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USE OF THE MICMAC TECHNIQUE TO EVALUATE THE INTERDEPENDENCE BETWEEN DENTAL DEVELOPMENT AND MORPHOLOGY IN PEDIATRIC PATIENTS

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Abstract

The interaction between dental development and craniofacial morphology in pediatric patients is a crucial topic in dentistry and orthodontics. This research aimed to systematically analyze these interdependencies through the MICMAC technique, classifying variables into four categories: key, determinants, autonomous, and results. An exhaustive bibliographic review was carried out and a direct influence/dependency matrix was created, assessing the relationships through the contribution of experts. Subsequently, a structural analysis was carried out to categorize the identified variables. Dental development and craniofacial morphology in pediatric patients are intricately interconnected. Occlusion and maxillomandibular growth emerged as key elements. Dental age, eruption sequence, dental anomalies, development of the temporomandibular joint, and facial profile play determinant roles. Measurements of facial morphology, nasolabial angle, and facial symmetry are considered autonomous. And the maxillomandibular relationship reflects the results of dental and craniofacial development. This study provides a solid basis for planning orthodontic, orthopedic, and stomatological treatments in pediatric patients. Additionally, it offers a comprehensive framework for dental health care and improves the quality of life in this constantly growing and developing population.

Keywords: Dental development, craniofacial morphology, pediatric patients, MICMAC technique, occlusion, maxillomandibular growth, orthodontics

Introduction

Dental development and craniofacial morphology represent fundamental areas of study in dentistry and orthodontics, and their understanding is essential to providing comprehensive clinical care to patients of all ages. However, in the context of pediatric patients, the intricate relationship and interdependence between dental development and craniofacial morphology takes on even greater relevance, given the active stage of growth and development in which they are found (Ornoy, 2020). The study of these interactions has been the subject of interest in the scientific community (Vucic, et al., 2019; Danze, et al., 2021) since their understanding has significant implications in treatment planning, preventing malocclusions, correcting dental anomalies, and improving the quality of life of patients.

The evolution of dental development in pediatric patients is a complex process that ranges from the eruption of temporary and permanent teeth to the complete formation of the adult dentition (Kovacs, et al., 2021). This process is intrinsically linked to craniofacial morphology, as teeth play a fundamental role in the structure and function of the stomatognathic system. Adequate dental occlusion, tooth alignment, and harmony of facial morphology are key aspects that define orofacial health and aesthetics (Calamita, et al., 2019).

On the other hand, craniofacial morphology in pediatric patients is dynamic and constantly evolving. The growth and development of the upper and lower jaws, the position of the jaw, the shape of the palate, and other factors directly influence facial morphology (Miranda-Viana, et al., 2021). Furthermore, the relationship between dental development and craniofacial morphology is bidirectional, meaning that changes in one can affect the other. This comprehensive approach is essential to understand the causes and consequences of malocclusions, dental anomalies, and alterations in craniofacial morphology.

This research focuses on addressing the interdependence between dental development and craniofacial morphology in pediatric patients through the application of the MICMAC technique (Multiplicative Cross Impact Matrix Applied to a Classification). This technique provides a systematic and quantitative framework to analyze the relationships and direct influences between key variables in this context (Nematpour, et al., 2021). The variables selected for this study have been categorized into two main sets: dental development and craniofacial morphology, each of which comprises a set of specific variables.

The objective of this research was to identify and classify the variables that exert a key, determinant, autonomous, or outcome influence on the interaction between dental development and craniofacial morphology in pediatric patients. Through a comprehensive literature review, clinical data collection, and application of the MICMAC technique, it is sought to shed light on the complexity of these interactions and their clinical importance. The study is divided into phases that include the creation of a matrix of direct influence/dependency, the assignment of values to these relationships through expert deliberation, and the structural analysis that leads to the classification of the variables into four main categories. This classification will allow the identification of the central variables that play a critical role in the interdependence between dental development and craniofacial morphology in pediatric patients.

Through this interdisciplinary approach, this research seeks to contribute significantly to scientific knowledge and clinical practice, providing a solid basis for planning orthodontic, orthopedic, and stomatological treatments in pediatric patients. Furthermore, it is expected that the results obtained will have broader applications in dental health care and improve the quality of life of this population.

In summary, this study represents a comprehensive effort to understand and quantify the relationships between dental development and craniofacial morphology in pediatric patients, to advance clinical practice and care for this constantly growing and developing population.

Methodology

This study was categorized as research of an observational and descriptive nature because it focuses on the detailed empirical observation of events or phenomena in their natural environment, without manipulation of variables. In the same way, it does not imply active intervention on the part of the researchers and seeks to thoroughly analyze the patterns and relationships between variables (Sampieri, 2018). The objective of this research was to evaluate the interdependence between dental development and craniofacial morphology in pediatric patients to understand the relationships between these two aspects and their possible influence on the oral health and facial health of this population.

Data collection covered both primary and secondary information. Two main sets of variables were identified: dental development variables and craniofacial morphology variables. The MICMAC technique was used to analyze the interdependence between the variables of dental development and craniofacial morphology in pediatric patients which includes the construction of the MICMAC matrix that represents the relationships between the variables studied. In this matrix, the variables are presented in rows and columns, and a numerical value is assigned that reflects the intensity of the relationship between each variable, according to scientific literature and expert knowledge, for which 5 experts participated, who contributed to the identification of variables and the construction of the MICMAC matrix.

The MICMAC matrix is analyzed using network analysis techniques to identify the most significant relationships and interdependencies between the variables. Special attention is paid to bidirectional relationships and feedback effects. Then, the results of the MICMAC matrix analysis are interpreted in terms of the strength and direction of the relationships between dental development and craniofacial morphology in pediatric patients using graphs and planes that are specific to the technique. Then, the clinical implications are explored, and it is discussed how these interdependencies may influence the oral and facial health of pediatric patients. Finally, the key conclusions of the research are summarized, and recommendations for future research in this field, as well as possible clinical and therapeutic implications, are provided.

Results

The bibliographic analysis revealed a list of elements that influence dental development and craniofacial morphology, which have been classified primarily into two main groups: dental development and craniofacial morphology. In the category of dental development, five (5) variables have been identified that include: Dental age, Eruption sequence, dental anomalies, development of the temporomandibular joint, and development of occlusion. In contrast, within the category of craniofacial morphology, six (6) variables were determined, which involve: measurements of facial morphology, growth of the maxilla and mandible, facial profile, nasolabial angle, maxillomandibular relationship, and facial symmetry.

Table 1 has been created to systematically record these variables, consisting of four columns: the number assigned to each variable, the corresponding code or abbreviated name, the full name of the variable, and a detailed description that clarifies its nature. For example, in the first row of the table, there is variable number one identified as DA, which refers to Dental age, and its associated description states: the age at which primary and permanent teeth appear and develop is essential to understand the chronology of dental changes in relation to craniofacial morphology. This structuring facilitates the interpretation and understanding of the information contained in Table 1.

Table 1. Selected factors to apply MICMAC.

#	Code	Factor	Description
Dental development variables			
1	DA	Dental age	The age at which primary and permanent teeth appear and develop is essential to understand the chronology of dental changes in relation to craniofacial morphology.
2	ES	Eruption sequence	The order and timing in which teeth erupt in the mouths of pediatric patients can have a significant impact on craniofacial morphology and dental occlusion.
3	DAN	Dental anomalies	The presence of dental anomalies, such as malocclusions, supernumerary teeth, or missing teeth, can influence the craniofacial morphology and oral health of patients.
4	DTMJ	Development of the temporomandibular joint	Measures of the health and development of the joint between the skull and jaw, which can influence chewing and craniofacial morphology.
5	DOC	Development of occlusion	The formation and adjustment of the bite and the relationship between the upper and lower teeth.
Craniofacial morphology variables			
6	MFM	Measurements of facial morpholog	These may include measurements of the length, height, and width of different facial regions, such as facial profile, interpupillary distance, nose height, etc.
7	GMM	Growth of the maxilla and mandible	Analysis of the relationship between the growth of these bone structures and dental development is essential to understand how craniofacial morphology affects dental occlusion.
8	FP	Facial profile	The facial profile is an important indicator of craniofacial morphology and may be influenced by the position and disposition of teeth.
9	NA	Nasolabial angle	This angle can provide information about the relationship between the nose and the upper lip, which is relevant to facial aesthetics.
10	MMR	Maxillomandibular relationship	Evaluating the relationship between the maxilla and mandible is crucial to understand occlusion and how it affects the disposition of the teeth.
11	FS	Facial symmetry	Facial symmetry is an important aspect of craniofacial morphology and may be related to dental occlusion and dental development.

Source: Authors

The list presented in Table 1 offers a tool that facilitates the execution of a holistic evaluation in collaboration with a panel of experts, with the purpose of analyzing the interactions that exist in terms of influence and dependence between each of the identified variables. This procedure was carried out by implementing a matrix that explicitly visualizes the direct connections of influence and dependence between these variables, which was complemented with values assigned through the collective deliberation of the experts. It is essential to highlight that this process corresponds to phase II of the technique known as MICMAC.

Figure 1 displays the Matrix of direct influence/dependency, which was completed with values that vary in a range from 0 to 3, according to the assessment of the experts who participated in the present study. When analyzing the figure, it is highlighted that the first row of the matrix corresponds to the relationships of the variable Dental age (DA) concerning the other variables considered. In the case of the relationship between the variable DA and the variable Eruption sequence (ES), a moderate connection is established, with a value of two (2), which indicates a significant correlation between both variables. Similarly, the relationship of the variable DA with the variable Dental anomalies (DAN) is also rated as moderate (2), and a strong relationship (3) with the variable Development of the temporomandibular joint (DTMJ). This same strong connection (3) is observed with the variable Development of occlusion (DOC), which suggests that the variable DA exerts a significant influence on these variables.

This graphic representation allows the detailed interpretation and understanding of the relationships between the variables contemplated in Figure 1. It should be noted that in cases where there is a one (1), it is because the relationship is weak.

Figure 1. Matrix of direct influence/dependency

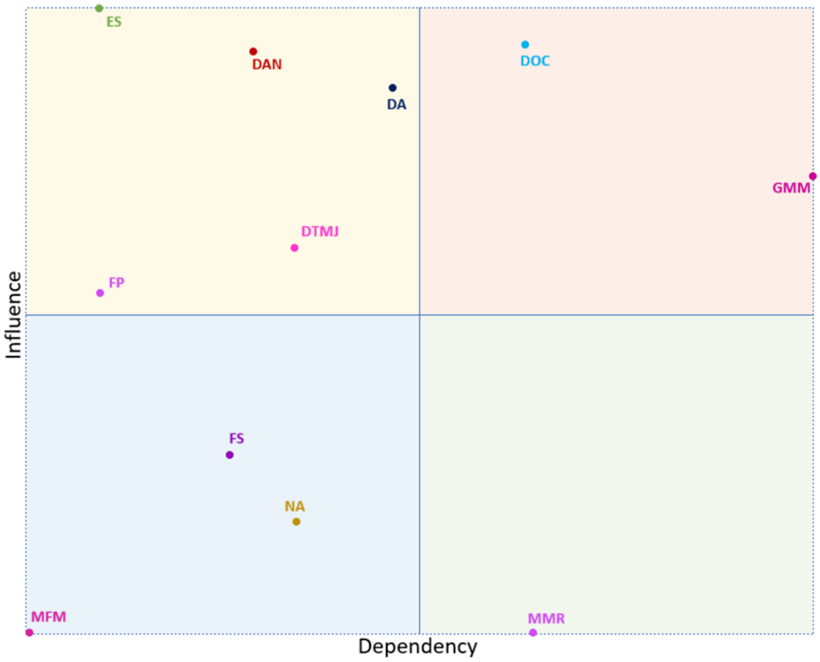
Influence ↱	DA	ES	DAN	DTMJ	DOC	MFM	GMM	FP	NA	MMR	FS
DA	0	2	2	3	3	2	3	2	1	2	2
ES	2	0	3	2	3	3	2	3	2	3	1
DAN	2	1	0	3	2	3	2	3	3	2	2
DTMJ	3	1	2	0	1	0	2	1	3	3	3
DOC	3	2	2	3	0	1	3	2	2	2	3
MFM	0	1	1	1	2	0	2	1	1	1	1
GMM	3	2	2	2	2	3	0	2	2	1	1
FP	2	2	1	1	1	1	3	0	2	3	2
NA	1	1	2	1	3	0	3	1	0	1	1
MMR	1	2	1	0	2	1	2	0	1	0	1
FS	2	1	1	2	2	0	3	0	1	3	0

Source: Authors

After completing the Matrix of direct influence/dependency with the values corresponding to the relationships of each factor, its structural analysis was carried out, which resulted in the location and classification of each factor. This classification is presented in a plane composed of four quadrants, which is used to identify the key, determinant, autonomous, and result factors. This plane is represented in Figure 2.

The structural analysis has revealed the presence of two key variables, which are located in the first quadrant (upper right corner). These key variables are: Development of occlusion (DOC) and Growth of the maxilla and mandible (GMM). In the second quadrant (upper left corner) five determinant variables were located, namely: Dental age (DA), Eruption sequence (ES), Dental anomalies (DAN), Development of the temporomandibular joint (DTMJ), and Facial profile (FP). The variables that were classified as autonomous were located in the third quadrant (lower left corner), namely: Measurements of facial morphology (MFM), Nasolabial angle (NA), and Facial symmetry (FS), and a single variable was classified as results, namely: Maxillomandibular relationship (MMR).

Figure 2. Plane of direct influence/ dependence



Source: Authors

Below, the results derived from categorizing the variables through the use of the matrix of direct influence are presented, with a detailed explanation of them presented in Table 2.

Table 2. Classification of variables by indirect influences and dependencies

Variable type	Variables	Code
Key, strategic or challenge factors	Development of occlusion	DOC
	Growth of the maxilla and mandible	GMM
Determinant or "influencing" factors	Dental age	DA
	Dental anomalies	DAN
	Eruption sequence	ES
	Development of the temporomandibular joint	DTMJ
	Facial profile	FP
Autonomous or excluded factors	Measurements of facial morpholog	MFM
	Nasolabial angle	NA
	Facial symmetry	FS
Dependent or outcome factors	Maxillomandibular relationship	MMR

Source: Authors

As seen in Table 2, the variable Development of occlusion (DOC) turned out to be key because it significantly impacts the relationship between dental development and craniofacial morphology in pediatric patients. Firstly, according to Shkarin, et al. (2019), the proper development of occlusion is essential for masticatory function, the stability of the dentition, and the harmony of facial morphology. While for Lee, et al. (2021), the development of occlusion not only depends on the growth and position of the teeth, but also on the growth of the maxillary and mandibular bones, the relationship between them (maxillomandibular relationship), and the temporomandibular joint (TMJ). Therefore,

occlusion is directly related to other variables in this study, making it a central point in the interdependence between dental development and craniofacial morphology.
On the other hand, the variable Growth of the maxilla and mandible (GMM) turned out to be key because it plays a fundamental role in the relationship between dental development and craniofacial morphology in pediatric patients. In this sense, according to Naqvi et al. (2022), the size, shape, and position of these bones largely determine the appearance and facial structure of an individual. Furthermore, according to Achmad, et al. (2021), the growth of the maxilla and mandible also affects the position and alignment of the teeth in the mouth and is especially relevant in pediatric patients since they are in a stage of active development. Understanding how these bones grow and develop during childhood and adolescence is essential to address the needs of these patients and anticipate potential problems in dental and craniofacial development.
Regarding the determinant variables, Dental age was one of the variables that were classified in this group, that is because this variable is directly related to the process of tooth development. According to Gross & Nowak (2019), as pediatric patients grow and age, they experience changes in tooth eruption. These changes have a direct impact on dental morphology and, therefore, on craniofacial morphology. Likewise, according to D'Agostino et al. (2020), dental age is linked to the eruption sequence of the teeth, which is essential for proper dental alignment and occlusion, which influences craniofacial morphology. On the other hand, dental age is an important tool in clinical evaluation and diagnosis in pediatric dentistry, because it helps determine if dental development is appropriate for the patient's age and if there are delays or advances in the process. This is crucial to plan appropriate treatments and anticipate possible problems in craniofacial morphology.
Regarding the variable Dental anomalies, it was determinant because these are conditions in which the teeth do not develop or align normally, generating a direct impact on the position, alignment, and shape of the teeth, which significantly affects craniofacial morphology. According to Saghiri, et al. (2021), dental anomalies can lead to dental malocclusions, which affect masticatory function and facial morphology and may influence the relationship between dental development and craniofacial morphology. It should be noted that the treatment of these anomalies may include tooth extraction, placement of orthodontic appliances, orthognathic surgery, among other procedures. Furthermore, the planning and execution of these treatments are essential aspects of the care of pediatric patients with dental anomalies, which underlines their importance in the study.
As for the variable Eruption sequence, it is determinant because this sequence is essential for proper dental development. Alterations in the eruption sequence can affect the alignment and position of the teeth, which directly influences dental development and, therefore, craniofacial morphology. According to Arhakis, et al. (2021), problems in the eruption sequence, such as late eruption, early eruption, or disordered eruption, are common in pediatric patients and may require orthodontic and orthopedic treatments. Similarly, Kaur et al. (2022) state that the eruption sequence is also linked to dental occlusion. That is, adequate tooth eruption is essential to achieve normal occlusion and a functional bite, while changes in the eruption sequence can lead to dental malocclusions, which affect both occlusion and craniofacial morphology.
On the other hand, the variable Development of the temporomandibular joint was also determinant because the adequate development of this joint is essential for masticatory function, speech, and craniofacial morphology. While alterations in the development of the temporomandibular joint directly influence facial morphology and the position of the teeth. On the other hand, the development of the temporomandibular joint is interrelated to other key variables, such as the growth of the maxilla and mandible, the maxillomandibular relationship, and the development of occlusion. According to Pawlaczyk-Kamieńska, et al. (2020), changes in the temporomandibular joint can affect the position and movement of the jaw, which in turn influences dental occlusion and ultimately craniofacial morphology. On the other hand, the development of the temporomandibular joint is a critical factor in planning orthodontic and orthopedic treatments, since anomalies in the temporomandibular joint may require specific interventions to correct them.

The variable Facial profile was also classified as determinant because it is closely related to other key variables in this study, such as the development of occlusion, growth of the maxilla and mandible, maxillomandibular relationship, and measures of facial morphology. Changes in the facial profile can be related to alterations in these variables and vice versa. According to Chaves, et al. (2021), any alteration in the shape and position of the jaw, nose, and chin can significantly affect the perception of facial harmony and aesthetics. It should be noted that problems in the facial profile can affect the self-esteem and quality of life of pediatric patients, especially during their development and growth, therefore, the correction of anomalies in the facial profile can be important from a psychosocial perspective.

In contrast, among the resulting autonomous variables is: Measurements of facial morphology, this is because it is generally considered an independent measure that does not have a direct impact on other variables of the system, but can provide valuable information about craniofacial morphology. According to Bannister, et al. (2022), these measurements are generally obtained through evaluation techniques and direct measurement of facial characteristics, such as angles, distances, and proportions. These measurements are objective and provide a quantitative description of facial morphology without the need to be influenced by other variables. They are often used to characterize specific aspects of facial morphology, such as the relationship between facial structures, symmetry, or the position of individual facial features.

Regarding the Nasolabial angle variable, it was classified as autonomous because it is a specific and isolated measure that provides information about a particular facial characteristic but generally does not have a direct impact on other variables in the system. That is, it is a measure that evaluates a specific facial characteristic, without directly considering other aspects of dental development or craniofacial morphology. According to Golshah, et al. (2022), the nasolabial angle is used in clinical practices to evaluate and diagnose possible abnormalities in facial aesthetics, such as harelip and cleft palate. Provides an objective measurement of the position and angle of the upper lip in relation to the nose. Finally, the nasolabial angle is generally evaluated in a specific context concerning facial aesthetics and is not used as a variable that has a direct impact on other variables of dental development or craniofacial morphology.

On the other hand, the variable Facial symmetry is autonomous because it is a specific measure that focuses on facial asymmetry or symmetry, without directly considering other aspects of dental development or craniofacial morphology. Its importance is mainly related to facial appearance and not necessarily to dental function or occlusion. According to Runte & Dirksen (2021), dental health and facial aesthetics professionals can use their experience and visual perception to evaluate symmetry, which can make it less influential in the quantitative analysis of other variables. Although facial symmetry can influence the perception of dental and facial aesthetics, it generally does not have a direct impact on dental development or the relationship between the growth of the maxilla and mandible.

Finally, the only variable classified as result was Maxillomandibular relationship, this is because its value or state is influenced by other variables and its measurement reflects the outcome of certain processes or changes in dental development and craniofacial morphology. According to Li et al. (2022), the maxillomandibular relationship is the result of the relative position of the maxilla and mandible. This position can be influenced by variables such as the growth of the maxilla and mandible, the development of occlusion, the development of the temporomandibular joint, and others. The maxillomandibular relationship is measured to evaluate the alignment and position of the upper and lower jaws in relation to each other. This measurement is used to determine if there is a normal relationship, malocclusion, or significant discrepancy between the jaws. It is a variable that is ultimately evaluated to characterize the outcome of dental development and craniofacial morphology.

Conclusions

In this research, the interactions between dental development and craniofacial morphology in pediatric patients were analyzed using the MICMAC technique. Five variables were identified in the dental

development category and six variables in the craniofacial morphology category. Through a matrix of direct influence/dependence and a structural analysis, these variables were categorized as key, determinants, autonomous, and dependent or results. Among the key variables were: Development of occlusion (DOC), and Growth of the maxilla and mandible (GMM). Among the determinant variables are: Dental age (DA), Eruption sequence (ES), Dental anomalies (DAN), Development of the temporomandibular joint (DTMJ), and Facial profile (FP). Among the Autonomous variables: Measurements of facial morphology (MFM), Nasolabial angle (NA), and Facial symmetry (FS) were found. As result variable: Maxillomandibular relationship (MMR).
The key, determinant, and autonomous variables identified in this study provide a deeper understanding of the interactions between dental development and craniofacial morphology in pediatric patients. These findings may be fundamental in treatment planning, clinical care, and anticipation of potential problems in dental and craniofacial development in this population. It is important to note that this research was based on current data and evaluations, and relationships may vary in different populations and contexts. It is recommended to conduct longitudinal studies and consider additional factors for a more complete understanding of these interactions. On the other hand, this study contributes to scientific knowledge by identifying the key variables that influence dental development and craniofacial morphology in pediatric patients. These findings may have significant clinical applications in the diagnosis, treatment, and follow-up of these patients.

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