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Review Article

Bioceramic in Endodontics – A Critical Assessment of Old and New Technologies

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Abstract

Endodontics is a specialized branch of medicine that deals with dental care mainly focusing on inner soft tissues. Several dental disease and injuries are associated with the compromised health of the tooth related to the degradation of its various parts. Bioceramics are materials used for healing damaged parts of the teeth and have to be biocompatible. In the field of dentistry discovery of bioceramics is considered one of the greatest achievements and extensively used in endodontistry. The bioceramics, in essence, are biocompatible ceramic materials capable of repairing the human hard tissues like tooth and bones. Since their discovery of bioceramics, their material development has further evolved significantly and as such the techniques utilized for implanting this material. The advancement in bioceramic technology has not only led to the development of highly biocompatible better materials rather newly developed formulations have antibacterial properties thus protecting the hard tissues like teeth from invading microorganisms.

This paper presents an overview and assessment of the new and old bioceramics materials and associated technologies. Existing gaps in the bioceramics clinical and pre-clinical research have been identified through extensive evaluation of the relevant literature. Furthermore, this review identifies the new avenues of research in material and technological aspects relevant to bioceramics biocompatibility and allied issues associated with their usage in dentistry. The analyses outline fundamental properties of bioceramics compounds that guarantee the best results in endodontics. Overall, based on the existing literature and empirical guidelines are proposed for achieving a better outcome in the field of dentistry.

Keywords: *Bioceramics; Endodontics; Hydroxyapatite; dental Health; Biocompatibility*

Introduction

Bioceramics are compounds mainly used for the replacement of hard tissues like bones and teeth. Among several others, one of their essential property is to be biocompatible and are synthesized in different ways in order to be incorporated into the human body [1,2]. Earlier studies report four broad categories of bioceramics including the bioinert including alumina and zirconia; resorbable molecules like tricalcium phosphate; alumina and hydroxyapatite-coated metals which are porous in nature and promote tissue ingrowth. The

fourth category of bioceramics are hydroxyapatite, bioactive glasses, and glass-ceramics. These are also known as bioactive materials [3]. Ceramic-based compounds have been adopted in endodontics over the years because of their compatibility with body parts, stemming from the hydroxyapatite in the compounds [4,5]. The similarity in composition and structure has enabled bioceramics to be used as a synthetic alternative to material linked medical purposes. The development of bioceramics represents a crucial discovery in science and has led to the formation of different other potential biocompatible materials [6]. As far as the utilization of bioceramics in the dental field is concerned, the hydration process is considered as crucial and involves the hardening of hydroxyapatite, which is able to induce a response in the human body [7]. Studies have demonstrated amalgamating hydroxyapatite bioceramics with antimicrobial silver and several other compounds [8]. This protects the tooth from infectious microbes and thus helping in quick healing. The ability to induce bone formation within the interface whenever bioceramics are in contact with the bone is one of its principal properties that have led to the widespread application of the compound in endodontics [9]. Moreover, the ability of bioceramics to enhance the healing process of bone is embedded in the biochemical nature of the absorption of osteoinductive substances at the location [10]. Over the years, the use of bioceramics in endodontics has been extensively studied based on its range of applications and advances in technology.

Historical Aspects of the Development of Bioceramics

The introduction of bioceramics dates back to 1969 when researchers found a new material called the bioglass when it was discovered that several glass components could be mixed with ceramic to create another compound that could be easily integrated into human bone [11]. This major revelation became the foundation of key inventions in endodontics. Its range of medical application such as in dental reconstruction and bone treatment has emanated from improvements in the compatibility of bioceramics [12]. The chemical properties of bioceramics, as well as it's biological compatibility, has encouraged scientists to conduct further scientific assessments to determine the best methods for addressing dental and bone problems using the compound. The range of advantages associated with the use of bioceramics is due to their widespread availability and application in different medical areas. The introduction of new approaches has been well received due to their efficiency based on the extensive scholarly research carried prior to designing new techniques [13-15].

Worth pointing out is that, although the use of bioceramics has been improved through new technologies, however, their appreciation, applications and relevant research on their usage is limited [16,17]. The level of sensitization is scarce because of the lack of product availability and affordability all across the globe. On the other hand, the commercial brands that retail in the market are not familiar to most dentists particularly in the underdeveloped countries where dental degradation and injuries are most common. Moreover, treatment of bones and teeth has become increasingly favored, and researchers have encouraged dentists to adopt bioceramics while regarding the original tooth as a building block. Such developments have contributed to the current awareness among academics and medical practitioners seeking to advance patient outcomes and recurrent diagnostics in endodontics [18]. Through the advancement of technology, the onset of bioceramics has evolved to include the need for stellar endodontic results that are associated with treatment efficiency and cost minimization. Currently, the focus of bioceramics is on materials science where this level of professionalism and technology has been maintained to provide excellent results for patients and dentists [14].

Bioceramics use has been increasing with the passage of time, and so is new approaches for refinements of this treatment option [19,20]. Across the globe, dentists have focused on the new methods and advancements that have been achieved in this field. Little literature exists assessing the progress which has been made with the view of presenting sustainable guidelines in line with future needs within the area [6]. Therefore, this review is focused on giving a critical assessment of technologies to determine the current trends from the perspective of existing scientific/clinical data. Although the previous studies and existing review have significant limitations of depending on data generated from other sources, the major findings of the research will be essential in filling this literature gap. Furthermore, a clear understanding of the fundamental discoveries relevant to bioceramics in dentistry will be indispensable to the medical practice because of the need to improve patient outcomes and to reduce the in-hospital period.

Bioceramics Prospects in Clinical Practice

This review is seeking to unravel and highlight the technological trends related to the application of bioceramics in endodontics. The demand for biochemical compounds that can be embedded into the bone system to facilitate healing and reconstruction has been on the rise across the globe [21]. Studies have been conducted to determine the efficiency and refinements in methodologies shifts in the technologies used in endodontics [22]. Although several reports have examined the extent to which bioceramics have been used, little emphasis has been placed on comparing changes in technology and applicability within endodontics. Therefore, this review also looks into the possibility of future systematic reviews of the old and new techniques that have been used in this field. Furthermore, recommendations and guidelines based on anticipated future developments regarding the application of bioceramics are also being highlighted. Such a move will allow scholars to focus on improving the current technology to meet challenging demands in the filed dentistry [23]. On the other hand, a critical review of current medical guidelines will be key to the establishment of an efficient approach to managing bioceramics treatments in endodontics. Therefore, the following is a list of objectives that have served as a guide in the development of this article.

- To identify new and the old technologies associated with the use of bioceramics in endodontics.
- To highlight the guidelines and recommendations for the use of bioceramics in endodontics in line with technology trends.
- What are the essential old and the new technologies associated with the use of bioceramics in endodontics?
- What are useful guidelines and recommendations for the use of bioceramics in endodontics in line with technology trends?

Bioceramics Compatibility and Associated Factors:

Over the years, bioceramics have been used based on some fundamental properties associated with their biochemical composition [24]. One of the key factors governing their widespread application is biocompatibility [25]. In endodontics, preference is given to compounds possessing the right characteristics allowing for their compatibility. Since the compounds used by dentists are implanted in the soft and delicate tissues within a tooth and, in most cases, involve contact with the reconstructed surface, it is essential to consider compatibility aspect. Studies have shown that bioceramics have the highest compatibility as compared to other commercial sealers on the market [26]. When the compound is used in endodontics, dentists have reported a significant level of correct, active host responses for different canal treatments. Therefore, according to research evaluations, the use of bioceramics has been associated with limited cases of post-treatment inflammation, allergy, irritation, and toxicity [27].

On the other hand, advancements in bioceramics usage in endodontics have been evaluated in line with the need for short setting times among patients [24]. However, cases of short setting times that affect outcomes have been linked to the onset of several issues [28]. Such occurrences have encouraged clinical assessments to enhance the results and limit the degree of toxicity. Studies suggest an estimated a four-hour setting time; however, in some cases, this has been exceeded [29]. Such rare occasions have been linked to the lack of surface moisture in some patients. Worth noting is that the need for more efficiency has seen the introduction of modern methods that allow for significant moisture presence when using paper points with limited absorption [30]. For example, Loushine., *et al*. showed that the use of EndoSequence BC Sealer was characterized by less than 168 hours of complete reconstruction and setting under various humid conditions [24]. Therefore, the choice of compound to be used for endodontics is based on a limited set time that correlates with working hours that will ensure effective results. Such characteristics have been exhibited when bioceramics have been used.

On the other hand, bioceramics have also been commended because of flow factors associated with products used. The degree of flow is critical because it enhances the filling of difficult-to-access locations [31]. Cases of thin and irregular dentin, accessory canals, and voids are common; however, the treatment process requires a complete refilling or reconstruction of distant regions including the isthmus. Therefore, the use of bioceramics has been noted to allow for complete reconstitution because of the high level of flow. Worth ascertaining is that the ISO 6786/2001 provisions require the rate of flow to be not less than 20 mm [32]. The rate of flow may be affected by the nature of the particles in the bioceramic compound, the time it takes to mix, and the shear rate. Studies have shown that these factors alter the flow, which is critical in endodontics [33]. The use of the Rheometer method has been useful in determining the flow rate of bioceramics

through tubes and canals. Such analysis has been essential in determining the rate of insertion and how to achieve the highest level of efficiency. Currently, different products on the market are associated with different flow rates based on the designated use [34,35].

Figure 1: *Bioceramic X-ray Images, Root Repair Material, and Material Ready for Delivery (Source: [4]).*

Furthermore, studies have evaluated different bioceramics based on various properties, which are based on advances in technology. According to Al-Haddad and Aziz, re-treatability and solubility are key determinants of the efficiency of a bioceramics that is used in endodontics [10]. Based on the available data it has been ascertained that the use of bioceramics, especially in root filling, is meant for the creation of a mechanical barrier to the periapical inflammatory bacteria as well as the possibility of postoperative pain [36,37]. The recurrent treatment process is usually associated with the removal of the remaining material. According to Wilcox., *et al*. and other the process of retreatment in endodontics involves the establishment of a healthy periapical tissue, which cannot be achieved unless the bioceramic is removed [20,38]. On the other hand, the property of solubility, which is the rate of loss of an element or compound in water after emersion, is equally important. Therefore, less solubility is necessary because it minimizes the chances of the gap formed within the bioceramic as well as within the dentin, which could affect the quality of treatment.

Other factors that have been examined regarding the properties of bioceramic compounds that will guarantee the best endodontic results revolve around the quality of products. According to Patrovi., *et al*. the effect of discoloration of the structure of the tooth is a critical factor in bioceramics [39]. Aesthetic outcomes are crucial in endodontics, and, therefore, the bioceramic used should not induce color changes on surfaces. Several studies have reported that whenever excess bioceramics used in endodontics are not removed, then the chromogenic effects are escalated [40]. On the other hand, the ability to distinguish the endodontic bioceramics from the adjacent structures, also known as the radiopacity property, allows the treatment process to be regularly examined through the use of radiographic-based technologies [37]. Furthermore, the elimination of microbial infections is a key target of endodontics; therefore, the use of bioceramics is focused on the creation of a protective barrier. Therefore, the antimicrobial properties of bioceramics a key factor in endodontics [41]. The need for a compound with a significant antimicrobial effect is the target of continual technological development.

Technical Aspects of Bioceramics

The objective of the current review is to highlight slow pace evolutionary process in the passage to new technologies and material development in bioceramics. Significant attention has been paid in assessing changes that have occurred in the utilization of biochemical compounds in treating various endodontic-based complications. Unfortunately, our critical analyses revealed limited available literature describing clinical studies in bioceramics usage in endodontics and developing a new one. A general trend among the clinician community has been to use pre-developed materials and the technical aspects they learn during their academic years. Almost every clinical specialty has certain existing guidelines as far as the techniques involving material, and the associated usage in human is concerned. There are limited pre-clinical and human subject research studies describing this aspect. An understanding of these trends is essential in presenting a baseline for future considerations and developing new research avenues.

Bioceramics A Unique Biomaterials in Endodontics

A careful evaluation of existing literature evaluated revealed that bioceramics development is usually seen as a biomaterial research relevant to tissue regeneration in both the bones and teeth. What is needed that biomaterial usage in dentistry needs to be developed as a separate discipline as far as material research or methodological aspects are concerned. Several commercially existing materials like the MTA Cement, Endosequence sealers, Biodentine, Bio-aggregate, and the Generex should be developed further and extensive research should be conducted on pre-existing formulation and targets should be identified for their improvements. This review has highlighted the need for few extensive meta-analyses relevant to bioceramics usage and their clinical benefits in the endodontics. Future meta-analyses have to be comprehensive in scope and address various issues related to their clinical usages like micro-leakage, microbiological properties, cytotoxicity, and biocompatibility. The results generated through such evaluations should be considered as a baseline for the future research.

This paper not only reveals key elements associated with technological trends regarding the use of bioceramics in endodontics but identify several unexplored avenues. Nevertheless, several methodological challenges in bioceramics usage in endodontics are evident. Current evaluations and recommendations are based on prior publications that were carried out using different research methods. As such this article proposes the development of a guideline for the future studies in this discipline. The preliminary assessment can be attained through highly focused meta-analysis approach to determine the extent to which the technology has changed is essential. Critics sometimes argue the validity and reliability of meta-analyses and their accuracy and relevancy of the search criteria in relation to the research topic. However, it significantly helps in defining future research and identifying the gaps.

Future Direction in Bioceramics Endodontic Research

In conclusion, based on the existing body of scientific information the technological changes governing the use of bioceramics is a crucial aspect of advancements in endodontics [6]. There is a need for extensive research to identify new bioceramics or changing the existing one to improve their beneficial properties. As described above efforts have been directed towards amalgamating bioceramics with antimicrobial agents like silver compounds and several other formations, however, what is needed an extensive clinical research on these scientific aspects. Scholars have assessed the extent to which dentists have advanced the treatment process through the use of a biocompatible compound for different treatment procedures. The focus of the analyses has been on the level of efficiency associated with the method. Therefore, researchers have been keen to carry out commercial products studies of bioceramics as applied in endodontics. On the other hand, the literature has pointed to some changes in market trends as well as the need for better patient outcomes as a key determinant of technological changes. There is an urgent need to develop bioceramics having better anti-microbial profiles, so the patient can have better outcome subsequent to the treatment procedures.

An important avenue emerging from this review is the lack of appropriate guidelines regarding bioceramics development and their usage in endodontics. The commercial ventures manufacturing various bioceramics have complete control over this industry, and there is a need to disseminate clinical experience knowledge and the development of appropriate guidelines so the knowledge can be empiri-

cally used globally. The shift from previously developed bioceramics to newly developed formulations is very slow, and there is an urgent need to boost clinical research. As the teeth are the major component of the oral cavity and healthy teeth guarantee overall human health.

The above described future avenues identified for bioceramics research in endodontics is based on limited data available in the field. In academic institutions involved in dentistry teaching there is need to promote more scientific/clinical research in this particular field.

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Volume 10 Issue 4 August 2017