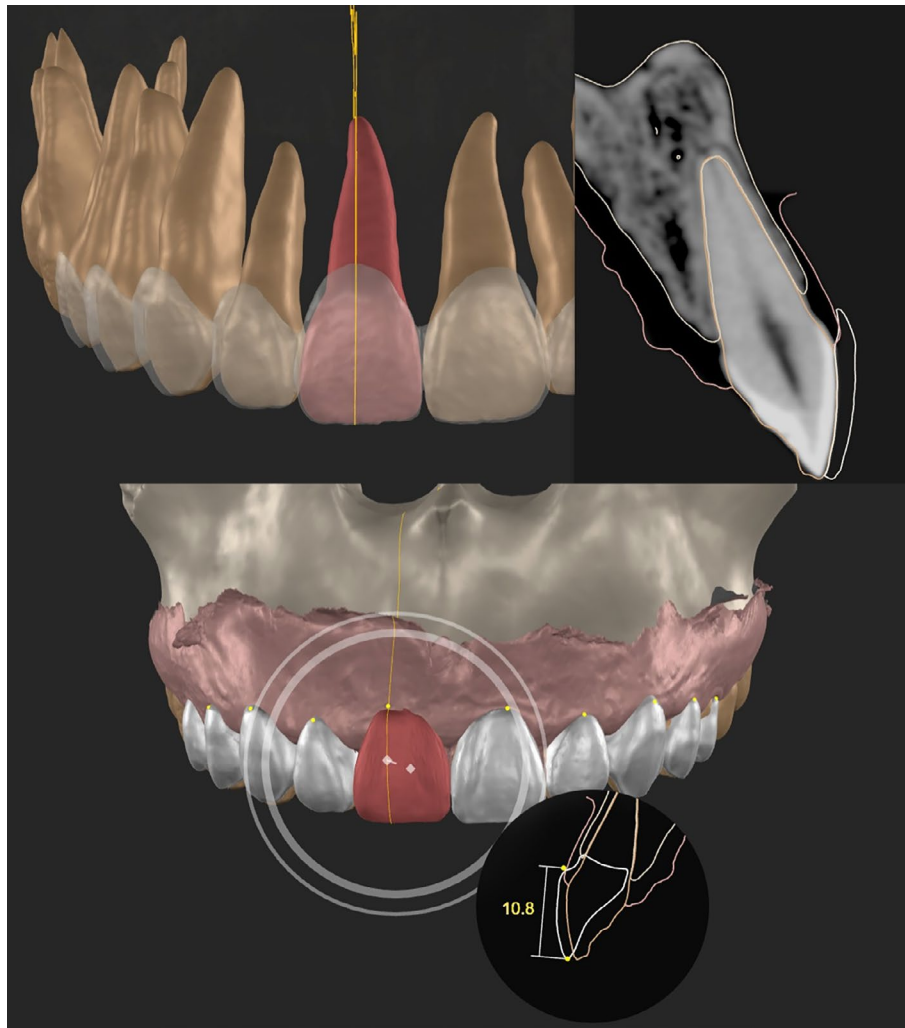


FIGURE 9 | Digital image of the design of the MAPs, preserving the clinical crown morphology and bringing the gingival margin of the MAPs to the anatomical CEJ (10.5 mm). By a Boolean command of subtraction, the internal face of the MAPs was intimately adapted to the buccal surface of each tooth to get a perfect coupling between the labial surface of the teeth and the inner surface of the MAPs.

consider the change of curvature to avoid an over/underestimation of the clinical crown length. Similarly, when designing these MAPs, the authors would like to emphasize the importance of considering the surgical tools (e.g., laser, blades, etc.) and the surgical technique (e.g., internal vs. external bevel) to be employed. Accuracy is critical in these procedures to avoid excessive gingivectomy. For instance, if a blade with an external bevel incision is used, the MAPs should be slightly shorter to ensure the incision is made precisely at the CEJ. However, if an internal bevel or electrocautery device is employed, the MAPs can be designed at the CEJ level. In any case, if over-cutting of the soft tissue occur, flaps can be coronally repositioned using sling sutures.

3.3 | Patient Communication

After virtually simulating the correction of the asymmetric GMs and the excessive gingival display (EGD) with Smilecloud, a virtual mock-up was presented to the patient for her approval (Figure 10B,E). This digital workflow not only allowed the

clinician to have the digital pre-visualization of the outcome, but also to have the agreement from the patient before the prototypes were produced, thus saving chair time and costs. Then the prototypes (i.e., MAPs) were designed using the sculpting tools of Smilecloud's Blueprint planning CAD tool. AI-driven virtual segmentation of teeth resulted in STL files. They were exported and using a Boolean command of subtraction in another CAD software (Codiagnostix, Straumann, Basel, Switzerland), MAPs were adapted to the buccal surface of each tooth to get a perfect coupling between the labial surface of the teeth and the inner surface of the MAPs (Figure 10). MAPs were designed splinted to ease their handling. They can be milled or 3D printed (Form 3B, Formlabs Inc.), and in the second appointment with the patient, a try-in was performed to get the final approval for our design. Static and dynamic smile recordings of the patient were taken to ensure that the patient's expectations were fulfilled. This is especially important because the diagnosis of EGD is multifactorial. Since only one of its etiologies (APE) will be treated, complete correction of the EGD won't be obtained. After definite approval by the patient, these prototypes were sterilized and used as surgical guides.



FIGURE 10 | Extraoral esthetics of our patient. (A) Baseline photography of the patient in smile. (B) Simulation of this extraoral photography after digitally performing the correction of the gummy smile. (C) Baseline smile of the patient more in detail. (D and E) Virtual simulation of the patient's smile before and after the virtually treated gummy smile.

3.4 | Execution: Surgical Crown Lengthening

As previously mentioned, the same MAPs prototypes were used for the mock-up and as surgical guide for the esthetic crown lengthening procedure (Figure 11A). Once the MAPs were in place their gingival limit was used to create the new GMs by an excisional gingivectomy (Figure 11B). After the raising a full-thickness flap (Figure 11C), this same gingival limit was used as a landmark to perform the ostectomy, placing the ABC at its new position and leaving enough space for the STA in each tooth using cutting-edge burs (Figure 11D). Ostectomy was performed to achieve a 3 mm distance between the ABC and the MAPs. This distance ensures adequate space for the various tissue compartments, including the sulcus, epithelial attachment, and connective tissue attachment [31]. This approach has been shown to effectively minimize tissue rebound, which is also influenced by the flap position following suturing and the patient's periodontal phenotype [32, 33]. Subsequently, osteoplasty was carried out as necessary to enhance flap adaptation and to mimic the natural interdental gingival grooves. The flaps were then sutured at the same position with vertical internal mattress sutures leaving the knots in the palatal aspect.

3.5 | Treatment Outcomes; Predictability

Esthetic crown lengthening is a challenging treatment in which the patient perception and expectations greatly influence the outcomes, and hence, the use of digital workflows allows the patient's involvement in deciding the expected outcomes. In Figure 12, the heat map chart shows the changes between the STLs registered at baseline and 12 months postoperatively. The red color stands for changes under $100\mu\text{m}$, whereas blue represents changes over $1100\mu\text{m}$. Between baseline (Figure 12A) and 12-months (Figure 1B), the 3–4 mm adjacent to the GM showed evident changes. The soft tissue margins were stable, what clearly improves the outcomes from classical surgical protocols in which there is a frequent tissue rebound between 3 and 6 months [32, 33].

4 | Contemporary Tooth Autotransplantation in the Esthetic Area

4.1 | Diagnosis

A 14-year-old systemically healthy male patient was referred for orthodontic therapy, under the parent's chief complaint



FIGURE 11 | Surgical sequence of the esthetic crown lengthening guided with the MAPs and follow up of the patient up to 1 year. (A) Baseline situation with MAPs delivered in place. (B) Excisional gingivectomy in all the teeth included in the crown lengthening. (C) Bony architecture after raising the full-thickness flap. (D) Bone morphology after performing osteotomy and osteoplasty. (E) baseline, (F) 12 months follow up.

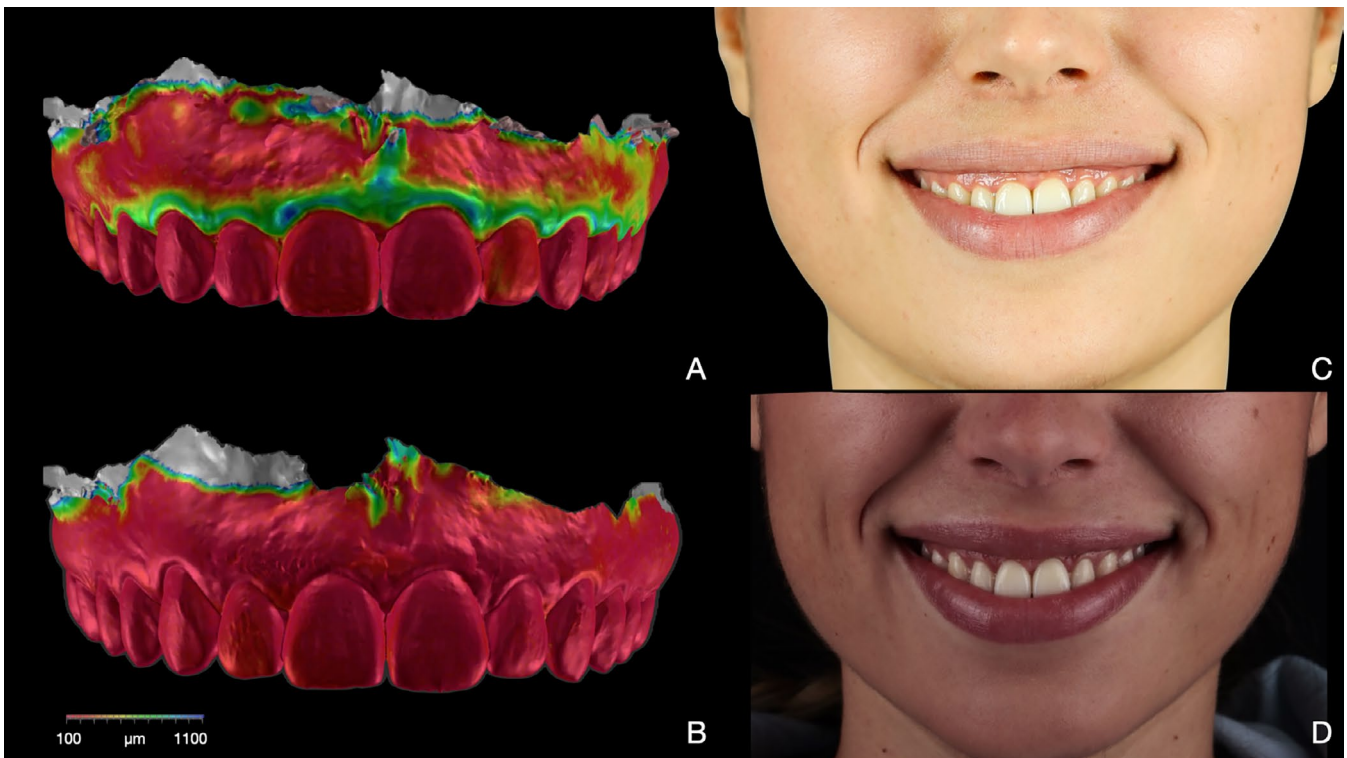


FIGURE 12 | (A and B) Heat map chart showing the changes between the STLs at (A) baseline and 3-months post-surgery, and (B) 3 with 6-months postoperatively. The red color stands for changes under 100µm whereas on the contrary, blue represents changes over 1100µm. Figure 5A stands for the comparison between the STLs of baseline and 3-months post-surgical, and Figure 5B represents the comparison of 3 with 6-months post-operative. (C) Smile of the patient at baseline. (D) Smile of the patient 6-months post-operative”

that “his teeth were erupting poorly aligned.” A comprehensive orthodontic evaluation was performed, combining an intraoral clinical exam and photographs, IOS, and panoramic and lateral telerradiograph X-rays to perform a cephalometric analysis. The patient was diagnosed with (A) mesofacial pattern, (B) definitive dentition with a bilateral molar class I, (C) deviated upper midline towards the right, (D) congenitally missing lateral incisor in the first quadrant (#12), (E) supernumerary lateral incisor in the second quadrant (#22+). At this point, an additional diagnostic CBCT was taken to digitally assess the supernumerary tooth with adjacent structures at the edentulous site and to evaluate possible treatment alternatives (Figure 13).

4.2 | Planning

Two treatment options were considered to manage the patient's clinical situation orthodontically. Both options had the common element of performing an initial orthodontic therapy with fixed appliances, extracting the supernumerary tooth to distribute spaces and center the midline, and the need to create prosthetic space to restore tooth #12, to obtain a bilateral canine class I not to disturb the ideal molar class I of the patient. The treatment strategies differed in the second stage and how to resolve the main challenge of how to manage the missing and supernumerary lateral incisors:

1. Space maintenance (#12) + bone augmentation + implant placement: After orthodontic tooth and space distribution, a temporary solution would be used to maintain the space in site #12 until craniofacial growth is completed [34]. Subsequently, a bone augmentation

procedure would prepare the site for a dental implant, followed by implant placement and temporary and definitive implant-supported restoration (ISR), with the potential need of an additional soft tissue augmentation procedure.

2. Autotransplantation of a supernumerary tooth (#22+): This approach would involve initially maintaining the supernumerary lateral incisor #22+ while the space is being created on site #12. Autotransplant the supernumerary tooth #22+ into the edentulous space (#12). A second orthodontic phase would then follow to realign the dentition and center the midline. Thus, all treatment aims would be accomplished by uniquely redistributing the patient's teeth and a single surgical appointment.

Due to the patient's age, tooth autotransplantation was selected as the preferred option for several reasons: (A) Provided a 100% autologous tooth with a vital PDL that could support natural facial development throughout the patient's life [35], can be moved orthodontically [36], and has proprioception. (B) to minimize patient morbidity (i.e., surgical interventions); (C) reduce the potential development of peri-implant diseases [37] on a patient with such a long-life span for an ISR. Thus, a digital planning workflow was initiated to confirm the feasibility of this treatment option. DICOM files were processed using an AI-driven virtual segmentation software (CoDiagnostiX, Straumann, Basel, Switzerland) and a virtual surgery were carried out. This allowed for verification that the supernumerary tooth #22+ was not fused with the primary #22 and that the edentulous site had suitable dimensions for receiving the donor tooth. Furthermore, it was demonstrated that an ideal bio-restorative 3D implant position would necessitate ancillary bone reconstructive procedures. Lastly, virtual planning with

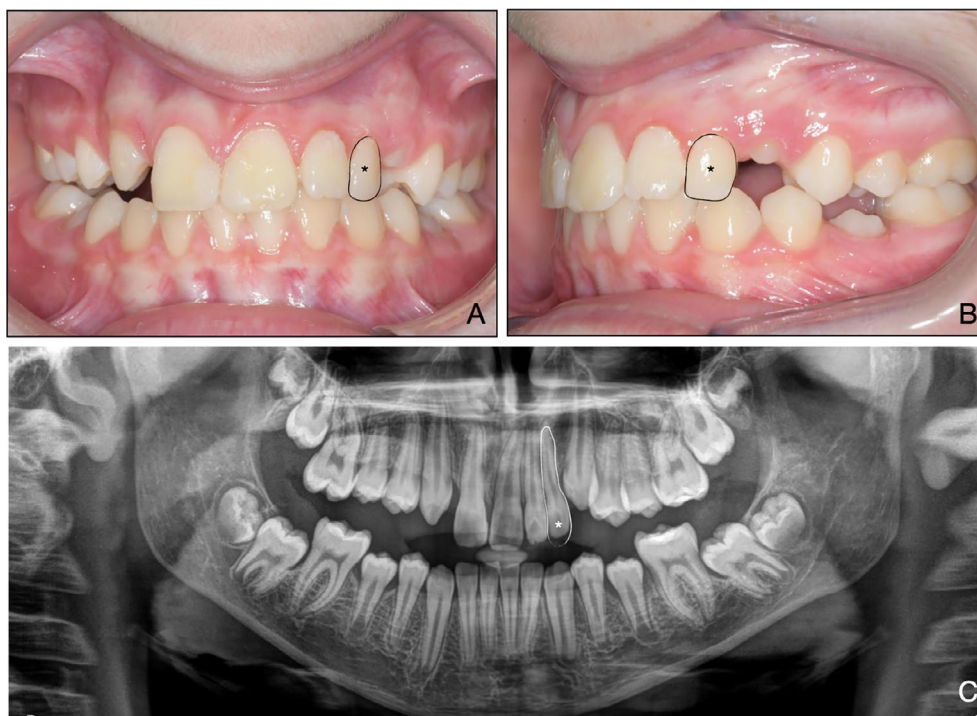


FIGURE 13 | Baseline situation of the patient: Intraoral view from a frontal (A) and lateral (B) perspective, as well as panoramic X-ray (C), showing the missing #12 and supernumerary #22+ (*).

dental implants simulating the anatomy of the root enabled the creation of a multiaxis surgical guide to prepare the recipient site for the autotransplant [38] (Figure 14).

4.3 | Patient Communication

Although tooth autotransplantation is a predictable treatment alternative with enough scientific evidence to support it [39, 40] it is not a standard procedure in regular clinical practice. Thus, when the patients are underage, clear communication with the parents or legal guardians so that they understand the treatment plan is essential. This becomes crucial as the treatment alternative presented is not widely accepted. In this case, digital technologies were key to explaining the intended treatment plan. AI-driven CBCT virtual segmentation generated STL files of the anatomical structures, enabling their digital manipulation to simulate the planned surgical procedure within a virtual environment (Figure 15). These STL files were then 3D printed (Formlabs 3B), producing stereolithographic models that allowed the patient's

legal guardians to visualize the procedure both digitally and physically. Additionally, a 3D smile design platform ([Smile cloud.com](https://smilecloud.com), Smilecloud SRL, Timisoara, Romania) was used to simulate the anticipated treatment outcomes following orthodontics and tooth autotransplantation and potentially a restorative procedure to improve esthetics in #12 (Figure 15). This comprehensive representation significantly contributed to the patient and guardians' understanding and acceptance of the proposed treatment plan (Figure 15).

4.4 | Execution: Guided Surgery

Once the first stage of orthodontic therapy was completed, the autotransplantation surgical phase was initiated. Different surgical aids were designed and a 3D printer (i.e., Surgical guide and re-positional stent) to ensure the utmost precision and predictability during surgery, which was performed according to a previously published protocol by our group, with the coadjuvant use of Enamel Matrix derivatives (EMD, Emdogain) [41]. First, a minimally invasive full-thickness flap was elevated on the edentulous site of #12, exposing the

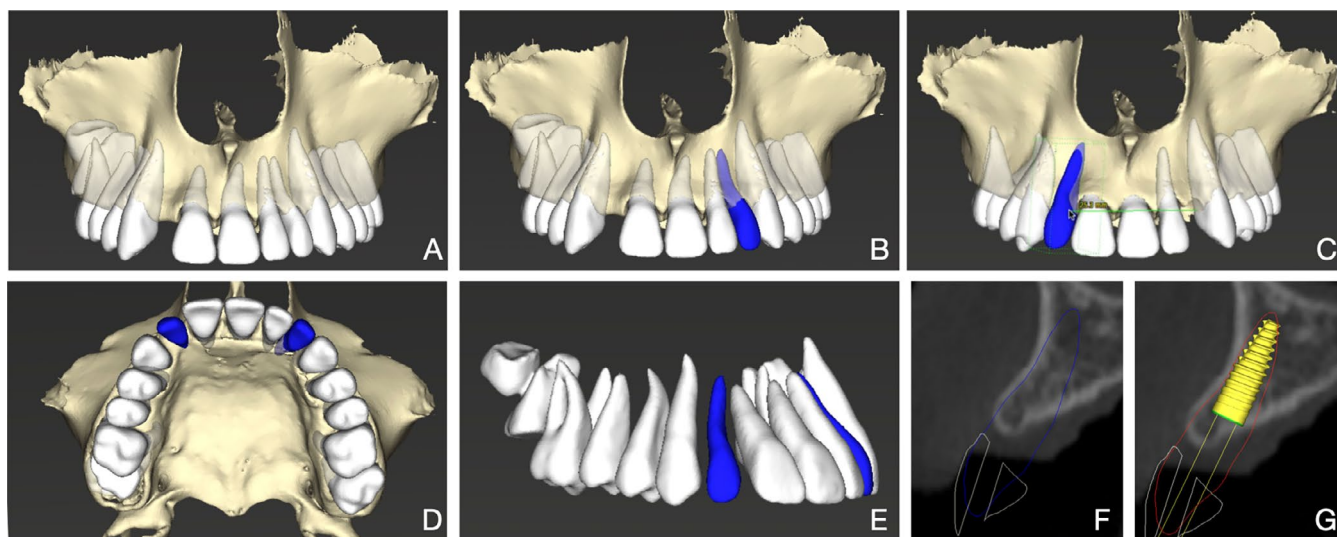


FIGURE 14 | Digital treatment planning of the tooth autotransplantation: AI-driven tooth segmentation (A), evaluation of supernumerary tooth #22+ (blue) as a possible donor tooth (B), virtual simulation into its new position of the supernumerary #22+ in position #12 (C-E), CBCT sagittal plane of the planned position of the autotransplanted tooth (F), and implant simulation for the guided osteotomy preparation (G).

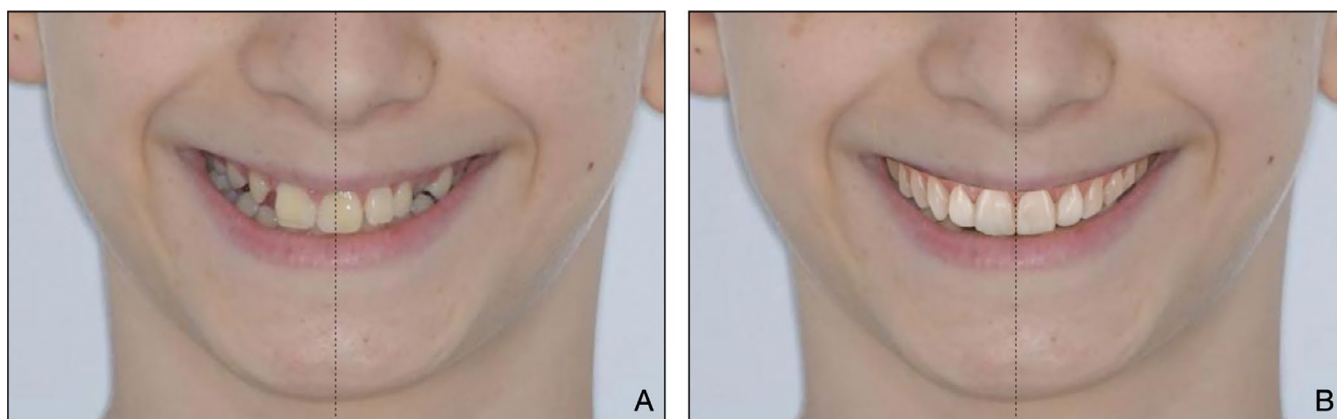


FIGURE 15 | Baseline smile photograph showing the deviation of the incisal midline (A), and after performing a digital smile design to simulate the expected treatment outcomes after tooth autotransplantation and orthodontics (B).

narrow available ridge. A multi-axis drilling guide [38] was used to perform a guided osteotomy according to the digital plan, with additional free-hand osteotomy. A 3D-printed replica of the donor tooth or computer-aided rapid prototype (CARP) [42, 43], was used to test the fit and final position of the donor tooth, minimizing the extraoral time and damage to the PDL [44]. Once the adaptation and insertion path of the 3D replica were ideal, the donor was ready to be extracted and transplanted. Donor tooth had already undergone root canal therapy prior to this surgical intervention due to its completed root formation and closed apex [45]. A minimally invasive extraction of the supernumerary 2.2 was performed, minimizing trauma to the PDL as much as possible. After the root surface was covered with EMD, it was placed within the recipient osteotomy site, with a total extraoral time of 23s. The donor tooth was repositioned according to the digital plan a 3D-printed repositioning guide, and was splinted to the adjacent teeth with a semi-rigid archwire [46]. Occlusal adjustments

were carried out to avoid occlusal loading during the healing period, and suturing was performed around the donor tooth with single interrupted sutures and 6/0 polypropylene suture (Figures 4 and 16).

4.5 | Case Evolution and Predictability

Initial healing was uneventful, and sutures and splinting were removed 2 weeks post-surgery to minimize the risk of root replacement (ankylosis). At follow-up, the autotransplanted tooth exhibited physiological mobility, no probing depths >3 mm or bleeding on probing (BOP), and radiographic evidence of a surrounding periodontal ligament (PDL). Consequently, the second stage of orthodontics commenced, aiming to close the edentulous space left by the supernumerary tooth and to center the midline. This process required 12 months in total (Figure 17).

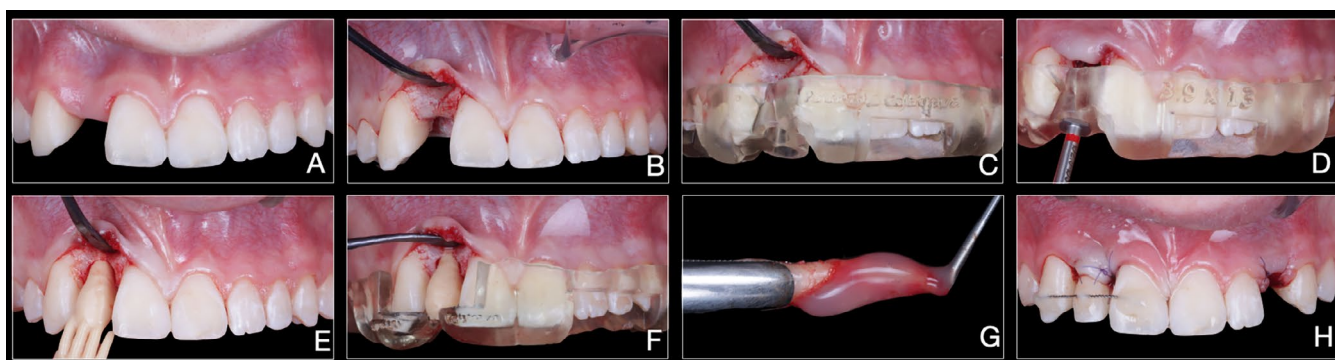


FIGURE 16 | Digitally guided tooth autotransplantation surgery: baseline situation (A), full thickness flap elevation (B), fit-test of the multi-axis drilling surgical guide (C), guided osteotomy of the surgically created socket (D), test of the 3D replica into digitally planned position (E), and with repositioning guide to ensure ideal planned position (F), donor tooth extraction and application of enamel matrix derivatives on the root surface (G), and final surgical situation after tooth autotransplantation, suturing and splinting (H).



FIGURE 17 | Tooth autotransplantation case evolution: Presurgical situation after the first stage of orthodontic therapy (A), and immediate post-surgical situation (B), 6 months after healing (C), and during the second stage of orthodontic therapy (D).

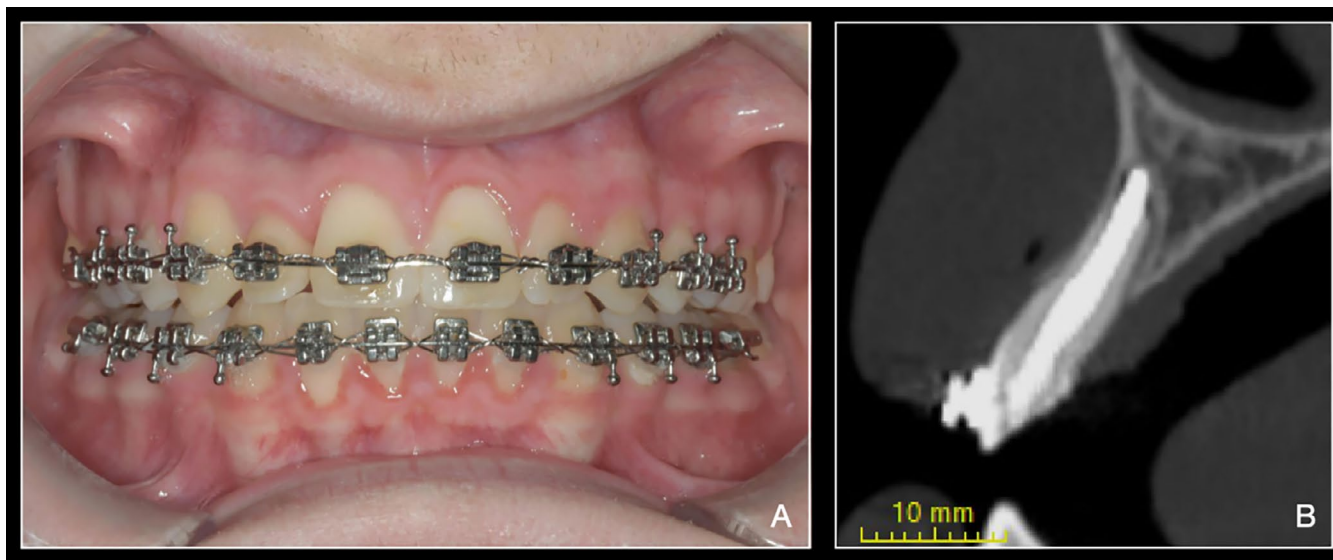


FIGURE 18 | Current situation of the patient: Clinical situation at the end of the orthodontic treatment (A), and sagittal CBCT slice of the transplanted tooth (B).

Following orthodontic treatment, the autotransplanted tooth demonstrated clinical and radiographic signs consistent with successful autotransplantation [47] (Figure 18). As planned digitally and communicated to the patient's guardians, the autotransplanted tooth had a shorter clinical crown than its contralateral #22. This compromise was accepted from the outset, with a consensus to perform a minimally invasive veneer at a more advanced patient age. This approach to digital patient communication improved acceptance of the expected outcome and satisfaction with treatment. Additionally, comprehensive digital planning and execution contributed to the high predictability of this treatment, which aligns with literature-reported success rates exceeding 90% when using digital protocols [41, 48, 49].

5 | Discussion

Digital technologies have redefined approaches to esthetically complex dental treatments, allowing for a level of accuracy, patient engagement and predictability that was previously unattainable. This article demonstrates a structured digital workflow—encompassing diagnosis, planning, patient communication, and treatment execution—to address different challenging esthetic cases through a contemporary digital workflow. Contemporary digital tools and technologies—including scanners, AI-driven DICOM segmentation, CAD software, and virtual simulation environments—enhance clinicians' diagnostic accuracy. For example, immediate implant placement has specific criteria for success [16], which can now be easily assessed digitally. These tools also help clinicians select less invasive treatment options, reducing patient morbidity and clinical appointments [50]. For instance, in the presented autotransplantation case, rather than extracting a supernumerary .22, performing bone reconstruction and soft tissue augmentation to place a dental implant (#12). Digital planning allowed us to address this missing congenital lateral incisor in just one surgical appointment with a different

treatment strategy. A significant advantage of digital tools is their impact on patient communication and medico-legal considerations. Virtual simulations significantly improve patient understanding and engagement, enhancing satisfaction and treatment adherence. Setting clear expectations before treatment—especially for cases where a complete solution may not be achievable, such as in esthetic crown lengthening for patients with EGD [9]—helps align patient expectations with realistic outcomes. Guided surgeries has demonstrated not only improved accuracy [51] in treatment planning and outcomes but also reduced chair time for both patients and the clinical team. This results in fewer, less invasive procedures with minimized bleeding and post-operative complications [52]. Ultimately, these digital advancements increase the predictability of results, such as reducing soft tissue margin rebound in crown lengthening procedures [32, 33] by allowing precise assessment of patient phenotype [19] and suprarenal tissue attachment [26]. By enhancing both accuracy and predictability, digital workflows contribute to more stable, long-term outcomes. Although adopting these tools requires initial investments in training and technology, such costs are becoming increasingly accessible. However, sound knowledge of biological principles, surgical skills and experience in the use of digital workflows are necessary for its successful implementation. Although adopting these tools requires initial investments in training and technology, such costs are becoming increasingly accessible. Integrating digital workflows into esthetic dental treatments has established a new standard of care, underscoring the central role of these technologies in contemporary practice—now essential rather than merely modern.

6 | Conclusion

This study highlights the transformative potential of contemporary digital workflows in managing complex esthetic cases. The integration of digital tools across diagnosis, planning, patient

communication, and execution stages resulted in highly individualized treatment strategies. These findings highlight the pivotal role of CDD in improving predictability in complex cases, replacing random outcomes with consistent results. This success is grounded in a thorough understanding of biological principles and their precise digital assessment. Consequently, digital dentistry facilitates higher precision, enhances patient satisfaction, and ultimately contributes to more successful treatment outcomes.

Author Contributions

I.P., J.C., and M.S. conceived and designed the idea. M.T.-O., N.Z., and A.L. contributed to data acquisition and analysis. All authors critically revised the manuscript, gave final approval, and agreed to be accountable for all aspects of the scientific work.

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Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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