PRINCIPLES AND MATERIALS USED IN PROSTHETIC TREATMENT OVER DENTAL IMPLANTS

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Abstract

Prosthetic treatment with dental implants was first introduced in the 1970s when the concept of implant osseointegration was formulated. The positive outcomes achieved led to their widespread use, and implant therapy became a standard protocol for rehabilitation following partial or complete tooth loss. The development of modern technologies and the creation of new materials have resulted in the evolution of various treatment methods. This article analyzes the fundamental principles of implantological treatment, the advantages and disadvantages of the materials used, as well as the indications for their application.

Keywords: dental implants, prosthetic treatment, dentistry, dental materials, CAD/CAM

Introduction

Studies indicate that the primary approach in implant placement relies on the presence of adequate bone structure to ensure their stable fixation. For the normal progression of osseointegration, most authors recommend loading implants within 4-6 months after placement [1]. However, others do not adhere to this idea and advocate for immediate prosthetic loading with guided tissue regeneration [2, 3, 4]. There exist divergent perspectives on the type, design, and processing of the superstructure, leading to the development of numerous treatment methods. In all cases, the establishment of a stable connection between the implant and the superstructure is crucial for treatment efficacy.

The aim of this literature review is to observe different types of materials, used in prosthetic treatment over dental implants.

Implant-Superstructure Connection

The connection between the implant body and the superstructure plays a pivotal role in the successful outcome of prosthetic treatment. According to Pita et al. [5], the type of connection between the implant and the prosthetic superstructure is closely associated with its mechanical stability, aesthetics, and longevity. Its relevance has been demonstrated in the development of inflammatory processes in peri-implant soft tissues [6].

Various types of prosthetic platforms have been extensively described in the literature, including external and internal hexagons, the Morse cone connection, and the platform-switching concept. Historically, Branemark initially introduced implants with an external hexagon configuration. Their main drawbacks are associated with reduced mechanical stability and loosening of the connecting screw due to an increased risk of rotation caused by lateral forces during the masticatory process [2, 7, 8, 9].

A large part of research on this type of connection documents bacterial accumulation and growth, which can lead to [10, 11, 12, 13, 14, 15]. Most contemporary implant systems possess an internal hexagon. Y. Liu and J. Wang [16] identify micro-movement of the implant superstructure as the most common cause of technical complications, such as fracture, loosening of the connecting screw, and stress distribution resulting in bone loss. To eliminate these detrimental factors, some implant systems feature a "friction fit" technology, which creates tight friction based on the principle of cold welding of metals and a difference in diameter between the implant and the implant abutment. According to Mangano et al. [17] and Vetromilla et al. [18], implants with a Morse cone provide good mechanical stability and minimal micro-gaps at the connection. Velez et al. [19] establish better accuracy of the Morse cone connection compared to the external hexagon. Other authors report that platform-switching systems create a safe zone around the alveolar bone by "moving" the connection. This reduces stress transmission, improves stability of the bone tissues, and decreases complications arising from bacterial accumulation, micro-leakage, and micro-movement [20, 21, 22, 23, 24]. Further studies indicate minimal bone loss around implants with platform switching compared to systems with an external hexagon [25, 26, 27, 28].

In their systematic review, Vetromilla et al. [29] identify the internal hexagon as the optimal choice for application in the esthetic zone, a finding corroborated by the studies of Lemos et al. [30] and Grasis et al. [31]a. Prosthetic restoration, in cases of partial edentulism, poses numerous challenges, for instance significant defects, where masticatory and speech function, as well as aesthetics is compromised [32].

Treatment of single tooth defects with implants and superstructures may represent an optimal therapeutic choice, but the restoration of such sites requires careful clinical planning and management of both hard and soft tissues. Prosthetic restoration of the implant is performed through the so-called implant superstructure (IS). This is a comprehensive concept encompassing the elements positioned above the implant platform - the implant prosthesis and the abutment [34, 35, 36, 37, 38, 39, 40].

Materials Used in Prosthetic Treatment over Dental Implants

Advancements in technology have facilitated the incorporation of a wide variety of restorative materials used in implantology. Computer-aided design and manufacturing (CAD/CAM systems) have streamlined the utilization of various materials such as metals, ceramics, and some modified polymer materials, enabling their successful integration into the fabrication of implant superstructures.

Metals

Metals and their alloys have been the most commonly used materials in dental prosthetic treatment for decades. The classic technology for manufacturing definitive prosthetic constructions utilizes two main types of metal alloys - noble and non-noble.

Non-noble alloys are based on cobalt-chromium, while noble alloys consist mainly of gold with added palladium, platinum, and others.

Titanium possesses several advantages that establish it as a classic material for the fabrication of implants, superstructures, and other components. It exhibits biocompatibility, optimal physical and chemical characteristics (hardness and mechanical strength, modulus of elasticity, relatively low density, low risk of corrosion), and is relatively lightweight [41, 42, 43]. However, its colour may lead to unsatisfactory results in the aesthetic zone [44, 45]. Currently, titanium alloys with aluminum and vanadium are used in implantology to improve its mechanical properties. Titanium serves as the primary material for all prosthetic and connecting components.

Some highly aesthetic ceramic restorative materials can compensate for the aesthetic drawback. They demonstrate relatively predictable behaviour as prosthetic constructions, but their application as implant superstructures is still debatable [44, 46, 76].

Ceramics

The application of ceramic components in implant prosthetics was first introduced by Andersson et al., K. Henriksson et al. [48, 49] in an attempt to use materials with higher aesthetic qualities to replace titanium. The authors used sintered aluminum oxide ceramics, and the components were manufactured in only one size. Glass ceramics are considered materials with excellent aesthetic qualities [50, 51, 83].

Lithium disilicate exhibits high optical and mechanical properties. Its flexural strength is 350–400 MPa, and its fracture toughness of 3.5-4.5 MPa·m^0.5 makes it a suitable material for the fabrication of highly aesthetic monolithic restorations [44, 50, 53, 55, 76]. It is considered a more aesthetic material than zirconium dioxide, which, due to its low translucency, often cannot meet aesthetic requirements [54, 55, 59].

Zirconium dioxide

Similar to titanium, it has good biocompatibility and response [56]. It was introduced by Piconi and Maccauro for the first time in 1999, and later Holst and M. Blatz [57] affirmed that yttria-stabilized zirconium dioxide has high biocompatibility and mechanical properties. Its flexural strength (900–1200 MPa), compressive strength (2000 MPa), and fracture toughness (6 MPa·m^0.5) [54, 58, 59, 60] define it as exceptionally hard. The authors compare zirconium dioxide with titanium and report similar values of fracture resistance for both materials (281 N as opposed to 305 N). The type of cements used also plays an important role in ensuring a stable and durable connection with the implant superstructure [61, 62, 63].

This material has some limitations in its application, such as inherent opacity and high value [64]. Bone loss around the implant is a serious problem that can lead to its poor prognosis. The forces acting on the superstructure are transmitted through the implant to the bone [65, 66, 67]. Some authors argue that ceramics are hard materials and may transmit excessive load to the prosthetic restoration-implant complex, which can lead to biological or functional complications [68, 69].

On the contrary, other authors [70] argue that the latest generations of zirconia materials have very good biological and mechanical qualities.

Modified Polymer Materials

In 1980, PEEK materials (polyetheretherketones) were introduced in medicine, and due to their biological and mechanical characteristics, they expanded their application [71, 72]. Modified composite materials such as HPP (hybrid polyetheretherketones, reinforced with ceramic particles high-strength polymers) and ceramic-reinforced polyetheretherketones can be an alternative choice to zirconia dioxide-based hybrid superstructures according to Atsu [73, 74]. The authors specify that additional clinical studies would be of great value in determining their long-term survival.

Several studies report good mechanical and biological behaviour of HPP [73, 75, 76, 79]. According to some authors, the lower modulus of elasticity of HPP compared to ceramics, close to that of human bone, makes it a suitable material for implant components. They believe that it can reduce the large occlusal forces transmitted to the implant [77, 78, 79].

The choice of an optimal restorative material should be coordinated with its interactions with tissues and other structures in the oral cavity. The study by Rimondini et al. [80] indicates that zirconia surfaces retain fewer bacteria than titanium. Abrahamsson et al. and Rasperini et al. [81, 82] establish a direct correlation between the quality and quantity of peri-implant soft tissues (PIMT) and the material of the superstructure. Yogesh Kumar et al. [83] found a greater degree of soft tissue modelling around titanium superstructures compared to zirconium dioxide.

Conclusion:

Prosthetic treatment on dental implants relies on the principles of biological compatibility, mechanical stability, aesthetics, durability, and tissue compatibility. The selection and application of appropriate materials in accordance with these principles are crucial for achieving successful and long-lasting prosthetic restorations on dental implants. The choice of material for dental implant prosthetics is not dictated solely by structural principles but must be consistent with the different mechanical and biological characteristics of the materials, as well as their interactions with other structures in the oral cavity.

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