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CLINICAL ARTICLE

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Orthodontic-assisted one step- no prep technique: A straightforward and minimally-invasive approach for localized tooth wear treatment using polymer-infiltrated ceramic network CAD-CAM prostheses

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Abstract

Objectives: To introduce a minimally invasive and simple ortho-pros approach for localized tooth wear treatment.

Clinical considerations: Four patients with localized anterior and/or posterior tooth wear were treated. Occlusal analyses were performed, and localized wax-up or digital setup were designed based on estimated tissue loss. No-prep anterior and posterior partial-coverage polymer-infiltrated ceramic network (PICN, Vita Enamic) restorations (eg, palatal and occlusal veneers) were computer-aided designed and manufactured (CAD-CAM), tried in, and bonded in supraocclusion, creating a posterior open bite. Then, brief partial (three patients) or global (one patient, for anterior teeth alignment request) orthodontic treatment was performed to extrude the posterior teeth and re-establish posterior occlusal contacts. The orthodontic treatment duration was ~2 months for extrusion. Direct composites were performed to mask the labial finish line of palatal veneers. Clinical results were successful after a follow-up of 15, 21, 23, and 47 months, with 100% success rate of PICN anterior restorations and some minor chippings of borders of thin (0.2 mm) posterior occlusal veneers. Patient-reported outcomes were positive.

Conclusion: Orthodontic-assisted one step-no prep technique is an advantageous and straightforward evolution of the Dahl concept. PICNs exhibit several advantages in this interdisciplinary approach.

Clinical significance: New hybrid-ceramic CAD-CAM materials and a collaborative interdisciplinary approach support the evolution of the Dahl concept for conservative treatment of worn dentitions. The orthodontic-assisted one step-no prep technique is predictable, efficient, and well tolerated by patients and conserves tooth structure.

KEYWORDS

dental material, digital dentistry, erosion, occlusion, orthodontics/restorative

1 | INTRODUCTION

Tooth wear is an important and increasing pathology, particularly in young patients.[1-3] A recent systematic review and meta-regression analysis reported an estimated prevalence of erosive wear in permanent teeth of children and adolescents of 30.4%, with rates ranging from 7.2% to 74%.[1] Two subtypes of tooth wear can be distinguished in the clinical signs and patient-reported medical history[4]: (a) chemical

wear, due to, for example, acidic food/drink consumption or gastro-esophageal reflux, and (2) mechanical wear, due to bruxism. If the origin of the problem is not treated, the development of severe tooth wear would lead young adults to seek dental treatment, which is currently indicated in case of substantial loss of tooth structure, dentin exposure and significant loss (≥ 1/3) of the clinical crown, and patient esthetic or functional (eg, tooth pain) complaints.[5] Current guidelines emphasize the importance of developing minimally invasive treatments that preserve as much as possible tooth tissues,[5] which are now possible due to the development of adhesive dentistry. However, treatments must be adapted to tooth wear localization, and it is mandatory to distinguish generalized severe tooth wear, which affects the full mouth, from localized tooth wear, which is restricted to some anterior and/or posterior teeth, such as the palatal surfaces of maxillary incisors in case of bruxism. In the management of generalized tooth wear cases, different techniques have been described in the literature, which involve the complex restoration of a functional occlusion combining a correct vertical dimension of occlusion (VDO) and esthetic result. The described minimally invasive approaches include the following: (a) direct techniques with light-cured composites, which constitute the most commonly reported treatments; (b) indirect techniques with ceramic or composite partial bonded restorations; and (c) a combination of these two techniques.[6] Among the indirect techniques, a novel technique (one step-no prep) for full-mouth rehabilitation of worn dentition using computer-aided designed and manufactured (CAD-CAM) composite restorations has been recently introduced.[7] It is characterized by the absence of tooth tissue preparation (no prep) and provisional phase (one step), use of polymer-infiltrated ceramic network (PICN) materials, occlusal analysis, and collaboration with physiotherapists to treat bruxism-associated symptoms, such as muscular pain.

In case of localized tooth wear, the effects of wear are compensated by tooth eruption, apical cementum deposition, and local

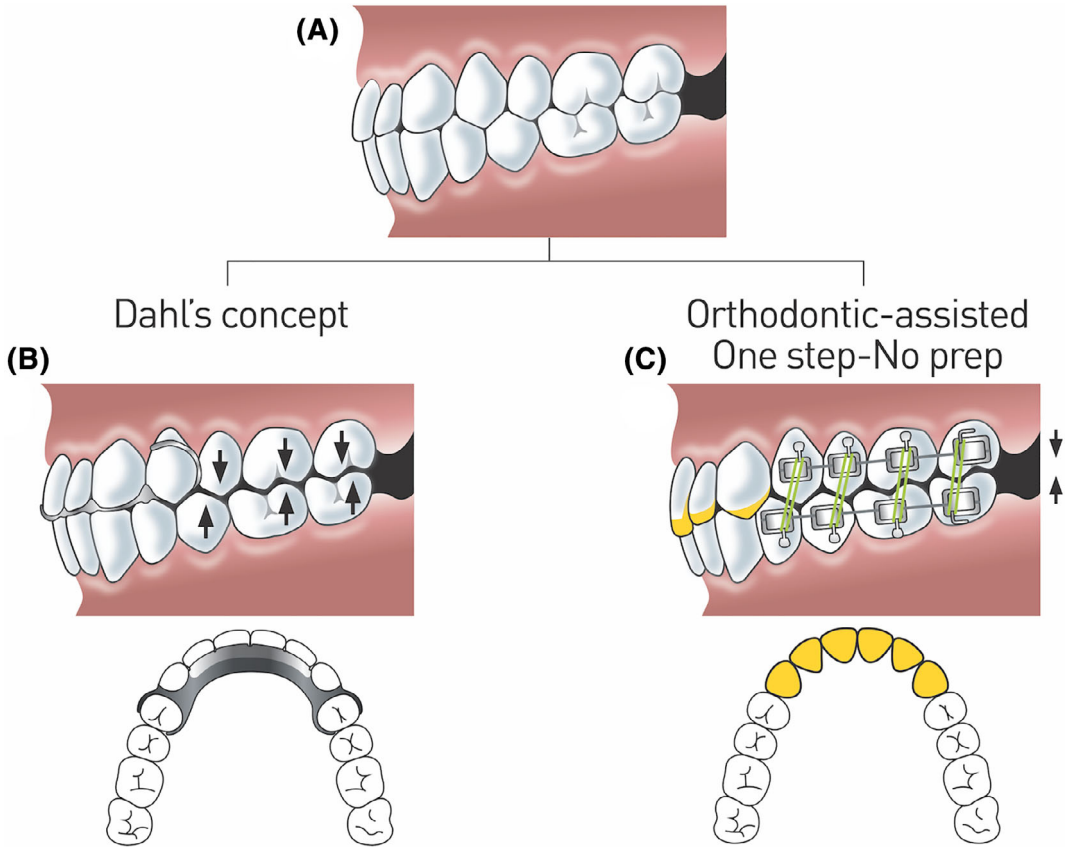

FIGURE 1 Schematic illustration of the Dahl concept and the orthodontic-assisted one step-no prep technique, respectively. A, Severe tooth wear of the maxillary anterior teeth (incisors and canines) with passive eruption. B, The original Dahl appliance (removable metal bite platform made with cobalt-chromium: fixed appliances were later developed) creates interocclusal space. Over time, the anterior space is created by a combination of intrusion of the anterior teeth, which are in contact with the appliance and in supraocclusion and of passive eruption of the posterior teeth, which permits re-establishment of the posterior occlusion. The anterior space obtained after removing of the appliance allows reconstruction of anterior teeth. More recently, the appliance was replaced by the placement of direct composites on the anterior teeth, those composites being placed in supraocclusion during the time of posterior teeth eruption. C, The orthodontic-assisted one step-no prep approach, where definitive PICN palatal veneers are placed in supraocclusion to restore the anterior teeth and extrusion of the posterior teeth is accelerated and controlled by a partial orthodontic treatment

alveolar bone growth, and lack of interocclusal space constitutes an important issue for restorative treatment. Some authors remove the remaining tooth tissues to perform crowns, for example, Hansen et al[8] recently proposed monolithic zirconia crowns in patients with severe tooth wear in the esthetic zone. They described some technical complications despite the high mechanical properties of zirconia. In particular, the procedure is invasive and does not follow current guidelines promoting tooth tissue preservation. In case of anterior wear, the creation of an interocclusal space by increasing the VDO with posterior occlusal veneers (also called "table tops") could be another option, but this option is far from ideal since the posterior teeth are intact. In contrast, in 1975, Dahl et al[9,10] proposed a remarkably interesting and conservative approach to create an anterior interocclusal space. The Dahl concept refers to the relative axial tooth movement that is observed when a localized appliance or localized restorations are placed in supraocclusion, in which the occlusion re-establishes full arch contacts over a period[11] (Figure 1A,B). In the original concept, which is a two-step procedure, a removable supraoccluding appliance system is supposed to induce both extrusion of posterior teeth and intrusion of worn anterior teeth to facilitate the placement of anterior restorations by creating interocclusal space (at that time, crowns were used as restorations since adhesive dentistry was not developed). Due to poor compliance with this removable appliance,[10,12] fixed Dahl appliances were developed, and subsequently, a one-step Dahl concept was proposed, which uses final direct composite restorations to increase the VDO.[13-16] According to the prospective observational cohort study of Milosevic et al[17] which involved 1010 direct composites applied in 164 patients, direct composite is an appropriate restorative material to restore teeth using the Dahl approach. However, full occlusal contact re-establishment is reported to be an issue.[12-15] Poyser et al reported that the occlusion re-establishes after an average period of 6 months, which can be prolonged to up to 18 to 24 months.[11] However, in a recent retrospective study on 41 subjects, Aljawad et al[18] showed that a mean period of 25.4 months (range, 6-60 months) is required to recreate the posterior occlusion. Moreover, the predictability of the extrusion of the posterior teeth was shown to be imprecise. Redman et al[13] reported a mean period of 7 months (range, 1.5-18.5 months) to re-establish the posterior tooth contact with 61% and 39% of complete and partial contacts, respectively. Gow and Hemmings[15] reported that approximately one-third of patients did not reach posterior contacts in the premolar region and that 17% of patients did not achieve posterior occlusion re-establishment. Finally, some transient difficulties were shown in terms of chewing and speaking.[10,13] The reported issues with the Dahl concept are presented in Table 1.

Therefore, this study aimed to describe a novel technique for localized tooth wear treatment. This technique constitutes an evolution of the Dahl concept and a one-step interdisciplinary approach, which uses no-prep PICN CAD-CAM restorations and a simple orthodontic system to ensure rapid, correct, and predictable extrusion of the posterior teeth.

TABLE 1 Summary table of reported limitations with the Dahl concept

Reported limitations with the Dahl concept	
Appliance-related	**Poor patient compliance associated with the removable appliance [11 12 13]** **Possible increase of plaque accumulation with the removable appliance[11]** **If cemented, difficulty to remove after treatment (damage to supporting teeth described) or risk of debonding[12]** **Poor esthetics [11 14]** **Possible transient periodontal tenderness after the insertion of the appliance [11 12 13]** **Possible transient discomfort[13]** **Risk of rapid attrition of antagonistic teeth[12]**
Dahl's concept with direct composites instead of appliance	Risk of restoration failure (such as wear, margin degradation)[13,14]
Treatment duration	Unpredictability of time needed to re-establish the posterior occlusion: 6 to 7 months on average but up to 18-24 months[11,13]
Functional aspects	Transient difficulties with chewing and speaking[11,13] Transient Temporomandibular joint dysfunction symptoms[11,12]
Final occlusion	Difficulty to predict final occlusal contacts and relationships[11] Risk of incomplete re-establishment of the posterior occlusal contacts[11,13] Need of posterior restorations by adhesive or other techniques in case of no re-establishment of proper posterior occlusal contacts[11]

2 | CLINICAL CONSIDERATIONS

2.1 | Clinical cases analysis

Four clinical cases were selected to present the orthodontic-assisted one step-no prep technique for localized tooth wear treatment using PICN CAD-CAM prostheses and, in some cases, direct composite restorations on teeth exhibiting limited wear (Figures 2-25). All patients were women (21 years, case #1; 33 years, case #2; 30 years, case #3; and 34 years, case #4) and had mechanical wear due to bruxism, all

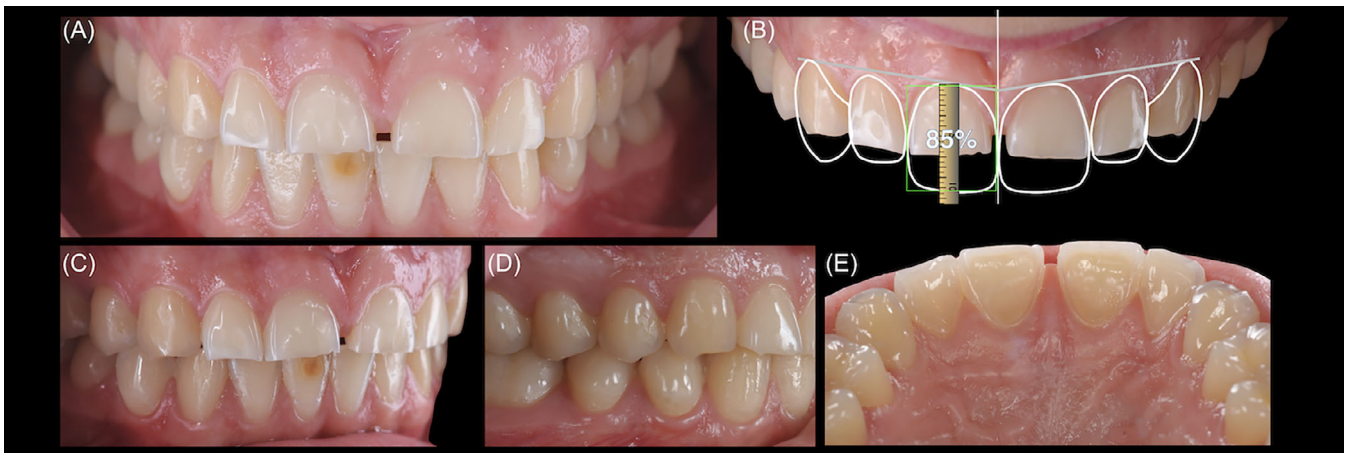

FIGURE 2 Case #1, a 21-year-old female patient. A, Frontal view before treatment: in this case only the maxillary anterior teeth show severe tissue wear, while a very slight tooth wear was observed on the mandibular incisors, which did not require treatment. B, Digital smile analysis highlighting tissue loss. C and D, Lateral views showing the absence of interocclusal space to place restorations. E, Occlusal view of the anterior teeth showing palatal tissue loss

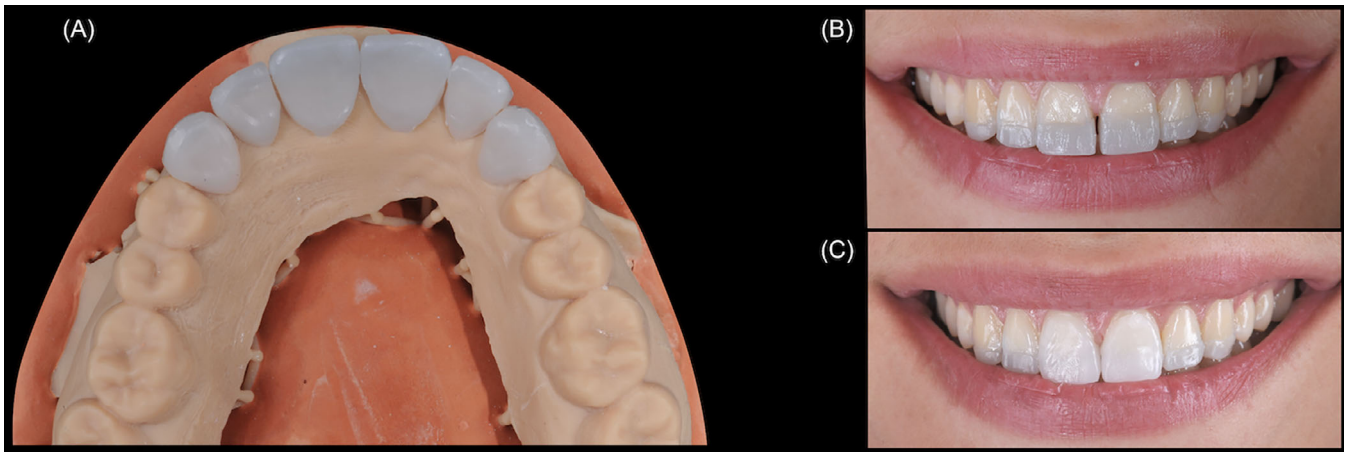

FIGURE 3 Case #1. A, A CAD-CAM anterior mock-up in wax on a printed model of the maxilla (Omnicam camera); B, Try-in using Vaseline of the first mock-up. It consists of palatal veneers, which do not close the diastema. C, Try-in of the second mock-up. Here, the diastema was closed, extending palatal veneers to the buccal surface of central incisors, providing the restoration an "envelope" design. On this basis, the patient decided to close the diastema

patients reporting tooth grinding at night or during the day. Cases #2, #3, and #4 also had chemical wear (erosion due to soda consumption). Esthetic appearance and restoration of tooth tissue were the main complaints. In case #3, the patient wanted to resolve anterior overcrowding. Case #1 presented severe tissue wear in the maxillary anterior teeth only (BEWE score = 3 in this sextant, that is, tooth dentin exposure with hard tissue loss ≥50% of the surface area and loss of the clinical crown ≥50%),[19] while the mandibular incisors showed very slight tooth wear, which did not require treatment (Figure 2). Case #2 showed localized severe tooth wear on the maxillary anterior teeth (BEWE score = 3 in this sextant), in addition to moderate tooth wear (dentin exposed) on teeth #29 and #30 (BEWE score = 2 in this sextant, that is, tooth dentin exposure with hard tissue loss <50% of the surface area and loss of the clinical crown ≥1/3). Slight tooth wear was also present on the mandibular incisors, but it was decided to leave them untreated (Figure 12). Case #3 presented not only localized severe tooth wear on the maxillary anterior teeth (BEWE score = 3 in this sextant) but also moderate tooth wear (dentin exposure) on teeth #19 and #30 (Figure 16) (BEWE score = 2 in these sextants) and mandibular incisors and canines. In case #4, localized tooth wear was observed on the anterior (teeth #8 and #9) (BEWE score = 2 in this sextant) and posterior teeth, only in the mandibular right side (teeth #29, #30, #31) (BEWE score = 3 in this sextant). The particularity of this posterior tooth wear is due to soda consumption, with cola stagnation within the right cheek before swallowing (Figure 20).

All cases were referred to an occlusodontist (a specialist in occlusion and temporomandibular disorders), and no temporomandibular joint disorder was detected. Three patients (cases #1 to #3) were

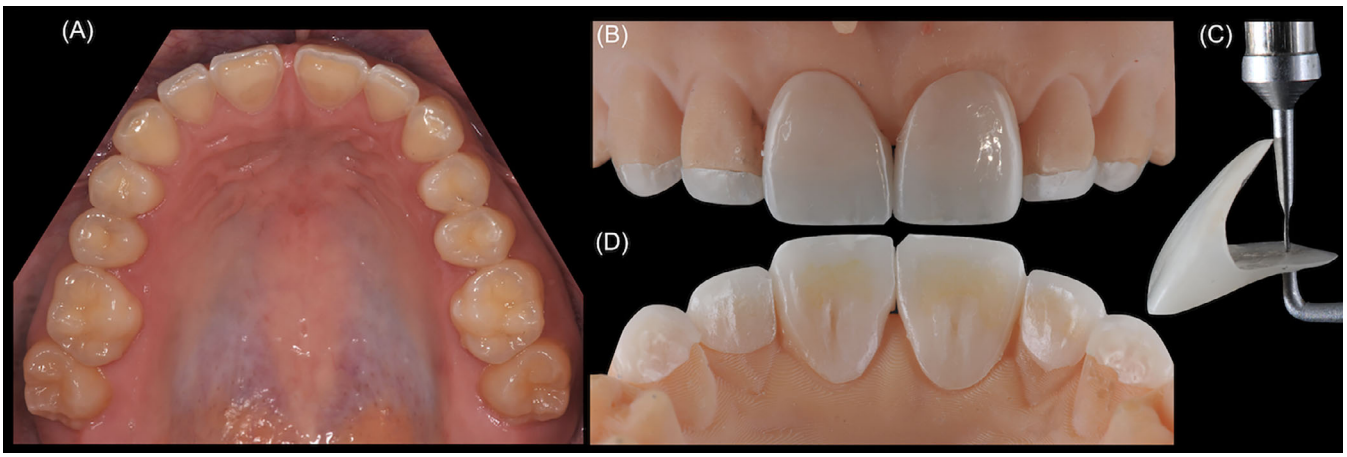

FIGURE 4 Case #1. A, Occlusal view of the maxillary anterior teeth before restoration placement: no tooth tissue preparation was performed (no prep, only sclerotic dentin is depolished with a diamond bur). B and C, PICN (Vita Enamic) palatal veneers (on laterals and canines) and "envelope" restorations (on centrals) on printed model after staining with Optiglaze. D. PICN "envelope" restoration for the central incisor. Dental technician: Jean-Michel Paulus, Liège

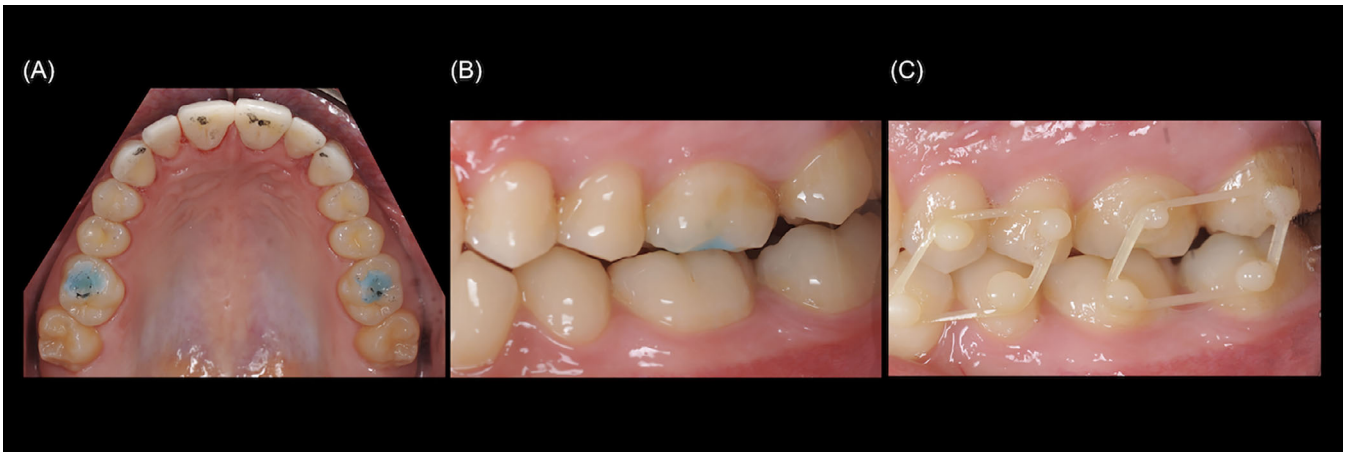

FIGURE 5 Case #1. A, Occlusal view after restorations bonding: occlusal contact is only present on restorations. Consequently, orthodontic posterior bites (OptiBand, Ormco, California) were placed on the first molars to improve patient comfort. B, Lateral view showing the posterior open bite. C, Lateral orthodontic system, which is composed of direct composite buttons bonded on buccal surfaces and linked with intermaxillary elastics. After only 13 days, the open bite was already closed

referred to a maxillofacial physiotherapist (a physical therapist specialized in temporomandibular disorders) for bruxism-associated symptom treatment, such as muscular pain.

First, pictures, radiographs, double-mix impressions with polyvinyl siloxane material (Imprint 4 Heavy and Light, 3 M, St Paul, Minnesota, or Aquasil Ultra Heavy and XLV, Dentsply Sirona, York, Pennsylvania) (cases #3 and #4), and/or optical impressions (Omnicam camera and CEREC 4 software, Sirona, Salzburg, Austria) (cases #1, #2, and #3, which are more recent) were obtained (for case #3, both types of impressions were obtained since it was in a transition phase). No preparation of tooth tissues was performed, except smoothing of sharp enamel edges with an Arkansas stone bur, if present. In cases #2, #3, and #4, an occlusal analysis was performed using a resin anterior deprogramming device and facebow (Quick Facebow, Sintec Inc., New Hampshire) (Figures 12A, 16A, and 19F). The anterior deprogramming device, which had one occlusal contact point located in the middle of the anterior region, was fixed in place for 5 minutes to induce muscular relaxation and mandibular jaw repositioning, and then occlusal relationships were registered with a double layer of wax (Moyco Beauty Wax, Pennsylvania). This analysis aimed to diagnose any mandibular mispositioning. In case of mandibular protrusion, the anterior interocclusal space can be found repositioning the mandibles correctly. No mispositioning was detected in any of the cases presented in this study. Finally, a digital smile analysis was performed using the Keynote software (Apple Inc., Cupertino, California) and sent to the dental lab (Figure 2B).

Then, either a wax-up (cases #3 and #4) and/or a digital setup (Ceramill Motion 2 System, Amann Girrbach) (cases #1, #2, and #3)

FIGURE 6 Case #1. A, Frontal view after restorations bonding and with lateral orthodontic system. Note that restorations shade was lighter since a bleaching procedure will be later performed (which is not possible when dentin is still exposed). B and C, Lateral views before and after restorations bonding and orthodontic treatment, respectively

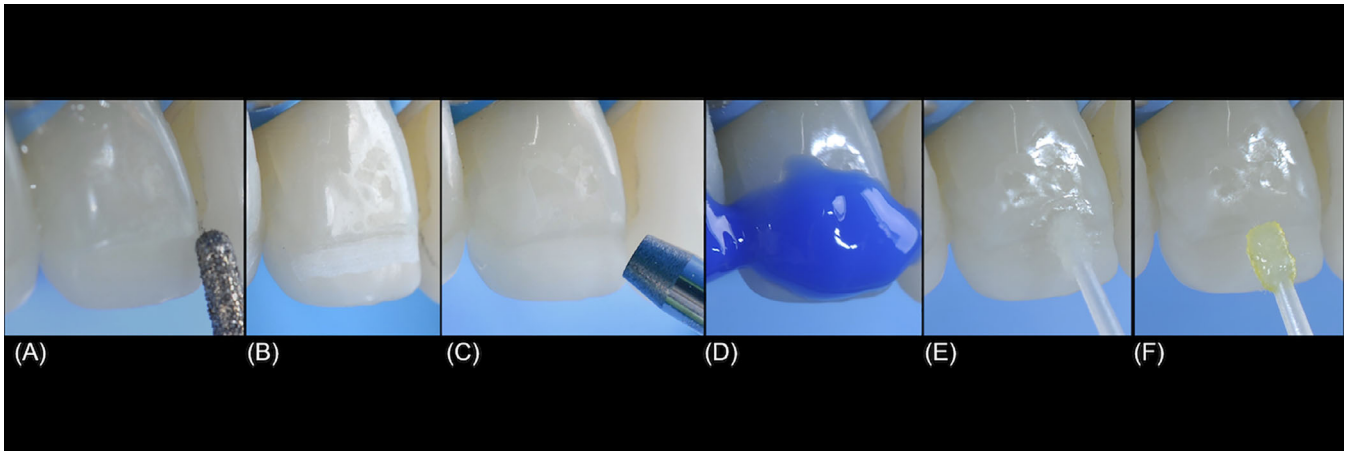

FIGURE 7 Case #1. Procedure to mask the junction between the palatal veneer and buccal surface of the lateral incisors and canines. A and B, After rubber dam placement, a slight chamfer is performed across the junction. C, PICN sandblasting at 2.5 bar with alumina particles. D, After rinsing with water, enamel etching with phosphoric acid. E, After rinsing with water, silane (Monobond S) application on PICN. F, Bonding application (Clearfil SE Bond, Kuraray Dental, Ijmuiden, Holland), which will be followed by high-value direct composite (Inspiro) layering

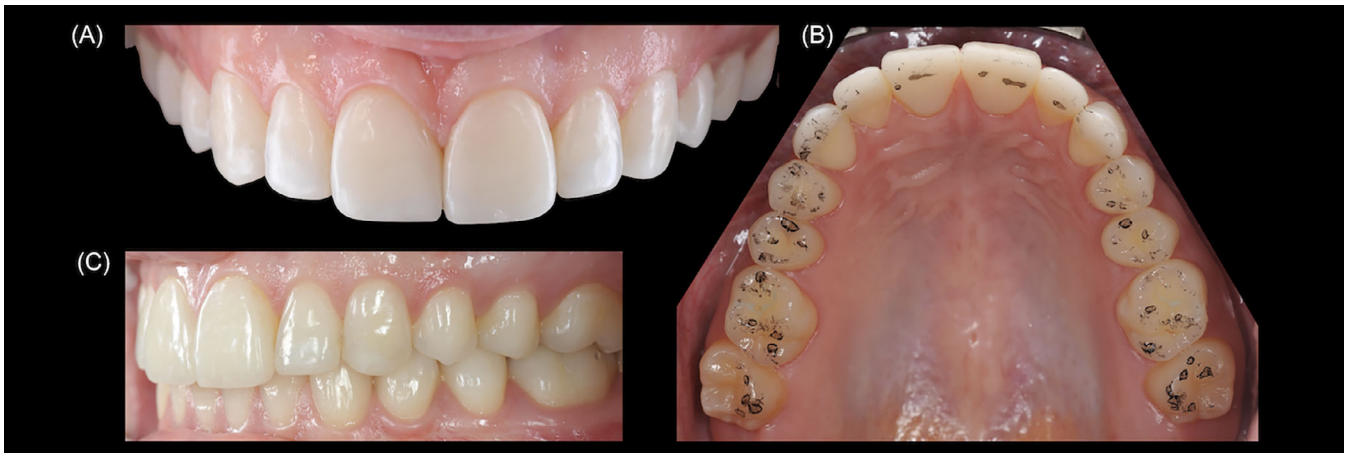

FIGURE 8 Case #1. A, Frontal view after bleaching and masking of the junction between buccal surfaces and palatal veneers with direct composite. B, Occlusal view at the end of treatment, showing proper occlusal contacts everywhere. C, Lateral view at the end of treatment

FIGURE 9 Case #1. A and B, Frontal view and smile pictures before treatment. C and D, Frontal view and smile pictures 9 months after restoration bonding. Orthodontics: Prof. Carole Charavet. Prosthodontics: Prof. Amélie Mainjot

FIGURE 10 Case #1. Face pictures before and after treatment highlighting the improvement in smile esthetics

FIGURE 11 Case #1. Acrylic occlusal splint

was designed using a "tissue-guided" approach, that is, based on the estimated amount of tooth tissue loss, the dental technician being guided by the residual tissues to reconstitute tooth anatomy. Occlusal relationships were not taken into account when designing the restorations, and the technique resulted in an empirical estimation of the new VDO and restorations in supraocclusion. On the posterior teeth, the "tissue-guided" approach resulted in extremely low restoration design (up to 0.2 mm thick) (Figures 16 and 20). On the anterior teeth, the restoration design was also determined by the digital smile analysis and reconstruction of harmonious incisor proportions. Consequently, in case #3, gingivectomy was performed on the central incisors before restorations were conducted.

The digital smile analysis and wax-up (cases #3 and #4) were shown to the patient for approval. For case #1, two different CAD-CAM mock-ups were performed in wax and tried in to validate the esthetic result, particularly with respect to the diastema (Figure 3). Indeed, in one of the mock-ups, the diastema was closed by the extension of palatal veneers (partial-coverage restoration aiming to restore palatal and incisal tooth surfaces) to the buccal surface of the central incisors, providing the restoration an original design that the authors called "envelope" design (no-prep partial-coverage restoration, restoring palatal and buccal surfaces of an anterior tooth, without recovering proximal surfaces). On this basis, the patient decided to close the diastema.

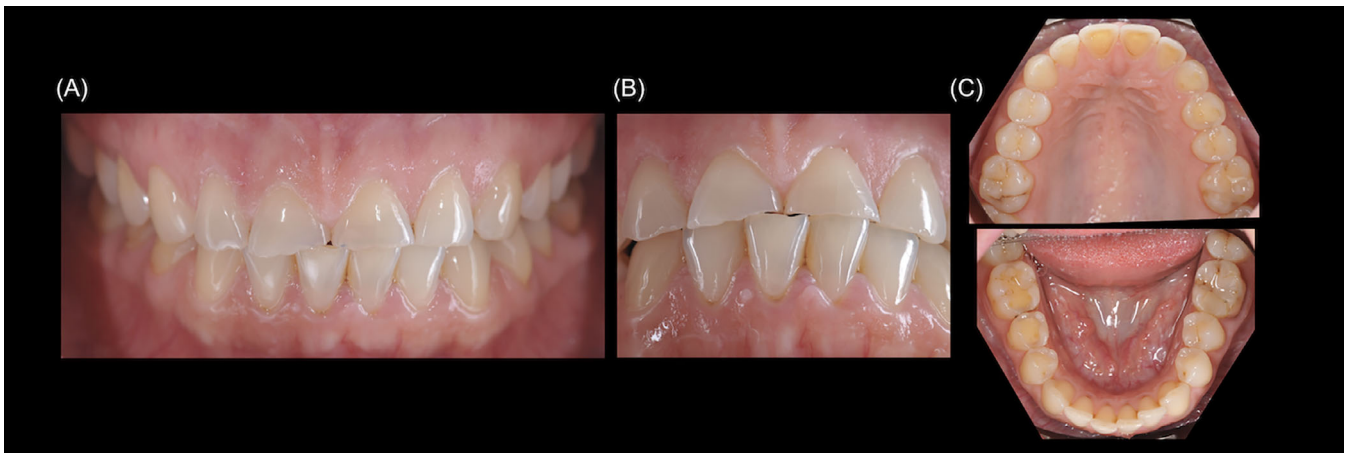

FIGURE 12 Case #2, a 32-year-old female patient. A and B, Frontal views before treatment showing severely worn maxillary anterior teeth and end-to-end occlusion with absence of interocclusal space to place restorations. C. Occlusal views showing localized severe tooth wear on the maxillary anterior teeth but also moderate tooth wear (dentin exposed) on teeth #29 and #30. Slight tooth wear is also present on mandibular incisors but it was decided to not treat it

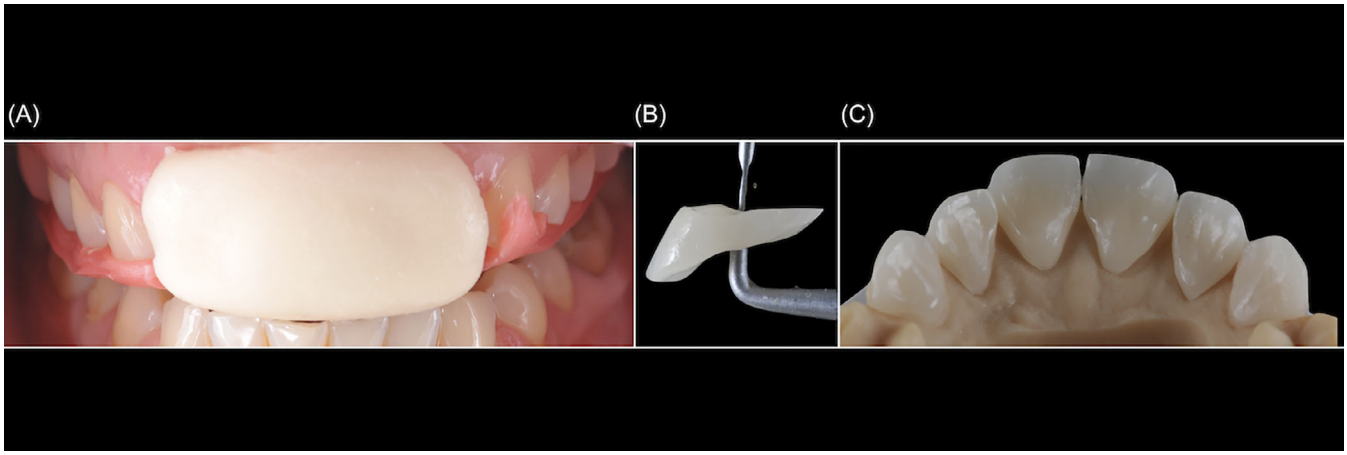

FIGURE 13 Case #2. A. Occlusal analysis: occlusal relationships registering using a resin anterior deprogramming device and double layer of wax (Moyco Beauty Wax), additionally a facebow was used (Quick facebow). This analysis aimed to diagnose any mandible mispositioning (in case of mandible protrusion, anterior interocclusal space could be retrieved repositioning the mandible correctly). Here, no mispositioning was detected. B and C. PICN (Vita Enamic) palatal veneers from tooth #6 to #11 on a printed model (Omnicam camera): restorations were polished and not stained. No tooth tissue preparation was performed, except smoothing of sharp enamel edges with an Arkansas stone bur. Moreover, sclerotic dentin was depolished with a diamond bur before restoration bonding. Dental technician: Jean-Michel Paulus, Liège

2.2 | Tooth tissues restoration

Afterward, PICN CAD-CAM restorations (Vita Enamic) were milled (Ceramill Motion 2 System, Amann Girrbach; for case #4, the double scan technique was used, with the scan of the wax-up and teeth superimposed). For case #1, four palatal veneers (maxillary lateral incisors and canines) and two "envelope" restorations (maxillary central incisors) were manufactured (Figure 4). For case #2, six palatal veneers (from tooth #6 to #11) were made, while it was decided to perform direct composites on teeth #29 and #30 (Inspiro, Edelweiss DR AG, Zug, Switzerland) (Figure 13). For case #3, six "envelope" restorations (from tooth #6 to #11) and two posterior occlusal veneers for teeth #19 and #30 were manufactured (Figure 17), while direct composite was selected to restore teeth from #22 to #27. For case #4, posterior occlusal veneers were made for teeth #29, #30, and #31 (Figure 21), while palatal veneers on teeth #8 and #9 were scheduled in a second visit. For case #2, restorations were just polished, while, for cases #1, #3, and #4, they were stained with a light-cured nanofilled composite coating agent (Optiglaze, GC Corporation, Tokyo, Japan). Restorations were tried in (to validate restoration design and new VDO) and then bonded in one appointment, which also included the placement of the direct composites in case #2 (in case #3, direct composites on the mandibular anterior teeth were placed later). Restorations were pretreated following the manufacturer's recommendations, which involved etching the surface with hydrofluoric acid (HF) for 60 seconds, then cleaning them in an ultrasonic bath in ethanol, and

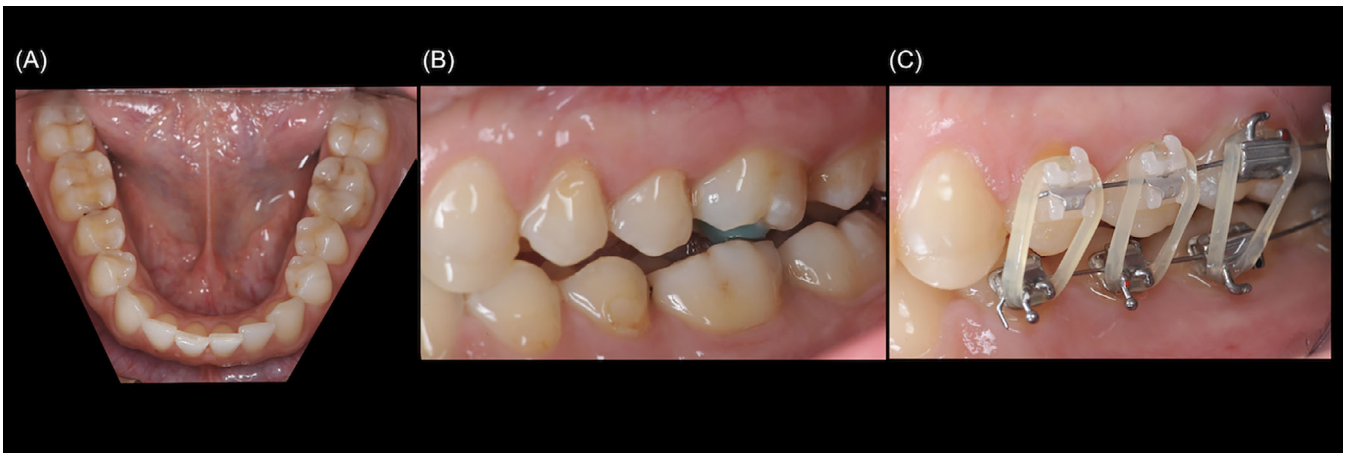

FIGURE 14 Case #2. A, The day of restorations bonding, occlusal surfaces of teeth #29 and #30 were restored with direct composite (Inspiro). B, Posterior open bite due to restorations placement. Orthodontic posterior bites (OptiBand, Ormco, California) were placed on the first molars to improve patient comfort. C. In this case, In-Ovation C active self-ligating brackets (Dentsply GAC, Bohemia, New York) were used with clear brackets on the first and second maxillary premolars and intermaxillary elastic (IntraOral Elastics, Medium Pull, 1,3 N, ∅ 3,2 mm/1/8 in, Dentaurum, Ispringen, Germany) were placed

FIGURE 15 Case #2. A, Frontal view before treatment. B, Frontal view after palatal veneers bonding and direct restoration of teeth #29 and #30. C and D, Frontal views at the end of treatment, after bleaching, masking of the junction between buccal surfaces and palatal veneers, and reshaping of teeth #8 and #9 with direct composite (Inspiro). Orthodontics: Prof. Carole Charavet. Prosthodontics: Prof. Amélie Mainjot

finally applying a layer of silane (Monobond S, Ivoclar Vivadent, Schaan, Liechtenstein). The rubber dam was placed (except for "envelope" restorations in case #3) (Figure 23B). Tooth tissues were cleaned with pumice and then treated with a two-step etch-and-rinse adhesive (Adhese, Ivoclar Vivadent). The adhesive application was preceded by the pretreatment of sclerotic dentin, in which the surface was depolished with a diamond bur at low speed to open tubules. Restorations were bonded with a composite resin cement (Variolink Esthetic DC, Ivoclar Vivadent), polymerization was conducted after excess removal, and final photopolymerization was performed under a film of glycerin to prevent the persistence of a polymerization inhibition layer. Occlusal adjustments were performed immediately after bonding of the mandibular restorations with an Arkansas stone bur, followed by polishing with silicon gums. The occlusal adjustments only consisted of equilibration of occlusal contacts on maxillary anterior restorations. Orthodontic blue posterior bites (OptiBand, Ormco, California) were placed on the first molars to provide the patients a posterior occlusal contact and improve comfort (Figures 5 and 14). Indeed, bonding of restorations resulted in a significant open bite in the posterior regions.

2.3 | Orthodontic treatment

Patient #1 (Figure 5): The orthodontic blue posterior bite (Figure 5A and B) was removed. After the bonding procedure was completed according to the manufacturer's instructions (Transbond Self Etching Primer, 3 M, Maplewood, Minnesota), direct composite buttons were

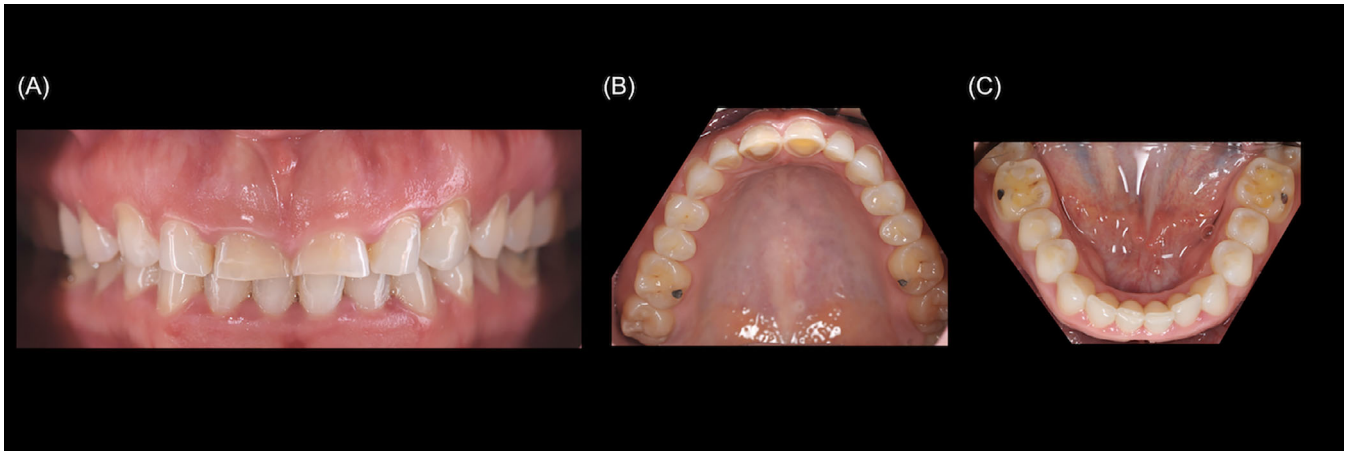

FIGURE 16 Case #3, a 30-year-old female patient. A, Frontal view before treatment showing severely worn maxillary anterior teeth, particularly central incisors (tooth #8 is nonvital). B and C, Occlusal views showing localized severe tooth wear on the maxillary anterior teeth but also moderate tooth wear (dentin exposed) on teeth #36 and #46. Moderate tooth wear is also present on mandibular incisors

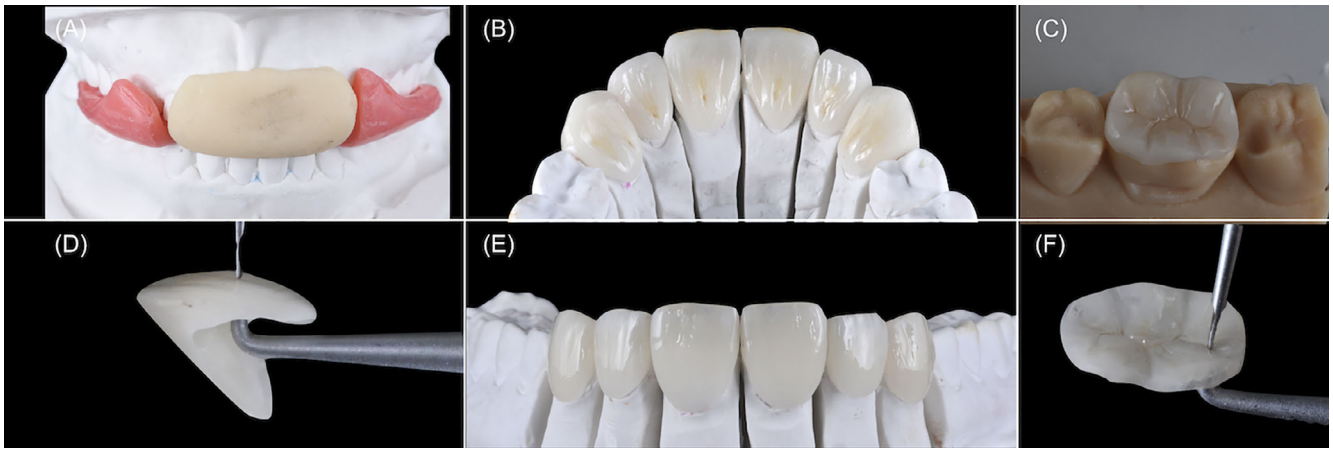

FIGURE 17 Case #3. A, Occlusal analysis: occlusal relationships registering using a resin anterior deprogramming device and double layer of wax (Moyco Beauty Wax), additionally a facebow was used (Quick facebow). This analysis aimed to diagnose any mandible mispositioning (in case of mandible protrusion, anterior interocclusal space could be retrieved repositioning the mandible correctly). Here, no mispositioning was detected. In this case, after occlusal and esthetic analysis (gummy smile), it was decided to perform a crown lengthening on teeth #8 and #9 to reestablish correct tooth proportion. B and E, PICN (Vita Enamic) "envelope" restorations from tooth #6 to #11 on a plaster model: restorations were stained (Optiglaze). No tooth tissue preparation was performed, except sclerotic dentin depolishing with a diamond bur before restoration bonding. D, Typical "envelope" design of restorations. C and F, 0.2-mm-thick PICN table tops for teeth #19 and #30. Dental technician: Jean-Michel Paulus, Liège

designed (Venus Flow, Kulzer, Hanau, Germany) from the first premolar to the second molar. Intermaxillary elastics (IntraOral Elastics, Medium Pull, 1,3 N, ∅ 3.2 mm/1/8 in, Dentaurum, Ispringen, Germany) were prescribed between all brackets 24 hours/day, except while eating or drinking and brushing the teeth, to close the posterior space (Figure 5C). Each elastic was changed twice daily. A debonding occurred 6 days after placement, which was immediately repaired. The re-establishment of the posterior occlusion was restored in 34 days, according to excellent patient compliance. Afterward, intermaxillary elastics were prescribed for ≥30 days (16 hours/day) during the retention phase; then, the composite buttons were removed. Therefore, the overall orthodontic treatment time was 64 days (34 and 30 days for active and retention phases, respectively) with a final equilibrated occlusion obtained (Figure 8C).

Patient #2 (Figure 14): The blue posterior bite (Figure 14B) was removed. After the bonding procedure was completed according to the manufacturer's instructions (Transbond Self Etching Primer, 3 M, Maplewood, Minnesota), In-Ovation C active self-ligating brackets (Dentsply GAC, Bohemia, New York) were used. Clear brackets were placed up to the first maxillary premolars, while metal brackets were used for the mandibular teeth and maxillary molar teeth (Figure 14C). After the brackets were bonded, 0.014-in nickel-titanium arch forms

FIGURE 18 Case #3. A and B, Damon Q metal self-ligating brackets (Ormco, California) were used from the first premolars to the second molars with additional lingual metal buttons on mandibular premolars and molars. Intermaxillary crossbite elastics (IntraOral Elastics, Medium Pull, 1,3 N, ∅ 3,2 mm/1/8 in, Dentaurum, Ispringen, Germany) were placed between each tooth on the right quadrant (eg, first premolar to first premolar) and between maxillary brackets with their corresponding lingual buttons on the left. C, Lateral view after treatment and restoration of the tip of the buccal cusps of tooth #14 with direct composite. D, Lateral view just after orthodontic treatment

FIGURE 19 Case #3. A, Frontal view before and after treatment. Bleaching was performed after orthodontic treatment. Mandibular incisors and canines, as the tip of buccal cusps of teeth #5 and #12, were restored with direct composite (Inspiro). B, Face pictures before and after treatment highlighting the improvement in smile esthetics. Orthodontics: Dr. Jean-Claude Bernard. Prosthodontics: Prof. Amélie Mainjot

were placed. Intermaxillary elastics (IntraOral Elastics, Medium Pull, 1,3 N, ∅ 3,2 mm/1/8 in, Dentaurum, Ispringen, Germany) were prescribed between each tooth (eg, first premolar to first premolar) 24 hours/day, except while eating or drinking and brushing the teeth. Each elastic was changed twice daily. In this case, the combination of brackets and elastics improved the predictability of posterior tooth extrusion displacement, with respect to the bigger open bite than that in case #1. The re-establishment of the occlusion was completed in 45 days, according to excellent patient compliance. The patient was advised to continue with the intermaxillary elastics for 30 days (16 hours/day) during the retention phase. Afterward, the orthodontic appliance was removed. The overall treatment duration was 75 days (45 and 30 days for active and retention phases, respectively).

Patient #3 (Figure 18): After performing the bonding procedure according to the manufacturer's instructions (Transbond Self Etching Primer, 3 M, Maplewood, Minnesota), Damon Q metal self-ligating brackets (Ormco, California) were fixed from the first premolars to the second molars, and lingual metal buttons were placed on the maxillary premolars and molars (Figure 18B). Intermaxillary elastics (IntraOral Elastics, Medium Pull, 1,3 N, ∅ 3,2 mm/1/8 in, Dentaurum, Ispringen, Germany) were prescribed between each tooth on the right quadrant (eg, first premolar to first premolar) and between maxillary brackets with their corresponding lingual buttons on the left (crossbite elastics) 24 hours/day, except while eating or drinking and brushing the teeth (Figure 18A). Lingual buttons were used in this clinical situation because the posterior teeth needed to be displaced horizontally due to an existing lateral overjet, in addition to the need for a vertical

FIGURE 20 Case #4, a 34-year-old female patient. A, B, and D, Occlusal views showing localized tooth wear of anterior teeth (teeth #8 and #9) and also posterior teeth, but only on the mandibular right side (teeth #29, #30, #31). The particularity of posterior tooth wear is due to soda consumption, with cola stagnation within the right cheek before swallowing. C, Frontal view of the maxillary anterior teeth. E, Lateral view showing the absence of interocclusal space to place restorations on worn posterior teeth. F, Occlusal analysis: occlusal relationships registering using a resin anterior deprogramming device and double layer of wax (Moyco Beauty Wax), additionally a facebow was used (Quick facebow)

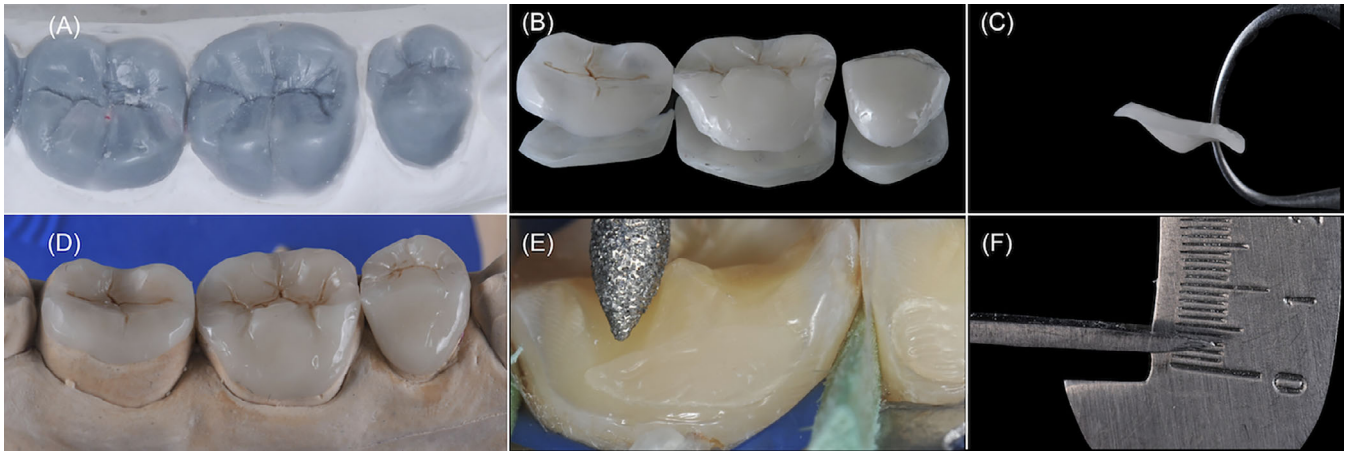

FIGURE 21 Case #4. A, "Tissue-guided" wax-up of teeth #29, #30, and #31. B-D, and F, After superimposition of the scans of the models and the wax-up, 0.2 mm-thick PICN (Vita Enamic) posterior occlusal table tops were milled and then stained (Optiglaze). E. These restorations were bonded on the teeth, which were not prepared (no-prep treatment). However, sclerotic dentin was depolished before bonding with a diamond bur to open tubules. Dental technician: Jean-Michel Paulus, Liège

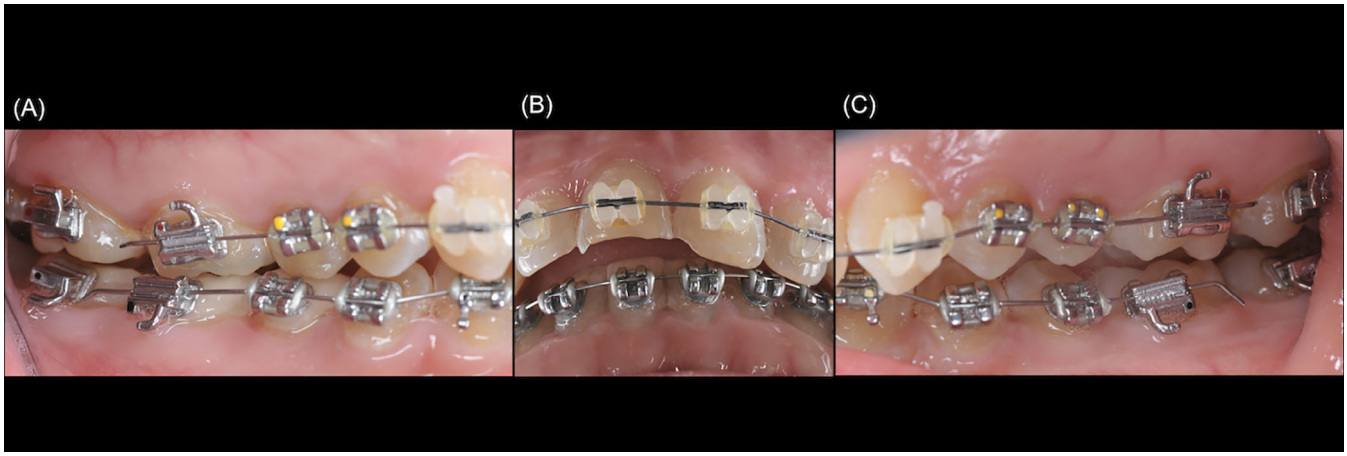

FIGURE 22 Case #4. A-C, Bonding of table tops results in an open bite in the anterior and posterior zones. Only teeth #29 and #30 have an occlusal contact. Here, the patient's demand was also to align the anterior teeth. Therefore, a global orthodontic treatment (conventional brackets [3M, St. Paul, Minnesota] with clear maxillary anterior brackets and 0.014-in nickel-titanium arch forms) was performed, and the palatal veneers on teeth #8 and #9 were placed after alignment

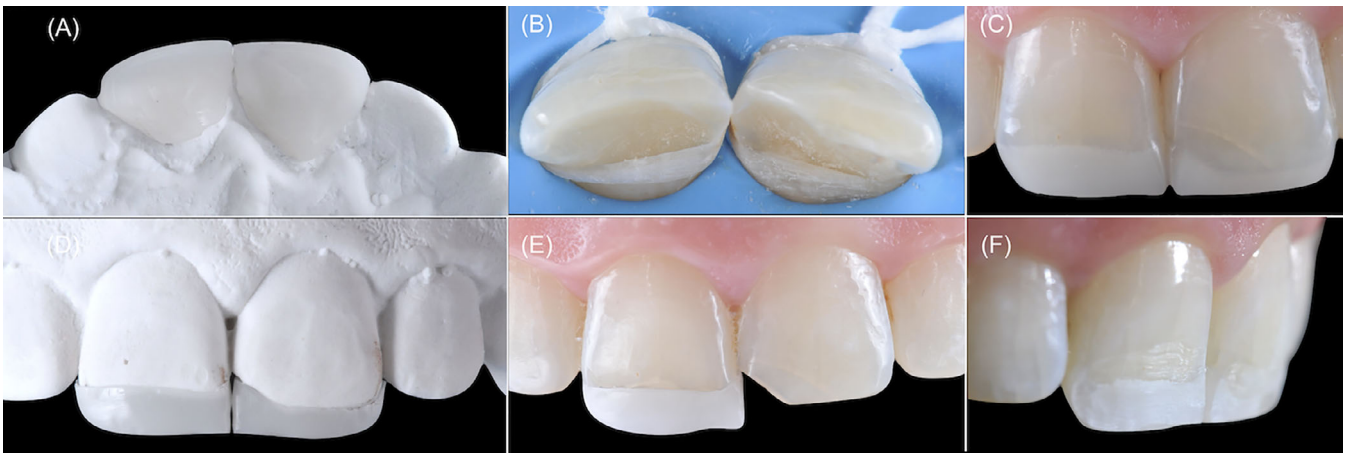

FIGURE 23 Case #4. Placement of PICN (Vita Enamic) palatal veneers on teeth #8 and #9 after orthodontic treatment and bleaching. A and D, Restorations on the plaster models: they were just polished and not stained. Note that the palatal veneer just reconstitutes the missing part of the tooth; it does not necessarily recover all the palatal surface. B, Occlusal view of the teeth before bonding: tooth tissues were not prepared (no-prep treatment). E, Try-in of restorations: the absence of resin composite bond highlights an important shade mismatch with the teeth. C, Restorations after bonding. F, A slight chamfer is performed across the labial finish line of veneer to mask it with direct composite (Inspiro)

FIGURE 24 Case #4. Frontal views before and after treatment. This additive technique is particularly minimally invasive. Orthodontics: Dr. Sophie Leroy. Prosthodontics: Prof. Amélie Mainjot

extrusion. After the completion of the final posterior occlusion, intermaxillary elastics were prescribed 16 hours/day during the retention phase. The overall orthodontic treatment was achieved in 168 days (120 and 48 days for active and retention phases, respectively).

Patient #4 (Figure 22): After the bonding procedure was completed according to the manufacturer's instructions (Transbond Self Etching Primer, 3 M, Maplewood, Minnesota), conventional brackets (3 M, St. Paul, Minnesota) were used. Clear brackets were placed in the maxillary anterior teeth, whereas metal brackets were used for the rest of the teeth. A complete orthodontic treatment was performed to align the teeth, in addition to closing the open bite in the left posterior quadrant and on teeth #27 and #32. The following sequence of archwires was used after bonding the brackets: 0.014-, 0.018-in, 0.014 × 0.025-in and 0.018 × 0.025-in nickel-titanium archwires for alignment. However, 0.019 × 0.025-in stainless steel archwire was used for fine-tuning. The overall orthodontic treatment duration was 210 days.

2.4 | Finishing

A bleaching procedure was performed (which was not possible when dentin was still exposed). To mask the labial finish line of palatal veneers of maxillary anterior teeth, direct composite was added on a slight chamfer made across the finish line and where needed to optimize tooth shape (Figures 7, 8, and 15). In case #4, the palatal veneers were designed and bonded after the orthodontic treatment and alignment of the maxillary anterior teeth (Figure 23). Finally, an acrylic occlusal splint (for the maxillary anterior teeth) was made for all patients (Figure 11).

FIGURE 25 Observed technical complications. A and C, In case #3, minor chipping of the extremely thin occlusal borders of the occlusal top on tooth #30 after 21 months. Minor chipping was also observed on tooth #19. B, The same type of failure in case #4, on tooth #31. D, In case #2, fracture of the direct composite added to reshape tooth #8. This failure could have been avoided with a better design of the palatal veneer (a small diastema was present, Figure 15B)

2.5 | Follow-up

After a follow-up period of 15 (case #1), 21 (case #3), 23 (case #2), and 47 months (case #4), observed complications included minor chipping of the very thin occlusal borders of the occlusal top on tooth #30 after 21 months in case #3 (Figure 25A,C). Minor chipping was also observed on tooth #19 (Figure 25B), and the same type of failure occurred in case #4, on tooth #31 (Figure 25B). These minor chippings were polished. Moreover, in case #2, the mesial part of the direct composite, which was added to reshape tooth #8, was fractured and had to be repaired (Figure 25D).

At recall, patients were asked to fill a patient-centered outcomes form, using a 10-point Likert scale. Patient-reported outcome measures (PROMs) through this satisfaction form showed extremely positive results. A mean score of 10 of 10 was obtained regarding the treatment esthetic and functional results, absence of provisional restorations, comfort of PICN material, and esthetics of PICN material. All patients would undergo the same treatment again if needed and would recommend it to a friend (mean score of 10). A mean satisfaction score of 8.3 of 10 was obtained with respect to the restoration bonding procedure. Regarding the orthodontic treatment, mean scores of 8.5, 8.0, and 8.3 were obtained for its duration, related functional handicap, and related esthetic handicap, respectively. Surprisingly, the patient with the global treatment was the most satisfied. Finally, the importance to undergo a minimally invasive treatment obtained a score of 9.8 of 10.

3 | DISCUSSION

The presented technique constitutes an evolution of the Dahl concept with (a) the use of simple orthodontic systems to ensure rapid, correct, and predictable extrusion of the posterior teeth and (b) the use of no-prep PICN CAD-CAM restorations (without using provisional restorations) (Figure 1). No-prep definitive restorations are placed before the orthodontic treatment, except in case of teeth and/or gingival level misalignment, which require a global orthodontic treatment before anterior restoration placement.

All presented cases constituted an indication of tooth wear treatment with respect to (a) the substantial loss of tooth structure characterized by dentin exposure (as demonstrated with BEWE scores) and significant loss (≥1/3) of the clinical crown and (b) the patient complaints.[5]

3.1 | Prosthodontic phase

PICN materials (hybrid ceramics) exhibit several advantages compared with ceramics and other indirect or direct composite materials, as follows: (a) ability to be milled to an extremely low thickness with less edge chipping than ceramics[20,21] which allowed for a "no-prep" approach and restoration design corresponding only to the estimated tissue loss; (b) ease of in-mouth adjustments, in which the management of occlusal relationships required meticulous adjustments, and from that point of view, PICNs were shown to be more adaptable than ceramics; (c) biomechanical properties, with an elasticity modulus value being intermediary between those of dentin and enamel, while ceramics are brittle and too stiff, and other composite materials are too soft[22]; (d) high degree of conversion of monomers, which improves mechanical resistance and chemical stability and reduces free monomer release compared with light-cured composites[22]; (e) bonding properties, which were shown to be higher than other CAD-CAM composites and as good as glass ceramics when the material is etched.[23,24] Moreover, PROMs indicated an excellent score (mean score of 10 of 10) for the comfort and esthetics of the material. Furthermore, the use of CAD-CAM indirect restorations facilitates tooth anatomy design with a reduced chairtime compared with direct composites. However, it must be noted that, in case of slight wear and small amount of tissue loss, direct composites remain indicated

(case #2 and #3), and the technique principle being to restore tissues in an additive way.

In the presented four pilot cases, the technique was shown to give successful short-term clinical results. Anterior PICN restorations did not encounter any failure, while Aljawad and Rees[18] recently reported an 88.8% success rate and 95.6% survival rate (25-month follow-up) of anterior direct composites used with the Dahl concept, and Milosevic and Burnside revealed an estimate failure rate of 5.4% in the first year.[17] Gulamali et al highlighted the need of maintenance with direct composites.[25] It is noteworthy to mention that minor chippings were observed on posterior restorations: they were related to borders of very thin occlusal veneers, which were submitted to occlusal contacts, while no major fracture of restorations was observed, despite the high occlusal stress.[26] The development of new generations of PICNs, with higher mechanical properties should reduce these types of complications.[26,27] The results confirm those of the 2-year study about the one step-no prep approach for treatment of generalized tooth wear, in which PICN palatal veneers behaved very well and some minor chippings were observed with very thin table tops.[28] Moreover, in case #2, the mesial part of the direct composite, which was added to reshape tooth #8, was fractured and had to be repaired (Figure 25D). This direct composite failure could have been avoided with a better design of the palatal veneer (a small diastema was present, Figure 15B).

From the esthetic point of view, the result with palatal veneers and addition of direct composite on the buccal surfaces of the anterior teeth were highly satisfactory and presented the advantage of avoiding tooth preparation and cost related to ceramic veneers, which can always be performed later if needed. Although the authors were hesitant at the beginning of the treatment, the “envelope” design restorations were shown to provide successful results from the esthetic point of view. It was proposed to the patients to perform ceramic buccal veneers in a second time if they were not satisfied; however, they were all extremely happy with the results. The use of a CAD-CAM mock-up is of particular value as the mock-up helps to validate the restoration design, allows for assessment of the proposed VDO, and facilitates patient consent. The CAD-CAM mock up technique also provides for increased efficiency over direct composite resin mock-up techniques. In addition, the CAD-CAM mock-up facilitates the dental technician's work since it constitutes a real draft of the final restoration: it reduces the risk of changes after prosthesis milling and its use is now systematic. Finally, from the author's experience, stains show better stability if applied after etching and silanization of the PICN.

From a functional point of view, the one-step and empirical VDO increase did not result in any complications. These results confirm previous findings of the one step-no prep technique for generalized tooth wear, in which PICN restorations are bonded on all teeth, without testing the VDO with provisional restorations.[7,29] The VDO determination is always an inaccurate and empirical process[30]; generally, it is based on dental restorative needs, and with the one step-no prep approach, the principle is simply to recreate missing tissues based on the remaining tooth anatomy, since PICN materials can be used in low thickness. Although it is rarely used with indirect restoration techniques, the one-step approach of VDO increase is already successfully used with direct techniques in tooth wear treatment[31,32] and it was previously reported that a 5-mm increase at the incisal pin did not lead to any undesirable effects on the temporomandibular joints and associated muscles.[30,33] The use of an occlusal analysis is not absolutely necessary since occlusal relationships are not taken into account in posterior restoration design, and in case #1, which was not performed with an occlusal analysis, occlusal contact on palatal veneers were easily adjusted after bonding. Only the mispositioning of the mandible should be evaluated by careful manipulation during the clinical case analysis.

The results are supported by PROMs, which indicated an excellent satisfaction score (mean score of 10 of 10) for the esthetic and functional results of treatment.

3.2 | Orthodontic phase

The use of an orthodontic system seems to ensure a rapid and predictable re-establishment of the posterior occlusion, which was reported to be an issue in Dahl's previous concept.[13,15] The orthodontic system was placed the same week as the restorations to directly close the posterior open bite. When simple extrusion was required (cases #1 and #2), a treatment duration of only 2 months was sufficient. Neither of the patients raised esthetic objections to the wear of posterior fixed orthodontic appliances.

Different orthodontics systems can be used, depending on the initial clinical situation. A small posterior open bite (case #1) can be solved using composite buttons combined with intermaxillary elastics, while a large posterior open bite is easier to treat with the bracket system to ensure better predictability of the posterior tooth extrusion movement (case #2). Composite buttons remain more fragile than the metal ones (a debonding occurred in case #1), which can therefore be preferred if the patient's esthetic demand is not too high. Palatal or buccal buttons combined with vestibular brackets allow the placement of crossbite elastics for additional horizontal shift (case #3). In the first three cases, patients were advised to wear intermaxillary elastics 24 hours/day during the active phase of closing the open bite. After the accomplishment of a posterior occlusion, the active phase was followed by a retention phase, in which the intermaxillary elastics were worn 16 hours/day for stability. Finally, a complete orthodontic system is only advised when the patient has additional complaints, alignment of teeth and related gingival levels is required (case #4). In such cases, complex orthodontic movements must be achieved (eg, alignment of the overall teeth and torque movement), regardless of the closure of the posterior occlusion using the Dahl approach. It must be noted that, in these cases, anterior restorations are performed after and not before the orthodontic treatment, alignment being needed in the restoration design.

With the Dahl concept, the re-establishment of posterior occlusion after rehabilitation was achieved after a period of 25.4 months (range, 6-60 months),[18] and the maintenance of non-occlusion due to a possible limited auto-eruptive potential was described[13,15] with some

transient difficulties in terms of chewing and speaking being also reported.[10,13] Moreover, if final restorations are performed after anterior space opening, the estimation of the needed space with respect to ideal teeth proportions is difficult to establish. In the presented pilot cases, the orthodontic-assisted extrusion required ~2 months if a simple open bite was present (cases #1 and #2) and 4 months if a lateral open bite had to be corrected (case #3), while case #4 involved full alignment of the teeth; therefore, the treatment duration was longer. The different employed orthodontics systems provided rapid final results, and the quick closure of the iatrogenic lateral open bite avoided any dysfunctional tongue or myofunctional problems.

PROMs highlighted a high level of acceptance and satisfaction regarding the different orthodontic systems. The perfect compliance for wearing intermaxillary elastics observed in these present cases could be related to the rapid orthodontic treatment, which involves a 24 hours/day patient implication only on a short term.

Finally, the extrusion of the posterior teeth was preferred to the intrusion of the anterior teeth because the latter is considered one of the most difficult movements to perform.[34] To ensure a safe orthodontic movement of intrusion, the use of additional mini-screws is necessary to provide fixed anchorage and avoid parasitic movements. The alveolar bone remodeling after maxillary incisor intrusion and retraction is unpredictable[35] and Han et al[36] demonstrated that intrusive forces significantly increase the percentage of root resorption compared to extrusion forces.[12]

4 | CONCLUSIONS

The ortho-pros collaboration associated to new CAD-CAM material development, such as hybrid ceramics (PICNs), offers the possibility of simplifying localized tooth wear treatment and performing minimally invasive (no-prep) restorations. Compared with the Dahl concept, the orthodontic assisted technique is more efficient and more predictable in terms of treatment duration. Partial orthodontic treatment accelerates posterior tooth extrusion and also allows the prediction and management of proper occlusal contacts. It was particularly well accepted by the patients and should be more often envisaged. In that view, it is important to obtain appropriate patient informed consent explaining the orthodontic extrusion technique simplicity, rapidity (~2 months if simple vertical open-bite closure), and lack of associated esthetic prejudice compared to common orthodontic treatments, compliance with intraoral elastic wear being a key success of the treatment. PICNs exhibited several advantages compared to ceramics and direct composite materials, and within the limitations of the presented cases, CAD-CAM palatal veneers and "envelope" restorations (no-prep partial-coverage restorations, restoring palatal and buccal surfaces of the anterior teeth, without recovering proximal surfaces) were shown to behave remarkably well in terms of mechanical resistance and esthetic results, even in the buccal area. Finally, PROMs indicate that the development of minimally invasive strategies is greatly important from the patient's point of view and that the present approach provided full satisfaction (mean score of 10 of 10) in terms of esthetics and function. If the presented preliminary results of these four pilot cases are promising, there is now a need to develop clinical research with this protocol and study future generations of experimental PICN materials, particularly to reduce minor chippings of thin posterior table tops.

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DISCLOSURE OF INTERESTS

Amélie Mainjot has a common life situation with the founder of the company Majeb, which participates in the development of PICN biomaterials.

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