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THE EVOLUTION OF ORTHODONTIC BRACES: FROM METAL TO REVOLUTIONARY MATERIALS

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Orthodontics has seen significant advancements due to innovations in the materials and technologies used for orthodontic brackets. This review examines the evolution of braces from the use of traditional metals to advanced materials such as ceramics, composites, and biocompatible polymers. 3D printing has revolutionized the customization of braces, ensuring a precise fit and reducing patient discomfort. Recent innovations include self-ligating brackets, which speed up the process of aligning teeth and diminish visits to the orthodontist, and the use of nanomaterials that improve durability and efficiency. Biodegradable materials offer environmentally friendly solutions, reducing the impact of medical waste. These advances not only improve the performance and comfort of orthodontic treatments but also contribute to their sustainability and accessibility. The future of orthodontic brackets is promising, with an increased focus on personalization, efficiency, and sustainability, continuously integrating discoveries to provide advanced solutions tailored to the individual needs of patients, thus revolutionizing orthodontic practice and significantly improving patient outcomes and experience.

Keywords*:* orthodontic brackets: 3D printing: biocompatible materials: self-ligating brackets: orthodontic innovations.

Introduction

Orthodontics has undergone a significant evolution in the last century, especially in terms of the materials used for braces. This review explores the technological and scientific progress that has allowed the development of more efficient, aesthetic, and comfortable materials for patients [1-3].

Orthodontics, a dynamic field of dental medicine, has evolved considerably over the decades, reflecting technological and scientific advances. Orthodontic braces, essential components of dental appliances, have undergone a significant transformation, moving from traditional materials to advanced solutions, adapted to the needs of modern patients. This evolution has not only improved the effectiveness of treatments but has also increased comfort and aesthetics for patients. Understanding these changes is crucial for practitioners in the field and those interested in medical innovations. This review aims to explore the history, current materials, and future innovations of orthodontic brackets [1-3].

Over time, the materials used for orthodontic brackets have been selected based on durability, functionality, and cost. At the beginning of their use, metal brackets dominated the market due to their robustness and clinical efficiency. However, aesthetic limitations and

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associated discomfort have led to the development of more advanced alternatives. The emergence of ceramic and composite materials was a turning point, offering superior aesthetic solutions and improved performance. These changes reflect a constant concern to improve the patient experience and treatment outcomes [3-6].

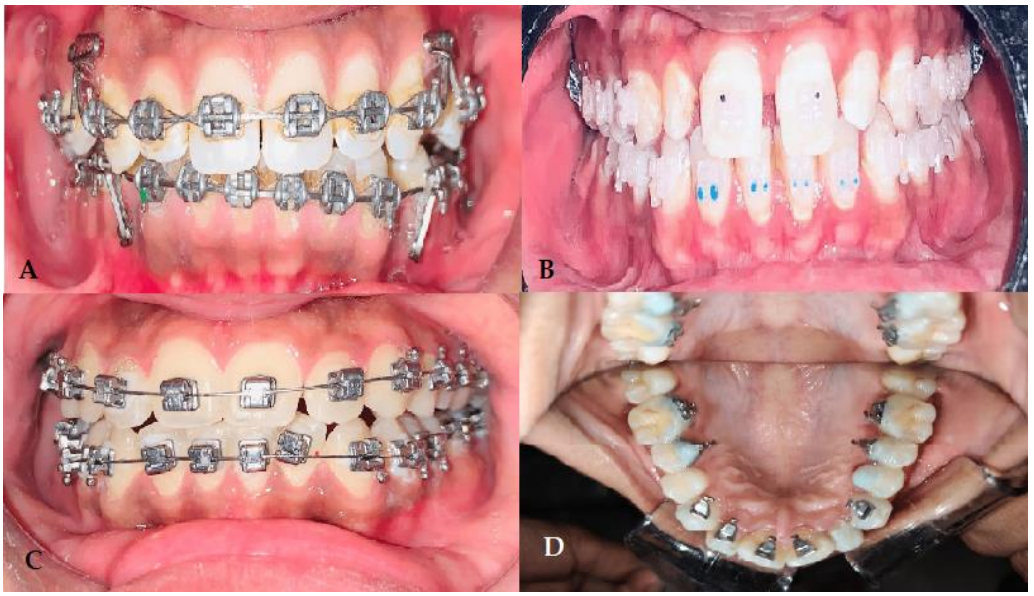

Fig 1. Orthodontic brackets. A) Stainless steel brackets, B) Ceramic brackets, C) Self-ligating brackets, D) Lingual brackets [4].

Currently, orthodontic brackets are made of a variety of materials, each with specific advantages and disadvantages. Ceramic brackets, for example, are appreciated for their aesthetic appearance, although they can be more fragile and expensive compared to metal ones. Composite materials, on the other hand, combine aesthetics with durability, providing a balanced option for many patients. In addition, new technologies such as 3D printing and the use of nanomaterials promise to revolutionize this field even more. These innovations open new horizons in the personalization and efficiency of orthodontic treatments [3-6].

The history of orthodontic brackets is marked by constant innovations that have transformed traditional orthodontic practices. From simple metal braces, orthodontics has gone through multiple stages of development, integrating increasingly sophisticated materials and technologies. Each discovery has brought significant improvements in treatment efficiency and patient comfort. The evolution of the materials used reflects not only technological advancements but also a deep understanding of patients' needs. This review will analyze these stages of development, providing a comprehensive perspective on the transformations in the field [4-6].

The introduction of ceramic brackets in the 1980s was an important step towards improving aesthetics. Ceramic braces are translucent and better match the natural color of the teeth, making them a popular option for patients who want a more discreet treatment. However, their fragility and higher costs compared to metal brackets remained significant challenges [3-6].

Over the past two decades, composite and plastic brackets have offered new solutions. Composite materials combine aesthetics with durability, being more resistant to stains and

fading. Also, plastic and polycarbonate brackets have been developed to provide an even more affordable alternative, although they are often less durable than metal or ceramic brackets [4-7].

Recently, technological innovations, such as 3D printing and the use of nanomaterials, have opened up new possibilities for customizing and improving the performance of orthodontic brackets. These technologies allow the creation of brackets that perfectly fit the anatomy of each patient, providing increased efficiency and improved comfort [5-7].

Recent innovations in orthodontic bracket materials have the potential to redefine treatment standards. Biocompatible and biodegradable materials, for example, are being studied intensively to provide safer and more comfortable solutions. At the same time, advanced technologies, such as 3D printing, allow unprecedented customization of braces, adapting them perfectly to the specifics of each patient. Nanomaterials, with their unique properties, promise to improve the durability and efficiency of braces. These advances point to a promising future for orthodontics, where treatments will be increasingly precise and effective [4-7].

Modern orthodontics is not limited only to correcting dental problems but places special emphasis on the aesthetics and comfort of the patient. Traditional braces, although effective, no longer fully meet the expectations of contemporary patients, who are looking for discreet and comfortable solutions. New materials, such as ceramics and composites, meet these requirements, providing superior aesthetic solutions without compromising the effectiveness of the treatment [5-8].

Metal brackets

They are orthodontic devices used in the treatment of alignment and correction of the position of the teeth and bite. They are composed of individual brackets that attach to each tooth and a metal spring that passes through them, applying constant pressure to move the teeth into the desired position. Metal braces are a popular option due to their effectiveness and relatively affordable cost compared to other types of orthodontic appliances, such as ceramic or invisible braces. Metal bracket treatment can vary in duration, depending on the complexity of the case, but generally lasts between one and three years. They are periodically adjusted by the orthodontist to ensure the progress of treatment [6-8].

Fig 2. Metal brackets A) right side norm, B) left side norm.

Ceramic brackets

Ceramic brackets are a significant innovation in orthodontics, introduced to improve the aesthetics of orthodontic treatments. These brackets are made of high-quality ceramic materials that are translucent and match the natural color of the teeth, providing a discreet and attractive solution for patients. Due to their superior aesthetic appearance, ceramic brackets are especially preferred by adults who want to avoid the visible appearance of traditional metal brackets [6-9].

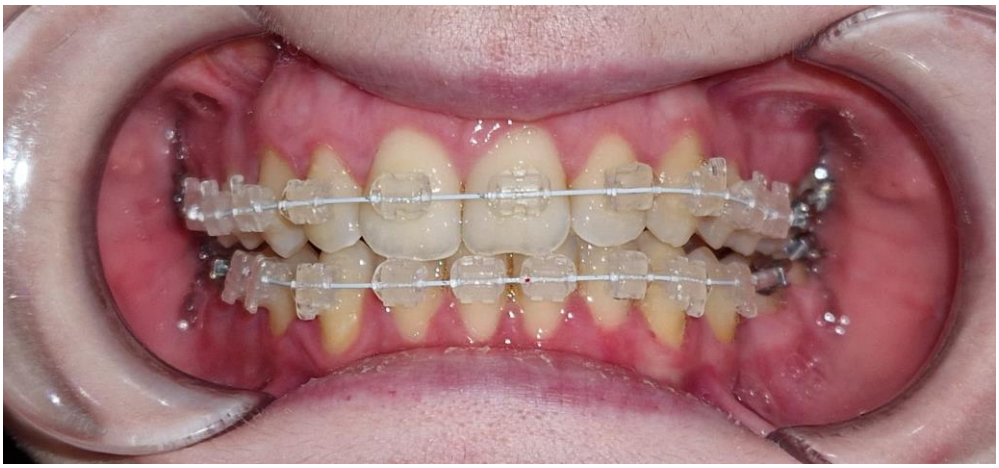

Fig 3. Ceramic brackets, the frontal norm.

One of the main advantages of ceramic brackets is their aesthetics. Being almost invisible, they give patients confidence during orthodontic treatment. Ceramic is also a biocompatible material, which means that it is well tolerated by the soft tissues of the oral cavity and does not cause allergic reactions [7-9].

Fig 4. Ceramic brackets, right side norm.

However, ceramic brackets also have some disadvantages. Ceramic is a more fragile material than metal, which can lead to broken brackets during treatment. In addition, the friction between metal springs and ceramic brackets can be greater, which can extend the duration of orthodontic treatment. Also, the cost of ceramic brackets is generally higher compared to metal brackets, which can be a deterrent for some patients [6-10].

Composite brackets

Composite brackets are an innovative solution in orthodontics, combining aesthetic and functional advantages in a single product. Made from a blend of resins and other durable materials, these brackets are designed to provide superior strength and pleasing aesthetics, while being almost imperceptible on the teeth. They are a popular choice for patients who want a balance between aesthetic appearance and the cost of orthodontic treatment [8-10].

One of the main advantages of composite brackets is their aesthetics. These brackets are available in a range of colors that can match the natural shade of the teeth, providing a discreet look. Composite materials are also resistant to stains and discoloration, maintaining their aesthetic appearance throughout the treatment [9-11].

In addition to the aesthetic aspect, composite brackets also offer considerable durability. These materials are designed to withstand the mechanical forces involved in tooth movement, ensuring the efficiency of orthodontic treatment. Also, being less rigid than ceramic braces, they have a reduced risk of breakage, making them a more durable and practical option for many patients [9-12].

However, composite brackets also have some drawbacks. Although they are more resistant to breakage than ceramic ones, they are not as strong as metal brackets and can suffer wear and tear over time. Additionally, there may be variations in the transparency and color of the material, which can affect aesthetics in certain cases [9-13].

Plastic and polycarbonate brackets

Plastic and polycarbonate brackets are an innovative and affordable option in orthodontics, offering aesthetic and functional solutions for tooth alignment. These brackets are made of lightweight, transparent synthetic materials that blend discreetly into the tooth surface. Being a more affordable alternative compared to ceramic or metal braces, they are often chosen by patients who want an efficient and aesthetic orthodontic treatment, at a lower cost [10-13].

A major advantage of plastic and polycarbonate brackets is their aesthetics. Being almost invisible, they offer a natural appearance and are difficult to notice on the teeth, which makes them ideal for patients concerned about their appearance during treatment. In addition, the materials used are biocompatible and comfortable, reducing the risk of irritation and allergic reactions [11-13].

Polycarbonate brackets are known for their flexibility and strength, being able to withstand the mechanical forces necessary for tooth movement. This makes them more durable than those made of plain plastic, offering superior performance during treatment. Polycarbonate is also stain-resistant, maintaining its aesthetic appearance over time.

However, plastic and polycarbonate brackets also have some limitations. Although they are more aesthetic than metal braces, they are not as durable and can be susceptible to wear and deformation under intense orthodontic forces. Additionally, plastic braces may be more prone to discoloration over time, affecting the overall appearance of the treatment [11-14].

Innovations and the future of orthodontic brackets

Biocompatible and biodegradable materials are a revolutionary innovation in orthodontics, providing safe and durable solutions for orthodontic braces. These materials are designed to be compatible with human tissues, reducing the risk of allergic reactions and inflammation. In addition, their biodegradable property ensures that, after the completion of treatment, the materials decompose naturally, minimizing the impact on the environment [12-14].

One of the main advantages of biocompatible materials is their safety. They are made of polymers and compounds that do not cause side effects when they come into contact with the oral mucosa or other tissues. This is essential for patients with sensitivities or allergies to traditional metals used in braces. Biocompatible materials also provide increased comfort during orthodontic treatment [12-15].

Recent innovations in the field of orthodontic brackets promise to radically transform orthodontic treatments by introducing advanced materials and cutting-edge technologies. 3D printing allows for highly precise customization of the brackets, adapting them perfectly to the anatomy of each patient, thus reducing discomfort and treatment time. The use of biocompatible nanomaterials and polymers not only improves the durability and effectiveness of braces but also minimizes the risks of allergic reactions and inflammation [12-15].

Also, self-ligating brackets, eliminate the need for elastic ligatures, provide constant force, and reduce friction, speeding up the process of aligning teeth and reducing visits to the orthodontist. In addition, research in the field of biodegradable materials opens up new perspectives for environmentally friendly orthodontic solutions, reducing the impact of medical waste on the environment. These innovations not only improve the performance and comfort of orthodontic treatments but also contribute to their sustainability and accessibility [13-16].

The future of orthodontic brackets is bright, with an increased focus on customization, efficiency, and sustainability. The continuous integration of new technologies and materials promises to provide increasingly advanced solutions tailored to the individual needs of patients, revolutionizing orthodontic practice and significantly improving patient outcomes and experience [14-17].

Conclusions

This review highlights the importance of the evolution of materials in orthodontics and their impact on the efficiency of treatment and patient comfort. From traditional metal brackets to today's advanced materials, continuous progress promises to bring innovations that will further revolutionize this medical field.

The evolution of orthodontic brackets illustrates an ongoing commitment to improving treatments and patient experience. From the initial use of robust metals to the integration of ceramics and composites to exploring the possibilities offered by nanomaterials and 3D printing technologies, each step has brought significant improvements. This review will provide a detailed analysis of these developments, highlighting their importance in modern orthodontic practice. By understanding the past and present, we can better anticipate the future of orthodontics and the innovations that will continue to redefine this field.

Ceramic braces offer a superior aesthetic alternative to traditional braces, being a popular option for patients who want a discreet and effective treatment. Although they have

some limitations related to fragility and cost, the aesthetic advantages and biocompatibility make ceramic braces an attractive choice in modern orthodontics.

Composite brackets offer an excellent compromise between aesthetics and durability, making them a viable option for patients who want effective and discreet orthodontic treatment. Although they are not as durable as metal braces, their aesthetic and functional advantages make them a popular choice in modern orthodontic practice.

3D printing technology has significantly improved the customization and efficiency of orthodontic brackets, offering solutions perfectly tailored to each patient. This not only optimizes clinical outcomes but also increases patient satisfaction, contributing to a more comfortable and efficient orthodontic experience.

The future of orthodontic brackets is bright, with an increased focus on customization, efficiency, and sustainability. The continuous integration of new technologies and materials promises to offer increasingly advanced solutions, tailored to the individual needs of patients, revolutionizing orthodontic practice and significantly improving patient outcomes and experience.

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