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REVIEWS

Polypropylene Surgical Meshes in Orthopedic Surgery: A Narrative Review

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Abstract

Restoring the continuity of the anatomical layers and the musculoskeletal soft tissues is fundamental in the reconstructive phases of all surgical proceduresSynthetic surgical meshes are commonly used augments in general surgery to fill flat gaps, but can also be used in other surgical fields, including orthopedics.

We evaluated the evidence in modern international literature on the use of polyethylene surgical meshes in the different fields of orthopedic surgery, including hip and knee arthroplasty, trauma surgery, shoulder surgery, and orthopedic oncology.

Polyethylene surgical meshes have been used to replace or reinforce musculoskeletal soft tissues. Flat mashes can be used to reinforce flat surfaces, like the cut articular capsules or torn rotator cuffs. Folded meshes provide good longitudinal resistance, allowing the reinforcement or reconstruction of tendons and ligaments in the lower and upper limbs. Also, orthopedic oncology could benefit from using meshes to replace resected soft tissues and provide attachment sites for remaining tendons and ligaments.

In conclusion, surgical meshes represent a reliable and adaptable reconstructive approach for several soft tissue lesions in orthopedics surgery. Alone or in combination with other augments, polypropylene surgical meshes should be considered when facing wide soft tissue gaps around the musculoskeletal system.

Keywords: Marlex, Prolene, Prosthesis, Surgical mesh, Synthetic, Reconstruction

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INTRODUCTION

Restoring the continuity of the anatomical layers and the musculoskeletal soft tissues is fundamental in the reconstructive phases of all surgical procedures. Most of the time, surgeons can quickly restore the continuity of muscles, tendons, and ligaments with sutures without requiring augments. However, when the treated disease caused a severe deficit of local tissue stock, or an extensive tissue sacrifice was necessary during the intervention, simple sutures could not close the wound, or coverage could come with excessive tension of the deep wound edges. Hence, surgical augments have been introduced to fulfill soft tissue gaps that could not undergo an adequate primary closure. Unlike local flaps and multilayer autologous grafts, which require the expertise of experienced plastic surgeons and the sacrifice of the patient's tissues in near or far donor sites, tissue augments do not need any harvesting time and do not require high-complexity procedures for their positioning[1,2].

Through the decades, several augments have been proposed in different fields of surgical practice. Augments can be divided according to their nature in biological and synthetic materials[3]. Biological augments, including tendon or fascia lata allografts, have sufficient mechanical properties to replace the native structures[4,5]. Their biocompatibility can generally have good integration between the graft and the host's native soft tissues since native cells could colonize the surfaces of the devitalized allogeneic tissues. Despite these advantages, allografts can be prone to fatigue ruptures or elongations depending on their size and length. Furthermore, tendon and fascia allografts can be limited in availability or burdened by excessive costs for some institutions[6,7]. Unlike biological reconstructions, modern synthetic augments do not have integrative potential but come at a much lower cost and can ensure good mechanical properties for thousands of use cycles, providing food strength performances, especially in short- and mid-term scenarios[8].

To this date, synthetic surgical meshes are commonly used in general surgery to fulfill flat gaps such as the ones that can occur in the abdominal wall. In particular, their most common field of use is represented by the reinforcement of the internal inguinal wall to treat inguinal hernias and prevent their recurrence[9]. Through the years, the use of these well-established devices has gradually spread to different surgical fields, including orthopedics. The aim of our study is to review the uses of polypropylene surgical meshes in orthopedics, evaluating their outcomes and complication rates in modern literature.

HISTORY AND ACTUALITY OF SYNTHETIC MASHES

Since the end of the nineteenth century, the disappointing results of the suture in bringing biological tissues closer together in some complex surgeries prompted the surgeons to use prosthetic material, driven by the desire to provide greater mechanical strength to tissue subjected to high mechanical stress.

In 1878, a great German surgeon named Theodore Billroth, talking about the poor results in the surgical treatment of inguinal hernia, reported that "If we could artificially produce tissue of the density and hardness of fascia and tendon, the secret of the radical hernia cure would be discovered." This historic sentence opened the door to experimentation and using prosthetic materials in soft tissue reconstruction. The traces go back to the XIX century when Phelps first reinforced an inguinal repair with a silver coil[10]. However, its structural rigidity, tendency to fragmentation, and exuberant scar response induced the use of other metallic materials. One of these was tantalum, which Burke used for the first time in 1940, but it raised problems similar to silver[11]. Later, stainless steel, considered to be the best of all metals and already used as a suture in 1929, was implanted as a mesh by Babcock in 1952[12]. Unfortunately, even in this case, the structural rigidity of the material made it unsuitable for soft tissue repair, and the discomfort often created in patients led to its replacement with materials other than metal fibers.

From the 20th century onwards, the rising industrial production of plastics allowed using less expensive and more performing materials, such as nylon. In 1944, Aquaviva and Bounet reported their experience with synthetic nylon meshes, used during the Second World War to repair the extensive loss of substance in the abdominal wall following severe abdominal wounds[13]. However, even a material like nylon, considered excellent for suturing, proved to be an unreliable prosthetic material due to progressive loosening and elongation in a long-term scenario. Thereby, even it suffered the same fate as metal materials and was soon replaced by more modern, high-performance materials not subject to loss of mechanical strength by host-induced hydrolysis.

In 1955, a synthetic polymeric material derived from ethylene (polyethylene) was presented under the trade name of Marlex[14]. It was hydrophobic, heat-resistant, chemically inert, and excellently resistant to mechanical stress. It also had a cross-linked structure. Unlike other synthetically derived materials, it was well tolerated by the host tissues due to its porous structure, which is capable of inducing a moderate inflammatory reaction and facilitating tissue integration. Further innovations were introduced in 1963 with the commercialization of polypropylene, also known with the trade name of Prolene. This new plastic material was considered the evolution of Marlex since it had a lower specific weight due to larger pore diameters, a bidirectional elasticity, and could be cut without fraying[15]. Compared to its predecessor, it had better bio-compatibility and evoked less scarring response.

Polyethylene terephthalate, another polyethylene variant, was marketed under the trade name Mersilene[16]. Known for its softness and adherence to anatomical planes, it was progressively abandoned after observing numerous cases of hernia recurrence from mechanical failure attributable to slow degradation of the implanted material. Moreover, the multi-filament structure was shown to favor the nesting of bacteria, a cause of prosthetic infection that is difficult to treat with conservative methods, to the extent that it requires explanation. For this reason, although polyethylene terephthalate is still in use as LARS artificial ligament for tendon reconstructions[17], it is no longer largely used as square surgical meshes.

In 2012, Klinge and Klosterhalfen published research on the host biological response to different prosthetic materials implanted[18]. After explanting 1000 meshes, they reported that the human organism responds to an external insult by developing an acute inflammatory reaction, which spontaneously wears off within 7-10 days.

In the case of implantation of a foreign body, such as a prosthesis, the intensity and duration of this response may vary, depending on the type of material implanted. In synthetic mesh prostheses, the size of pores may influence the extent of the biological response, inducing a more or less intense prolonged inflammatory reaction. Prostheses with larger pore sizes tend to have better integration, promoting a more physiological healing process facilitated by the host's rapid colonization of the implant.

Any mesh induces fibrosis, and the resulting scar tissue is part of the healing process. However, an excess can induce a reduction in prosthetic size due to shrinkage, which exposes the host to the risk of recurrence and/or chronic post-operative pain problems.

In addition, synthetic wide-meshed prostheses are less prone to infectious risk due to their better integration than narrow-meshed ones, which tend to be encapsulated.

Over time, some materials, such as polyester, can undergo degradation processes and lose their structural integrity, which in turn causes mechanical failure such as herniation recurrence. The enormous amount of work carried out by these authors has led to defining how to choose between the numerous types of prosthesis, subordinating it to the patient's state of health, the extent of the pathology to be treated, and the clinical scenario in which the implantation takes place (elective or emergency surgery, level of contamination of the surgical site, size and location of the defect, etc.), exercising a personalized choice, universally recognized as 'tailored surgery'[8,9].

FIELDS OF USE IN ORTHOPEDICS

Synthetic surgical meshes have been used in many orthopedics surgery fields, aiming to reconstruct or reinforce damaged soft tissues. In the following paragraphs, we reported the surgical approaches that included polypropylene surgical meshes (Figure 1) and summarized their outcomes, including functional performances, stability, range of motion, stability, and pain relief. All the case series studies published in international modern literature between 1980 and June 2024 indexed in Pubmed or Scopus that met the research criteria *[((Polypropylene Mesh) OR (Synthetic Mesh)) AND ((Orthopedics) OR (Orthopedic Oncology) OR (Arthroplasty) OR (Limb) OR (Tendon) OR (Ligament))]* have been evaluated and, if consistent with the aim of our research, included in our review.

Hip arthroplasty

Hip dislocation represents one of the most frequent and threatening complications in hemiarthroplasty or total hip replacements. Severe loosening or focal defects of the hip capsule can cause articular instability and increase the risk of dislocations[19]. In case of massive loss of periarticular soft tissues, especially in complex primary arthroplasty or revision surgery, orthopedic surgeons may benefit from using augments to

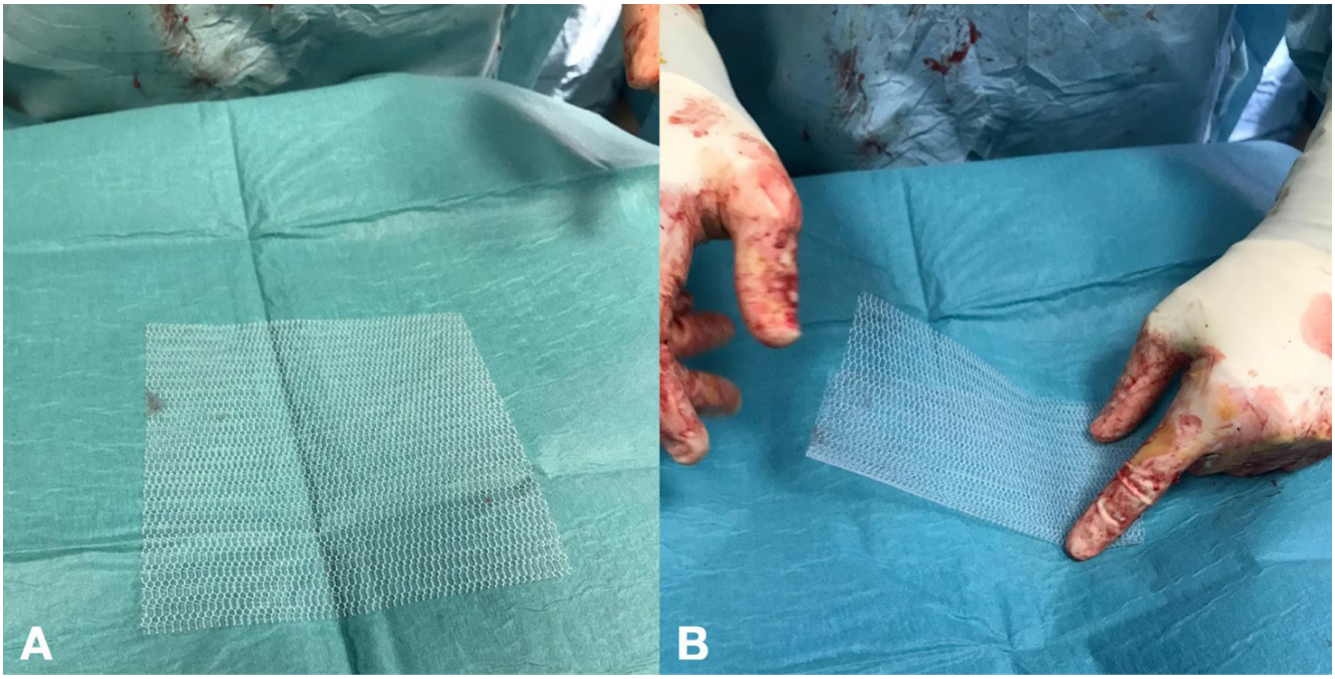

Figure 1. A polypropylene surgical mesh exposed in a surgical theater. The mash can be used flat (A, on the left) or folded (B, on the right) depending on the necessities of the single case.

restore the continuity of the hip capsule[20]. Theoretically, Polypropylene meshes could represent a reconstructive strategy able to mimic the native capsule and externally increase the prosthetic hip's stability due to their good tensile strength and low tendency to elongation. Although the literature still needs more case studies on this topic, some authors have published case series and case reports using surgical meshes in hip arthroplasty with promising results[21-23]. Nassler and Nassler[23] used polypropylene mesh (Bard PPP mesh) to restore and strengthen the hip joint capsule in five patients with total hip arthroplasties who had had previous episodes of dislocation. The authors applied a mesh along the entire perimeter of the tissue defect, thus forming a mechanical "patch" over the defect and acting as a plateau for the formation of a durable, fibrous scar. None of the treated patients had dislocations or other signs of articular instability after the implant of the surgical meshes. Three of the five cases included in the study had a history of previous infections and revisions before final revision surgery. One had post-operative infections, while the remaining four cases were infection-free through their mean post-operative follow-up of 16.6 months.

Shoulder

Chronic tears of the superior rotator cuff and glenohumeral capsule represent a serious burden for patient's shoulder mobility and functionality. If not properly treated, these lesions result in wide tissue gaps that might impede a one-step suture anchor reconstruction. When the two ends of the cuff tear could adequately approach one to the other, augments could be necessary to restore the continuity of capsule and rotator cuff. Among the augments described in literature, such as fascia lata grafts[24] and the modern bioengineered patches[25], polyethylene surgical meshes can be considered an alternative for superior glenohumeral capsule tears. Ciampi et al.[26] reported their experience with a group of 152 patients treated with open surgery to restore the rotator cuff's continuity using polypropylene surgical. The outcomes of the group were compared to two other groups, treated with simple sutures and biological patches, respectively. After a follow-up of 36 months, patients treated with polypropylene meshes had better strength, scapular plane elevation and functionality according to the UCLA shoulder scale compared to the other two groups. Ben et al.[27] fashioned a single-layer polypropylene mesh (Prolene Mesh; Ethicon) inside of a folded fascia lata allograft. The complex, whose margins were sealed with a running stitch, was fixed at the glenoid and humeral site using suture anchors. Comparing the post-operative MRI images of patients treated using fascia lata allografts and surgical meshes with those who had fascia lata alone, authors reported better imaging evidences in cases treated with the composite approach, thereby suggesting that the healing and remodeling of an FLA may be enhanced by the use of a mesh.

A combination of a fascia lata allograft and a polypropylene mesh was also used with an arthroscopic approach by Kholinne et al.[28]. Similarly to what has been reported by Ben et al., the outcomes of Kholinne et al. suggested that also using an arthroscopic approach, the addition of a polyethylene allograft to a folded fascia lata graft reduced post-operative pain and increased treated shoulder's post-operative range of motion.

None of the aforementioned authors had deep infections that caused mesh failure[24-28].

Knee

Extensor mechanism (EM) disruption is a catastrophic complication in patients treated with total knee arthroplasty (TKA). Quadriceps or patellar tendon ruptures during or after TKA lead to severe extensor lag, chronic pain, and articular instability, significantly impairing the treated knee's functionality. Several reconstructive approaches have been proposed and described for significant defects of the extensor apparatus in modern literature, including biological reconstructions (such as muscular flaps and allografts) and synthetic implants[29,30]. Among these latter, surgical meshes have emerged as one of the most reliable tendon augments in modern literature, also for tears involving the extensor apparatus of the knee.

From a technical point of view, many authors fold a single sheet of mesh onto itself to create a tubular graft, which is then secured with a heavy, nonabsorbable suture to the ends of the torn ligament or the bone using suture anchors or through tunnels. Mesh coverage with host tissue ventrally and dorsally is essential to avoid mesh exposure and abrasion against the implant. Free tissue from the iliotibial band or muscle flaps can occasionally be brought down to cover the mesh[31-37].

Several authors reported their experience using folded surgical meshes to restore the continuity of the knee extensor apparatus. Table 1 summarizes their clinical and functional outcomes.

Study	N° patients	Use of mesh	Outcome	Infections	Other major complications involving mesh	Mean follow-up
Abdel et al.[31]	77	40 patellar tendon; 27 quadriceps tendon; 10 patellar fractures	Excellent functional outcomes with a mean improvement in extensor lag of 26°	None	5 patellar tendon rupture; 5 quadriceps tendon rupture; 2 symptomatic lengthening of the mesh	4 years
Browne et al.[32]	13	13 patellar tendon	The mean post-op extensor lag measured 2.8°; the mean Knee Society function score improved from 20 points pre-op to 50 points post-op	1 patient with previous sepsis had recurrent infection and was treated with a knee arthrodesis (7.7%)	3 mesh failures	3.5 years
Buller et al.[33]	30	33 patellar tendon	Excellent functional outcomes with a mean improvement in extensor lag of 34°	7 cases explanted for infection (5 recurrent and 2 new) (21%)	-	25 months
Fuchs et al.[34]	28	19 patellar tendon; 9 quadriceps tendon	After surgery, the mean extension lag improved by 31° to 4° post-op; the mean active flexion was 87°; after surgery, patients had a mean KOOS score of 48	None	2 mesh failure	23 months
Perry et al.[35]	16	16 extensor mechanism	General improvement about extensor lag and active flexion	2 reinfections (12.5%)	2 mesh ruptures	4 years
Nodzo & Rachala[36]	6	7 quadriceps tendon	4 clinical successes defined as an extensor lag less than 30°	2 infections (28.6%)	2 mesh ruptures	34 months

Table 1. A summary of case series available in literature on the use of polypropylene meshes to reconstruct the knee extensor apparatus.

Despite the differences attributable to the single cohorts and lesions treated, all authors reported encouraging functional outcomes, with reduced extension lag for most treated patients. Abdel et al.[31] and Fuchs et al.[34] recorded no infection in cohorts of 77 and 28 cases, respectively. Only Nodzo and Rachala[36] had infection rates higher than 25% among the examined studies. The overall data in the literature, therefore, suggest that surgical meshes can have reasonable infection rates even in a relatively superficial setting like the anterior knee. Buller et al.[33] hypothesized a correlation between the risk of infections and diabetes, suggesting that the vascular degenerations and metabolic alterations induced by diabetes could increase the chances that bacteria could reach and colonize the mesh.

Although globally rare, several authors have described mechanical failures due to mesh ruptures, with rates ranging between 0 and 33% of treated cases[31-37].

Globally, the encouraging functional outcomes and reasonable complication rates suggest that folded polypropylene meshes could be considered reconstructive strategies in massive gaps in the knee extensor apparatus that require a planned or unplanned reconstruction, particularly in the absence of tendon-specific augments, such as LARS[38].

Orthopedic Oncology

The main aim of orthopedic oncology is the removal of neoplastic masses in bones and soft tissues. Especially when treating malignant tumors, surgeons aim to achieve wide resection margins, eventually implying massive tissue losses. The sacrifice of tendons and muscles can limit movements and reduce contractile strength. In contrast, the lack of capsules and ligaments may cause articular instability, especially for those who also underwent massive bone resections and the implant of mega-prostheses[39]. In this scenario, several strategies have been proposed to restore the continuity of capsules and ligaments after major interventions of orthopedic oncology. Alongside biological approaches, including muscle flaps and autografts of allografts, synthetic augments have been used to replace short and large segments of capsules or tendons after tumor resections[40-42].

Kapoor et al.[43] used polyethylene surgical meshes in 116 oncologic patients in different body segments of the upper and lower limb, providing reattachments for soft tissues and eventually reattachment sites around prosthetic implants. The authors stated that using proline meshes to reconstruct soft tissues after massive resections of bone tumors enhances local stability, as testified by a mean post-operative MSTS score of 24.3. These functional outcomes do not increase the risk of wound dehiscence or deep infection (as low as 2.6%).

The shoulder joint, in particular, is one of the most complex articulations in the human body. The resection of the proximal humerus due to malignant bone tumors generally implies the sacrifice of extensive soft tissue segments in the glenohumeral joints, including the capsule, ligaments, and the tendons of the rotator cuff and the biceps brachii, whose loss can cause stability in the glenohumeral joint post-operatively[44]. Polyethylene meshes can be used to provide anchor sites for tendons in the shoulder girdle (Figure 2).

Figure 2. A polypropylene surgical used to cover a total humerus implant during a reconstructive surgery in orthopedic oncology .

Wang et al.[45] used polypropylene meshes to reinforce or reconstruct the articular capsule of eighteen oncologic patients who underwent an endoprosthetic replacement of the proximal humerus. The stability of prosthetic shoulders, also provided by the articular capsule, including surgical meshes, was testified by the absence of postoperative dislocations. Similarly, Fujibuchi et al.[46] wrapped 21 of their proximal humerus endoprostheses with Marlex or Bard meshes, anchored to the remaining soft tissues or, in case of major tissue deficiency, directly to the native scapula. In this cohort, three cases had radiographic signs of subluxation but no actual dislocation. Both studies had meager infection rates, as within the two cohorts, only one in 39 cases developed a postoperative infection.

The use of surgical meshes has also been described to restore the continuity between the lateral end of the clavicle and the humeral head after a total scapulectomy. Salunke et al.[47] described using a surgical mesh to increase the stability of humeral suspensions after total scapulectomy. Their technique involved using a polyethylene mesh wrapped around itself, sutured with transosseous wires to the clavicle and humerus. Externally, the mesh was further sutured to the nearby remaining soft tissues. Although patients treated with this technique still had limited shoulder movements and similar hand mobility compared to those who received standard humeral suspensions, the mean MSTS score of patients treated with meshes was higher (67.3%) than the one recorded by the ones that received standard humeral suspension (61%). One of nine treated cases had a deep infection two years after surgery exposed mesh and was treated with antibiotics, debridement, mesh removal, and resection of the proximal humerus.

In ortopedic oncology settings, surgical meshes have also been used to provide anchoring sites between prosthetic surfaces and patients' native tendons. In 1999, Ozaki et al.[48] used folded Marlex meshes to cover the anterior surface of proximal tibia prostheses, providing attaching sites for the native patellar tendons. The three oncologic patients treated with this technique had good knee extensions, with a mean extension lag of only 1.7°. In 2022, Andreani et al. reported on the use of a folded polypropylene mesh covered with a layer of fascia lata allograft to replace the whole extensor apparatus of the knee in a case with a patellar giant cell tumor, completely restoring the patient's range of motion[49]. These outcomes suggest that the potential effectiveness of synthetic augments can be as effective as more complex and expensive biological reconstructions, even in cases that involve the patella, without the necessity of its replacement[50].

More recently, Aycan et al.[51] compared the outcomes of direct reattachment and synthetic augments to connect knee extensor apparatus with proximal tibia megaprosthesis in oncologic patients. In their surgical approach, polypropylene meshes were folded into two and tightly wrapped around the tibial component by nylon sutures. The loose proximal end of the mesh was further folded, and the remaining patellar tendon was sutured via a flap of medical textile to the patellar tendon insertion on the body of the megaprosthesis. Those who received mesh augmentation had fewer extension lags and better MSTS scores than those with direct reattachments. Infection rates in cases treated with surgical meshes were 13%, a value slightly inferior to those recorded in the control group that did not receive the synthetic augment (17%). The incidence of patella alta did not vary between the two groups.

Study	N	Use of Mesh	Mesh type	Outcome	Infections	Other major complications involving mesh
Kapoor et al.[43]	116	Soft tissue reconstruction for orthopedic oncology in upper and lower limb (no further detail)	PROLENE mesh	Prolene mesh increases local stability. No increase in the risk of wound dehiscence or deep infection.	3 (2.6%)	2 Dislocations (hip)
Wang et al.[45]	18	Glenohumeral capsule reinforce or replacement in proximal humerus megaprosthesis.	PROLENE mesh	No dislocation. Good below the shoulder functionality.	None	None
Fujibuchi et al.[46]	21	Glenohumeral capsule reinforce or replacement in proximal humerus megaprosthesis.	Marlex or Bard mesh	No dislocation. Good below the shoulder functionality.	1 (4.8%)	None
Salunke et al.[47]	9	Suspension between lateral clavicle and humeral head	PROLENE mesh	Shoulder movement and hand stability comparable to standard technique. Slightly better MSTS scores.	1 (11.1%)	1 Clavicule impingement
Ozaki et al.[48]	3	Cover for anterior proximal tibia megaprosthesis; attachment site for the patellar tendon	Marlex mesh	Good post-operative knee flexion and extension.	None	None
Aycan et al.[51]	23	Cover for anterior proximal tibia megaprosthesis; attachment site for the patellar tendon	*Not specified*	Good post-operative knee flexion and extension. Better extension and global functionality compared to those who had direct reconstruction without mesh.	3 (13%)	None

Table 2. A summary of case series available in literature on the use of polypropylene meshes in orthopedic oncology.

Achilles Tendon repair

Due to its good tensile strength and resistance to elongation, polypropylene can be a suitable augment to reconstruct even large tendons that are called and bear heavy loads. Extensive tears of large tendons, such as the Achilles one, can be treated with polyethylene meshes to restore anatomical continuity and allow the transmission of muscular forces from the muscular soma to the insertion bone.

Choksey et al.[52] used Marlex meshes to treat five cases with neglected Achilles tendon ruptures. In all cases, the ruptured ends of the tendon were separated by scar tissue, which was resected. Both ends were splitted in the coronal plane into two layers. On both sides of the tear, a tensioned Marlex mesh folded into three layers was interposed and sutured between the two layers of the tendon. After a mean follow-up of 23 months, all treated patients had good functional outcomes, recovering 85% of their power of plantar flexion and almost 80% of their heel height of tip-toe. Polypropylene has also been used for acute Achilles lesion lesions. Hauron et al.[53] used synthetic surgical meshes to treat acute Achilles tears in thirteen patients with pre-existing tendinopathy. A polypropylene mesh was folded three times over itself and applied inside the split proximal and distal stumps, bridging the tendon. The authors suggested securing the proximal portion first to facilitate tensioning adjustments before securing the distal end. The tendon-graft construct was finally reinforced with a tension suture in a circumferential Krackow stitch configuration. Patients had good clinical post-operative outcomes, as testified by a mean AOFAS score of 92.2. In light of these encouraging results, polyethylene meshes might be considered for larger use in case of complete acute or chronic Achilles tendon tears with extensive tissue gaps. Furthermore, the data available at the moment suggest a low risk of complications despite the superficial location of the tendon, as neither study had wound dehiscences or infections[52,53].

CONCLUSION

Polypropylene surgical meshes, a well-established synthetic augment for the reconstruction of the abdominal wall and pelvic floor, have been experimented with in different fields of orthopedic surgery due to their affordability, versatility, and ease of use. Modern literature suggests that once folded and sutured, surgical meshes can be resistant enough to reinforce or replace tendons and ligaments in the musculoskeletal apparatus. Used alone or in association with biological augments such as fascia lata allografts, they can provide good functional outcomes for treated limbs. Despite the absence of a biointegrative potential and their synthetic nature, authors reported an extremely low rate of failures and complications, including deep infections. Surgical meshes represent a reliable and adaptable reconstructive approach for several soft tissue lesions in orthopedics surgery. Alone or in combination with other augments, such as fascia lata grafts, polypropylene surgical meshes should be considered when facing wide soft tissue gaps around the musculoskeletal system.

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CONFLICTS OF INTEREST

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