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Function, Aesthetics, and Strategy: Orthodontic–Orthognathic Concepts in The Treatment of Skeletal Deformities

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ABSTRACT
The surgical correction of skeletal deformities dates back to the beginning of the twentieth century, but rapid progress did not occur until the 1950's. Since that time, orthognathic surgery has made great strides in the area of diagnosis and surgical techniques. The process of orthodontic and surgical treatment planning involves a synthesis of clinical judgment, observation of the functional relationships of soft tissue to underlying hard tissue, knowledge of the soft tissue response to hard tissue movements, and the experience of the involved clinicians. With the integration of soft tissue surgical procedures combined with orthognathic surgery, there has been a growing interest in not only the analysis of soft tissue abnormalities in the presence of skeletal dysplasia, but also in improving communication with the patient about the effect of orthognathic surgery on the soft tissue. This paper presents the use of video imaging techniques in the planning and execution of comprehensive functional and aesthetically orientated orthodontic and surgical treatment.

Keywords: Presurgical Orthodontics, Orthognathic Surgery, Aesthetics, Treatment Planning

Introduction

The term "handicapping malocclusion" was used in a 1975 report by the National Research Council addressing issues related to dentofacial deformities—an expression that has since become commonly associated with such conditions [1]. However, the term has largely fallen out of use, as the primary concerns in affected individuals typically involve jaw function and facial aesthetics rather than dental occlusion itself. Although patients with dentofacial deformities often present with significant malocclusions (even though they may not wish to be constantly reminded of their condition), the malocclusion is not the root cause of the disorder [2].

Even when orthodontic treatment succeeds in aligning the dentition, the underlying skeletal discrepancies may persist, meaning that psychological distress may not be entirely alleviated. As a result, effective treatment often requires soft tissue surgery and orthognathic procedures involving repositioning of the jaws [3]. The term orthognathic originates from the Greek words "orthos" (straight) and "gnathos" (jaw).

In the 1880s, orthodontic diagnostics and treatment planning were based on the so-called Angle paradigm, which regarded ideal dental occlusion as nature's intended optimal form, with a primary focus on hard tissue interactions. According to this concept, nature and clinician were seen as partners working together to achieve perfection [4-6].

In contrast, the current biological approach recognizes that perfect occlusion is more the exception than the rule. It also considers that there may be contradictions between natural conditions and therapeutic interventions. The primary goal of modern orthodontics is to achieve the best possible functional, stable, and aesthetic outcome for each individual patient—with aesthetics often playing a leading role [1-7].

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There exists an inseparable correlation between form, function, and craniofacial morphology. These three parameters are dynamically interrelated: functional demands (e.g., respiration, mastication, articulation) significantly influence skeletal and dental form, while morphologic structures, in turn, determine the efficiency of functional processes. A harmonious balance among these factors provides the foundation for an aesthetically pleasing appearance and ensures long-term functional and structural stability of the stomatognathic system (Figure 1). Therefore, treatment planning must be based on the adaptability and contours of the soft tissues, as these define the functional and aesthetic boundaries of orthodontic intervention [1- 9].

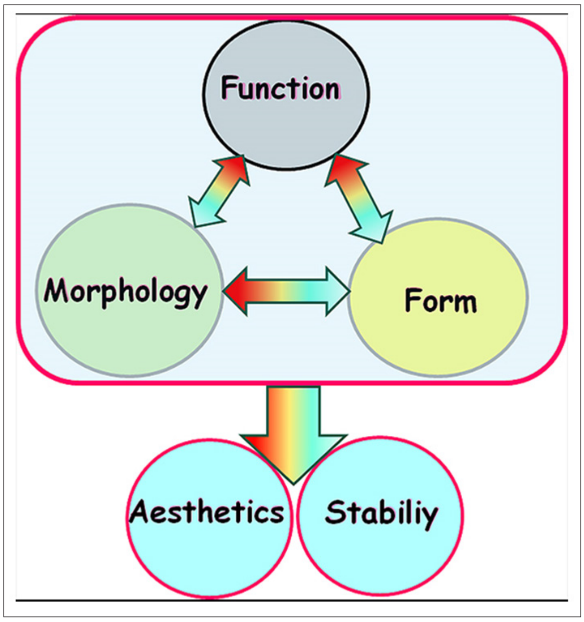

Figure 1: The illustration highlights the close interrelationship between form, function, and craniofacial morphology. Their interaction determines both aesthetics and functional as well as structural stability.

This paradigm shift highlights the increasing importance of understanding soft tissue function and aesthetics in achieving improved diagnostics and treatment outcomes. Consequently, clinical evaluation of soft tissue parameters is gaining relevance in everyday orthodontic practice [8].

A 1998 study by Phillips et al. conducted at the Dentofacial Clinic at the University of North Carolina found that between one-third and one-half of referred patients experienced significant psychological stress, negatively affecting their overall quality of life [4].

There are three primary treatment approaches for correcting malocclusions caused by disproportions in jaw size or position that led to facial imbalance [7-8]. (Figure 2):

1. **Growth modification / dentofacial orthopedics**
2. **Orthodontic camouflage**, in which the skeletal discrepancy is compensated through dental adjustments, with or without extraction of permanent teeth
3. **Orthognathic surgery**, a surgical procedure for repositioning the jaws and/or dentoalveolar segments, often in combination with orthodontic treatment

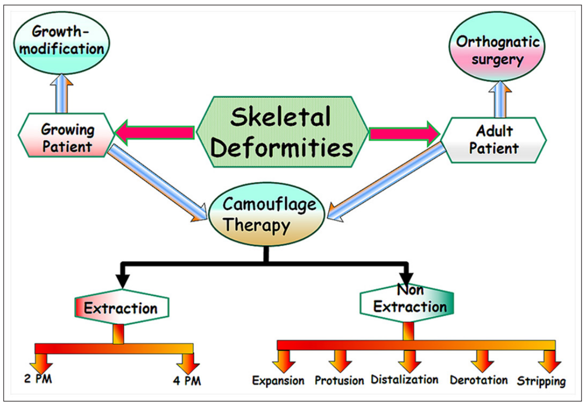

Figure 2: This diagram illustrates the paradigm shift in the treatment of skeletal deformities toward an individualized, age-dependent therapeutic approach. Depending on growth status, the clinician chooses between growth modification, camouflage therapy, or orthognathic surgery—always aiming to harmonize function, morphology, aesthetics, and stability.

Orthognathic surgery represents the ultima ratio for patients with severe skeletal discrepancies for whom all other treatment options have been exhausted. Once skeletal growth is complete, surgical correction remains the only viable option in cases of pronounced jaw deformities [7].

Although surgery can correct substantial deviations, its capabilities are not without limitations. These limitations depend on both the type of skeletal anomaly and the desired direction of jaw movement—some defects are more surgically manageable than others [1-7].

If dental compensations are present—either spontaneously or as a result of prior orthodontic treatment—they must be reversed prior to surgical jaw repositioning. This approach is referred to as “reverse orthodontics”, in which the teeth are first moved into an apparently less favorable position to enable the desired surgical outcome.

Dental compensation can restrict the extent of jaw movement required to achieve a functionally and aesthetically optimal result. However, if sufficient compensation exists, the amount of necessary surgical repositioning can be accordingly reduced.

Therapeutic Concepts in the Treatment of Skeletal Dysgnathia

Skeletal dysgnathias are among the most common causes of functional and aesthetic impairments in the craniofacial region. They are defined by structural discrepancies between the jaw bases in the sagittal, vertical, or transverse planes and may occur in isolation or in combination. Typical presentations include skeletal Class II and Class III dysgnathias, open bites, vertical overgrowth, as well as transverse asymmetries or hypoplasias [2-5].

Treatment planning requires a differentiated analysis of craniofacial growth, dental compensation, and soft tissue aesthetics. The goal of any treatment is to restore harmonious occlusion, physiological function with correct condylar positioning, and balanced facial aesthetics. In the context of orthodontic and interdisciplinary treatment of skeletal dysgnathias, several evidence-based therapeutic strategies are available. These should be individually selected based on patient age, severity of the malocclusion, skeletal baseline condition, and dentofacial aesthetic considerations (Figure. 2).

Causal Functional-Therapeutic Approach (Growth-Modifying Measures)

The causal functional-therapeutic approach aims to specifically influence craniofacial growth in order to correct skeletal dysgnathias. By using functional orthopedic appliances (bimaxillary devices), growth processes can be stimulated, modulated, or inhibited—depending on the location and type of the deformity.

Different mechanisms are applied depending on the nature of the malocclusion:

In cases of mandibular hypoplasia—typically observed in skeletal Class II dysgnathia—mandibular growth is therapeutically stimulated, for example through the use of functional appliances such as the activator, bionator, or twin block [5,12,16].

The treatment is based on the fabrication of a so-called construction bite, in which the mandible is positioned three-dimensionally in a therapeutically defined, protruded position. The goal is to approximate a skeletally and dentally stable Class I occlusion, thereby achieving both functional and aesthetic improvements. (Figure 3 A–G)

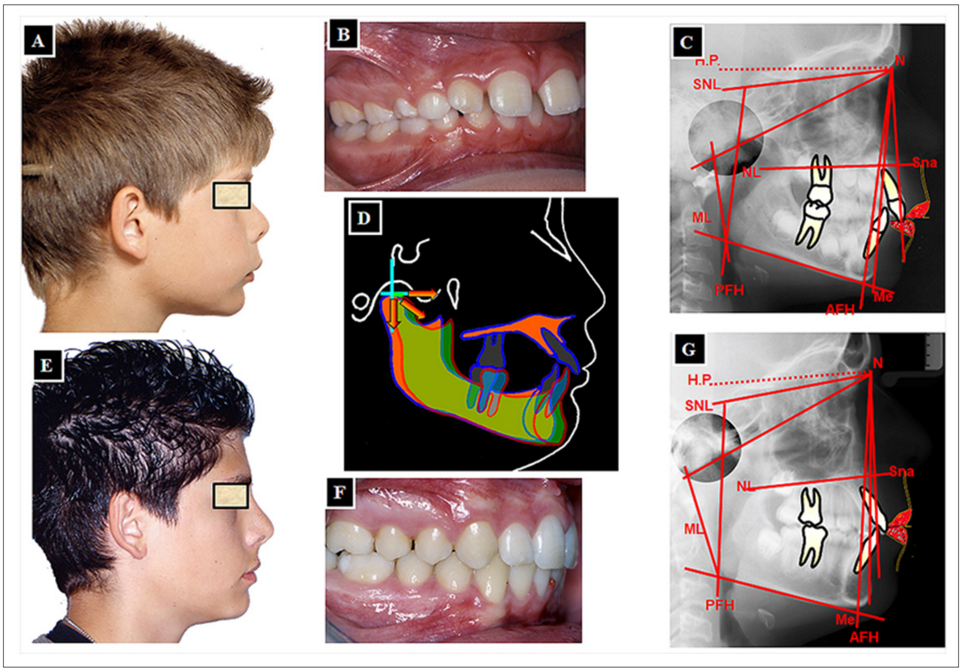

Figure 3 A–G: Figures A–C depict the initial situation of a patient with skeletal Class II dysgnathia. To stimulate mandibular growth, a functional orthopedic appliance was fabricated based on an individually defined construction bite (D), in which the mandible was repositioned three-dimensionally into a therapeutic forward position. Figures E–G show the treatment outcome with the establishment of a stable Class I occlusion, physiological anterior tooth alignment in sagittal and vertical dimensions, and a marked improvement in the facial profile.

In cases of midface hypoplasia, maxillary growth is therapeutically promoted during the phase of highest growth potential—typically in early childhood. This is accomplished primarily using extraoral appliances such as the Delaire face mask or functional orthopedic devices like the Frankel Type III appliance [16-19].

1) The most effective treatment period is before the age of 8, as the skeletal sutures of the midface are not yet fused and allow for a more favorable skeletal response. As growth potential declines with age, combination therapies—such as face mask therapy in conjunction with rapid palatal expansion (RPE)—are often indicated to enhance treatment efficiency. (Figure 4 A–G)

2) In cases of maxillary prognathism or vertical overdevelopment of the maxilla, its growth can be selectively inhibited in the sagittal and vertical planes—for example, by using headgear or combined orthodontic appliances. In addition to their skeletal growth-inhibiting effect, these devices also produce dentoalveolar changes, particularly through the distalization of the posterior teeth. (Figure 5 A–G)

In transverse dysgnathias, growth stimulation can be achieved by means of rapid palatal expansion (RPE or Q-Hyrax) [16]. (Figure 6 A–I)

3) In skeletal open bites, appliances are used to control posterior vertical growth by inhibiting vertical development of the maxilla. This results in an automatic mandibular response in the form of mandibular autorotation, leading to a positional change of the mandible in cranial and ventral directions. As a consequence, this treatment not only corrects the skeletal dysgnathia but also harmonizes the facial profile in both the vertical and sagittal dimensions. (Figure 7 A–G)

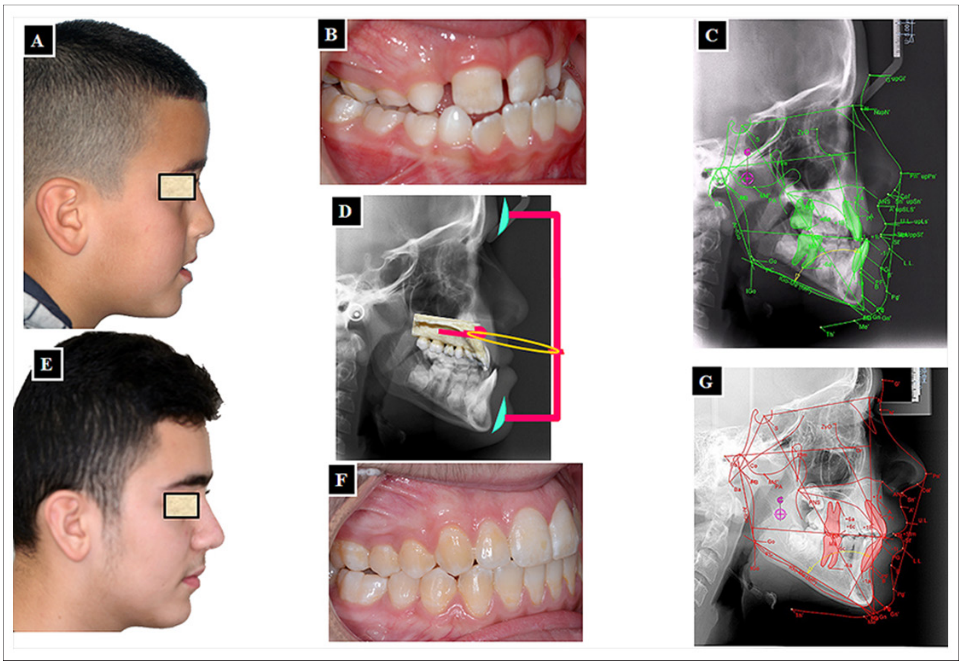

Figure 4 A–G: Figures A–C show the initial condition of a patient with skeletal Class III dysgnathia. To promote midfacial growth, a Delaire face mask was used (D). Figures E–G display the final treatment outcome with a stable Class I occlusion, correct anterior alignment, and a harmonized facial profile.

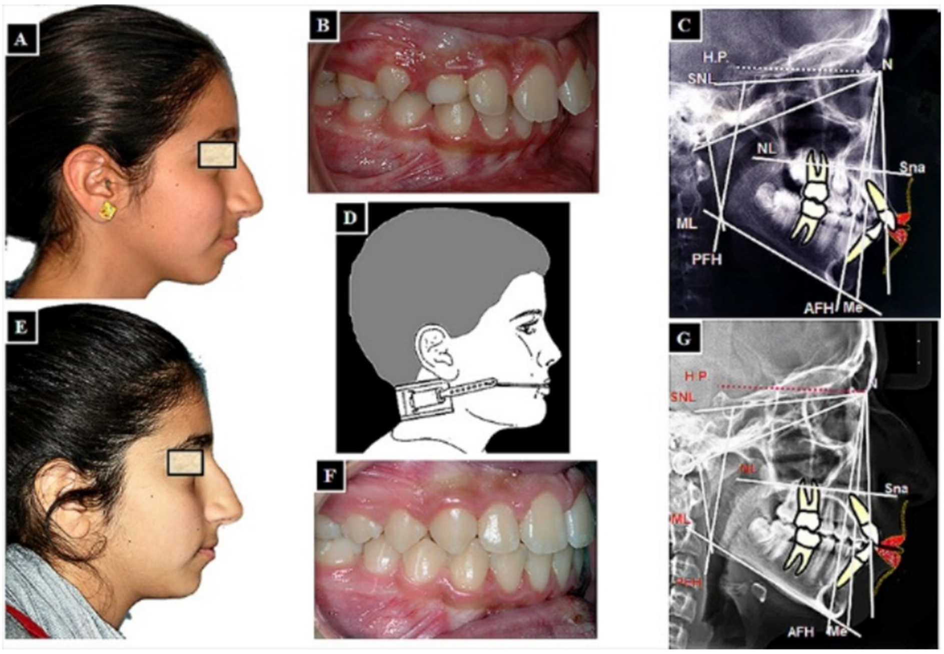

Figure 5 A–G: Figures A–C show the baseline condition of a female patient with skeletal Class II dysgnathia and mild maxillary prognathism. A headgear was applied to restrict midfacial growth (D), which also produced a dentoalveolar distalization of the posterior teeth. Figures E–G demonstrate the final result, showing a stable Class I occlusion and an overall harmonized facial profile.

This form of therapy is indicated only during the growth period and requires careful analysis of the patient's growth phase, e.g., based on cervical vertebral maturation stages or hand-wrist radiographs. The objective is to utilize individual growth potential to achieve skeletal harmonization and thus avoid more invasive procedures—such as extractions or surgical interventions—or at least reduce their extent [15,16].

Dentoalveolar Conservative Treatment Approach

The dentoalveolar conservative treatment approach aims to enable or optimize dental compensation of skeletal discrepancies through targeted space-gaining measures. In this approach, the dental arches are selectively modified using mechanical forces, without resorting to extractions. (Figure 8 A–H)

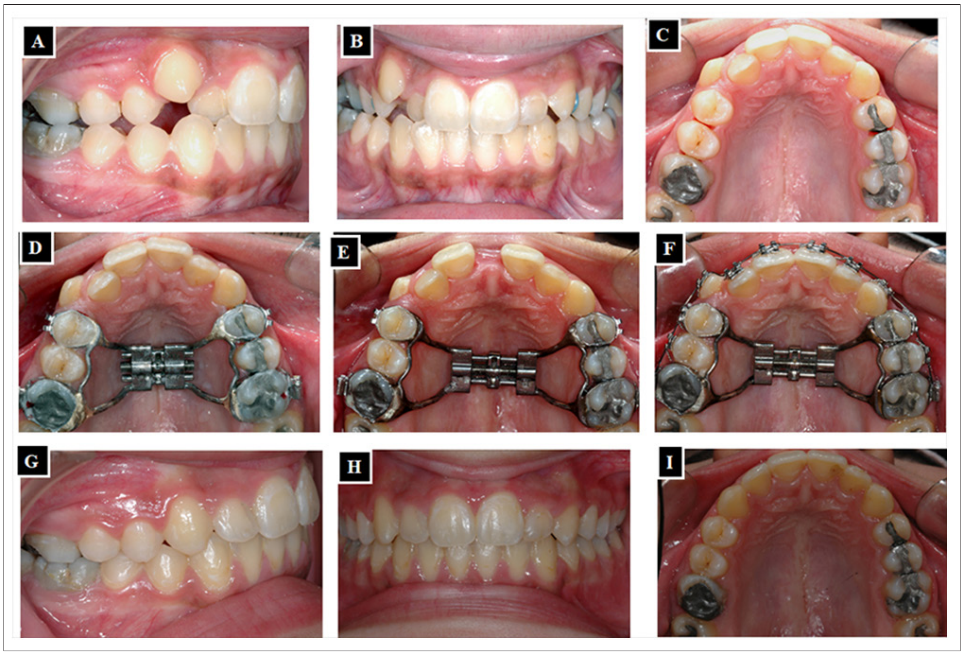

Figure 6 A–I: Figures A–C: show the initial condition of a patient with a narrow maxilla and a right-sided crossbite. A Hyrax screw was used for transverse expansion (D). Activation led to the formation of a diastema, indicating palatal suture separation (E), which spontaneously closed after eight weeks (F). Figures G–I show the stable final result with corrected occlusion and a harmonized dental arch form.

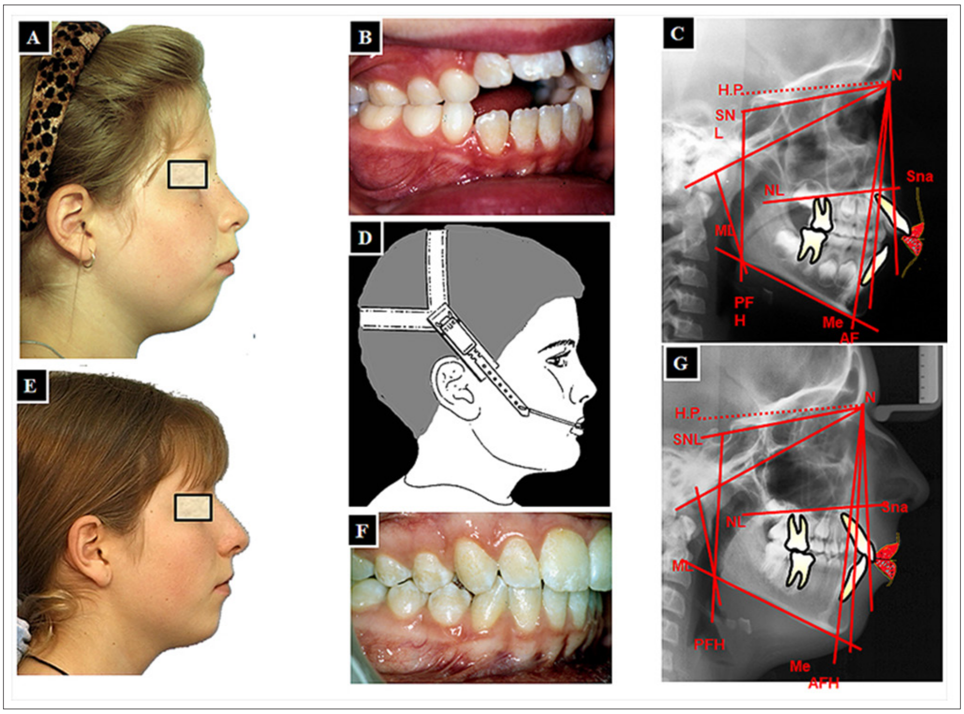

Figure 7 A–G: Figures A–C show a growing patient with Class II dysgnathia, anterior open bite, convex profile, and incomplete lip closure. A headgear was applied for growth modification (D). Figures E–G demonstrate the treatment outcome with Class I occlusion, balanced skeletal relationship, and a harmonized profile.

Commonly applied measures include:

- Distalization of molars to allow retraction of the anterior teeth in skeletal Class II cases
- Mesialization or protrusion in skeletal Class III malformations to partially compensate for mandibular prognathism
- Transverse expansion in cases of maxillary hypoplasia or transverse discrepancies
- Intrusion or extrusion of specific segments to modify the vertical dimension (e.g., in open bites or vertical maxillary growth)

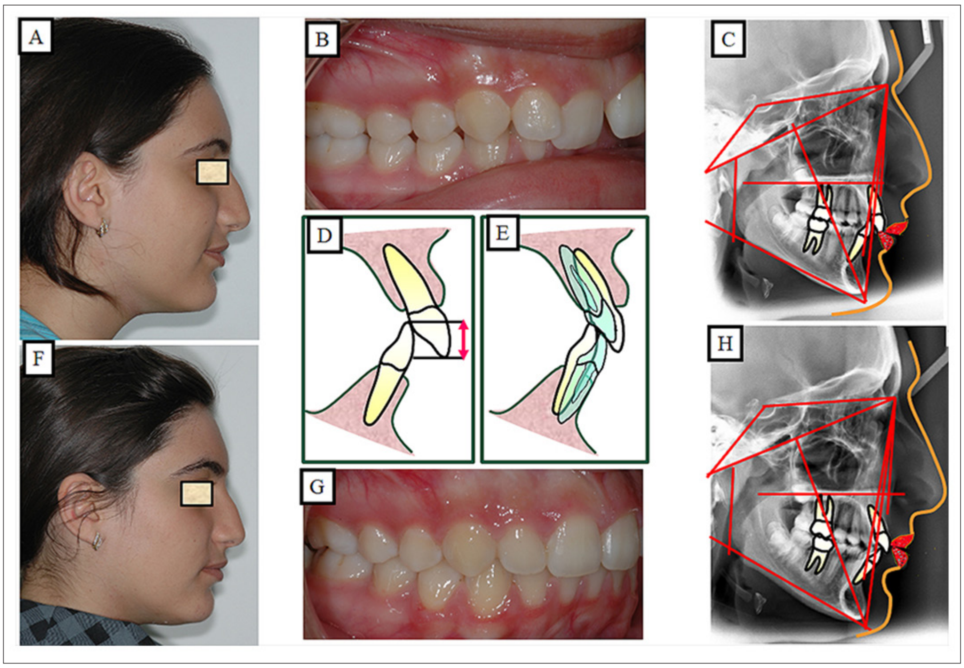

Figure 8 A–H: Figures A–D depict a 15-year-old female patient with Class II/2 dysgnathia and deep bite, with minimal remaining growth. Treatment was performed via dentoalveolar compensation, including intrusion and protrusion of the anterior teeth and distalization of the maxillary posterior teeth (E–H).

The choice of measure depends on the individual malocclusion pattern, available space within the arch, skeletal configuration in sagittal, vertical, and transverse planes, as well as the patient's functional and aesthetic demands [16,18,19].

The objective is to achieve functional and aesthetic compensation of skeletal discrepancies through dentoalveolar adjustments—as far as possible without the need for surgical intervention.

Dentoalveolar Treatment Approach via Absolute Space Gain (Extractions)

A dentoalveolar treatment approach for skeletal malformations may also include the strategic extraction of permanent teeth to gain space—particularly when dental compensation of the skeletal dysgnathia is intended and conservative measures are insufficient. (Figure 9 A–F)

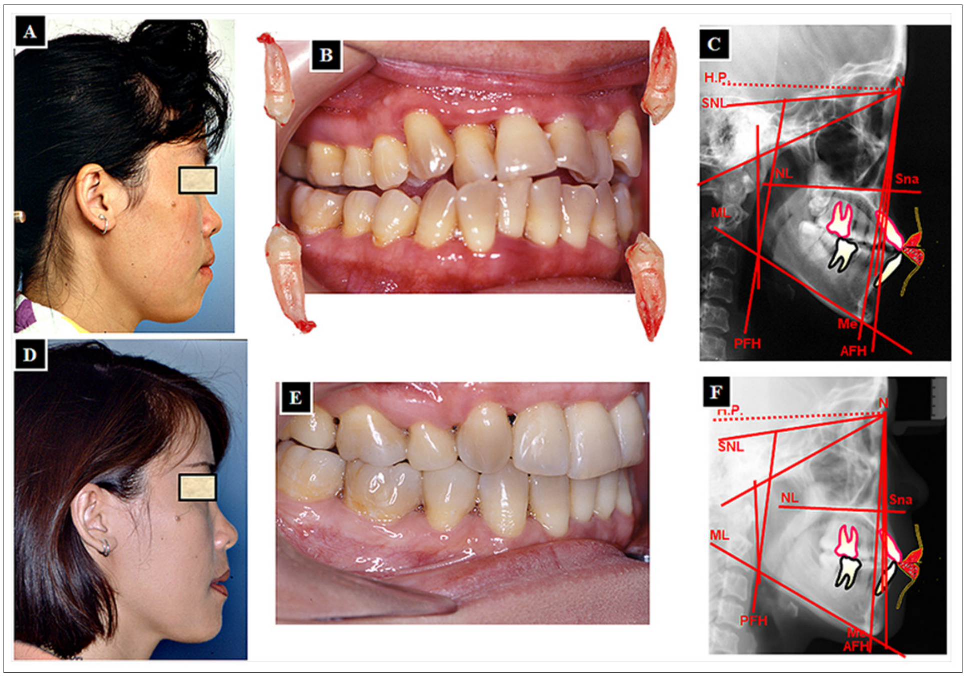

Figure 9 A–F: Figures A–C show the initial findings of a patient with skeletal Class III dysgnathia and pronounced dental malalignments. Dentoalveolar compensation was achieved through orthodontic treatment with extraction of four premolars. Figures D–F document the course and result of the treatment.

systematic extraction of premolars—typically in the upper and/or lower jaw—is performed in order to:

- Retract anterior teeth in cases of protrusive profiles or dental overjet
- Create space for the uprighting or alignment of displaced teeth
- Improve sagittal, vertical, or transverse occlusal relationships
- modality can be adapted based on the type of skeletal discrepancy:
- In skeletal Class II malocclusions: extractions in the maxilla to retract the protrusive anterior segment
- In skeletal Class III cases: extractions in the mandible to compensate for mandibular prognathism
- In vertical dysgnathias: extrusion or intrusion of segments combined with leveling of available space
- In transverse or asymmetric deformities: selective extractions to harmonize the dental arches

The decision regarding the extent and location of extractions is based on a comprehensive analysis of:

- Tooth axis inclination, lip profile, and soft tissue balance
- Degree of required dental compensation
- Prognosis of the skeletal baseline condition
- Aesthetic objectives and patient preferences

The desired occlusion is typically planned to achieve a neutral canine relationship with functional intercuspation. However, overextraction or improper indication may lead to undesired changes in soft tissue support or impair functional outcomes [16,18,19].

Surgical-Combined Therapy: Orthognathic Surgery

In cases of completed skeletal development and insufficient effectiveness of conservative or dentoalveolar measures, orthognathic surgery represents the primary treatment option for correcting severe skeletal deformities. It aims at the structural repositioning of the bony jaw bases and is always carried out within the framework of an interdisciplinary treatment concept, in combination with pre- and postoperative orthodontic therapy. (Figure 10 A–F)

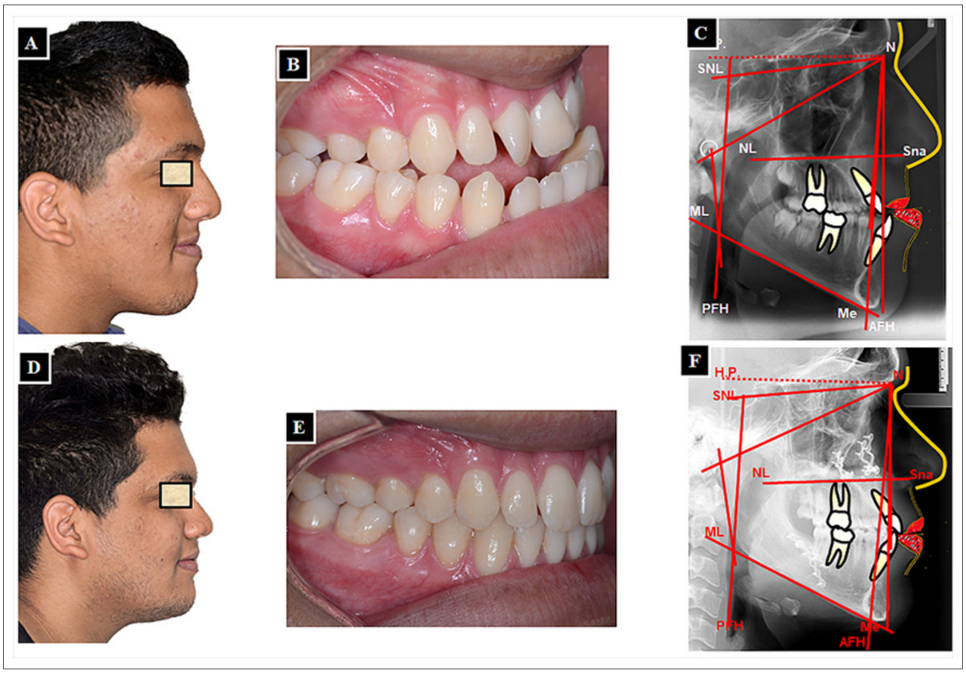

Figure 10 A–F: Figures A–C show a Class III dysgnathia with dental malpositions. Correction was achieved via bimaxillary osteotomy. Figures D–F show the outcome with harmonized jaw relationship and stable occlusion.

Depending on the type of dysgnathia, different surgical techniques are applied:

- Sagittal split osteotomy of the mandibular ramus (BSSO): e.g., for mandibular advancement in cases of retrognathia or for mandibular setback in prognathism (Figure 10 A–F)
- Le Fort I osteotomy: for repositioning of the maxilla in the sagittal, vertical, or transverse dimension (Figure 11 A–G)
- Segmental osteotomies: for the correction of asymmetric or segmental deformities
- Three-dimensional corrections in cases of combined deformities (e.g., rotation or translational displacements) (Figure 12 A–N)
- Distraction osteogenesis: in cases of pronounced hypoplasia or for skeletal expansion

Orthognathic surgery enables comprehensive functional and aesthetic rehabilitation in:

- Skeletal Class II or Class III malocclusions
- Open bites with vertical disproportions
- Transverse asymmetries
- Combined deviations in sagittal, vertical, and transverse planes

The timing of surgery is based on the completion of skeletal growth, which can be determined using hand-wrist radiographs or cervical vertebral maturation indicators. The goal is to achieve a stable, functionally appropriate, and aesthetically pleasing occlusion and facial appearance.

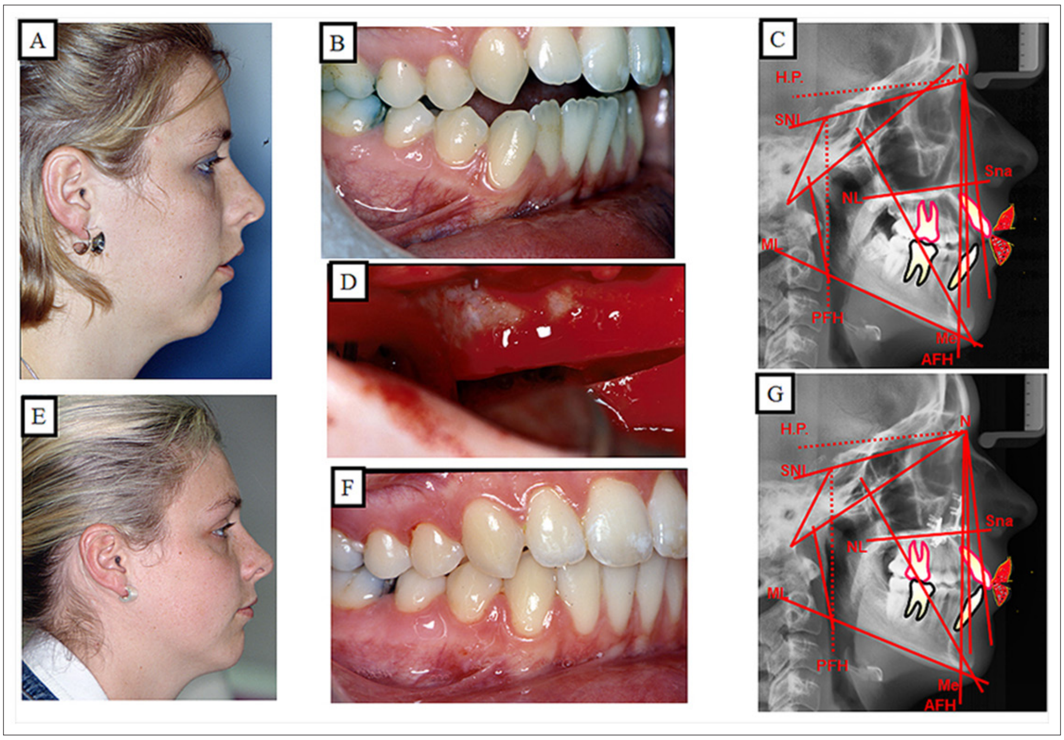

Figure 11 A–G: Figures A–C show the initial findings of a patient with skeletal and dental open bite and compromised mouth and lip closure. Treatment was performed using a Le Fort I osteotomy with dorsal impaction of the maxilla (D). Figures E–G document the treatment outcome, showing stable occlusion and harmonious function and aesthetics.

Chronological Development of Orthognathic Surgery

Chronological Development of Orthodontic Surgery of the Mandible

The close collaboration between orthodontists and surgeons in the field of orthognathic surgery can be traced back to the late 19th century—a time that is today considered the birth of orthognathic surgery. In 1849, Dr. S.P. Hullihen performed the first orthognathic operation: an intraoral anterior subapical osteotomy to correct mandibular prognathism [26]. According to Steinhauser, St. Louis, Missouri, is regarded as the origin of orthognathic surgery. Dental Cososand Vilray Blair, both with a background in dentistry, developed the first horizontal osteotomy of the mandible for the treatment of prognathism [27].

In his work "Operations on the Jaw Bone and Face", Blair described craniofacial anomalies [28]. Due to the two World Wars, surgical orthodontics received little attention in the U.S. for nearly a century. Only after World War II did Central Europe become the cradle of modern orthognathic surgery [29]. Centers for oral and maxillofacial surgery were established in the first half of the 20th century by pioneers such as Pichler in Vienna and Wassmund in Germany [30]. These experts not only developed new surgical techniques but also trained a new generation of surgeons—including Trauner, Kole, Obwegeser (who founded the maxillofacial surgery center in Zurich), and Schuchardt. Together with several British surgeons, they helped advance the field. In later years, three North American surgeons who had trained exclusively in European techniques played a key role in restoring and further developing orthognathic surgery [15.16].

Until the mid-1950s, mandibular prognathism was treated using the mandibular body osteotomy introduced by Blair in 1896 [28]. A section of the mandible in the premolar or molar region was removed. Depending on the type of open bite, the osteotomy was rectangular, V-shaped, or trapezoidal. Erich and Trauner preferred a step osteotomy distal to the last molar to ensure greater bone contact and improved stability. Digman (1948) described this technique both intraorally and extraorally. It was first performed purely intraorally by Burch in 1951 [31]. Converse (1964) described a horizontal vestibular incision that provided access to the mandibular symphysis for median osteotomies, genioplasties, and anterior subapical procedures [32].

Condylectomy (Jacbulay, 1895) was the first procedure on the ascending ramus of the mandible for treating prognathism. Despite its instability, restricted movement, and high complication rate, it remained in use until 1970 [33]. Blair (1907) and Babcock (1908) supported ramus osteotomy below the incisura mandibulae, though the so-called "St. Louis operation" was also unstable[5]. In 1930, Kostecka introduced the use of the Gigli saw, which allowed only limited posterior repositioning and posed challenges in controlling the condylar position as well as a high risk of facial nerve injury. This method was eventually replaced entirely in the early 1970s by the intraoral subcondylar vertical-oblique osteotomy (IVO) [29].

This technique, first described by Moose (1967 and Winstanley (1968), was further developed in 1970 by Drs. Herbert, Hinds, and Kent, who introduced a right-angled sawing technique. In its modified form, this procedure is still used today for mild symmetric or asymmetric mandibular setbacks, as well as in cases of inferior alveolar nerve paresthesia[6] [34].

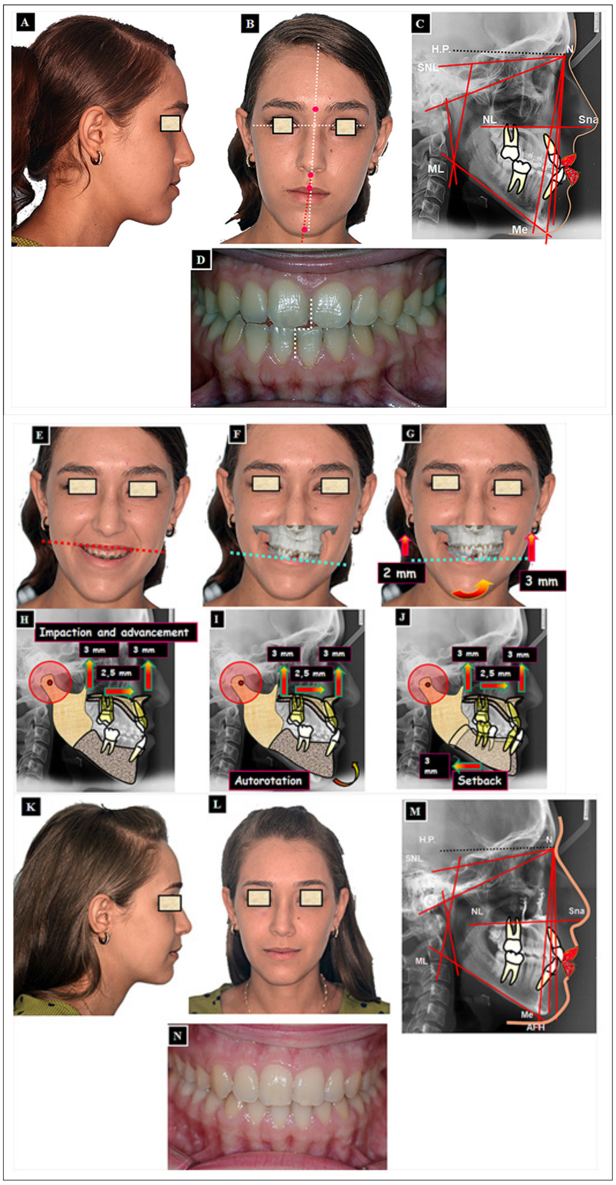

Figure 12 A–N: Figures A–D show a patient with Class III dysgnathia, facial asymmetry, and an inclined occlusal plane. Correction was achieved via bimaxillary osteotomy with asymmetric impaction and advancement of the maxilla (E–H), followed by autorotation and setback of the mandible with lateral rotation (I–J). Figures K–N show the outcome with Class I occlusion and a harmonized facial profile.

Before the introduction of sagittal split ramus osteotomy and the intraoral vertical-oblique osteotomy (IVO), the primary surgical approach was the extraoral vertical-oblique access (EVO) or subcondylar approach. Hinds and Robinson introduced this technique in 1955, replacing a similar method published a year earlier by Caldwell and Letterman. EVO proved particularly effective for correcting significant asymmetric mandibular setbacks [35].

However, despite its effectiveness, this method carried certain risks, such as facial nerve palsy and visible scarring. These disadvantages ultimately led to the refinement and establishment of the IVO technique and the sagittal ramus osteotomy. Trauner and Obwegeser popularized sagittal splitting in Europe in 1957 and in North America during the 1960s. The original approach, which extended to the posterior border of the ramus, was initially considered technically difficult and unpredictable. Through the modifications introduced by Dal Pont (1961) and Hunsuck (1968), the technique became more practical and replaced nearly all other ramus osteotomies—especially after the introduction of rigid internal fixation (RIF), except in cases where the high incidence of irreversible nerve damage represented a contraindication (Figure 13 A–C, Figure14 A–G) [35,36].

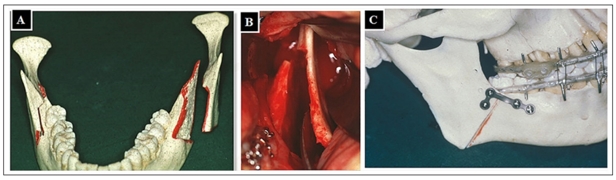

Figure 13 A–C: Figures A and B show the performance of a sagittal split osteotomy of the mandible according to Obwegeser-Dal Pont. Figure C illustrates the fixation of the osteotomy segments using osteosynthesis plates and screws.

Sagittal split osteotomy has become the standard method for mandibular advancement in cases of mandibular retrognathism and other skeletal Class II malocclusions, and is also used for mandibular setbacks. It has largely replaced previous procedures for these indications. Earlier techniques—such as mandibular body, vertical or horizontal ramus, or subapical osteotomies—were either technically demanding, required bone grafts, or necessitated an extraoral approach, as seen in the C-osteotomy described by Caldwell and Hayward (1968). These limitations led to the widespread adoption of sagittal splitting as the preferred mandibular repositioning technique in the 1970s and 1980s [35].

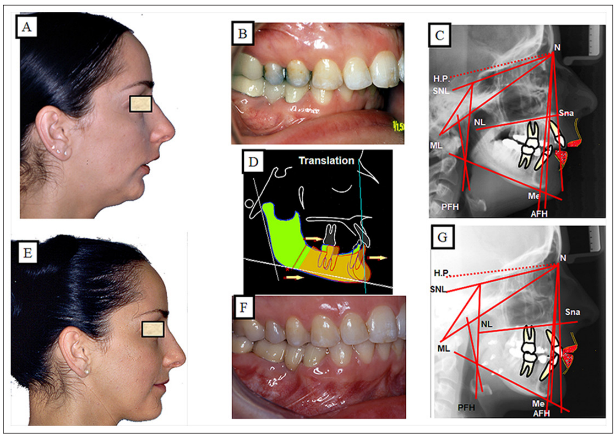

Figure 14 A–G: Figures A–C show the initial findings of a patient with skeletal Class II dysgnathia and uniform mandibular retrognathia. Correction was performed via sagittal mandibular osteotomy (D). Figures E–G document the outcome with stable Class I occlusion and a harmonized facial profile.

Chronological Development of Orthodontic Surgery of the Maxilla

As early as 1927, Wassmund developed a method for correcting malocclusion through repositioning of the entire maxilla[8]. Most maxillary surgeries—referred to as Le Fort I osteotomies—are based on the work of the French surgeon Henry Le Fort and were originally developed for the management of displaced maxillary fractures[9]. Many surgeons were long hesitant to perform such procedures due to concerns about compromising the vascular supply to the maxilla. The detachment of the maxillary tuberosity from the pterygoid plates was also controversial for some time. Earlier procedures were staged and used external traction to gradually reposition the maxilla [30,36].

Obwegeser ultimately developed a technique in which the maxilla was fully mobilized by vertical buccal incisions that separated it from the cranial structures and the pterygoid plates. This allowed complete mobilization of the maxilla and immediate repositioning [35- 41].

Early maxillary procedures were often performed subapically to intrude, retrude, or extrude segments—especially in the treatment of anterior open bites or camouflaging Class II malocclusions. Posteriorly, segments were intruded, widened, or narrowed to correct vertical or transverse discrepancies. With advancing biological understanding and technical innovation, stable osteosynthesis techniques were introduced that improved both the stability of the outcome and patient acceptance [42].

A milestone of the past three decades was the rediscovery of distraction osteogenesis and its application in craniofacial and orthognathic surgery [41].

Until the mid-1960s—and in some cases into the early 1970s—orthognathic procedures continued to rely on ramus and subapical osteotomies of both the mandible and maxilla. Only gradually did sagittal splitting become widely adopted among surgeons. When prognathism was not caused by mandibular overdevelopment but by a hypoplastic maxilla (pseudoprognathism), some surgeons cautiously began to attempt Le Fort I osteotomies—though only in clearly indicated cases [38,41-43].

During this period, American researchers began conducting animal experiments to study the biological aspects of surgical procedures. Their focus included vascular supply, healing after osteotomies, management of the condylar segment in relation to stability and relapse, functional outcomes, muscular adaptation, and fixation techniques. Of particular note were Bell's groundbreaking studies on the vascular supply of the maxilla, which demonstrated that single-stage maxillary repositioning using horizontal vestibular incisions and anterior/posterior subapical osteotomies was possible—even when the arteria palatina major, once thought critically, was ligated [30].

What proved crucial was that, as long as the palatal and buccal soft tissue attachments remained intact, they were sufficient to preserve vascular supply to the osteotomized segments. This made effective regeneration of soft and hard tissues possible [35].

These insights led Bell to develop the "down-fracture" technique for Le Fort I osteotomy in 1975. A horizontal incision is made in the buccal vestibule—from one molar to the contralateral side—for the sagittal split. This approach provided improved visualization and facilitated repositioning of the maxilla in all directions (intrusion, protrusion, inferior repositioning) [37].

The technique enabled previously two-stage subapical procedures described by Cupur and Schuchardt to be performed in a single stage—via the same buccal approach[11]. This concept was first introduced in 1977 by Bell and Epker, who combined anterior (Cupur) and posterior (Kufner) osteotomies with slight modifications (Figure 11 A–G, Figure 15 A–D).

The segmental Le Fort I osteotomy allows the surgeon to reposition the maxilla and/or its segments in all three spatial dimensions and offers a comprehensive solution for both occlusal and aesthetic problems.

Numerous procedures on the ascending mandibular ramus and subapical osteotomies of the mandible were also investigated in similar studies, leading to significant technical refinements. To prioritize control of the condylar segment, minimize the risk of aseptic bone necrosis, and improve the predictability of bone healing and overall stability, great importance was placed on preserving muscular and soft tissue attachments [45].

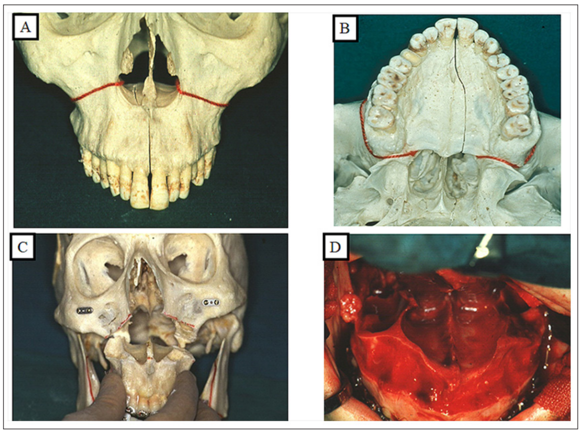

Figure 15 A–D: Figures A and B show the anatomical depiction of osteotomy lines in the Le Fort I osteotomy. Figures C and D illustrate the down-fracture of the maxillary segment following complete osteotomy.

Obwegeser was also the first to advocate for simultaneous surgery of the maxilla and mandible in 1970. This approach increasingly gained acceptance as both practical and safe.

An American surgeon with deep biological insight into human physiology further expanded orthognathic surgical techniques by applying modified or pure forms of Le Fort II and Le Fort III osteotomies to higher midfacial structures. This made these techniques applicable to a broader patient population [41,46].

Surgeons and orthodontists continued this biologically driven approach by exploring the phenomenon of relapse and developing treatment methods to prevent it. A major breakthrough was the introduction of rigid internal fixation (RIF), which ushered in a new era in surgical orthodontics [46,47].

Chronological Development of Distraction Osteogenesis and Surgically Assisted Palatal Expansion

It is worth noting that in 1972, Snyder described the potential application of distraction osteogenesis (DO) for mandibular lengthening using an animal model (dog) . This served to illustrate the potential of distraction forces in orthognathic surgery [48].

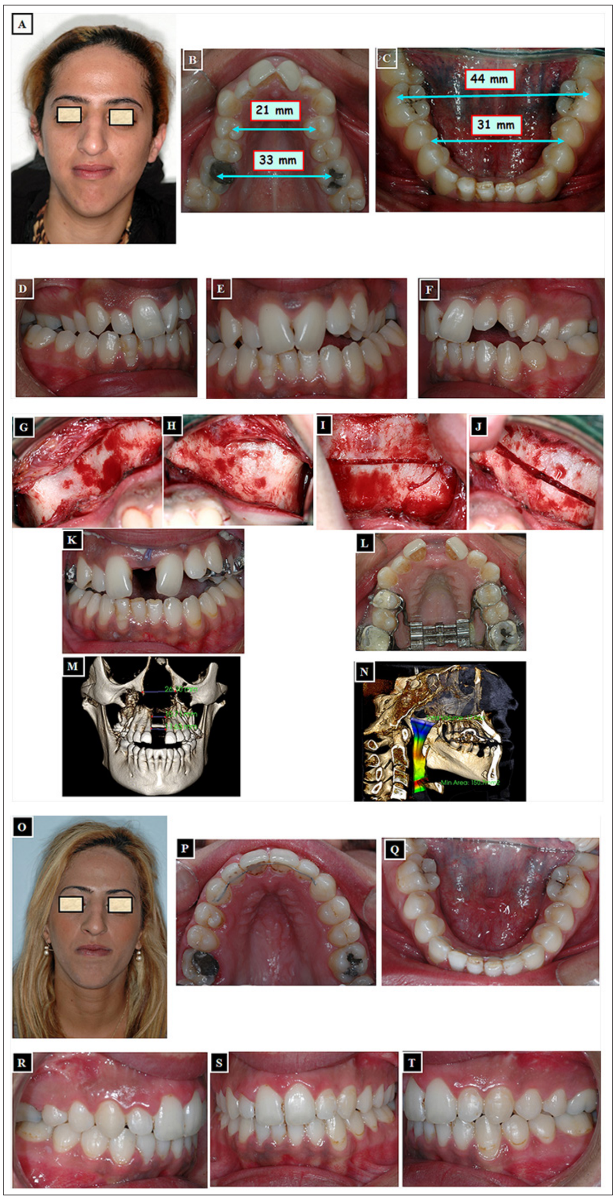

Figure 16 A–T: Figures A–F show the initial findings of a patient with a narrow face and mouth, extremely narrow maxilla, and bilateral crossbite. A surgically assisted rapid palatal expansion (SARPE) was performed to achieve transverse widening (G–L). This resulted in a median split of the maxilla and simultaneous expansion of the nasal airways (M, N). Figures O–T document the treatment outcome, with the achievement of the intended functional and aesthetic goals.

Following this, Michicli and Meoti described mandibular lengthening in a dog model using distraction forces generated by an intraoral appliance anchored to the teeth. The goal was to increase the length of the mandible [49].

Similarly, early European oral and maxillofacial surgeons unknowingly applied the principles of distraction osteogenesis to reposition malunited Le Fort I fractures. Surgeons such as Wassmund (1927) and Schuchardt—initially skeptical of Le Fort I osteotomy—used external traction forces to gradually pull the maxilla into the desired position [50].
For approximately the past 25 years, oral and maxillofacial surgeons, in collaboration with orthodontists, have routinely applied the principles of distraction osteogenesis in a procedure known as surgically assisted rapid palatal expansion (SARPE). This technique is used to treat transverse maxillary disharmonies in non-growing patients[14]. (Figure 16 A–T)

It was not until 1989 that a U.S. craniofacial surgeon named McCarthy, based on further animal experiments, reintroduced distraction osteogenesis into clinical practice for mandibular lengthening—first published in 1992[14]. According to some sources, however, it was Cuerro who in 1990 first performed mandibular symphysis expansion using a distractor similar to the one used in SARPE, with further reports emerging in 1992 [51].

Unfortunately, the details of the first clinical mandibular distraction procedure, conducted as early as 1973–74 by plastic surgeon B. Coclough, orthodontist R. Latham, and co-author Holmes in London, Ontario (Canada), were never published—but the procedure is considered the earliest clinical application of its kind [47].

Since McCarthy's publication, numerous clinicians have successfully used distraction osteogenesis to treat severe mandibular deficiencies—especially in cases of iatrogenic growth disturbances or syndromic malformations such as Goldenhar syndrome or Apert syndrome. The method has proven particularly helpful in cases where early-onset temporomandibular joint (TMJ) ankylosis had led to significant growth inhibition. In such complex scenarios, DO has established itself as a valuable technique [52].

The causes of mandibular growth disturbances can often be traced back to early-onset TMJ ankylosis. At the same time, significant advances have also been made in applying DO to the maxilla and midface. The first mandibular distractors were externally fixed pin-based systems, which acted unidirectionally—moving the bone segment in only one direction [53]. (Figure17 A–K, Figure 18 A–J).

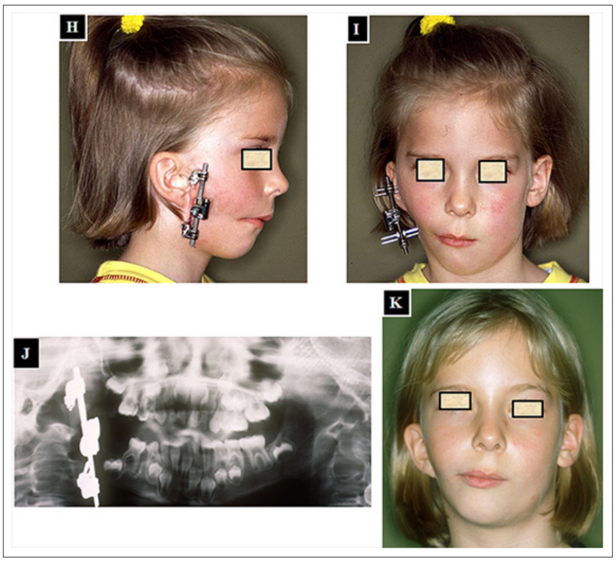

Figure 17 A–K: Figures A–C show a patient with Goldenhar syndrome and a hypoplastic mandibular ramus. An external distractor was used and activated for distraction osteogenesis to lengthen the ramus (D–G). Figures H–K document the course and result of the treatment with improved mandibular structure.

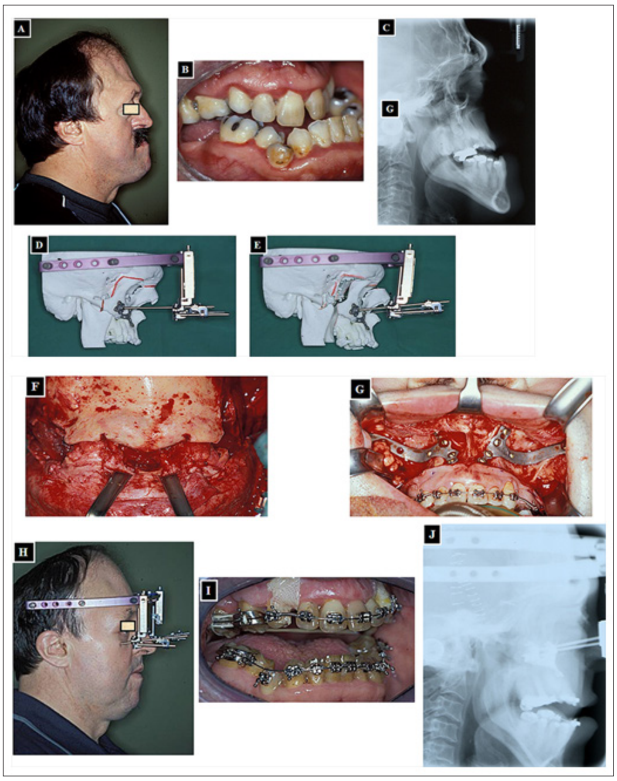

Figure 18 A–J: Figures A–C show the baseline condition of a patient with a mild form of Apert syndrome. For craniofacial correction, a custom extraoral facial distractor was designed using a stereolithographic skull model, including virtual planning before (D) and after activation (E). Distraction was carried out at the Le Fort III level (F, G). Figures H–J show the clinical situation three months after completion of the distraction.

In recent years, however, internal, bone-borne, multidirectional distractors have been developed—addressing the drawbacks of external appliances such as bulkiness, scarring, and social stigma. Although some experts believe that distraction osteogenesis may eventually replace traditional osteotomies altogether, only time will ultimately answer that questi [54].

Primary Surgical Intervention with Subsequent Orthodontic Treatment (Surgery-First Approach)
Another major advancement is the increasing use of the Surgery-First Approach (SFA). This concept has gained considerable traction in recent years, particularly in Asian countries such as Japan and South Korea. The first scientific article on SFA was published in 2002 in the Korean Journal of Clinical Orthodontics, although at the time the approach was still the subject of considerable debate .

In that article, the modern concept of SFA was described for the first time under the term "functional orthognathic surgery." Based on innovative laboratory research, this concept proposed performing the surgical correction first, followed immediately by postoperative orthodontic treatment—without any prior orthodontic preparation [47-54].

To simulate the occlusal situation immediately after surgery, clinical plaster models were used, with all teeth separated from one another—without any previous orthodontic alignment. This allowed both surgeons and orthodontists to carry out the SFA without adhering to conventional pre-surgical orthodontic protocols. This model of complete dental simulation still serves today as the foundation for all clinical applications of the SFA [55].

Function and Aesthetics in Harmony – The Aesthetic Axis as a Guiding Principle in Dysgnathia Surgery
Modern dysgnathia surgery operates in the field of tension between functional requirements and aesthetic expectations. Particularly in profile-altering procedures within interdisciplinary treatment concepts, it becomes evident that functionally and orthodontically indicated measures often lead to a significant improvement in external facial appearance. This correlation reflects the principle of "form follows function" and is based on the close physiological relationship between function and morphological structure [55-61].

The Aesthetic Axis: Concept and Relevance
Central to the understanding of facial harmonization is the so-called aesthetic axis—an imaginary profile line extending from the tip of the nose across the prominence of the maxilla and mandible down to the chin (Figure 19 A, B). It serves as a key orientation tool in planning orthodontic-surgical procedures with aesthetic objectives [55-61].

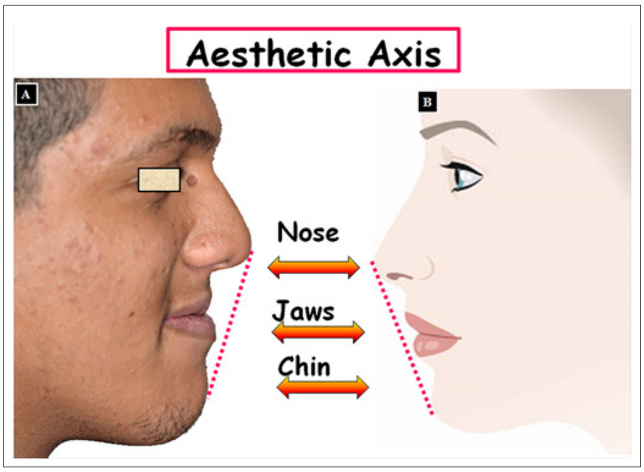

Figure 19 A, B: Figures A and B illustrate the so-called aesthetic axis—a conceptual profile line running from the tip of the nose through the prominent points of the maxilla and mandible to the chin—which plays a central role in treatment planning. A shows a disharmonious alignment, B a harmonious alignment of this axis.

The aesthetics of the human face are largely defined by the interaction of three prominent structures: the nose, the mouth, and the chin—collectively known as the facial aesthetic triad. A balanced configuration of these elements is not only essential for subjective perceptions of attractiveness but also contributes to a youthful appearance regardless of age [55-61].

Orthodontic interventions—whether skeletal, functional, or dentoalveolar—allow for the targeted modification of these profile relationships. Sagittal and vertical repositioning, as well as dental compensation, can be used to harmonize asymmetries and imbalances along the aesthetic axis [54]. (Figure 20 A, B).

Aesthetic-oriented surgery, however, has its limitations. While osteotomy-based repositioning procedures of the midface and lower face are well established within the scope of aesthetic-functional surgery, craniofacial surgery—such as procedures involving the orbits or the frontal skull—is generally restricted to reconstructive or syndromic cases due to strict indications and elevated surgical risks [55-61].

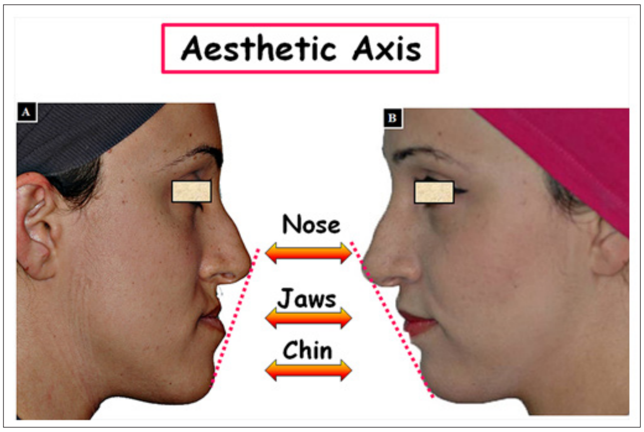

Figure 20 A–B: Figures A and B show the progression of the aesthetic axis in a female patient in profile before (A) and after (B) combined orthodontic–surgical treatment. The harmonization of the profile line demonstrates the therapeutic impact on facial aesthetics.

The interdisciplinary treatment of skeletal dysgnathias must always proceed with the awareness that aesthetic and functional goals are inseparable. In this context, the aesthetic axis functions as a clinically relevant compass for evaluating and optimizing the facial profile [60,61].

Indication, Diagnostics, and Documentation

Malocclusion is defined as a misalignment of the teeth caused by unfavorable growth patterns in the skeletal relationship between the upper and lower jaws (maxillomandibular). Such growth patterns may lead to dysplastic development in the horizontal, vertical, or transverse dimensions—or a combination of all three [55-61].

Conversely, even with a favorable maxillomandibular relationship resulting from physiological growth, an ideal occlusion is not automatically achieved, as the final occlusal outcome depends on numerous additional factors. Thus, malocclusion may still develop despite healthy and physiological skeletal growth, due to changes in the dentoalveolar region (e.g., tooth migration, congenital absence of teeth, tooth loss, tooth shape anomalies, or dental malpositions) [54].

The treatment of malocclusions that are purely dentoalveolar in origin is essentially limited to aligning and leveling the teeth into an occlusally and aesthetically acceptable position [55-61].

Diagnosis based on the available documentation, as well as indication, treatment planning, and implementation, is divided into four phases:

Phase I: Data Collection and Initial Diagnosis

This phase involves establishing a comprehensive database, generating a problem list, diagnosing the findings, and conducting an interdisciplinary team consultation. To illustrate the potential changes achievable through various treatment approaches, Proffit and Ackerman developed the concept of the "Envelope of Discrepancy." This model highlights the relationship among the three primary treatment options for skeletal dysgnathias:

- The innermost envelope represents the limits of purely orthodontic camouflage treatment.
- The middle envelope reflects the boundaries of orthodontic treatment combined with growth modification.
- The outermost envelope defines the limits of surgical correction.

It is important to note that treatment capabilities across the three spatial planes (sagittal, vertical, transverse) are not symmetrical. For example, mandibular hypoplasia can typically be addressed more effectively through growth guidance than mandibular hyperplasia [57].

Growth modification, also referred to as dentofacial orthopedics, remains the preferred treatment approach for severe skeletal deformities in growing patients. However, despite the ability to positively influence growth to some degree, the potential for significant skeletal enhancement is limited. Moreover, the individual response to such measures varies greatly—indicating that growth modification should be considered especially in pre-adolescent patients [57,60].

Phase II: Interdisciplinary Planning

This phase involves the development of an interdisciplinary problem list, in which the findings are prioritized and potential solutions for dentofacial problems are proposed. This list serves as the foundation for a preliminary treatment timeline [16-19].

To discuss the treatment plan with the patient and their family—and to finalize the therapeutic strategy—a joint meeting is held between the patient, the parents, and the interdisciplinary treatment team [55-61].

Phase III: Patient-Centered Decision-Making

It is essential for clinicians to recognize the importance of involving patients and their parents in the treatment planning process. According to Ackerman and Proffit, patients are often more influenced by subjective factors (such as individual values and needs), while professionals tend to focus on objective findings (such as the clinical problem list) [55-61].

This discrepancy underscores the necessity of clear communication especially when choosing between orthodontic camouflage and surgical-orthodontic correction. The modern concept of patient autonomy has shifted the clinician's role away from a traditionally paternalistic model toward a participatory model of decision-making [57].

A patient-centered treatment plan should consist of three essential elements:

Compilation and prioritization of the orthodontic problem list in an interdisciplinary context: The orthodontist is responsible for recording and structuring the clinical problem list based on comprehensive diagnostics. The prioritization of treatment-relevant findings is carried out in close collaboration with the patient. This process is based on a detailed evaluation of all available diagnostic materials, including conventional and digital imaging (e.g., radiographs, CBCT), as well as extraoral and intraoral photographic documentation [1,18,19].

Additionally, a thorough clinical examination is conducted, integrating functional analysis methods—both manual and instrumental. In complex cases or when further diagnostic clarity is required, an interdisciplinary consultation may be initiated, involving specialties such as nuclear medicine, sleep medicine, otolaryngology, psychology, and speech therapy.

Risk-Benefit Analysis and Informed Decision-Making in Elective Orthodontic Procedures

Since most orthodontic-surgical interventions are elective, a careful and individualized risk-benefit analysis is an essential part of the therapeutic decision-making process. In this context, the option to decline treatment must be explicitly considered and presented to the patient as a fully valid alternative.

The planned procedure must therefore be clearly classified as an elective intervention, distinct from emergency care or medically mandatory procedures. This necessitates comprehensive, objective, and open-ended patient education, in which the potential advantages, risks, and limitations of the treatment are transparently communicated [57].

Any form of persuasive or coercive communication is ethically unacceptable in the context of responsible patient education. Instead, patients must be given the opportunity to make a self-determined and informed decision, based on evidence-based information and in alignment with their individual values and personal priorities [54].

The risk-benefit discussion—including the legitimate option of not undergoing treatment—is especially important because elective procedures, by definition, are not urgent or medically imperative. This requires a clear, thorough, and neutral explanation of the pros and cons of the proposed treatment and must never involve attempts to pressure or convince the patient [57].

Integration of patient-specific expectations, values, and life circumstances

A cornerstone of modern patient-centered medicine and dentistry is the systematic consideration of individual expectations, value systems, and life contexts in the treatment planning process. This includes not only assessing the patient's functional and aesthetic goals, but also addressing personal priorities, psychosocial background, and cultural or ethical beliefs that may influence the treatment decision and its acceptance [16-19].

Actively incorporating these subjective factors fosters a stronger therapeutic alliance between clinician and patient and contributes significantly to ensuring a personalized, context-sensitive, and successful long-term outcome. This participatory approach enables the alignment of medical recommendations with the patient's personal goals and supports the development of a treatment strategy that is both clinically sound and personally acceptable [44-52].

The clinician must work with the patient to finalize the treatment plan only after all risks have been clearly explained and informed consent has been obtained. Since the patient's subjective perception of the problem often differs from the clinical assessment, an honest and transparent dialogue between provider and patient is essential.

Phase IV: Preoperative, Operative, and Postoperative Phase
This phase includes:

- Pre-treatment procedures, such as restorative, endodontic, and periodontal measures
- The orthodontic preparation phase for the surgical intervention
- The actual orthodontic-surgical procedure
- The postoperative orthodontic treatment, aimed at precise adjustment and long-term stabilization of the occlusion
- Ongoing interdisciplinary monitoring, re-evaluation, communication within the treatment team, and, if necessary, modification of the treatment plan

Indication for Combined Orthodontic-Surgical Treatment

Orthognathic surgery often has profound effects on the external appearance of the face, which—particularly in adults—represents an integral component of personal identity due to the consolidation of morphological structures over time. As a result, it plays a significant role in a person's self-image. Moreover, since people are perceived by others primarily through their face, the quality of social interactions is also directly influenced by facial appearance. Consequently, such far-reaching interventions require careful indication and psychological evaluation [57].

The treatment outcome as perceived by the patient—particularly in terms of dental and general facial aesthetics, the subjective cost–benefit or pain–benefit ratio, and the "social success" of the therapy—must therefore be considered as evaluation criteria of exceptional importance. For this reason, alongside functional considerations (e.g., temporomandibular joint health, masticatory function), the psycho-aesthetic dimension—including skeletal and soft tissue changes as well as the patient's self-assessment—constitutes a crucial element in the indication process [45-57].

Although combined orthodontic-surgical procedures are typically elective and generally follow well-established treatment protocols with relatively low risk, they are still subject to strict indication criteria [58].

The main indications include:

- Functional impairments
- Severely compromised dentofacial aesthetics
- Temporomandibular joint (TMJ) disorders
- Inadequate feasibility of prosthetic rehabilitation
- Comprehensive rehabilitation, such as in patients with cleft lip and palate

The logical answer to the question, "Which patient is a candidate for combined orthodontic-surgical treatment?" is: any patient with a significant skeletal or severe dentoalveolar problem that cannot be corrected by orthodontic treatment alone. This raises further questions such as: "When is a discrepancy too severe to be resolved by orthodontics alone?" and "What treatment plan will best achieve the desired outcome?"

To answer these questions, not only are comprehensive diagnostic records required—clinical examination, functional diagnostics, radiographs, intraoral and extraoral photographs, and study models—but also a thorough medical and dental history, in order to understand the patient's concerns and motivations for seeking treatment [61-70].

The success of combined orthodontic-surgical therapy depends not only on optimal tooth alignment and correct jaw positioning, but also significantly on the patient's motivation, expectations, and overall satisfaction [54].

Numerous studies have been conducted on the motivations of orthodontic patients, analyzing factors such as age, gender, and educational background. Research by Flanary [71,72]. Jacobson, and Kiyak on motivation, expectations, and satisfaction has shown that 79% to 89% of patients undergoing combined orthodontic-surgical treatment do so not only for functional reasons, but especially for aesthetic purposes. The emphasis placed on these reasons varies depending on the extraoral manifestation of the dysgnathia [73-79].

Furthermore, Kiyak found that more women than men expressed a desire to improve their facial aesthetics. In a study by Scott et al., which evaluated patient motivations and expectations before and after surgery, it was discovered that patients often reported postoperative motives—especially aesthetic ones—that were not mentioned or deemed important prior to surgery [73-80].

Therefore, orthodontists must align the treatment objectives with both functional and aesthetic goals that best meet the individual's needs, as a treatment focused solely on occlusion may not result in a satisfactory facial aesthetic or psychosocial outcome.
The social and psychological constitution of the patient is of central importance, since even an objectively successful treatment may be perceived negatively by the patient—particularly in the presence of unrealistic expectations.

Two Patient Groups Considered Particularly at Risk:
- Individuals with acquired deformities
- Individuals with external motives for seeking treatment (e.g., legal, familial, or social reasons)

Such patients should only be treated after careful consideration, and if necessary, in consultation with a psychologist. Since dissatisfaction with the outcome is common in these cases, it may be advisable to refrain from treatment altogether. A targeted sociopsychological history is helpful for identifying such patients at an early stage [73-80].

The assessment of potential contraindications that could preclude surgical intervention falls under the clinical responsibility of the surgeon during the preoperative diagnostic phase. A thorough risk-benefit analysis is required, taking into account the patient's general health status as well as any systemic or local risk factors.

Relevant contraindications include, in particular:
- Cardiovascular diseases that significantly increase perioperative risk and may render surgery inadvisable
- Poorly controlled or uncontrolled diabetes mellitus
- Lack of treatment adherence (e.g., due to underlying psychiatric disorders or cognitive impairment)
- Active infectious diseases, especially hepatitis B, hepatitis C, or HIV infections
- Hematological disorders or coagulation abnormalities, such as clotting factor deficiencies, and diseases of the hematologic or lymphatic systems, including vascular anomalies like hemangiomas or lymphangiomas in the surgical area.

The identification and assessment of these risk factors are essential for ensuring patient safety, as well as for the legal and medical-ethical justification of the planned surgical procedure [16,57,60].

Treatment

A structured, comprehensive, and standardised diagnostic process forms the essential foundation for therapeutic decision-making in combined orthodontic-orthognathic treatment. Beyond the collection of clinical, imaging, and functional findings, thorough documentation is imperative to ensure interdisciplinary planning, surgical execution, and long-term treatment stability [77].

Precise diagnostics and comprehensive documentation are prerequisites for the successful planning and implementation of combined orthodontic-orthognathic treatment. Given the complexity of this therapeutic approach, standardised diagnostic procedures must be adhered to, and a multitude of records meticulously collected, analysed, and archived [72-80].

Medical History and Clinical Examination

The process begins with a detailed general and specific medical history, including information on existing medical conditions, prior treatments, temporomandibular joint complaints, and functional limitations. This is followed by a systematic clinical examination of facial aesthetics, extraoral and intraoral soft tissues, as well as dental alignment and occlusion [15,16].

Photographic Documentation

Standardised extraoral and intraoral photographs are required for analyzing facial proportions and dental structures. These include:
- Extraoral images: frontal view, left and right profile views with natural head position
- Intraoral images: maxillary arch, mandibular arch, frontal and lateral occlusion views

The profile analysis is conducted in the sagittal, vertical, and transverse dimensions to assess facial structure and harmony.

A comprehensive analysis of facial soft tissue conditions is key to achieving a treatment result that aligns with the patient's expectations and satisfaction, since the patient primarily judges the outcome based on the change in their extraoral [73-80].

The definition of an attractive facial appearance has long been a concern in orthodontics, and numerous orthodontic studies have investigated this topic (e.g., Burstone 1958; Di Paolo et al. 1983). These studies attempted to determine the structure of the "ideal" face and to relate various orthodontic treatment modalities to changes in facial appearance (Downs 1952; Holdaway 1983, 1984). Riedel (1952) and Peck & Peck (1970) provided a comprehensive review of the literature in this area [15,16].

Models of Jaw Relation
Digital or conventional plaster models are essential for the precise analysis of individual dental arches across the sagittal, vertical, and transverse planes. These models facilitate the assessment of space conditions, arch width, tooth positioning, and jaw alignment. For functional evaluation, models should ideally be mounted in centric relation using bite registrations. This approach enables the accurate simulation of mandibular movements and occlusal relationships, which is crucial for comprehensive diagnosis and treatment planning.

Advancements in digital technology have introduced intraoral scanners and virtual articulators, offering enhanced accuracy and efficiency in recording jaw relations. Studies have demonstrated that digital bite registrations can achieve clinically acceptable precision, making them a viable alternative to traditional methods in orthodontic practice [75-80].

The integration of digital models into treatment planning not only streamlines the workflow but also allows for better visualization and communication among interdisciplinary teams. By employing these technologies, clinicians can ensure more predictable outcomes and improved patient satisfaction [76-80].

Radiological Diagnostics
To thoroughly assess skeletal structures, the following imaging modalities are required:

- Orthopantomogram (OPG) for an overview of dental status, tooth development, jaw structures, and pathological changes
- Lateral cephalometric radiograph (LCR) for cephalometric analysis (e.g., according to Steiner, Ricketts, or Hasund)
- (Optional) Posteroanterior (PA) cephalometric radiograph for the analysis of asymmetries
- (Optional) Three-dimensional imaging (e.g., digital volume tomography or cone-beam CT) for complex cases or for preoperative planning

If temporomandibular joint (TMJ) pathology is suspected, additional imaging methods may be necessary, such as:

- Computed tomography (CT)
- Magnetic resonance imaging (MRI)
- Nuclear medicine scintigraphy

These specialized modalities enable detailed visualization of the TMJ structures and contribute to more accurate diagnosis and precise treatment planning.

In specific cases, hand-wrist radiographs may be indicated to assess remaining growth potential. This method allows the evaluation of skeletal maturity and assists the interdisciplinary team in determining the appropriate timing and extent of surgical intervention [75-80].

By combining these radiological techniques, the clinician gains a comprehensive view of:

- Craniofacial skeletal structures
- Tooth position and occlusion
- Potential facial asymmetries
- Condition of the temporomandibular joints
- Growth potential

This diagnostic foundation is critical for developing an individualized, precisely tailored treatment plan and ensuring optimal outcomes in orthognathic procedures.

Radiographic analysis may also be supplemented by the Burstone hard tissue analysis[7] to quantify skeletal relationships with high precision [73-80].

Cephalometric Analysis
Cephalometric analysis is a fundamental diagnostic tool in orthodontics and orthognathic surgery, enabling a detailed assessment of craniofacial morphology. It provides critical insights into the sagittal, vertical, and transverse discrepancies of the maxillomandibular complex, as well as growth patterns and skeletal disproportions. This analysis forms the cornerstone for precise surgical and orthodontic treatment planning [15,16].

Key Components of Cephalometric Analysis:

- Sagittal Assessment: Evaluates anteroposterior relationships between the maxilla and mandible using parameters such as the ANB angle, Wits appraisal, Beta angle, and Downs angle of convexity. These measurements help classify skeletal patterns into Class I, II, or III malocclusions, guiding decisions on whether orthodontic camouflage or surgical intervention is appropriate [75-80].
- Vertical Assessment: Analyzes facial height proportions and growth direction through measurements like the mandibular plane angle, lower anterior facial height (ANS-Me), and Jarabak ratio. This helps identify tendencies toward open bite or deep bite malocclusions and informs vertical control strategies in treatment planning.
- Transverse Assessment: Assesses facial symmetry and transverse discrepancies using posteroanterior (PA) cephalograms or cone-beam computed tomography (CBCT) scans. Measurements of maxillary and mandibular widths, as well as dental midline deviations, are crucial for diagnosing crossbites and planning maxillary expansion procedures.
- Growth Direction and Skeletal Disproportions: Determines the direction of facial growth (vertical, horizontal, or balanced) and identifies any disproportions between skeletal structures. This information is vital for timing interventions and predicting treatment outcomes.
- By integrating these assessments, cephalometric analysis facilitates the development of individualized, evidence-based treatment plans that address both functional and aesthetic concerns [73-80].

Clinical Functional Analysis
The clinical examination involves assessing mandibular movements, including mouth opening, lateral excursions (laterotrusion), and forward movements (protrusion). It also includes palpation of the TMJs and masticatory muscles to detect pain, joint sounds (such as clicking or crepitus), and deviations in movement patterns. This analysis helps in identifying functional limitations or abnormalities that may impact treatment planning [80].

Instrumental Functional Analysis
Instrumental diagnostics provide quantitative data on mandibular function. Tools such as jaw motion tracking systems,

electromyography (EMG), and computerized mandibular scanning (CMS) are employed to measure jaw movements and muscle activity. These methods offer objective insights into the functional status of the masticatory system, aiding in the diagnosis of temporomandibular disorders (TMDs) and in formulating individualized treatment plans [81-87].

Integration into Treatment Planning

The findings from both clinical and instrumental analyses are integrated into the overall treatment strategy. Addressing functional disorders before surgical procedures is imperative to prevent postoperative complications and to enhance the stability and success of the treatment. A multidisciplinary approach, involving orthodontists, surgeons, and other specialists, ensures that functional considerations are adequately addressed throughout the treatment process [73-80].

In summary, thorough functional diagnostics are a cornerstone in the planning and execution of combined orthodontic and orthognathic treatments, ensuring both functional efficiency and patient satisfaction.

Interdisciplinary Assessment and Planning Documentation

In complex cases, the involvement of additional specialties—such as speech therapy, otolaryngology (ENT), and physiotherapy—may be necessary to comprehensively address the patient's needs. Insights from these disciplines are integrated into the overall treatment plan to ensure a holistic approach [80-85].

Furthermore, the preparation of detailed planning materials is essential for simulating surgical procedures. These may include model surgeries, digital setups, or splint designs, which serve as visual and functional guides for the surgical team. Such tools facilitate precise planning and execution of the surgical intervention [85-90].

Documentation and Patient Information

All findings, analyses, and treatment plans must be systematically documented. Comprehensive patient education regarding the proposed treatment process, associated risks, alternative options, and expected outcomes is mandatory and should be provided in written form [73-80].

Treatment Strategy for Combined Orthodontic–Orthognathic Cases

The treatment sequence follows the concept we published for combined orthodontic–orthognathic therapy. It consists of four phases (Figure 21 A–J):

I). Preoperative Measures and Orthodontic Preparation

1. "Splint Therapy" to establish the physiologic condylar position ("centric relation") prior to final planning
2. Orthodontics to shape and coordinate the dental arches and to decompensate the underlying skeletal dysgnathia
3. "Splint Therapy" again—worn for 3–4 weeks immediately before surgery—to verify and maintain the condylar centric relation

II). Orthognathic Surgery
Surgical repositioning of the jaws to correct the skeletal dysgnathia.

III) III) Postoperative Orthodontics
Fine adjustment of the occlusion to achieve optimal dental interdigitation and function.

IV).Retention
Use of retainers and adjunctive measures to secure and stabilize the achieved result over the long term.

Phase 1: Splint Therapy

The occlusal splint was inserted for diagnostic purposes for a period of 4–6 weeks prior to final treatment planning [2-6,46].

This allows the determination of the physiologic condylar position (centric relation) before finalizing the treatment plan [15].

Phase 2: Orthodontic Preparation

During the orthodontic preparation phase, the dental arches are aligned and harmonized with the goal of eliminating dental compensations related to the underlying skeletal dysgnathia. Particular attention is given to the transverse relationships in the canine region to ensure a stable, interdigitating occlusion after surgical correction [78-88].

The type and extent of orthodontic preparation are individually tailored according to the skeletal dysgnathia type and the defined therapeutic objectives. For example, treatment strategies differ significantly between patients with skeletal Class II dysgnathia combined with deep bite and short-face syndrome and those with Class II cases exhibiting a normal vertical overbite (FigureA–D) [16].

Phase 3: Splint Therapy

Splint therapy is used to determine the centric condylar position approximately 4–6 weeks prior to surgery. The objective is to record the temporomandibular joint in its physiological centric position, in which the condyles will be positioned intraoperatively. An incorrect mandibular or condylar position can result in erroneous surgical planning, incorrect centric relation transfer during surgery, and ultimately a relapse. Previously, we used a laboratory-fabricated occlusal splint; today, we apply a prefabricated Aquasplint, which is customized to fit the patient's occlusion [80-92]. (Figure 21E).

Phase 4: Orthognathic Surgery for Correction of Skeletal Dysgnathia

After completion of the model surgery, determination of the displacement distance, and fabrication of the occlusal splint in the target occlusion, the planned jaw advancement is performed. In our treatment concept, precise intraoperative positioning of the condyles in centric relation is a standardized procedure to maintain their correct anatomical orientation.

Fixation is achieved using functionally stable osteosynthesis, which not only secures the osteotomy fragments and prevents undesired displacement, but also allows for immediate postoperative functional loading and therapy without the risk of fragment detachment (Figure 21F).

Phase 5: Postoperative Orthodontics

Post-surgical orthodontic treatment typically begins a few days after surgery—usually on the fourth postoperative day—and serves to stabilize and finely adjust the occlusion.

The design of the postoperative orthodontic phase aimed at achieving a functionally and aesthetically optimal final occlusion varies depending on the individual case. It is significantly influenced by the type of underlying skeletal dysgnathia, the therapeutic objectives, the extent and quality of preoperative orthodontic preparation, as well as the specific surgical intervention performed [81,82]. (Figure 21G–J).

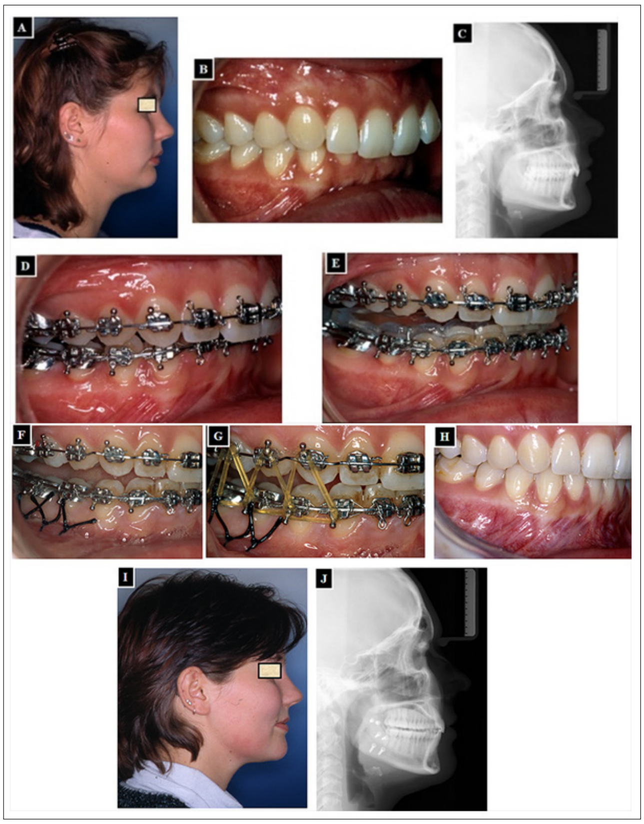

Figure 21 A–J: Figures A–C show the initial findings of a patient with Class II/2 dysgnathia. After orthodontic preparation (D), an occlusal splint was used to determine the centric condylar position (E). Figures F and G depict the early postoperative phase with intermaxillary elastics to stabilize occlusion. Figures H–J document the final result with stable occlusion and a harmonized facial profile.

Phase 6: Retention

To ensure long-term stabilization of treatment outcomes, our interdisciplinary treatment concept incorporates three forms of retention:

a). A fixed retainer, in the form of a bonded lingual wire from canine to canine, is used to maintain the position of the anterior teeth and prevent relapse in the anterior segments [81,82].

b). To support muscular adaptation to the new skeletal and dental situation, physiotherapy is initiated both preoperatively and postoperatively. This measure promotes myofunctional reorganization and contributes to the overall stability of the treatment outcome [16].

c). Additionally, a functional orthodontic appliance is employed to further assist in muscular adaptation and to stabilize the newly established jaw relationship.

Physiotherapeutic interventions and functional orthodontic appliances are particularly used in patients with skeletal Class II dysgnathia, where muscular imbalance often represents a key factor contributing to relapse tendencies [81-94].

Discussion

Combined orthodontic–orthognathic therapy has become an integral component in the treatment of complex skeletal dysgnathia. This article presented a comprehensive treatment protocol that incorporates growth modification techniques, dentoalveolar compensation strategies, and surgical corrections. This multi-phase approach addresses the multifactorial origins of dentofacial deformities and is guided by functional, structural, and aesthetic objectives [89-94].

The delineation of therapeutic options according to growth potential enables a differentiated indication process. While functional appliances and orthopedic measures such as activators, Bionator, face masks, or headgear are effective in growing patients, orthognathic surgery remains the only causal approach for patients with completed growth to correct severe skeletal discrepancies. The consistent application of individualized treatment pathways based on age and growth phase represents a paradigmatic shift toward personalized dysgnathia surgery [78-84].

Central to the success of this therapy is its interdisciplinary nature, combining orthodontic, surgical, and—where appropriate—physiotherapeutic interventions. Accurate diagnostics and planning are essential. In particular, the integration of soft tissue considerations—the so-called soft tissue paradigm—has become increasingly established in treatment planning, emphasizing the aesthetic outcome as an equally important goal alongside functional rehabilitation [80-94].

A major contribution of this article is the systematic presentation of the treatment process across six distinct phases—from centric splint therapy, through orthodontic preparation, surgical execution, and ending with postoperative orthodontics and retention. This structured approach enhances treatment quality and creates transparency for both patients and practitioners [89-92].

Special attention is warranted for the concept of reverse orthodontics, where pre-surgical decompensation of dentoalveolar adaptations is performed to facilitate optimal skeletal correction. This step demands high orthodontic expertise and close coordination with surgical planning [81-94].

The photographic documentation of various case types highlights the versatility of the described therapeutic approaches—from early functional interventions to dentoalveolar compensation (with or without extractions), and advanced surgical techniques such as Le Fort I osteotomies, bimaxillary procedures, and distraction osteogenesis. It becomes clear that modern dysgnathia therapy cannot follow rigid protocols but instead requires individualized, dynamic concepts [41,87-94].

Moreover, the integration of emerging techniques, such as distraction osteogenesis and the surgery-first approach, demonstrates that the article reflects both current scientific knowledge and technological advancement. The surgery-first approach, in particular, is gaining interest due to its potential to shorten treatment duration and increase patient compliance. However, this method demands strict indication criteria and meticulous planning to minimize functional and aesthetic risks [16,89-94].

Another key component of the work is the consideration of psychosocial factors. Numerous studies confirm that many patients seek treatment more for aesthetic than functional reasons. This creates an ethical responsibility for clinicians to thoroughly assess expectations, ensure informed consent, and evaluate the patient's psychological suitability. Distinguishing orthognathic surgery from purely aesthetic procedures is as essential as respecting individual patient values [57,90-94].

Despite all advances, certain limitations remain. Surgical outcomes depend on baseline anatomy, surgical technique, soft tissue response, and postoperative compliance. In cases involving temporomandibular disorders, extreme asymmetries, or syndromic conditions, there are risks of relapse and functional complications. The structured approach presented—particularly the standardized determination of centric condylar position—contributes significantly to minimizing such risks [15,18,57].

Consistent with other studies, it was revealed that patients with CL III have a significantly lower risk of complications compared to CL I and especially CL II patients. We hypothesize that the anterior movement of the mandible in CL II surgeries is a specific risk factor for condylar problems, as was presented in previous reports [95,96]. Another risk factor may be the size of the mandible, which is frequently retrognathic and hypoplastic in these patients, the opposite of that for CL III patients. This phenomenon leads to increase in the operation time, which in turn, may lead to increase in complications rate [97].

The data from this retrospective study show that severe complications are relatively
rare in orthognathic surgery; this finding is consistent with other studies. Statistical analysis revealed interesting links between diagnoses, surgeries and complication probabilities. We found firstly that one-jaw surgery is safer that two-jaw surgery; secondly, we found that the skeletal condition with the highest risk for complications in Skeletal Class II [41,57,95-97].

The Surgery First approach emphasizes the need for collaboration between oral surgeons, orthodontists, and other healthcare professionals. As interdisciplinary teamwork becomes increasingly vital, the development of comprehensive care protocols is anticipated. These protocols could streamline the treatment process, improving both patient satisfaction and clinical outcomes [98,99]. The future of the Surgery First method in orthognathic surgery appears promising, especially in terms of shortening treatment durations, enhancing patient satisfaction, and utilizing technological advancements to achieve more accurate and predictable results. As the technique continues to advance and incorporate state-of-theart
technologies, it could become a more significant component of orthognathic surgery, providing a moreefficient, patient-centered approach for treating complex malocclusions. [98,99].

Conclusion

Combined orthodontic–orthognathic therapy is a highly complex yet extremely effective approach for treating skeletal dysgnathia—provided it is well planned. This article makes a valuable contribution to the systematization of this treatment strategy, bridging scientific rigor with clinical applicability. Key to long-term treatment success are interdisciplinary collaboration, consistent consideration of functional, aesthetic, and psychosocial dimensions, and the individualized application of diagnostic and therapeutic tools.

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