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TMJ Disorders

Alloplastic total temporomandibular joint replacements: do they perform like natural joints? Prospective cohort study with a historical control

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Abstract. The aim of this study was to qualitatively and quantitatively describe the biomechanics of existing total alloplastic reconstructions of temporomandibular joints (TMJ). Fifteen patients with unilateral or bilateral TMJ total joint replacements and 15 healthy controls were evaluated via dynamic stereometry technology. This non-invasive method combines three-dimensional imaging of the subject's anatomy with jaw tracking. It provides an insight into the patient's jaw joint movements in real time and provides a quantitative evaluation. The patients were also evaluated clinically for jaw opening, protrusive and laterotrusive movements, pain, interference with eating, and satisfaction with the joint replacements. The qualitative assessment revealed that condyles of bilateral total joint replacements displayed similar basic motion patterns to those of unilateral prostheses. Quantitatively, mandibular movements of artificial joints during opening, protrusion, and laterotrusion were all significantly shorter than those of controls. A significantly restricted mandibular range of motion in replaced joints was also observed clinically. Fifty-three percent of patients suffered from chronic pain at rest and 67% reported reduced chewing function. Nonetheless, patients declared a high level of satisfaction with the replacement. This study shows that in order to gain a comprehensive understanding of complex therapeutic measures, a multidisciplinary approach is needed.

Key words: biomechanics; digital volume tomography; prosthesis; mandibular motion; temporomandibular joint; replacement.

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Temporomandibular joint (TMJ) pathologies, if unresponsive to non-surgical treatment, may require surgical intervention. For those cases where a TMJ replacement is indicated, the discussion is ongoing as to embodiment paradigms. The first references to attempts at alloplastic TMJ reconstruction date back to the second half of the 19th century, when prostheses of different natural materials were implanted immediately after joint excision.[1,2] TMJ reconstruction surgery progressed significantly in 1965 when Christiansen modified his fossa replacement device by adding a condylar element, thus creating the first alloplastic total joint replacement (TJR) system.[3] Later on, several other systems brought substantial diversity to the market.[4,5] The alloplastic TJR underwent continuous development until the 1980s, when serious adverse events were reported in relation to Vitek-Kent (Vitek, Houston, TX, USA) and Silastic (Dow Corning, Midland, MI, USA) replacements, including foreign-body giant cell reactions, bone erosion, persisting pain, alterations in occlusion, and mandibular hypomobility, necessitating the removal of numerous prostheses.[6–8] This caused a general mistrust in alloplastic TJR among clinicians and a return to autologous transplantation techniques.[9]

Recently, promising outcomes have been reported for new generation alloplastic TJR systems.[10–16] These joint replacements have a better prognosis with respect to the reduction in pain level and improvement in jaw function.[17] However, the variety of alloplastic TJR systems available shows that none has achieved the status of a gold standard. Therefore, the replacement system is chosen according to the surgeon's preference and their understanding of TMJ function.[5]

Despite the considerable literature on the long-term results of TJR, there is still little information on the biomechanical features of the alloplastic replacements, especially in function. Typically, the functional outcome has been assessed by taking clinical measurements of the range of motion at the inter-incisal point,[13,18,19] which does not provide a deep insight into actual joint kinematics.

Developments made in the authors' laboratory in the field of dynamic stereometry have allowed the thorough assessment of mandibular kinematics, in particular the tracking of jaw motion and measurement of the biomechanical environment of the TMJ. Therefore, the goal of the present study was to describe mandibular- and especially TMJ-kinematic patterns in patients with an existing TJR by means of dynamic stereometry. Secondary objectives were the clinical examination of the range of motion of the jaw and the assessment of pain level and subjective interference with eating, as well as patient perceived satisfaction.

Materials and methods

This was a prospective cohort study with a historical control. Patient contact data were obtained from the clinicians who had performed the alloplastic total joint reconstructions at the participating centres between February 2005 and February 2015. Recruitment took place between December 2014 and August 2015.

Inclusion criteria were the following: current presence of an alloplastic TJR, an interval of at least 6 months since the last surgery, and age between 18 and 80 years. Patients who were pregnant, currently breast-feeding, planning a pregnancy during the course of the study, drug or alcohol abusers, and those who were unable to follow the procedures of the study, e.g. due to language problems, psychological disorders, or dementia, were excluded.

The control group consisted of subjects from a normative database established previously. For inclusion in the control group, the subject had to meet the following criteria: age within the same age range as the patients, no history, or signs or symptoms of a temporomandibular disorder (TMD) based on assessments performed according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) by calibrated examiners,[20] and available bilateral magnetic resonance images (MRI) and computed tomography (CT) images of the TMJs.[21]

This study was performed in accordance with the Declaration of Helsinki on medical protocol and ethics and was approved by the necessary ethics committee. Written informed consent was obtained from all participants.

Clinical measurements

Pencil markings were drawn on the lower incisors to define the mandibular midline, and a conventional dental ruler was used for the assessment of the range of motion and opening pattern at the inter-incisal point. The patient was asked to open their mouth to the maximum (even if experiencing pain), protrude the mandible, and eventually to shift it to the right and left as far as possible. After performing each movement, the patient was given a break of approximately 5 s in order to relax their muscles. All measured values were recorded to the millimetre. The resulting opening pattern was classified into one of three groups according to the Diagnostic Criteria for Temporomandibular Disorders (DC-TMD) standard protocol: (1) straight, defined as deviation of the mandible ≤ 2 mm from the midline; (2) corrected, defined as a deviation of the mandible ≥ 2 mm and return to the midline before or upon reaching maximum opening; (3) uncorrected, defined as deviation of the mandible ≥ 2 mm from the midline.

Assessment of pain and self-perceived function

After the clinical measurements had been taken, the patient was asked about their current pain intensity. The pain level was assessed on a numerical rating scale (NRS) from score 0 'no pain' to score 10 'worst imaginable pain'.[22–25] Additionally, patients classified the level of interference with eating using a similarly constructed Likert scale, from score 0 'ability to chew toughest food, e.g. almonds' to score 10 'only liquid nutrition'. Finally, the patient's level of satisfaction with the replacement was rated between 0 'absolutely dissatisfied' and 10 'completely satisfied'.

Dynamic stereometry

The biomechanical characteristics of the TJR were assessed by means of dynamic stereometry. This non-invasive method consists of a combination of three-dimensional (3D) imaging and jaw tracking and provides an indirect insight into the patient's TMJ movements in real time. For the purpose of this study, coronal X-ray image stacks with $0.4\ \mathrm{mm} \times 0.4\ \mathrm{mm} \times 0.4\ \mathrm{mm}$ voxels were obtained using a digital volume tomography (DVT) scanner (KaVo 3D eXam 1; KaVo GmbH, Leutkirch, Germany) with the patient biting into a reference custom-made occlusal splint. The basic technique of dynamic stereometry and its characteristics have been described previously.[26]

Experimental procedure

At the first appointment, a 3D scanner (TRIOS; 3Shape, Copenhagen, Denmark) was used to acquire digital models of the patient's dental arches. Based on the scans, two custom-made splints were designed (Rhino 5; Robert McNeel & Associates, Seattle WA, USA; https://www.rhino3d.com) and printed with a 3D printer (Objet Eden 260V; Stratasys, Eden Prairie, MN, USA). At the second appointment, the splints were rigidly attached to the patient's