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An Interdisciplinary Clinical Technique Integrating Guided Bone Regeneration, Early Orthodontic Activation, and Muscular Force Control: A 3-Year CBCT Validation

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Case Report

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Additional Declarations: Competing interest reported. KK is Chief Executive Officer of Impress. The Impress aligner system had been selected and used as part of the patients' routine clinical treatment before KK became involved in this retrospective study. KK was not involved in the clinical treatment of the patients or in the selection of the aligner system. Impress had no role in the clinical treatment, study design, data collection, or decision to conduct the retrospective analysis. VJG and AGB declare no competing interests.

Abstract

Background

Management of orthodontic tooth movement beyond the alveolar envelope remains challenging in patients with thin periodontal phenotypes and unfavorable muscular patterns because of the increased risk of alveolar defects and periodontal compromise. This study describes an interdisciplinary clinical technique integrating guided bone regeneration, early orthodontic activation during the regional acceleratory phenomenon (RAP), and muscular force control using a modified lip bumper. Initial clinical validation was performed through longitudinal cone beam computed tomography (CBCT) assessment.

Methodology

The proposed clinical technique was applied in two adult female patients presenting severe dentoalveolar limitations and increased risk of periodontal compromise. CBCT scans were obtained at baseline (T0), immediately after surgery (T1), at 6 months (T2), and at 3 years (T3). Dehiscence, fenestration, root length, buccal bone volume, and bone density (grayscale values) were evaluated longitudinally.

Results

Application of the clinical technique resulted in complete resolution of fenestrations in all evaluated teeth without recurrence during follow-up. Dehiscences decreased or remained stable despite the magnitude of orthodontic movement performed. Buccal bone volume increased from near-zero values at baseline to measurable levels after treatment and remained stable throughout follow-up. Bone density initially decreased during the immediate postoperative period and progressively increased over time, suggesting ongoing bone remodeling and maturation. No clinically relevant root resorption was observed.

Conclusions

This interdisciplinary clinical technique may provide a reproducible therapeutic approach for managing orthodontic tooth movement in anatomically and functionally challenging situations. Longitudinal CBCT observations demonstrated maintenance of periodontal support and stability of regenerated buccal bone throughout the 3-year follow-up. Further prospective controlled studies are required to validate the clinical applicability of this technique.

Introduction

Proper function of the orofacial system is associated with improved long-term psychosocial well-being.[1] Recently, the demand for orthodontic treatment using clear aligners has increased considerably, with mandibular anterior crowding representing one of its most frequent clinical indications.[2,3]

Management of orthodontic tooth movement beyond the alveolar envelope remains a major biological challenge in patients with narrow symphyses, thin periodontal phenotypes, or unfavorable muscular patterns. In these situations, the sagittal movements or substantial changes in tooth inclination often required to resolve crowding may displace roots beyond the buccal cortical plate, increasing the risk of alveolar defects such as dehiscence and fenestration.[4]

Several surgically facilitated orthodontic approaches have been proposed to extend the biological limits of orthodontic tooth movement. Among them, periodontally accelerated osteogenic orthodontics is based on the regional acceleratory phenomenon (RAP), which enhances bone remodeling during healing.[5] However, despite its biological rationale, clinical acceptance remains limited because of the invasiveness of the procedures and the heterogeneity of the available evidence.[6,7]

In parallel, advances in guided bone regeneration have provided less invasive alternatives for managing dentoalveolar deficiencies. Barrier membranes promote selective osteogenic repopulation of bone defects while preventing invasion by undesirable soft tissues, thereby improving regenerative outcomes.[8,9] Nevertheless, in patients presenting both compromised periodontal phenotypes and unfavorable muscular function, successful regeneration depends not only on the surgical procedure itself but also on maintaining graft stability throughout the biologically active RAP period.[10] Perioral musculature exerts continuous forces on the mandibular anterior dentoalveolar complex and may influence both alveolar morphology and the long-term stability of regenerative procedures.

Although these biological and therapeutic concepts have traditionally been applied independently, complex orthodontic patients frequently require simultaneous management of regenerative support, accelerated bone remodeling, and muscular force control. The interdisciplinary clinical technique presented in this study was developed to address this clinical need by integrating guided bone regeneration, early orthodontic activation during the RAP, and temporary muscular control using a modified lip bumper within a single coordinated therapeutic strategy. Rather than simply facilitating tooth movement, the proposed technique aims to biologically and functionally stabilize the alveolar environment during treatment.

Therefore, the aim of this study was to describe an interdisciplinary clinical technique integrating guided bone regeneration, early orthodontic activation during the regional acceleratory phenomenon (RAP), and temporary muscular control using a modified lip bumper, and to illustrate its clinical application and longitudinal CBCT outcomes in two patients with severe dentoalveolar limitations and increased risk of periodontal compromise.

Patients and Diagnosis

This observational clinical report presents a clinically derived therapeutic protocol applied in two adult patients with severe dentoalveolar limitations and increased risk of periodontal compromise during orthodontic treatment. Longitudinal CBCT evaluation was performed to document alveolar changes over a 3-year follow-up period.

Two systemically healthy adult female patients were referred for management of dentoalveolar complexity and the risk of periodontal compromise associated with the required tooth movements. Both patients were treated in a private orthodontic practice specialized in interdisciplinary management of complex dentoperiodontal cases.

Case 1

A 25-year-old patient presented with mandibular anterior crowding. She had undergone prolonged orthodontic treatment during childhood and adolescence that resulted in treatment fatigue and a preference for aligner-based therapy.

The patient exhibited a Class III skeletal and dental pattern, reduced dentoalveolar width, and generalized apical root resorption. Functional evaluation revealed alterations in the lower facial third, characterized by a low tongue posture, anterior interposition, and lip incompetence associated with hyperactivity of the inferior orbicularis oris muscle.

Case 2

A 28-year-old patient presented with increased overjet and overbite, along with severe maxillary anterior crowding. She exhibited a brachyfacial pattern with a Class I skeletal and dental relationship in the posterior segment, and periodontal compromise in the mandibular anterior region. Functional analysis revealed the presence of parafunctional habits, notably lower lip sucking.

In both cases, the combination of skeletal pattern, compromised periodontal phenotype, and muscular imbalance posed a high risk for the development or worsening of alveolar defects if conventional orthodontic movements were performed. The role of the musculature in developing and maintaining malocclusions has been widely described, and the musculature is a determining factor in the relationship between form, function, and stability of the orofacial system.[11]

Consequently, both cases were managed using the protocol described herein, which entailed combining guided bone regeneration, early orthodontic activation, and control of muscular forces. Both patients were also referred for speech therapy.

Treatment Protocol

The protocol was structured into five sequential phases (G0–G5), ranging from diagnostic planning to long-term follow-up (Table 1).

Table 1
Sequence of the clinical protocol from phase G0 to G5, including examinations, planning, treatment, and follow-up.

	Stage	Description
G0	1. Records acquisition	Extraoral and intraoral photographs, intraoral STL records, panoramic radiographs, and maxillomandibular CBCT scans (T0).
	2. Periodontal treatment	Performed 2–3 months prior to initiation of G1.
	3. Lip bumper fabrication	Digital simulation of the final and ideal tooth positions. Printing of the model, followed by design and fabrication of the appliance.
G1	3. Patient evaluation	Placement of separation elastics and assessment of periodontal status.
	4A. Verification for bracket cases	Placement of the lip bumper, verifying band fit and adaptation of the buccal arch between the teeth and lower orbicularis oris muscle. Appliance removal and disinfection.
	4B. Verification for aligner cases	Placement of the lip bumper, verifying band fit and adaptation of the buccal arch between the teeth and lower orbicularis oris muscle. Intraoral scanning of the teeth, gingiva, and appliance for planning of aligner-based treatment. Appliance removal and disinfection.
G2	5. Surgery	VISTA technique + bone grafting + membrane placement. Mandibular CBCT (T1).
	6. Patient follow-up	Evaluation of mucosal integrity 1 week after surgery
G3	7. Lip bumper placement	Cementation of the appliance 2 weeks after Stage G2.5.
	8. Initiation of aligners/orthodontic treatment	Bonding of attachments or placement of fixed multibracket appliances, with instructions for use.
G4	9. Lip bumper removal	Debonding of the appliance at 6 months; treatment with aligners or fixed appliances continues according to patient needs. Mandibular CBCT (T2)..
G5	10. Radiographic follow-up	CBCT at 3 years after Stage G2.5 (T3).

CBCT, cone beam computed tomography; VISTA, vestibular incision subperiosteal tunnel access.

Phases G0 and G1: Records, Periodontal Phase, and Appliance Design

During the initial phases, complete records were obtained, including intra- and extraoral photographs, intraoral scans (STL files), panoramic radiographs, and maxillomandibular CBCT scans. Prior to surgery, periodontal treatment was administered over a period of 2 to 3 months to ensure tissue stability.

Based on the STL files and CBCT data, tooth movement was digitally planned, simulating an initial alignment and leveling phase. Thus, a printed model was fabricated, to which an elastic material was added to simulate the expected increase in soft tissue volume following surgery (Fig. 1A).

A modified lip bumper was designed and fabricated in a dental laboratory using this model, soldered to molar bands and reinforced with a lingual arch. The appliance incorporated an enlarged buccal shield, adapted to the patient's anatomy, to reduce pressure from the perioral musculature and protect the grafted area (Fig. 1B). Prior to surgery, the appliance was tested intraorally to verify a passive fit, proper adaptation within the vestibule, and absence of interference with soft tissues.

Phase G2: Surgery

The surgical phase was performed using a minimally invasive approach based on the vestibular incision subperiosteal tunnel access technique.[12] Under local anesthesia, a vertical incision was made in the vestibular mucosa distal to the mandibular canines. A subperiosteal tunnel was then created using blunt dissection. The periosteum was released to create space and allow proper graft adaptation.

The cortical surface was conservatively prepared using superficial curettage to promote integration of the graft material. Subsequently, a 30×40-mm resorbable collagen membrane (Creos™ Xenoprotect; Matricel GmbH, Herzogenrath, Germany) was placed and fixed using 3-mm titanium tacks (Trutack Bone Tack; ACE Surgical Supply®, USA). In this way, a stable compartment was created for guided bone regeneration according to the classic principles of cell exclusion and space maintenance described in guided bone regeneration.[13]

Next, 2 cm^3 of particulate bone graft (demineralized freeze-dried bone allograft—Salubone™ chips; Salugraft Dental, Barcelona, Spain) was inserted between the membrane and bone surface, ensuring adequate adaptation and volume. Finally, the membrane was repositioned, and the incisions were sutured. The sutures were removed after 7 days.

No corticotomies were performed. The procedure relied on the biological response induced by periosteal manipulation, which is capable of triggering an osteoclastic response consistent with the RAP even in the absence of direct injury to the bone cortex.[14]

Phases G3 to G5: Orthodontic Phase

Orthodontic treatment was initiated 14 days after surgery, once proper soft tissue healing was confirmed and within the biological window of the RAP, described as being between 10 and 120 days postoperatively.[15]

At that time, the lip bumper was cemented and worn for approximately 6 months. The period during which the lip bumper was worn coincided with the period of highest biological activity associated with

the RAP. Delayed placement of the appliance facilitated postoperative hygiene and reduced mechanical stress on the surgical site during the initial healing phase. The appliance acted as a barrier against perioral muscular forces and as an anchor, protecting the graft during the period of greatest biological activity.

Clear aligners were used, available through a commercial system (Impress, Barcelona, Spain). Attachments were bonded and bands cemented using a light-cured adhesive (Transbond™ Plus Light Cure Band Adhesive; 3M Unitek, Monrovia, CA, USA). Movement of the lower incisors was planned to take advantage of the active phase of the RAP, synchronizing orthodontic mechanics with the biological tissue response.

Radiographic Evaluation

To assess changes in buccal bone morphology, we analyzed the following parameters in all mandibular anterior teeth (4.3 to 3.3) from T0 to T3 (Fig. 2):

Dehiscence was defined as the distance between the cementoenamel junction and buccal alveolar bone crest.

Fenestration was defined as discontinuity of the buccal cortical plate along the root surface, measured from the coronal to apical limit of the defect.

Root length (mm) was the measured distance between the cementoenamel junction and root apex.

Buccal bone volume (cm^3) was determined from three axial slices (medial, mesial, and distal), defined relative to the long axis of the tooth, with 1.6 mm spacing between slices.

Bone density was calculated as the mean grayscale value within the analyzed volume.

All scans were obtained using the same CBCT unit (ProMax; Planmeca Oy, Helsinki, Finland), using a standardized protocol with an 8-cm field of view and voxel size of 0.40 mm. The acquisition parameters 90 kV and 7.1 mA were kept constant across all scans to ensure comparability between time points.

Image analysis was performed using dedicated software (Romexis®; Planmeca Oy). Multiplanar reconstructions were used to standardize the orientation of each tooth prior to measurement (Fig. 3).

Bone density was assessed using grayscale values. Although the software expresses these as Hounsfield units, they should be interpreted as relative values dependent on the device rather than absolute measurements.

All measurements were performed by a single examiner who was calibrated prior to data collection to ensure consistency. Indication for CBCT imaging followed the ALARA principle, in accordance with international recommendations in dental radiology.[16]

Given the observational nature of the present report, no inferential statistical analysis was performed. Radiographic findings were analyzed longitudinally across the different time points and should be interpreted as clinical observations rather than inferential evidence.

Results

Quantitative and qualitative changes in the alveolar bone in the mandibular anterior region were evaluated using CBCT at T0 (baseline), T1 (immediate postoperative), T2 (6 months), and T3 (3 years; Fig. 4).

Bone Defects

At baseline, both patients presented with multiple fenestrations and varying degrees of dehiscence at the lower incisors. Following the surgical and orthodontic procedures, the fenestrations resolved completely in all the teeth evaluated and did not recur during the follow-up period (T2–T3). Dehiscence remained stable or decreased in most instances. Despite the orthodontic tooth movement performed, no worsening of bone defects was observed.

Bone Volume and Density

Buccal bone volume, which was virtually absent at most sites at baseline, increased after the surgical intervention and remained stable over time, suggesting adequate graft integration and stability of the alveolar environment. Mean values increased from approximately 0 cm^3 at T0 to close to 0.2 cm^3 at subsequent follow-ups.

Bone density showed an initial decrease in the immediate postoperative period (T1), consistent with the presence of low-radiopacity graft material. This was followed by a progressive increase at 6 months (T2) and at 3 years (T3), reflecting an active process of bone remodeling and maturation (Fig. 4).

Root Integrity

Root length remained stable in both patients throughout the follow-up period. No clinically relevant signs of root resorption associated with orthodontic treatment were observed.

Radiographic Evolution

Qualitative CBCT analysis demonstrated a consistent pattern of bone healing. At T1, the graft exhibited a heterogeneous structure with low radiopacity and clear delineation from the native bone. At T2, progressive trabecular organization and increased definition of the buccal cortical plate were observed, along with increased radiopacity. At T3, the cortical plate appeared continuous and well-defined, with a homogeneous trabecular pattern comparable to that of the adjacent bone and no distinguishable interface between the graft and host bone (Fig. 5).

Digital Simulation and Root Position

Pretreatment digital simulation indicated that, in the absence of bone augmentation, the planned movements would have resulted in root displacement beyond the cortical boundaries. However, posttreatment CBCT analysis confirmed that the roots remained within the regenerated bony contour, suggesting that modification of the alveolar environment may facilitate controlled expansion of the limits of orthodontic tooth movement (Fig. 6).

Clinical Outcomes

The total duration of treatment was 10 months for Case 1 and 18 months for Case 2. Satisfactory alignment and leveling of the mandibular anterior segment were achieved in both patients, without periodontal complications occurring.

Discussion

The results of the present study suggest that combining guided bone regeneration, early orthodontic activation during the RAP, and control of perioral muscular forces may have enabled modification and stabilization of the alveolar environment in complex clinical situations. This was associated with resolution of fenestrations and stability of dehiscences without compromising root integrity.

The thickness of the buccal bone is limited in the mandibular anterior region and exhibits high interindividual variability; thin periodontal phenotypes frequently present with values below 1 mm.[17] In this context, orthodontic movement beyond cortical boundaries has been associated with the development of dehiscence and fenestration, particularly at lower incisors that show excessive protrusion or inclination.[4] Conflicting results regarding the association between tooth inclination and the development of gingival recession have been reported in the literature. Although studies based on models and lateral radiographs have not demonstrated a clear relationship,[18] the findings of investigations using CBCT suggest that movements exceeding ± 5° may increase the risk of bone loss.[19] These discrepancies are likely due to methodological differences and the multifactorial nature of these changes.[20] Therefore, it appears reasonable to consider that the risk is determined by the magnitude of tooth movement as well as by the interaction among mechanical, anatomical, and functional factors.[21]

The present observations support the concept that the development of alveolar defects during orthodontic treatment should not be interpreted as an exclusively mechanical phenomenon. Instead, these changes likely result from the interaction among alveolar anatomy, periodontal phenotype, muscular function, and the magnitude and direction of tooth movement. From this perspective, modification of the biological and functional environment may be as relevant as the orthodontic mechanics themselves when treating patients with severe dentoalveolar limitations. [11, 20, 21]

The cases presented herein represent borderline clinical situations in which the required movements may have exceeded the limits considered safe in an unmodified biological environment. In such

circumstances, the aim of the proposed approach is to enable the alveolar environment to change in a more predictable manner, not to restrict tooth movement.

The use of a combination of bone grafting and RAP activation in surgically facilitated orthodontic techniques has been demonstrated to increase alveolar volume and promote tooth movement.[5] However, their indication remains controversial due to the invasiveness of the procedures and variability in clinical outcomes.[8] Furthermore, in the present study, fully discriminating the relative contributions of the bone graft and RAP to the changes we observed was impossible; this should be considered when interpreting the results.

Traditionally, RAP activation has been associated with corticotomies. However, experimental studies have shown that elevation of a mucoperiosteal flap can induce a significant osteoclastic response and trigger bone remodeling processes consistent with this phenomenon.[14,22,23] The use of the described protocol enables corticotomy to be avoided, and is based on a less invasive approach that relies on the biological response initiated by periosteal manipulation. This approach introduces a potential conceptual shift, suggesting that direct injury to the cortex of the bone may be unnecessary for inducing a biological environment that favors orthodontic tooth movement.

In the present protocol, the objective was not primarily to accelerate orthodontic treatment, but rather to maintain the integrity of the regenerative environment during the period of greatest biological activity associated with the RAP. From a clinical standpoint, protecting the grafted area from continuous perioral muscular pressure may contribute to greater stability of the healing environment and potentially improve adaptation of the alveolar housing to orthodontic movement.

From this perspective, biological activation and control of muscular forces should be considered complementary components. The surgical approach creates a window of enhanced bone remodeling, but control of the perioral musculature may play an important role in maintaining stability of the regenerative environment. The role of the perioral musculature has been widely described in the literature, with its capacity to influence tooth position and alveolar bone morphology being demonstrated; this is in line with classical orthodontic principles of interaction among function, form, and occlusal development.[11,24] In the protocol described, the lip bumper was modified both to facilitate dentoalveolar changes and act as a protective barrier for the graft during the active phase of the RAP.

Previous studies have shown that appliances incorporating buccal shields can reduce muscular pressure and promote changes in the dentoalveolar architecture.[25,26] However, the effect of conventional lip bumpers on the mandibular anterior region is limited.[27] The modifications we made to the design of the buccal shield, namely, increasing its volume and muscular decoupling effect, may explain the observed results.[28]

The protocol described may be particularly relevant in orthodontic patients presenting a combination of thin periodontal phenotype, significant dentoalveolar discrepancy, and unfavorable muscular function. In

these situations, conventional orthodontic mechanics alone may be insufficient to maintain alveolar integrity during extensive tooth movement.

Regarding the materials used, the effectiveness of collagen membranes employed in guided bone regeneration has been demonstrated, although the behavior of the membranes may vary depending on their origin and structural characteristics.[29] The use of demineralized freeze-dried bone allograft as a graft material has also shown favorable results in bone regeneration, and it is compatible with early initiation of orthodontic tooth movement.[30] However, these materials may undergo a certain degree of resorption during the first year after placement.[31] In the present cases, bone volume and density values stabilized at 6 months and were maintained over the long term, suggesting adequate graft integration and stable bone remodeling. These findings are consistent with previous studies reporting progressive increases in bone density following combined regenerative and orthodontic procedures.[32]

Although the present observations are limited to two patients, the longitudinal radiographic findings suggest that coordinated management of biological activation, regenerative support, and muscular control may represent a clinically relevant therapeutic strategy in selected high-risk orthodontic patients.

These results should, however, be interpreted within the limitations inherent to an observational study with a small sample size. Future studies with larger sample sizes and controlled designs are needed to confirm the reproducibility and clinical applicability of this protocol.

Conclusion

The protocol described may enable modification and stabilization of the alveolar environment during the RAP, facilitating orthodontic tooth movement in anatomically and functionally challenging situations without compromising periodontal integrity in the medium term. However, these findings require confirmation through studies with larger sample sizes and controlled designs.

Abbreviations

CBCT
Cone beam computed tomography
RAP
Regional acceleratory phenomenon
VISTA
Vestibular incision subperiosteal tunnel access
DFDBA
Demineralized freeze-dried bone allograft

Declarations

Conflict of interest

The authors declare no conflicts of interest related to this study.

Ethics approval and consent to participate

This manuscript reports a retrospective case series of two adult patients treated entirely as part of routine clinical care in a private dental practice. All surgical procedures, orthodontic interventions, and CBCT examinations were clinically indicated and were not performed for research purposes. The decision to analyse and report the cases was made after completion of treatment and clinical follow-up. No prospective research protocol was therefore submitted for ethics review, and no prior ethics approval or waiver reference number is available. Written informed consent for treatment and for the scientific use of anonymised clinical and imaging data was obtained from both patients.

Consent for publication

Written informed consent for publication of the patients' anonymised clinical data, photographs, radiographic images, and CBCT records was obtained from both patients.

Competing Interests

KK is Chief Executive Officer of Impress. The Impress aligner system had been selected and used as part of the patients' routine clinical treatment before KK became involved in this retrospective study. KK was not involved in the clinical treatment of the patients or in the selection of the aligner system. Impress had no role in the clinical treatment, study design, data collection, or decision to conduct the retrospective analysis. VJG and AGB declare no competing interests.

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The authors declare no conflicts of interest related to this study.

Author Contribution

Authors' contributionsVJG conceived the study and therapeutic protocol, coordinated the clinical management, performed data interpretation, and drafted the manuscript. AGB performed the surgical

procedures and critically reviewed and approved the manuscript. KK contributed to data analysis, manuscript drafting, and final approval of the submitted version. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Data Availability

The datasets generated and/or analysed during the current study are not publicly available because the clinical and imaging records may contain potentially identifiable patient information. De-identified data may be available from the corresponding author upon reasonable request, subject to patient privacy, applicable data-protection requirements and any necessary ethical authorisation.

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Figures

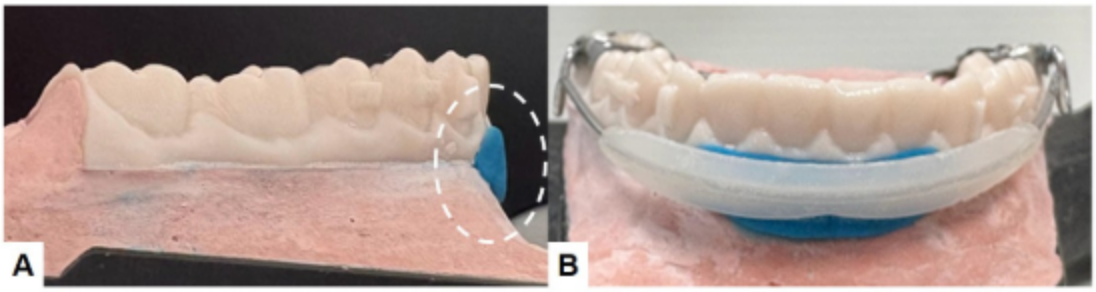


Figure 1

(A) Sequence of the clinical protocol from phase G0 to G5, including examinations, planning, treatment, and follow-up. (B) Printed model derived from the STL file following digital planning of tooth movement. Lateral view showing simulation of increased soft tissue volume using elastic material. (C) Frontal view showing the modified lip bumper fabricated on the model.

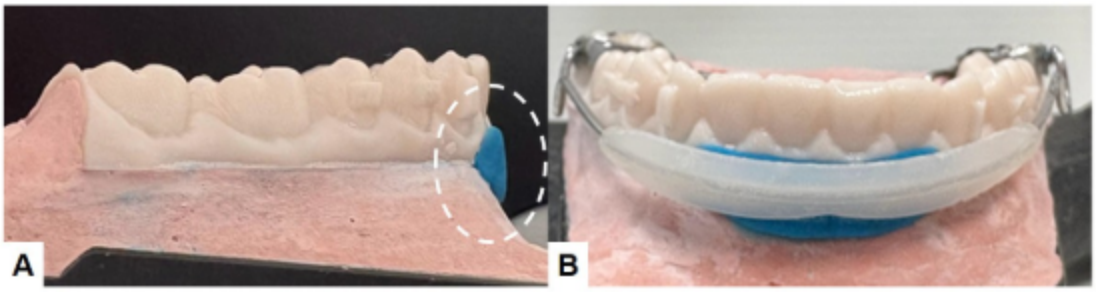


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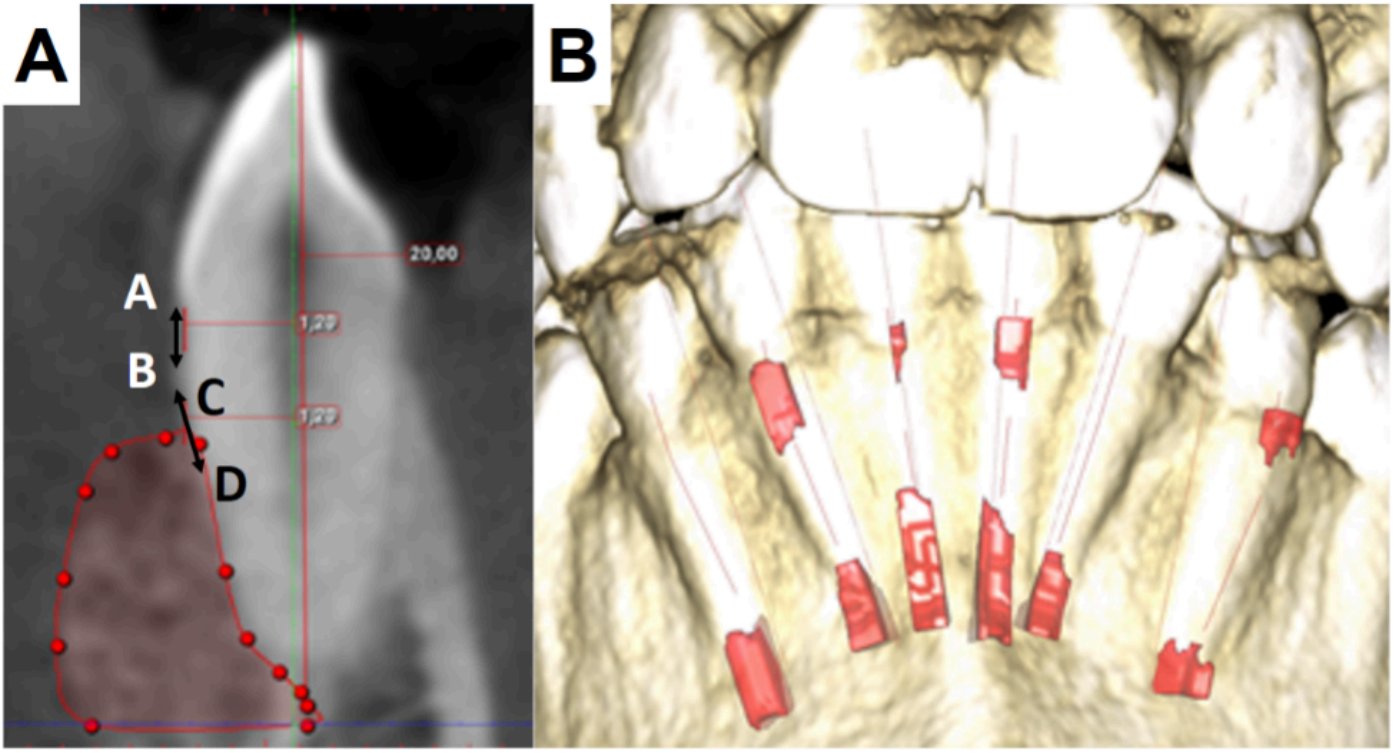


Figure 2

Methodology used to measure the bone parameters. (A) Identification of dehiscence (A–B), fenestration (C–D), root length, and delineation of the buccal bone volume in axial slices. (B) Three-dimensional reconstruction of the volume analyzed from serial sections.

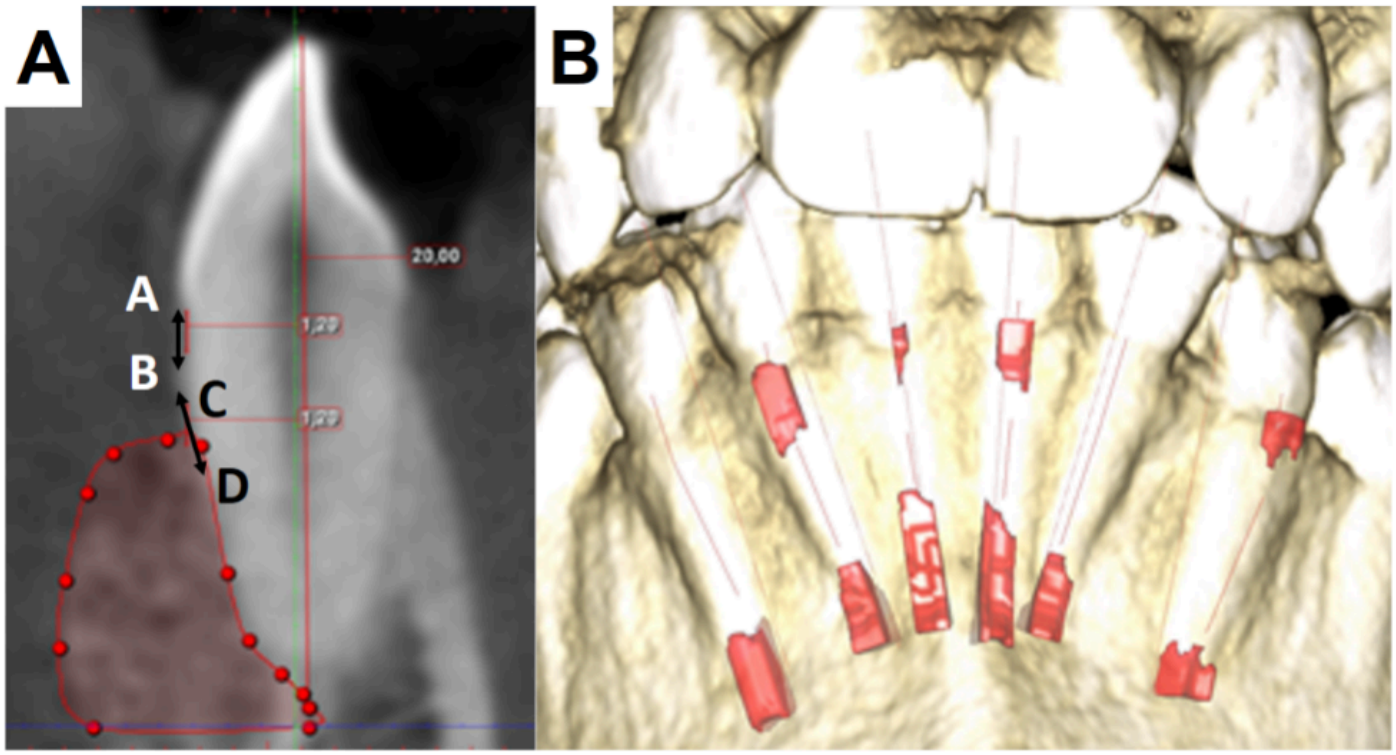


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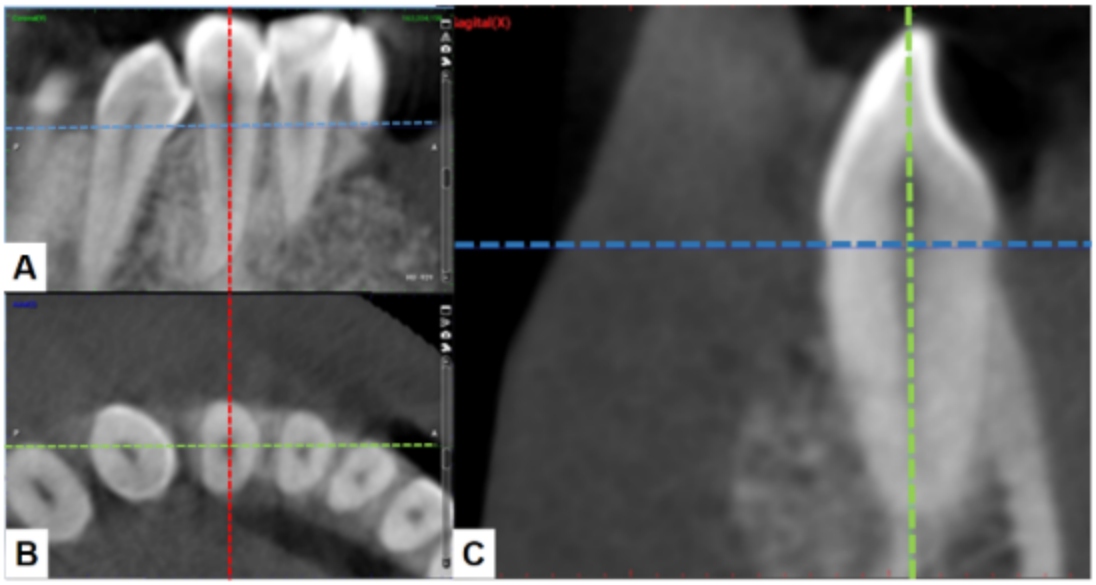


Figure 3

Method for orienting the cone beam computed tomography section planes to standardize measurements. (A) Axial plane defined at the level of the buccal cementoenamel junction. (B) Coronal plane aligned with the long axis of the tooth. (C) Sagittal plane corresponding to the greatest root length and buccolingual dimension.

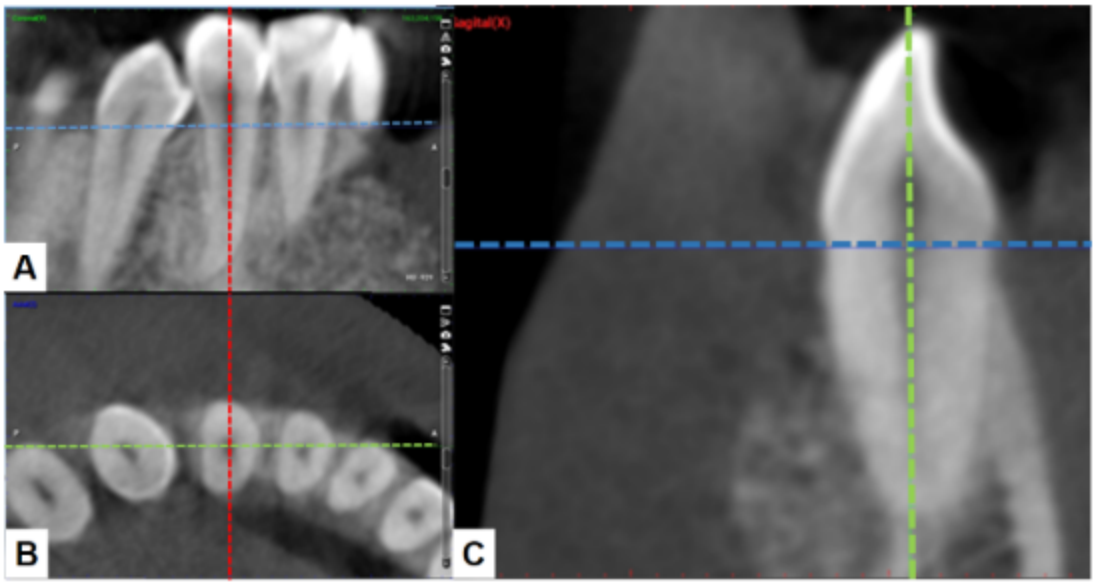


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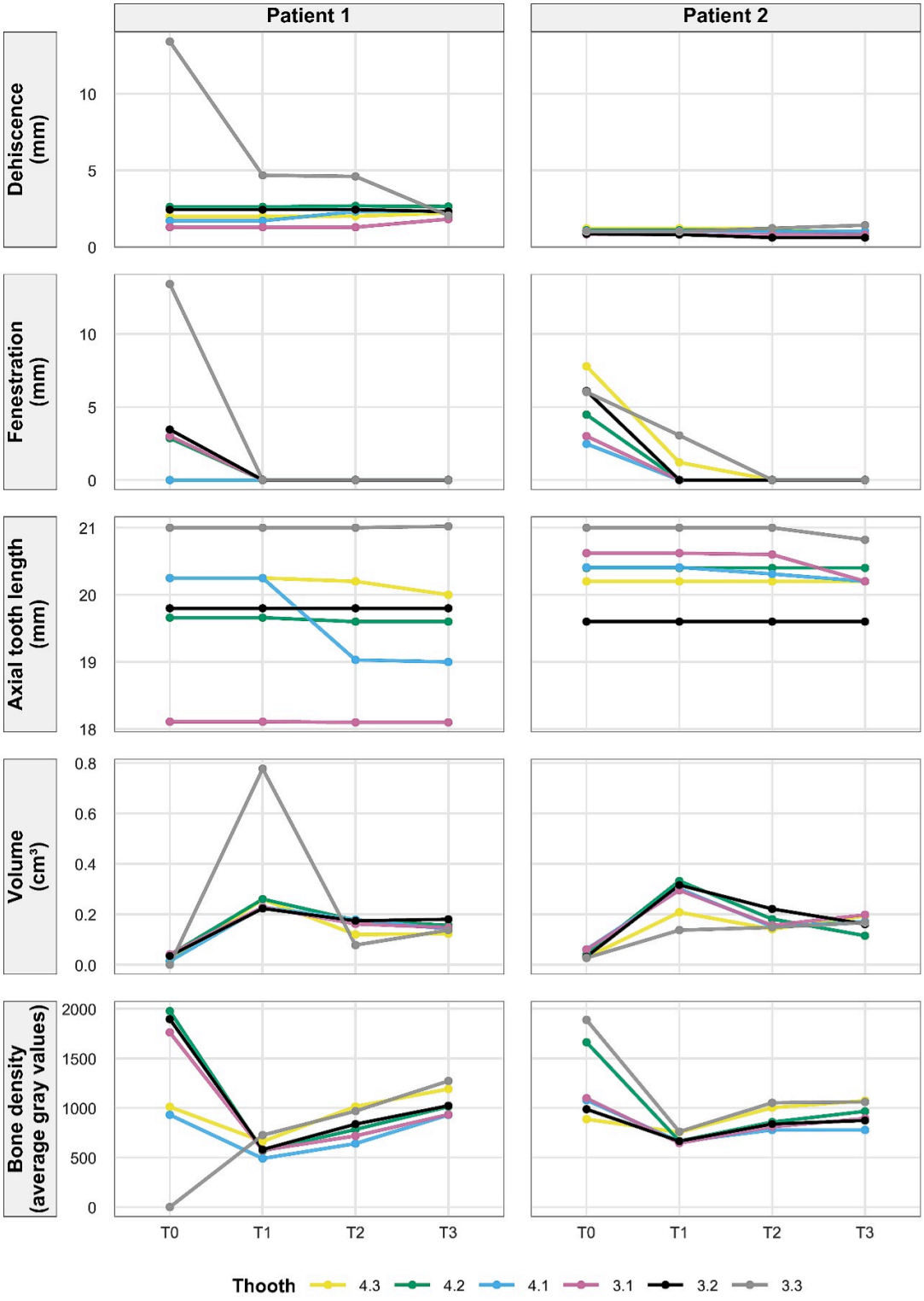


Figure 4

Quantitative evaluation of changes in both patients in the buccal alveolar bone of the mandibular incisors and canines at baseline, immediately after surgery, and at 6 months and 3 years after surgery. Dehiscence (mm), fenestration (mm), root length (mm), buccal bone volume (cm³), and bone density (grayscale values) are shown.

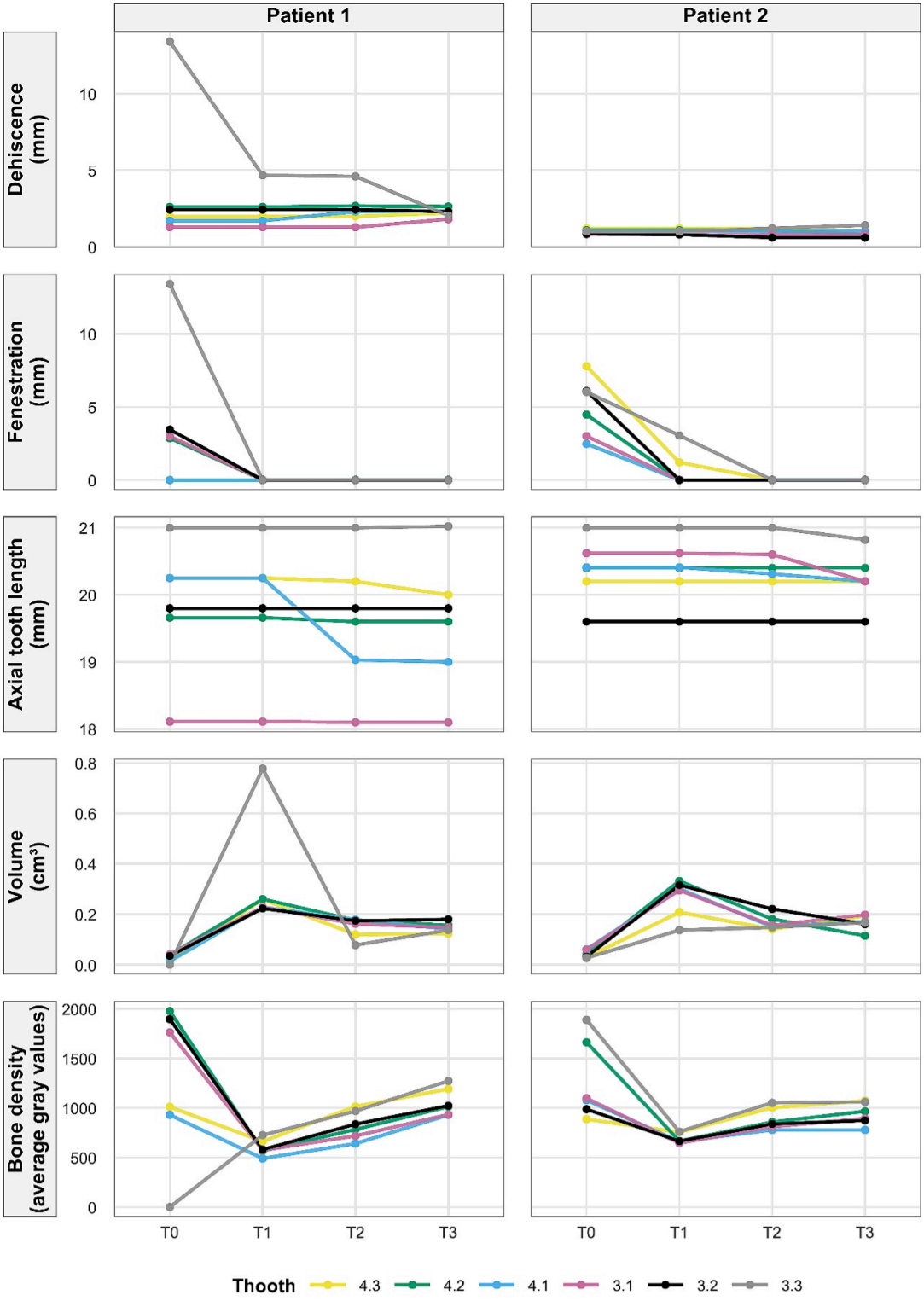


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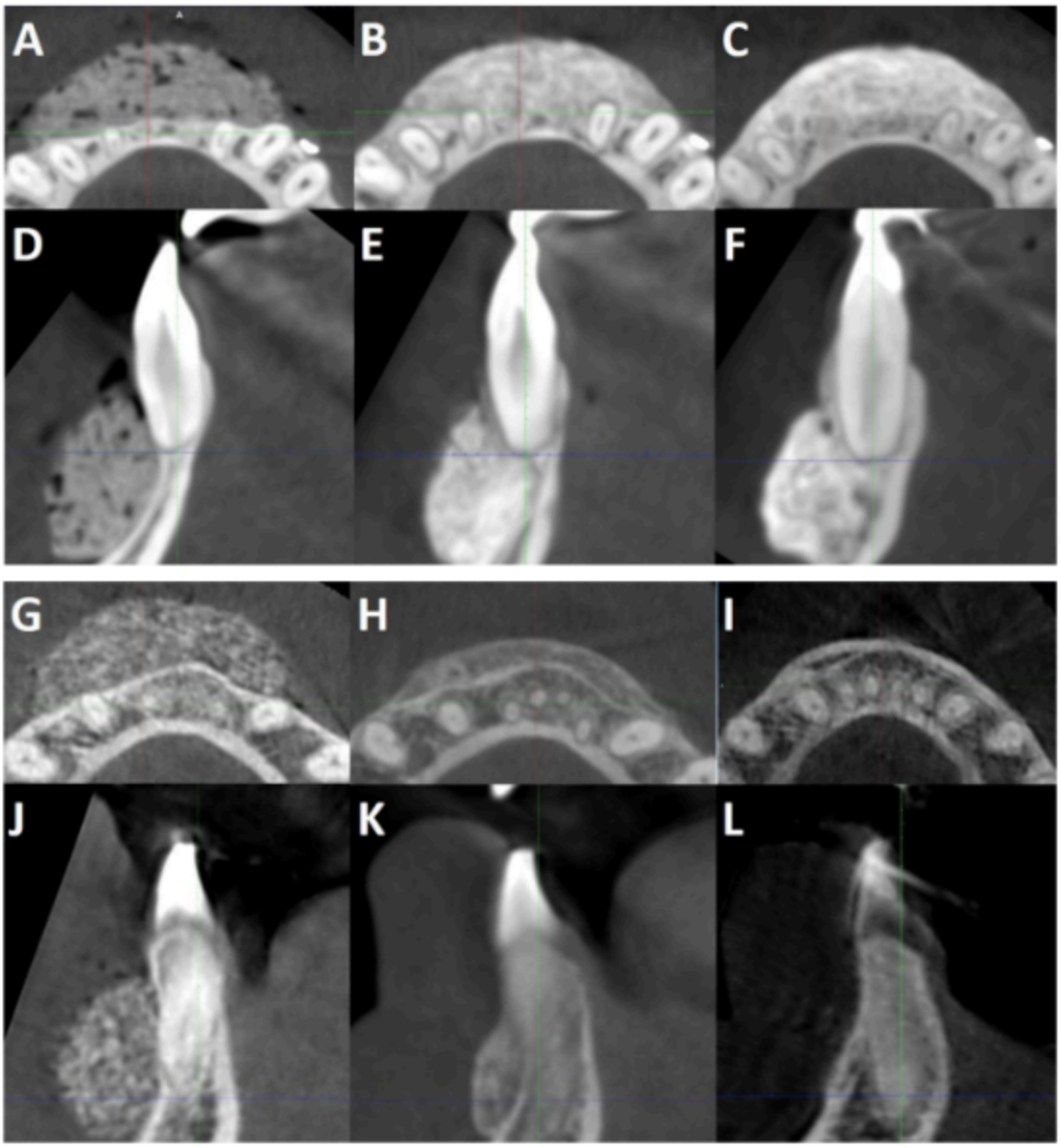


Figure 5

Radiographic evolution of the alveolar bone following guided bone regeneration. (A, D, G, J) Immediately after surgery with low-radiopacity graft and irregular contour. (B, E, H, K) At 6 months after surgery, showing trabecular reorganization and increased density. (C, F, I, L) At 3 years after surgery, showing a continuous cortical plate and homogeneous bone pattern comparable to that of native bone.

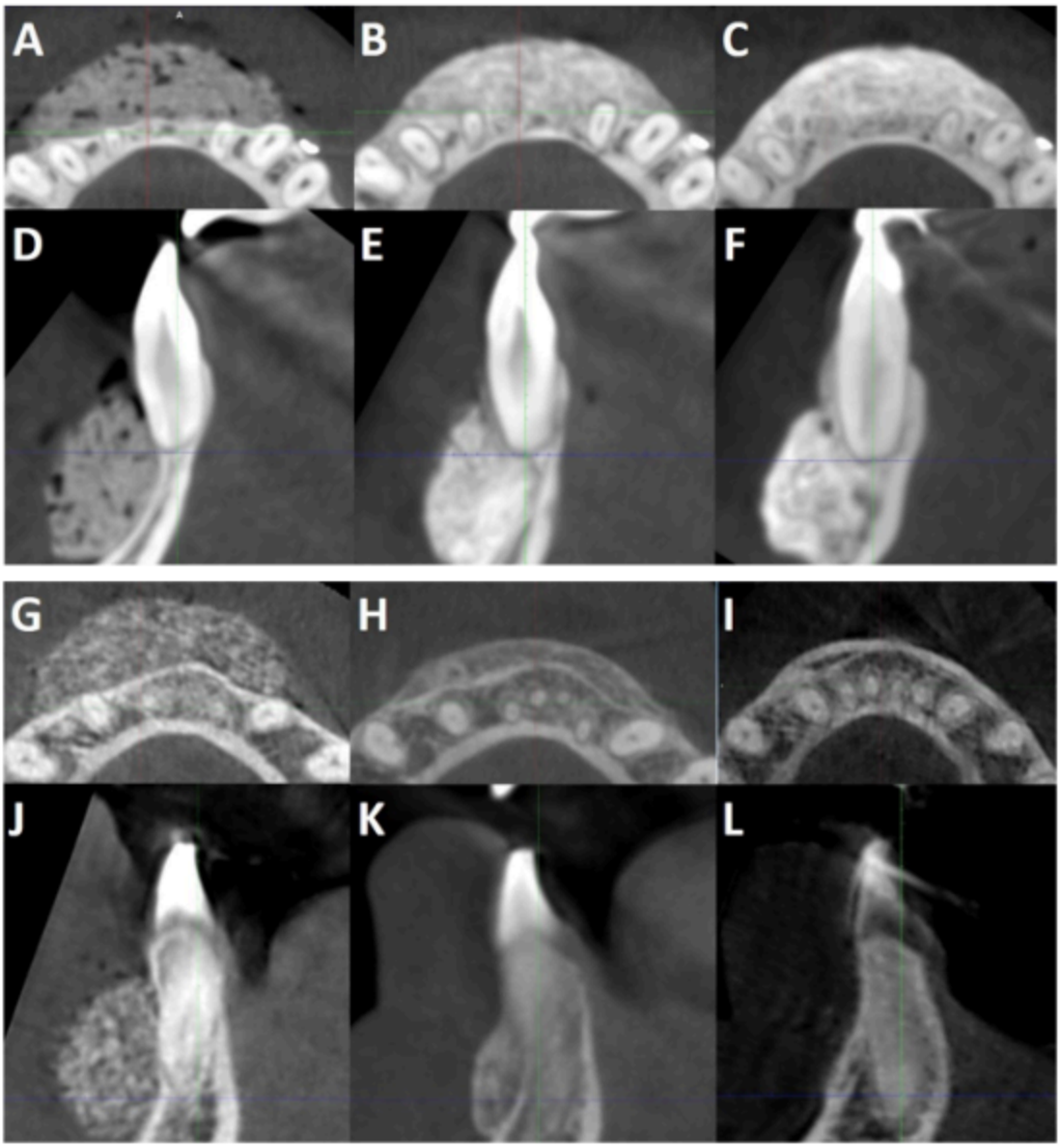


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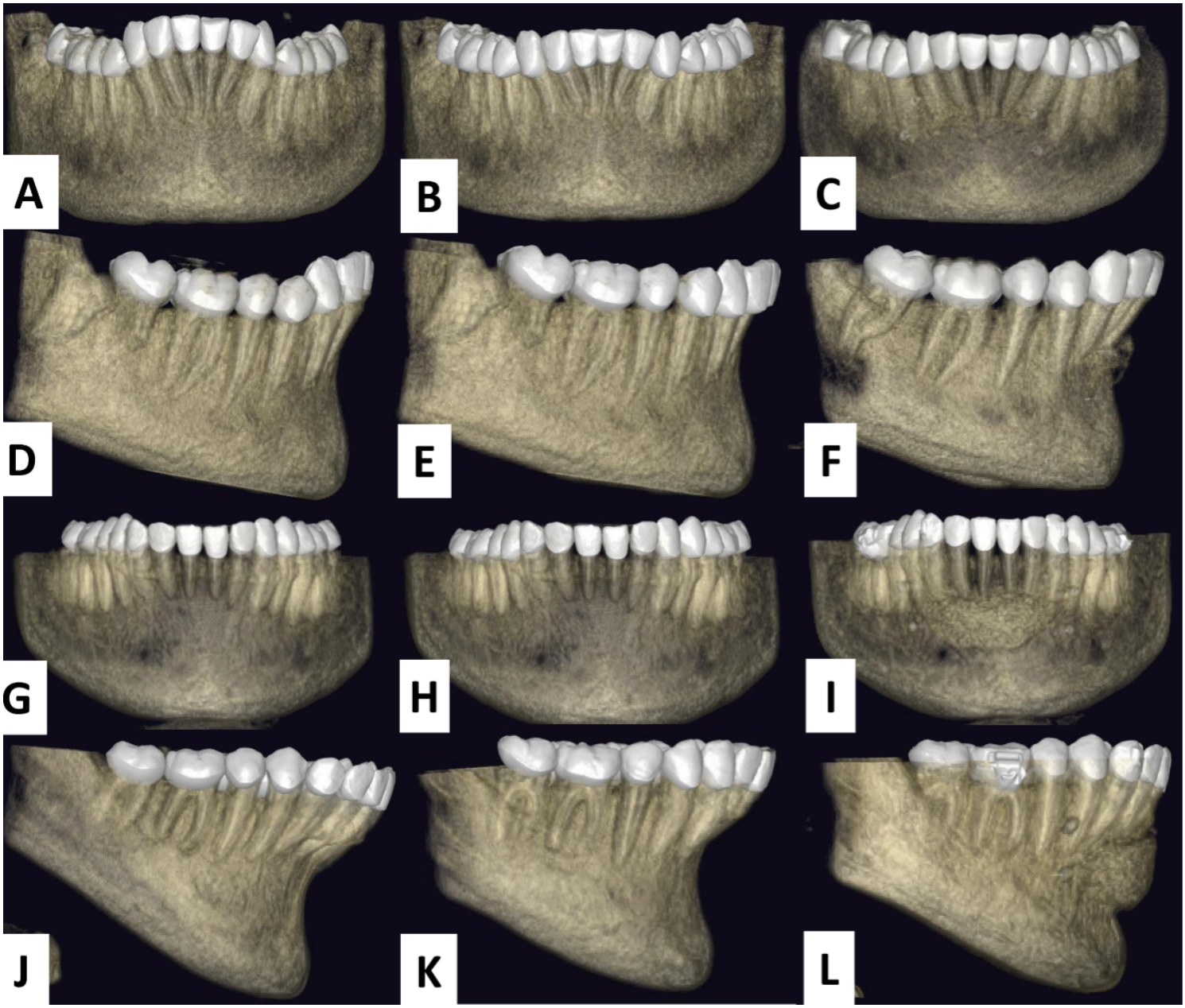


Figure 6

Digital simulation of tooth movement and its relationship to the bony limits. (A–D, G–J) Initial position. (B–E, H–K) Final planned position without considering cortical limits. (C–F, I–L) Posttreatment position, showing root adaptation within the regenerated bony contour.

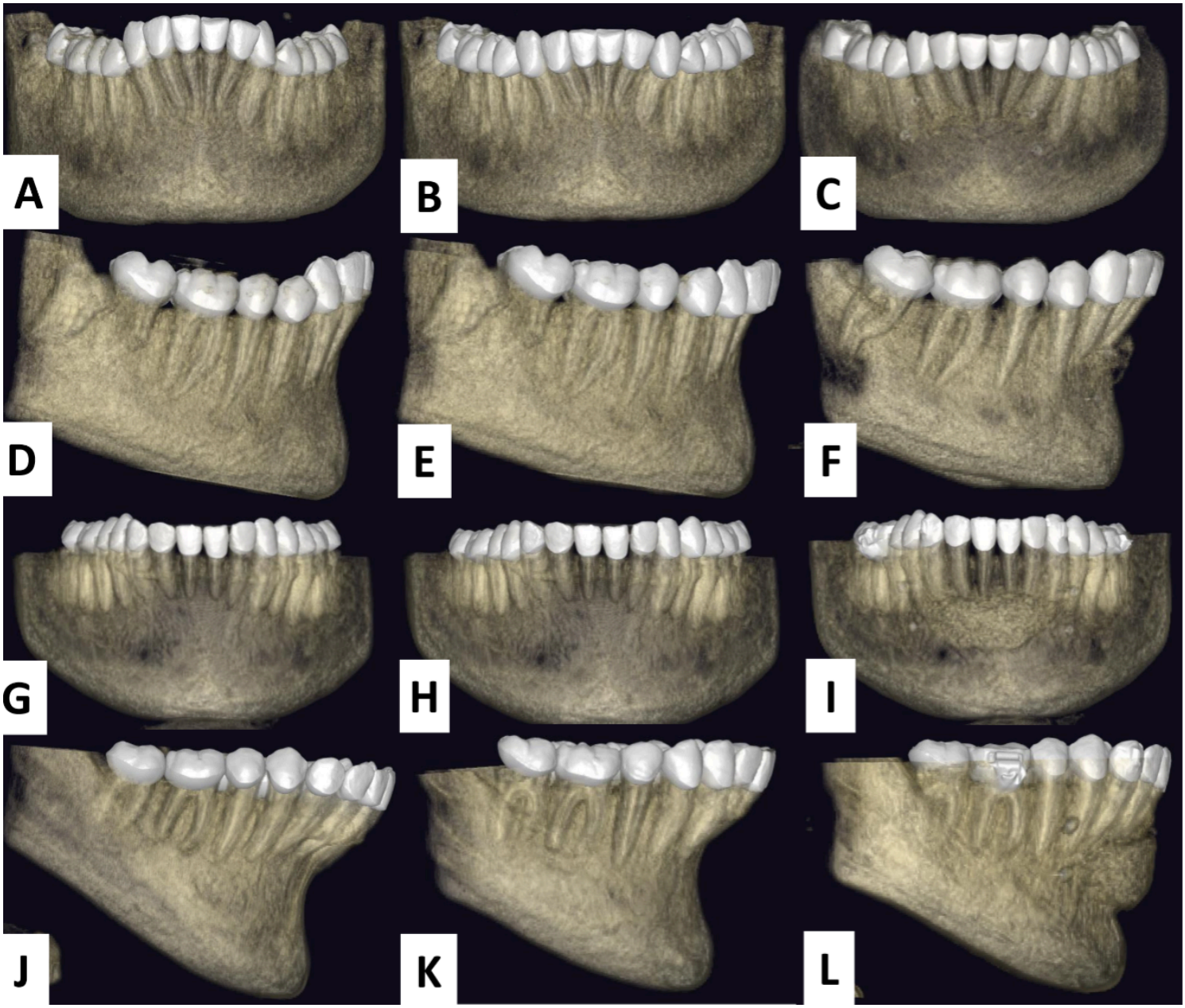


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