REVIEW ARTICLE

The role of tenodesis in surgery of the upper limb

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This paper describes the presence of tenodesis effects in normal physiology and explores the uses of operative tenodesis in surgery of the upper limb.

Operations which include tenodesis are often used in both elective orthopaedic and trauma surgery. This is especially true in the upper limb, where maintenance of joint stability, power and range of movement is necessary for accurate, three-dimensional prehension.

Etymologically, ‘tenodesis’ is derived from the Ancient Greek words teno- (denoting tendon) and -desis (meaning a binding). In broad terms, the term refers to any situation where a tendon is anchored at both ends to a fixed point.

Tenodesis can be classified into two broad categories. Static tenodesis crosses one joint only and acts as a ‘check rein’ to excessive movement. Dynamic tenodesis acts across two or more joints, with the forces generating movement in the first joint being transferred to subsequent joints. Because the fixed tendon must remain at a constant length, joint movement which increases the working length of the tenodesis, increases the tension within the tendon. Direct dynamic tenodesis is routed along the same side of all joints, and therefore flexion in the first joint produces extension in the others. Crossed dynamic tenodesis crosses the midline, and flexion of the first joint flexes the remaining joints.

Physiological tenodesis

In the upper limb, physiological tenodesis aids the precision of movements. An example of static tenodesis is the ‘quadriga effect’ of the tendon of flexor digitorum profundus (FDP). This muscle comprises a single belly with four tendons, and flexion of the distal interphalangeal joint (DIPJ) cannot be initiated independently among the digits. Therefore, physiological tethering, such as holding one finger static, may result in altered flexion of the DIPJ in the remaining ipsilateral digits. This allows an accurate power grip involving all four fingers equally, such as when carrying a suitcase. Operative static tenodesis aims to recreate the restraint acting on a joint but can alter the position during movement at which the restraint takes effect.

A good example of the dynamic tenodesis effect is used by surgeons to gauge accurate tension in tendon transfers and repair. As the long flexors and extensors of the fingers cross both the wrist and the interphalangeal joints, when the wrist is fully extended the long finger flexors are put under significant tension, resulting in flexion of the fingers. Conversely, full flexion of the wrist tensions the finger extensors, meaning that greater forces are required to flex the fingers when the wrist is also flexed, compared with when it is fully extended.

Another example of dynamic tenodesis in the hand arises via the oblique retinacular ligament of Landsmeer. Although correctly termed a ligament, it was originally described by Weitbrecht in 1742 as the ‘retinaculum tendini longi’, owing to its histological and functional tendinous properties. Arising from the lateral periosteum of the proximal phalanx and the A4 pulley, the oblique retinacular ligament passes volar to the proximal interphalangeal joint (PIPJ) before turning to run dorsal to the DIPJ, inserting into the terminal extensor digitorum communis tendon. Thus, when the PIPJ is extended the oblique retinacular ligament is tensioned, which extends the distal interphalangeal joint, thereby helping to co-ordinate extrinsic and intrinsic muscle function. Although the oblique retinacular ligament creates difficulty in actively flexing the DIPJ alone with the finger extended, the tenodesis force can be overcome by flexor digitorum profundus once the PIPJ is stabilised by the other hand.

In practice, physiological dynamic tenodesis is usually relatively weak, and can be easily overcome by antagonistic forces acting across a joint until ligamentous or bony restraints take effect. Therefore, operative intervention must not only recreate these forces but also augment them by
careful positioning of the anchor to achieve maximal biomechanical advantage.

Operative tenodesis in surgery of the upper limb
Long head of biceps brachii. During its course, the long head of biceps is subject to considerable bony restraints as it runs beneath the coracohumeral ligament into the intertubercular groove.³ This in turn leaves the tendon vulnerable to attrition and impingement along its course. Implicated causative factors for tendinopathy of the long head of biceps include inflammation due to impingement within the intertubercular groove,⁴,⁵ instability related to rotator cuff pathology,⁶ and trauma related to the supraglenoid insertion.⁷ Each of these pathologies probably acts through a common pathway of painful tenosynovitis leading to degenerative tendinosis and ultimately rupture of the tendon.⁸

When undertaking tenodesis of the biceps brachii, the diseased portion of the tendon is excised from the shoulder joint and the distal stump is re-implanted, thereby preserving the function of biceps. Despite extensive research,⁹,¹⁰ the role of the longhead of biceps at the shoulder remains controversial. Its role as a depressor¹¹ and abductor of the humeral head is probably clinically insignificant, and it is likely that it acts as a dynamic stabiliser of the head during abduction.¹²,¹³

Although instability of the long head of biceps was described as far back as 1694 by Cowper,¹⁴ more formal case series first began appearing in the literature in the first half of the 19th century.¹⁵,¹⁶ However, it was not until 1926 that the first use of tenodesis was described by Gilcreest,¹⁷ who treated two spontaneous ruptures of the long head of biceps by anchoring the distal end of the tendon to the coracoid process. Over the following 80 years the technique has been modified many times, but controversies persist regarding the indications for tenodesis, the site and the surgical technique for anchoring the tendon, and whether it should be undertaken as an arthroscopic or an open procedure.

The indication for tenodesis as opposed to simple biceps tenotomy has been controversial for a long time. The proponents of biceps tenodesis argue that the operation carries a lower incidence of muscle discomfort, reduces cosmetic defects of the muscle belly and prevents loss of power.¹⁸ However, a meta-analysis of publications in the English literature showed no overall difference in outcome between biceps tenotomy and tenodesis, although it was difficult to compare the studies.¹⁹

Concerns regarding discomfort and cosmesis may be unfounded, especially in the elderly patient with lower expectations.¹⁷ Similar rates of discomfort having been reported in both tenodesis and tenotomy groups.²⁰,²¹ A review of 40 tenotomies²² found a correlation between pain due to fatigue of biceps and patients under the age of 40, but no symptoms were noted in those over 60. Up to 60% of patients undergoing biceps tenotomy demonstrate no apparent cosmetic asymmetry – the so-called ‘Popeye’ sign – as adhesions between the residual distal tendon and the bicipital groove help prevent retraction.¹⁹,²¹

A significant difference between the tenotomy and tenodesis groups is the resultant muscle power acting across the elbow joint. Whereas only minimal loss of power can be expected following tenodesis,²³²⁴ tenotomy can result in loss of 8% of the power of flexion of the elbow and 20% of the force of supination of the forearm.²²,²³ This difference has led many authors to advocate tenodesis in high-demand patients under 60 years of age, while reserving tenotomy for the elderly with low demands.²²,²⁴ Up to three-quarters of young sports persons are able to return to full sporting activity following tenodesis.²⁵

A second area of debate has concerned the appropriate position for anchoring the tendon. Gilcreest²⁶ originally advocated tenodesis to the coracoid process, but this is now rarely performed because of concerns regarding pain caused by traction to the pectoralis insertion. Tenodesis to the greater tuberosity of the humerus has also been proposed, but concerns remain regarding potential subacromial impingement of the tendon.

The remaining sites can be classified into two broad groups, anatomical and extra-anatomical. Anatomical tenodesis aims to re-implant the distal stump of the long head of biceps into a fixed point of the humerus along the original course of the tendon, in order to restore the anatomical force vectors. However, this does not address potential inflammatory synovium within the groove, which may cause persistent pain.²⁷,²⁸ A number of extra-anatomical techniques have been developed to overcome this.

Proximal methods which involve tenodesis to the rotator cuff during its repair have given good early results,²⁹ but have shown a high incidence of recurrent subluxation of the long head of biceps and hypertrophic scarring of the rotator cuff in the longer term.¹⁶,³⁰ This has led some authors to advocate its use only in the older patient, especially those with concomitant rotator cuff tears.²⁴

An operation which has grown in popularity in recent years involves fixing the tendon to the humerus beneath the pectoralis major outside the intertubercular groove.³¹ Using arthroscopically assisted tenotomy, the tenodesis can then be performed arthroscopically or via a 3 cm axillary wound. Although there are no long-term results for this technique, early reports are encouraging.³⁰

There are a number of options for anchoring the stump of the tendon, including a bone tunnel, a bone anchor, the keyhole method³² and fixation with an interference screw,³³ which has the highest pull-out strength of around 200 N to 250 N.³³,³⁴ This is followed by the bone tunnel technique (220 N) and double suture anchors (129 N to 164 N), with the keyhole technique achieving only 50% of the strength of screw fixation. Time-dependent changes in the loads to failure of these techniques have also shown fixation with an interference screw to be superior, with no weakening within the first nine weeks. However, owing to the relatively low clinical failure rates of these techniques, it is difficult to extrapolate these data to in vivo situations.³⁴
There are few prospective data in the literature to support arthroscopic versus open tenodesis. Many authors advocate the use of arthroscopic techniques, and despite early concerns regarding iatrogenic damage to the axillary nerve when drilling the proximal humerus, complications appear to be comparable with those of open methods.

**Subclavius.** The role of subclavius tenodesis in the stabilisation of recurrent sternoclavicular dislocation was first described by Burrows in 1951. Although the technique has now largely been superseded by internal fixation of the joint with fascial loops or sutures such as fiberwire (Arthrex, Sheffield, United Kingdom), his paper remains an elegant demonstration of the principles of tenodesis. He described two cases where repositioning the subclavius tendon via drill holes through the clavicle to produce a posterosuperior force on the medial end of the bone resulted in good post-operative function. However, owing to significant complications with screw and plate fixation of the sternoclavicular joint and the poor results of resection of the medial end of the clavicle, many adaptations to Burrows’ technique have been advocated using the tendons of subclavius, pectoralis major and sternocleidomastoid to attain stability of the joint, with good short-term results.

**Distal tendon of biceps.** Originally considered a rare injury, rupture of the distal biceps tendon has been reported with increasing frequency in recent decades. It constitutes about 3% of ruptures of the tendon, and occurs almost exclusively in men, with an average age of 50 years. It results in a loss of 30% of the power of flexion of the elbow and of 40% of that of supination.

Good power and function have been consistently reported following anatomical repair of the ruptured tendon to its insertion into the radial tuberosity. However, the procedure is not without complications. The single-incision approach risks damage to the radial nerve as it passes from the antecubital fossa into the supinator muscle. The two-incision technique of Boyd and Anderson may be complicated by heterotopic ossification and subsequent proximal radioulnar synostosis. When presentation of a distal biceps rupture is delayed, repair can be difficult owing to proximal retraction of the tendon. In these patients, extra-anatomical repair may be necessary.

The most common method of extra-anatomical repair is by tenodesis of the distal biceps tendon to the brachialis tendon via simple side-to-side suturing. Few complications have been reported with this technique, and post-operative function is reasonable measured by range of movement, flexion and supination, maximum strength power and endurance time against a constant force. Up to 90% of restoration of the power of elbow flexion can be expected, but about half the patients have no increase in the power of supination, as the force of the biceps is realigned away from the radial tuberosity to a more vertical direction. Therefore, distal bicipital tenodesis is generally reserved for those in whom the operative risks of reconstruction outweigh the inconvenience of weakened supination.

**Distal radioulnar joint instability.** The skeletal architecture of the distal radioulnar joint (DRUJ) provides minimal inherent stability, as the sigmoid notch is shallow and its radius of curvature is 50% greater than that of the head of the ulna. The DRUJ therefore relies on soft-tissue stabilisers, with the triangular fibrocartilage providing primary stability and secondary constraint being provided by the joint capsule, pronator quadratus and the extensor carpi ulnaris (ECU). Instability of the DRUJ following fractures of the distal radius is significant, with 15% demonstrating pathological movement between distal radius and ulna and 19% experiencing pain over the joint. Despite this, the diagnosis is often missed in the acute phase and presentation is often late, with chronic pain and reduced rotation of the forearm. Soft-tissue reconstruction for chronic instability of the DRUJ is associated with significant pain and weakness. Therefore, salvage procedures involve joint fusion, arthroplasty and resection of the distal ulna.

Excision of the distal head of the ulna for pathology of the DRUJ in the lower-demand patient has become increasingly popular following its description by Darrach. Although many studies have reported good success with the procedure, there is often post-operative pain. This was designated in 1985 as the ulnar impingement syndrome, with demonstrable scalloping of the distal shaft of the radius due to impingement by the unstable ulnar stump. It is now considered that the bony resection should be combined with soft-tissue stabilisation.

Stabilisation of the DRUJ by tenodesis has been described by a variety of methods, the most popular being that of Breen and Jupiter. Isolated techniques using flexor carpi ulnaris (FCU) and ECU had been previously reported with reasonable results, but Breen and Jupiter combined the two, theoretically maintaining bidirectional control of the ulnar stump. The technique involves passing distally based ECU and FCU tendons through the distal ulnar canal and out through a drill-hole in the shaft of the ulna. The tendon ends are then tensioned around the ulna and sutured together. The authors found that all eight patients in their series had improved rotation of the forearm and a clinically stable ulna. Over the subsequent 20 years, many modifications of this technique have been described. These involve altering the position and direction of the bony tunnel to influence the force vector of the tenodesis, augmenting the stabilisation with dorsal transfer of the ulnar insertion of pronator quadratus, and use of the distally based palmaris longus tendon. Each method has reported similar results.

**Scapholunate instability.** Carpal instability was first described in the 1940s and has become increasingly recognised. Instability can occur with or without associated fractures. About 20% of injuries to the wrist without radiological evidence of a fracture demonstrate a widened scapholunate gap. There are a number of options regarding the treatment of scapholunate instability, including
fusion, tendon repair and tenodesis, depending on the functional demands of the patient and the chronicity of the injury. Tenodesis is generally reserved for stage 3 to stage 4 chronic scapholunate injuries with easily reducible scaphoid and lunate bones and no evidence of osteoarthritis of the lunate fossa or mid-carpal regions.

Early techniques of tenodesis for scapholunate instability aimed to reduce the flexed proximal pole of the scaphoid by passing a strip of tendon through the proximal scaphoid and looping it around the scapholunate joint. However, the drilling of anteroposterior bone tunnels through the poorly vascularised proximal pole was associated with fracture and collapse of the scaphoid.

Brunelli and Brunelli found that upon sectioning the scapholunate ligament in cadavers, dissociation between the two bones did not occur until the scapho-trapezo-trapezoid ligament was also divided, allowing the scaphoid to flex. This ligament lies directly beneath and in the line of the flexor carpi radialis, attaching to the volar aspect of the distal scaphoid. They subsequently developed a technique by which a distally attached section of the flexor carpi radialis tendon, 7 cm long, is passed from anterior to posterior through a tunnel in the distal pole of the scaphoid. The tendon passes dorsal to the body of the scaphoid and is attached to the postero-ulnar aspect of the distal radius. This technique aims to stabilise both the proximal and the distal scaphoid, preventing it from adopting an excessively flexed position. Clinical and cadaveric biomechanical data have demonstrated high levels of satisfaction with regard to pain and function, and radiological evidence of maintenance of the scapholunate angle.

The technique has since been modified, most notably by Van Den Abbeele et al., who advocated anchoring the tendon to the dorsal lunate or dorsal radiotriquetral ligament so as not to cross the radiocarpal joint. Garcia-Elias et al recommended passing the tendon through and thereby tensioning the radiotriquetral ligament to prevent ulnar translation of the lunate. This latter method is associated with instability of the lunate fossa or mid-carpal regions.

A further variation involves the use of the proximally attached palmaris longus tendon, as advocated by Ogunro. This technique attempts to provide an additional dynamic force vector towards the midline of the forearm to directly counter the dissociation between scaphoid and lunate.

A further dynamic tenodesis procedure described in the literature involves stabilising scaphoid flexion via a dorsal approach using a slip of the extensor carpi radialis longus (ECRL) tendon. The scaphoid is first extended to a neutral position and the tendon is then attached to its dorsal aspect using a screw and washer. This produces a dynamic extension force on the scaphoid throughout the range of movement of the wrist. The results of this technique are satisfactory, all patients returning to their normal occupation within four months with reduced pain scores.

**Lunotriquetral instability**. Although much has been written on the aetiology and treatment of scapholunate instability, similar pathology on the ulnar side of the wrist is less well understood.

There has been limited research into tenodesis for lunotriquetral instability. One study investigated the use of ECU tenodesis for chronic instability. The technique used a distally based slip of the ECU which is passed from distal to proximal through tunnels drilled through the triquetrum. The mobilised tendon is then passed through the triangular fibrocartilage and the capsule of the DRUJ before being tensioned and sutured to itself. The tension in the ECU slip prevents excessive movement of the triquetrum during supination of the wrist, thereby preserving its relationship with the lunate. Although the procedure improved overall pain and function in patients with isolated lunotriquetral dissociation, the results were unpredictable in those with more extensive pathology.

**Trapeziectomy**

Much controversy still exists regarding this procedure. Various methods involve trapeziectomy alone, interposition of soft tissue, insertion of an implant and tenodesis/ligament reconstruction. Bettinger et al demonstrated 16 distinct ligaments providing stability to the trapezium. Ligament reconstruction following trapeziectomy has two main roles. First, it aims to recreate the stabilisation of the resected trapezial ligaments, especially the volar oblique or ‘beak’ ligament, which allows mobility of the trapezio-metacarpal joint but prevents dislocation. Secondly, it provides additional stability for trapezial implants, where used, thereby limiting radioulnar subluxation. Although these implants had fallen out of favour following unsatisfactory results, there is renewed interest in a new generation of pyrocarbon spacers such as the P12 (Tornier, Edina, Minnesota).

Although there is much variation in surgical techniques involving ligament reconstruction, most operations closely follow the method described by Eaton and Littler and subsequently by Burton and Pellegrini. With the trapezium excised, a distally based slip of the flexor carpi radialis tendon is passed through a hole drilled from the volar corner of the base of the first metacarpal to the opposite cortex and sutured under tension to itself to recreate the pull of the volar oblique ligament. Modifications involve recruiting a distally based slip of the tendon of abductor pollicis longus or palmaris longus to perform a similar role.

The efficacy of ligament reconstruction following trapeziectomy remains unclear. Although many studies have shown it to be a reproducible, effective procedure, others...
have shown no benefit of ligament reconstruction as opposed to trapeziectomy alone as regards to post-operative pain and function,\textsuperscript{84,85} and although ligament reconstruction has been shown to reduce significant subluxation of silicone implants,\textsuperscript{86} there are no data to show whether this is true for contemporary pyrocarbon implants. 

**Swan neck deformity.** Swan neck deformity describes hyperextension of the PIPJ with concomitant flexion of the DIPJ. It arises from a number of aetiologies which can originate from the DIPJ with a mallet injury, the PIPJ due to volar plate attenuation, the metacarpophalangeal joint (MCPJ) with volar subluxation and intrinsic tightness, or from inflammatory conditions such as rheumatoid arthritis, in which 14% of patients have a swan neck deformity of at least one digit,\textsuperscript{87} equating to around 250,000 cases in the United Kingdom.

Irrespective of the primary cause, the deformity is associated with attenuation of the volar plate. The resultant hyperextension of the PIPJ brings the axis of the flexor tendons dorsal to the joint, creating difficulty in initiating flexion of the joint. The classification of the swan neck deformity\textsuperscript{88} provides guidance as to treatment. While tenodesis aims to prevent excessive hyper-extension of the PIPJ, joint flexion is required for the tenodesis to be useful. Therefore type 1 (full PIPJ movement) and type 2 (intrinsic tightness) are generally suitable for tenodesis whereas type 3 (restricted PIPJ movement) and type 4 (end-stage disease with joint involvement) deformities may be considered for PIPJ fusion and arthroplasty.

There are two main types of tenodesis for swan neck deformity. The flexor digitorum sublimis procedure is a static tenodesis which provides a check rein to hyperextension of the joint, allowing it to remain in an advantageous position to initiate flexion. The operation requires exposure of the flexor sheath between the A2 and A4 pulleys. Once the tendon sheath is incised, a slip of flexor digitorum sublimis tendon is sectioned proximally at the level of the decusation, with the distal end remaining attached to its insertion. This slip is then passed through a slit made through the A2 pulley and tensioned with the PIPJ in approximately 20° of flexion. The tendon is then sutured to itself or anchored to the middle phalanx. Satisfactory results have been reported with this procedure, although there is a risk of inducing a fixed flexion contracture.\textsuperscript{89}

The second procedure available for the correction of swan neck deformity is the lateral band (Littler) tenodesis, which also produces a check rein to hyperextension using a tendon from the extensor apparatus. The extensor apparatus is exposed via a dorsal approach over the PIPJ. The dorsally subluxed lateral band is freed from its attachments to the central slip and the triangular ligament. Cleland’s ligament is divided to expose the flexor sheath, and the PIPJ is flexed to bring the lateral band volar to Cleland’s ligament. The lateral band is then sutured either to itself, having passed around the A2 pulley or through a flap of flexor sheath, or to the bone of the middle phalanx. This tenodesis is atypical, as it does not involve sectioning the tenodesed tendon. The procedure aims to recreate the course of the oblique retinacular ligament of Landsmeer, which not only prevents hyperextension of the PIPJ joint but also acts as a dynamic extensor of the DIPJ as the PIPJ is extended. The results for this procedure\textsuperscript{90} appear similar to those for flexor digitorum sublimis tenodesis. The choice between this and lateral band tenodesis is generally a matter of personal preference.\textsuperscript{91}

**Rupture of flexor digitorum profundus.** A simple tenodesis can be used in injuries to the flexor digitorum profundus in zone 1 in which the rupture is proximal enough to result in a sufficient distal stump, but the quality of the tendon is unsuitable for direct repair. There must also be a fully functioning flexor digitorum sublimis to allow flexion of the PIPJ. The distal stump is anchored to the volar surface of the distal end of the middle phalanx with the DIPJ joint flexed to 5° or 10°. This eliminates hyperextension of the joint, allowing accurate pinch grip with the thumb.

**The paralytic hand.** In extensive paralysis of the hand where adjacent tendons are therefore not suitable for transfer, tenodesis can restore pinch between thumb and fingers via both dynamic and static techniques. The paralytic ‘claw hand’ comprises hyperextension of the metacarpophalangeal joints and flexion of the interphalangeal joints due to loss of function of the intrinsic muscles.\textsuperscript{92} Static tenodesis of the fingers aims to prevent hyperextension of the MCPJs. The simplest of these procedures was described by Zancolli.\textsuperscript{93} Via a volar incision, a length of tendon is fixed to the volar aspect of the distal metacarpal and passed through the lumbrical canal volar to the MCPJ to attach to the interosseous hood. The graft is tensioned to limit extension of the MCPJ to around 20° short of neutral. The technique has been modified many times, most notably by Srinivasan,\textsuperscript{94} who fixed the proximal end of the graft to the extensor tendon, and Smith,\textsuperscript{95} who advocated a tendon sling around the deep transverse metacarpal ligament. In addition, Zancolli\textsuperscript{96} has also described the use of a sectioned flexor digitorum sublimis graft, creating a ‘lasso’ around the A1 flexor pulley and suturing the tendon to itself to prevent hyperextension of the MCPJ.

Static tenodesis of the thumb acts as a check rein against excessive movement to place the digit in a suitable position for opposition. Various techniques are advocated, notably that of Gschwind and Tonkin,\textsuperscript{97} which involves the use of a distally based extensor pollicis graft anchored to the first metacarpal, and of Eiken,\textsuperscript{98} who used a free palmaris longus graft. Both techniques provide a limit to hyperextension of the first MCPJ.

Dynamic tenodesis aims to transfer the power of movement to an adjacent joint. It is therefore particularly useful when hand movements are paralysed while wrist extension is preserved. The technique described by Fowler\textsuperscript{99} used free graft of extensor indicis proprius to recreate lumbrical function powered by wrist movement. The graft is routed from the radial side of the proximal phalanx, through the
lumbral canal, and anchored to the extensor retinaculum. Thus, when the wrist is flexed, the graft is tensioned and the MCPJ is flexed with the interphalangeal joint remaining in extension. The major complication with this technique is that the extensor indicis graft is placed under considerable tension, with a subsequent incidence of intrinsic plus deformity. Riordan subsequently described the use of an adequate length of palmaris longus or a plantaris graft in order to achieve the correct tension.

The technique was further modified by Parkes, who routed the graft proximal to the flexor retinaculum, allowing a more powerful grip with the wrist in extension. A follow-up of eight patients for two to six years demonstrated fair to good results. A further recent modification uses a distally based extensor digitorum communis tendon attached to the extensor retinaculum. This differs from the above techniques as movements of the MCPJ and IPJ cannot occur independently of each other. However, the authors report an early improvement in hand function, with MCPJ extension occurring at 2.5° of wrist flexion.

Dynamic tenodesis of the thumb was first described by Moberg. This ‘key grip’ procedure aims to recreate the lateral pinch grip required such as when holding a door key. The flexor pollicis longus tendon is tenodesed to the volar side of the index finger. In order to allow the tendon to run more obliquely, the A1 flexor pulley is divided, allowing subluxation of the tendon at the level of the MCPJ. The procedure is often performed with fusion of the IPJ to prevent excessive flexion of that joint during tension of the tenodesis.

Long-term follow-up of the Moberg procedure has demonstrated progressive bow-stringing of the tenodesis, thus subluxation of the volar aspect of the digit and therefore follows a more oblique course across the wrist. On extending the wrist, the thumb is drawn obliquely across the palm and contacts the radial side of the index finger. In order to allow the tendon to run more obliquely, the A1 flexor pulley is divided, allowing subluxation of the tendon at the level of the MCPJ. The procedure is often performed with fusion of the IPJ to prevent excessive flexion of that joint during tension of the tenodesis.

An enhancement of the key-grip technique is the House two-stage procedure. Whereas the flexor phase involves tendon transfer, the extensor stage uses a dynamic tenodesis of extensor digitorum communis, extensor pollicis longus and abductor pollicis longus to the dorsal radius to provide active extension of both the thumb and the fingers during flexion of the wrist.

Tenodeses, both static and dynamic, play a wide role in surgery of the upper limb, often alongside other procedures such as fusion and tendon transfer. Although many techniques were originally described in the first half of the 20th century, improved techniques of fixation and advances in the understanding of joint biomechanics have led to a number of new procedures which have been described in the literature. Many of these have shown satisfactory early results, but large case series and long-term follow-up are often not available.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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