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Overview of Ceramic Minerals Applications in Dentistry and New Perspectives: An Integrative Review

Ilan Hudson Gomes de Santana[1]; Mayara Rebeca Martins Viana[2]; Kaio Kennuir Gomes Palmeira[1]; Edmundo Junio Rodrigues de Almeida[1], Lívia Silva Galiza[1], Maysa Monica de Melo Silva[1], Katia Caetana Pereira[1], Karolayne Dutra Felix[1], Sandro Lira Gomes da Silva Filho[1], Isabella Bezerra Araujo Cirilo[1], Flavia Regina Maria da Silva[1], Maria Eduarda Batista Henriques[1], Geissyelly Martins de Araujo Oliveira Brito[1], Andressa de Souza Sobral[1], Lucas Elias Silva[1], Lais da Costa Nascimento[1]; Marcondes Mendes de Souza [3].

REVIEW ARTICLE

ABSTRACT

Modern dentistry is constantly searching for new materials that meet specific clinical requirements. Among these materials, ceramics stand out for their superior properties, such as biocompatibility, and are widely used in areas such as prosthetics, dentistry, implantology, and other related specialties. The biocompatibility of ceramic materials is one of the main reasons for their numerous applications in clinical practice, providing significant benefits for the recovery and maintenance of oral health. Objective: The present study aimed to carry out a comprehensive survey of scientific productions related to the applications of ceramic materials in dentistry. Materials and Methods: The research was conducted as an integrative literature review, covering five electronic databases to ensure broad and detailed coverage of relevant studies. Results: Initially, 1329 study records were found. After applying the inclusion and exclusion criteria, 13 studies were selected for analysis. These studies addressed several facets of the clinical applications of ceramic materials, highlighting their advantages and limitations. Conclusion: Despite the significant potential of ceramic materials in the area of dental health, the analysis revealed a deficit in the global literature on the approach to this specific topic. There is a clear need for further research to explore in more depth the applications of these materials, their physical and chemical characteristics, and their interactions with biological tissues, in order to optimize their use in clinical practice.

KEYWORDS: Dentistry, Ceramics, Minerals, Dental Materials.

Panorama das Aplicações de Minerais Cerâmicos na Odontologia e Novas Perspectivas: Uma Revisão Integrativa

RESUMO
A Odontologia moderna está em constante busca por novos materiais que atendam às exigências clínicas específicas. Entre esses materiais, os cerâmicos se destacam por suas propriedades superiores, como biocompatibilidade, e são amplamente utilizados em áreas como prótese, dentística, implantodontia e outras especialidades correlatas. A biocompatibilidade dos materiais cerâmicos é uma das principais razões para suas numerosas aplicações na prática clínica, proporcionando benefícios significativos para a recuperação e manutenção da saúde bucal. **Objetivo:** O presente estudo teve como objetivo realizar um levantamento abrangente das produções científicas relacionadas às aplicações dos materiais cerâmicos na odontologia. **Materiais e Métodos:** A pesquisa foi conduzida como uma revisão integrativa da literatura, abrangendo cinco bases de dados eletrônicas para garantir uma cobertura ampla e detalhada dos estudos relevantes. **Resultados:** Inicialmente, foram encontrados 1329 registros de estudos. Após a aplicação dos critérios de inclusão e exclusão, 13 estudos foram selecionados para análise. Estes estudos abordaram diversas facetas das aplicações clínicas de materiais cerâmicos, evidenciando suas vantagens e limitações. **Conclusão:** Apesar do significativo potencial dos materiais cerâmicos na área da saúde odontológica, a análise revelou um déficit na literatura global sobre a abordagem desta temática específica. Há uma necessidade evidente de mais pesquisas para explorar de forma mais aprofundada as aplicações desses materiais, suas características físicas e químicas, e suas interações com os tecidos biológicos, a fim de otimizar sua utilização na prática clínica.

PALAVRAS-CHAVE: Odontologia, Cerâmicas, Minerais; Materiais dentários.

Dentistry student at the Federal University of Paraíba- UFPB[1]; Dental surgeon at the João Pessoa University Center-UNIPÊ[2]; Professor at the Federal Institute of Education, Science and Technology of Rio Grande do Norte-IFRN[3]

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Autor correspondente*:* Ilan Hudson Gomes de Santana *ilan.hudson@academico.ufpb.br*

INTRODUCTION

Since the earliest civilizations, ceramic minerals have been used for a variety of purposes, as hominids took advantage of their intellectual and observational capacity to explore the world around them and maximize the use of available natural resources. In the field of dentistry, in 1774, Alexis Duchateau developed the first ceramic dental prostheses, seeking to overcome the limitations of the ivory prostheses of the time. Since then, dental ceramics have undergone numerous modifications to improve their properties and expand their applications in the dental market. The versatility of these materials is attributed to their diverse properties, especially when combined with other compounds or chemical elements, allowing for a wide range of applications [1,2].

The scientific field of contemporary dentistry is constantly searching for new materials that offer better physical-chemical properties and biocompatibility with the tissues of the maxillofacial complex. The goal is to develop products that provide better structural qualities and greater comfort for both the patient and the dentist. In Brazil, innovative research into dental materials is revolutionizing dental practice, promoting a transition from "curative dentistry" to "preventive dentistry". This advancement is driven by the increasing availability of technologies in the dental field, as research into new dental materials progresses [3,4].

Dental ceramics are composed of minerals and materials of natural or synthetic origin and are known for their biocompatibility. They are widely used in dentistry in direct contact with the tissues of the maxillofacial complex and can also be used in medicine in other parts of the human body. These materials stand out for their stability at high temperatures, chemical resistance, good resistance to corrosion and fractures, high wear resistance and high hardness. Structurally, dental ceramics are composed mainly of three minerals: quartz, feldspar and clay. These materials can be combined with other compounds to produce products with different structural properties [5,6]. In dentistry, ceramic materials are routinely used in many specialties, such as dentistry, prosthetics, implantology, orthodontics and indirectly in other areas. Single crowns, inlays, onlays, fixed prostheses and aesthetic veneers are some of the ceramic materials used in daily dental procedures. The wide application of dental ceramics in dentistry is justified by the biocompatibility of these materials with the

tissues of the oral cavity, allowing tissue recovery after trauma, tumor resection or long-term tooth loss [7].

Dental software is increasingly gaining prominence in dentistry. These technological resources allow the dentist (DS) and the patient to predict the result without even having started the procedure or treatment, thus reducing unexpected aesthetic and functional results. These technologies enable more optimized clinical planning and, consequently, provide greater precision in the procedures performed by the DS. The application of these technologies in the area of ceramic materials is extremely important, since these materials mimic the functional structures of the oral cavity and require precision in shape and anatomical and morphological characteristics. A technological resource widely used in dentistry is CAD/CAM (Computer-aided design/computer-aided manufacturing), which allows the design and manufacture of prosthetic parts using 3D printers or milling machines. CAD/CAM can quickly create different types of models, such as crowns, bridges, and restorations, with superior aesthetic quality than models produced by traditional molding [8,9,10].

Given the relevance of the application of ceramic minerals in Dentistry and the need for studies that encompass and delve deeper into this topic, the objective of this integrative review is to survey the applications of ceramic minerals in Dentistry and discuss the current and future perspectives of these materials and their associated technologies.

MATERIALS AND METHODS

Since this is an integrative literature review, submission of this study to the Research Ethics Committee was not necessary, as regulated by Normative Instruction No. 510/2016 of the National Health Council (CNS). The main objective of an integrative review is to provide consistent information on a specific topic or issue within a given period. This methodology presents a structured mechanism for searching and selecting studies, with analysis of the relevance and legitimacy of the results obtained, allowing the collection, synthesis, interpretation and comparison of the collected data [11].

To begin this integrative review, a control protocol was developed that included the identification of the research, definition of the guiding question, search strategies and the databases to be used. Based on this protocol, the previously defined databases were

consulted to search for relevant studies. Then, the studies that answered the central question of this research were selected: "What are the applications of ceramic minerals in dentistry?". The study followed the six phases of an integrative review as described by Sousa et al. (2018) [11], which are illustrated in Figure 1: In order to answer the guiding question of this research, a search was carried out in four databases: Web of Science, Scopus, Embase and Pubmed. As for gray literature, searches were carried out through Google Scholar. For the search in the databases, the use of controlled vocabulary descriptors - DeCS/MeSH (Health Sciences Descriptors/Medical Subject Headings) was used: "Dentistry, Ceramics, Evaluation Study, Dental Materials", in English, combined by the Boolean operators "AND" and "OR". Regarding the search stage in the databases, the following exclusion criteria were adopted: course completion papers (monographs, dissertations and theses), duplicates, editorials, preliminary notes and abstracts published in event proceedings and manuals. Regarding the studies included, those that answered the guiding question of this study were selected. The search and evaluation of the studies found in the researched databases were carried out by two independent researchers, adopting the blind method, on December 26, 2022. Of the results found, 39 documents were duplicated, and the resolution of these duplicates was performed using the Rayyan® software [12]. Subsequently, divergences were observed, at the inclusion stage, among the researchers regarding the inclusion of 54 articles, however, after the evaluation of a third evaluator, a consensus was reached in the inclusion of 13 studies for this research.

RESULTS

In total, 13 studies were selected, published between 2009 and 2022, of which two were written and published in Portuguese and eleven in English. The studies included in this research point, in their entirety, to the applications of ceramic minerals and new perspectives in Dentistry. All studies included, after the selection stages, are of the scientific article type, as shown in Table 1.

The works selected to compose the sample are indexed in different databases and were published in different journals during the years 2009 (n=1/7.7%), 2011 (n=2/15.38%), 2016 (n=3/23.07%), 2018 (n=1/7.7%), 2019 (n=1/7.7%), 2021 (n=3/23.07%) and 2022 (n=2/15.38%). Regarding location, the continent that presented the highest number of

publications was Europe (n=5/38.46%), followed by the Asian continent (n=4/30.77%), South America (n=3/23.07%) and North America (n=1/7.7%). Among the studies analyzed, (n=3/23.08%) addressed the application of ceramic materials in the area of dentistry, (n=3/23.08%) of the studies showed the application of ceramic materials in the area of dental prosthetics, (n=2/15.38%) of the studies indicated that ceramic materials are favorable for total or partial composition in the area of dental materials, (n=1/7.7%) addressed the potential applications of these materials in the area of implantology and some studies simultaneously cited the application of ceramic materials in different areas of dentistry, of these, (n=2/15.38%) associated the application of ceramic materials in the areas of dentistry and implantology and (n=2/15.38%) related the areas of dentistry and dental prosthetics.

DISCUSSION

The results of this study show that ceramic minerals have several applications in various areas of dentistry, including dentistry, dental prosthetics and implantology. However, there is a significant deficit in the literature regarding studies that directly address the use of minerals, both metallic and non-metallic, natural or synthetic, in dentistry. This demonstrates the urgent need for more research that explores and discusses the multiple possibilities of application of these compounds, providing a solid basis for future investigations on their physical, chemical and biological characteristics. Considering that many of these materials are widely available in nature and have high rates of biocompatibility with biological tissues, it is crucial to expand knowledge in this area to optimize their uses in dental practice.

The studies selected for this research address the applications of ceramic minerals in four areas of dentistry. The study by Pelaez-Vargas et al., (2011)[13] sought to reproduce alternative surface modification techniques to promote guided tissue regeneration in zirconia materials, for applications in implantology. In line with the author cited above, Iftikhar et al., (2021) [14] sought to analyze and describe the innovations of the main dental biomaterials and, with this, highlighted the regeneration potential of bioceramics for use in implantology. Miyazaki et al., (2009) [15] and Sobrinho, Gomes and Junior, (2021) [16] complement each other by arguing that the use of new technologies associated with ceramic materials, such as CAD/CAM dental systems, are promising in the area of dentistry and prosthetics, which can give rise to materials with better structural and aesthetic properties.

Beketova et al., (2018) [17] and de Matos et al., (2022) [18] agree by stating that even with the various materials currently available, there are still structural, aesthetic and biocompatibility weaknesses, which shows the need for more in-depth studies. Following this reasoning, Tredici et al., (2016) [19] state that the improved use of a ceramic material with zirconia with a tetragonal crystallographic structure allows its application in dental prosthetics. Pekkan et al., (2016) [20] and Galante, Pina and Serro, (2019) [21] emphasize that ceramic materials can be used to restore damaged dental tissues, and that they can be enhanced with technological evolution in the field of dentistry. Chen et al., (2011) [22], de Paula Nascimento, (2021) [23] and Alves and Sant'ana, (2022) [24] concluded that due to the physical, chemical and biological properties, the application of ceramic materials for the restoration of anterior dental elements allows for better results in terms of aesthetics and durability of this type of clinical procedure, as well as for application in the various areas of Dentistry. Gautam et al., (2016) [26] and Iftikhar et al., (2021) [14], reinforce that due to their good aesthetic properties and high mechanical strength, zirconia-based ceramic materials have the potential to be applied in restorations, CAD/CAM dental systems, and implantology.

After analyzing the selected studies, it was observed that there was no disagreement among researchers regarding the applications of ceramic materials in Dentistry, since all studies indicate similar and complementary results, changing only the area of application. It was found that there is a deficit in the world scientific literature regarding studies that present specific and scientific studies on the subject of this research.

CONCLUSION

The scientific literature presents different applications of ceramic materials in Dentistry, however, there are still many that are not described. Advances in technologies and investments in new research will increasingly accelerate the search for better properties and applications of ceramic materials in the dental materials market. These new researches in dental materials have been revolutionizing Dentistry for decades, changing traditional (curative) Dentistry into preventive Dentistry. Regarding the physical-chemical and biocompatibility properties, these materials present thermal, mechanical and chemical stability, which enhances their applications in different parts of the human body. Thus, the association of existing technologies in Dentistry with dental materials will enhance the

resolution of current problems. To this end, it is necessary to address the subject in more depth in future research, to discuss the applicability of ceramic materials through different methodologies, thus contributing to the advancement of health sciences, since the aforementioned material has the potential to be applied not only in the dental area, but also in the medical and related areas.

Table 01: Authors and main results on the applications of ceramic materials and new perspectives in Dentistry

ID	Autor (ano)	País	Título	Objetivo	Quais são as aplicações de materiais cerâmicos e/ou suas novas perspectivas na Odontologia?
1	Sobrinho, Gomes e Junior, (2021) [16]	Brasil	*Dental ceramics: their varieties and structures: a literature review*	Carry out an analysis of dental ceramics and their diversity and their use for the production of indirect prosthetic restorations.	Ceramic materials associated with CAD/CAM methods and new microstructures, creating materials with more resistant structural characteristics that meet the desired aesthetics. These materials can be applied in the area of prosthetics and dentistry.
2	Miyazaki *et al.,* (2009) [15]	Japão	*A review of dental CAD/CAM: current status and future perspectives from 20 years of experience*	To review the recent history of the development of dental CAD/CAM systems in the manufacture of crowns and fixed partial dentures.	The association of new technologies with dental ceramic materials, such as the use of dental CAD/CAM systems, is promising not only in the field of dental crowns (dentistry and prosthetics), but also in other areas of dentistry, even if the contribution is currently limited. CAD/CAM technology has contributed and will continue to contribute increasingly to the health and quality of life of patients in an aging society.
3	de Matos *et al.,* (2022) [18]	Estados Unidos	*Dental Ceramics: Fabrication Methods and Aesthetic Characterization*	Discuss the various staining protocols for most commonly used dental ceramics.	There are currently different types of ceramics used in dental prosthetics. However, the authors point out that further studies are needed on the structural, aesthetic and biocompatibility properties of these materials.

4	Pekkan *et al.,* (2016)[20]	Turquia	*A study on microstructural characterization of the interface between apatite-wollastonite based glass ceramic and feldspathic dental porcelain*	To investigate the characteristics of the interface between an Apatite-Wollastonite (A-W) glass-ceramic and molded glass compacts, sintered at 1100 °C to obtain A-W glass-ceramic added with alumina for use in restorative dentistry.	Apatite-Wollastonite (A-W) glass-ceramic with alumina addition and feldspathic dental porcelain produce an interface that has similar interfacial characteristics to currently commercially available dental materials that are used in restorative dentistry. Therefore, this material has special characteristics as it can be used for the restoration of damaged dental tissues and can be further processed for potential clinical applications.
5	de Paula Nascimento, (2021)[23]	Brasil	*Theoretical approach to the behavior of mechanical properties of* Al_2O_3-ZrO_2 *ceramic composite*	To evaluate the influence of the addition of zirconia on the static and cyclic mechanical properties of the Al_2O_3-ZrO_2 ceramic composite.	The study of the physical, chemical and biological properties of bioceramics and biomaterials can allow the development of new compounds with improved mechanical properties for application in various dental and medical areas.
6	Gautam *et al.,* (2016) [25]	Índia	*Zirconia based dental ceramics: structure, mechanical properties, biocompatibility and applications*	To carry out a systematic review covering studies on the characteristics of zirconia-based ceramics and their applications in Dentistry.	Due to their high fracture resistance properties and the possibility of use in areas of masticatory load, zirconia-based ceramic materials have potential applications in Dentistry in different procedures such as dental restorations, CAD/CAM dental systems and implants. Thus, the future of such material is quite promising, in addition, its application is currently well consolidated in the dental area.

7	Galante, Pina e Serro, (2019) [21]	Portugal	*Additive manufacturing of ceramics for dental applications: A review*	To provide a detailed and comprehensive description of the work published in the last decade on AM of ceramic materials with potential applications in dentistry.	Ceramic materials play an important role as dental materials. Their high chemical and mechanical resistance, as well as their aesthetic properties, make them an excellent option for replacing damaged dental tissues. The expansion of additive manufacturing (AM) technologies opens up the possibility of mass production of customized dental products, with clear benefits for patients and/or healthcare systems.
8	Alves e Sant'ana, (2022)[24]	Brasil	*Predictability of aesthetic restorations in composite resin and ceramic: literature review*	Point out the predictability of aesthetic restorations in composite resin and ceramic, discussing the advantages, disadvantages, success factors and main reasons for failure that will influence their clinical longevity.	Dentistry currently has different types of materials available. Ceramics and composite resins can provide better results for the aesthetic restoration of anterior teeth.
9	Iftikhar *et al.*, (2021)[14]	Arábia Saudita	*The trends of dental biomaterials research and future directions: A mapping review*	Compare, analyze and describe innovations in the main dental biomaterials used.	It was found that research on dental ceramics and bioceramics has grown, especially with regard to their mechanical properties. Thus, the aesthetic characteristics of zirconia and other ceramics and the regenerative capacity of bioceramics for use in Dentistry were emphasized.

10	Tredici *et al*., (2016)[19]	Itália	*Low temperature degradation resistant nanostructured yttria-stabilized zirconia for dental applications*	To demonstrate the applicability of High Pressure Field Assisted Sintering (HP-FAST) for the preparation of dense and nanostructured samples of yttria-stabilized tetragonal zirconia for technological application.	Recently, it has been demonstrated that size-induced stabilization helps maintain zirconia in the tetragonal shape when the grain size is reduced to the nano range, enabling its application in prosthetic dentistry.
	Pelaez-Vargas *et al*., (2011)[13]	Portugal	*Isotropic micropatterned silica coatings on zirconia induce guided cell growth for dental implants*	To develop alternative surface modification techniques to promote guided tissue regeneration in zirconia materials, for applications in implantology.	The study described a technique that combined sol-gel and soft lithography to modify 3YTZP surfaces with micropatterned silica. These tests demonstrated behavior indicative of a cytocompatible pattern, alluding to its potential applications as coatings for use in implantology.
	Beketova *et al.*, (2018) [17]	Grécia	*Evaluation of the micro-mechanical and bioactive properties of bioactive glass-dental porcelain composite*	To evaluate the microhardness and elastic modulus of a new dental ceramic (BP67) and investigate its microstructure and bioactivity.	The study suggested that the new bioactive composite has potential to be applied in Dentistry in the prosthetic area, however, its thermal and optical properties should be further investigated in future studies.
	Chen *et al.,* (2011)[22]	Reino	*Crystallization and flexural strength optimization of fine-*	Optimize the microstructure of a fine-grained leucite glass-ceramic to increase its flexural strength and	The leucite glass-ceramic that was improved in this study showed high flexural strength and reliability properties. Thus, its application in dentistry for the realization of durable and strong esthetic dental

		Unido	*grained leucite glass-ceramics for dentistry*	reliability measured by its Weibull modulus.	restorations is possible. Thus, the optimized material was adopted for clinical use in esthetic restorations and used in the fabrication of more than 100,000 dental restorations.

Source: Authors (2023)

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