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Multidisciplinary Planning in Orthognathic Surgery for Prosthetic Patients

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Abstract: The correction of malocclusions with severe skeletal deformity generally requires surgery combined with orthodontic or prosthodontic treatment; partially or totally edentulous patients, and patients with a prosthetic fixed crown, represent treatment restrictions and, therefore, challenges. The purpose of this study is to show a complete multidisciplinary approach and the planning involved (pre-, intra-, and post-operative) for a patient with a class-II or -III dento-skeletal malformation, who presents a total or partial edentulism or a fixed-type rehabilitation and, therefore, requires a combined orthognathic surgical treatment with prosthetic rehabilitation. Orthognathic surgery can be performed on an edentulous or prosthodontic patient to correct discrepancies between the jaws, followed by the placement of implants or a mobile prosthesis to rehabilitate the maxillary bones maxillary Different surgical approaches and technical variations have been proposed; however, the key to the success of such treatments lies in the multidisciplinary nature of the entire diagnostic, programmatic, and therapeutic path, which, therefore, necessitates close collaboration between different specialists—in particular, the maxillofacial surgeon, the orthodontist, and the prosthetist.

Keywords: orthodontics; class-III malocclusion; class-II malocclusion; surgical-orthodontic treatment; oral and maxillo-facial surgery; dental rehabilitation; prosthodontics; dental implants; fixed implant-supported prosthesis

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1. Introduction

The occlusal and aesthetic rehabilitation of jaw deformities in patients with a partially or totally edentulous maxilla is a challenging procedure [1]. Class-III malocclusion is characterized by a variety of skeletal and dental components, including a large or protrusive mandible, retrusive maxilla, protrusive mandibular dentition, retrusive maxillary dentition, and combinations of these components [2]. Class-II malocclusion is often characterized by a deficient mandible, leading to a convex profile, unaesthetic facial proportions, and occlusion disharmonies. Class-II malocclusion has been further subdivided into division1 (div.1) and division 2 (div.2), depending upon the upper incisors' proclination or retroclination, respectively, although additional skeletal and dental differences exist between the subdivision types beyond upper incisor angulations [3]. The correction of malocclusions with a severe skeletal deformity generally requires surgery combined with orthodontic or prosthodontic treatment. An orthodontic camouflage or a pure prosthetic treatment may result in an unsatisfactory, unstable, and irreversible outcome [4,5]. In cases of total or partial edentulism, a satisfactory reconstruction cannot be achieved via dental rehabilitation alone: to restore function and aesthetic balance, such patients require corrective jaw surgery. In orthognathic surgery planning for edentulous patients, prosthetic restoration is often a compromise between the ideal restoration for stability and function on one hand, and aesthetics and appearance on the other hand [6].

In these cases, an interdisciplinary approach between the oral and maxillofacial surgeons guarantees a result that restores the aesthetics, function, and balance of the oral cavity and contributes significantly to improving the self-confidence and psychosocial well-being of the patient. The scientific literature has already discussed orthodontic treatment in edentulous patients.

In 1951, Kazanjian described the treatment of mandibular prognathism, with special reference to edentulous patients: his approach included extraoral ramus osteotomy associated with the use of splints anchored to a cranial mask (to ensure adequate immobilization) and intraosseous sutures [7]. In 1953, Van Alstine and Dingman described the treatment of prognathism in edentulous patients with an osteotomy of the body of the mandible, fixed with intraosseous sutures, and the use of acrylic splints, fixed with circumferential sutures, to place the mandible in a favourable position [8] (Figure 1).

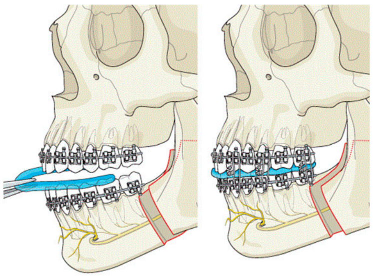


Figure 1. Application of the splint after a sagittal osteotomy to guide the surgeon in correct mandibular repositioning.

In 1954, Caldwell and Letterman established the extraoral vertical ramus osteotomy (EVRO) technique to treat prognathism, a technique later modified in 1970 by Hebert, Kent, and Hinds into the intraoral vertical ramus osteotomy (IVRO) technique commonly used by today's surgeons [9].

In 1952, Obwegeser started developing the bilateral sagittal split osteotomy (BSSO) to treat mandibular prognathism and retrognathia; perhaps the most astounding aspect of this technique is that the first 15 cases were reportedly treated under local anaesthesia and in a dental chair [10].

A malformed, or partially or totally edentulous patient's treatment goal is functional and aesthetic oral rehabilitation, and it is, therefore, essential to consider this aspect in orthodontic planning. For this reason, evaluation with traditional orthodontic X-ray and cephalometric studies should be combined with traditional prosthetic studies, such as the assembly of the models in the articulator, diagnostic digital wax-up, computer analysis via 3D CT, virtual design, or the processing of surgical splints. In most orthognathic procedures, a surgical splint is an integral part of surgery, guiding the surgeon to position the maxillofacial skeleton in a pre-established ideal position. In addition, the position of the teeth and occlusion help guide the surgical movements. In partially or totally edentulous patients, these splints are even more important, as there may not be enough teeth to help guide the surgical movement of the jaw.

With recent advances in 3D imaging, computer-assisted surgical planning and simulation are now routinely used not only for the analysis of craniofacial structures but also for accurate predictions of the surgical outcomes. The currently available literature regarding the use of 3D-printing methods in orthognathic surgery includes 3D computer-aided design (CAD), computer-aided manufacturing (CAM), rapid prototyping, additive manufacturing, 3D printing, printed models, surgical occlusal splints, custom guides, models, and fixation plates. Lin and Lonic state that the use of 3D printing methods in orthognathic surgery offers the advantage of optimal functional and aesthetic results, patient satisfaction, and precise translation of the treatment plan [11]. Unfortunately, in this work we have the potential of digital and 3D imaging only in the planning part, using digital software (Dolphin Orthodontics) for surgical VTO and cephalometric analysis, and for the fixed prosthetic rehabilitation using optical impressions and CAD/CAM equipment. The surgical phase was completely carried out according to traditional techniques. Our future goal is to use digital and 3D imaging and printing, making use of both CAD and CAM technologies.

This study aimed to show a complete multidisciplinary approach for the patient with II or III dento-skeletal malformation, who presents a total or partial edentulism or a fixed-type rehabilitation and, therefore, requires a combined orthognathic surgical treatment with prosthetic rehabilitation: this work attempts to illustrate this multidisciplinary approach and planning (pre-, intra- and post-operative) through the analysis of the cases treated in the Implantoprosthesis Department of the Policlinico Umberto I of Rome, classifying them according to Kennedy's edentulism classes (Figure 2) and indicating for each clinical case the correct design approach.

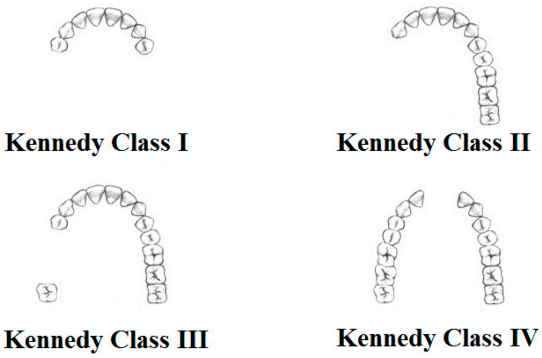


Figure 2. Kennedy's Edentulism Classification (KC): class I—Bilateral distal edentulism; class II—Unilateral distal edentulism; class III—Lateral intercalated edentulism; class IV—Median intercalated edentulism.

2. Materials and Methods

This study is a single-institution retrospective review. It was conducted on 17 patients (6 males and 11 females, with an average age of 60 years), presented in our Implantoprosthesis Department of the Policlinico Umberto I of Rome between 2014 and 2023. All patients were informed about the procedure and rehabilitation protocol and all patients gave their informed consent for inclusion. Inclusion criteria are (1) patients with a malocclusion of II or III dental-skeletal class due to maxillary and/or mandibular skeletal malformation in conjunction with total or partial edentulism or with fixed-type prosthetic rehabilitation; (2) patients prosthetically rehabilitated in Implantoprosthesis Department of the Policlinico "Umberto I", Rome; (3) complete clinical and radiological documentation. Exclusion criteria are patients with systemic diseases, smokers, and cancer patients treated with radiotherapy or bisphosphonates. In total, 17 patients satisfied our inclusion criteria and were therefore included in this study, with different types of dento-skeletal malocclusions, different types of edentulism, and the presence or not of fixed crowns for rehabilitation (Table 1).

Table 1. Classification of patients enrolled in this study.

Dento-Skeletal Angle Class	Number of Patients		
	Total Edentulism	Partial Edentulism with Kennedy Classification	Fixed Crowns for Rehabilitation
Type II	1	2 with I KC 1 with IV KC	1
Type III	2	4 with I KC 2 with II KC 1 with II KC	3

2.1. Rehabilitation Protocol

Occlusal stability in the immediate post-operative period is a fundamental factor in the pre-operative planning of orthognathic surgery. This principle applies both to patients with natural teeth and to partially or totally edentulous patients and it is the main factor guiding the entire treatment [12,13]. There are multiple factors involved in denture stability: for instance, the anteroposterior relationship of the maxilla and mandible affect the stability of the denture. The stability of class I maxillo-mandibular relationship is generally more than those of class II or III. Appropriate positioning of the jaw requires a clinical assessment of zygomatic regions, paranasal area, and nasolabial angle and it follows the general examination of the facial profile by the surgeon. Spray splints are an excellent fastener and are relatively quick and easy to apply for edentulous patients [6].

A clear distinction must be made between patients whose vertical dimension can be supported by their dental elements and those whose primary stability is not guaranteed by their natural dental elements [14–16].

Patients who could base occlusal stability and vertical dimension on their own elements are those with Kennedy class III and IV; conversely, this condition cannot be obtained by patients with total edentulism, with partial edentulism in the posterior sectors (Kennedy class I and II) and patients with fixed prosthesis.

Therefore, in this study, we distinguish two groups of patients. This distinction is not only important for the final prosthetic rehabilitation, but it leads the whole therapeutic plan. Indeed, for each edentulous patient, it was necessary to obtain a partial or total prosthesis, depending on the clinical case, and to base on it the primary stability of the occlusal complex in the immediate postoperative period. Instead, for patients with fixed prostheses, it was first necessary to perform temporary acrylic resin prostheses according to the current vertical dimension and, later, after the complete assessment of cephalometric and surgical VTO (Visual Treatment Objective), it was possible to produce new temporary prostheses, based on the occlusal conditions of the patient after surgery. The final prosthetic rehabilitation can be provided after a minimum of 6 months.

A fundamental aspect of the pre-surgery planning for the edentulous patient is represented by the study of the function of the Temporomandibular Joint (TMJ) [17]. This aspect has been studied in all 17 patients, first clinically and later through instrumental investigations, such as open and closed mouth TMJ CT.

To limit any post-surgical consequences, the treatment of joint dysfunction is always performed before orthognathic surgery. Once the TMJ disorder has been treated and the temporary prostheses are in place, the patient is ready for surgical treatment. For each patient, models' assembly in the articulator is performed to evaluate the three-dimensional inclination of the upper jaw. After evaluating the relationship between the jaw and the Frankfurt plane, the bi-pupillary line, and the smile line, it is possible to correct these parameters according to the correct cephalometric values, in anticipation of surgical treatment [18]. Once the position of the upper jaw is stable, another cardinal aspect of planning is to determine the correct position of the lower jaw. Two elements guide the achievement of this important task: adherence to the class-I of Angle and occlusal stability. Therefore, it is necessary to individually analyse the different clinical cases in detail to get the most accurate work plan.

2.2. Totally Edentulous Patients

In this study, 3 totally edentulous patients decided to undergo jaw repositioning surgery due to bone atrophy, following tooth loss, which greatly worsened Angle's Class III condition. In these cases, it is important to distinguish between class III due to the physiological reabsorption resulting from the loss of teeth with the actual vertical and sagittal malformation: cephalometric diagnosis and clinical study are essential for this assessment. Therefore, it is first necessary to balance any bone difference due to different levels of reabsorption of alveolar ridges. These values are measured according to the Cawood and Howell classification [12,19]:

Class I: Presence of teeth;
Class II: Immediately post-extraction;
Class III: Well-rounded ridge form, adequate in height and width;
Class IV: Knife-edged ridge form, adequate in height and inadequate in width;
Class V: Flat ridge form, inadequate in height and width;
Class VI: Depressed ridge form, with some basilar loss evident.

This procedure must be done by building flat joint bases that do not follow the residual bone ridge. Then, the prosthetic elements are assembled: as in any prosthetic assembly, these must always be ideally mounted following the bone crest as a parameter [20,21]. In addition, it is very important that the upper midline follows the palatine raphe of the upper jaw (which coincides with the nasal spine), and that the inferior midline follows the centre of the chin. This allows the surgeon to place the jaw in the centre of the face during the intraoperative phase, after stabilizing the jaw according to the cephalometric parameters previously assessed. Once the group of the upper and lower front teeth has been assembled according to the above assessments, the vertical dimension can be determined. This is done first by assembling the elements of the upper prosthesis according to the future Frankfurt plan and then mounting the elements of the lower mobile prosthesis [22–24]. Logically, the parameters for the assembly of these prosthetic elements are those followed for the assembly of a normal mobile prosthesis with respect to the anatomical curves of Spee and Wilson.

Edentulous patients are certainly the most complex cases to treat, due to the use of mobile prostheses to plan their surgery; however, the possibility of using both the dental portion and the gum portion of the prosthetic device provides, provides the prosthetist with the elements to improve the best aesthetic result.

2.3. Partially Edentulous Patients: I and II Kennedy Class

These cases, compared to the previous ones, have some advantages: they provide some important parameters in the determination of the median line and, in the case of Kennedy's classes II, also of the vertical dimension. The evaluation of bone atrophy of the jaws is fundamental, as for edentulous patients [25,26]. In case of bilateral atrophy (Kennedy's I class), it is always recommended to level the bone planes by filling, if necessary, the discrepancy on the models with pink resin, before proceeding with the prosthetic assembly of the dental elements according to Angle's first class; only after that, it is possible to proceed to the identification of the occlusal plane. This puts the dental elements on the same plane; otherwise, they can be staggered causing a malposition of the skeletal bases and, consequently, a final facial misalignment.

2.4. Partially Edentulous Patients: III and IV Kennedy Class

In these cases, the presence of natural dental elements preserves the vertical dimension. Therefore, defining intermaxillary relationships is less difficult than in previously studied cases. However, there are critical problems, due to the determination of the correct midline and the first-class dental relationship. To minimize the risk of error, diagnostic waxes of the edentulous sectors are also performed in these cases. For the case of Class III of Kennedy, it is possible to determine the right dental relationship by identifying the correct position of the midline. In the case of Class IV of Kennedy, the correct intermaxillary relationship is established to ensure that the vertical dimension, guaranteed by natural dental elements, is not distorted by the rotation of mesial teeth; since this condition has occurred, the vertical dimension had to be raised by 1 mm. For both cases, the production of partial resin prostheses (following established relationships) is combined with the study of diagnostic wax, to ensure the surgeon has the correct mandibular ratio and to help him identify the correct midline.

2.5. Patients with Fixed Prosthetic Crowns

The vertical dimension is guaranteed by the support of natural elements in the posterior sectors. In these cases, there are two possible strategies. The first route involves the production of surgical splints that guarantee occlusal stability during the stages of intraoperative surgery; however, this way does not guarantee the necessary stability once the splint is removed from the oral cavity at the end of the surgery. The second route involves the production of new temporary resin crowns built based on proper surgical planning; these are fixed in the mouth before surgery and are not removed for six months after [27].

In the cases examined in this work, the second technique is followed: temporary crowns are made earlier and are fixed to the teeth the day before surgery to reduce the risk of any decementation. Even in these cases, the modelling of temporary restorations must consider all the classic gnathological rules. In fact, the anatomical curves of Spee and Wilson and the Frankfurt plane for the upper jaw and the mandibular profile for the mandible (in determining the correct occlusal plane and the vertical dimension) guide the design of the occlusal plane [28].

3. Results

For each case, instrumental evaluations are performed: orthopanoramics (OPT), Latero-Lateral (LL) and Antero-Posterior (AP) teleradiographs, 3D Cone Beam CT (CBCT). More specifically, the CBCT scans were performed both with and without the diagnostic prostheses: this was done to allow for the 3D evaluation of the relationship between the prostheses and the skeletal bases before the surgical phase (if necessary). Lastly, a CT of the condyles in both open and closed positions was performed. VTO and cephalometric analysis are always performed before and after surgery [29,30] (Figure 3). The preliminary study and design phase was carried out digitally using 3D software (Dolphin Orthodontics software) while the fixed prosthetic rehabilitation using optical impressions (digital scanner) and CAD/CAM equipment. The surgical phase, on the other hand, was carried out according to traditional techniques.

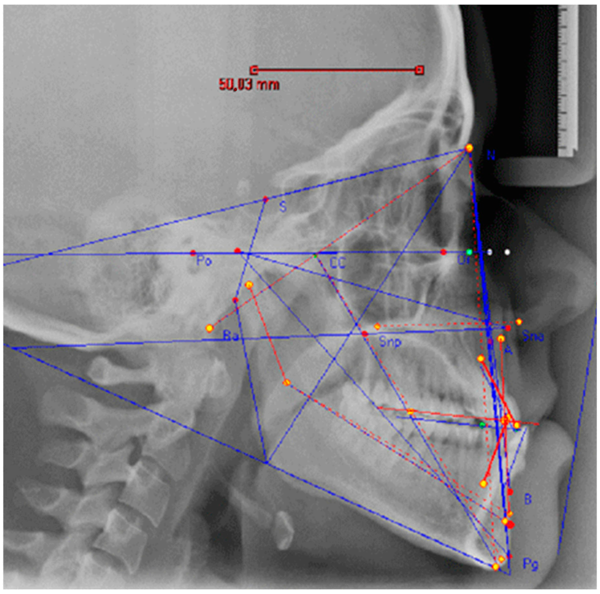
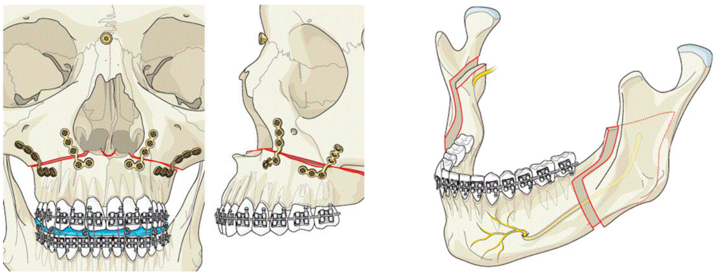


Figure 3. VTO and cephalometric analysis: N—nasion; S—sella; Po—porion; Or—Orbital point; CC—craniocranical point; Ba—basion; A—subspinal point; B—supramental point; Pg—pogonion. Different color lines have been used to make the image easier to read.

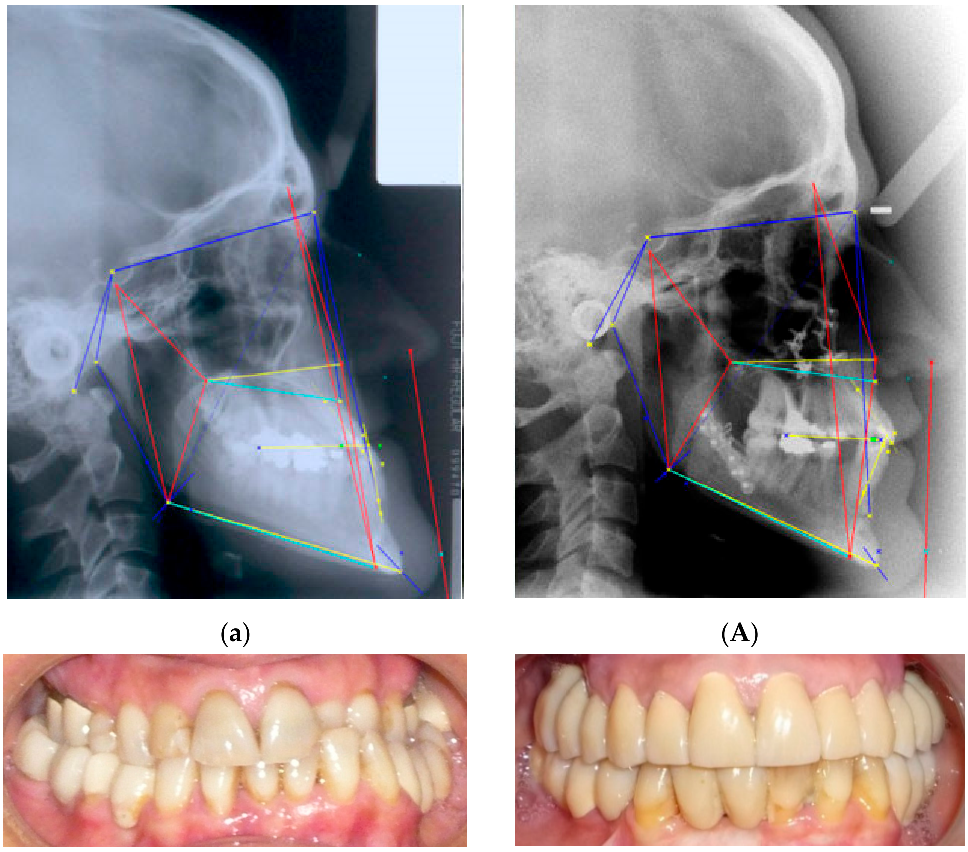
In the case of total edentulous, the fracture of a plaque is observed during the sedimentation phase, and this causes a recurrent displacement of the mandible; however, a first dental class of Angle is obtained.

In one out of four patients with fixed crowns, prosthetic rehabilitation is not completed for both arches because the patient died prematurely during the finalization stages due to non-oral comorbidities. For each case, a complete surgery of LeFort I osteotomy and BSSO is performed (Figure 4). In 12 out of 17 cases, prosthetic work is finalized with implant-supported prostheses (implants used are "Zimmer Trabecular Metal" manufactured by Zimmer Dental Inc. 1900 Aston Avenue Carlsbad, CA, USA). The remaining five cases are finalized with removable prostheses (Figures 5–7).



(**a**) (**b**)

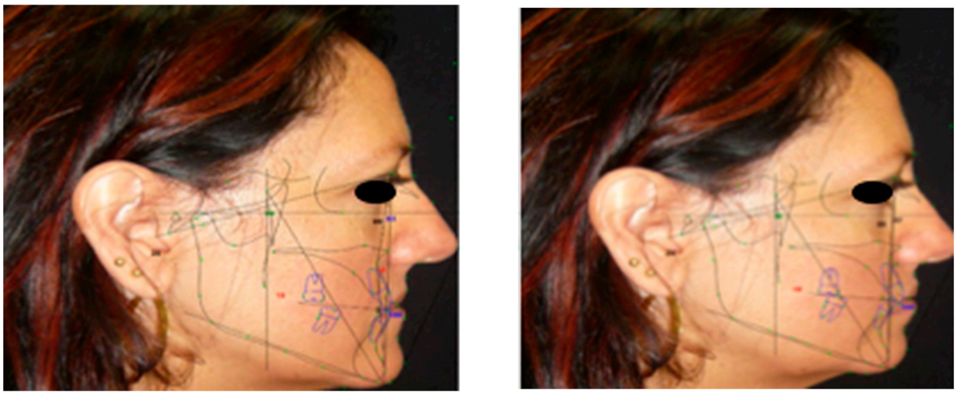
Figure 4. LeFort I Osteotomy (**a**) and BSSO (**b**).



(**a**) (**A**)

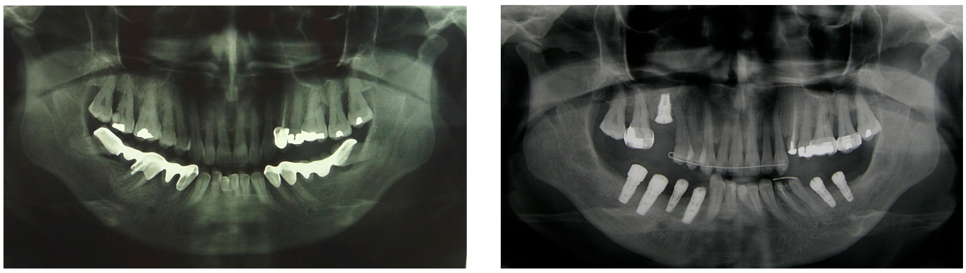
(**b**) (**B**)

Figure 5. *Cont.*

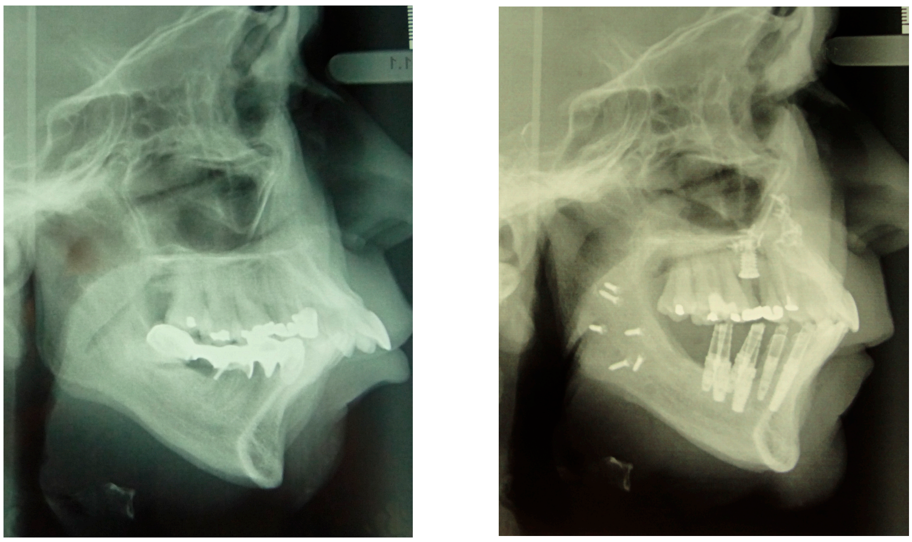


(**c**) (**C**)

Figure 5. A 45-year female patient with III dento-skeletal malocclusion, bilateral cross-bite, and TMJ's dysfunction: VTO and intraoral views before (**a**–**c**) and after orthodontic surgery and new prosthetic rehabilitation (**A**–**C**). Different colored lines were used to facilitate comparison between the two pre- and post-treatment images.



(**a**) (**A**)



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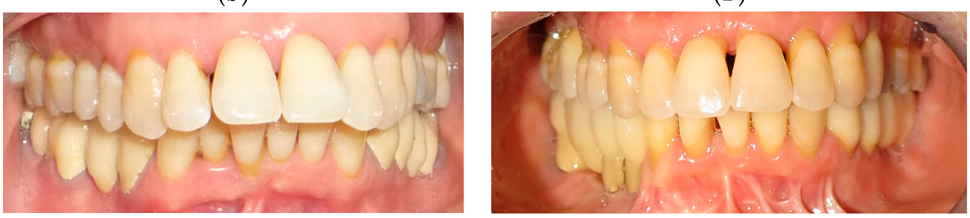

(**c**) (**C**)

Figure 6. *Cont.*


(**d**) (**D**)


(**e**) (**E**)

Figure 6. A 40-year female patient with II dento-skeletal malocclusion: orthopanoramic, VTO, and intraoral views before (**a**–**e**) and after orthodontic surgery and new prosthetic rehabilitation (**A**–**E**).


(**a**) (**b**)

(**c**)

Figure 7. A 46-year male patient with III dento-skeletal malocclusion and extensive IV Kennedy's class, caused by myeloid leukemia: intraoral view before orthodontic surgery, without (**a**) and with temporary prostheses (**b**), and after surgery and rehabilitation treatment (**c**).

During the surgical and prosthetic rehabilitation phases, no significant difference was found for the purposes of the result in relation to gender and age. Clinical manifestations following orthognathic surgery, such as swelling, may have varied in individual patients. However, these common complications remained within a normal range and therefore were not sufficient to compromise or complicate healing and the following rehabilitation.

All patients are monitored over time, so an average follow-up of 24 months is recorded from the end of the prosthesis without surgical or prosthetic complications. Three of the five patients who received the removable prosthesis expressed a desire to perform a fixed prosthesis.

4. Discussion

For patients with skeletal malocclusion who are still in the growth period, orthodontic treatment that takes advantage of growth modification should be considered as the first option for the correction of the underlying skeletal deformity. However, if the patient has already completed their growth, it is necessary to take other treatment approaches into account, such as orthodontic camouflage or orthodontic-surgical treatment. Orthodontic camouflage treatment is a compensatory orthodontic treatment that involves displacing teeth within the boundaries of the supporting bone to mask jaw discrepancy with the goal of attaining acceptable occlusion, aesthetics, and function. However severe cases with unacceptable facial profiles are only amenable to orthognathic surgery, which includes maxillary advancement, mandibular setback, or a combination of both [31,32].

In this study, the multidisciplinary planning, and the orthognathic surgery of prosthetic patients with severe skeletal malformations of the maxillo-mandibular complex is described, especially those patients who hesitate in malocclusions of II or III Angle's dental-skeletal class and who present a total or partial edentulism or a fixed-type rehabilitation. According to Ashy et al., Siadat et al., and Jain et al.'s works [4,6,24], the procedure for the rehabilitation of patients who are totally or partially edentulous candidates for orthognathic surgery begins with surgical and orthodontic analyses through clinical and radiographic examinations. Firstly, temporary prostheses, designed according to the patient's natural occlusion, are manufactured. Once the surgical treatment plan is established, based on clinical and radiographic analysis, prosthetic devices that can maintain predicted future occlusion form after surgery are produced. The results of these studies document the maintenance of post-operative occlusal stability, the absence of relapses, and the short-term success of rehabilitation. In contrast, Abdel-Azim et al. and Khojasteh et al. [33,34], after routine clinical and radiographic analyses, preferred to insert implant fixtures before orthognathic surgery. Intraoperative occlusal stability was achieved by screwing temporary acrylic prostheses into some of the previously inserted implant fixtures. These prostheses were kept in place for the period of healing and then were replaced with total permanent implant prostheses, also in acrylic resin. The study carried out by Abdel-Azim reports a follow-up of 6 years that documents, at this distance of time, the clear functional and aesthetic improvement, the maintenance of occlusal and implant stability, and the absence of relapses. Khojasteh's study, however, does not report follow-up.

Although this study produced excellent results using mainly conventional methods, recent advances in 3D imaging for computer-assisted surgical planning and simulation have shown their utility in predicting better treatment outcomes for complex aesthetic rehabilitation involving orthodontic, orthognathic, and prosthetic interventions. The constantly evolving 3D technology might be a possible solution for the overall treatment simulation before the whole complex interdisciplinary treatment starts [35]. According to Lv et al., the choice to use 3D digital planning and simulation before the complex aesthetic rehabilitation of orthodontic, orthognathic, and prosthetic treatment establishes success for several reasons: it facilitates interdisciplinary work, represents a useful platform for communication and decision-making between dental specialists and provides an effective communication tool between doctors and patients [36]. In complex dental treatments, such as those examined in this study, digital planning and simulation can minimize the likelihood of errors and increase the predictability of the achieved result [37]. Among the different innovations in virtual technology, Zinser et al. present a computer-assisted protocol that uses surgical navigation supplemented by Interactive Image-Guided Visualization Display (IGVD, used to transfer virtual jaw planning with precision) that completes virtual surgical navigation and provides a more accurate technique of stereotactic waferless jaw positioning. It can offer an alternative approach to the use of arbitrary splints and two-dimensional orthognathic planning. The advantage of the interactive IGV display is that the virtually planned maxilla and its real position can be completely superimposed during operation through a video graphics array (VGA) camera [38].

5. Conclusions

The correction of malocclusions with severe skeletal deformity generally requires surgery, combined with orthodontic or prosthodontic treatment. Multiple decayed or missing teeth may increase the difficulty and duration of orthodontic treatment due to the lack of appropriate anchorage for tooth movement, especially in adult cases that present with multiple long-spanned prostheses [4]. The crucial element for successful orthognathic surgery in partially or completely edentulous patients is occlusal stability.

The key to success in such treatments lies in the multidisciplinary aspect of all the steps for rehabilitation (diagnostic phase, planning phase, executive phase), which, therefore, necessarily provides for close collaboration between the different specialist figures, in particular the surgeon maxillofacial, the orthodontist and the prosthetist.

In conclusion, for the treatment of complex cases such as those discussed in this study, the first and fundamental element is a complete study associated with an in-depth analysis of the case in all its aspects and its specialized components. Despite recent advances in 3D imaging (3D), surgical planning, and computer-assisted simulation are now regularly used for the analysis of craniofacial structures and for better prediction of surgical results in orthognathic surgery, the principles we have indicated remain valid.

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Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflict of interest.

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