Synovial metaplasia has been reported to occur in tissue surrounding silicone breast implants\(^1\)\(^-\)\(^6\) and in tissue adjacent to joint prostheses.\(^7\)\(^-\)\(^8\) It has also been described in skin and soft tissues, most frequently in healing or healed traumatic or surgical wounds.\(^9\)

Heterotopic bone formation (HBF) is defined as the formation of bone within the temporomandibular joint (TMJ) that may cause partial or complete ankylosis of the joint, causing pain and limited range of motion.\(^10\) Multiple previous surgeries, a history of trauma, and ineffective postsurgical physical therapy regimens have been postulated as possible contributing factors to its development. Different therapeutic options have been proposed, each showing variable success in preventing reankylosis.

We report the first case in which papillary synovial metaplasia occurred due to placement of a temporary silicone implant in a patient in whom HBF developed after total alloplastic TMJ replacement with a stock prosthesis and present a review of the literature.

**Report of Case**

A 56-year-old woman was referred to the Department of Oral and Maxillofacial Surgery of the University Hospital Infanta Cristina, Badajoz, Spain, after facial trauma occurred during a road traffic accident, which resulted in a displaced left mandibular condylar neck fracture (Fig 1). The patient was initially managed by placement of intermaxillary fixation for 3 weeks. Postoperative physiotherapy was recommended, but she was not cooperative. Six months later, she complained of increasing pain in the left TMJ and decreasing maximal interincisal opening (MIO). A computed tomography (CT) scan showed heterotopic calcifications within the joint. The patient underwent a left TMJ replacement with a total stock TMJ prosthesis (Biomet Microfixation, Jacksonville, FL) (Fig 2A) to manage the incipient ankylosis.

The surgery and initial post-replacement course were uneventful; however, 2 years later, pain and limited range of mandibular motion again developed. A new panoramic radiograph (Fig 2B) and CT scan (Fig 2C) showed the redevelopment of heterotopic bone around the prosthesis especially posterior to the articulation. The patient refused any invasive management at that time; however, she agreed to return for a re-evaluation every 6 months.

After 18 months, because the patient’s mandibular pain and dysfunction symptoms were increasing, a panoramic radiograph and new CT scan were obtained; they exhibited complete calcification around the prosthesis (Fig 3). She consented to undergo further treatment, and a 2-staged left TMJ replacement with a patient-fitted total TMJ prosthesis was planned (TMJ Concepts, Ventura, CA).

At the first-stage surgery, the stock device components were removed and a gap resection of the heterotopic bone block was performed (Fig 4). The gap between the remaining bony surfaces was maintained by implanting a spherical silicone spacer (Fig 5A) (Bausch & Lomb, Rochester, NY).

Once the patient-fitted device components had been designed and manufactured, the second-stage surgery was planned during which the spacer would be removed and the left TMJ replaced with a patient-fitted TMJ Concepts prosthesis. During the second-stage surgery, when the silicone spacer was removed, it was noted that a glistening, white, fibrous-looking encapsulating tissue had developed around the spacer (Fig 5B). This tissue was only removed from areas that required bone-to-prosthesis contact and was maintained everywhere else that it had formed to potentially deter future HBF.
HBF or ossification was first described in 1883 by Riedel. HBF is defined as the abnormal formation of mature lamellar bone in soft tissues. The overall incidence of HBF has been reported to be between 5% and 90%.

However, the incidence of clinically significant HBF varies from 3% to 7%. The incidence after total knee replacement is less, 15%, but of these patients, only 1% complained of symptoms.

When HBF affects the TMJ, partial or complete bony ankylosis will be the result, leading to complaints of pain and limited range of mandibular motion. TMJ-related HBF has been reported in 52% of cases after gap arthroplasty for ankylosis and rheumatoid cases and reconstruction with a condylar prosthesis without a fossa prosthesis. Topazian found that there was a 53% incidence of reankylosis with gap arthroplasty. Popescu noted a 100% rate of recurrence of ankylosis when a simple arthroplasty was performed, even when a variety of mesenchymal allografts were interposed. Wolford and Karras stated that 35% of the patients managed with total alloplastic TMJ prostheses without fat grafting exhibited HBF and required reoperation.

HBF is believed to result from inappropriate differentiation of pluripotent mesenchymal stem cells. A definitive cause for this phenomenon is not yet clear, but it appears that there is an interaction between local and systemic factors. Growth factors and bone morphogenetic protein have been identified as affecting the initiation, differentiation, and proliferation of osteogenic cells. Although no definitive studies have been conducted to identify specific risk factors for the development of heterotopic bone after TMJ surgery, multiple previous surgeries, a history of trauma (e.g., fracture of the condyle), inadequate intraoperative hemorrhage control, and an ineffective postsurgical physical therapy regimen have all been postulated as potential contributing factors.

The size of the gap created during surgical management of TMJ ankylosis has been postulated as playing an important role in the prevention of HBF/reankylosis. A critical size defect is a bone-to-bone gap that cannot be bridged by normal callus formation and secondary healing. It has been recommended that this defect be 2.5 to 3.5 cm. Moreover, it has been suggested that the surgeon limit periosteal stripping of adjacent bone, carefully debride all devitalized tissue in the area, irrigate copiously with normal saline solution to remove as many loose bony fragments as possible, obtain good local hemostasis to minimize the development of a hematoma, and promote aggressive and active postoperative physiotherapy.

Patient-fitted TMJ Concepts device components are designed and manufactured for each specific clinical situation from a protocol CT scan-generated stereolithographic model with a reported mean dimensional accuracy of 97.9%. Therefore, in cases of ankylosis and/or reankylosis, the surgeon, during a first-stage procedure, must remove the ankylosic bone and create an adequate gap and must place an anatomic spacer to prevent the reformation of tissue and/or bone; placement of intermaxillary fixation is recommended to prevent movement of the spacer or

**FIGURE 1.** Panoramic radiograph taken after road traffic accident. The displaced left mandibular condylar neck fracture can be observed (arrow).

FIGURE 2. Immediate postoperative panoramic radiograph (A) made after implantation of left total TMJ stock prosthesis and panoramic radiograph (B) and CT scan (C) taken 2 years later. HBF can be observed around the stock prosthesis, mainly in the posterior part of the articulation (arrows).

change in bony architecture and/or occlusion during stage 1 surgery.

Because the components of the TMJ Concepts device interface so closely with the host bone, allowing for the screw fixation to be stable immediately after implantation, mandibular function and active physical therapy can begin immediately after implantation. This is essential in cases of ankylosis and reankylosis because muscle function has been compromised over time in such cases. Salter,28 in his work on continuous passive motion after orthopedic joint surgery, has shown the importance of this concept to the long-term functional results of any joint surgery.

Besides active and aggressive physical therapy, ancillary postoperative management options to prevent reformation of heterotopic bone and reankylosis have been recommended. These include ionizing radiation, medications, and intraoperative placement of autogenous fat around the articulation of either autogenous or alloplastic total TMJ replacements. Ionizing radiation interferes with the processing of nuclear DNA formation during cell division and may thus impede
the differentiation of osteoprogenitor cells. Durr et al reported favorable outcomes in two-thirds of their patients with TMJ ankylosis who received postsurgical radiation. However, significant concerns exist relative to the effects of this treatment on nearby structures (brain, orbit, and parotid gland).

Nonsteroidal anti-inflammatory drugs act by inhibiting the production of prostaglandins, particularly prostaglandin E2. Perioperative nonsteroidal anti-inflammatory drugs have also been reported to reduce the incidence of HBF by one-half to two-thirds. The efficacy of indomethacin (25 mg 3 times a day for 5-6 weeks) in preventing HBF has been shown.

There are reports in the literature discussing the use of bisphosphonates as prophylaxis against HBF after total hip arthroplasty. However, despite the fact that bisphosphonates have the ability to inhibit mineralization of osteoid, unfortunately, they have no inhibitory effect on the formation of osteoid. Therefore, their use has been discontinued because it was found that these drugs only postpone ossification until their use is stopped.

The transplantation of autogenous free fat graft into the TMJ was reported as early as 1914. The use of autologous fat transplantation has been reported by Thomas as a way of preventing HBF after hip replacement. The presence of dead space after extensive joint debridement leads to hematoma formation. According to Lexer, fat tissue has hemostatic properties, caused by the fast attachment of fat tissue to a bleeding site, therefore stopping the bleeding. It has also been postulated that fat may be a factor in preventing scar formation tissue.


**FIGURE 4.** A, Intraoperative view showing the bony ankylosis (arrows) around the TMJ stock prosthesis. B, Same view after removal of ankylosic bone.

Synovial metaplasia was first described by Brody and White after their studies on implanted silicone joints in chickens. The first human cases were descriptions of the formation of synovial-like mem-

![Image of intraoperative view showing the bony ankylosis (arrows) around the TMJ stock prosthesis.](image-url)
branes reported by investigators studying the reaction of the periarticular tissues to joint and tendon prostheses.\(^7,8\) Later, Gonzalez et al.\(^9\) reported the occurrence of synovial metaplasia occurring in the skin in healed surgical scars. There have also been numerous reports of synovial metaplasia occurring adjacent to silicone breast implants and expanders\(^1,6\) or silicone voice prostheses\(^36\) or produced experimentally after repetitive subcutaneous injections of air after surgical procedures.\(^37\)

The term “synovial metaplasia” is based on the morphologic resemblance of villous structures of the hyperplastic synovial membrane at histologic examination. These histologic features include epithelioid cells with basally oriented nuclei overlying a fibrous membrane; cytoplasmic processes, oriented perpendicular to the surface; occasional multinucleated giant cells; and a well-formed reticulin network. There is no evidence of elastin fibers or basement membrane (Fig 7). Studies comparing the breast capsular membranes with synovial membranes found in villonodular synovitis have shown similar histologic, histochemical, and immunohistochemical features, in terms of both transmission appearance and scanning electron microscopic appearance.\(^1,4\) Unfortunately, because there are no unique and specific biomarkers for synovial cells, until one becomes available, it appears reasonable to assume that this membrane is synovial metaplasia.

**FIGURE 5.** A, Silicone orbital implant spacer (Bausch & Lomb) in place before being removed. B, Glistening, white, fibrous connective tissue capsule-like structure (arrow) found on removal of silicone orbital spacer.


**FIGURE 6.** Intraoperative view of custom-made TMJ Concepts prosthesis articulation.

The presence of a lining membrane with the histologic features of synovial tissue has important implications for determining the origins and functional significance of this tissue. A number of theories have been suggested to explain this phenomenon. Some studies suggested that the tissue reaction can be correlated with the implant surface or that the age of the implant could be a significant factor. Raso et al. attributed stimulation of synovial metaplasia formation more to the silicone than to the surgical procedure. Another hypothesis suggests that mechanical stress may influence the development of synovial metaplasia.

There is now consensus that movement is important. Drachman and Sokoloff showed that synovial tissue fails to develop in the embryo in the absence of motion. They suggested that traction or motion provides the biological signal that stimulates differentiation and organization of individual cells into synovial tissue. That is, mechanical forces (movement, shear forces, repeated surgery, trauma, and so on) are necessary for the development of synovium. These authors also named other rarely cited factors necessary for the formation of normal joint spaces: loose areolar tissue that would develop spaces due to the movement and relatively smooth gliding surfaces that would resist penetration by growing fibroblast processes.

Edwards et al. provided data supporting this concept. They repeatedly injected air into subcutaneous tissue. Analysis of the lining tissue of this cavity by light and electron microscopy and histochemical techniques showed that after 5 to 30 days, the lining membrane was indistinguishable from synovial tissue. These studies appear to show that mechanical forces, in association with the natural developmental re-

FIGURE 7. Histologic appearance of papillary synovial metaplasia. A, A single papillary fold, showing the synovial lining cells supported by fibrovascular tissue. The nuclei of these cells are basally oriented and are polarized perpendicular to the cavity surface (arrow) (hematoxylin-eosin stain, original magnification ×40). B, A number of spaces representing dissolved silicone surrounded by foreign-body giant cells (arrows) (hematoxylin-eosin stain, original magnification ×40). C, D, Immunohistochemical stain for CD-68 (C) and PGP-9 (D) with strong staining of all cells within papillae (original magnification ×40).

sponse of mesenchymal tissues surrounding an implanted foreign body, and the chemical and physical composition of the foreign body are most likely primarily involved with the formation of the synovial metaplasia. 37

Several manuscripts reported reactive tissue to temporary or permanent silicone spacers placed after disc removal decades earlier. Destructive lesions of the condyle 41 in conjunction with histopathologic findings of foreign-body reactions in articular tissues and regional lymph nodes 12,43 were reported. Sanders et al 44 affirmed that silicone elastomer became encapsulated by connective tissue in a reasonably short period, which worked as a reasonably smooth articular surface.

Westmark et al 45 report histologic findings in soft tissue samples obtained from around 2 types of TMJ prostheses (Biomet Microfixation and TMJ Concepts) after up to 8 years of function. All joint capsule samples showed dense, fibrous connective tissue with no inflammatory cells or foreign-body reactions. The joint disc tissues showed even denser fibrous connective tissue, free from inflammatory reactions. Some samples from the junction between capsule and disc showed synovial-like tissue. 45

After a review of the literature, the case presented appears to be the first reported case in which papillary synovial metaplasia occurred due to the use of a silicone temporary spacer implant during a 2-staged alloplastic TMJ replacement in a patient in whom HBF developed after reconstruction of the TMJ with a stock prosthesis.

Although further investigation into this phenomenon in the TMJ is warranted, it seems reasonable to suggest a 2-staged procedure to replace the TMJ in patients who have had repeated failed surgical procedures or trauma and in whom ankylosis or reankylosis developed because of HBF. In our opinion, such patients could benefit from a 2-staged surgery, with placement of a temporary silicone spacer implant at the first-stage surgery; then, at the second-stage surgery after formation of the synovial lining, the clinician will implant the components of the prosthesis and place autogenous fat around the articulation, with active physical therapy thereafter. This recommendation is based on the assumption that this implant maintains the gap and could induce the formation of a synovial lining that prevents new heterotopic ossification. However, further studies are necessary in this area before a firm conclusion can be drawn.

References


