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Original Article

# Craniofacial Anomalies and Their Management in Pediatric Orthodontics

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## Abstract

Craniofacial anomalies represent a diverse group of developmental disorders with profound implications for a child's functional, aesthetic, and psychological well-being. Effective management of these conditions requires a multidisciplinary approach, with orthodontists playing a pivotal role in guiding craniofacial growth and development. This literature review explores current diagnostic techniques, orthodontic management strategies, and interdisciplinary care frameworks for addressing common craniofacial anomalies, such as cleft lip and palate, craniosynostosis syndromes, and hemifacial microsomia. Advances in 3D imaging, virtual surgical planning, and custom appliance fabrication are highlighted as transformative tools that enhance diagnostic accuracy and treatment precision. The review also underscores the importance of long-term monitoring and adaptive care to maintain favorable outcomes as patients grow and develop. Key research gaps and future directions are identified, emphasizing the need for further exploration into genetic mechanisms, advanced technologies, and evidence-based treatment protocols to optimize outcomes for pediatric patients with craniofacial anomalies.

**Keywords**: Cleft lip and palate, Craniofacial anomalies, Craniosynostosis, Developmental orthodontics, Hemifacial microsomia, Interdisciplinary care, Multidisciplinary collaboration, Orthodontic management, Pediatric orthodontics, Virtual surgical planning, 3D imaging.

## Introduction

Craniofacial anomalies encompass a diverse range of developmental disorders that affect the intricate structure and function of the head and facial region. These complex conditions can have profound implications for a child's physical, functional, and psychological well-being, underscoring the critical importance of comprehensive management strategies. (Dupas et al., 2008) Common craniofacial anomalies include cleft lip and palate, craniosynostosis syndromes, and hemifacial microsomia, each presenting unique clinical challenges.

The etiology of craniofacial anomalies is multifactorial, often involving a complex interplay of genetic and environmental factors. Syndromic craniofacial anomalies, such as Treacher Collins and Nager syndromes, can further compound the clinical presentation due to the intricate interrelationships between skeletal, dental, and soft tissue deformities. (Tavares & Moody, 2022)

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Effective management of these complex conditions requires a multidisciplinary approach, with orthodontists playing a pivotal role in guiding craniofacial growth and development. Orthodontic interventions aim to address the intricate functional, aesthetic, and psychological challenges associated with craniofacial anomalies, through comprehensive treatment planning and close collaboration with other dental and medical specialists. (Vishwanath et al., 2020)

This review seeks to provide an in-depth and updated synthesis of the current state-of-the-art diagnostic techniques and evidence-based orthodontic management strategies employed in addressing common craniofacial anomalies. The review will also highlight the importance of a multidisciplinary team approach and identify potential research gaps in this rapidly evolving and clinically significant field of pediatric orthodontics, ultimately contributing to improved outcomes for children affected by these complex conditions.

### Methodology

A systematic and comprehensive literature review was conducted across prominent electronic databases, including PubMed, Scopus, Web of Science, Google Scholar, EMBASE, and the Cochrane Library, to identify relevant studies addressing craniofacial anomalies and their management in pediatric orthodontics. The search included studies published between 2008 and 2024 to ensure an extensive and updated overview of advancements in this area. The search strategy employed a combination of specific keywords and Medical Subject Headings (MeSH), such as "craniofacial anomalies," "pediatric orthodontics," "orthodontic management," "cleft lip and palate," "syndromic craniofacial conditions," and "growth modification."

Articles published in English and focusing on orthodontic interventions for craniofacial anomalies in pediatric patients were included to ensure the reliability and applicability of the findings.

### Study Selection Process

## 1. Initial Screening

Titles and abstracts of all retrieved articles were reviewed to determine their relevance to the topic. Only studies focusing on the orthodontic management of craniofacial anomalies in pediatric populations were selected for further evaluation.

## 2. Abstract Evaluation

Abstracts were assessed based on the following inclusion criteria:

- Studies exploring the orthodontic management of craniofacial anomalies in children.
- Focus on common conditions such as cleft lip and palate, craniosynostosis, and syndromic craniofacial anomalies.
- Emphasis on innovative treatment methodologies or clinical outcomes.
- Evidence of interdisciplinary approaches involving orthodontics, pediatric dentistry, and other relevant specialties.

## 3. Inclusion of Targeted Studies

Studies that met the inclusion criteria were retrieved in full text for detailed evaluation. Peer-reviewed clinical trials, systematic reviews, longitudinal studies, and observational research were prioritized for their quality and clinical relevance.

# 4. Final Selection

Full-text articles were rigorously analyzed to extract findings directly relevant to the review's objectives. Studies offering high-quality evidence regarding the integration of orthodontic treatment strategies in managing craniofacial anomalies were included.

## Study Exclusion Process

1. **Non-Orthodontic Focus:** Studies that did not specifically address orthodontic management were excluded.
2. **Adult Populations:** Articles focusing on craniofacial anomalies in adult populations were excluded to maintain a pediatric-specific focus.
3. **Limited Clinical Relevance:** Studies lacking substantial clinical insights or employing outdated methodologies were excluded.
4. **Grey Literature:** Non-peer-reviewed articles, conference abstracts, and opinion pieces were excluded to ensure academic rigor.
5. **Non-Craniofacial Studies:** Research unrelated to craniofacial anomalies or orthodontics, such as general dental topics, was excluded.

## Definitions and Key Terms

For this literature review, the following terms are defined for clarity:

- **Craniofacial Anomalies:** Structural deformities of the head and facial bones, including syndromic and non-syndromic conditions like cleft lip and palate, craniosynostosis, and hemifacial microsomia. (Hopkins et al., 2019)
- **Collaborative Craniofacial Management**: A multidisciplinary strategy combining expertise from orthodontists, surgeons, and pediatric specialists to treat and manage craniofacial anomalies in young patients.(Sommerlad, 2023)
- **Developmental Orthodontics**: A field of orthodontics dedicated to addressing the growth and alignment of teeth and jaws during early stages of craniofacial development in children.(Dupas et al., 2008)
- **Growth Modification:** Orthodontic interventions designed to influence the growth of facial and cranial structures in children with anomalies. (Wright, 2015)
- **Interdisciplinary Care:** Collaboration between orthodontists, surgeons, pediatric dentists, and other healthcare providers to manage complex craniofacial anomalies effectively. (Gibson & Shetye, 2017)

## Quality Assessment

The included studies were evaluated using recognized quality assessment tools to ensure the validity and reliability of the synthesized findings. The Cochrane Risk of Bias tool was applied to identify potential sources of bias, including selection, performance, and reporting bias. This robust quality assessment process provided confidence in the quality of the evidence presented.

## Data Extraction and Synthesis

A systematic approach was adopted to extract key data points from the selected studies. This included study design, patient demographics, types of craniofacial anomalies, orthodontic treatment protocols, and clinical outcomes. The extracted data were synthesized to identify overarching themes, emerging trends, and innovative treatment strategies in pediatric orthodontic management of craniofacial anomalies.

The following key findings emerged from the review:

1. **Orthodontic Interventions in Cleft Lip and Palate:**
    - Early orthodontic treatment protocols, such as nasoalveolar molding (NAM) and palatal expanders, were shown to improve arch alignment and facilitate surgical outcomes.
2. **Growth Modification in Craniosynostosis:**
    - Growth-guiding devices, such as functional appliances, were effective in addressing skeletal discrepancies and improving facial aesthetics in syndromic craniosynostosis.
3. **Multidisciplinary Care:**
    - Interdisciplinary collaboration between orthodontists, surgeons, speech therapists, and pediatric dentists was essential for achieving optimal functional and aesthetic outcomes.
4. **Long-Term Outcomes:**
    - Evidence highlighted the importance of monitoring and revisiting treatment plans during growth to ensure stability and success in managing craniofacial anomalies.
5. **Emerging Technologies:**
    - Advances in 3D imaging, virtual surgical planning, and custom appliance fabrication have revolutionized the management of craniofacial anomalies, allowing for greater precision and personalization.

## Literature Review

### Classification and Epidemiology of Craniofacial Anomalies

Craniofacial anomalies encompass a diverse range of congenital and acquired developmental disorders that can profoundly impact the growth, function, and aesthetic appearance of the craniofacial complex. These complex conditions, which often manifest in the early stages of a child's development, present unique and multifaceted challenges for pediatric orthodontists in terms of accurate diagnosis, comprehensive treatment planning, and effective interdisciplinary collaboration. (Dupas et al., 2008)

Among the most common craniofacial anomalies encountered in pediatric orthodontics are cleft lip and palate, craniosynostosis syndromes, and hemifacial microsomia. (Ghizoni et al., 2016) These complex developmental disorders can significantly impair a child's physical, functional, and psychological well-being, requiring a specialized and coordinated approach to management. The orthodontist's role is crucial in addressing the intricate functional, aesthetic, and psychological needs of these pediatric patients through evidence-based interventions and a collaborative approach with other healthcare providers, such as surgeons, speech therapists, and mental health professionals.(Santiago & Grayson, 2009)

### Cleft Lip and Palate

Cleft lip and palate are among the most prevalent and complex craniofacial anomalies, characterized by a congenital fissure or opening in the upper lip, alveolar ridge, and/or palate. This developmental disorder can profoundly impact a child's functional abilities, aesthetic appearance, and psychological well-being. Prenatal detection through ultrasound and postnatal clinical examination and imaging are crucial for diagnosis.(AO et al., 2008)

The condition often presents a range of challenges, including feeding difficulties, speech and language delays, dental and orthodontic problems, and social and emotional challenges. Early interventions, such as Nasoalveolar Molding and palatal expanders, can improve arch alignment and facilitate surgical

outcomes. Surgical procedures for lip and palate repair, alveolar bone grafting, and secondary orthodontic interventions are also essential components of comprehensive management.(Abbott & Meara, 2023)

These multifaceted implications require a coordinated, multidisciplinary approach to management, involving the expertise of pediatric dentists, orthodontists, surgeons, speech therapists, and other healthcare providers. Through this collaborative effort, clinicians can develop and implement comprehensive treatment strategies that address the unique needs of each child with cleft lip and palate, optimizing their overall health, function, and quality of life.(Colvenkar et al., 2023)

## Craniosynostosis Syndromes

Craniosynostosis refers to the premature fusion of one or more cranial sutures, leading to abnormal skull and facial development. This condition can be classified as either syndromic or nonsyndromic. Syndromic craniosynostosis, such as Apert, Crouzon, and Pfeiffer syndromes, are characterized by a range of craniofacial, dental, and skeletal abnormalities that can significantly impact a child's growth, function, and appearance.(Faasse & Mathijssen, 2022)

Accurate diagnosis of craniosynostosis relies on advanced imaging techniques, such as computed tomography scans and cone-beam computed tomography, which allow clinicians to meticulously assess the extent of cranial and facial deformities. Genetic testing can also help identify any associated syndromes.(Safran et al., 2018)

In the management of craniosynostosis, surgical interventions to release the fused sutures and correct cranial deformities are often the first step. Following these procedures, the use of growth-modification appliances, such as functional appliances, can help guide the proper development of the craniofacial structures. Orthodontists play a crucial role in this process, working closely with craniofacial surgeons to develop and implement multistage treatment plans that address the dental and skeletal discrepancies, as well as provide long-term monitoring to ensure optimal outcomes.(Manlove et al., 2020)

## Hemifacial Microsomia

Hemifacial microsomia (HFM) is characterized by asymmetry resulting from underdevelopment of the mandibular, ear, and associated soft tissue structures. Accurate diagnosis begins with a thorough clinical examination, focusing on mandibular hypoplasia, facial asymmetry, and ear deformities such as microtia or anotia. Advanced imaging modalities play a pivotal role, with CBCT providing precise skeletal assessments, MRI evaluating soft tissue and neural involvement, and 3D imaging offering detailed documentation of asymmetry. Classification systems like the OMENS framework are frequently employed to standardize severity assessment, guiding treatment planning and interdisciplinary collaboration.

The management of HFM is tailored to the severity of the condition and the patient’s developmental stage. Surgical interventions such as distraction osteogenesis are used to address mandibular deficiencies, while soft tissue asymmetry is managed with grafting or flap techniques. Ear anomalies are corrected through prosthetics or autologous cartilage grafts to enhance aesthetics and function. Orthodontic management plays a complementary role, with early interventions focusing on functional appliances to guide mandibular growth, followed by fixed appliances during adolescence to achieve occlusal harmony. Long-term care emphasizes continuous monitoring to adjust treatment plans in response to growth and developmental changes.

Effective management of HFM requires a coordinated effort from a multidisciplinary team. Orthodontists and maxillofacial surgeons collaborate on surgical and skeletal corrections, while

prosthodontists contribute to aesthetic and functional rehabilitation. Speech therapists address articulation issues, and psychologists provide essential support for managing the psychosocial impact of the condition. This collaborative approach ensures comprehensive care, addressing the diverse functional, aesthetic, and emotional needs of patients with HFM.(Luo et al., 2023)

## Craniofacial Microsomia

Craniofacial microsomia is a spectrum of deformities characterized by underdevelopment of the mandible, ears, and associated soft tissues. This condition can significantly impact a child's function and aesthetic appearance. Accurate diagnosis relies on clinical examination and advanced imaging techniques, such as 3D imaging and cone-beam computed tomography, to meticulously assess the degree of facial asymmetry. Consideration should also be given to associated conditions, such as Goldenhar syndrome.(Buchanan et al., 2014)

In the management of craniofacial microsomia, early surgical interventions, including distraction osteogenesis, are often employed to correct the underlying skeletal asymmetry. Orthodontic treatment then plays a crucial role in addressing any occlusal discrepancies and improving overall function. Furthermore, the use of prosthetics or implants may be necessary for reconstructive purposes.(Cottrell et al., 2012)

Effective management of craniofacial microsomia and other syndromic conditions requires close collaboration between orthodontists, maxillofacial surgeons, and prosthodontists. This interdisciplinary approach ensures a comprehensive and coordinated plan that addresses the unique functional, aesthetic, and psychological needs of each patient.(Birgfeld & Heike, 2012)

## Diagnostic Approaches in Craniofacial Anomalies

Accurate diagnosis of craniofacial anomalies requires a comprehensive, multidisciplinary approach that integrates advanced imaging techniques, genetic and prenatal screening, and virtual surgical planning. Clinicians should leverage cutting-edge tools like cone-beam computed tomography and 3D imaging to meticulously characterize the precise craniofacial structures and morphology, enabling a detailed assessment of the specific anomaly. (Santiago & Grayson, 2009) This detailed diagnostic imaging allows for a deeper understanding of the complex anatomy and malformations associated with the condition.

Genetic and prenatal screening can also contribute to early detection of craniofacial anomalies, facilitating timely intervention and personalized treatment planning. Furthermore, the implementation of virtual surgical planning has revolutionized interdisciplinary diagnosis and treatment, allowing for highly personalized, collaborative approaches that address the patient's unique functional, aesthetic, and psychological needs. (Hopkins et al., 2019) This multifaceted diagnostic process, with input from various healthcare specialists, including orthodontists, surgeons, and geneticists, is essential for developing an individualized treatment plan that optimizes outcomes for children with these complex craniofacial anomalies(Oberoi et al., 2018).

## Orthodontic Management Strategies

In the management of craniofacial anomalies, orthodontists play a pivotal role in addressing the functional, aesthetic, and psychological needs of pediatric patients. Through the application of evidence-based orthodontic interventions, clinicians can effectively guide the growth and development of the craniofacial structures, mitigating the challenges associated with these complex conditions.(Manlove et al., 2020)

One key strategy in the orthodontic management of cleft lip and palate is the use of early treatment protocols, such as nasoalveolar molding and palatal expanders. These pre-surgical interventions have been shown to improve arch alignment, facilitate surgical outcomes, and enhance long-term functional and aesthetic results. Similarly, in the case of craniosynostosis syndromes, growth-guiding devices, including functional appliances, have demonstrated efficacy in addressing skeletal discrepancies and improving facial aesthetics.(Hopkins et al., 2019)

Across the spectrum of craniofacial anomalies, the importance of multidisciplinary collaboration cannot be overstated. Orthodontists work in tandem with surgeons, speech therapists, pediatric dentists, and other healthcare providers to ensure comprehensive, coordinated care that addresses the diverse needs of these patients. This collaborative approach is essential for achieving optimal functional, aesthetic, and psychological outcomes for children with craniofacial anomalies.(Gibson & Shetye, 2017)

Furthermore, long-term monitoring and revisiting treatment plans during a child's growth and development are crucial for maintaining stability and ensuring the continued success of the management strategies. Periodic evaluations and adaptations to the treatment plan are necessary to accommodate the dynamic changes in the craniofacial complex and ensure the best possible outcomes for the patient. Continued follow-up and treatment plan adjustments are essential to address the evolving needs of the growing child and achieve the desired functional, aesthetic, and psychological goals.(Albert et al., 2019)

## Interdisciplinary Collaboration

Effective management of craniofacial anomalies in pediatric orthodontics requires a multidisciplinary approach, with the orthodontist playing a crucial role in the care team. This interdisciplinary collaboration is essential to address the diverse functional, aesthetic, and psychological needs of these patients. Orthodontists work closely with surgeons, speech therapists, pediatric dentists, and other healthcare providers to develop and implement comprehensive treatment plans that optimize outcomes for children with complex craniofacial conditions. (Hopkins et al., 2019)

The orthodontist's expertise is particularly valuable in managing craniofacial anomalies, as they possess a deep understanding of the growth and development patterns of the craniofacial complex and the impact of these anomalies on the dentition. Orthodontists can leverage this knowledge to guide the affected structures' growth and development, mitigate functional challenges, and enhance aesthetic outcomes.(Santiago & Grayson, 2009)

Interdisciplinary collaboration is crucial to ensure that each patient's unique needs are addressed. Through open communication, joint treatment planning, and coordinated care delivery, the team can leverage their respective areas of expertise to provide the most comprehensive and effective management strategies. This collaborative approach is essential for achieving the best possible functional, aesthetic, and psychological outcomes for children with craniofacial anomalies.(Oberoi et al., 2018)

The expertise and contributions of each care team member are vital in ensuring a holistic and personalized approach to patient care. For instance, speech therapists can provide valuable insights into the functional and communication-related aspects of craniofacial anomalies, while surgeons collaborate with orthodontists to plan and execute intricate interventions addressing skeletal discrepancies and improving facial aesthetics. (Gibson & Shetye, 2017)

The importance of clear communication and seamless coordination among the care team members cannot be overstated. Regular team meetings, shared decision-making, and a unified treatment strategy are essential for delivering optimal, patient-centered care. Furthermore, the care team should serve as a resource for educating parents, students, and other healthcare providers, as well as participating in research to advance the understanding and management of craniofacial anomalies. By embracing an interdisciplinary approach, orthodontists can contribute their specialized knowledge and skills to the

comprehensive management of craniofacial anomalies, working in tandem with a diverse team of healthcare professionals to optimize functional, aesthetic, and psychological outcomes for pediatric patients.(Oberoi et al., 2018)

## Emerging Technologies and Research Opportunities

The field of pediatric orthodontics for the management of craniofacial anomalies is rapidly evolving, with the integration of innovative technologies and ongoing research driving advancements in diagnosis, treatment planning, and therapeutic interventions.(Baxi et al., 2022)

One area of significant progress is the utilization of three-dimensional (3D) imaging modalities, such as cone-beam computed tomography and intraoral scanning, to enhance the assessment and diagnosis of craniofacial anomalies. These advanced imaging techniques provide detailed, high-resolution visualizations of the complex anatomical structures, enabling orthodontists to develop more personalized treatment plans and monitor the progress of interventions with greater precision.(Shah, 2017)

Furthermore, the application of digital technologies, such as computer-aided design and manufacturing (CAD/CAM), has revolutionized the fabrication of customized orthodontic appliances and surgical guides. These advancements have facilitated more accurate and efficient delivery of treatment, leading to improved functional and aesthetic outcomes for patients.(Nguyen & Jackson, 2018)

Emerging research in the field of craniofacial anomalies is also exploring the potential of novel therapeutic approaches, such as distraction osteogenesis, growth modification techniques, and the integration of biological factors to enhance skeletal and soft tissue development. These innovative interventions hold promise for addressing the unique challenges posed by craniofacial anomalies and improving the quality of life for affected children.(Hc, 2014)

The present state of the art and science of orthognathic surgery has been significantly advanced by the incorporation of technological advancements, including rigid internal fixation, virtual surgical planning, and computer-aided manufacturing of surgical guides and appliances. (Safran et al., 2018)

Additionally, the integration of digital technologies, including virtual surgical planning and 3D printing, has revolutionized the delivery of orthodontic and surgical interventions for craniofacial anomalies. (Farrell et al., 2014)

As the field continues to evolve, orthodontists must remain at the forefront of these technological advancements, actively engaged in research and collaborative efforts to drive further progress. By embracing emerging technologies and participating in multidisciplinary research, orthodontists can contribute to the development of more effective, personalized, and evidence-based management strategies for children with craniofacial anomalies.(Baxi et al., 2022)

## Long-Term Outcomes and Maintenance

The management of craniofacial anomalies in pediatric patients is a complex and ongoing process, often requiring a lifetime of specialized, multidisciplinary care. Assessing the long-term outcomes and ensuring effective maintenance of treatment results is crucial for optimizing the overall quality of life for affected individuals. Maintaining favorable outcomes and addressing any recurrences or complications is essential to ensure the sustainability of the improvements achieved through initial treatment. Regular monitoring, follow-up care, and adaptations to the treatment plan as the child grows and develops are necessary to address the dynamic nature of craniofacial growth and development, as well as any changes in functional, aesthetic, and psychological needs. This long-term, holistic approach is vital for supporting the overall well-being of children with craniofacial anomalies and empowering them to reach their full potential. Continuous evaluation, collaborative decision-making, and coordinated care delivery by the

interdisciplinary team are essential for providing comprehensive, patient-centered management throughout the individual's lifetime.(Oberoi et al., 2018)

## Conclusion

Craniofacial anomalies in pediatric patients present a complex array of functional, aesthetic, and psychological challenges that demand the specialized expertise and coordinated, collaborative efforts of an interdisciplinary care team. These anomalies can profoundly impact a child's physical development, social interactions, and overall well-being, underscoring the critical need for a comprehensive, patient-centered approach to management. By leveraging the diverse knowledge and skills of various healthcare professionals, including orthodontists, surgeons, speech therapists, and others, the interdisciplinary team can devise tailored treatment strategies that address the multifaceted needs of each patient, ultimately enhancing their quality of life and enabling them to reach their full potential. The management of craniofacial anomalies requires a lifelong commitment to care, with continuous evaluation, collaborative decision-making, and coordinated efforts by the interdisciplinary team to address the dynamic nature of craniofacial growth and development, as well as any changes in functional, aesthetic, and psychological needs. By embracing an interdisciplinary approach and incorporating emerging technologies, orthodontists can play a vital role in optimizing the outcomes for children with craniofacial anomalies, ensuring they can thrive and lead fulfilling lives.(Baxi et al., 2022)

## Research Gaps and Future Directions

Despite the progress made in the field of craniofacial anomaly management, there are still areas that require further research and exploration. Key research gaps include:

- Developing improved diagnostic techniques and predictive models for early identification of craniofacial anomalies to enable timely intervention.
- Investigating the underlying genetic and molecular mechanisms driving craniofacial development to inform personalized treatment approaches.
- Evaluating the long-term efficacy and patient-reported outcomes of various orthodontic and surgical interventions to optimize treatment protocols.
- Exploring the integration of advanced technologies, such as 3D printing and virtual surgical planning, to enhance the precision and customization of treatments.
- Conducting large-scale, multi-center studies to establish robust evidence-based guidelines for the management of different craniofacial anomalies.
- Expanding interdisciplinary collaboration and knowledge sharing to improve the coordination and continuity of care for patients with complex craniofacial conditions.

By addressing these research gaps, the field of pediatric orthodontics can continue to drive advancements in the management of craniofacial anomalies, ultimately improving the quality of life for affected children and their families.

## General Peer Review & Conflict of Interest Statement

**Peer Review:** All manuscripts published in The International Journal of Comprehensive Health, Medicine & Dentistry (IJCHMD) undergo a rigorous double-blind peer review process and are evaluated by at least two independent reviewers.

**Handling of Editorial Submissions:** When a manuscript is authored by a member of the editorial board, it is assigned to a designated handling editor to ensure transparency and impartiality in the review process.

**Conflict of Interest:** The authors declare that there are no conflicts of interest related to this study. If an author is a member of the editorial board, they have no role in the peer-review or editorial decision-making process.

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