Application of the MICMAC technique to assess the causes and effects of craniofacial anomalies from a dental perspective

Piedad Mary Martelo Gómez[1], Raul José Martelo Gómez[2], Heybertt Moreno Díaz[3]

[1]Odontologist, Independent researcher, Professor of the Dentistry Program at the Universidad de Cartagena, Colombia, Email: pmartelog@hotmail.com.
[2]Specialist in Networks and Telecommunications, Master in Computer Science, Systems Engineer, Full-time Research Professor of the Systems Engineering Program at the Universidadde Cartagena, Leader of the INGESINFO Research Group. Cartagena de Indias, Colom-bia. Email: rmartelog1@unicartagena.edu.co
[3]Specialist in telecommunications. Systems Engineer, Professor of the Systems Engineering Program at the Universidad de Cartagena, Cartagena de Indias, Colombia, Email: hmorenod@unicartagena.edu.co

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ABSTRACT
The objective of this study was to analyze the factors that influence the development of craniofacial anomalies from a dental perspective. It is a descriptive and analytical study, where a structural analysis is performed using the MICMAC technique (Multiplicative Cross-Impact Matrix Applied to a Classification). As a result of a review of the literature, twelve factors related to this topic were identified, and it is highlighted that malocclusion, abnormal development of the jaws, pernicious oral habits, and dentoalveolar trauma are highly influential and dependent factors. It is concluded that these results offer valuable information to understand the interactions between dental and craniofacial factors that influence abnormal development and that the application of the MICMAC technique was essential to understand the relationships between the identified factors. Although the need for additional research and the focus on personalized treatments is recognized, this study provides a solid basis and a reference for future prevention strategies and clinical approaches to craniofacial anomalies.

Keywords: craniofacial anomalies, dentistry, prevention, dental and craniofacial interactions.

INTRODUCTION

Craniofacial anomalies represent a multidisciplinary field of study of vital importance in dentistry and oral health in general (Wells, 2013). These alterations can manifest themselves in different forms and degrees of severity and can have a significant impact on the function, aesthetics, and well-being of individuals. According to sociologists and psychologists, an attractive external appearance influences the development of interpersonal relationships, self-esteem, and perceived social well-being. In this sense, understanding the factors that contribute to the development of these anomalies is essential for the creation of effective prevention and treatment strategies to improve the quality of life of individuals. From a dental perspective, the analysis of the dental and facial factors involved in the development of these conditions can help to understand the interactions that shape craniofacial morphology (Liberton, et al., 2020).

Previous research has explored the influence of genetics (Ornoy, 2020), environmental factors (Golovcencu et al., 2019), and biomechanical interactions (Ortún-Terrazas et al., 2022) in the development of craniofacial anomalies. Likewise, clinical and experimental research has been conducted on the effectiveness of orthodontic treatments and maxillofacial surgery in correcting and preventing these conditions. However, few studies take into account factors ranging from misalignments in dental alignment and abnormal growth of the jaws to the presence of pernicious oral habits and temporomandibular disorders. Therefore, the objective of this research is to assess these factors, among others identified, that may influence the development of craniofacial anomalies. By limiting this study in this context, the understanding of the causes and effects of these anomalies from a dental perspective is expanded.

To achieve the objective of the study, the MICMAC technique (Multiplicative Cross-Impact Matrix Applied to a Classification) was applied, which is suitable for this purpose, because it has the ability to analyze the relationships of variables or factors in a complex system (Arango & Cuevas, 2014). The MICMAC

technique allows to identify and classify factors in a structured and systematic way, which is essential in the exploration of a multidimensional and multifactorial phenomenon such as craniofacial anomalies in this case (Nematpour et al., 2022). The benefits of using this technique are reflected in that it provides a more complete and organized view of how these factors interact with each other and qualifies them by measuring the level of influence or dependency on other factors.

The application of the MICMAC technique in this study is appropriate because the complexity of craniofacial anomalies requires an approach that considers not only the presence or absence of factors but also reveals how they relate to each other and how they contribute to their manifestation. The MICMAC technique addresses this need by allowing to visualize and analyze how factors interact and affect each other (Arango & Cuevas, 2014). In the following sections, the methodology used in this study will be detailed, as well as the results obtained and their contribution to the global understanding of craniofacial anomalies.

METHODOLOGY

This study is descriptive and analytical. Descriptive, because it describes the characteristics or properties of a population, phenomenon, or particular situation and is based on direct observation and collection of relevant data on a specific topic, without manipulating variables (Mohajan, 2018). In this case, it describes the network of causes and effects of craniofacial anomalies from the dental point of view. Analytical, because associations between variables are identified (Apuke, 2017). In this case, it explores the network of causes and effects of craniofacial anomalies through the MICMAC technique.

Method procedure

Document review: An exhaustive search was carried out in reference books, medical databases, and academic documents related to dentistry and craniofacial genetics.

Selection of factors: the factors that were considered influential in the development and progression of craniofacial anomalies were identified and selected. Some of these factors may include, but are not limited to, genetic, environmental, nutritional, mechanical factors, oral habits, among others, which served as input for the application of the MICMAC technique.

Application of the MICMAC technique: a structural analysis was carried out using the MICMAC technique through specialized statistical software, applying a cross-impact matrix that measures the influence and dependency to determine the degree of impact of each factor. This matrix is based on the assessment of the influence and dependency of each factor on the others. In this sense, with the number three (3) it is considered that the association between the factors is strong, while with the number two (2) it is considered a moderate relationship, and with the number 1, the relationship is considered weak, in contrast, if there is no relationship between the factors, then the assessment will be zero (0).

Report of the results: with the application of the Micmac technique, a report was obtained that reveals the factors associated with craniofacial anomalies, the location of each factor, and the relationship between each of them, which reveals the most important factors to prevent these conditions.

On the other hand, this study considered the ethical principles established in the Declaration of Helsinki and the applicable local regulations regarding research. No personal information was collected from patients, as it was based on previously published sources of scientific literature. It is recognized that the study has certain limitations, such as the dependence on the availability of the information collected in the literature. In addition, due to the exploratory nature of the study, the results obtained must be interpreted with caution and definitive causal relationships cannot be established.

RESULTS

The findings presented in this section show the analysis of the data collected and the observations made during the development of the study, which are shown through tables and figures, accompanied by their respective interpretation to provide a comprehensible and well-founded explanation of the findings.

Twelve (12) factors were identified through the literature review, which were considered relevant in the progression and development of craniofacial anomalies. These factors may include but are not limited to, genetic, environmental, nutritional, mechanical factors, oral habits, among others. Table 1 presents the factors selected for the application of the MICMAC technique, as can be seen, the table is composed of four columns. The first corresponds to the factor number, the second, to the code or short name of the factor, the third, to the name of the factor and the fourth corresponds to the description of the factor. In this sense, factor number one (1), has the code or short name, MO, the name is Malocclusion, and as the description: The presence of a bad dental alignment and/or of the dental arches can contribute to the development of craniofacial anomalies. In this way, Table 1 can be interpreted.

Table 1. Factors identified to apply MICMAC.

#	Code	Factor	Description
1	MO	Malocclusion	The presence of poor dental alignment and/or dental arches can contribute to the development of craniofacial anomalies.
2	POH	Pernicious oral habits	Habits such as bruxism (teeth grinding), thumb sucking, tongue thrusting, and prolonged pacifier use can affect the normal development of facial bones.
3	TMA	Temporomandibular ankylosis	Stiffness or immobility of the temporomandibular joint can alter the growth and development of the jaw.
4	LTER	Lack of tooth eruption or retention	The absence of teeth or their retention within the bone can affect the development of surrounding craniofacial structures.
5	DM	Dentofacialmal formations	Problems in the shape, size, or position of the teeth and their relationship to the facial bones can contribute to craniofacial anomalies.
6	OD	Occlusaldys function	Alterations in the bite and the relationship between the upper and lower teeth can influence craniofacial development.
7	SBD	Sleep breathing disorders	Sleep apnea and other breathing disorders can affect the normal growth of facial bones in growing children.
8	DT	Dentoalveolar trauma	Dental or bone injuries around the teeth can impact craniofacial development.
9	PD	Periodontal diseases	Problems with the gums and supporting tissues can affect the health of facial bones and their growth.
10	ADM	Abnormal development of the maxillas	Alterations in the growth and development of the maxillas can contribute to craniofacial malformations.
11	TJA	Temporomandibular joint alterations	Disorders in the function and position of the temporomandibular joint can influence craniofacial development.
12	IOT	Influence of orthodontic treatments	Orthodontic and functional orthopedic treatments can affect the development and growth of craniofacial structures.

Source: Authors

Next, the results of the literature review are presented on the factors that were considered potentially involved in the development and progression of craniofacial anomalies. First of all, according to Zimmerman et al. (2019), malocclusion is a dental condition in which the teeth of the upper arch do not fit properly with the teeth of the lower arch when closing the mouth. In other words, it is a misalignment between the upper and lower teeth when biting or chewing. Regarding the factor harmful habits, according to Patano et al. (2022), they are also known as harmful oral habits, they are behavioral patterns that involve repetitive and harmful actions that affect oral health and the proper development of dentofacial structures. These habits usually begin in infancy or early childhood and can persist into adolescence and adulthood if not properly corrected.

Regarding temporomandibular ankylosis, according to Lau et al. (2023), it is a condition in which the temporomandibular joint (TMA), which is the joint that connects the jaw to the skull, has an abnormal bony fusion or union between the joints. In other words, temporomandibular ankylosis involves a loss of normal mobility of the joint due to the fusion of the bones that comprise it. Regarding lack of tooth eruption or retention, according to Fu & Wang (2020), it is a condition in which the teeth do not emerge properly in the oral cavity or fail to position themselves correctly in their natural place within the dental arch. This situation can occur in both baby teeth (temporary teeth) and permanent teeth.

For their part, Rojare et al. (2019), state that dentofacial malformations are conditions that can affect both the teeth and the bones and soft tissues of the face, leading to deformities or misalignments in the harmony and function of the oral and facial region. Occlusal dysfunction is defined by Kumar et al. (2022), as a problem that affects the way the upper and lower teeth fit together when the mouth is closed and dental occlusion refers to the relationship and contact of the teeth based on mandibular movements when chewing, speaking and at rest. Regarding sleep breathing disorders, Abtahi et al. (2020), define them as a group of medical conditions that affect breathing during sleep. These disorders can disrupt the normal sleep pattern and have a detrimental effect on a person's quality of life and overall health. One of the most common sleep-breathing disorders is obstructive sleep apnea.

Regarding dentoalveolar traumas, Yeng et al. (2020) define them as injuries that affect both the teeth and the tissues surrounding them, including the alveolar bone and gums. These traumas can occur as a result of accidents, blows, or injuries involving the mouth and teeth. Dentoalveolar traumas are common in children and adolescents, mainly in those who participate in high-risk sports activities or who are exposed to accidental situations.

Regarding the factor Periodontal diseases, also known as gum diseases, Boitsaniuk et al. (2021) define them as a group of disorders that affect the tissues that surround and support the teeth, including the gums, alveolar bone, and the periodontal ligament. These diseases are caused by bacteria present in dental plaque, a sticky, transparent film that constantly forms on the teeth. For the factor abnormal development of the maxillas, Roth et al. (2021), point out that it refers to alterations or malformations in the normal growth and development of the maxillary bones, which are the bony structures that form the upper part of the mouth and support the upper teeth. These malformations can affect the shape, size, and position of the maxillas, which can have significant consequences on chewing function, facial aesthetics, and overall oral health.

Regarding the factor Alterations in the temporomandibular joint, Wilkie& Al-Ani (2022), define it as problems or dysfunctions that affect this important joint, which is the one that allows the connection between the jaw (lower jaw) and the skull (temporal bone) on both sides of the head. The temporomandibular joint is a complex and highly mobile joint that plays a crucial role in vital functions such as chewing, speech, and jaw movement. Finally, the factor Influence of orthodontic treatments, Mudjari et al. (2019), define it as the impact that orthodontic procedures and therapies have on the development, alignment, and position of a patient's teeth and facial structures. Orthodontic treatments are designed to correct problems of malocclusion, dental misalignment, and other irregularities in the position of the teeth and jaws.

After identifying, tabulating, and defining the factors, a joint analysis was carried out by a group of four experts to analyze the influence/dependency relationships between each factor. The assessment was carried out by implementing a square matrix, specifically corresponding to Phase II of the MICMAC technique. Figure 1 shows the matrix that shows the direct influence and dependency, which was completed with the values derived from the joint reflection of the experts involved in the study.

Below, Figure 1 presents the Matrix of direct influence/dependency, whose values were assigned in a range from 0 to 3, based on the criteria of the experts consulted for this study. The figure illustrates the relationships of the factor "MO" (Malocclusion) with other factors. For example, the relationship between "MO" and "POH" (Pernicious oral habits) shows a strong connection, represented by a value of three (3). As with the factor "TMA" (Temporomandibular ankylosis) which was also considered strong, assigning it a value of three (3). In contrast, the relationship with "LTER" (Lack of tooth eruption or retention) was considered moderate, as well as with the factors "DM" (Dentofacial malformations), "OD" (Occlusal dysfunction), "SBD" (Sleep breathing disorders), for which they were assigned a value of two (2). While with the factor "ADM" the relationship was considered weak, which translates into a value of one (1). Thus, the Matrix of direct influence/dependency is interpreted.

Influence ↱	MO	POH	TMA	LTER	DM	OD	SBD	DT	PD	ADM	TJA	IOT
MO	0	3	3	2	2	2	2	3	2	1	3	3
POH	3	0	2	2	1	3	2	3	3	2	2	2
TMA	1	2	0	1	1	1	1	2	2	1	3	0
LTER	3	2	2	0	3	2	1	3	2	3	1	3
DM	3	3	0	3	0	2	2	3	1	3	2	3
OD	3	2	2	0	0	0	0	3	2	1	0	1
SBD	3	3	1	2	1	1	0	3	1	2	2	1
DT	3	2	0	1	2	3	1	0	2	3	3	2
PD	2	1	1	1	1	1	2	0	0	2	3	1
ADM	3	3	2	2	1	3	3	3	1	0	3	1
TJA	0	2	1	1	2	3	1	1	0	1	0	1
IOT	3	2	2	3	1	0	1	3	1	3	1	0

Figure 1. Matrix of direct influence/dependency
Source: Authors

After completing the process of filling out the matrix with the values corresponding to the relationships between the factors, the location and classification of each of them was determined. This classification is represented in a four-quadrant plan, in which the key, determinant, autonomous, and results factors are identified. This graphic representation can be seen in Figure 2. The structural analysis revealed that four key factors were identified and located in the first quadrant (upper right corner), which are the following: Malocclusion (MO), Anomalous development of the jaws (ADM), Pernicious oral habits (POH) and Dentoalveolar trauma (DT).
In the second quadrant (upper left corner) four determinant factors were located: Lack of tooth eruption or retention (LTER), Dentofacial malformations (DM), Sleep breathing disorders (SBD), and Influence of orthodontic treatments (IOT). In the third quadrant (lower left corner), two autonomous factors were located: Periodontal diseases (PD) and Temporomandibular ankylosis (TMA). Finally, in the fourth quadrant (lower right corner) two independent or result factors were located: Occlusal dysfunction (OD) and Temporomandibular joint alterations (TJA).

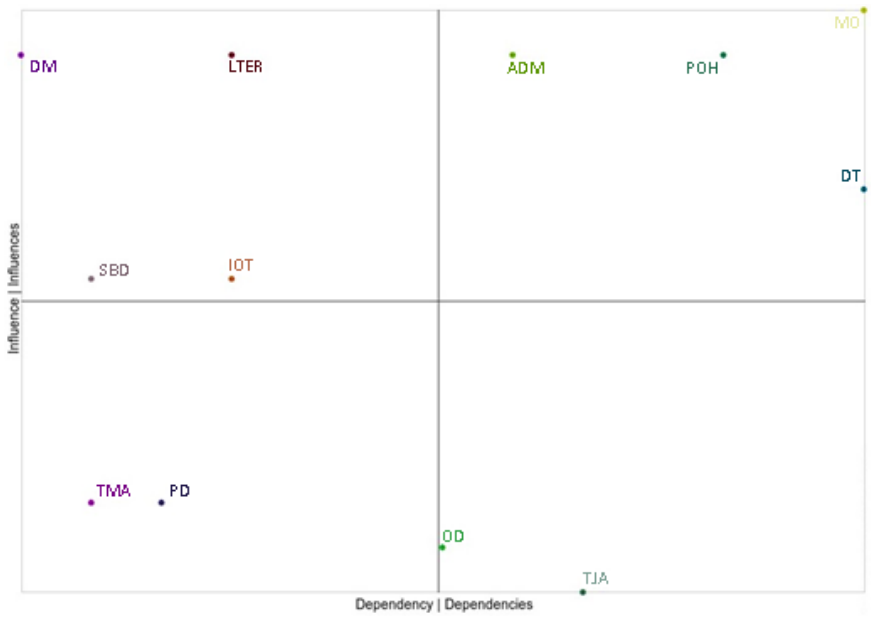

Figure 2. Plane of direct influence/dependency
Source: Authors

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

Table 2. Classification of factors by indirect influences dependencies

Typeoffactors	Factors	Code
Key, strategic or challenge factors	Malocclusion	MO
	Abnormal development of the maxillas	ADM
	Pernicious oral habits	POH
	Dentoalveolar trauma	DT
Determinant or influencing factors	Lack of tooth eruption or retention	LTER
	Dentofacialmalformations	DM
	Sleep breathing disorders	SBD
	Influence of orthodontic treatments	IOT
Autonomous or excluded factors	Periodontal diseases	PD
	Temporomandibular ankylosis	TMA
Dependent or result factors	Occlusaldys function	OD
	Temporomandibular joint alterations	TJA

Source: Authors

As seen in the plan and Table 2, Malocclusion turned out to be a key factor in the development and progression of craniofacial anomalies from a dental perspective due to its ability to impact the growth of facial bones, alter chewing function, and breathing, and affect the relationship between teeth and bone structures. According to D'Onofrio (2019), this condition can trigger changes in the position of the jaw and be related to harmful habits. Early detection and appropriate treatment through orthodontic and orthopedic procedures are essential to prevent additional problems in craniofacial development.

Similarly, another key factor that influences the development and progression of craniofacial anomalies from a dental perspective turned out to be the abnormal development of the jaws. This is because malformations in the growth and position of the maxillary bones can affect facial harmony, dental alignment, and masticatory function. According to Ali et al. (2021), inadequate development of the jaws can cause bite problems, facial imbalances, dental malpositions, and breathing difficulties. Treating these alterations at early stages is essential to prevent complications, since orthodontic treatments and, in more complex cases, maxillofacial surgery may be necessary to correct them.

Another key factor identified was pernicious oral habits. These habits, which include thumb sucking, pushing the tongue against the teeth (lingual thrust), persistent mouth breathing, and other behaviors that exert forces on the teeth and facial structures, contribute to the progression of these anomalies. According to Grippaudo et al. (2016), pernicious habits cause malocclusions, alter the normal growth and development of the jaws, and contribute to problems in the upper respiratory tract. On the other hand, Silk and Kwok (2017) state that it is essential to identify and correct these habits early to avoid complications in oral and craniofacial health.

Dentoalveolar traumas, which were classified as a key factor, may be due to the fact that these are injuries that are usually caused by a physical impact, and can result, first of all, in malformations in bone growth, alterations in the position of the teeth, and deformities in the jaws. According to Iyer et al. (2021), these injuries negatively influence dental alignment, in addition to causing mandibular deviations and triggering problems in masticatory function. Zou et al. (2018) support these statements, highlighting that early care can help minimize the adverse effects of these traumas and preserve the integrity of dental function and aesthetics..

La falta de erupción o retención dental resultó ser un factor determinante, debido a que, aunque no depende de otros factores para manifestarse, tiene la capacidad para generar cambios característicos en la estructura bucal, en algunos casos puede estar relacionada con factores genéticos o condiciones médicas subyacentes. Según Zanwar y otros(2022), cuando los dientes no erupcionan correctamente, causan desequilibrios en la alineación y el desarrollo de los maxilares.

Likewise, dentofacial malformations are presented as a determinant and highly influential factor in the development of craniofacial anomalies from a dental perspective. According to Francisco et al. (2021), these malformations directly affect facial appearance, regardless of other factors, so early detection is of vital importance to correct or minimize these malformations and achieve normal craniofacial development.

Sleep-disordered breathing also exerts a significant influence. According to Li et al. (2022), sleep apnea alters breathing patterns, affecting jaw morphology and mandible position. Achmad& Ansar (2021) support this claim and add that recurrent airway obstruction leads to changes in facial shape, muscle imbalances, and malocclusions. Although they can have various causes, such as obesity or airway

anatomy, sleep-disordered breathing stands out for its independent ability to influence craniofacial morphology and function.

The influence of orthodontic treatments is presented as a determinant and highly influential factor due to its ability to actively correct and guide the growth and development of dental and maxillofacial structures. According to Gupta et al. (2023), orthodontic treatments can achieve significant changes in dental alignment, occlusion, and facial aesthetics by applying controlled forces to the teeth and maxillas. Although they may require collaboration with other factors, such as patient cooperation and careful professional evaluation, their impact on craniofacial development is notable for their ability to actively shape oral form and function.

The autonomous factors were: Periodontal diseases and Temporomandibular ankylosis. According to Hajishengallis&Chavakis (2021), periodontal diseases can cause periodontal tissue loss and eventual tooth loss, however, its impact might not necessarily contribute greatly to morphological changes in the face and craniofacial structures. On the other hand, Covert et al. (2021), state that this factor can limit mandibular mobility and cause local discomfort and its influence could be minor compared to other factors related to dental alignment, bone growth, and other broader aspects of facial development.

Finally, the factors that were classified as result factors were two: Occlusal dysfunction. This factor was classified as such because its influence is more closely related to the relationship between the teeth and their bite, rather than exerting a significant impact on the overall development of craniofacial structures. According to Kumar et al. (2022), occlusal dysfunction, which involves problems with how the teeth fit together when the patient bites or closes his or her mouth, can cause local discomfort, tooth wear, and temporomandibular joint problems. Although it can have negative effects on oral health, its influence on the overall development of the face and craniofacial structures tends to be more limited compared to other factors that can alter form and function more broadly.

Finally, the factor Alterations in the temporomandibular joint is classified as Alterations in the temporomandibular joint are classified as a result factor onebecause its influence is mainly focused on the function and comfort of the jaw and temporomandibular joints, rather than generating substantial morphological changes in general craniofacial development. According to Ananthan et al. (2023), alterations in the TMA, which may include problems such as clicking, pain, or limitations in opening and closing the mouth, are more related to the biomechanics and function of the jaw and joints.

CONCLUSIONS

In the course of this study, the factors that influence the development of craniofacial anomalies were identified and analyzed. It was observed that the factors with the greatest influence and dependency are, among others, dentoalveolar trauma, malocclusion, and abnormal development of the jaws. In this sense, the results suggest that greater attention should be paid to these factors since they have an important impact on craniofacial development. Therefore, in order to make clinical decisions and create appropriate therapeutic strategies, it is necessary to approach the issue from the perspective of both key and determinant factors.

The application of the MICMAC technique was essential to understand the relationships between the identified factors, which allowed this contribution to the literature in the field of dentistry, by providing this knowledge about craniofacial anomalies, however, it is necessary to mention that the study has some limitations, among which is the need to consider additional genetic and environmental factors that could also play an important role in this aspect.

Despite these limitations, the study can be taken as a reference for future research because it offers a new insight into craniofacial anomalies since it is approached from a dental perspective. The results and contributions also contribute significantly to the knowledge and practice in this field, in addition to highlighting the continued need for rigorous research to effectively manage the prevention and management of these conditions that affect oral and facial health.

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