BIOMECHANICAL CONSIDERATIONS IN ORTHODONTIC CORRECTION OF MESIAL OCCLUSION IN UNILATERAL CLEFT LIP AND PALATE PATIENTS

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Introduction

The orthodontic management of mesial occlusion in patients with unilateral cleft lip and palate (UCLP) involves complex biomechanical considerations and treatment strategies that must be adapted to the unique anatomical and functional challenges associated with cleft conditions. Mesial occlusion, often associated with a prognathic skeletal pattern, is characterized by altered sagittal relationships between the maxilla and mandible, leading to compromised occlusal function and facial harmony. In individuals with UCLP, these discrepancies are frequently exacerbated by maxillary hypoplasia, dental arch asymmetry, and the long-term effects of surgical repair.

Successful correction of mesial occlusion in this patient population relies on the strategic use of both removable and fixed orthodontic appliances to normalize dental arch relationships, manage transverse deficiencies, and address dentoalveolar compensations. Treatment planning must carefully balance orthodontic mechanics with skeletal considerations, particularly in cases where surgical intervention is anticipated. The timing of orthodontic procedures—especially pre-surgical orthodontics—plays a critical role in optimizing occlusal relationships, facilitating surgical correction, and improving facial esthetics.

Ongoing debate exists regarding the optimal sequencing of maxillary expansion in relation to alveolar bone grafting. Emerging clinical evidence suggests that maxillary expansion performed after bone grafting may offer advantages, including improved dental alignment, enhanced stability of the grafted bone, and reduced complications related to scar tissue formation. These findings underscore the need for individualized treatment protocols based on cleft severity, dental development, and surgical timing.

The management of associated dental anomalies, such as hypodontia, ectopic eruption, and malpositioned teeth, further complicates orthodontic care in UCLP patients. Coordinated collaboration among orthodontists, maxillofacial and plastic surgeons, pediatric dentists, and other specialists is therefore essential. This multidisciplinary approach not only addresses the structural and functional aspects of mesial occlusion but also considers the psychosocial implications of long-term treatment, including facial appearance, speech, and self-esteem.

Long-term clinical outcomes indicate that well-structured, multidisciplinary treatment protocols can result in functional occlusion and oral health–related quality of life comparable to that of non-cleft individuals. Nevertheless, challenges persist in achieving optimal occlusal stability and managing the biomechanical forces exerted by scarred soft tissues and altered muscular function. These complexities highlight the need for continued research, refinement of orthodontic techniques, and individualized, growth-sensitive treatment planning to further improve outcomes for patients with unilateral cleft lip and palate.

Biomechanical Principles

Biomechanical principles play a central role in the orthodontic treatment of patients with unilateral cleft lip and palate (UCLP), as successful outcomes depend on precise control of

forces applied to compromised skeletal and dental structures. The presence of maxillary discontinuity, altered alveolar bone morphology, surgical scarring, and asymmetrical muscle function requires orthodontic mechanics that differ substantially from those used in non-cleft patients. An understanding of these biomechanical considerations is essential for achieving stable occlusion, maintaining skeletal corrections, and minimizing relapse.

Orthodontic Techniques and Their Biomechanics

Orthodontic treatment in UCLP patients commonly involves a combination of removable and fixed appliances designed to correct sagittal, transverse, and vertical discrepancies while accommodating cleft-related anatomical limitations. These appliances aim to establish appropriate overjet and overbite relationships, normalize transverse arch dimensions, and coordinate maxillary and mandibular arches.

Biomechanically, force application must be carefully controlled to prevent undesirable tooth movement, alveolar bone resorption, or destabilization of surgically repaired segments. The altered quality and quantity of alveolar bone adjacent to the cleft demand lighter, well-distributed forces to reduce the risk of tipping and periodontal compromise. Fixed appliances allow for greater precision in force control and are often preferred during comprehensive treatment phases, while removable appliances may be useful during early interceptive stages to guide growth and correct functional shifts.

Treatment Timing and Developmental Considerations

The effectiveness of orthodontic biomechanics is strongly influenced by treatment timing and the stage of craniofacial development. Early orthodontic intervention can take advantage of greater skeletal adaptability and improved response to orthopedic forces, particularly in the correction of transverse discrepancies and functional anterior crossbites.

Treatment planning must account for the developmental status of the dentognathic system, the type and extent of the cleft, and the patient's surgical history. Prior surgical repair can alter tissue elasticity and resistance to orthodontic forces, necessitating individualized biomechanics. Additionally, psychosocial considerations—such as treatment tolerance, compliance, and emotional well-being—must be incorporated into appliance selection and force application strategies.

Maxillary Expansion and Bone Grafting

One of the most important biomechanical considerations in UCLP treatment concerns the relationship between maxillary expansion and alveolar bone grafting. Maxillary transverse deficiency is common in this population, and expansion is often required to correct posterior crossbites and improve arch form.

Recent clinical evidence supports the use of maxillary expansion following alveolar bone grafting in selected cases. Post-grafting expansion may promote better alignment of maxillary segments, enhance integration of the grafted bone, and reduce cleft width while improving gingival closure. Rapid maxillary expansion applied after grafting has been shown to be biomechanically safe when carefully monitored, as it does not compromise graft stability and can contribute to improved transverse development.

Managing Complications and Biomechanical Challenges

Despite advances in orthodontic techniques, several biomechanical challenges persist in the treatment of UCLP patients. Palatal scar tissue resulting from surgical repair often generates contractile forces that oppose transverse expansion and increase the risk of relapse. Long-term

retention strategies are therefore essential to counteract these forces and maintain treatment gains.

The use of skeletal anchorage systems, such as miniscrews, has significantly enhanced biomechanical control in UCLP orthodontics. These devices provide stable anchorage for tooth movement and orthopedic force application, particularly when combined with intermaxillary elastics for maxillary protraction. Skeletal anchorage reduces unwanted dental side effects and allows more effective transmission of forces to the maxillary complex.

Clinical Considerations

Mesial occlusion, commonly referred to as prognathism and classified as Class III malocclusion under the Angle classification system, presents distinct diagnostic and therapeutic challenges in orthodontics, particularly in patients with unilateral cleft lip and palate (UCLP). Clinically, this malocclusion is characterized by an altered sagittal molar and canine relationship, in which the maxillary dentition is positioned posteriorly relative to the mandibular dentition. These occlusal discrepancies frequently result in anterior crossbite, negative overjet, and compromised facial balance, all of which are often intensified by maxillary hypoplasia and asymmetrical growth associated with cleft conditions.

In UCLP patients, mesial occlusion is rarely an isolated dental problem; rather, it reflects an underlying skeletal imbalance compounded by previous surgical repair, altered muscle function, and abnormal growth trajectories. These factors necessitate careful clinical evaluation and individualized treatment planning.

Treatment Approaches

The primary management of mesial occlusion relies on appliance-based orthodontic therapy, with the selection of removable, fixed, or orthopedic appliances depending on the severity of the discrepancy and the patient's stage of growth. In selected cases, adjunctive approaches such as myofunctional therapy may be employed to address abnormal muscle activity and functional mandibular positioning, although these methods alone are rarely sufficient in patients with significant skeletal involvement.

Treatment complexity is largely determined by the magnitude of the negative overjet, the extent of sagittal skeletal discrepancy, and the presence of transverse maxillary deficiency. Mild cases may be managed through orthodontic camouflage and dental compensation, whereas moderate to severe cases often require a comprehensive treatment strategy combining orthodontic mechanics with surgical intervention. Such integrated approaches aim to restore functional occlusion, improve facial esthetics, and enhance long-term stability.

Multidisciplinary Team Approach

Successful management of mesial occlusion in patients with UCLP requires coordinated care from a multidisciplinary team that typically includes orthodontists, oral and maxillofacial surgeons, plastic surgeons, pediatric dentists, speech-language pathologists, and otolaryngologists. Each specialist contributes essential expertise to address the functional, structural, and developmental challenges associated with cleft conditions.

Orthodontic care must be carefully sequenced within the broader treatment timeline, which is generally divided into neonatal, primary dentition, mixed dentition, and permanent dentition phases. Decisions regarding the initiation and progression of orthodontic treatment must be synchronized with surgical interventions to avoid compromising growth potential or surgical outcomes. Effective communication among team members is therefore critical to

ensure that orthodontic mechanics complement surgical objectives and support overall rehabilitation.

Considerations for Dental and Functional Anomalies

Patients with UCLP frequently present with additional dental anomalies that further complicate orthodontic management. These may include hypodontia, supernumerary teeth, ectopic eruption, enamel defects, and dentoalveolar compensations that mask underlying skeletal discrepancies. Orthodontic treatment often requires deliberate removal of these compensations through dental decompensation to achieve optimal tooth positioning and to facilitate accurate surgical correction when indicated.

Functional impairments, particularly related to speech, hearing, and velopharyngeal competence, are also common in this population and must be considered when planning orthodontic intervention. The timing and type of orthodontic procedures may need to be adjusted to accommodate ongoing speech therapy or otologic management. Addressing both dental and functional considerations in a coordinated manner is essential for achieving comprehensive, patient-centered outcomes.

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