Facially Driven Rehabilitation of a Cleft Lip and Palate Patient with an Implant-Supported Complete Fixed Dental Prosthesis: Outcome of a Multidisciplinary Approach

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Patients with a facial malformation due to a cleft lip and palate (CLP) usually suffer from a reduced ability to function normally associated with a poor oral health–related quality of life. This condition often requires multiple significant surgical interventions, and the prosthetic restoration, when needed, is not always included in the initial treatment plan. In order to obtain the highest possible degree of functional, occlusal, and phonetic performance, as well as esthetics, a facially guided prosthodontic treatment sequence should be established. The case presented in this publication shows a multidisciplinary approach for reconstruction of a compromised maxilla with an implant-supported prosthesis via a minimally invasive, digitalized approach.


Facial clefts are complex congenital deformities that require precise treatment planning. Lip and palate clefts (CLP) are the most frequent type of facial malformations and are considered a public health issue by the World Health Organization, occurring in approximately 0.15% of newborn children. The prevalence of this condition varies from 1 in 500 to 1 in 2,500 newborns. In terms of development time, CLP tends to appear between embryonic weeks 4 and 12. The most affected community is the Asian population, followed by the American Indian population. These deformities can either be associated with a multiorgan syndrome, such as Pierre Robin syndrome, or be nonsyndromic, isolated lesions. The origin is unknown in most cases. Risk factors include smoking during pregnancy, diabetes, obesity, an older mother, and certain medications (eg, some antiseizure drugs).
Palatal clefts are defined as a nonunion of the maxillary bony areas. Among the various treatment options, it is generally accepted that reconstructive surgery is preferred over a prosthetic solution. It is usually necessary to perform several surgical interventions to achieve functional and stable closure of the cleft, starting soon after birth and continuing up to early adulthood. One of the main considerations is the balance between surgical reconstruction and growth.6 The goals of the cleft grafting approach are to close the oronasal/oroantral fistula;7 enhance facial esthetics by augmenting lip and nasal support;7 improve phonetics and nasal function;8 allow for an easier, prosthetically guided implant placement;9 allow for proper development and eruption of teeth in the fistular area;10 and prevent collapse of the bony support of teeth adjacent to the cleft area.7

Even though this protocol has a high success rate, it is not exempt from relevant drawbacks, namely morbidity and extended treatment time prior to dental implant placement or to the alternative treatment, a fully removable prosthetic solution.11,12 Along with the maxillary bone defect, most patients suffer from dental anomalies such as agenesis, tooth malformation and malposition,13 and a high prevalence of caries.14 An interdisciplinary treatment plan is indicated, as, apart from the bone and hard tissue reconstruction, orthodontic management in addition to a prostodontic treatment plan is essential. Due to the complex anatomy of the maxilla in these patients, a removable prosthesis may not be ideal. Thus, osseointegrated implants may be an adequate treatment option in these cases.15

Implant positioning should be dictated by the prostodontic requirements of the particular case. Correct 3D placement should not be based on bone availability but rather on the functional, biologic, and esthetic demands of the patient’s final prosthesis.16 Once this phase of the treatment plan is defined, it may be necessary to perform anatomical modifications, including possible soft and/or hard tissue reconstruction following the virtual future implant position. This has been defined as prosthetically guided implant placement.17–19

Guided surgery protocols were developed in order to improve implant placement accuracy.20,21 The main advantages of virtual surgical planning and execution have been described in the literature.22 They can be summarized in two aspects: First, the possibility to combine the radiologic information and the patient’s clinical anatomy together with the prosthetic reconstruction enables the dentist to visualize the treatment plan with much greater detail than with conventional methods. The virtual environment provided by the surgical software allows for detailed analysis of implant positioning, prosthetic design, and surgical needs. Second, the fabrication of a surgical template reduces the dependence on the surgical skills of the operator and optimizes the implant placement according to a predefined plan. The main advantages of the guided surgical approach are also clearly described in the literature: reduction in treatment time (faster surgery), better tissue preservation, reduced postoperative discomfort, possibility to avoid the need for grafting (anatomical exploitation), and a high level of accuracy.23

This case report presents the outcome of multidisciplinary treatment of a young adult suffering from a congenital malformation of CLP via a digital approach for full-mouth rehabilitation following the facial needs of the patient. The patient had previously undergone several cleft reconstruction procedures involving extraoral bony donor grafts, without completely successful bone defect closure. Previous dentists and maxillofacial surgeons had recommended another intervention aimed at reconstructing the large bony defect affecting the left anterior maxillary region prior to implant placement. However, the patient requested to be rehabilitated, avoiding a new attempt at defect grating. Special consideration of the fistular area was made; due to the unpredictable nature of oronasal fistulae, the team agreed that the area in contact with the fistula should be “modifiable.” This meant that, if need be, prosthetic material could be added (seal effect) or removed (ease of drainage). Due to this special consideration, a particular material choice and prosthetic design were chosen. The initial digital assessment allowed for detailed, facially guided surgical-prosthetic planning, including the design of the final prosthesis, material choice, and implant position.

**CLINICAL SEQUENCE**

**Diagnosis**

A 37-year-old male patient presented to the office with the chief complaint of wanting to improve the appearance of his smile and chewing ability, seeking complete oral function and esthetic improvement. The patient was classified as philosophical,24 motivated, and fully cooperative, or “ideal” according to the Gamer classification.25 He claimed to have a history of several surgical attempts at cleft closure at the hospital during childhood. Among his main requests was the avoidance of maxillofacial reconstruction of the current cleft situation. The patient presented with a CLP with incompetent lip closure, oronasal fistula in the anterior region corresponding to the area of the maxillary left lateral incisor, deficient and irregular anatomy of the maxilla, severely worn dentition in the maxillary arch and posterior mandibular teeth, skeletal Class III malocclusion, moderate crowding of the mandibular dentition, generalized mild gingivitis and plaque accumulation, and a mandibular left central incisor with severe periodontal apparatus insertion loss and suppuration, which had been splinted to the adjacent teeth. Due to the complex relationship...
between the patient’s maxilla and mandible, he had developed gastroesophageal reflux derived from his insufficient chewing capacity as well as his severe Class III malocclusion. This had probably led to an increase in the rate of erosion, especially in the anterior maxilla and posterior mandibular teeth26 (Fig 1). The maxillary posterior teeth suffered from severe crowding and caries.

The panoramic and CBCT examinations showed a bone defect in the maxillary anterior region and confirmed the clinical observations (Fig 2). Along with the suppurating fistula on the sulcus of the maxillary left lateral incisor, another fistula was present 5 mm palatal to the interincisal palatal papilla, around 2 mm in diameter. This secondary fistula was also suppurating but otherwise asymptomatic. Moreover, the posterior right sector of the maxilla also presented a continuity solution defect compatible with a cleft, although no fistula was present in that area.

The cephalometric analysis indicated the presence of a skeletal Class III malocclusion with dolichofacial growth and mandibular posterior rotation, along with mandibular prognathism and hypoplasia of the maxilla27 (Fig 3).

**Treatment Plan and Execution**

After a comprehensive analysis, only a few teeth in the maxillary arch were diagnosed to have a good prognosis (molars and left canine).28 Periodontal support was not an issue, but the level of acidic erosion and/or caries...
affection was severe in many maxillary teeth. Thus, keeping those teeth would have compromised the overall rehabilitation plan, as it would have meant restoring several teeth with a limited amount of remaining tooth structure, thereby affecting the overall long-term prognosis of a tooth-supported restoration. On the other hand, those tooth areas were adequate bony sites for implant placement, thus avoiding the need to perform major bone reconstruction procedures in posterior sectors and thus simplifying the treatment for this patient.

A digital study of the smile allowed for the creation of an esthetic prototype. This permitted the team to visualize the ideal final prosthesis as well as highlight the esthetic and functional challenges that the patient presented. The patient was offered a complete removable prosthesis and an implant-supported restoration. Thus, after discussion of the treatment options with the patient, a full-arch fixed implant-supported rehabilitation (full-arch fixed dental prosthesis [FAFDP]) was selected as the most adequate solution for the maxilla. An overdenture was rejected, as there was no need for additional lip support from a vestibular flange, and the patient presented with an adequate level of oral hygiene. In the mandible, an orthodontic treatment was chosen to address the discrepancy between the large mandible and the small maxilla, to regularize the occlusal plane, and to improve the crowding in the anterior sector. Due to the large size of the mandible, a cross bite was planned for the posterior sectors, as the aforementioned size difference would not allow for a buccal overlap of the maxillary buccal cusps over the mandibular ones.

One of the key goals of the final treatment was to provide the patient with a highly biocompatible prosthetic solution that was also mechanically resistant. The prosthetic design and material selection accounted for two main possible complications: First, the fistula in the area of the maxillary left lateral incisor could become symptomatic in the future. This is the reason why resin gingiva was chosen, as it is modifiable chairside. Thus, the area of the prosthesis in contact with the fistula can be altered to apply or release pressure in that area. To have an adequate level of adhesion of the resin to the rest of the prosthesis, a titanium mesostructure was chosen. Second, due to the age of the patient, common mechanical complications such as chipping or zirconia fracture are to be expected in the long term. A cross-arch structure was chosen splinting all the maxillary implants, as the fistular area and the other defect sites in posterior sectors meant that there were large spans where implants could not be placed. In order to deliver a multiple, separated fixed partial denture (FPD) solution, the final number of implants would have probably been higher and closer to each other, hence increasing the risk for peri-implantitis due to a more complex and difficult-to-clean architecture. Thanks to the sectional zirconia FPD approach, repairs will not require removal of the whole prosthesis, but rather refabrication of the affected FPD.

To deliver the maxillary prosthesis, the maxillary teeth had to be extracted. Due to the compromised shape of the maxilla, which included a deep fossa along the central portion of the central palatal raphe and an irregular vestibular depth, a removable transitional prosthesis was not recommended. Five teeth were kept as transitional abutments, and a provisional resin transitional prosthesis was delivered (Fig 4). After 4 months of healing and observation of the fistular behavior, the patient was deemed ready for the next step.

Extraction of the mandibular left central incisor was planned in order to maintain the straight profile and to relieve the mandibular anterior crowding because there was a tooth-size to arch-length discrepancy of > 4 mm in the mandibular arch.29 When placing the fixed appliance in the mandible, during the first phases of alignment and leveling, the mandibular teeth were expected to protrude excessively and make the Class III malocclusion more evident.30 Therefore, arches with a low force had to be placed from the beginning due to the bony defect after the extraction.

Fig 3 Cephalometric analysis. The orthodontic treatment plan was incorporated from the beginning for correct alignment and leveling of the mandibular arch, taking into account that crowding of the incisors had to be addressed because the maxilla was going to receive a fixed implant-based prosthesis. The cephalometric reference of the maxilla established the need for retrusion of the mandible.
A new set of records allowed for the creation of a new esthetic prototype, following the guidelines of the original one (Fig 5). This prototype would guide the future final maxillary restoration, as well as the orthodontic project for the mandible. A new CBCT was taken, and both the patient’s digital impression and prototype were integrated into a guided surgery software (NobelClinician, Nobel Biocare). The implant positioning was planned according to the prosthetic plan comprehended in the prototype. Due to the patient’s anatomy, only the gingiva in the first quadrant was visible when smiling. Taking the patient’s asymmetric gummy smile into consideration, and since the final prosthesis would be a cross-arch, fixed, implant-supported FPD, a den- toalveolar approach was elected. A tooth-supported guided surgery template was fabricated for the placement of five implants in the first stage, and two additional implants would be placed at the final surgery (NobelClinician, Nobel Biocare). Five implants were placed (Nobel Biocare; Nobel Parallel CC 4.3 × 13 mm on both maxillary second molars, NobelReplace CC PMC 4.3 × 13 mm on both maxillary right premolars, and Nobel Replace CC PMC 4.3 × 11.5 mm on the maxillary right lateral incisor and both maxillary left premolars), and healing abutments were placed at the same intervention (Fig 6). The provisional tooth-supported resin FPD was modified and recemented.

After 6 months of healing, transepithelial multiple-unit abutments were placed, and an abutment-level impression was taken. An implant-supported provisional was fabricated (Fig 7). The remainder of the maxillary dentition was extracted, and two implants were placed in the distal aspects utilizing the initial surgical guide. A particulate xenograft was placed around the immediately placed implants (Bio-Oss, Geistlich Pharma).

The mandibular right third molar was extracted due to the overall prosthodontic strategy (occlusal interference), and an osseointegrated implant was placed on the site corresponding to the right second molar (NobelParallel 4.3 × 13 mm, Nobel Biocare). The anterior mandibular sector was restored via direct composite resin veneers upon completion of the alignment.
Once the orthodontic treatment was finished, indirect composite restorations were created for the posterior sectors of the mandible to restore the severely worn posterior dentition. A facebow record was produced. Final impressions were taken using polyvinyl siloxane (PVS). To transfer the vertical dimension, centric relation, and esthetic parameters to the lab technician, once the cast was produced, the provisional prosthesis was used as a reference for the craniomaxillary transfer (Fig 7). The final prosthesis was fabricated as decided in the preoperative plan: a milled titanium mesostructure, monolithic zirconia FPDs in the posterior sector, and porcelain-veneered zirconia FPDs in the anterior sector. Lastly, the gingival areas were created using composite resin (see Figs 10 and 11).

The orthodontic treatment left a pronounced curve of Spee on the patient’s lower left side. This could lead to interferences and consequent dynamic occlusal complications. However, no interferences were present once the mandibular teeth restorations and maxillary final prosthesis were delivered.

Prosthesis Fabrication Process
The design of the titanium bar followed that of the esthetic try-in. Thus, a silicone index was made over the wax-up try-in. Scanning for the CAD/CAM customized titanium suprastructure was performed using a desktop scanner (KaVo LS3, KaVo Dental). The CAD/CAM titanium suprastructure was milled (NobelProcera, Nobel Biocare; Fig 8). The implant master cast was mounted.
in the articulator, and the titanium suprastructure was placed on the mounted master cast to verify the available space for milling of the zirconia crowns. The framework was then tested in the model, and passive fit was verified. A digital tooth library from the CAD/CAM software was used for the initial design of the crowns. Individual adjustments were performed according to the desired esthetic and occlusal needs for this case. The occlusal and palatal monolithic design ensures the longevity of the implant restoration, and ceramic microveneering was applied on the buccal aspect of the six anterior teeth. This software allows the on-screen visualization of the dioxide zirconium crowns and FPDs, making the designed crowns transparent to better judge the available occlusal space and thickness of the zirconia crowns.

A mutually protected occlusion scheme was designed for this patient.

Zirconium dioxide has a high modulus of elasticity. It has a color similar to teeth, is semitranslucent, and is one of the highest-performance materials in dental technology. The flexural strength of 3Y-TZP (yttria tetragonal zirconia polycrystal) is approximately 1,200 MPa. The microveneering ceramic for this case was VITA VM 9 (VITA Zahnfabrik). Characterization of the sintered structures was carried out with VM 9 ceramics (VITA Zahnfabrik; Fig 9).

A light, hygienic, convex contact with the patient’s gingiva was chosen, following the main principle from the patient of ease of maintenance. A try-in of the bisque bake not only allows the patient to approve the results so far but also represents the ideal phase for precisely adjusting both occlusal surfaces and, especially for this case, lip support.

Minor finishing touches and characterization can be applied during glaze firings with the use of staining (AKZENT Stains, VITA Zahnfabrik). These stains offer natural-looking 3D effects. The goal of the glazing layer (VITAVM 9, VITA Zahnfabrik) is to minimize roughness and wear against the opposing arch.

It is recommended to use a universal primer promoting an adhesive bond between luting composites and all indirect restorative materials; in this case, titanium. The primer serves a bonding agent and is used to create a durable chemical bond between the titanium suprastructure and the zirconia restoration. The titanium bar is sandblasted until an even matte surface has been
Fig 10  (a to c) Finished prosthesis showing the combination of materials: milled titanium bar, zirconia FPDs (with ceramic veneering on the buccal aspect of the anterior teeth), and composite resin in the gingival area. Note also the convex, hygienic design.

Fig 11  (a and b) Final prosthesis in situ. (c) Panoramic radiograph at the 2-year follow-up. Note the distinct radiographic densities of the different materials of the maxillary prosthesis.
achieved. Zirconium oxide was sandblasted according to the instructions of the manufacturers and rinsed with water spray. A thin coat of primer was applied to the pretreated titanium bar and the zirconia crowns. The zirconium dioxide restoration was bonded to the top of the titanium superstructure using a self-curing dental luting composite.

Last, the pink wax was replaced by pink composite (VITA VM LC and VITA VM LC Flow, VITA Zahnfabrik).

After the orthodontic treatment, indirect hybrid ceramic resin onlay restorations (VITA Enamic, VITA Zahnfabrik) were fabricated for the posterior sectors of the mandible, and a monolithic zirconium oxide crown was delivered at the mandibular right second molar implant. Occlusion and posterior support are of paramount importance for the long-term survival of restorations.

The final prosthetic delivery was performed 18 months after the first visit. Check-up appointments were performed at 6, 12, 18, and 24 months postdelivery. Dental hygiene procedures were performed at such appointments, as well as oral hygiene instructions and occlusal and radiographic assessments. Because the patient refused to use a Michigan night guard, an Essex occlusal protection splint was delivered.

**DISCUSSION**

Treatment planning is probably the most crucial and defining step of a patient’s treatment outcome at the dentist. In particular, patients suffering from a complex anatomical condition such as CLP greatly benefit from a comprehensive approach. The morphologic alterations in patients with CLP are related to a high degree of plaque retention and thus to a higher level of incidence of caries, periodontitis, and other dental diseases. Patients suffering from CLP have been reported to have higher hygienic difficulties compared to those who only suffered from cleft lip (palate not involved). CLP patients often undergo numerous reconstructive procedures during childhood, which are mandatory in order to obtain a high level of oral health–related quality of life (OHRQoL) but may not achieve complete closure of the intraoral defect in every case. A prosthetic solution is often necessary and can greatly improve the patient’s OHRQoL. The reason for this need is compromised phonetic, respiratory, and feeding functions. A removable prosthesis can be considered; however, the functional improvement brought by a fixed solution is greater compared to a removable device.

The patient in this case report had been advised to be treated via a conventional bone augmentation procedure. One option that was recommended to the patient was a new iliac crest graft. However, the patient established in the first visit that he did not want to undergo any further major surgical interventions. One of his requests was to have a fixed solution. This is a valid treatment option for CLP patients in accordance with the scientific literature. The planning and production of the definitive restoration first involved the preparation of a diagnostic setup. This setup was based on parameters to satisfy the very demanding esthetic indications. A wax try-in was initially created following lip support, facial integration, and functional optimization. Phonetic principles are an important but often-forgotten issue and were of utmost importance in this case. Even if a person loses their teeth, their speech pattern is still existent. The speech pattern is directly dependent on the position of the anterior teeth; this means that the anterior tooth position should not only follow esthetic concerns but also phonetics, particularly when a speech alteration is present. The difficulty in pronouncing certain sounds due to implant-supported restorations lies at the phonetic level, where the tongue sometimes has difficulty achieving the correct position. It may happen that the tongue touches the front teeth excessively. In this situation, instead of the “s” sound, only “th” comes out. When producing an “f” sound, the incisal edges of the maxillary anterior teeth should meet at the transition zone from the moist-to-dry lip region. In the present case, the patient’s initial phonetics were severely compromised. By the end of the treatment, there was a considerable improvement in this regard, although the short nature of the patient’s cleft lip, as well as the shape of the palate and change from Angle Class III to Class I malocclusion, required a phonetic learning process for this patient.

The orthodontic treatment aimed for an ambitious degree of compression of the mandibular arch in the transversal dimension. A nonextraction treatment plan could have been performed using a self-ligating appliance, but this could have resulted in excessive proclination of the mandibular teeth. The whole rehabilitation was guided by the position of the anterior maxillary sector. This followed the aforementioned facial projection, and thus, the mandibular incisor needed to be extracted to provide space for a lingualized alignment. In the posterior sectors, it was not possible to achieve a normal transversal occlusion, and a cross bite was left. It would have been possible to overlap the buccal cusps of the maxillary molars buccal to those of the mandibular molars, but that would have meant that the buccal corridors would have been filled in excess, creating an esthetic compromise or “denture appearance.”

The kind of solution for CLP patients mostly depends on the size of the defect. Although it is usually preferred to close the anatomical malformation surgically, large clefts may require a prosthetic solution, especially in older patients. In the case of a fully removable solution, the goal should be to close the possible communication between mouth and nose and/or sinus (obturator prosthesis). The clinician must consider an implant...
overdenture in these cases to improve retention. It is possible to fabricate an overdenture with unconventional attachment systems, such as magnets. Unfortunately, implant longevity in CLP patients is somewhat inferior to non-CLP subjects, with a 5-year survival rate ranging from 80% to 96% with a mean of 88.6%. A plausible cause for this reduced survival might be poor bone quality in areas around the cleft or large cantilever areas due to lack of bone. Other alternative treatments include fixed, tooth-supported prostheses (conventional FPD), adhesive solutions such as Maryland bridges, or even precision prostheses such as telescopic bridges and/or dentures.

The manufacturing of full-arch implant-supported FPDs with the use of the traditional lost-wax technique remains a technical challenge with inconsistent results. Distortion of the gold-platinum alloy during casting and deformation in the ceramic furnace during ceramic firing causes numerous problems. In contrast, computerized engineering technology is related to consistent precision and reproducible production results in a streamlined work process. The establishment of CAD/CAM technology has been of great aid for the production of implant-supported suprastructures by means of digital designing with dental software applications. The fitting problems can be easily eliminated by utilizing CAD/CAM technology, especially in the manufacturing of long-span titanium FPDs. Titanium has been used extensively as an implant material due to its high strength, high fatigue limit, good compatibility, and excellent corrosion resistance. The suprastructure guarantees a long-term stability due to its high fatigue limit.

The advantage of using a titanium infrastructure and cemented zirconia FPDs is that the suprastructures, including the most complex ones, do not suffer deformation during sintering or during firing ceramics in the furnace. Firing ceramics on precious alloys causes tension and deformation on long-span implant-supported FPDs, especially those with a large volume. The biocompatible titanium suprastructure described previously guarantees stability, and the full-contour zirconia crowns in the posterior sectors avoid possible ceramic chipping.

One of the most complex and time-consuming aspects of the previously described treatment is the transfer of clinical information to the lab technician. The maxillary-mandibular integration was the most difficult aspect to visualize. This full-mouth rehabilitation counted on the stability of the oronasal fistula after extractions, the orthodontic compression of the mandible and integration with the maxillary prostheses, and the adaptation of the patient from a severely dysfunctional occlusion to a mutually protected guidance. The initial analog process implied a first acquaintance visit; a second one for photographs, impressions, and radiographs; a third one for record base try-in and border molding; and fourth, fifth, and sixth visits for try-in assessment prior to final treatment proposal. New protocols such as facial scanning and smile design may contribute to the efficiency of the diagnostic phase and clinician-technician communication. This can considerably accelerate the orofacial visualization of any given treatment plan, as it notably enhances the clinical-technician collaboration.

CONCLUSIONS

Treatment of CLP patients is a prime example of the need for a comprehensive multidisciplinary approach. Involvement of the restorative and technical team should begin in the first appointments. A facially driven treatment plan will guide the way for a more predictable coordination of the clinical resources and treatment execution to improve the patient’s quality of life and to provide a long-lasting rehabilitation with an esthetic and functional outcome.

REFERENCES


