

Identification Of The Main Drivers And Dependencies In The Adoption Of Digital Technologies In Dentistry: A Micmac Analysis

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Abstract

The methodological strategy used in this research was based on a mixed approach, combining qualitative and quantitative methods. The research design was non-experimental, cross-sectional, correlational and descriptive. A comprehensive review of existing literature and interviews with dental professionals were conducted to gather relevant information on the drivers and dependencies in the adoption of digital technologies in dentistry. To analyze the relationships and the dynamic structure between the variables, the MICMAC technique was used. The results of the classification showed that the key variables in the adoption of digital technologies in dentistry were technological advances in digital dentistry, clinical and aesthetic benefits, education and training, perception of risks and barriers, and integration with the clinical workflow. The MICMAC technique provided a robust and structured analytical framework to understand the interrelationships between variables and rank them based on their importance and effect on the adoption of digital technologies in dentistry.

Key Words: digital dentistry, transformation, innovation, technological advances, patient experience, efficiency.

1. Introduction

Dentistry has experienced significant advances in recent decades, especially with the introduction of digital technologies that have revolutionized the way this medical discipline is practiced (Prithviraj, et al., 2010). The adoption of these technologies in dental practice has opened up new possibilities and has significantly improved the quality of care that dental professionals can provide to their patients (Javaid, et al., 2021). From treatment planning to manufacturing custom dentures, digital dentistry has revolutionized the way dental procedures are performed (Matsubara, et al., 2021; Jurado, et al., 2021; Lasica, et al., 2021).

In this context, it is crucial to understand the factors that influence the adoption of digital technologies in dentistry. Identifying and analyzing these factors will allow a better understanding of the drivers and barriers

associated with the successful implementation of these technologies in clinical practice (Mathivathanan, et al., 2021). Furthermore, by better understanding the determinants of adoption, more effective strategies can be developed to foster acceptance and use of these technologies among professionals and patients. Therefore, the objective of this study was to carry out an exhaustive analysis of the factors that influence the adoption of digital technologies in dentistry, using a mixed methodological strategy that combines qualitative and quantitative methods. Through this approach, we seek to obtain a more complete and detailed understanding of the key factors that affect the adoption of these technologies in the dental field.

The methodology used in this study includes the MICMAC technique (Applied Multiplication Cross Impact Matrices for a Classification), which allows the identification and evaluation of influence and dependency relationships between variables related to the adoption of digital technologies in dentistry. This technique is especially useful for analyzing the complexity and interaction between the different factors that influence adoption, which is why it has been used in different investigations such as those mentioned below: In (Martelo, et al., 2018) it was used together with the brainstorming technique to determine key factors in determining programmatic proposals for higher education institutions. In (Nematpour, et al., 2021), it was used to assess the key strategic variables of Iran's tourism development system. And, in (Akbar, et al., 2019), it was implemented to determine and understand key variables in agriculture.

The results of this study will provide a clearer view of the key, determinant and autonomous factors associated with the adoption of digital technologies in dentistry. These findings may have significant implications for dental professionals, researchers, and technology providers, providing valuable information on how to improve the implementation and use of these technologies in clinical practice. In addition, this study will contribute to the existing knowledge in the field of digital dentistry, by providing a comprehensive and updated perspective of the factors that influence the adoption of these technologies.

2. Material and methods

The methodological strategy used in this research was based on a mixed approach, combining both qualitative and quantitative methods (Sampieri, 2018). The research design was defined as non-experimental, cross-sectional, correlational, and descriptive. In order to gather relevant information on the main drivers and dependencies in the adoption of digital technologies in dentistry, an exhaustive review of the existing literature and interviews with professionals in the dental field were carried out. The next step was to carry out a structural analysis to identify the nature of the relationships and the dynamic structure between the variables under study. For this analysis, a qualitative approach was adopted based on the methodology proposed by Herrera (2017).

The technique used to carry out the structural analysis was the MICMAC technique. This technique combines both quantitative and qualitative methods to identify key factors or variables through the construction of a square matrix. Subsequently, this matrix is classified in a plane that contains four quadrants, which represent key, autonomous, determinant, and result factors or variables, as established by Arango and Cuevas (2014). The different phases of the MICMAC technique used in this study are described below. These phases allow a detailed analysis of the relationships and dependencies between the variables:

Identification of variables: In this phase, the relevant variables that were considered pertinent for the analysis of the adoption of digital technologies in dentistry were identified.

Construction of the cross-impact matrix: A square matrix was prepared to reflect the relationships between the identified variables, evaluating the direct impact of each variable on the others in the analysis of the adoption of digital technologies in dentistry.

Matrix analysis: Specific calculations and analyzes were carried out using the cross-impact matrix to determine the relationships and dependency between the system variables, in this case, the analysis of the adoption of digital technologies in dentistry.

Classification of the variables: Based on the results obtained in the analysis of the matrix, the variables were classified into the four quadrants: keys, determinants, autonomous, and results. This made it possible to identify the most influential and relevant variables in the adoption of digital technologies in dentistry. The MICMAC technique provided a solid and structured analytical framework to understand the interrelationships between variables and classify them based on their importance and effect on the phenomenon studied. This integrative approach provided a comprehensive view of the key factors and their impact on the situation under investigation.

3. Results

In this section, the results of the research are presented. After collecting the data from the interviews and conducting a bibliographic review, the experts were presented with a list of 11 variables, of which they agreed on their selection. To apply the MICMAC technique in Phase I, a coded table containing the variables and their corresponding descriptions was created. This table, called Table 1, consists of four columns: the number of the variable, the code or short name of the variable, the full name of the variable, and its description. For example, the first row of the table corresponds to variable number one (1), identified with the abbreviated name TADD, which represents Technological Advances in digital dentistry. The description of this variable is as follows: "Includes the development of new technologies such as intraoral scanning, digital radiographs, 3D printing, and CAD/CAM systems." The rest of the table can be interpreted similarly.

Table 1. Variables selected to apply MICMAC.

#	Code	Variable	Description
1	TADD	Technological Advances in digital dentistry	Includes the development of new technologies such as intraoral scanning, digital radiographs, 3D printing, and CAD/CAM systems.
2	CAB	Clinical and aesthetic benefits	Includes the improvement in the precision, efficiency, and quality of dental procedures through the use of digital technologies, as well as the aesthetic results obtained.
3	CRI	Cost and return on investment	Includes analysis of the costs associated with the acquisition and maintenance of digital equipment and software, and assessment of the long-term financial benefits.
4	ET	Education and Training	Includes the availability of education and training programs for dental professionals in the use of digital technologies, as well as the associated learning curve.
5	AP	Acceptance by patients.	Includes patients' perception of digital technology and their willingness to undergo digital procedures instead of traditional methods.
6	RR	Rules and regulations.	Includes compliance with standards and regulations related to data privacy, cyber security and quality standards in digital dentistry.
7	IC	Interoperability and compatibility	Includes the ability to integrate digital technologies into existing dental practice systems and interoperability between different systems and software.

8	TSAS	Technical support and after-sales service.	Includes the availability and quality of technical support, software updates, and equipment maintenance offered by digital technology providers.
9	IOR	Influence of opinions and references.	Includes the impact of peer recommendations, expert opinions and scientific reviews on the adoption of digital technologies in dentistry.
10	ICW	Integration with the clinical workflow.	Includes the ability of digital technologies to seamlessly integrate into existing dental practice workflow, minimizing disruptions and optimizing efficiency.
11	PRB	Perception of risks and barriers	Includes concerns related to data security, the reliability of digital technologies, and potential financial or logistical barriers that could hinder the adoption of digital technologies in dentistry.

Source: Authors.

Once the list of variables related to the adoption of digital technologies in dentistry was drawn up, a collective reflection was carried out with a group of experts to assess the relationships of influence and dependency between each of the variables. This was done using a square matrix, corresponding to Phase II of the MICMAC technique. Table 2 shows the matrix of direct influence/dependency, which was completed with the values obtained from the collective reflection of the experts.

Table 2. Matrix of direct influence/dependency

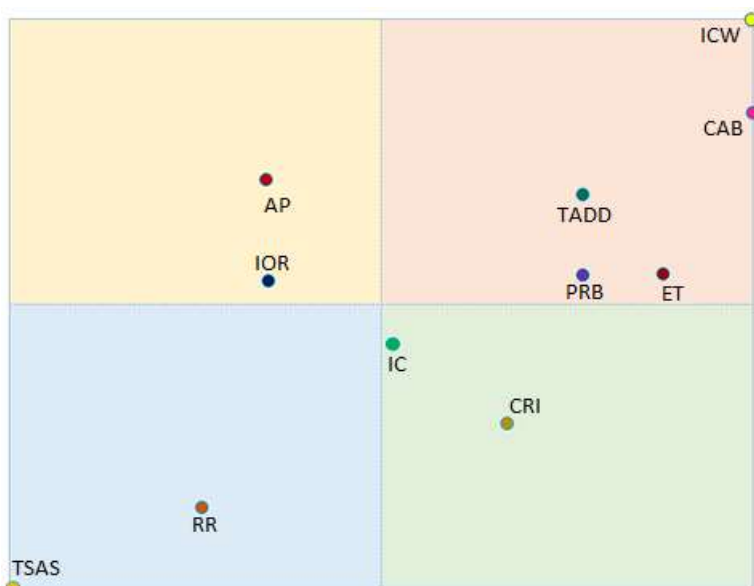
	TADD	CAB	CRI	ET	AP	RR	IC	TSAS	IOR	ICW	PRB
TADD	0	3	2	2	1	2	2	1	2	3	2
CAB	3	0	2	3	2	1	2	1	2	3	2
CRI	1	2	0	3	2	2	1	2	1	1	2
ET	2	3	3	0	2	1	1	2	1	2	2
AP	2	3	2	3	0	2	1	1	2	2	2
RR	2	1	2	1	2	0	1	1	2	2	2
IC	2	2	1	1	1	1	0	3	2	3	2
TSAS	1	1	2	2	1	1	3	0	1	1	2
IOR	2	2	1	2	2	2	2	1	0	3	2
ICW	3	3	2	2	2	2	3	1	2	0	2
PRB	2	2	2	2	2	2	2	1	2	2	0

Source: Authors

In the Table, the first row represents the TADD (Technological Advances in digital dentistry) variable. For example, it can be observed that the direct influence/dependence relationship between the TADD variable and itself is zero (0), while the relationship with the CAB variable (Clinical and aesthetic benefits) is strong (3), with the variable CRI (Cost and return on investment) is moderate (2), with the ET variable (Education and training) it is also moderate (2), and with the AP variable (Acceptance by patients) it is weak (1). In this way, the direct influence/dependence relationships between each variable are described.

After establishing the relationships in the matrix of direct influence/dependency, the variables were classified. This classification is visualized in a plane of direct influence/dependence, as shown in Figure 1. The analysis revealed the presence of five key variables located in quadrant I: TADD, CAB, ET, PRB, and ICW. In quadrant II, two variables were found, AP and IOR, which were classified as determinants. In quadrant III, two other variables were identified: TSAS and RR. Finally, in quadrant IV, the IC and CRI variables were located.

Figure 1. Plane of direct influence/dependency



Source: Authors

Below are the results obtained by classifying the variables using the matrix of direct influence/dependency, which are detailed in Table 3.

Table 3. Classification of variables by direct influences/dependencies

Type of Variable	Variable	Code
Key, strategic or challenge factors	Technological Advances in digital dentistry	TADD
	Clinical and aesthetic benefits	CAB
	Education and Training	ET
	Perception of risks and barriers	PRB
	Integration with the clinical workflow	ICW
Determinant or influencing factors	Acceptance by patients	AP
	Influence of opinions and references	IOR
Autonomous or excluded factors	Technical support and after-sales service.	TSAS
	Rules and regulations.	RR
Dependent or result factors	Interoperability and compatibility.	IC
	Cost and return on investment	CRI

Source: Authors

First, the Technological Advances in Digital Dentistry variable was key because these advances influence the adoption of digital technologies by improving dental procedures, the patient experience, and the efficiency of dental practice in general. Likewise, technological advances have allowed the development of more precise and efficient tools and techniques for dental diagnosis, planning, and treatment. Regarding the variable Clinical and aesthetic benefits, it was key because these benefits play a fundamental role in the adoption of digital technologies in dentistry. Improved clinical outcomes, esthetic improvement, and patient satisfaction are important aspects that influence the decision of both dental professionals and patients to adopt and use digital technologies in dental practice.

For its part, the variable Education and training was key in the adoption of digital technologies in dentistry because dentistry is a field in constant evolution, and digital technologies are playing an increasingly important role in diagnosis, treatment, and patient management. Likewise, this factor ensures that professionals are up-to-

date, competent in the use of these technologies, improve the quality of care, and generate trust in patients. Regarding the variable Perception of risks and barriers, it is key in the adoption of digital technologies in dentistry because it allows identifying obstacles, evaluating risks, influencing decision-making, and understanding patient acceptance. By properly addressing these perceptions, successful and beneficial adoption of digital technologies in the dental field can be promoted.

Finally, the variable Integration with the clinical workflow was key in the adoption of digital technologies in dentistry because it allows improving efficiency and productivity, facilitating its use by professionals, ensuring consistency in patient care, and promoting communication and collaboration among members of the care team. Successful integration ensures that digital technologies are used effectively and their benefits are maximized in the clinical setting.

About the determinant variables, the Acceptance by patients variable is determinant in the adoption of digital technologies in dentistry due to its influence on the demand for services, patient satisfaction and experience, the generation of trust and credibility, as well as its impact on the adoption of technologies by other professionals. Patient acceptance plays a crucial role in the success and integration of digital technologies in dental practice. Regarding the variable Influence of opinions and references, it was determinant in the adoption of digital technologies in dentistry due to its impact on credibility and trust, the dissemination of information, the influence on decision-making, and the formation of collaboration networks. Positive opinions and references can motivate professionals and patients to adopt these technologies and contribute to the progress and success of their implementation in dental practice.

Regarding the autonomous variables, the Technical support and after-sales service variable is considered autonomous in the MICMAC analysis because its existence and quality can influence the adoption of digital technologies, but it is not directly influenced by any other variable in the model. In this sense, adequate technical support and after-sales service are essential to guarantee operation, customer satisfaction, and success in the adoption of digital technologies in dentistry. It is an independent or autonomous variable that can act as a key driver for the successful adoption of these technologies, as it provides support, training, and solutions to the professionals who use them. Its autonomy lies in its ability to influence other system variables without directly depending on them.

As for the Rules and regulations variable is considered autonomous in the MICMAC analysis carried out, unlike other system variables, it is not directly influenced by any other variable in the model, but it can influence other dependent variables. The autonomy of the Rules and regulations variable lies in the fact that it can influence the adoption of digital technologies by establishing a legal and regulatory framework for their implementation and use. For example, if there are clear and favorable regulations that support and promote the use of digital technologies in dentistry, professionals and organizations are more likely to adopt them. Similarly, if there are restrictive or uncertain regulations, there may be resistance or delay in the adoption of these technologies.

Interoperability and compatibility is a result variable because they are results or consequences of the adoption of digital technologies in dentistry, that is, they are one of the key outcomes that can be observed or measured once dental practices or healthcare institutions have successfully implemented digital technologies. When dental practices adopt digital technologies such as electronic health records (EHR), imaging systems, or communication platforms, one of the crucial factors to consider is the interoperability and compatibility of these technologies with the current systems and workflows.

Finally, the Cost and return on investment variable is considered an outcome variable because it is also one of the key outcomes that can be observed or measured once digital technology has been successfully implemented in dental practices. When dental practices adopt digital technologies, such as patient management systems, billing software, or advanced imaging equipment, it is important to assess the costs associated with implementation and the return on investment that can be realized through these technologies.

4. Discussions

The results show the variable Technological advances in dental dentistry, which, according to Pitta (2019), includes digital radiography systems, intraoral scanners, computer-aided design, and manufacturing systems (CAD/CAM), and 3D printing technologies, among others. These innovations improve the precision, quality, and speed of treatments, and can increase the adoption of digital technologies in dental practice. While Tallarico (2020), states that these technologies can also improve the patient experience by reducing discomfort, treatment time, and errors (Larsson & Sabolová, 2019).

Regarding the variable clinical and aesthetic benefits, Goh, et al. (2016), state that some of the digital technologies in dentistry provide more precise and detailed information on the oral condition of patients, which allows increasing the precision of the diagnosis and the effectiveness of the treatment plan, which translates into an improvement in clinical results. For example, the accuracy of intraoral scanners can prevent errors in impression-taking and fabrication of dental prosthetics, which improves the fit and functionality of restorations. This helps ensure an optimal aesthetic result and allows patients to make more informed decisions about their treatment.

As for the variable Education and training, Van der Zande, et al. (2018) state that education and training in these technologies allow dentists to stay up to date and acquire the necessary skills to effectively use these tools in their daily practice. Likewise, Harris, et al. (2012), state that adequate training guarantees that dentists can make the most of these technologies to provide high-quality care to their patients.

Regarding the perception of risks and barriers, Thyvalikakath, et al. (2018) state that the perception of risks and barriers allows the identification of possible obstacles and challenges that may arise when adopting digital technologies in dentistry. These obstacles may include concerns about the security of patient data, the cost of acquiring and implementing the technologies, resistance to change by staff, or a lack of awareness of the advantages of the technologies. By understanding and analyzing these barriers, effective strategies and solutions can be developed to overcome them.

In relation to the Integration with clinical workflow variable, Obadan-Udoh, et al. (2017), state that the successful integration of digital technologies into clinical workflow allows greater efficiency and productivity in dental practice. When digital technologies are seamlessly integrated into existing clinical processes, duplication of work is reduced, practitioner time is optimized, and procedures are streamlined. This can result in faster and higher quality care for patients.

Regarding the variable Acceptance by patients, according to Rattan & Tiernan (2019), acceptance by patients plays a fundamental role in the demand for dental services. If patients have a positive attitude towards the use of digital technologies in their dental care, they are more likely to seek and request services that use them. On the other hand, if patients show resistance or mistrust towards these technologies, demand may be negatively affected. For this reason, acceptance by patients can influence the adoption and success of the implementation of digital technologies in dental practice.

About the variable Influence of opinions and references, Alaiad, et al. (2019) state that the opinions and references of other professionals, colleagues, and patients have a significant impact on the credibility and trust placed in digital technologies. When dental professionals share their positive experiences and recommend the use of these technologies, confidence in their efficacy and benefits is built. Similarly, positive references from satisfied patients can influence the positive perception of digital technologies and motivate others to adopt them.

Regarding the variable Technical support and after-sales service, Hole, et al. (2018), state that digital technologies in dentistry require efficient and reliable technical support and after-sales service to guarantee their proper functioning. If any issues or glitches arise with the technologies, timely and effective technical

support is essential to quickly resolve issues and minimize any disruption to clinical workflow. Proper technical support gives professionals peace of mind and allows them to use technologies continuously and effectively.

Regarding the interoperability and compatibility variable, Benson & Grieve (2016) state that the adoption of digital technologies in dentistry often involves the integration of multiple systems and devices, such as EHR, diagnostic tools, patient management software, and communication platforms, and according to Zhang & Liu (2010), if these systems are not interoperable or compatible, it can lead to inefficiencies, data inconsistencies, and difficulties in sharing information between different stakeholders, such as dentists, dental hygienists, and laboratory technicians. On the other hand, about the variable Cost and return on investment, Hillestad, et al. (2005), state that in the context, when considering the cost and return on investment as a result variable, it allows understanding the importance of analyzing and managing costs. associated with the implementation of digital technologies, as well as assessing the return on investment to make informed decisions about their adoption.

5. Conclusions

In conclusion, this study used a mixed methodological strategy, combining qualitative and quantitative methods, to analyze the adoption of digital technologies in dentistry. Using the MICMAC technique, key variables were identified and the influence and dependency relationships between them were evaluated.

The results revealed that Technological advances in digital dentistry, Clinical and aesthetic benefits, Education and training, Perception of risks and barriers, and Integration with clinical workflow are key variables in the adoption of digital technologies. These factors influence the decision of professionals and patients to adopt and use these technologies in dental practice.

In addition, determinant variables such as Acceptance by patients and Influence of opinions and references were identified. These factors play an important role in the acceptance and adoption of digital technologies, as they influence demand for services, trust in technology, and decision-making. On the other hand, autonomous variables such as Technical support and after-sales service, and Rules and regulations were found. These aspects are important to guarantee the correct operation and compliance with standards in the use of digital technologies in dentistry.

Finally, the outcome variables were Interoperability and compatibility, and Cost and return on investment. These factors are influenced by the key and determinant variables, and reflect the effects and results of the adoption of digital technologies in dentistry. Taken together, this study provides a comprehensive view of the drivers and dependencies in the adoption of digital technologies in dentistry. The results may be useful to dental professionals, researchers, and technology providers in better understanding the factors that influence the successful adoption of these technologies and the improvement of dental care.

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