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The role of muscle integrity following midshaft clavicular resections: a cadaveric study

Klavikula orta kısım rezeksiyonu sonrası kas devamlılığının rolü: Kadavra çalışması

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Objectives: There are conflicting reports in the literature regarding midshaft clavicular resections, and the role of muscle integrity has not been studied before. This cadaveric study was designed to investigate the effects of the integrity of muscles after midshaft clavicular resections.

Materials and methods: In an experimental design, seven fresh cadaver shoulders were used. After resection of 1.5 cm of the clavicle, the trapezius, sternocleidomastoid, deltoid, pectoralis major, and subclavius muscles were detached in five combinations from none to all and with or without the subclavius muscle included. Graded radiographs were taken to measure the movements of the fragments during abduction, flexion, and extension of the shoulder. Measurements were repeated three times for each procedure.

Results: Preservation of all muscle attachments to the clavicle resulted in no abnormal coronal plane motion at the osteotomy site. Similarly, no significant motion in the coronal plane was observed upon detachment of the four muscles with the subclavius muscle being intact. However, detachment of the subclavius muscle alone or in combination with the other muscles resulted in abnormal motion between the fragments.

Conclusion: The subclavius muscle appears to be the only structure preventing independent movement of the fragments; thus, special care should be taken to maintain the integrity of the subclavius muscle after midshaft clavicular resections.

Key words: Clavicle/injuries/surgery; osteotomy/adverse effects; periosteum/surgery; shoulder fractures/surgery.

Amaç: Literatürde, klavikula orta kısım rezeksiyonu konusunda çelişkili bilgiler bulunmakta ve bu işlem sonrasında kas devamlılığının araştırılmadığı görülmektedir. Bu kadavra çalışmasında, klavikula orta kısım rezeksiyonu sonrasında kas devamlılığının etkileri araştırıldı.

Gereç ve yöntem: Bu deneysel çalışmada yedi taze kadavra omzu kullanıldı. Klavikula orta hattından 1.5 cm rezeksiyon yapıldıktan sonra, trapezius, sternokleidomastoid, deltoid, pektoralis majör ve subklavius kasları beş değişik kombinasyonda (tümü-hiçbiri, subklavius dahil-değil) klavikuladan kesilerek ayrıldı. Omza abdüksiyon, fleksiyon ve ekstansiyon verilerek, fragmanların hareketini ölçmek için işaretli radyografiler çekildi. Her bir durum için ölçümler üç kez tekrarlandı.

Bulgular: Tüm kas bağlantılarının korunması durumunda, osteotomi alanında anormal herhangi bir koronal hareket gözlenmedi. Benzer şekilde, subklavius kası klavikulaya tutulu durumdayken, diğer dört kasın ayrılması da, koronal planda önemli bir harekete neden olmadı. Subklavius kasının tek başına veya diğer kaslarla birlikte ayrılması ise fragmanlar arasında anormal hareket oluşumuyla sonuçlandı.

Sonuç: Fragmanların birbirinden bağımsız hareketini engelleyen tek kasın subklavius olduğu görüldü. Bu nedenle, klavikula orta kısım rezeksiyonu yapılırken, subklavius kasının devamlılığını korumaya özel bir dikkat gösterilmelidir.

Anahtar sözcükler: Klavikula/yaralanma/cerrahi; osteotomi/yan etki; periosteum/cerrahi; omuz kırığı/cerrahi.

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Although nonunion of the clavicle is uncommon, its management presents a challenging problem.[1-4] Serious complications encountered in surgical procedures have led several authors to recommend nonoperative management because nonunions of the clavicle are not always symptomatic.[4,5] Wilkins and Johnston[4] differentiated the atrophic form from the hypertrophic form of nonunion and found that patients with atrophic nonunion had fewer symptoms, possibly due to the absence of callus, diminished grating and crepitation that could be responsible for pain. However, this conception was not supported by others.[1,3] On the other hand, Patel and Adenwalla[6] reported 11 clavicular fractures treated by immediate resection of the fractured ends, simulating a nonunion, and the results were excellent. Similarly, congenital pseudoarthrosis of the clavicle is not always symptomatic.[7,8] However, Connolly and Dehne[1] cautioned against midclavicular resections, for this procedure had risk for impingement of the fragments on the brachial plexus. These conflicting reports led us to design a cadaveric study to investigate the effects of the integrity of muscles after midshaft clavicular resection.

MATERIALS AND METHODS

Four fresh, unembalmed cadavers were used in the study. The specimens were placed on the radiographic table in supine position and cassettes graded with 0.5 cm^2 were placed between the shoulder region and the table. First, radiographs were taken with the arm in neutral position. This revealed a healed fracture in one shoulder. This shoulder was excluded and a total of seven clavicles were used for the study.

The clavicle was exposed by a transverse incision over the midshaft. The dissection was carried down to the clavicle and 1.5 cm of the clavicle was removed with special care not to disturb the attachments of the trapezius, sternocleidomastoid, deltoid, pectoralis major and subclavius muscles (Fig. 1). Kirschner wires were driven into the medullary canals of the medial and lateral fragments for more precise measurements. Then, the shoulder was moved to 45, 90 and 120 degrees of abduction, 45 and 90 degrees of flexion, and 45 degrees of extension and radiographs were taken in each position. The position of the arm was measured with a manual goniometer, with the stationary arm being on the trunk and the movable arm parallel to the humerus. No traction was applied to the arm during these movements. In the second stage, the trapezius, sternocleidomastoid, deltoid, and pectoralis major muscles were stripped off the clavicle (only the subclavius muscle was left undisturbed) and the study was repeated. In the third stage, the subclavius muscle was also detached and the radiographs were taken with the same shoulder movements. In the last cadaver (two shoulders), detachment of the muscles was began with the subclavius muscle (stage 4) and went on with the other muscles (stage 5). Additionally, the periosteum between the fragments was repaired in this cadaver.

The motion in the coronal plane was directly measured on graded radiographs as the difference between the levels of the fragments. The change in the level of the Kirschner wires was assessed as the motion in the transverse plane. Changes equal to, or less than two millimeters of the cortical thickness of the clavicle were assessed as insignificant. Measurements were repeated three times for each procedure.

RESULTS

No significant motion was observed with either in flexion or extension of the shoulder. The results with shoulder abduction are displayed in Table I. Preservation of the muscle attachments to the clavicle resulted in no abnormal coronal plane motion at the osteotomy site. Similarly, detachment of the

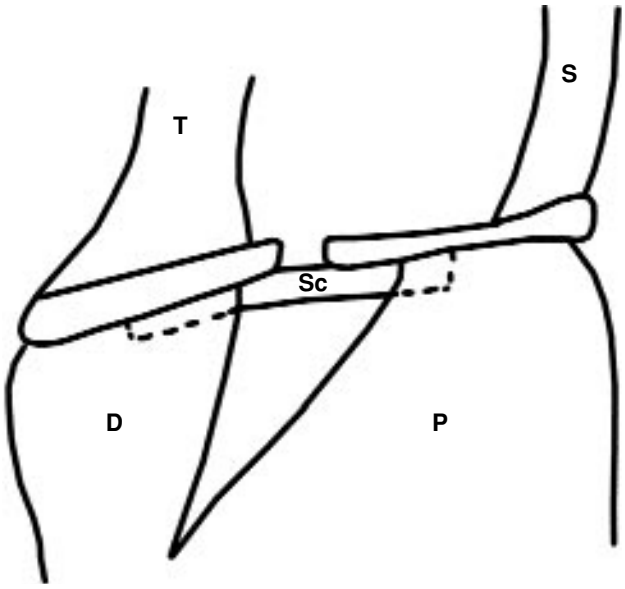

Fig. 1. Muscle attachments of the clavicle. T: Trapezius; D: Deltoid; P: Pectoralis major; S: Sternocleidomastoid; Sc: Subclavius.

TABLE I

Motion of the clavicular fragments by abduction of the shoulder (mean±standard deviation)

	45°	90°	120°
Stage 1 (T, D, P, S, Sc)	–	–	–
Stage 2 (Sc)	–	–	–
Stage 3 (–)	–	5.42±0.98	7.57±1.96
Stage 4 (T, D, P, S)	–	4.30 and 5.00	6.50 and 6.20
Stage 5* (–)	–	–	3.20 and 2.80

Intact muscles are given in parentheses. T: Trapezius; D: Deltoid; P: Pectoralis major; S: Sternocleidomastoid; Sc: Subclavius; *Periosteum was repaired.

trapezius, sternocleidomastoid, deltoid, and the pectoralis major muscles did not give rise to any significant motion in the coronal plane (Fig. 2). However, when the subclavius muscle was also detached, there was abnormal motion between the fragments. In two shoulders, repair of the periosteum between the fragments prevented motion below 120 degrees of abduction (Table I). When the subclavius muscle was detached while keeping the other muscles intact (stage 4), the motion was similar to the situation when all the muscles were detached (stage 3, Fig. 3).

DISCUSSION

The clavicle is the bony link between the thorax and the shoulder and serves several important functions: it acts as a rigid base for muscular attachments, forms a strut holding the glenohumeral joint, increases the power of the arm-trunk mechanism, provides protection for the subclavicular neurovascular structures, and is relevant to cosmesis.[9] Although some authors recognize these functions and avoid resection of the clavicle,[2,4,10,11] total or partial excision have been advocated by others.[6,12-17] This approach is based mainly on the relatively benign nature of the congenital pseudoarthrosis of the clavicle.[7,8,18,19] Similar controversy exists as to whether to operate on nonunions of the clavicle.[1-3,11,20] These conflicting reports suggest that the integrity of muscles may be the reason for discrepant results and concepts.

Fig. 2. All the muscles except for the subclavius are detached and no abnormal motion is present at 120 degrees of shoulder abduction.

Fig. 3. When only the subclavius muscle is detached, abnormal motion is present even at 90 degrees of shoulder abduction.

The clavicle serves as a base for the attachment of five muscles. When the trapezius, sternocleidomastoid, deltoid, and pectoralis major muscles were detached off the clavicle no significant motion was observed between the fragments (stage 2, Table I). In this situation the only muscle left intact was the subclavius, keeping the fragments together and preventing abnormal coronal plane motion. However, when only the subclavius muscle was detached, there was abnormal motion between the fragments, proportional to the degree of abduction of the shoulder (stage 4, Table I), almost identical to the situation when all muscles were detached (stage 3, Table I).

These results clearly indicate the importance of the integrity of the subclavius muscle to coronal stability after clavicular fractures or midshaft resections. The exact function of the subclavius muscle in physiologic conditions is not known; it probably pulls the point of the shoulder down and forward, and braces the clavicle against the articular disc of the sternoclavicular joint.[21] However, because of its location, it serves as a protective cushion between the clavicle and the neurovascular structure when this bone is broken.[22] Our findings show that the subclavius muscle protects the neurovascular structures by not only acting as a cushion, but also avoiding independent motion of the fragments in the coronal plane.

A similar situation may occur in cases of congenital pseudoarthrosis of the clavicle, which rarely produce symptoms.[7,8,18,19] It was observed that, in congenital pseudoarthrosis of the clavicle, two portions of the clavicle were united by a ligament.[7] In our opinion, the subclavius muscle may act like this ligament in midshaft clavicular resections, for it is the only structure that crosses the two fragments at this region.

Previous reports on midshaft clavicular resections did not mention the integrity of the subclavius muscle.[1,2,4,6,20] Patel and Adenwalla[6] reported that resecting the segment of the clavicle subperiosteally and suturing the periosteum was associated with excellent clinical results. In the present study, suturing the periosteum between the fragments prevented motion up to 120 degrees of abduction (stage 5).

The occurrence of pain following clavicular fractures was associated with the grating and crepitation of the ends of the fragments and with direct impingement on the brachial plexus.[4,20] Resection of the ends of the fragments may eliminate grating and crepitation. Additionally, if the integrity of the subclavius muscle is not disturbed, it continues serving as a protective cushion between the clavicle and the neural structures.[22]

In conclusion, although the mechanical functions of the clavicle is not in the scope of this study, our results suggest that abnormal motion of the fragments is avoided if the integrity of the subclavius muscle is maintained after midshaft clavicular resections. Yet, studies with more specimens are mandatory for more conclusive implications.

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