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ELBOW

A combination of an anteromedial, anterolateral and midlateral portals is sufficient for 360° exposure of the radial head for arthroscopic fracture fixation

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Abstract
Purpose Arthroscopic fixation of radial head fractures is an alternative to open reduction and internal fixation; the latter, however, presents the advantage of minimal soft-tissue damage. The exposure of the radial head for adequate screw placement can be technically challenging. The aim of this study was to evaluate the inter-observer agreement on the effective contact arc in the axial plane of the radial head of three different elbow arthroscopy portals.
Methods A fresh-frozen cadaver specimen was obtained and prepared in an arthroscopic setting. Standard anterolateral (AL), anteromedial (AM), and midlateral (ML) portals were established and a circular reference system was marked on the radial head. Ten orthopaedic surgeons were then asked to move the forearm from maximal supination to maximal pronation and indicate with a Kirschner wire from each portal the extension in which they would feel confident in placing a cannulated screw passing through the centre of the articular plane of the radial head (axial contact arc). The Shapiro–Wilk normality test was used to evaluate the normal distribution of the sample. A coefficient of variation (CoV) was calculated to determine agreement among observers.
Results The average arc of axial contact arc that could be contacted from the AM portal measured 150 ± 14.1°, or 41.7% of the radial head circumference; the one from the AL portal measured 257 ± 29.5°, or 71.4% of the radial head circumference; that from the ML portal measured 212.5 ± 32.6°, or 59.0% of the radial head circumference. Considering all three portals, the whole radial head circumference could be contacted. The AM portal showed the smallest CoV (9.4%) as compared to the AL (11.5%), and the ML (15.3%) portals.
Conclusions With an appropriate use of the standard AL, AM, and ML portals, the whole radial head circumference can be effectively exposed for adequate fixation of radial head fractures. The contact arc of the AM portal presents the smallest variability among different observers and the AL portal shows a superiority in axial contact arc. This information is important for pre-operative planning, and helps to define the limits of arthroscopic radial head fracture fixation.

Keywords Elbow · Arthroscopy · Radial head · Fracture · Fixation · Anatomical study

Introduction

Arthroscopic fixation of radial head fractures is, in specific fracture types, an alternative to the classic open reduction and internal fixation (ORIF), which presents the advantage of minimal damage to the soft tissues and maintenance of blood supply. This allows for a decrease in analgesic requirement, hospital stay and improved healing [1–3].

Arthroscopy also allows better understanding of the fracture's morphology by visualization of the articular surface of the radial head, allowing for a precise anatomical reduction of articular fractures. Moreover, it gives the concrete possibility of testing the joint stability and treating associated bony, soft tissue or cartilage lesions, allowing for better assessment of any other intra-articular pathology [4–9].

Although specific risks and complications have been described and the procedure is technically demanding,

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encouraging results have been reported [6, 8, 10, 11]. The indications for arthroscopic fixation of radial head fractures are steadily evolving as the surgeons' skills increase, currently being accepted for type II fractures and less comminuted type III fractures [12] (according to the Mason classification [13]).

To achieve a stable anatomical reduction, the correct placement of the Kirschner wires which are used for temporary fixation and to guide the cannulated screws for definitive fixation is of critical importance [6, 8].

Screws or pins can be introduced into the radial head from different portals, each of which permits to address a different area of the radial head. Most fractures involve the anterolateral quadrant of the radial head, which makes the anterior portals the most versatile option for radial head fracture fixation; however, a minority of fractures involve also the posterior quadrants, which are amenable to fixation from a posterior portal [14]. Therefore, knowledge of which portion of the radial head circumference is accessible by each portal provides important information for pre-operative planning, and can also define the limits of arthroscopic fixation in each specific case.

This parameter, as well as the superiority of one portal over another, has been seldom analysed [15]. Moreover, no study yet investigated the role of the midlateral portal in assisting radial head screw fixation in a simulated arthroscopic setting. The aims of this study were to evaluate the agreement among observers on the effective contact arc in the axial plane reachable from three different elbow arthroscopy portals (anteromedial, anterolateral, midlateral), to fix radial head fractures and to compare the inter-observer reproducibility and the amplitude of this parameter (defined as "axial contact arc") between the different portals.

Materials and methods

The primary goal of this study was to test the hypothesis that a difference exists in the portion of the radial head that can be addressed for a screw insertion from anterolateral (AL), anteromedial (AM), and midlateral (ML) portals. This "axial contact arc" on the radial head for arthroscopically assisted fracture fixation was defined as the proportion of the radial head circumference accessible from each portal, in which a group of experienced surgeons could simulate the placement of a screw passing through the centre of the articular disk of the radial head.

A fresh-frozen cadaver specimen was obtained and prepared in an arthroscopic setting. Arthroscopy was performed with the elbow positioned at 90° of flexion, with the hand and forearm hanging free with only gravity force. Standard AL, AM, ML and posterolateral portals were established (Fig. 1) and diagnostic arthroscopy was performed. A circular reference system was marked on the radial head with a precision burr by an examiner with extensive experience in elbow surgery (E.G.): the radial styloid was used as an anatomic reference for 0° and two perpendicular troughs were first created from 0 to 6-o'clock and from 3-o'clock to 9-o'clock; subsequently, smaller incisions were created at equal distance (30°) to complete the circumferential

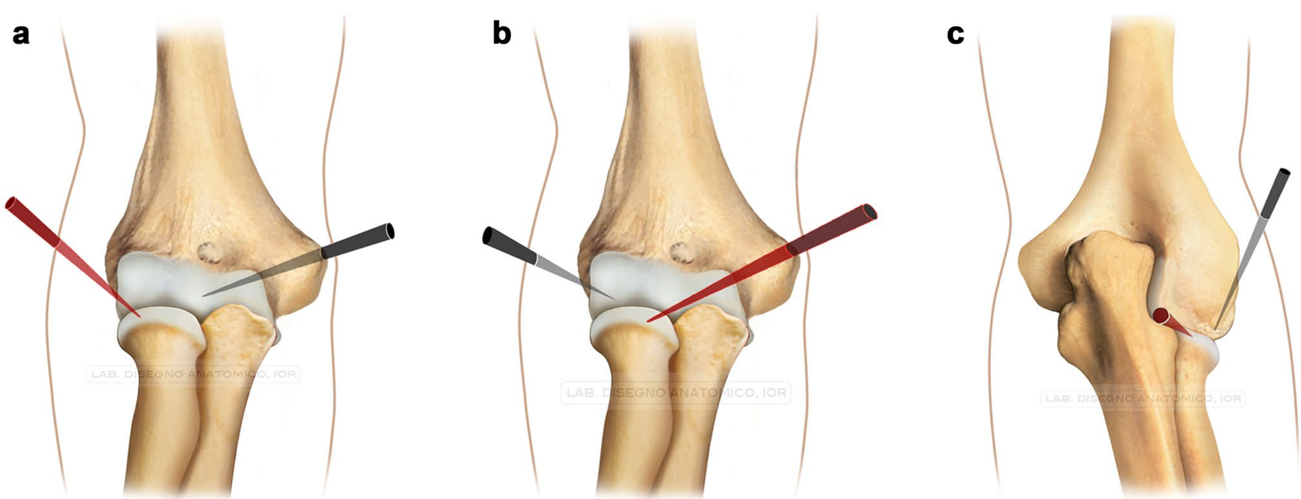

Fig. 1 Graphic illustration of the simulated arthroscopic setting and (arthroscope and Kirschner-wire positions) to address the radial head from: **a** anterolateral (AL) portal, created 2 cm proximal and 1 cm anterior to the lateral epicondyle; the arthroscope is in the AM portal; **b** anteromedial (AM) portal, created 2 cm proximal and 1 cm anterior to the medial epicondyle; the arthroscope is in the AL portal; **c** midlateral (ML) portal, created in the middle of a virtual triangle formed by the olecranon's tip, the medial epicondyle and the supinator crease, immediately above the superior margin of the radial head. A posterolateral portal, lateral to the olecranon's tip was created to visualize the posterior radioulnar joint. The arthroscope's position is represented in black and the Kirschner-wire's one in red

reference system (Fig. 2). The annular ligament was not released or altered in any way throughout the study.

Subsequently, to evaluate the agreement among observers, ten independent examiners, all with experience in elbow arthroscopy and surgical treatment of radial head fractures (members of the ESSKA Elbow and Wrist Committee 2016–2018) were asked to perform the following exercises: (1) move the forearm from maximal supination to maximal pronation; (2) illustrate with a Kirschner-wire the range in which they would feel confident with placing a cannulated screw (to be passed through the centre of the articular plane of the radial head—axial contact arc). For each portal, the values obtained in maximal pronation and supination that every examiner considered as limits of his confidence range were recorded. This process was repeated for all three portals by each examiner. Every examiner remained blinded to other examiners' measurements. Finally, open dissection was conducted to evaluate possible damage to neurovascular structures and the radial head was resected to verify the appropriateness of the circular reference initially marked.

Institutional approval of the study protocol was obtained by the Nicola's Foundation & ICLO Research Center (ID10602).

Statistical analysis

Statistical analysis was performed using GraphPad Prism v 6.0 software (GraphPad Software Inc.). The Shapiro–Wilk normality test was used to evaluate the normal distribution of the sample. Continuous variables were expressed as mean ± standard deviation and median and interquartile range [first quartile–third quartile]. A coefficient of variation (CoV) was calculated to determine agreement among observers. Statistical evaluation of the differences among the groups was performed using one-way analysis of variance (ANOVA) with post hoc Tukey's multiple comparisons test. The significance level was set at p value lower than 0.05. The number of ten members of the ESSKA Elbow and Wrist Committee 2016–2018 was chosen to evaluate agreement among observers.

Fig. 2 Intra-articular view of the circular reference system created on the radial head with a precision burr

Results

All ten examiners could indicate an axial contact arc from each of the three portals.

The AM portal showed the smallest CoV (9.4%) as compared to the AL (11.5%) and the ML (15.3%) portals. The distribution of the collected measures was normal for the AL portal only.

The average axial arc that could be contacted from the AM portal measured 150 ± 14.1° [median 145° (140°–155°), 41.7% of the radial head circumference], while the one from the AL portal measured 257 ± 29.5° [median: 250° (227.5°–290°), 71.4% of the radial head circumference], and that from the ML portal 212.5 ± 32.6° [median: 210° (201.3°–215°), 59.0% of the radial head circumference] (Table 1).

In a practical approximation using the clock reference, the AM portal's axial contact arc was comprised between 8-o'clock and 1-o'clock, the AL portal's one between 10+½ and 7-o'clock, the ML portal's one between 2-o'clock and 9-o'clock (Fig. 3).

A significant difference could be identified when comparing the arc of axial contact of the three portals (AM vs AL: $p < 0.0001$; AM vs ML: $p < 0.0001$; AL vs ML: $p = 0.0025$) (Table 1; Fig. 4).

Considering all three portals, the whole radial head circumference could be addressed. No difficulty or

Table 1 Mean and median arcs of axial contact arc that could be contacted from the investigated portals

	AM total	AL total	ML total	p value[a]	p value[b]
Number of values	10	10	10	< 0.0001	1 vs 2 < 0.0001
Mean (± SD) (°)	150 (± 14.1)	257 (± 29.5)	212.5 (± 32.6)		1 vs 3 < 0.0001
Median [Q1-Q3] (°)	145 [140–155]	250 [227.5–290]	210 [201.3–215]		2 vs 3 0.0025

AM anteromedial portal, *AL* anterolateral portal, *ML* midlateral portal, *SD* standard deviation, *Q1* first quartile, *Q3* third quartile

[a]One-way analysis of variance (ANOVA)

[b]Tukey's multiple comparison test

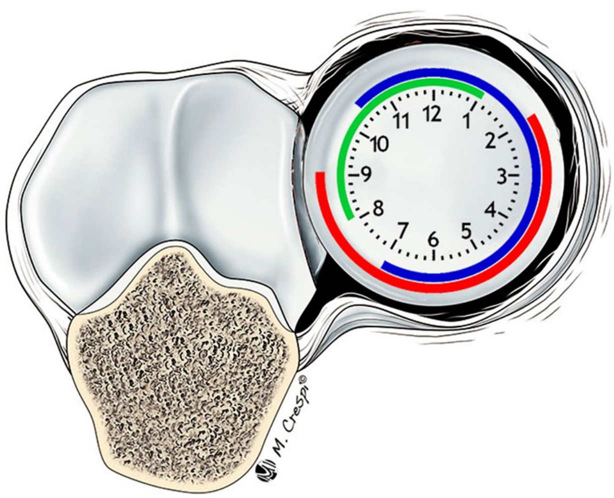

Fig. 3 Diagram of the radial head with superimposed clock reference demonstrating the average arc of the radial head available from the anteromedial portal (green), anterolateral portal (blue) and midlateral portal (red)

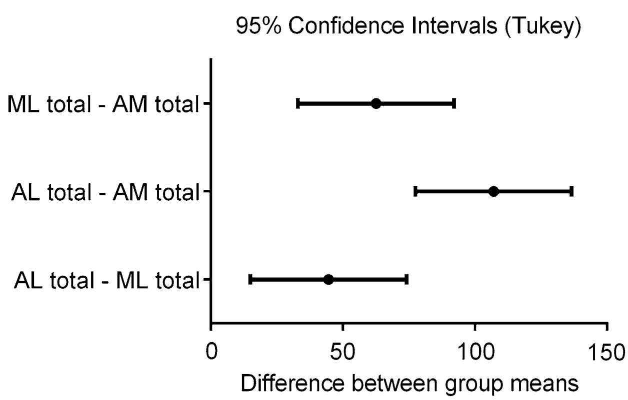

Fig. 4 Ordinary one-way ANOVA graph showing the 95% confidence intervals computed by Tukey's multiple comparisons test for the difference between the average arc of axial contact arc that can be contacted from one portal compared with every other portal. The confidence intervals for the mean pairs does not include zero, which indicates that the difference between these means is statistically significant

complications were reported by any examiner and no damage to neurovascular structures was documented.

Discussion

The main finding of this study is that the whole radial head circumference can be effectively addressed for fixation of radial head fractures with appropriate use of standard AL, AM and ML portals. Moreover, a greater agreement among observers was recorded for the AM portal as compared to the AL and ML portals. Finally, this study showed a significant superiority of the AL portal in axial contact arc as compared to the AM and ML portals.

The radial head is a crucial structure for stability and function of elbow and forearm [16–18].

Optimal treatment should ensure anatomical reduction and stable fixation, avoiding unnecessary soft tissue damage. Reduction and fixation is indicated in type II and some type III or IV fractures (Mason classification [13] subsequently modified by Hotchkiss [19]) of low complexity, whereas, in cases of extreme comminution, radial head resection or replacement is to be considered. Arthroscopic fixation can be considered for type II fractures and less comminuted type III fractures [12].

Arthroscopic fixation of radial head fractures is an appealing alternative to ORIF, which presents the advantage of minimal surgical trauma to the soft tissues. In fact, an open approach may cause injuries to nerves, blood vessels and ligaments and thus result in post-operative stiffness and delayed recovery; in contrast, arthroscopic fixation may decrease analgesic requirement, hospital stay, and the need for a second surgery when compared to radial head ORIF. Therefore, arthroscopic fixation has an established safe and effective role in the treatment of selective elbow pathologies, also in the paediatric and adolescent population [9].

Furthermore, elbow arthroscopy allows to directly visualize the articular surface of the radial head, which leads to a better understanding of the fracture lines and fragment morphology [4, 6, 8] and to assess any other intra-articular pathology [7]. Other advantages of arthroscopic fixation as compared with ORIF are the possibility to diagnose and, in selected cases, treat associated intra-articular soft-tissue lesions. Eventually, arthroscopy could permit to combine procedures extremely demanding with an open approach [9].

Encouraging results have been reported for arthroscopic fixation of radial head fractures [6, 8, 11]. To ensure an optimal arthroscopic treatment, proper placement of fixation devices is fundamental. In open surgery, it is well documented that different degrees of forearm rotation permit to expose different parts of the radial head: this is of utmost importance to avoid impingement of radial head plates with the ulna in maximal pronation and supination. An arc of approximately 110° of radial head surface non-articulated with the proximal ulna, which becomes fully visible through a standard lateral approach pronating and supinating the forearm, has been defined [20].

In an arthroscopic setting, screws or pins can be introduced into the radial head from different portals during elbow arthroscopy. Each portal permits to address a different area of the radial head, and forearm rotation permits to reach a variable working space for placement of fixation devices from each portal. In our opinion, the knowledge of which portion of the radial head circumference is accessible by each portal provides primary information for pre-operative planning, and can also define the limits of arthroscopic fixation.

A first anatomical evaluation of the effective working area of the AL and AM portals was provided by Hodax et al., who analysed the angles between pins inserted in full pronation and full supination with computed tomography: the AL portal allowed access to approximately 156° of the radial head, whereas the AM to a 147°. Superimposition of both areas showed that an average arc of 220° can be covered by these two portals [15].

The innovative aspect of this study is the evaluation of the inter-observer agreement on the arc of radial head that can be addressed arthroscopically from each portal (considering also the ML portal) which is a further new investigation.

Although our study was performed on a single specimen, it documents that a similar working area can be reached by different examiners from the AM portal (150°), whereas a wider area can be contacted from the AL portal (257°). The reason for such a difference might lie in slightly different portal placement or in anatomical characteristics of the studied specimen.

The axial contact arc from the AL portal plays a relevant role in radial head fracture fixation, since most of the radial head fractures involve the AL quadrant of the radial head, which is best accessed from the AL portal [14, 21, 22]. Moreover, the annular ligament's course becomes more distal with respect to the radial head articular plane in its anterior portion, the farthest from the ulnar insertions and the lateral collateral ligament complex, which could allow a slightly more distal portal placement for screw insertion [23, 24]. Furthermore, in our study, a relatively wide contact arc for the ML portal was documented (212°). When comparing portals, the AL portal offered a superior contact arc, permitting to reach 71% of the radial head circumference (Fig. 3).

An arc of 140° of the ulnar side of the radial head has been described as not accessible from anterior portals [15]. This study has demonstrated that, using also a ML portal, the whole radial head circumference can be accessed. This information is precious to plan the operative treatment of radial head fractures. However, the agreement among observers for the axial contact arc obtained from this portal was lower than that registered for the other portals: this finding indicates that also experienced surgeons show divergence when performing a radial head osteosynthesis from this portal, suggesting care in the clinical practice when planning or performing it, especially for less-experienced surgeons.

Intra-operative complications of arthroscopically assisted radial head fracture osteosynthesis include damage to neurovascular structures, ligaments and cartilage. Neurovascular damage is the most feared complication of elbow arthroscopy, in particular with anterior portals [25, 26]. In arthroscopic radial head fixation, injury to the posterior interosseous nerve may occur during portal placement and after accidental damage to the anterior joint capsule, which is separated from this nerve just by a thin layer of tissue [10, 27–30]. No damage to neurovascular structures was documented in the study specimen.

Limitations of this study include the fact it is an anatomical study on a single specimen; this does not allow differentiating between any anatomical variants and may amplify bias related to technical aspects of the procedure. This choice was made to emphasize the role of the agreement among observers, which was not yet investigated by any previous paper. Moreover, arthroscopic setting preparation and portal placement were performed by a single examiner; since minimal, experience-based, variations on the standard portals are possible, other examiners with different habits might have been confounded by entering in a procedure initiated by a different surgeon. Nevertheless, consensus on the relative position of the study portals to elbow anatomical landmarks was obtained prior to study initiation between all involved investigators.

The focus of this was primarily on performance description of selected arthroscopic portals for fixation of radial head fractures. The nature of the study did not allow investigating on local pathologies of the soft tissues or systemic diseases, which may influence pronosupination amplitude. Nevertheless, care was taken in evaluating the specimen for any visible signs of previous trauma, gross instability or deformity. Furthermore, the study was designed to evaluate a mere geometric parameter (axial contact arc) and not the possible technical difficulties related to the visualization or instrument positions that can arise when choosing these working portals in a clinical setting. For instance, although the AL and ML portals allowed a superior contact arc when compared to the AM portal, less experienced surgeons may prefer to avoid them due to the less distensible capsule in these areas and the subsequently limited working volume.

Finally, this experimental setting was designed to evaluate the performance of an arthroscopic technique and no investigations were directed to the evaluation of possible alternative treatments.

Conclusions

Arthroscopic fixation can be a valid alternative to open reduction and internal fixation for specific radial head fractures. With an appropriate use of the standard AL, AM and ML portals, the whole radial head circumference can be effectively exposed for fixation of radial head fractures. The measurements from the AM portal showed the best reproducibility among different observers, whereas the AL portal shows a significant superiority in axial contact arc as compared to the AM and ML portals.

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Compliance with ethical standards

Conflict of interest Author DC declares that he has no conflict of interest. Author EG declares that he has no conflict of interest. Author FL declares that he has no conflict of interest. Author AL declares he has no conflict of interest. Author SN declares that he has no conflict of interest. Author PR declares consultancy for Arthrex, Microport and Depuy (Johnson&Johnson), outside the submitted work. Author DCW declares that he has no conflict of interest. Author DE is educational consultant for AO and educational consultant for Lima. Author PA declares payment for development of educational presentations from Arthrex, outside the submitted work.

Ethical approval Nicola's Foundation & ICLO Research Center (ID10602).

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