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Case report

Use of digital technology in maxillofacial prosthetic treatment of cleft lip and palate in patients with severe periodontitis: A case report

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Abstract

Patients: A 56-year-old man with a left-sided cleft lip and palate was referred to our department due to mastication and speech difficulties. His existing prostheses have become unstable owing to changes in the remaining dentition over 10 years. For the fabrication of the new interim maxillofacial prostheses, a digital impression technique was selected as the conventional technique posed medical risks due to hypermobile teeth and maxillary defects. New interim maxillofacial prostheses were fabricated using a combination of the digital impression technique and a bite-seating impression, performed with trial prostheses and impression material. The patient has been using the new interim prostheses comfortably since delivery. The oral functional evaluation yielded favorable results.
Discussion: Patients with cleft lip and palate should use their existing maxillofacial prostheses during the fabrication of new ones, even if they are of suboptimal quality. Although addressing these issues using conventional techniques is challenging, digital technology provides a viable solution. However, impression material is essential for capturing mucosal defects and complex anatomy in cleft lip and palate cases; therefore, digital data should be supplemented by either well-adjusted existing prostheses or bite-seating impressions using impression material before new prostheses fabrication. Although his occlusal force was lower than the criterion for the oral hypofunction test, his masticatory performance remained favorable. Speech analysis revealed persistent air leakage; however, all scores improved with the prostheses.
Conclusions: Digital technology has enabled the safe fabrication of interim maxillofacial prostheses, resulting in improved masticatory and speech performance.

Keywords: CAD-CAM, Cleft lip and palate, Digital impression, Maxillofacial prosthesis, Oral hypofunction

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1. Introduction

Patients with cleft lip and palate (CLP) require more complex prosthetic treatment than typical patients to improve speech, mastication, and dysphagia[1]. Despite improved treatment outcomes for CLP due to advancements in bone grafting surgery and orthodontic treatment[2], some patients continue to experience defects, malocclusions, and velopharyngeal deficiencies. This is because some patients with CLP may be ineligible for surgery, experience unsuccessful procedures, or relapse after orthodontic treatment[3–5]. In such cases, prosthetic treatment is necessary to improve the oral functions. Prosthetic treatment tends to be difficult for patients with maxillary defects, those with few remaining teeth, and significantly displaced condylar position due to the relapses, maxillary hypoplasia, or condylar volumetric asymmetry[6–8]. Regardless of the plastic surgery, patients with CLP may retain defects, posing a risk of impression material leaking into the defects during impression taking[9,10]. Digital technology addresses medical risks and treatment challenges by reducing the need for impression materials and accurately replicating the morphology of existing functional prostheses[11].

Evaluation of the treatment outcomes of maxillofacial prostheses in terms of improving speech and other oral functions is crucial,

WHAT IS ALREADY KNOWN ABOUT THE TOPIC
» *Digital technology has become widely adopted in the fabrication of removable prostheses, benefiting not only partially edentulous patients but also postoperative patients with jaw defects. Moreover, objective assessments, such as oral hypofunction tests, have been increasingly used to assess the outcomes of prosthetic treatment.*

WHAT THIS STUDY ADDS?
» *Digital technology offers a treatment option for the fabrication of maxillofacial prostheses that preserve oral function without iatrogenic tooth extraction, in patients with cleft lip and palate (CLP) with severe periodontitis. This case reported the prosthetic functional outcomes in an adult patient with CLP, which have rarely been documented.*

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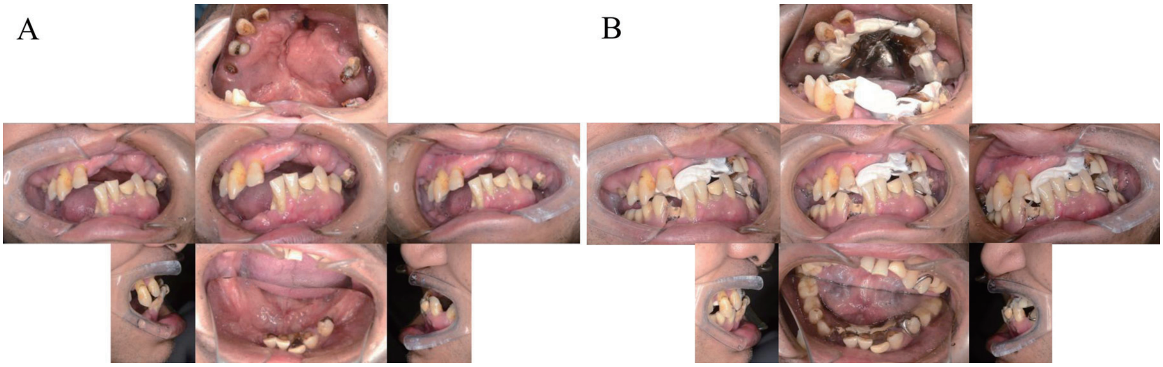

Fig. 1. Intraoral views before treatment: (A) Without the existing prostheses; (B) With the existing prostheses.

particularly as patients with CLP exhibit severe functional impairments. Few reports have evaluated oral function following prosthetic treatment in adult patients with CLP, although evidence for general prostheses in oral hypofunction tests has been accumulating[12–14]. The evaluation of oral function in patients with CLP using a standardized method, such as the oral hypofunction test[15], can provide insight into the degree of functional decline compared to reference values in the general older population and other maxillectomy cases[16,17]. The food intake questionnaire is another method to evaluate masticatory performance, where patients rate the ease of eating 25 specific food items[18]. Although this was a subjective evaluation, the questionnaire allowed for a comprehensive assessment of masticatory performance[19]. Furthermore, the calculated masticatory score enabled the evaluation of chronological changes in masticatory performance.

Previous studies evaluating speech performance have demonstrated that nasalance measurement[20,21] and the presence of fog on a mirror during the blowing test[22] are effective methods for assessing velopharyngeal deficiencies in patients with CLP. However, the comparative effectiveness of maxillofacial prostheses and those fabricated using digital technology for patients with CLP remains unclear.

This case report aimed to evaluate the oral functional performance of a patient with CLP who was managed using digitally designed maxillofacial prostheses.

2. Outline of the case

2.1. Participant

A 56-year-old Japanese man was referred to our hospital in July 2023. His chief complaint was difficulty in mastication and speech due to instability of the existing maxillofacial prostheses. The patient had a history of left-sided CLP and diabetes. He had undergone several surgical procedures for CLP, speech therapy, and maxillofacial prosthetic treatment when he was a child.

2.2. Intraoral and radiographic examinations

The patient had multiple missing teeth, with most of his remaining dentition being dynamically displaced (**Figs. 1 and 2**). Due to their severe mobility, the probing depth of certain teeth could not be determined. The stability of the existing maxillofacial prostheses was significantly poor; therefore, he used denture stabilizers to enhance retention (**Fig. 3**). However, he needed to use his tongue to prevent the displacement of the maxillary prosthesis. Furthermore, because of the patient's psychological state before treatment, preoperative oral functional evaluation was not feasible.

2.3. Treatment plan

As the patient was expected to lose most remaining teeth in the near future, a high risk of tooth loss during the initial impression-making could render the existing maxillofacial prostheses unusable if conventional techniques were employed. In this patient, the sudden inability to use existing maxillofacial prostheses could lead to significant impairments in appearance, mastication, and speech, resulting in a substantial decline in the quality of life. Furthermore, although existing maxillofacial prostheses exhibited a significantly poor fit, replicating the maxillomandibular relationship established over the years of use was considered essential during the transition. Departing from this familiar maxillomandibular relationship could render the new interim maxillofacial prostheses nonfunctional. Given these considerations, the use of the digital impression technique to fabricate interim maxillofacial prostheses was deemed the most appropriate approach to restore function while maintaining continuity of care.

2.4. Maxillofacial prostheses fabrication

Figure 4 displays the workflow for the fabrication of maxillofacial prostheses. First, oral scanning data with and without the existing maxillofacial prostheses were obtained using an intraoral scanner (Trios 3 Wired; 3Shape A/S, Copenhagen, Denmark) and imported into dental computer-aided design (CAD) software (Meshmixer; Autodesk, Inc., San Rafael, CA, USA). Before the initial scanning, #13 and #25 exfoliated naturally, and epithelialization of the extraction site was observed. Based on the scanned data, including the maxillomandibular relationship of the existing maxillofacial prostheses, CAD-computer-aided manufacturing (CAM) trial maxillofacial prostheses were fabricated from photopolymerized resin (Surgical Guide Resin; Formlabs Inc., Somerville, MA, USA) using a stereolithography printer (Form 3B+; Formlabs Inc., Somerville, MA, USA). These prostheses were used to obtain a bite-seating impression with a silicone impression material (Exahiflex Regular; GC Corporation, Tokyo, Japan), along with a bite-registration material (Correct Plus Bite Superfast Material; Pentron Clinical, Inc., Bohemia, NY, USA) and to assess tooth alignment. The surface of the silicone bite-seating impression was

	18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28
Tooth mobility			3		0	3	0						3			
Probing depth (Buccal)			-		336	-	333						-			
Probing depth (Lingual)			-		435	-	333						-			

	48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38
Probing depth (Lingual)								-	-	-	11 64	444				
Probing depth (Buccal)								-	-	-	224	433				
Tooth mobility								3	3	3	2	1				

Fig. 2. Periodontal and radiographic examinations before treatment

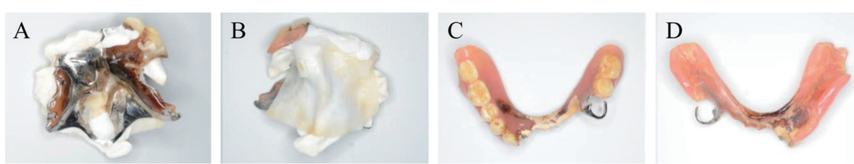

Fig. 3. The existing prostheses: (A) The polished surface of the maxillary prosthesis; (B) The intaglio surface of the maxillary prosthesis; (C) The polished surface of the mandibular prosthesis; (D) The intaglio surface of the mandibular prosthesis.

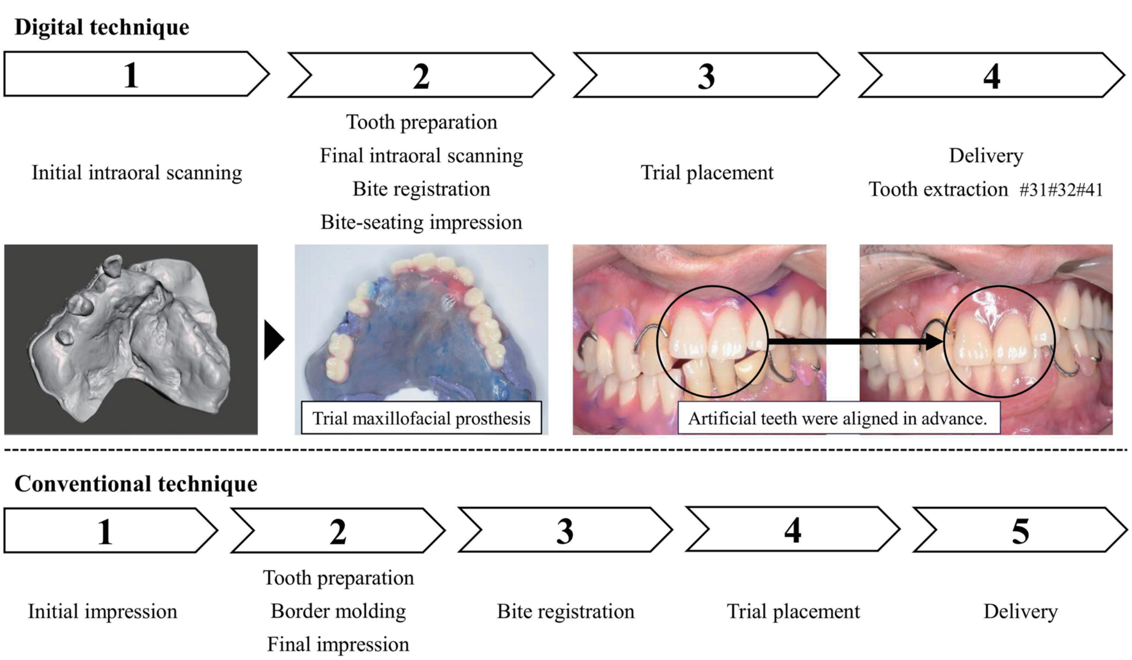

Fig. 4. Workflow of maxillofacial prostheses fabrication using digital and conventional techniques

Fig. 5. Intraoral views after the treatment: (A) Without the new prostheses; (B) With the new prostheses.

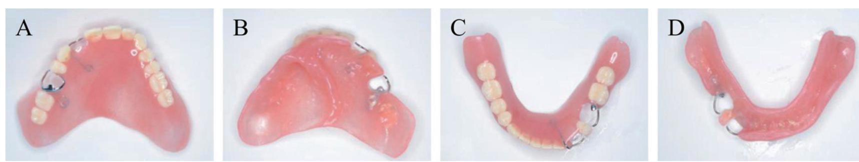

Fig. 6. The new interim prostheses: (A) The polished surface of the maxillary prosthesis; (B) The intaglio surface of the maxillary prosthesis; (C) The polished surface of the mandibular prosthesis; (D) The intaglio surface of the mandibular prosthesis.

scanned and converted into standard triangulated language (STL) data, which was then superimposed onto the STL data obtained from the intraoral scanning after tooth preparation. After trimming the tooth data obtained from the intraoral scan and mucosal surface data from the reversed intaglio surface, the two datasets were merged and smoothed. The CAD-CAM maxillary trial maxillofacial prosthesis was fabricated based on the combined data. During trial placement, the extraction of the three mandibular anterior teeth was planned at the time of delivering the new interim maxillofacial prostheses, as they were too mobile to preserve. Accordingly, the anterior tooth alignment in the new interim maxillofacial prostheses was modified to the ideal position. Customized autopolymerizing acrylic resin blocks (Palapress Vario; Kulzer GmbH, Hanau, Germany) were milled using a milling machine (52DC; DGSHAPE; Roland DG Corporation, Shizuoka, Japan) to fabricate the denture base. An Akers clasp was fabricated on #14, a wrought wire clasp with an occlusal rest on #34, and wrought wire clasps were fabricated on #12 and #33. The Akers clasp was fabricated using only the STL data without the use of plaster models. A printed wax pattern based on the STL data was cast to produce a clasp. In contrast, the fabrication of wrought wire clasps involved bending wires on three-dimensional (3D)-printed urethane models (Model V2; Formlabs Inc., Somerville, MA, USA) from the STL data. The clasps, artificial teeth (Veracia SA; SHOFU DENTAL GmbH, Tokyo, Japan), and denture base were assembled using an autopolymerizing acrylic resin (Palapress Vario; Kulzer GmbH, Hanau, Germany) on the 3D-printed urethane models, after priming each part with Palabond (Kulzer GmbH, Hanau, Germany). Polymerization was performed in a pressurized oven (Polymax 5; Dreve Dentamid GmbH, Unna, Germany). The maxillary and mandibular maxillofacial prostheses were fabricated using identical materials. At the time of extraction, the three mandibular anterior teeth nearly exfoliated naturally, with no preservation of the surrounding bone and minimal bleeding. As epithelialization had already been observed, tissue conditioning was deemed unnecessary. One month after delivery, the mandibular prosthesis was relined using a hard relining material (TOKUYAMA REBASE III NORMAL; Tokuyama Dental Corporation, Tokyo, Japan).

Figures 5 and 6 illustrate the intraoral views and new interim maxillofacial prostheses, respectively, while **Figure 7** displays the periodontal and radiographic examinations after treatment. After confirming the stability of the new interim maxillofacial prostheses, several oral functional evaluations were performed. No additional tooth loss was observed at 20 months after delivery, and the denture remained functional without any complications. The patient underwent follow-up examinations every 4 months.

2.5. Oral functional evaluations

Masticatory performance was evaluated using oral hypofunction tests[15] and food intake questionnaire[18]. The oral hypofunction test comprised seven components, and patients meeting three or more of the criteria were diagnosed with oral hypofunction. The test results are presented in **Table 1**. Two months after delivery, the patient met the criteria for only one item. However, 14 months later, the patient met the criteria for three components. The masticatory score was calculated based on the answers to the food intake questionnaire, resulting in 84.8% for the new interim maxillofacial prostheses, while 72.5% for the existing maxillofacial prostheses.

Speech performance was analyzed using nasalance, blowing, and conversational intelligibility tests. Nasalance was assessed to quantify the degree of sound leakage through the nasal cavity[20]. The patient wore a device (Nasometer II Model 6450; KayPENTAX, Inc., Bohemia, NY, USA) equipped with a metal plate and microphones on each side. The articulation of specific sentences was also assessed. Nasalance was calculated using the following formula:

Tooth mobility			3		1		2									
Probing depth (Buccal)			-		345		322									
	18	**17**	**16**	**15**	**14**	**13**	**12**	**11**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Probing depth (Lingual)			-		666		223									

Probing depth (Lingual)											745	656				
	48	**47**	**46**	**45**	**44**	**43**	**42**	**41**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**
Probing depth (Buccal)											232	222				
Tooth mobility											2	1				

Fig. 7. Periodontal and radiographic examinations following treatment

Table 1. The oral hypofunction test results 2 and 14 months after delivery

	Criteria for oral functional impairment	Scores	
		2 months after delivery	**14 months after delivery**
i. Tongue Coating Index	≥ 50 (%)	33.3 (%)	22.2 (%)
ii. Oral Moisture	< 27	31	**23.7**
iii. Occlusal Force	< 350 (N)	**133.8** (N)	**210.6** (N)
iv. Oral Diadochokinesis	> 6 (/s)	Pa 6.4 (/s) Ta 7.6 (/s) Ka 7.2 (/s)	Pa 7.4 (/s) Ta 7.8 (/s) Ka 7.8 (/s)
v. Tongue Pressure	< 30 (kPa)	37.1 (kPa)	35.1 (kPa)
vi. Masticatory Ability	< 100 (mg/dL)	101.3 (mg/dL)	**82.0** (mg/dL)
vii. Swallowing Questionnaire	≥ 3	0	0

$$Nasalance(\%) = \frac{Nasal\ sound\ pressure}{Nasal + Oral\ sound\ pressure} \times 100$$

The nasalance in both low- and high-pressure sentences decreased, indicating improvement with the new interim prostheses (**Fig. 8**).

The blowing test measures the duration a patient can sustain blowing through a straw[23]. During blowing, fogging on the mirror placed under the nose was observed simultaneously[22]. The blowing ratio was calculated by dividing the duration without prostheses by the duration with prostheses. In this case, the blowing ratio was 50%, indicating that, with the prostheses, the patient could blow twice as long as without the prostheses. A large fog area on the mirror, significant air leakage, was observed with and without the prostheses.

Conversational intelligibility was evaluated by five listeners unfamiliar with the patient, using recorded speech samples and the following criteria: 1. intelligible, 2. partially intelligible, 3. intelligible when the topic is known, 4. mostly unintelligible, and 5. unintelligible[24]. The average score was 1.4 with the new maxillofacial prostheses, compared to 2.6 without the prostheses, indicating improved speech clarity.

3. Discussion

Although the fit of the existing maxillofacial prosthesis was too poor to reflect its morphology in the new denture base, the pre-treatment maxillomandibular relationship and tooth alignment could still be referenced. This allowed the prostheses to be fabricated in fewer visits than with the conventional technique (**Fig. 4**) and allowed immediate use after delivery, despite the inability to perform the conventional impression. Although the conventional technique typi-

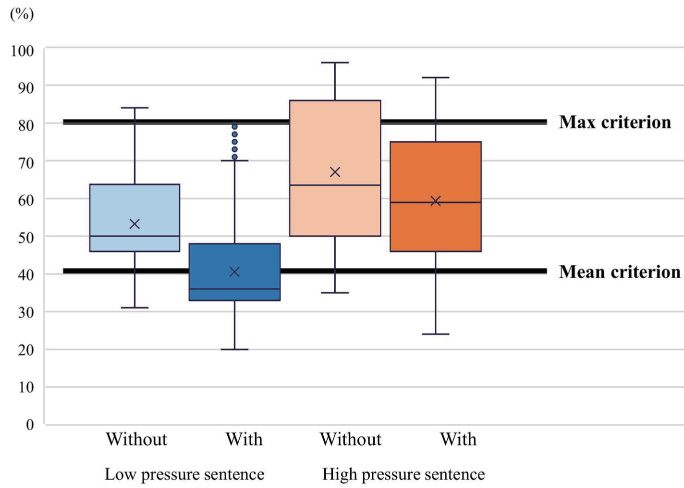

Fig. 8. The results of nasalance measurements with and without the new prostheses

cally requires separate visits for final impressions, bite registration, and trial placement, these procedures can be completed in a single visit using the digital impression technique. Moreover, aligning the artificial teeth on the initial trial prostheses allowed for preliminary evaluation of tooth positions during the final impression and bite registration steps, thereby reducing the total number of visits.

The use of impression materials for fabricating functional removable prostheses is still considered necessary, as intraoral scanners cannot accurately capture defects, record border positions, or apply functional pressure to shape the residual ridge during impression-taking[25–27]. However, the digital impression technique helps reduce the amount of impression material used and the frequency of impression procedures. Digital impression technique reduces medical risks, including retained impression materials in defects[9,10], accidental ingestion, pulmonary aspiration, and unintentional tooth extractions. For patients with CLP, transitioning from existing maxillofacial prostheses to new ones can be psychologically challenging, especially when existing maxillofacial prostheses have long supported essential functions such as speech, mastication, and aesthetics in daily social life. Therefore, careful consideration is required to minimize the discomfort and inconvenience associated with the treatment steps. The risk of unintentional tooth extraction could be mitigated by using the digital impression technique[28] and bite-seating impressions, which use less impression material. This combination of an intraoral scanner and impression material was used for cases with postoperative defects and was demonstrated to be beneficial for patients with CLP[11]. In this case, the interim maxillofacial prostheses were fabricated. However, once the patient loses most of the remaining teeth, definitive maxillofacial prostheses must be fabricated based on the well-adjusted interim maxillofacial prostheses used as treatment dentures, with digital technology facilitating the transfer of information from the interim to the definitive prostheses[29].

Oral functional evaluations demonstrated that the patient achieved sufficient masticatory and speech performance while wearing the new prostheses. **Table 1** displays the results of the oral hypofunction tests. The patient exceeded the criteria in six of the seven tests; however, only the occlusal force remained below the criterion 2 months after delivery. In the occlusal force test, a threshold of 350 N was established as indicative of a sound dentate. The occlusal force of Japanese individuals wearing normal complete dentures was reported to be 328.1 ± 120.3 N[16]. In addition, an occlusal force of 230 N was identified as the threshold for occlusal impairment in Japanese individuals using maxillofacial prosthesis[17]. Based on these reports, the occlusal force of the patient remained insufficient, despite wearing dentures. Conversely, the patient achieved an 84.8% masticatory score in the food intake questionnaire[18], indicating that he could eat most of the listed foods easily. The score also improved with the new interim prostheses compared to that noted with the existing maxillofacial prostheses, suggesting that the masticatory performance of the patient was favorable.

In the oral hypofunction tests assessed 14 months after delivery, the patient scored below the criteria in three components of the test. The patient's masticatory ability exhibited a slight decline, whereas the occlusal force increased yet remained below the criterion. The tongue coating index and oral diadochokinesis improved, while oral moisture and tongue pressure decreased; however, tongue pressure remained within the acceptable range. Implementing these evaluations before treatment was considered impossible, as the existing prostheses were unstable. These parameters were expected to demonstrate significant improvement compared to pre-treatment levels. The increase in occlusal force and oral diadochokinesis may be attributed to the patient's adaptation to the new maxillofacial prostheses or may fall within the range of normal variability. Patients' subjective assessments indicated greater comfort with the new interim maxillofacial prostheses immediately after delivery, with perceived effectiveness improving further as they adapted to their use. The new interim maxillofacial prostheses were well adjusted; however, periodic fine adjustments were necessary due to the dynamic nature of the oral conditions. Improvement in masticatory performance requires well-adjusted maxillofacial prostheses and favorable oral conditions. Targeted lip and tongue exercises may contribute to the improvement and maintenance of oral function.

The 50% blowing ratio and nasalance changes suggested that the new interim maxillofacial prostheses decreased air leakage; nevertheless, the patient continued to exhibit high nasalance scores and a large fog area on the mirror, even while wearing the new interim maxillofacial prostheses. According to a previous study, patients' velopharyngeal function is considered poor when the mean values for both low- and high-pressure sentences exceed 40%, and the maximum value for high-pressure sentences exceeds 80%[21]. This phenomenon may not be attributable to the defect itself but rather to velopharyngeal deficiency, suggesting that a speech aid prosthesis could provide improvement.

4. Conclusions

This case revealed that digital technology can be used to fabricate interim maxillofacial prostheses safely and efficiently, allowing patients to continue using their existing prostheses and transition to new ones smoothly. Digital technology provides a viable treatment option for patients with CLP with severe periodontitis, as the technique allows the fabrication of maxillofacial prostheses that could restore oral function and avoid iatrogenic tooth extraction during treatment procedures.

Informed consent

Written informed consent was obtained from the patient for publication of clinical details and images.

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Conflict of interest declaration

The authors declare no conflict of interest.

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