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Review Paper
TMJ Disorders

Biomaterials in temporomandibular joint replacement: current status and future perspectives—a narrative review

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Abstract. The alloplastic total temporomandibular joint (TMJ) prosthesis has a long history, with many different materials and designs used. While several of these materials have proven valuable over time, many others have not been suitable for implantation, resulting in failure and the need for explantation of the implant. Because of the failure of several of these systems, the use of alloplastic prostheses has reduced dramatically, despite their advantages over autogenous restoration. The aim of this narrative review is to discuss the criteria that must be met by a biomaterial in order for it to be considered suitable for implantation, as well as the common complications that can occur. Currently used materials are highlighted, as well as potential future materials that might prove better suitable for implantation. Several surface modification techniques are proposed as an alternative to the materials used in current TMJ prosthesis systems.

Key words: temporomandibular joint; arthroplasty; prostheses and implants; biomaterials.

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The temporomandibular joint (TMJ) is a relatively complex joint, consisting of an upper and lower compartment, separated by a fibrocartilaginous disc. Both rotational and translational motions allow for the opening and closing of the mouth, mastication, talking, and other activities.

Although the prevalence of TMJ diseases is high, treatment using a TMJ prosthesis remains relatively rare[1,2]. According to Sidebottom, up to 80% of all patients seen by a specialist can be treated with a more conservative approach, such as rest and anti-inflammatory medications[3]. Less than 10% of all patients in a specialist centre will present the need for arthroscopy or arthrocentesis, and even fewer patients will require open surgery. TMJ replacement is widely accepted as end-stage therapy, which should only be considered for certain well-specified indications when previous, more conservative (non-invasive) treatments have proven unsatisfactory.[4] This widespread highly prudent approach is partly the result of overuse of surgery in the past, in combination with catastrophic experiences with early alloplastic TMJ replacements (e.g., the Vitek-Kent prosthesis)[5–11]. Indications for total joint

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replacement (TJR) include the following: inflammatory arthritis involving the TMJ, recurrent fibrosis or bony ankylosis after failed tissue grafts (bone and soft tissue), failed alloplastic joint reconstruction, or loss of vertical mandibular height or a proper occlusal relationship because of bony resorption, trauma, developmental abnormalities, or pathological lesions[5–10].

For a TMJ prosthesis to be successful, it must provide a good imitation of the function of the joint, a close fit between the prosthesis and host bone, and a reasonable lifetime, which should equal that of other prostheses. Furthermore the prosthesis should reduce the suffering and disability of the patient, not be unduly expensive, and not require excessive treatment[5,10,12,13].

Although the problems with the Vitek-Kent prosthesis were later determined to be due to inappropriate material selection, leading to the formation of severe wear debris and subsequent osteolysis, the alloplastic TMJ prosthesis was abandoned for many years, and autologous alternatives, such as sternoclavicular, costochondral, and fibular grafting, became more prevalent[5,14]. However, the rapid evolution of biomaterial science over the last couple decades, providing a rational basis for the selection of materials, as well as the development of computer-aided design and computer-aided manufacturing (CAD/CAM) planning, allowing the production of patient-fitted components, has led to substantial progress in the construction of alloplastic TMJ prostheses. Consequently, alloplastic prostheses have steadily gained more acceptance by craniomaxillofacial surgeons.

The selection of appropriate materials for the different components is key to successful implementation. However, while other fields of expertise, such as orthopaedic surgery, have an extensive history of debating the advantages and disadvantages of various materials, the literature and research concerning the selection of materials for TMJ prostheses is relatively scarce. Therefore, the aim of this review is to discuss several previously used biomaterials and the current state-of-the-art with respect to the different biomaterials used in alloplastic TMJ prostheses, as well as to consider the potential of future materials that address some of the current shortcomings.

Materials and methods

Information about TMJ prostheses was gathered through a computerized literature search using multiple databases and following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The PubMed Central, ScienceDirect, Wiley Online Library, Ovid, and Cochrane Library databases were used to conduct the search. The following heading was used to perform the search: (''Temporomandibular joint'' OR ''TMJ'') AND (''Material'' OR ''Biomaterial'' OR ''Biocompatible'') AND (''Prosthesis'' OR ''Prostheses'' OR ''Replacement'' OR ''Implant''). While the search terms remained unchanged, the combination in which they were used depended on the database.

To assess the methodological soundness of each article, a quality evaluation was performed using the 2011 Oxford Centre for Evidence-Based Medicine LOE65 (Level of Evidence) recommendations. The quality was categorized from levels I to IV; level V studies were not included.

The initial search returned 10,433 published articles. Subsequently the number of hits was reduced by removing all duplicates and reviewing the titles of these articles. This led to a total of 113 articles, which were evaluated by reading through the abstract. Articles not containing a reference to the TMJ in the abstract were excluded, leading to the exclusion of a further 37 articles. The full texts of the remaining 76 articles were read with reference to the inclusion criteria and finally a total of 37 articles were included in the systematic review. Reasons for exclusion were: article written in a language other than English, Dutch, or French; full text not accessible. An additional 16 articles were identified following a hand-search of the reference lists of the included articles.

Finally, in order to provide a sound biomaterial background, an additional eight articles were handpicked by a biomaterial engineer from the specialized literature, to provide further unbiased details on material specifics and properties, while still maintaining the methodological soundness and objectivity of the systematic search results. A summary of the article selection process is given in the PRISMA flow diagram in Fig. 1.

History of materials used in temporomandibular joint reconstruction

The importance of the appropriate selection of prosthetic materials has clearly marked the history of TMJ prosthesis design, as many designs have been conceived, yet only a few remain. The use of inadequate materials can, for instance, result in metal hypersensitivity, foreign body giant cell reaction, heterotopic ossification, and even implant loosening and failure. A short summary of the history of the different types of prostheses, with their respective materials, is provided below[15–20].

Early developments

Fossa prostheses

Nearly one century after John Murray Carnochan inserted a block of wood between the skull and mandible as a treatment for ankylosis in 1840[7], several surgeons, including George Fulton Risdon, William ''Bill'' Nordholtz Eggers Jr, and Goodsell, started using interpositional materials such as tantalum (Ta) foil as a treatment for TMJ disorders (TMD). Smith and Robinson first introduced the use of stainless steel to replace the fossa in 1950, and during the 1960s, cobalt–chromium (Co–Cr) alloys such as Vitallium made their way into the TMJ thanks to Robert W. Christensen and Douglas Morgan[6,12,21,22]. Besides metals, polymer materials, such as silicone and polytetrafluoroethylene (PTFE), were also used as disc replacement materials. Two of these polymer fossa prostheses worth mentioning are the Vitek Proplast–Teflon disc prosthesis and the Silastic disc prosthesis. The inner part of the Vitek disc implant contained a high-density PTFE (Teflon), while the outer layers consisted of a mixture of Teflon and carbon fibres, known as Proplast. While initially highly popular, it became apparent several years after the first placement that the disc was not suited for in vivo functional loading, resulting in excessive wear and leading to debris accumulation in the fossa region. This triggered a foreign body giant cell reaction and eventual bone resorption. As a result, production was halted in 1990, and in 1991 the US Food and Drug Administration (FDA) recommended the removal of all Proplast/Teflon devices[6,7,12,23,24]. The Silastic disc had a similar fate, as functional loading led to fragmentation of the silicone elastomer, and this disc prosthesis was abandoned in 1993[6,25].

Condylar prostheses

Polymer materials also came into use for condylar prostheses. The first polymer prosthesis was released in 1964 by Hahn, which consisted of an acrylic (poly(methyl methacrylate), PMMA) head and a Vitallium mesh condyle[26]. Shortly thereafter, several more prostheses followed, such as the vitreous carbon-coated

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