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CLINICAL ARTICLE

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Fully digital workflow of occlusal reconstruction treatment in a patient with congenital dentition defects

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Abstract

Objective: Occlusal reconstruction is a critical intervention for patients with dental hard tissue defects, temporomandibular joint (TMJ) disorders, and jaw position abnormalities. Clinical efficiency and outcomes of these procedures have improved with advances in digital technologies. This case report aims to illustrate a comprehensive digital workflow for occlusal reconstruction in a patient with congenital dentition defects, emphasizing the application of digital technologies to enhance treatment outcomes.

Clinical considerations: A 28-year-old woman with previously installed porcelain-fused-to-metal bridge restorations presented with a fractured prosthesis and TMJ symptoms. A multidisciplinary approach was adopted involving the use of digital facebow, intraoral scanners, digital smile design, and CAD/CAM technologies. The process included the extraction of defective restorations, temporary restorations to refine jaw position, and final permanent restorations. The digital workflow facilitated precise diagnostics and treatment, culminating in the successful installation of permanent restorations. Regular follow-ups at one- and three-months post-treatment confirmed stable occlusal function and high patient satisfaction.

Conclusions: This case report showcases the potential of multiple digital technologies to streamline complex dental treatments and achieve high-quality results.

Clinical significance: The integration of digital technologies in occlusal reconstruction treatments offers significant benefits in terms of precision, patient comfort, and esthetic outcomes.

KEYWORDS

occlusal reconstruction, digital dentistry, congenital tooth agenesis, dentition defect, digital facebow

1 | INTRODUCTION

Occlusal reconstruction refers to a treatment approach aimed at adjusting occlusion in patients with abnormal occlusion, for example, malocclusion, upper and lower jaw disorders, and temporomandibular disorders (TMD).[1] Clinically, the most common need for occlusal reconstruction involves excessive loss of dental hard tissues due to factors such as congenital abnormal dental development, oral

Abbreviations: CAD/CAM, computer-aided design and computer-aided manufacturing; CBCT, cone beam CT; DSD, digital smile design; MRP, modified reference position; OVD, occlusal vertical distance; PFM, porcelain-fused-to-metal; TMD, temporomandibular joint disorders; TMJ, temporomandibular joint.

parafunctional activities, and acid erosion, among others. These conditions severely affect both the esthetics and functionality of the oral and maxillofacial system, which underscores the importance of occlusal reconstruction procedures in restoring oral health and balance.[2]

In recent years, computer-aided design and computer-aided manufacturing (CAD/CAM) technology have gained popularity in the field of restorative dentistry.[3] Gradually, the advancement of digital technology has led to an upsurge in digital assistive devices that can be utilized in the course of occlusal reconstruction,[4] including digital intraoral and facial scanning, digital facebow, and digital smile design (DSD) technology. This trend is attributable to the great benefits, which these technologies offer.[5] The utilization of digital technology allows for precise acquisition and delivery of occlusal information, improving the accuracy of restoration design and fabrication. This, in turn, enhances treatment efficiency and patient satisfaction,[6–10] while also increasing clinical precision and predictability, especially in complex restorative cases.

This report details a clinical case involving a comprehensive occlusal reconstruction procedure that merged conventional techniques with advanced digital process. We employed a multifaceted approach in addressing the complex challenges posed by congenital tooth agenesis, malocclusion, associated esthetic concerns, and temporomandibular joint (TMJ) disorders. This approach involved implementing a digital smile protocol, utilizing CAD/CAM zirconia fixed bridges and gingival-colored porcelain, and incorporating precision attachments.

2 | CLINICAL REPORT

A 28-year-old woman presented to the Prosthodontics Department with defects in her dentition. The patient had a history of "congenital tooth agenesis" for which she received a full-mouth porcelain-fused-to-metal (PFM) bridge prosthesis at a foreign clinic 10 years prior. The prosthesis exhibited metal exposure at several sites and a fracture in the lower left posterior area resulting in compromised oral function and esthetics. The patient expressed a desire for a full-mouth prosthesis replacement upon presentation at our hospital. She complained of a history of TMJ clicking for several years but denied any history of systemic diseases, smoking or bruxism. Female relatives with similar symptoms of missing teeth had been present in the family.

Clinical examination revealed that the patient had a mild bilateral facial asymmetry, with the left mandibular body being slightly larger than the right, the lower 1/3 of the face being slightly shorter in height than other thirds, and a generally normal lateral appearance. No tenderness was observed in the bilateral TMJ and masticatory muscle areas, but clicking sounds could be heard frequently in the joint area during the examination. Oral hygiene was notably compromised throughout the entire mouth. The PFM bridge prostheses from teeth #16 to #11, #21 to #26, and #34 to #46 exhibited marginal misfit and chipping at multiple sites. Additionally, mild gingival erythema was observed throughout the mouth (Figures 1 and 2). Radiological examinations showed marked vertical resorption of the alveolar bone in the edentulous areas of teeth from #15 to #17, #35 to #37, and #45 to #47, coupled with bilaterally asymmetrical position of the TMJ and a slight posterior displacement of the right condyle. Fortunately, the bone cortex of the condyles remained intact bilaterally (Figure 3).

The clinical diagnosis included congenital tooth agenesis, malocclusion, defective restorations, chronic apical periodontitis in teeth #11, #21, and #24, as well as chronic periodontitis throughout the mouth. Additionally, the patient exhibited TMD with joint clicking as the main manifestation. Based on the diagnostic findings, it was clear that the patient required a full-arch occlusal reconstruction procedure to address these anomalies to correct the abnormal centric relation, restore the occlusal vertical distance (OVD), establish a normal occlusal relationship, and alleviate any other abnormal complicating symptoms.

The procedure used for occlusal reconstruction in patients consisted of three primary phases: the pre-restoration preparation, the temporary restoration, and the permanent restoration phase. These

FIGURE 1 Facial smiling appearance before treatment, including front and side views.

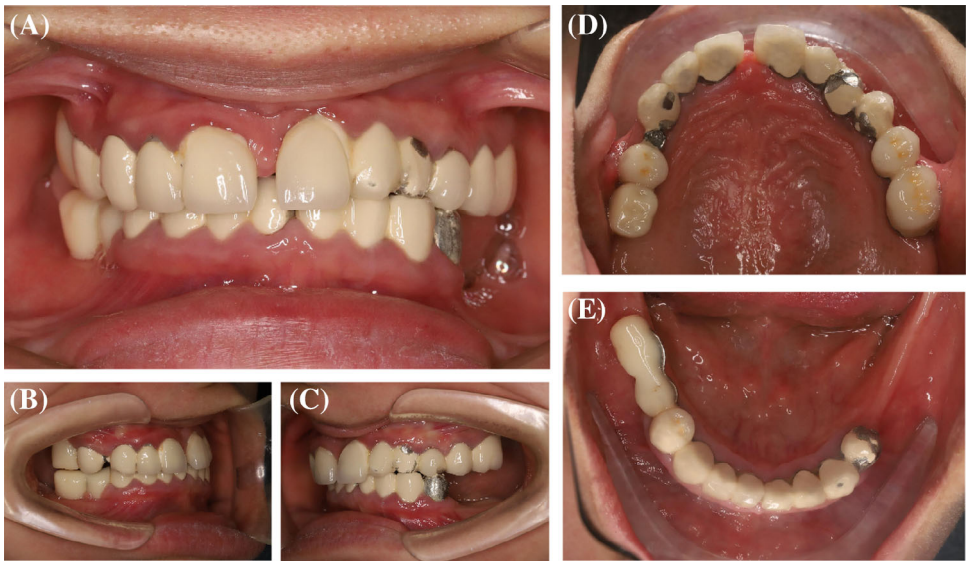

FIGURE 2 Intraoral occlusal condition before treatment, consisting of a frontal view (A), as well as lateral views from both sides (B and C), and occlusal views from both the maxillary and mandibular arches (D and E).

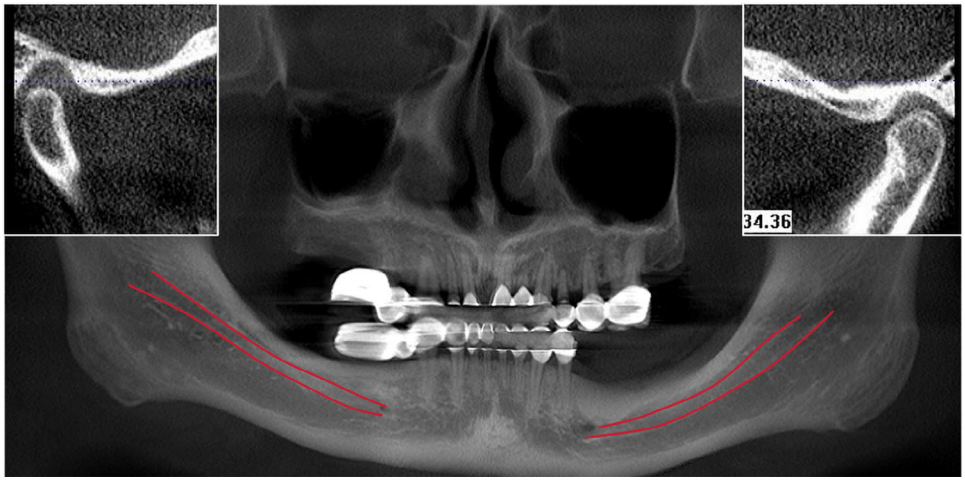

FIGURE 3 The radiological examination displays a frontal image of the patient's upper and lower jaws, with bilateral temporomandibular joint areas visible in the upper two inset boxes. The mandibular, or inferior alveolar nerve, canal is traced by the red lines.

were subdivided into five distinct stages to ensure the successful implementation of the aforementioned procedures with this patient.

The initial stage involved the preparatory phase prior to restoration, which necessitated a multidisciplinary assessment and a series of corresponding basic treatments. Maxillary and mandibular impressions were taken to record the current intraoral condition for use during the period of multidisciplinary assessment and treatment. After removing all defective prostheses, the patient's abutment teeth were exposed and assessed through both intraoral examinations and imaging techniques (Figure 4). The evaluation results revealed that teeth #22 and #24 were not clinically viable and required extraction; teeth #11, #21, and #23 were determined to be restorable and received appropriate endodontic therapy, and full-mouth periodontal systemic therapy was deemed necessary. Temporary intraoral crown restorations were fabricated using an impression-guided techniques and placed over the patient's entire arch.

After completing the treatments above, the second stage, known as the temporary repair stage, was initiated. The modified reference position (MRP) was determined by elevating the OVD and establishing the horizontal jaw position. To be specific, the OVD of the posterior region was elevated by approximately 1.5 mm using the resting jaw gap method combined with the facial profile ratio.[11] The horizontal jaw relationship was determined through bimanual palpation after deprogramming of the masticatory muscles.[12] Subsequently, once the positional relationships of the patient's maxillary and mandibular were determined, facebow transfer and articulator registration were carried out clinically. The fabrication of segmented resin provisional restorations was then finished by the dental technician (Figures 5–7). The patient's maxillary dentition was restored up to the first molar while the mandible was restored up to the second premolar, based on the position of the remaining abutment teeth in the patient's oral cavity. Additionally, there was a substantial diastema observed between the two maxillary central incisors. In order to prevent any esthetic compromise caused by oversized incisors, we designed three incisors (Figure 6). Once the restoration was in place, occlusal adjustments were performed to ensure normal occlusion, occlusal stability, and the absence of muscular or TMJ discomfort. The patient was instructed to utilize this temporary prosthesis for a duration of 5 months, during

FIGURE 4 Intraoral conditions after removal of poor restorations.

FIGURE 5 Intraoral condition after full-mouth tooth preparation.

which time regular clinical examinations and restoration adjustments were required.

During the 5-month follow-up appointment period, the patient reported a progressive reduction in the frequency of joint clicking and reported no other TMJ or muscle discomfort. However, 5 months after treatment, although much improved, it was noted that the patient's TMD symptoms had not completely resolved. Furthermore, additional occlusal and esthetic concerns were gradually being identified. Firstly, an abnormal curve of Spee was identified during the intraoral examination, which may had contributed to the incomplete resolution of the patient's joint symptoms. Additionally, the patient expressed dissatisfaction with the appearance of her maxillary anterior region and voiced concerns about the excessive length of her teeth. A series of digital techniques were then introduced to verify the accuracy of the MRP obtained through traditional methods and to achieve better functional and esthetic outcomes. A digital facebow (Zebris JMAnalyser +, Germany) was utilized to reassess the median position of the relationship and the muscle electrophysiology of the masticatory muscles (Figure 8). These results indicated that the new MRP was slightly shifted backward compared with the previous MRP. A desktop scanner (3Shape TRIOS 3, Copenhagen, Denmark) was applied to capture digital impressions of the patient's intraoral condition. Facial features were gathered by using a digital facial scanner (EinScan Pro 2X, Shining 3D, Zhejiang, China). Subsequently, the digital data were imported into Exocad (Version 1.6.4, Germany), a specialized design software, to generate a 3D virtual patient, which, together with the results from DSD (PowerPoint, Microsoft Office 2019, USA), enabled a second set of temporary restorations to be designed and fabricated (Figure 9). The restorations were placed and meticulously adjusted to ensure optimal alignment using the same

FIGURE 6 Intraoral (A) and facial (B) photographs after the first set of temporary restorations.

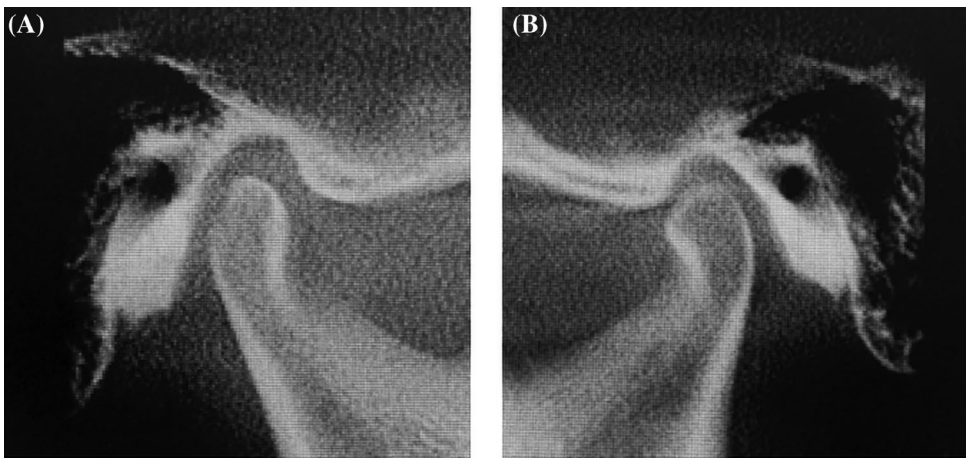

FIGURE 7 Images of the right (A) and left (B) temporomandibular joint (TMJ) located in modified reference position, showing that the condyles are located in the anterosuperior position of the TMJ fossa.

method as previously described (Figure 10). The digital facebow was applied to confirm the proper jaw position, with bilateral assessment of the TMJ accomplished through cone beam CT (CBCT) (Figure 11).

The subsequent 3 months constituted the second part of the temporary restoration stage—the occlusal adjustment phase. During this period, regular visits were scheduled to evaluate the intraoral occlusal relationship, as well as to assess the extraoral joints and masticatory muscle groups for any abnormalities. Any necessary adjustments were made accordingly. After that, the patient completely adapted to the new occlusal condition and conveyed satisfaction with the esthetic improvements, with no reports of discomfort in the bilateral TMJ or associated muscles.

Three months later, the third stage, known as the final restoration phase, was implemented. In this stage, digital technology played a crucial role. Digital technology, specifically a combination of digital facebow and intraoral scanning, was utilized to precisely document and transfer the stable jaw relationship. This was achieved by gradually removing the intraoral temporary restorations during the process (Figure 12). The collected data were integrated into 3Shape and Exocad software, allowing for the digital design and fabrication of the final restorations (Figure 13). The final restorations consisted of segmental zirconia all-ceramic bridge restorations (SHOFU Vintage ZR, Japan; UPCERA Corporation, China) for the maxillary teeth (#16 to #13, #12 to #23, and #24 to #26). Gingival-colored porcelain (SHOFU Vintage ZR, Japan) was used additionally to address soft tissue defects in the maxillary anterior region for better esthetic outcomes. Additionally, segmental PFM bridges were employed for the mandibular teeth (#34 to #31 and #41 to #44) to enhance esthetics

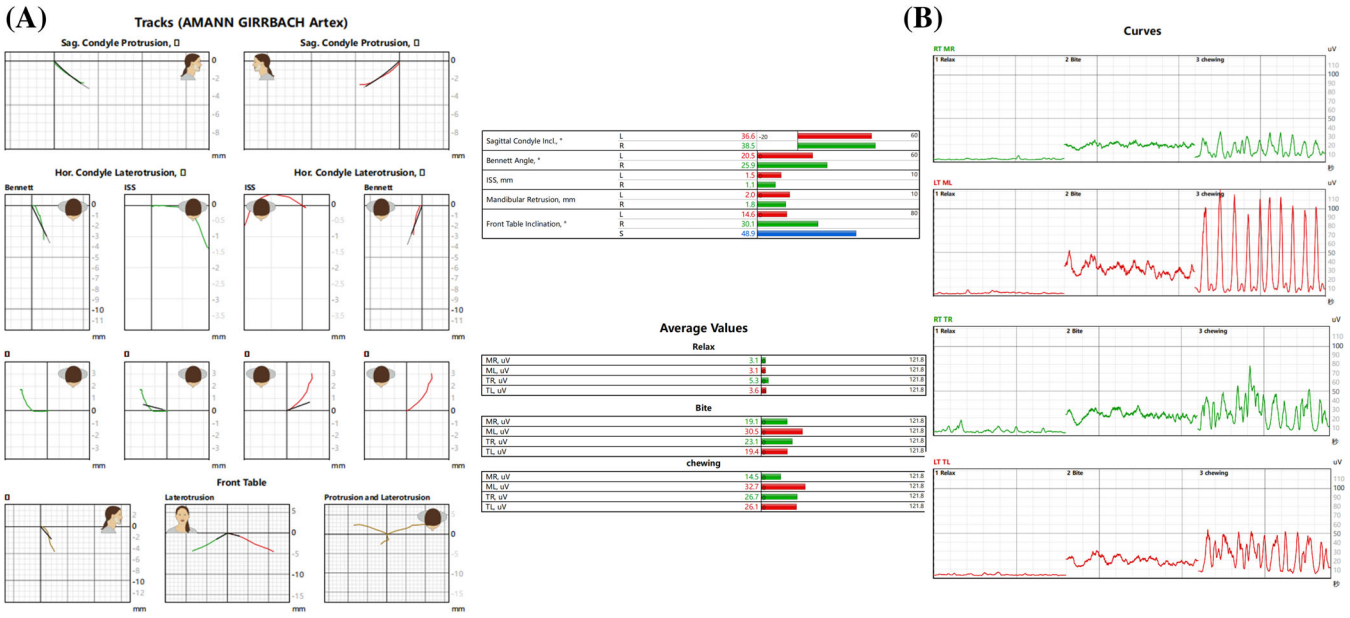

FIGURE 8 First report of the digital facebow, which consists of the functional mandibular movement tracks and related average values (A) and the electrophysiological results of the temporalis and masseter muscles (B).

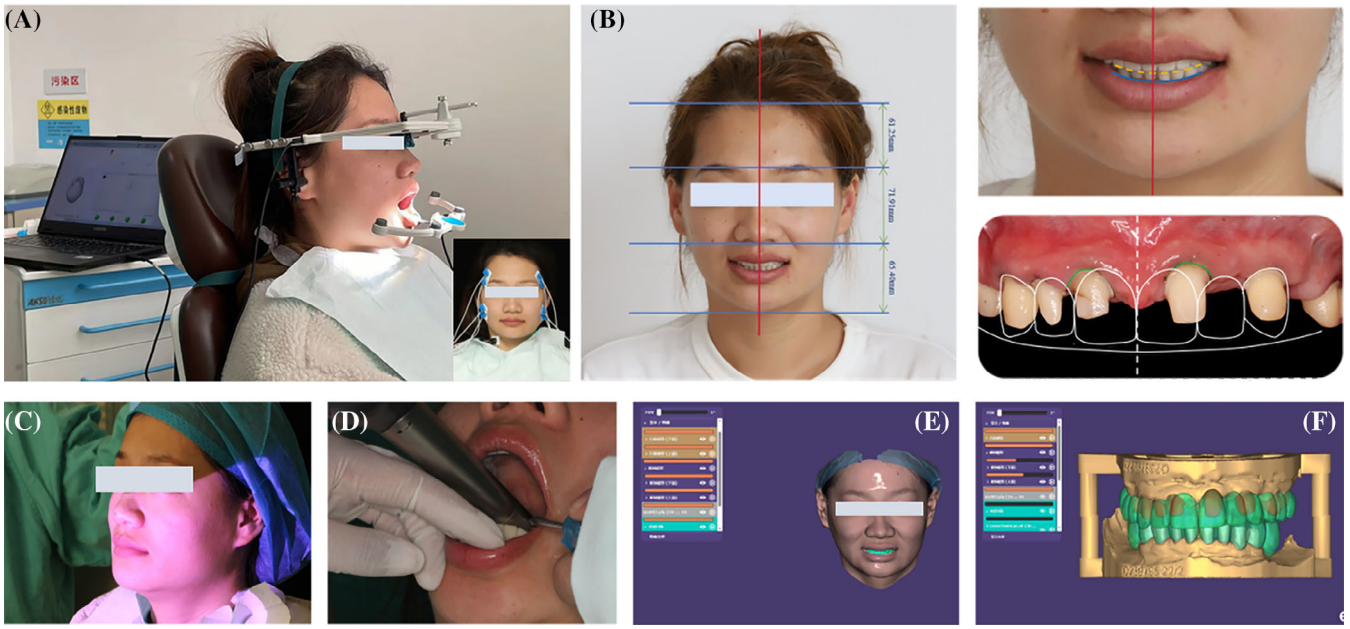

FIGURE 9 Fully digital techniques were employed during the temporary restoration phase. These included recording mandibular movements and determining the treatment jaw position using an e-facebow. Electrophysiological testing of the masticatory muscles was also conducted (A). Additionally, a comprehensive analysis of facial and dental esthetics was performed by using digital smile design method, resulting in the precise design of the position and shape of the maxillary anterior teeth (B). A three-dimensional virtual patient was obtained through electronic face scanning (C) and intraoral scanning (D). Finally, the restorations were designed in the virtual patient using an Exocad software (E and F).

and facilitate the attachment of bilateral precision attachment type removable partial dentures. These dentures, which covered teeth #35 to #36 and #45 to #46, were designed with large rod-type metal connectors on the lingual side (Figure 14). In accordance with the manufacturer's instructions, the bridge restorations in the maxilla were adhesively cemented to the abutment teeth with a dual-curing resin bonding agent (Huge Dental Material Corporation, Shandong, China), whereas a glass ionomer adhesive cement (3 M ESPE Ketac Cem Easymix, 3 M Corporation, USA) was employed for cementation in the mandible.

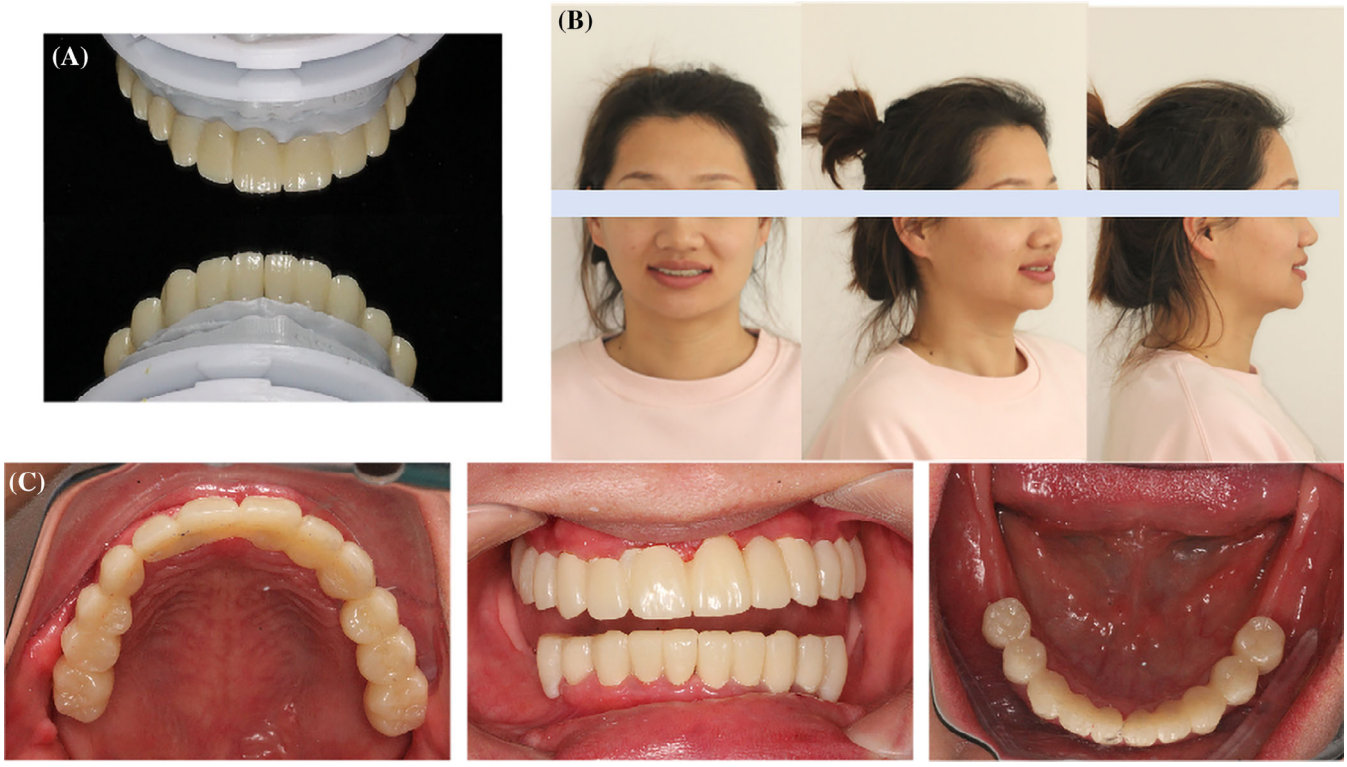

FIGURE 10 The second set of temporary prosthesis (A) designing and fabricating by digital tools, as well as the facial (B) and intraoral (C) photographs after restoration.

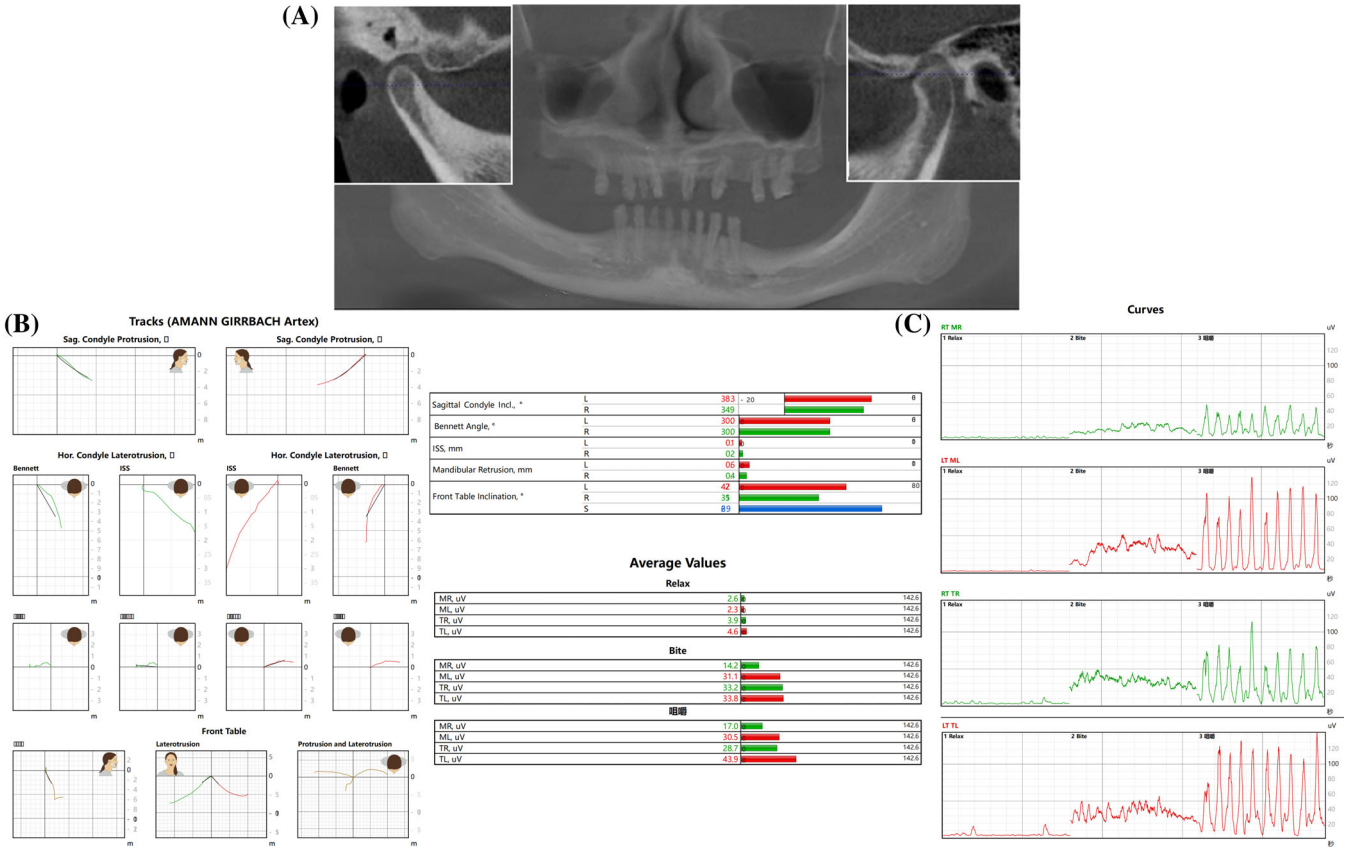

FIGURE 11 Auxiliary examination results after temporary restoration, including cone beam CT (CBCT) to assess bilateral temporomandibular joint (A) and digital facebow for functional mandibular movements and masticatory muscle function (B and C).

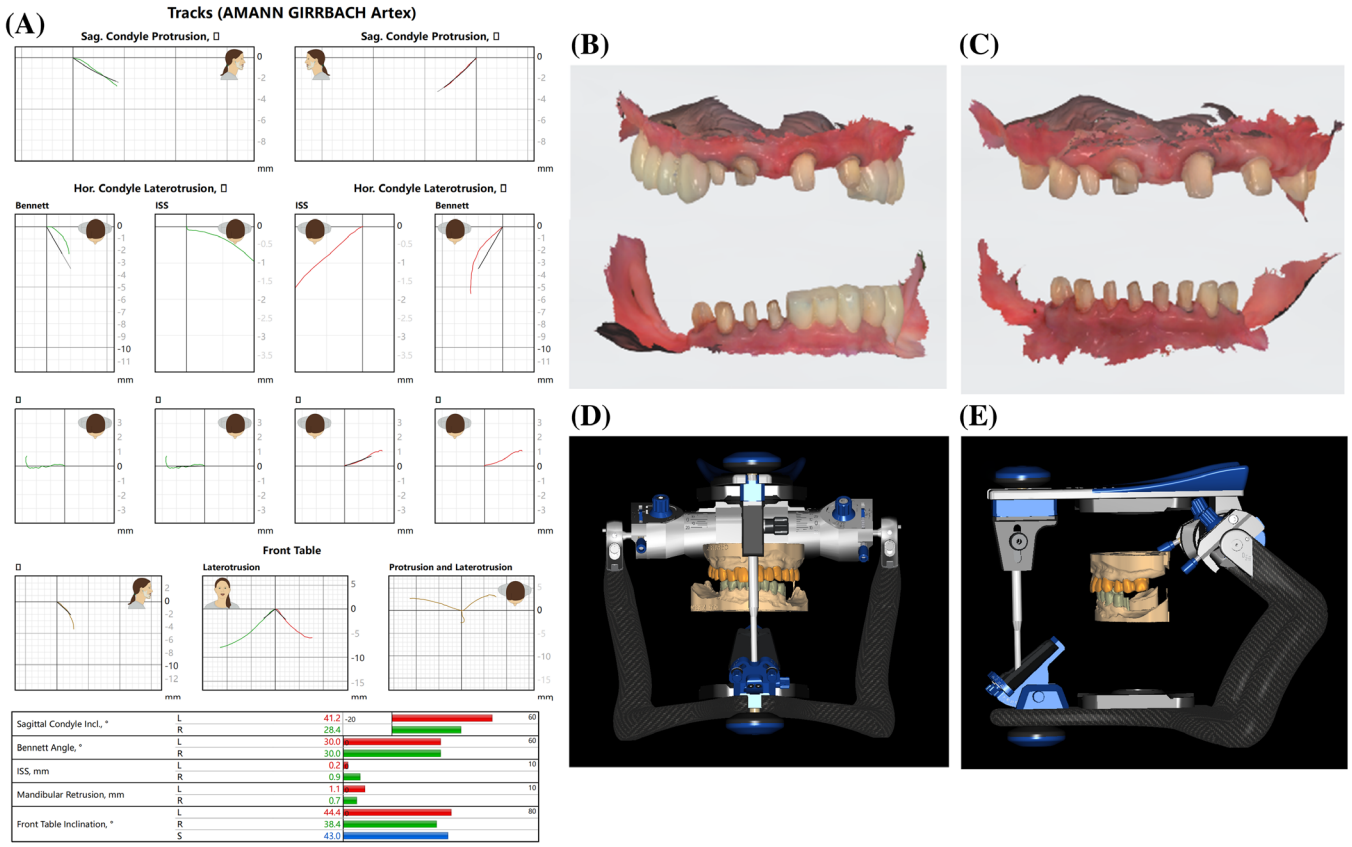

FIGURE 12 Digital techniques were used in the final restoration stage, including the application of digital facebow and intraoral scanning techniques. These techniques were employed to record and precisely transfer the jaw relationships (A and B), capture the profiles and positions of the abutment teeth (C), and implement the transfer of the virtual articulator system (D and E).

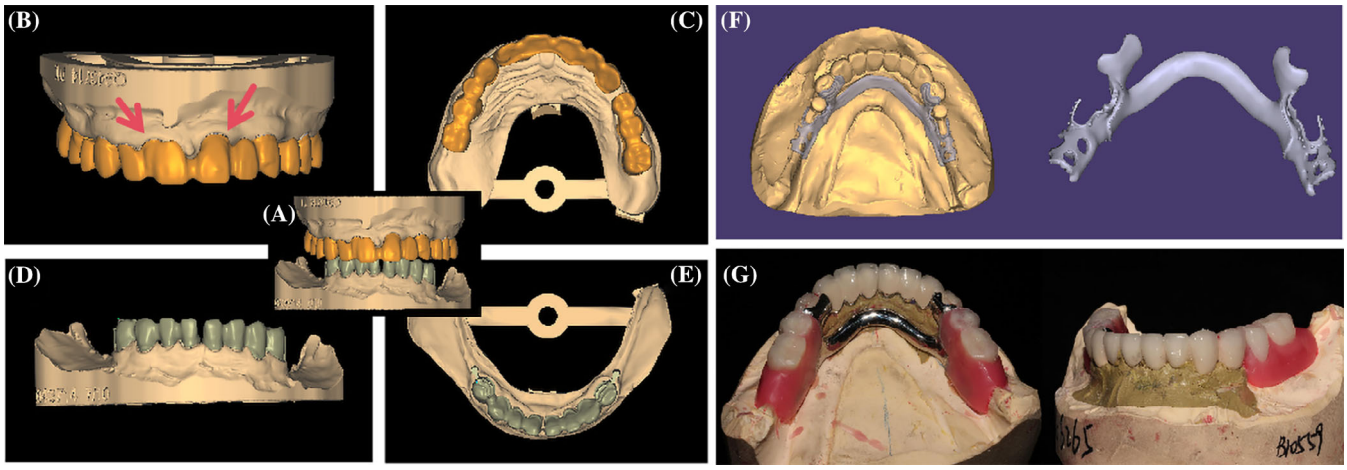

FIGURE 13 The digital fabrication process for the final restorations includes designing the inner crown for the maxillary and mandibular fixed bridge restorations (A–E), as well as the bracket for the mandibular precision attachment (F). The bracket was fabricated and positioned on the model, and the teeth of the precision attachment were arranged (G). The specially designed gingival-colored porcelain sites were indicated by the red arrows in (B).

Intraoral conditions were documented through photography after finishing the treatment procedure (Figure 15). Auxiliary examinations were conducted to check the patient's occlusion and TMJ conditions. Intraoral scanning techniques were used to assess the status and distribution of occlusal contacts throughout the entire dentition. Radiological examination showed that the bilateral condyles were appropriately positioned and free of abnormalities (Figure 16). The patient expressed contentment and satisfaction with the results of

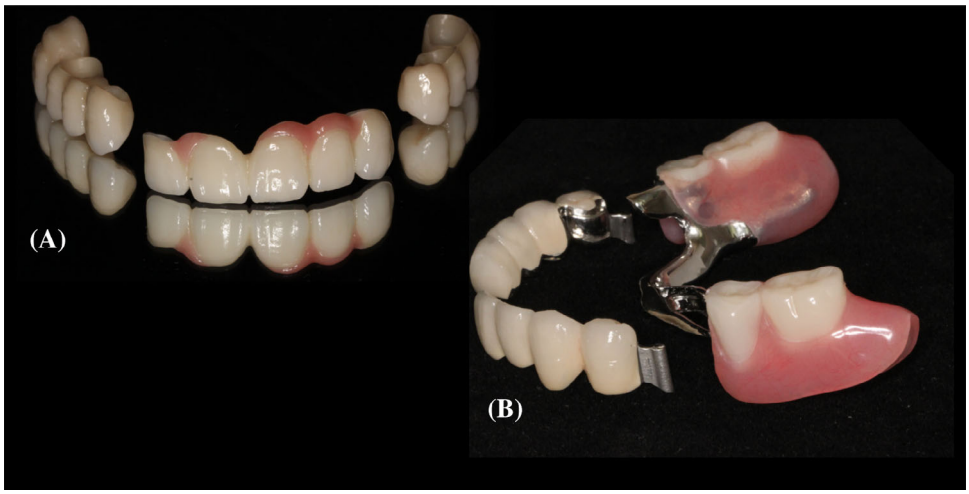

FIGURE 14 The final restorations comprised of segmental zirconia all-ceramic bridge restorations for the maxillary arch (A), along with mandibular porcelain-fused-to-metal bridge restorations and precision attachments (B).

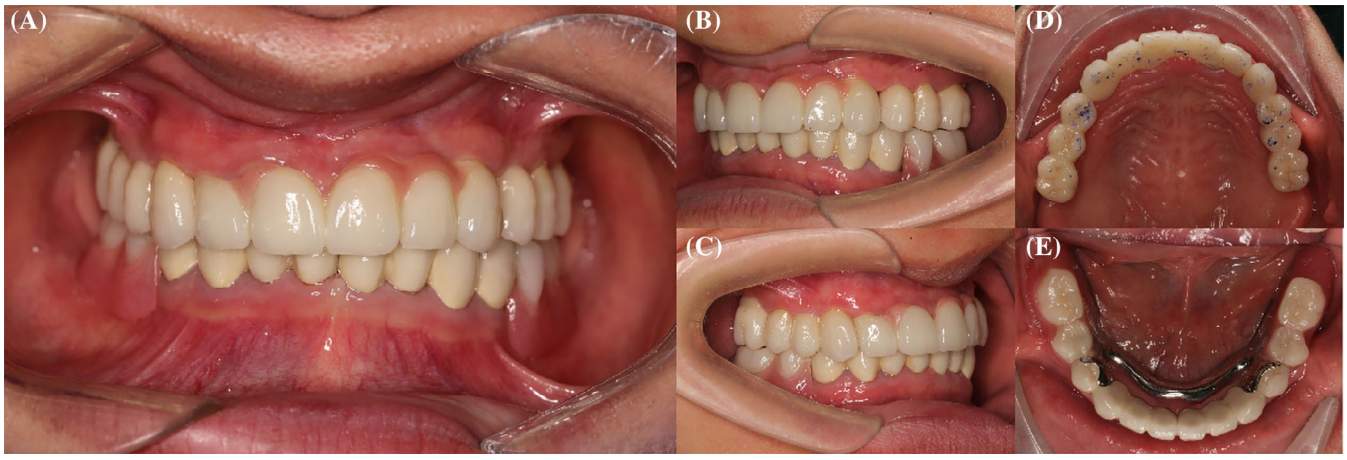

FIGURE 15 Intraoral photographs of the final restorative treatment were captured, showcasing frontal (A), lateral (B and C), and occlusal views (D and E). The occlusal contact points were clearly visible on the surface of the maxillary teeth (D).

the restorations (Figures 17 and 18). After the ultimate repair was accomplished, the patient proceeded to the final stage, which involved scheduled follow-up appointments. 3 months later, no failures were observed in the restorations, and the patient exhibited satisfactory occlusal function without any reported TMJ or masticatory muscle discomfort.

3 | DISCUSSION

The stomatognathic system, responsible for essential functions such as mastication, speech, and esthetics, requires harmonious coordination among its components.[13] Effective maintenance and execution of these functions relies on optimal positioning of the maxillary and mandibular regions, as well as the proper function of the TMJs and the masticatory muscles. Therefore, occlusal reconstruction should not only focus on the restoration of teeth, but also prioritize the establishment of a healthy stomatognathic system.[2] Historically, occlusal reconstruction predominantly emphasized jaw position, vertical distance, and occlusal relationship. However, contemporary approaches in this field have expanded to incorporate not only the masticatory muscles and TMJs of the stomatognathic system but also consider the morphology of the teeth, as well as the esthetics of both the teeth and the maxillofacial region.[4] This evolution has resulted in a modern occlusal reconstruction theory that comprises four main components: mandibular position, vertical distance, occlusal plane, as well as dynamic guidance and static occlusion.[4] Yang[14] et al. summarized a six-stage practical treatment principle for occlusal reconstruction, which consists of examination and design, oral preparation, jaw relationship adjustment, temporary restoration, permanent restoration, and follow-up maintenance. Locating the precise treatment position proves to be crucial during occlusal reconstruction treatment.[15]

However, Liu[2] points out that the concept of "centric relation position" currently employed in occlusal reconstruction is ineffective with uncertain implications and controversies. Some scholars[16] even suggest that up to seven theoretical systems for centric relation position are now commonly utilized in clinical operations. The maxillomandibular relationship used for occlusal reconstruction does not

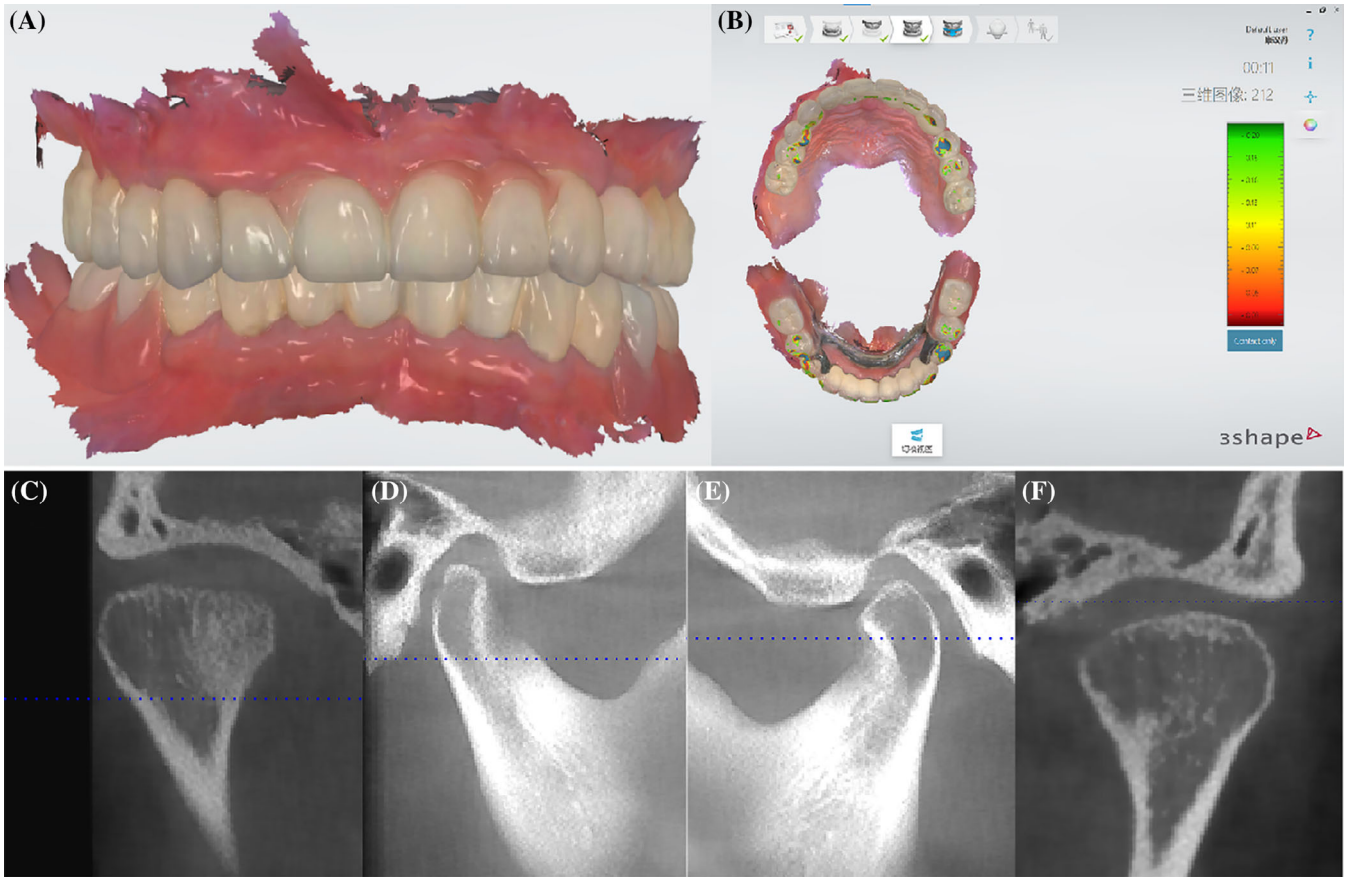

FIGURE 16 The auxiliary examination results after permanent restoration, including intraoral scanning to assess the occlusal relationship of the maxillary and mandibular arches and cone beam CT to assess the position of the bilateral condyles in temporomandibular joint. Intraoral scanning indicated that the patient's occlusal contacts were distributed throughout the dentition, with the bilateral molars adjusted for lighter occlusal contacts (A and B). Radiographic examination revealed that the condylar bone cortex remained intact bilaterally (C and F) and the condylar position was significantly closer to the anterior-superior position compared with before the treatment (D and E).

FIGURE 17 Facial smiling appearance after permanent restoration treatment, including front and side views.

necessarily have to adhere to a strict "specific relationship." Instead, it should be reconstructed in harmony with the stomatognathic system. This entails rebuilding the occlusion through a process of "trial and error adjustment" to identify a new jaw relation that will ultimately yield a healthy, functionally sound, and stable outcome in the long run. Consequently, once the accurate position has been identified and

FIGURE 18 Comparison photographs before and after treatment, including facial and intraoral aspects.

the new occlusion has been developed, it is necessary to subject the stomatognathic system to testing in order to attain the objective of optimal function and sustained health.

Innovations in the aforementioned clinical concepts have facilitated the development and application of multiple digital technologies, such as intraoral scanning, digital facebow, DSD technology, and CAD/CAM. This is because traditional techniques are no longer capable of meeting the clinical demands for precision, efficiency, as well as esthetics, particularly when dealing with complex cases. For instance, during the functional reconstruction phase, digital facebow can record the trajectory and range of the patient's jaw movement in real-time. This data can then be projected to determine the optimal therapeutic jaw position, which can subsequently be transferred to a fully adjustable virtual articulator. Compared with the traditional approach, this method is more efficient and accurate.[5] During the esthetic reconstruction phase, DSD technology can be employed to design and modify the esthetics of a patient's smile,[17] since some academics[18] have proposed esthetically oriented occlusal reconstruction for patients with severely worn dentition. Moreover, the integration of oral scanning, electronic facial scanning, and other technologies in conjunction with professional design software allows for the creation of a three-dimensional virtual patient.[19] This enables the assessment of the patient's facial shape and lip–tooth relationship from a three-dimensional perspective, thereby facilitating the completion of the patient's esthetic design and visualization of the esthetic restoration results. The utilization of such technology can significantly enhance communication between doctor and patient, as it allows patients to preview their new smile design in advance. This leads to a better understanding and collaboration, ultimately resulting in the achievement of ideal esthetic restoration results.

As previously mentioned, congenital dental hypoplasia is one of the primary factors contributing to extensive loss of dental tissue and occlusal abnormalities. In this case, the patient's medical history revealed a familial inheritance of congenital dentition defect, with only female members of the family being affected. Congenital tooth agenesis is a common developmental anomaly of the oral cavity with an unclear pathogenesis.[20] The prevalence of this condition ranges from 2.2% to 11.3%.[21] Genetic factors are considered the main cause of the disease. Several genes, including MSX1, PAX9, WNT10A, WNT10B, EDA, and AXIN2, have been associated with non-syndromic congenital tooth agenesis.[20] Congenital tooth agenesis may also be influenced by environmental factors such as trauma, infection, radiation, and chemicals.[20] Most cases of congenital tooth agenesis involve partial absence of permanent teeth. Clinically, a combination of orthodontic treatment and restorative procedures, or implant restoration, is frequently employed to address esthetic or functional deficiencies in such cases. In this case, the patient was not eligible for orthodontic treatment. Additionally, there was inadequate alveolar bone volume in the edentulous areas, particularly in the posterior mandibular region, which posed challenges for implant restorations. Altogether, bone augmentation surgery in this condition appears to be challenging, traumatic, risky, and deemed unacceptable by the patient.[22] In summary, the patient's specific conditions and individual requirements and preferences posed a significant obstacle in the treatment planning process. Since the patient was not willing to undergo periodontal surgery, which could have improved the positional relationship of the gingiva in esthetic area, we opted to utilize gingival-colored porcelain in the restorations as an alternative to achieve a satisfactory esthetic outcome.[23,24] Precision attachments were selected as the preferred method for restoring the mandibular edentulous areas that cannot be effectively restored with fixed or implant restorations.[25] In order to minimize the functional strain on the stomatognathic system, the occlusal design incorporated bilateral first molars with light contact and a cuspid-protected dentition for anterior and lateral occlusion.[2]

After completing the treatment plan, digital technology was again implemented and played a crucial role in ensuring a long-term, reliable prosthetic outcome in this case. Firstly, after establishing the occlusal relationship in the initial treatment position determined through

conventional methods, the patient's TMD symptoms were partially alleviated. In the "error adjustment" phase that followed the initial "trial" process, the digital facebow was applied to find a new treatment position. Second, additional digital techniques, such as electronic facial scanning and oral scanning, were simultaneously introduced during the "adjustment" phase. CAD design software was applied to improve the unsatisfactory esthetics and abnormal occlusal curves of the first set of temporary prosthesis through the esthetic and functional design of provisional occlusal reconstruction restorations. Third, in the final stage of the treatment, the jaw relationship adapted in the provisional restoration stage, along with the intraoral conditions, were recorded and transferred using digital facebow and intraoral scanning technology. The restorations were then designed and adjusted for both esthetic and functional considerations using CAD software. Finally, CAM technology was integrated with CAD software to digitally process and fabricate the restorations.

In addition to the clinical examination of the function of the orofacial system and digital technical evaluation, the reduction or elimination of clinical symptoms caused by occlusal anomalies prior to the treatment can also serve as one of the criteria for assessing the success of occlusal reconstruction treatment. The patient presented with significant symptoms of TMJ clicking at the time of her first visit. Temporomandibular joint disorder (TMD) is a general term used to describe a range of disorders that affect the TMJ and/or the masticatory muscle system. These disorders are mainly characterized by symptoms such as pain, limited mouth opening, and joint clicking.[26] The disease has a complex etiology and often follows a chronic course. Some studies suggest that occlusal factors may contribute to its development.[27] When a patient presents with symptoms of TMD, it is crucial to meticulously design the treatment plan. Treatments that may induce or exacerbate TMD symptoms should be avoided. Temporary restorations should be worn and observed for an extended period of time. Additionally, a stable occlusion coordinated with the articulating muscles should be established to prevent potential occlusal factors from triggering or exacerbating TMD symptoms.[28] In this case, the two treatment jaw positions were determined and adjusted during the temporary phase, gradually restoring the patient's stomatognathic system to a stable and coordinated state, effectively eliminating the patient's TMD symptoms, and preventing the occurrence of new TMD symptoms.

Patients who undergo full occlusal reconstruction may experience changes in their newly established occlusion within a relatively short period of time. Therefore, it is important for patients to undergo regular follow-up examinations to check the occlusion in the oral cavity and assess the physiological and functional status of the stomatognathic system. Even after achieving occlusal stability, regular review and assessment are still required to make necessary adjustments to the restorations in order to accommodate changes in the oro-mandibular system as it ages.[2] Follow-up maintenance for occlusal reconstruction is typically divided into periodontal maintenance, occlusal maintenance, and other maintenance.[14] Patients who are at risk of periodontal disease should undergo assessments that primarily focus on their periodontal status. The symptoms of TMD and chronic periodontitis that existed prior to treatment in this case were also the focus of regular follow-up examinations.

4 | CONCLUSIONS

1. The development of digital technology has made occlusal reconstruction procedure more precise and comfortable. This enables greater patient engagement in the whole course of treatment and fosters improved communication between patients and doctors, ultimately resulting in ideal treatment outcomes.
2. Given the holistic and coordinated nature of the oro-mandibular system, it is imperative for clinicians to pay close attention to the overall function and health of the oro-mandibular system in patients undergoing occlusal reconstruction during treatment and subsequent follow-up, rather than focusing only on the teeth and occlusion.

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CONFLICT OF INTEREST STATEMENT

The authors do not have any financial interest in any of the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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