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CLINICAL ARTICLE

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Minimally invasive prosthodontics using the concept of prosthetically guided orthodontics

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Abstract

Objective: This case report aims to present how digital technology can be employed to plan the orthodontic movement of teeth into their final positions for prosthodontic rehabilitation. An interdisciplinary approach to treatment planning and the result of prosthodontic treatment involves the cooperation of an orthodontist and a prosthodontist. When planned to achieve optimal results for a minimally invasive and functional prosthodontic treatment, orthodontic pretreatment provides superior esthetic results and favorable long-term success.

Clinical Considerations: The orthodontic movements of the teeth were planned so that the prosthodontist could reconstruct an optimally functional and esthetic occlusion while preserving the hard dental tissues. The orthodontic pretreatment minimized the need to prepare the teeth, avoiding any mucogingival surgery to improve the gingival architecture.

Conclusions: In complex clinical cases, it is essential to evaluate the advantages of an orthodontic pretreatment before starting a prosthodontic treatment. This pretreatment can help preserve dental tissues, reduce or eliminate the need for surgical intervention, and achieve long-term stability and esthetic results.

Clinical Significance: This case clearly shows the benefits of orthodontic pretreatment for prosthodontic outcomes. With modern digital tools, such an orthodontic pretreatment should become standard clinical practice when planning a complex clinical case.

KEYWORDS

case report, ceramic veneers, esthetic prosthodontic rehabilitation, minimally invasive dentistry, prosthetically guided orthodontics

1 | INTRODUCTION

Rapid progress in digital technologies and new materials has been a characteristic of dentistry in recent years. Prosthodontic treatments have shifted toward minimally invasive procedures, achieving a natural

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and esthetic appearance for the restored teeth.[1] Patients often desire a high-quality esthetic outcome while expecting minimal interventions in the hard dental tissues, leading to more conservative prosthodontic treatment.[2] The preparation of teeth for full crowns is increasingly being replaced by direct or indirect additive clinical procedures using composites or various ceramics.

The basis of any esthetic prosthodontic treatment is proper planning, in which we, among biological and mechanical factors, also comply with the objective criteria for oral esthetics.[3,4]

Available digital technologies enable a modern approach to planning and visualizing the final appearance of the prosthodontic treatment.[5] Furthermore, new digital technologies in orthodontics allow a computer simulation of the teeth's movements and a visualization of the final treatment results for both the clinician and the patient. An important innovation in orthodontics was the emergence of computer-designed clear aligners for teeth movements, which have clinically acceptable accuracy and are welcomed by patients due to the aligners' transparency.[6–8] When an orthodontic treatment is performed on adult patients, there is usually an increased need for interdisciplinary collaboration since these patients often present with comorbidities requiring the expertise of periodontists, endodontists, oral surgeons, and prosthodontists.

Interdisciplinary collaboration between an orthodontist and a prosthodontist is often essential because the combined action of both specialties can result in a more functional and esthetic treatment.[9] An orthodontic, preprosthetic treatment with planned and programmed tooth movement often reduces the need for extensive preparation of the teeth, thus enabling the minimal invasiveness of the final prosthodontic treatment and a more biologically oriented approach, which further results in a more natural appearance of the treatment's outcome.[10] This form of interdisciplinary collaboration is becoming increasingly popular, resulting in the development of the concept of prosthetically guided orthodontics (known as the PGO concept).[11,12] Before the digital tools for orthodontic and prosthodontic planning were developed, PGO was a very arduous procedure, demanding a lot of prosthodontic knowledge from the orthodontist, regardless of any close teamwork with the prosthodontist to visualize the required teeth movements in order to secure enough space and the proper inclination of the teeth in providing the optimal final prosthodontic outcome.

With this article, we would like to emphasize the increasing importance of involving an orthodontic pretreatment in prosthodontic rehabilitation. In the case presented, the orthodontic treatment was prosthetically guided by measurements and calculations of the required widths for modifications to a future prosthetic restoration. Nowadays, this arduous procedure is facilitated by digital orthodontic and prosthodontic planning development.

As shown in Figure 1, independent of the system used, the stereolithography (STL) file from the final orthodontic treatment plan can be extracted and implemented in any prosthodontic planning program, where virtual mock-ups can be produced and assessed by the prosthodontist, the orthodontist, and the patient, leading to less time-consuming planning. This new digital tool could make the PGO concept relevant in every case of orthodontic planning where a prosthodontic treatment is required.

The purpose of presenting this case is to show the benefits and demonstrate a procedure that might encourage prosthodontists to consider an orthodontic pretreatment and more orthodontists to plan an orthodontic treatment with the early involvement of a prosthodontist in complex clinical cases. Including an orthodontic pretreatment in prosthodontic planning would ultimately allow the patient to make an informed decision, considering whether their time and financial resources permit an orthodontic pretreatment. Orthodontic involvement should become a self-evident consideration in prosthodontic treatment planning, as are endodontics, periodontology, and oral surgery.

2 | CASE PRESENTATION

A 43-year-old patient expressed the desire for an esthetic transformation of his teeth and smile (Figure 2). His main complaints were unkempt look of his teeth, the central diastema, and gingival exposure during smile. Furthermore, he complained about frequent inflammations in the lip corners.

The clinical examination revealed initial secondary caries present on the right first and second lower molars and gingival inflammation in the area of the fixed dental prosthesis (FDP) on the left side of the maxilla (Figure 4F). Radiological examination showed a skeletal Class I pattern, skeletal deep bite, slight hypo-divergent jaw bases, retroinclined upper incisors, and proclined lower incisors (Figure 3A). Secondary caries detected clinically on molars was confirmed by analysis of x-ray picture (Figure 3B).

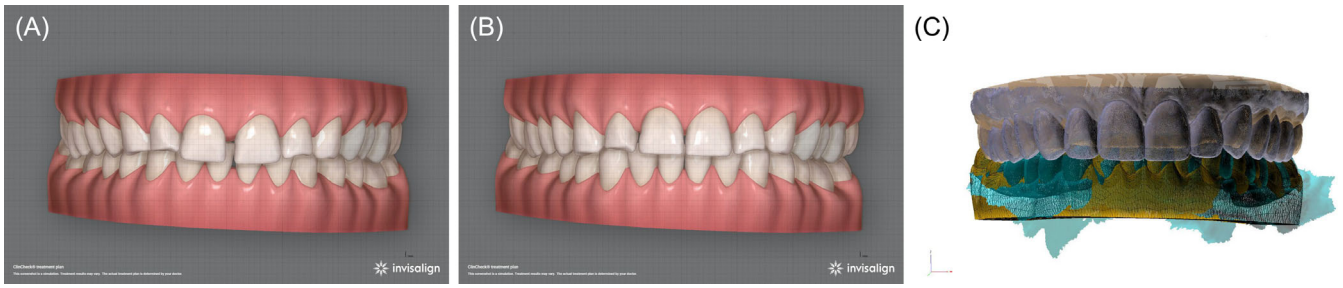

FIGURE 1 An STL file of a final orthodontic treatment plan can be extracted and implemented in a prosthodontic planning program. (A) Initial scan, (B) planned tooth movements, and (C) superposition of STL files. For demonstration purposes, a posttreatment scan (Trios 3, 3Shape) was superposed to the final orthodontic treatment plan (Invisalign®, Align Technology).

FIGURE 2 Extraoral photographs of the patient. (A) The inflammation of the lip corners is visible. (B) His main complaints were central diastema, worn teeth, and gingival display during a smile.

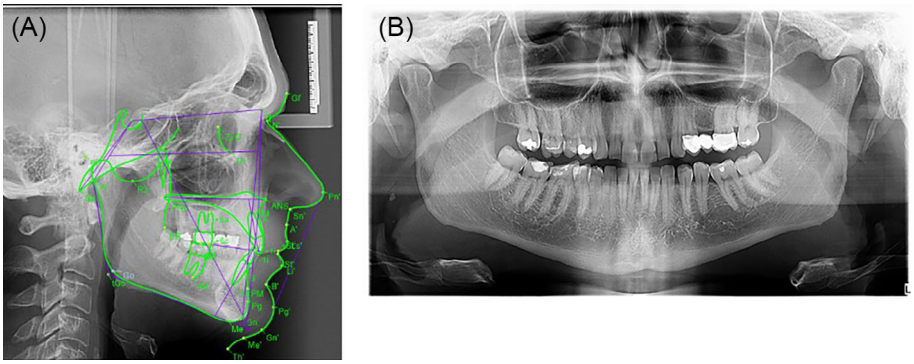

FIGURE 3 (A) Lateral cephalometric and (B) panoramic radiographs before treatment.

Extraoral and intraoral photographs were taken following a standard protocol for complete documentation. The esthetic-functional analysis revealed numerous problems, listed as follows (Figures 2–5):

- central upper diastema (Figures 2B and 4);
- increased gingiva exposure during a smile (Figures 2B and 4A);
- deep bite (overbite 4.5 mm) (Figure 4B,F);
- retroclined upper incisors (Figure 3A);
- generalized tooth wear (Basic Erosive Wear Examination [BEWE] score 2 for upper anterior teeth, others obtained score 1) (Figure 4)[13];
- Angle Class I on the right side, Angle Class II on the left side (Figure 4E,G);
- nonsymmetrical levels of gingival margins of the upper teeth (Figures 4 and 5);
- increased curve of Spee depth on the left side (Figure 5);
- spacings and rotations in the lower left posterior area (Figure 4D,F);
- asymmetrical transversal arch width (the right side of the dental arches is wider than the left side) (Figure 5);
- axial tipping of the mandibular incisors and lower midline to the left (Figure 5);
- occlusal plane canting (Figure 5);
- overeruption of upper molars and premolars (Figure 5);
- initial secondary caries on the first and second right lower molars (Figure 3B);
- gingivitis at the FDP on the first upper left premolar and first molar (Figure 4C,F);
- inflammation of the lip corners (Cheilitis angularis) (Figure 2A);

The need for an orthodontic pretreatment was recognized as necessary to symmetrize the widths of the dental arches and the course of the gingiva in the upper anterior region. Furthermore, intruding the over-erupted teeth would enable a less-invasive preparation in securing the occlusal plane. Retrusion, spacing, and rotation of teeth could be addressed, and, most significantly, orthodontic treatment could enable redistribution of the spacings in the upper jaw in a planned way to ensure a proper width/length ratio for the planned prosthetic crown modifications.

FIGURE 4 Intraoral pictures. (A) The patient displayed a gingiva with a smile. (B, F) In the upper arch, an fixed dental prosthesis was present with gingival inflammation. (C, F) In the lower arch, premolars were rotated, and spacings were in the left posterior area. (A, B, C, E, F) A central diastema was present in the upper jaw, with additional spacing in both jaws. (E) The overbite was 4.5 mm. (D) Angle Class I was on the right side, and (F) Class II was on the left.

FIGURE 5 Analysis of esthetic problems: green lines mark the asymmetry of arch widths; black lines mark tilting of the lower incisors; red lines mark a nonsymmetrical gingival contour; the blue line marks a tilted occlusal plane, and yellow lines mark overeruption of the upper posterior teeth.

The position of the maxillary central incisors relative to the upper lip at rest and during a smile was assessed. The teeth display was insufficient, so the position of the incisal edges was to be elongated by 2 mm. Since there was tooth wear, the width/length ratio was not appropriate, and also, the patient complained of too much gingival display during a smile, a decision was made to orthodontically intrude the central incisors and the left-lateral incisor by 1 mm to improve the level and symmetry of the gingival display. The incisal edge position and the proper width/length ratio would be achieved later using ceramic veneers. The planned position of the gingival margins of the maxillary central incisors served as a vertical reference point for the orthodontic alignment of the gingival margins of other upper anterior teeth. The establishment of the future incisal edge position of the maxillary central incisors would direct the movements of all the posterior upper teeth to be aligned in the correct and acceptable sagittal occlusal plane. The future dimensions of the esthetic ceramic veneers were determined through calculations of the proper width/length ratio of the anterior teeth. After subtracting the actual widths of the teeth, the necessary space between them was calculated (Figure 6).

3 | ORTHODONTIC TREATMENT

The goals of the orthodontic treatment were to redistribute the spacings in the upper arch according to prosthodontic requirements (Figure 6), align the gingival margins of the upper anterior teeth with an intrusion, correct the torque of the upper incisors, derotate the lower left premolars, mesialize the lower left posterior teeth to close the spacings in the lower arch, apply proper torque to the maxillary and mandibular posterior teeth, apply proper axial inclination to the lower incisors, achieve better arch symmetry, and improve the canting of the occlusal plane. Due to the presence of an FDP, the limited treatment time, and the age limitations of the patient, the Class-II malocclusion was not addressed. A clear aligner therapy with the Invisalign® system (Align Technology, Santa Clara, USA) was chosen for the planned orthodontic movements.

The ClinCheck Pro 6.0 software (Align Technology, Santa Clara, USA) was used to simulate the teeth movements and as a tool for communication with the prosthodontist and the patient to confirm the treatment goals. An initial set of 39 maxillary aligners and 58 mandibular aligners was required for the programmed orthodontic movements. Each aligner was worn for 10 days, resulting in a total treatment time of 19 months.

The posttreatment results revealed that all the orthodontic treatment goals were achieved, except for correcting the torque of the upper incisors (Figure 7). Only a few clinical problems remained:

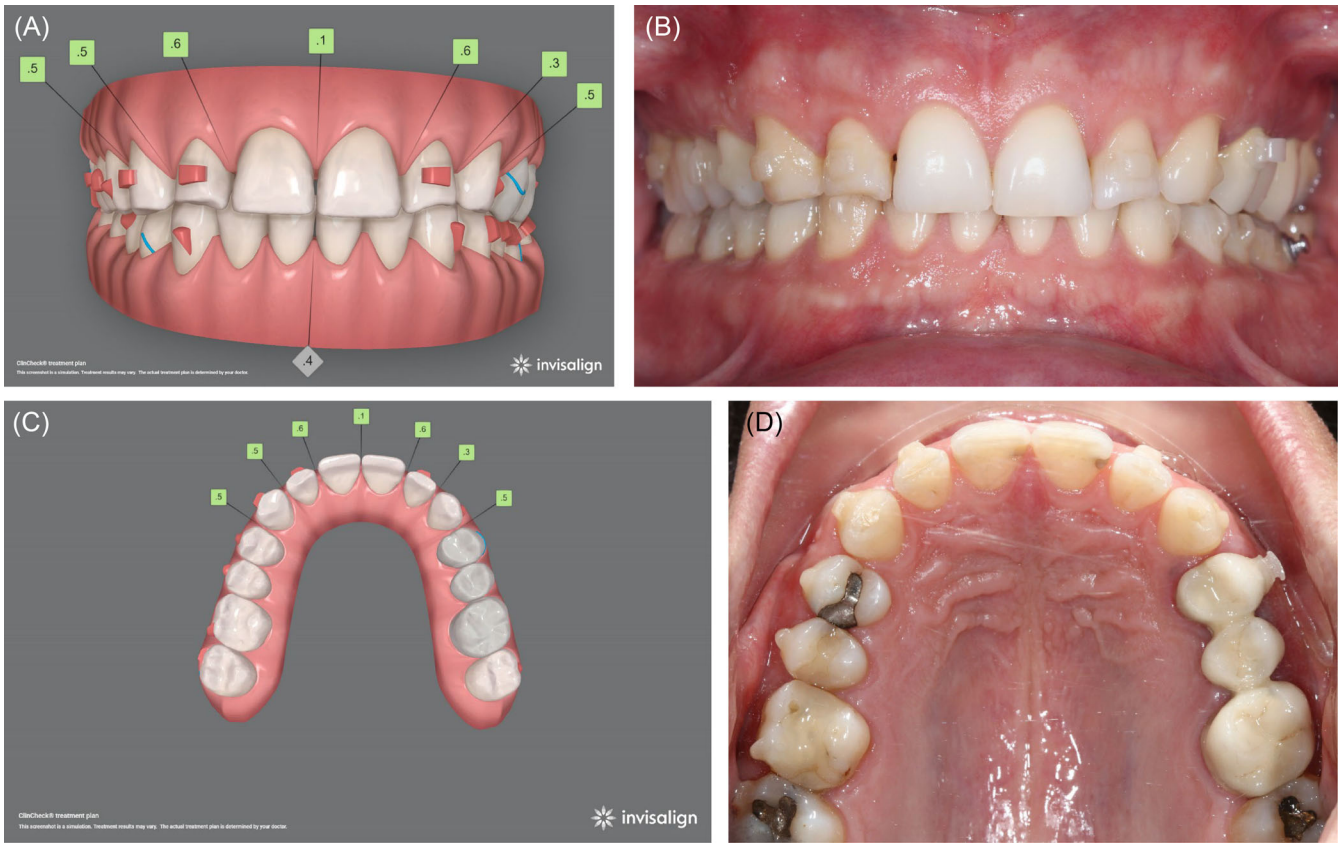

FIGURE 6 An orthodontic treatment simulation shows a strategic redistribution of space in frontal (A) and occlusal (C) views for planned porcelain veneers. Frontal (B) and occlusal (D) views after completion of orthodontic treatment.

FIGURE 7 Completion of orthodontic pretreatment. (A) There was less gingival display during a smile, while light inflammation of the lip corners was still present. (B) Analysis of problems after orthodontic pretreatment: green lines mark the achieved symmetry of arch widths, black lines mark the improved tilting of the lower incisors, red lines show symmetrical gingival contour, blue line shows canted occlusal plane, and yellow line shows over-contouring of the upper premolar in an fixed dental prosthesis.

- generalized tooth wear (BEWE score 2 for upper anterior teeth, others obtained score 1) (Figure 7B)[13];
- oblique course of the occlusal plane in the posterior area (viewed from the disto-buccal [DB] cusps of the lower second molars) (Figure 7B);
- light inflammation of the lip corners (Cheilitis angularis) (Figure 7A);
- gingivitis at the FDP in the left maxilla (Figure 7B).

4 | PROSTHODONTIC TREATMENT

The goals of the prosthodontic treatment were to establish a new vertical dimension of occlusion (VDO), improve esthetics, and establish anterior guidance and stable intercuspal occlusion.

An increase of the VDO by 2 mm was intended in the planned prosthodontic treatment. This increase provided sufficient space in

the anterior segment to establish the anatomical harmony of the teeth dimensions and achieve stable anterior guidance. Additionally, it aimed to enhance the display of the teeth in the rest position and treat the still occasionally present inflammation of the lip corners.[14,15]

The prosthodontic plan included the reconstruction of the anterior teeth with ceramic veneers, including the first upper and lower premolars, except for the first upper left premolar. Additionally, replacing an inadequate FDP in the maxilla with an FDP made from monolithic zirconia was planned. The rest of the posterior teeth were reconstructed with direct and indirect composite restorations. After a retention time of 2 months, the treatment was planned in five consecutive prosthodontic appointments to maintain the orthodontic results without the need for provisional retention splints.

According to the "three-step technique,"[16] in the first appointment, a planned preliminary reconstruction of the anterior region, including the first premolars, was evaluated through a mock-up (3M™ Protemp™ 4, 3 M ESPE, Seefeld, Germany) in both jaws. Mock-up enabled an assessment of the esthetic appearance of the incisal line, the occlusal plane, the anterior guidance, and the upper anterior teeth proportions. The mock-up was slightly changed in the mouth and returned via impressions and photographs to the laboratory to modify the wax-up (Figure 8).

In the second appointment, the patient accepted a modified mock-up. At the same appointment, the first upper right molar and second premolar, as well as the first lower left molar and the first and second right lower molars, were prepared for indirect composite restorations, and the existing FDP in the left maxilla was removed for a planned indirect provisional FDP (Figure 9). The mock-up was left on the teeth to provide guidance for the preparations of the posterior teeth. It was scanned (Trios 3, 3Shape, Copenhagen, Denmark) along with the prepared teeth to assist the laboratory in producing the posterior onlays and a provisional FDP in accordance with the planned dimensions and the emergence profile of the anterior teeth. Additionally, the mock-up helped to establish the incisal line and the occlusal plane. Furthermore, it served as an anterior jig for the maxillomandibular relationship record at an increased VDO (Figure 9).

The third appointment began with the insertion of the mock-up on the anterior teeth in both jaws. This mock-up served as an evaluation tool to ensure adequate dimensions of the onlays and the provisional prosthesis. Additionally, it served as a guide for the direct free-hand composite build-ups on the second maxillary molars, second mandibular premolars, and left lower second molar, using microfilled composite resins (Estelite Asteria A1B, A2B, WE, and BL, Tokuyama, Tokyo, Japan).

FIGURE 8 Mock-up for both jaws, including the first premolars, allowed for esthetic and functional analyses. (A) The initial mock-up was slightly changed, and (B) was retried.

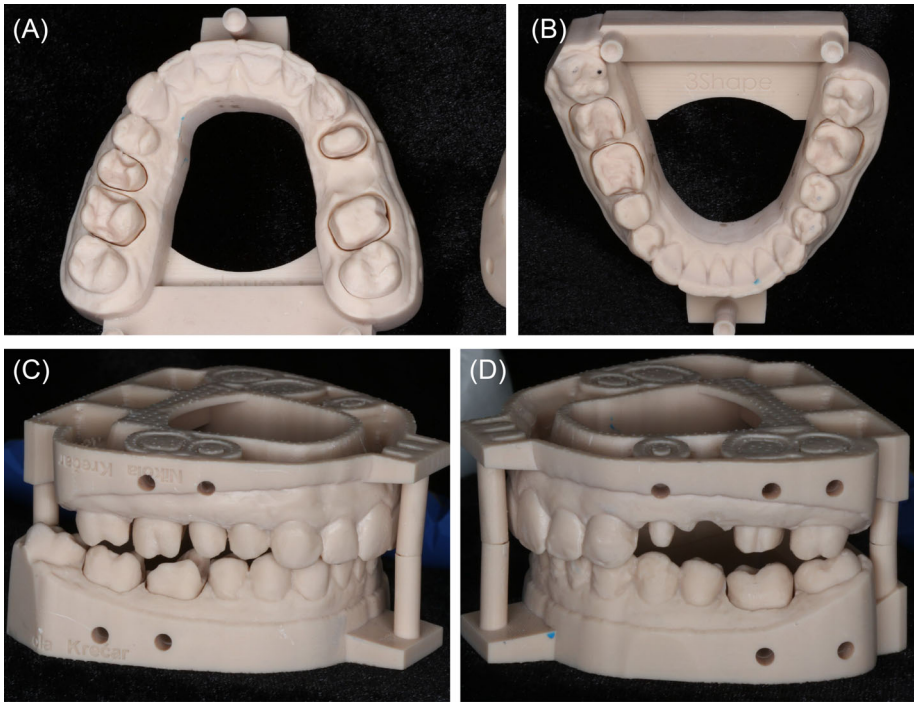

FIGURE 9 Preparation of the posterior teeth. (A, B) After the mock-up was produced, the first upper right molar and second premolar, the first lower left molar, and the first and second right lower molars were prepared for indirect composite onlays. The fixed dental prosthesis (FDP) on the first upper left premolar and first molar was removed, and the teeth were scanned for a provisional FDP. (C, D) The mock-up was scanned along the preparations to help the laboratory determine the dimensions and emergence profile to establish the incisal line and occlusal plane, and it served as an anterior jig for the maxillomandibular relationship record at an increased vertical dimension of occlusion.

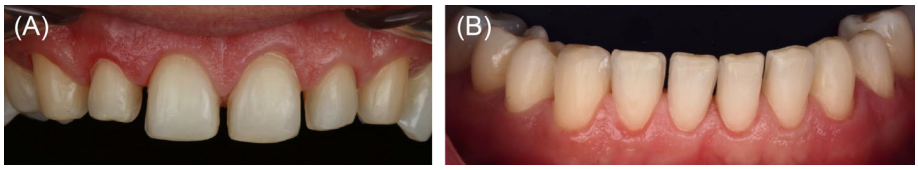

FIGURE 10 Strategically positioned spacings enabled minimally invasive veneer preparation in both (A) upper and (B) lower jaws.

FIGURE 11 Ceramic veneers after cementation. Upper and lower veneers were partially layered to achieve a more natural appearance.

After cementation, the last aligner used for orthodontic retention could not be applied. Therefore, preparation for veneers on the upper and lower anterior teeth and the first premolars, excluding the first upper left premolar, was carried out during the same appointment to create fixed provisional restorations for the anterior teeth, which would serve as retention. Through the mock-up, the reduction grooves (depth of 0.3 mm) were made to guide the tooth preparation to preserve as much enamel as possible (Figure 10).

The diagnostic silicone index had to be adapted to the changed posterior anatomy to help produce the fixed provisional restorations in the anterior region (3M™ Protemp™ 4, 3M ESPE, Seefeld, Germany). In the time needed for the veneers' fabrication, the retention of the posterior region was secured with just a stabile occlusion.

The veneers were manufactured so that the pressed framework (IPS e.max Press, Ivoclar, Schaan, Liechtenstein) represented two thirds of the thickness of the restorations, while the remaining buccal third was veneered (IPS e.max Ceram, Ivoclar, Schaan, Liechtenstein) to create a more natural appearance of the restorations.

No modification was needed; hence, the veneers were bonded (Choice II, Bisco, Schaumburg, USA) during the same appointment (Figure 11).

The fixed retainer was bonded in the lower arch. After establishing a healthy periodontal tissue, the provisional FDP in the upper left maxilla was removed, and the first premolar and first molar were scanned (Trios 3, 3Shape, Copenhagen, Denmark).

The final prosthodontic appointment was the cementation of the monolithic FDP made of y-TZP (Luxor Z True Nature, Bredent, Senden, Germany) in the upper left maxilla (Panavia V5, Kuraray, Osaka, Japan) (Figures 12 and 13). The impressions were taken, and the retention aligners were produced in the office.

5 | DISCUSSION

There are many situations where an orthodontic pretreatment can be beneficial to a patient in need of prosthodontics.[17–22] The benefits of orthodontic involvement in the presented case and the problems that would arise if prosthodontic rehabilitation was performed without orthodontic pretreatment are outlined in Table 1 and Figure 14.

If the asymmetry of the dental arches was to be addressed solely with prosthodontics by over-contouring the buccal emergence profiles of the left posterior teeth, the asymmetry could not be fully resolved in this manner. The surplus of available space in the central diastema in the upper jaw could not be appropriately redistributed among the anterior teeth, consequently leading to an improper width/length ratio of the anterior teeth. Alternatively, the central incisors should have been prepared distally into the dentin to provide enough space for the lateral incisors. Instead of using an orthodontic intrusion, a surgical treatment to correct the gingival asymmetry would result in dentin exposure in the cervical areas of the left anterior teeth and require a prosthodontist to work with less-stable adhesion to the dentin. Additionally, if an orthodontic pretreatment was not carried out, the erupted upper posterior teeth would need to be prepared more invasively (e.g., for full crowns) to achieve the proper occlusal plane.

Clear aligners have many advantages[23,24] but are less effective for specific orthodontic movements.[6,23,25–27] The knowledge, skills, and expertise of an orthodontist are extremely important to overcome the limitations of aligners. Considering our patient's strong motivation for esthetics, the desire for a shorter treatment time, and the planned prosthetic treatment, we decided to use a clear aligner system for his treatment.

In this case, all the limitations of the clear aligner treatment were overcome, and the orthodontic treatment goals were achieved after the initial set of aligners, except for the correction of the torque of the upper incisors. The latter was anticipated, given that studies have shown that correcting the torque of the upper incisors with a clear aligner system is successful in approximately 50% of cases.[25] This could be improved with an orthodontic refinement treatment.[25] Nevertheless, the decision to start the prosthetic treatment was made as ceramic veneers had been planned, and a slight retroinclination of the incisors is beneficial for preserving as much enamel as possible.

Regarding the treatment options and the material selection, an effort was made to be as conservative as possible while also using modern ceramic systems and composite resin materials. The treatment option of direct and indirect composites was chosen to restore the posterior teeth in the upper and lower jaws. Since some posterior teeth needed only minor modifications of the occlusal morphology, we considered composite material using only an additive approach as the best choice, according to our clinical experience and the

FIGURE 12 Recall after 1 year. Improvement of teeth display for (A) rest and (B) smile esthetics. (C, D) Occlusal views show the closure of the spacings by ceramic veneers. (G) Improved width/length ratio of anterior teeth. (E, F) Composite direct and indirect restorations and biological incorporation of y-TZP fixed dental prosthesis provide a natural appearance of teeth. (F) Class-II malocclusion on the left side was partially improved.

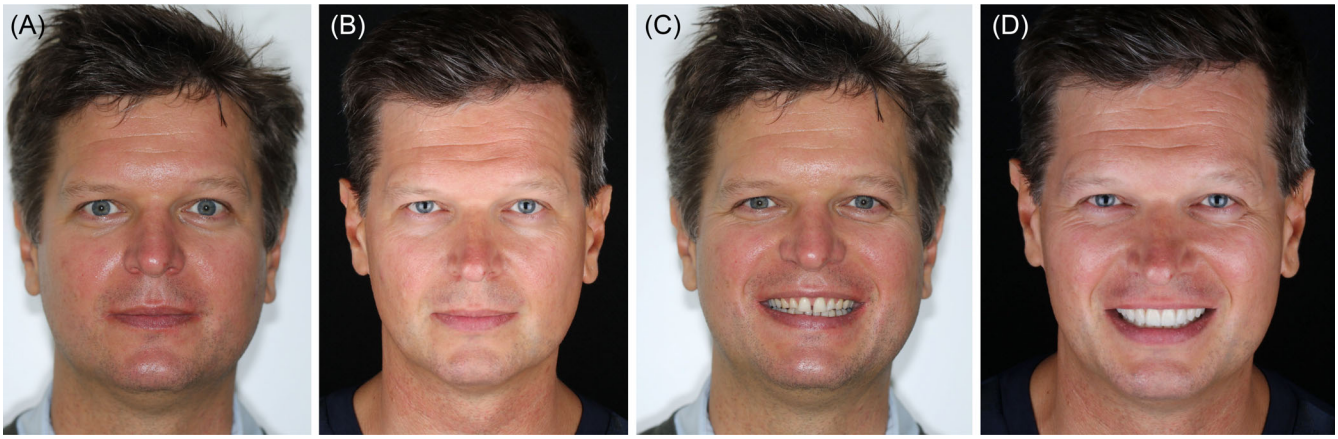

FIGURE 13 Comparison of the extraoral pictures. Pictures at rest (A) before and (B) after; and during a smile (C) before and (D) after.

literature.[28–30] A recent in vitro study showed outstanding results in ultra-thin, occlusal ceramic veneers on the molars bonded to enamel.[31] However, further studies in which ceramic veneers are bonded to a combination of enamel, dentin, and composite, thus mimicking real-life situations, would be beneficial. The larger defects of the posterior teeth were restored by indirect composite onlay restorations. The composite material generally allows for safe occlusal adjustments and easy repairs due to secondary caries. In contrast, ceramic table tops that represent an alternative would, in this case, require the removal of the already-existing restoration and exchange for a new

TABLE 1 A comparison of prosthodontic treatment results without and with the help of orthodontic pretreatment.

Prosthodontic treatment	Arch symmetry	Width/length ratio of anterior teeth	Preparation of posterior teeth	Gingival symmetry
Without orthodontic pretreatment	Asymmetry of arch widths would remain	More invasive teeth preparation with dentine exposure or improper width/length ratio of anterior teeth	A need for more invasive preparation of overerupted teeth	A need for mucogingival surgery for the achievement of gingival symmetry
With orthodontic pretreatment	Symmetry of arch widths could be achieved	The ideal width/length ratio of anterior teeth could be achieved	Even and minimally invasive teeth preparation was enabled	White–red esthetics can be achieved by orthodontic intrusion of teeth

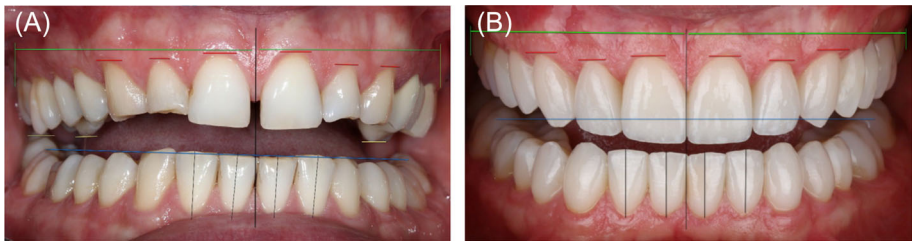

FIGURE 14 Comparison of the problem analysis (A) before and (B) after the treatment. Green lines show the asymmetry of the jaw widths; black lines mark the axis of the lower incisors; red lines show the gingival contour; blue line shows the position of the occlusal plane, and yellow lines show overeruption of the upper posterior teeth.

one. Because of the inconclusive long-term results of rehabilitation with composite and ceramic restorations in the posterior region, the decision for the best treatment option lies in the clinical experience of the prosthodontist.[32–34]

The treatment option of direct or indirect composite restorations in the esthetic area was not chosen due to the long-term esthetic instability of composite materials.[35] To fulfill the patient's esthetic demands, layered lithium disilicate veneers were used, although monolithic porcelain restorations with better mechanical properties could be better suited in regard to the patient's history of bruxism.[36,37] For the upper left lateral 3-unit FDP, a y-TZP monolithic FDP was chosen due to its better esthetic appearance and comparable survival rate to porcelain-fused-to-metal FDP.[38,39] The superior esthetics of a lithium disilicate ceramic in the posterior region were not chosen due to the unreliable long-term clinical performance.[40]

In prosthodontics, the safety of increasing the VDO,[14] together with modern adhesive systems and techniques, contributes to a more biologically oriented treatment, enabling an additive prosthodontic treatment, resulting in the building up of missing tooth substance.[41] From a biological perspective, such an additive prosthodontic treatment primarily ensures fewer biological complications while maintaining favorable clinical success and the survival of such procedures.[38,42] When there is a need to increase the VDO, the facial esthetics, the space for restorative material, and the proper occlusal relationship should be considered.[43]

Retention of the results is a crucial factor in the course of prosthodontic treatment for an orthodontically prepared patient. Prosthodontic clinical steps need to be planned so that the treatment is rapid. The patient should be stabilized with provisional retention splints or fixed provisional restorations between the prosthetic appointments.

A drawback of this kind of interdisciplinary collaboration is the financial and time component. To motivate patients for the treatment, it is necessary to explain the treatment procedures and goals and show them a simulation of the final result.

6 | CONCLUSION

Based on the presented clinical case, interdisciplinary collaboration between prosthodontics and orthodontics proved superior for achieving optimal results. The patient's treatment was successful in terms of minimal invasiveness, improved oral and facial esthetics, better function of the stomatognathic system, and the expected long-term stability of the restorations.

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CONFLICT OF INTEREST STATEMENT

The authors do not have any financial interest in the companies whose materials are included in this article. We declare that none of the images used in this article have been manipulated in any way except for brightness, contrast, or color balance adjustments. Images have been cropped or rotated to suit their purpose.

DATA AVAILABILITY STATEMENT

Research data not shared.

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