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IDENTIFICATION OF KEY INTERACTIONS BETWEEN DENTOFACIAL STRUCTURES IN PATIENTS WITH CRANIOFACIAL MALFORMATIONS THROUGH MICMAC ANALYSIS

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Abstract:
In this study, focused on craniofacial alterations from the dental perspective, identifying the key factors that play a fundamental role in developing these conditions is sought. Through a detailed analysis of the interactions between these factors with the MICMAC technique, it was intended to improve the understanding of the complexity of craniofacial disorders and facilitate the planning of more effective and personalized treatments. The obtained results offer a solid basis for the design of comprehensive and efficient clinical strategies that meet the needs of patients with craniofacial malformations, thus improving their quality of life and general well-being. This multidisciplinary approach is intended to empower dental professionals to make informed decisions and optimize treatment outcomes in this complex and diverse category of conditions.

Key Words: Dentistry, interactions, facial development, oral health.

1. Introduction

Craniofacial disorders represent a complex and diverse category of conditions that affect the development and structure of the cranial and facial regions. These alterations can have a significant influence on the oral health and quality of life of patients, which requires a comprehensive approach to their study and treatment (Ajwa, et al., 2022). From the dental point of view, the relationship between craniofacial disorders and dentistry is close and relevant (Paolantonio, Ludovici, Saccomanno, La Torre, & Grippaudo, 2019). Dental professionals play a fundamental role in the

diagnosis, treatment, and management of these disorders, working in collaboration with other medical specialists, maxillofacial surgeons, and orthodontists to provide comprehensive and personalized care to patients (Heit, et al., 2022).

Craniofacial disorders can involve dental malocclusions, mandibular misalignments, alterations in the position of the teeth, and problems related to maxillary and mandibular growth. In the literature various studies have been addressed regarding this issue: some are mentioned below: Kim & Nielsen (2002) evaluated the intensity of condylar growth, the rotation of mandibular growth, and the association between the intensity of growth and rotation in untreated subjects with malocclusion, where condylar growth during the juvenile period was found to vary considerably between individuals. In (Nardoni, Siqueira, Cardoso, & Capelozza, 2015), cephalometric variables are analyzed to predict the results of orthopedic treatment and it was found that orthopedic treatment of malocclusion may have an unfavorable prognosis when completing growth in certain conditions.

On the other hand, in (Gülşen, Şibar, & Ismail, 2023), the relationship between the nasal profile and other craniofacial structures is evaluated and it was revealed that individuals with previously upward-curving maxillary development have a straighter and smaller nasal profile, while those with downward-curving maxillary development have a larger, more arched nasal profile. In this context, the present study focuses on exploring the interactions between different factors that contribute to craniofacial alterations, applying the MICMAC technique. Specific factors, such as maxillary inclination, upper incisors' position, palate size, maxillary growth, and mandible position, are examined for their relevance to the development and treatment of these conditions.

Therefore, the objective of this study was to identify the key factors that play a determining role in craniofacial alterations from the dental point of view. Aware of the complexity of these conditions, a comprehensive and meticulous approach was proposed to explore the interactions between various factors and their influence on the facial development and oral health of patients. Through the meticulous analysis of these elements, shedding light on the underlying mechanisms that link craniofacial alterations with dentofacial structure and masticatory function was sought. By addressing these interactions, the study expects to enrich scientific knowledge in the dental field, providing a deeper understanding of the factors that contribute to the development and progression of craniofacial malformations. It was considered essential not only to identify these key factors but also to assess their hierarchy and relationships of influence, thus establishing a solid foundation for the design of personalized and effective therapeutic approaches.

The results of this research have significant potential for improving clinical practice and patient well-being. By providing a more complete view of the determining factors in craniofacial alterations, it is intended to empower dental professionals with essential tools for making informed decisions in the diagnosis and treatment of these complex cases. The planning of more effective interventions adapted to the individual needs of each patient could lead to notable improvements in the quality of life of those who suffer from these conditions, by optimizing masticatory function, facial aesthetics, and general health. Ultimately, the findings of this study are expected to contribute to enriching the multidisciplinary approach in the management of craniofacial disorders, fostering more comprehensive and efficient care for affected patients, and opening new perspectives for future research and developments in the field of dentistry.

2. Methodology

This study was observational and cross-sectional (Sampieri, 2018), with the aim of analyzing the key interactions between dentofacial structures in patients with craniofacial malformations. A bibliographic review of cephalometric studies and dental models was carried out, in addition to the different cases existing in the literature. The 11 factors that were considered relevant for the study were selected, for example, upper incisors' position, maxillary inclination, among others. From the collected data, a data matrix representing the interactions between the selected factors was constructed. The MICMAC matrix allowed us to analyze the interdependence and cross-impact between these factors in the development of craniofacial alterations.

For data analysis, the MICMAC technique was applied to the matrix constructed to analyze the key interactions between dentofacial structures in patients with craniofacial malformations (Arango & Cuevas, 2014). This allowed the identification of the most influential factors and the dependency relationships between them. The results of the MICMAC analysis were then interpreted and the identified interactions were discussed. Significant patterns or trends were sought that provided valuable information on the relationship between the factors studied and craniofacial malformations. Then, based on the findings, conclusions about the identified interactions and their clinical relevance in the context of craniofacial disorders were established. Then recommendations for future research and potential multidisciplinary treatment approaches were offered.

On the other hand, compliance with ethical principles in scientific research will be guaranteed. In addition, the confidentiality and privacy of the data collected will be protected. Likewise, the limitations of the study were identified and discussed, such as possible biases or methodological restrictions, which may affect the validity of the results.

3. Results

The review of the scientific literature has revealed various factors that influence the dentofacial structure in patients with craniofacial malformations within the dental field. Of these factors, eleven (11) have been identified as the most relevant for the study. To apply the MICMAC technique in its first phase, it is necessary to code these factors in a table. First, each is assigned a number, followed by a code or short name, then the full name of the factor, and finally a brief description. For example, in the following table, labeled Table 1, it consists of four columns: the variable number, the code or short name of the variable, the full name of the variable, and its description. It can be seen in the table that factor number one (1) corresponds to the factor Upper incisors' position (UIP) whose description is: "Location and alignment of the upper front teeth in relation to the facial midline and other dentofacial structures". The interpretation of the other elements in the table can be carried out similarly.

Table 1. Selected factors to apply MICMAC.

#	Code	Factor	Description
1	UIP	Upper incisors' position	Location and alignment of the upper front teeth in relation to the facial midline and other dentofacial structures.
2	MI	Maxillary inclination	Angulation of the maxillary bone with respect to the skull, which may be altered in patients with craniofacial malformations.
3	MP	Mandible position.	Location and alignment of the mandible in relation to other facial and dental structures.
4	CP	Chin protrusion	Forward chin extension, which may be influenced by mandible position and other facial features.
5	MG	Maxillary growth	Development and growth of the maxillary bone over time, which can affect the shape and position of the dentofacial structures.
6	PC	Posterior crossbite	Condition in which the upper and lower back teeth do not fit together properly, which may be related to craniofacial malformations.
7	PS	Palate size	Dimensions and shape of the palate, which may have implications for the alignment and position of the teeth.
8	PDA	Position of the dental arches	Alignment of the upper and lower teeth and their relationship with the shape of the dental arches.
9	MCP	Mandibular condyle position	Location and orientation of the temporomandibular joints, which can affect the position and function of the jaw.
10	FA	Facial asymmetry	Unequal shape or position of facial structures on both sides of the face, which may be a characteristic feature in patients with craniofacial malformations.
11	DDSOT	Development of dentofacial structures over time.	Longitudinal studies that allow analyzing the growth and development of dentofacial structures over time in patients with craniofacial malformations.

Source: Authors

After drawing up the list of factors linked to the interactions of the dentofacial structures in patients with craniofacial malformations, a joint evaluation was carried out with a group of five (5) experts to analyze the relationships of influence and dependency between each factor. This evaluation was carried out by using a square matrix, corresponding to Phase II of the MICMAC technique. Figure 1 shows the direct influence/dependence matrix, which was completed with the values obtained from the joint reflection of the experts.

Next, in Figure 1 it can be seen that the Matrix of direct influence/dependence (MID) was completed with values that vary from 0 to 3, based on the criteria of the experts consulted for this study. The figure shows the representation of the relationships of the "UIP" (Upper incisors' position) factor with other factors. For example, the relationship between "UIP" and "MI" (Maxillary inclination) is strong, which is reflected in a value of three (3). On the other hand, with "MP" (Mandible position) the relationship is moderate, obtaining a value of two (2). Similarly, the relationship with "CP" (Chin protrusion) is also moderate, while with "MG" (Maxillary growth) it is weak, which translates into a value of 1. This is how the influence/dependency matrix is interpreted direct.

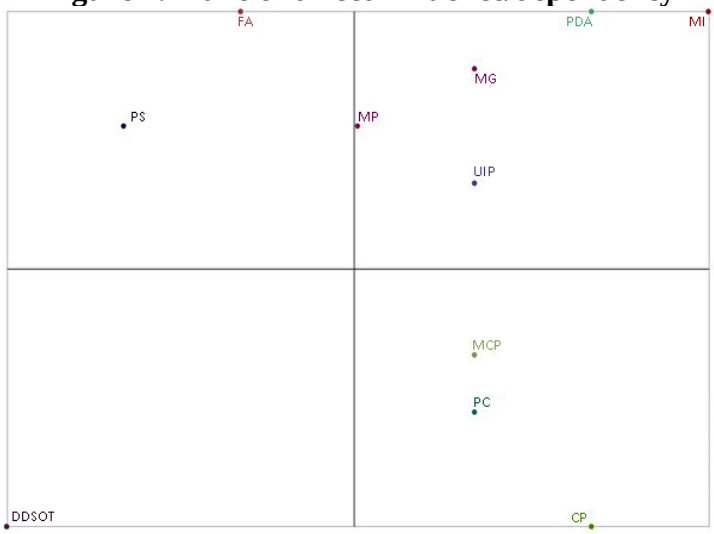
Figure 1. Matrix of direct influence/dependence

Influence ↱	UIP	MI	MP	CP	MG	PC	PS	PDA	MCP	FA	DDSOT
UIP	0	3	2	2	1	2	2	1	2	3	2
MI	3	0	3	2	2	2	2	3	2	2	2
MP	3	2	0	3	2	1	2	1	2	3	2
CP	2	1	1	0	2	1	1	2	2	1	1
MG	1	2	2	3	0	3	2	3	3	2	1
PC	1	3	2	1	3	0	1	2	1	1	1
PS	2	2	2	3	2	3	0	3	2	1	1
PDA	1	3	1	3	2	3	3	0	3	2	2
MCP	1	1	2	1	3	1	1	3	0	2	2
FA	3	3	3	2	1	3	2	2	2	0	2
DDSOT	3	2	1	1	2	1	1	1	1	1	0

Source: Authors

After completing the direct influence/dependence matrix with the values of the relationships of each factor, the location and classification of each one was obtained. This classification is represented in a four-quadrant plane, where the key, determinant, autonomous, and result factors are found. This plane is presented in Figure 2. The structural analysis revealed that there are five key factors located in the first quadrant (upper right corner), namely: UIP (Upper incisors' position), MP (Mandible position), PDA (Position of the dental arches), MI (Maxillary inclination), MG (Maxillary growth). In the second quadrant (upper left corner) two determinant factors were located, namely: FA (Facial asymmetry), and PS (Palate size). A single factor that was classified as autonomous was located in the third quadrant (lower left corner), namely: DDSOT (Development of dentofacial structures over time), and finally three factors were classified as outcome (lower right corner): CP (Chin protrusion), PC (Posterior crossbite), MCP (Mandibular condyle position).

Figure 2. Plane of direct influence/dependency



Source: Authors

The following table (Table 2) presents the categorization of the resulting factors from the matrix of direct influence.

Table 2. Classification of factors by indirect influences/dependencies

Type of factors	Factors	Codes
Key, strategic or challenge factors	Maxillary inclination	MI
	Position of the dental arches	PDA
	Maxillary growth	MG
	Mandible position	MP
	Upper incisors' position	UIP
Determinant or influencing factors	Facial asymmetry	FA
	Palate size	PS
Autonomous or excluded factors	Development of dentofacial structures over time	DDSOT
Dependent or result factors	Mandibular condyle position	MCP
	Posterior crossbite	PC
	Chin protrusion	CP

Source: Authors

As observed in Table 2, a key factor turned out to be the maxillary inclination (MI) due to several reasons: its interaction with other dentofacial structures, such as the upper incisors, mandible, and chin, affects the alignment of the teeth and the Facial aesthetics. In addition, it influences the bite and dental occlusion, being able to cause malocclusions and chewing problems. The maxillary inclination can also impact the facial appearance, causing asymmetries and alterations in the harmony of the face, and can have effects on the development of dentofacial structures in young patients. Finally, it is a relevant factor in the diagnosis and treatment of craniofacial malformations, being crucial in the planning of surgical procedures or orthodontic treatments.

Another key factor identified was the Position of the dental arches (PDA). This factor is relevant due to its influence on the dentofacial structure and its impact on the alignment of the teeth. The position of the dental arches can affect bite and dental occlusion and plays an important role in facial aesthetics and masticatory function. The interaction between the Position of the dental arches and other factors, such as the maxillary inclination, the upper incisors' position, and the mandible, is essential to understand craniofacial alterations. Its adequate evaluation can contribute to the accurate diagnosis and planning of orthodontic treatments or maxillofacial surgeries in patients with craniofacial malformations.

The maxillary growth (MG) was another key factor that was relevant in the study. This factor is of great importance due to its influence on the development and formation of the maxillary bone in patients with craniofacial malformations. The maxillary growth can affect the position and alignment of the dentofacial structures, including the upper incisors, the mandible, and the Position of the dental arches. Understanding how maxillary growth relates to other key factors, such as maxillary inclination, upper incisors' position, and mandible, is essential to gaining an understanding of craniofacial abnormalities in the dental field. Its study makes it possible to identify possible deviations in normal development and can be crucial for the diagnosis and planning of adequate treatments.

The "Mandible position" (MP) factor was key in the study due to its relevance in craniofacial alterations from the dental approach. Its classification as a key is based on its strong interaction with other structures, such as the upper incisors, maxilla, and chin, which affects dental alignment and facial harmony. In addition, it influences dental occlusion and can cause malocclusions and functional problems in chewing. Its position also impacts facial aesthetics, being able to generate asymmetries and changes in the shape of the face. In growing patients, its correct alignment is essential for the normal development of dentofacial structures. Finally, its relevance lies in its importance in the diagnosis and treatment of craniofacial malformations, being a crucial element in therapeutic planning from the dental point of view.

The "Upper incisors' position" (UIP) factor was classified as key due to its relevance in craniofacial alterations from the dental approach. Its importance lies in its aesthetic impact on the smile and facial harmony, its interaction with other dental structures, and its influence on dental alignment and masticatory function. In addition, its evaluation is crucial for the diagnosis and planning of orthodontic and maxillofacial treatments, especially in growing patients. Guaranteeing its proper position is essential for the normal and healthy development of the dentofacial structures. In summary, the UIP factor is key to a comprehensive approach to craniofacial alterations from the dental perspective, considering its aesthetic and functional effects in the context of diagnosis and treatment.

About the factors that resulted as determinants, regarding the "Facial asymmetry" (FA) factor, this was so because it is considered a factor that exerts a significant influence on craniofacial alterations. Facial asymmetry refers to the lack of symmetry or balance between the structures of the face, such as the right and left sides. Its classification as a determinant is due to several relevant aspects: one of them is that facial asymmetry is visually noticeable and can have a significant impact on the patient's appearance, which can affect their self-esteem and quality of life; likewise, facial asymmetry can have their origin in early stages of facial development and growth. Their presence can influence the way dentofacial structures develop and position over time. On the other hand, facial asymmetry can interact with other key factors, such as the maxillary inclination, the upper incisors' position, and the mandible, aggravating or accentuating the present craniofacial alterations.

Regarding the "Palate size" (PS) factor, it was placed in the quadrant of determinants due to its great influence on craniofacial alterations and its fundamental role in the structure and development of the dentofacial complex. Its classification as a determinant is because it is a relevant factor in the development and maxillary growth. An improperly sized palate can influence the position and alignment of the teeth, as well as the overall shape and size of the jawbone. Likewise, the palate size can affect the position of other dentofacial structures, such as the upper incisors, the mandible, and the position of the dental arches. This interaction is relevant for correct dental occlusion and facial harmony. On the other hand, the presence of an abnormally sized palate can make the treatment more complex, since it is necessary to correct its size and position to achieve adequate function and dentofacial aesthetics.

As for the only factor that resulted as autonomous "Development of dentofacial structures over time" (DDSOT), it was located in the autonomous quadrant because its evolution and development occur naturally and are not directly linked to interaction with other key factors identified in the study. Although the development of dentofacial structures over time is of great importance in the context of craniofacial disorders and its adequate follow-up is essential in diagnosis and treatment planning, this

factor is not directly affected by other specific elements considered in the study. However, classification in the autonomous quadrant does not diminish its clinical relevance; rather, it points out that its development follows its independent course and it is crucial to consider it as a factor influencing the natural evolution of dentofacial structures over time in patients with craniofacial malformations.

Finally, three factors were classified as dependent or results, one of them was "Mandibular condyle position", which was located in the dependent or result quadrant because its position and state are a consequence of the interactions and changes that occurred in other factors and is not an independent variable that directly affects other elements of the study. It is important to consider Mandibular condyle position as an outcome factor to assess and understand how changes in other key study elements may have effects on mandibular function and stability. Its location in the result quadrant highlights its clinical relevance and its role as a factor that reflects the response of dentofacial structures to interventions or changes made during the treatment of patients with craniofacial malformations.

Another dependent factor or result was "Posterior crossbite" (PC), because its presence or absence is the result of interactions and changes that occur in other key factors identified in the study, and it is not an independent variable that directly affects other elements of the study. Posterior crossbite is the result of the position and alignment of the dentofacial structures, such as the maxilla and mandible, as well as the inclination and position of the teeth. For example, the abnormal inclination of the maxilla or the incorrect position of the upper incisors can influence the occurrence of a posterior crossbite. By considering Posterior crossbite as a result factor, it is sought to assess and understand how changes in other key elements of the study may have effects on the occurrence and severity of this condition. Likewise, it allows for identifying its importance in the diagnosis and planning of orthodontic and maxillofacial treatment to correct this malocclusion and achieve adequate function and dentofacial aesthetics.

The last factor to be placed in the dependent or result quadrant was "Chin protrusion" because its position and degree of protrusion are the result of interactions and changes that occur in other key factors identified in the study. Chin protrusion is the result of the position and alignment of the dentofacial structures, such as the mandible, the maxilla, and the upper and lower incisors. For example, alterations in the mandible position or the maxillary inclination can influence the protrusion or retrusion of the chin. Therefore, the Chin protrusion is a factor that is affected by other key factors and its position is a consequence of the changes and imbalances that occur in other structures. Its location in the result quadrant highlights its clinical relevance and its role as a variable that reflects the response of dentofacial structures to interventions or changes made during the treatment of patients with craniofacial malformations.

Discussions

The application of the MICMAC technique made it possible to identify and classify the factors that influence craniofacial alterations from the dental approach. Among the key factors identified are the maxillary inclination, the upper incisors' position, the maxillary growth, the mandible position, and the position of the dental arches.

The maxillary inclination is a factor that influences the dentofacial structure, masticatory function, its aesthetic impact on the smile, and its role in the diagnosis and treatment of craniofacial malformations. According to Elnagar, Aronovich, & Kusnoto (2020), these aspects make it a relevant factor to comprehensively address craniofacial alterations from the dental perspective, while Girard, et al. (2022) affirm that the maxillary inclination not only influences the structure function, masticatory function, and facial esthetics, but can also affect facial profile, breathing, and orthodontic treatment focus, as well as having predictive value for growth and interacting with other key factors.

On the other hand, the Position of the dental arches has been identified as a key factor due to its influence on the dentofacial structure and its potential impact on oral and facial function and aesthetics. According to de Castro, et al. (2021), its study and detailed analysis can provide valuable

information to address craniofacial alterations from the dental approach, since it affects dental occlusion, facial aesthetics, masticatory function, maxillomandibular relationship, and development of the dentofacial structures, while for de Menezes (2012), its adequate evaluation and treatment are essential to achieve optimal function and satisfactory aesthetics, thus improving the quality of life of patients with craniofacial malformations.

Regarding maxillary growth, it may have implications for masticatory function and facial aesthetics. According to Proffit, Fields, Larson, & Sarver (2018), its detailed analysis and consideration allow a comprehensive approach to craniofacial alterations in patients with malformations, providing valuable information for orthodontic and maxillofacial treatment. Likewise, Nguyen & Kapadia (2023), affirm that its adequate evaluation and management are essential to correct malocclusions and ensure harmonious facial and dentofacial development, thus improving the quality of life of patients with craniofacial malformations.

As for the mandible position factor, it was ranked as key due to its influence on dentofacial structures, dental occlusion, and its relevance in the diagnosis and treatment of craniofacial malformations. Its proper alignment is essential for normal and healthy development. According to Fagundes & Flores-Mir (2022), in the context of craniofacial alterations, the mandible position may be altered due to various factors, such as problems in facial growth and development, dental malocclusions, and craniofacial malformations. In the same way, Gupta, Schendel, & Wolford (2019), affirm that the precise evaluation of the mandible position is crucial to identify and address these problems early, avoiding the appearance or aggravation of temporomandibular disorders and ensuring an adequate masticatory function without discomfort for the patient.

Finally, the upper incisors' position was also classified as a key factor because its interaction with the maxilla and mandible highlights its role in dental alignment and facial harmony. In this regard, Li, et al. (2023), delimit that when the upper incisors are poorly positioned, an overload can be generated in the periodontium, that is, in the tissues that support the teeth, including the gums and the alveolar bone. Poor alignment can cause excessive forces in specific areas, which can lead to uneven load distribution during chewing and speaking. This load imbalance can cause premature wear of the periodontal tissue, gingival recession, tooth mobility, and, in more severe cases, even tooth loss. In addition, Chaudhary, Ahmad, & Sinor (2021), state that poor upper incisors' position can hinder proper dental hygiene, which increases the risk of periodontal diseases and caries.

On the other hand, facial asymmetry was identified as a determinant factor due to its aesthetic effect, its interaction with other key factors, and its complexity in treatment. Its presence can influence facial development and the stability of dental structures. According to Waite & Kau (2022), the presence of facial asymmetry can be a determinant factor in choosing the most appropriate therapeutic approach for each patient. Its consideration is essential to plan surgical interventions or specific orthodontic treatments. Similarly, Andrade, Mathai, & Aggarwal (2021), state that the presence of facial asymmetry can make treatment more complex since it is necessary to address and correct imbalances in facial structures to achieve proper alignment and satisfying aesthetics.

Likewise, palate size was considered decisive due to its impact on maxillary development, respiratory function, and its complexity in treatment. Its classification in the determinants quadrant highlights its importance in determining the treatment plan and its clinical relevance. According to Heit and others (2022), palate size is a relevant factor in the study of craniofacial alterations due to its impact on respiratory function, nasal breathing, sleep quality, and its relationship with facial development and oral health in general. Its adequate evaluation and management are essential to promote adequate breathing and prevent long-term health problems related to the upper airway.

Finally, the MICMAC technique proved to be a useful tool for the identification and classification of key factors, allowing a better understanding of the complexity of these alterations and facilitating the planning of personalized and effective treatments for each patient. However, it is important to consider that research must continue to improve the understanding of these factors and their interaction in the context of craniofacial disorders, which can lead to significant advances in dental practice and patient well-being.

4. Conclusions

In this study on craniofacial alterations from the dental point of view, the application of the MICMAC technique has made it possible to identify key factors that play a crucial role in the complexity of these conditions. Among the most relevant factors are the maxillary inclination and the upper incisors' position. These factors significantly influence the dentofacial structure, masticatory function, facial aesthetics, and the diagnosis of craniofacial malformations. Likewise, maxillary growth, palate size, and mandible position also play determining roles in the facial development and oral health of patients.

The contributions of this study lie in providing a deeper understanding of the key factors that must be considered in the comprehensive approach to craniofacial disorders. The MICMAC technique has been shown to be a valuable tool for the identification and classification of these factors, which facilitates the planning of personalized and effective treatments. The results also highlight the importance of early evaluation and timely treatment of these alterations to prevent functional and aesthetic problems in the long term.

However, it is important to recognize the limitations of this study. The subjective nature of the technique may affect the generalizability of the results. In addition, there are multiple factors that influence craniofacial abnormalities, and the interaction between them can be complex and multifactorial. On the other hand, future research with large and prospective studies could deepen the understanding of these factors and their relationships. Despite the limitations, this study provides a solid foundation to continue advancing in the improvement of therapeutic approaches and the well-being of patients with craniofacial malformations in the dental field.

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