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ORIGINAL PAPER

Below- vs above-elbow cast for distal radius fractures: is elbow immobilization really effective for reduction maintenance?

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Abstract

Purpose The choice of the cast length in conservative management of distal radius fractures still represents a debated controversy. Historically, the elbow is immobilized to reduce the risk of secondary displacement; however, short-arm casts are currently felt to be equally effective with less complications and better patient comfort. This paper investigates whether immobilization of the elbow is actually effective in reducing the risk of loss of reduction in conservatively manipulated distal radius fractures.

Methods We retrospectively studied 297 consecutive patients with distal radius fractures requiring manipulation and subsequently immobilized with above-elbow cast or below-elbow cast. Maintenance of reduction, radial height, radial inclination, and volar tilt were assessed after the reduction and at 35 days. Appropriate statistical analysis was performed to correct data selection bias and to assess any difference in the effectiveness among the two treatments.

Results The mean difference of loss of radial height, inclination, and volar tilt between the two groups was 0.8 mm, 0.4°, and 0.9° respectively, being not statistically significant. Average difference in reduction maintenance probability between the two groups stratified with a statistical propensity score was 1.2%.

Conclusions Above- and below-elbow casts had comparable performance in maintaining reduction of manipulated distal radius fractures.

Keywords Above-elbow cast · Below-elbow cast · Distal radius fractures · Conservative management of DRF

Introduction

Distal radius fractures (DRFs) represent a common clinical challenge in the everyday practice of an orthopaedic trauma department. The rising number of people affected by DRFs is most likely due to an aging population and the necessity of understanding the best possible treatment for these lesions is mandatory [1]. The absence of a consensus strategy has negative implications for the management of these common fractures, particularly in terms of quality of care and highest patient comfort. Optimal standard care for DRFs that are deemed to be treated conservatively has long been a matter of controversy [2]. Currently, there is no general agreement on how to immobilize a DRF. Various methods have been described, but no one approach has been proved more effective than the others. Sarmiento in 1975 and later Bünger in 1984 proposed the use of a long-arm cast to lock the forearm in supination to neutralize the brachioradialis muscle, which was considered responsible for loosing reduction [3–5]. Based on electromiographic studies, Sarmiento argued that immobilizing the wrist in supination, with brachioradialis in a resting position, would minimize the muscle's influence on fracture displacement. Wahlstrom proposed the pronator quadratus muscle as a major deforming force, thus suggesting locking the wrist in pronation [6]. This was based on the assumption that even minimal movements of the distal radio-ulnar joint could endanger the maintenance of reduction. However, there is no evidence that locking prono-supination plays a role in maintaining reduction. Indeed, many prospective randomized trials have failed to support this theory, concluding that there is no difference in the risk of secondary displacement with or without elbow immobilization [7–11]. However, most of these reports were biased and lacking statistical evidence, thus preventing clinicians from putting these

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findings into practice. In 2003, a Cochrane review concluded that there was insufficient evidence to make any recommendations as to what is the best conservative treatment for DRFs [12]. The latest clinical practice guidelines of the American Academy of Orthopaedic Surgeons, released in 2009, labeled the evidence available for or against elbow immobilization in patients treated with cast as "inconclusive," leaving the choice between them to the clinician's judgment [13]. An above-elbow cast (AEC) is cumbersome and uncomfortable to wear and is poorly accepted by patients. If no clear advantage could be shown in favour of AECs, then their use should be discontinued in favour of a lighter, shorter, and more comfortable cast. This would allow for both better patient compliance and less risk of adjacent joint stiffness. The aim of this study is to retrospectively assess the rate of secondary displacement in all DRFs treated conservatively, with either a below-elbow cast (BEC) or an AEC, performed at a University Hospital orthopaedic and trauma surgery department over 2.5 consecutive years.

Materials and methods

All DRFs conservatively treated at a University Hospital orthopaedic and trauma surgery department from April 2014 to December 2016 were considered. For this type of study, patients' formal consent is not required. This retrospective study was approved by the Institutional Research Committee. Exclusion criteria of this study were as follows: skeletally immature patients (all patients aged less than 18); undisplaced fractures not requiring manipulation; fractures with unsuccessful closed reduction according to Graham's criteria [14], as described below, and therefore addressed to open reduction internal fixation (ORIF); Goyrand's fractures; fractures involving any homolateral upper limb segment; bilateral fractures; patients with incomplete follow-up in which at least postero-anterior (PA) and lateral (LL) x-rays pre- and post-reduction, and at four weeks, were not available. A total of 297 patients were included in the study. One hundred and four fractures (35%) were extra-articular (type 2.3A according to AO classification), 116 (39%) were complete articular (type 2.3C), and 77 (26%) were partial articular (type 2.3B). All patients were assessed with standard wrist radiographs (PA, LL), classified according to AO [15], and then treated either by an orthopaedic senior resident or a board-certified orthopaedic surgeon. Local anaesthesia (haematoma block with 10 ml of mepivacaine 2%) was used before manipulation. Fractures were treated with manual closed reduction and cast immobilization; the forearm was immobilized in opposite-to-the-dislocation position or neutral position in the case of severe metaphyseal comminution without angular deformity. Standard arm cast was a radial gutter manufactured using plaster of Paris. None of the fractures were treated in an operating room or using a C-arm image intensifier. Post-reduction radiographs were obtained in the same standard views. The decision of using AEC or BEC was left to the personal clinical judgment of the treating physician. Hospital records were used to provide demographic and type of cast information. Seventy-three patients (24.6%), 55 females and 18 males, with an average age of 67 years (range 22–94 years) were treated with a BEC (group A) while 224 (75.4%), 181 females and 43 males, with an average age of 68 years (range 18–95 years) with an AEC (group B) (Fig. 4). Patients were assessed after seven and 35 days with PA/LL x-rays of the wrist. The radial gutter was closed at the first visit and removed at the final one. Radiographic parameters were determined for each x-ray examination from the time of injury to the end of treatment. Radial length (RL) was measured on the PA view as the distance between two lines drawn perpendicular to the radial shaft's long axis: one line was drawn at the tip of radial styloid and the other line was drawn at the ulnar border of radius articular surface at the central reference point (Fig. 1) [16]. Radial inclination (RI) was measured on the PA view by determining the angle between a line passing through the tip of the radial styloid and the medial corner of the articular surface of the radius and a line perpendicular to the shaft of the radius (Fig. 2). Volar tilt (VT) was measured on the LL view by the angle between the line of the distal articular surface (a line passing through the two most distal points of the dorsal and volar lips of the radius) and a line perpendicular to the longitudinal axis of the radius (Fig. 3). Fracture stability

Fig. 1 Measurement of the "radial length" pre- and post-reduction, as the distance between two lines drawn perpendicular to the radial shaft's long axis: one line was drawn at the tip of radial styloid and the other line was drawn at the ulnar border of radius articular surface at the central reference point

Fig. 2 Measurement of the "radial inclination" pre- and post-reduction: the angle between a line passing through the tip of the radial styloid and the medial corner of the articular surface of the radius and a line perpendicular to the shaft of the radius

Fig. 3 Measurement of the "volar tilt" pre- and post-reduction by the angle between the line of the distal articular surface (a line passing through the two most distal points of the dorsal and volar lips of the radius) and a line perpendicular to the longitudinal axis of the radius

was assessed according to Lafontaine (dorsal angulation $>$ 20°, dorsal comminution, articular involvement, associated ulnar fracture, age $>$ 60 years) on pretreatment radiographs: if three or more of these criteria were present, the fracture was defined as unstable [17]. Cast index was determined, as described by Chess on post-reduction radiographs, as the ratio between the cast widths measured respectively on LL view and on PA view [18]. Maintenance of reduction was considered acceptable when it met the following criteria described by Graham: loss of radial length $<$ 5 mm, radial inclination $\geq$ 15°, volar tilt between + 15 and − 20°.

Statistical analysis

Data analysis focused on the fracture reduction maintenance rate and radiographic parameter variation. The former was analyzed using a logistic model, while changes in radiographic parameters between post-reduction and end-treatment (35 days) imaging were tested using an ANCOVA model. To reduce the effects of confounding variables in observational studies, one of the best statistical solutions is to introduce a propensity score (PS). PS is the probability of treatment assignment (in our case AEC or BEC) conditional on observed baseline characteristics. This allows for the design and analysis of an observational (i.e., non-randomized) study so that it mimics some of the characteristics of a randomized controlled trial. PS is essentially a balancing score: it ensures that the distribution of observed baseline covariates will be similar between the considered patient groups [19]. PS, calculated to control the clinician's preference between AEC and BEC assignments, was used to correct the logistic model while post-reduction parameters were introduced as covariates in the ANCOVA model to control for baseline differences between the groups. This allowed for any selection bias due to the clinician's preference to be removed from the dataset. A different logistic model was then created to calculate the expected fracture reduction maintenance rates in each group of patients, treated with AEC or BEC, considering the following confounding variables: PS, type of cast (AEC vs BEC), AO fracture classification, cast index, age and quality of the obtained reduction (QR), which was subjectively assessed with a rating ranging from 1 to 10, based on optimal alignment, restoration of radial parameters (RL, RI, VT), and adequate alignment of volar and dorsal cortices (1 = worst reduction; 10 = best reduction).

Results

The mean time of immobilization was 34 (IC 95% = 32–36) days for patients treated with a BEC and 36 (IC 95% = 34–38) days for those with an AEC. Fifty-one out of 73 patients (70%) belonging to group A (BEC) maintained

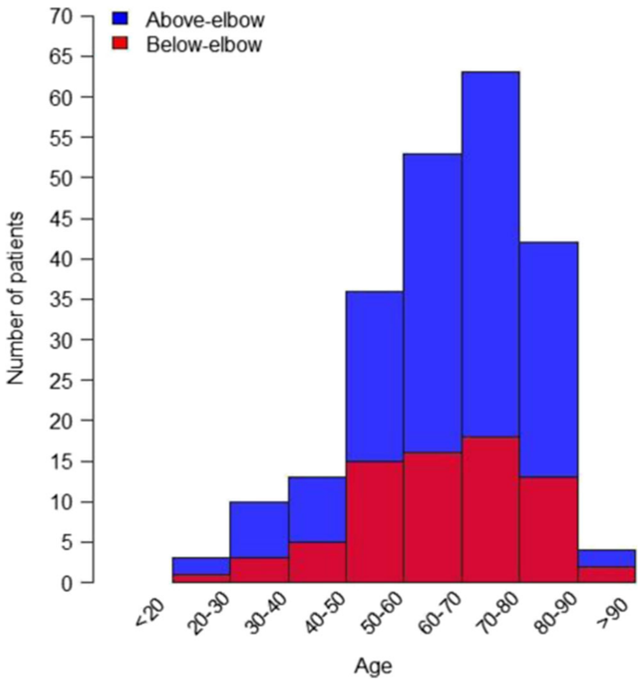

Fig. 4 Age distribution and type of cast assignment among the study population

satisfactory alignment of the fracture, according to Graham's criteria, at the end of the immobilization period as opposed to 117 out of 224 (52%) of those belonging to group B (AEC) (Fig. 4). These percentages, although statistically different when tested (chi-square test, $p = 0.0083$) are biased, as they were derived from raw, non-randomized data. In order to remove any selection bias (the clinician's preference) from the dataset, we calculated the propensity score (PS). According to this model, the average difference between the probability of having satisfactory fracture alignment maintained at the end of the immobilization period between the two study groups was 1.19% (IC 95% = 1.05–1.33%) in favour of group A; however, this difference was not significant ($p = 0.337$), net of all confounding variables. However, age ($p = 0.0001$), stability ($p = 0.0002$), and quality of reduction ($p < 0.0001$) all had a significant effect on fracture reduction maintenance. Quality of reduction (QR) and age showed a significant correlation with maintenance rate for both stable and unstable fractures (Figs. 5 and 6). AO fracture type and cast index had no effect ($p > 0.1$). Considering the raw dataset, mean initial post-reduction values of RL, RI, and VT were respectively 11.5 mm, 22.6°, and − 7.2° for patients in group A (BEC) and 11.4 mm, 22.4°, and − 8.1° in group B

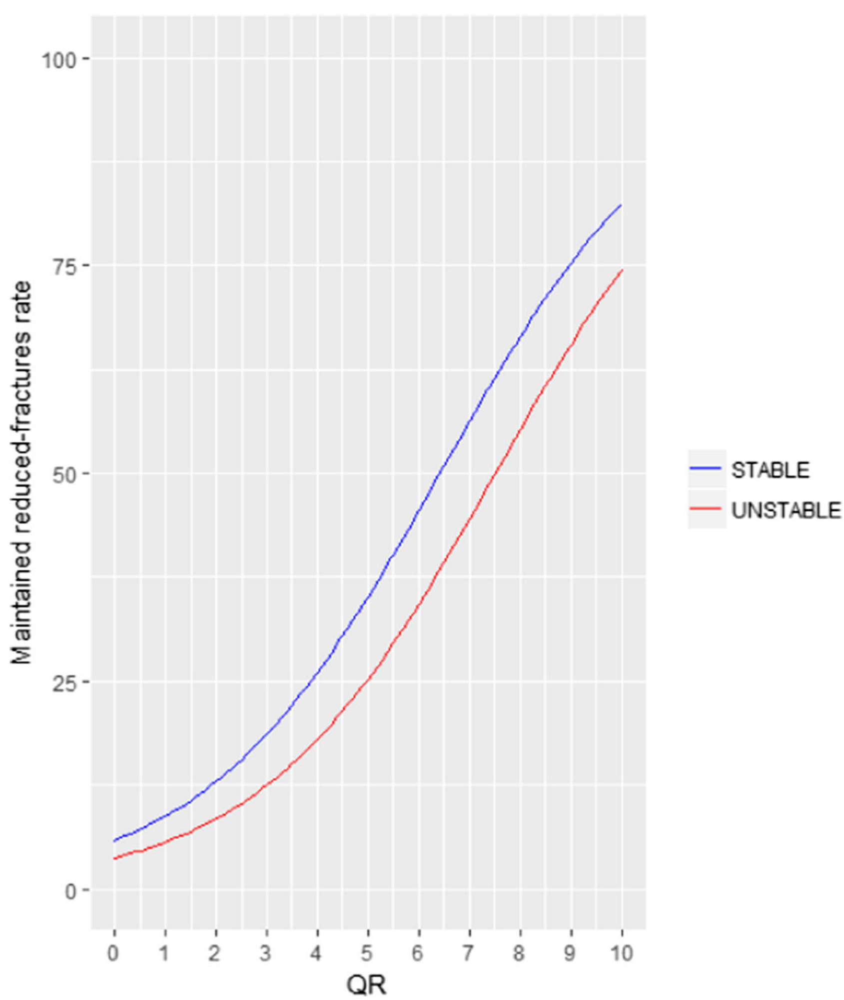

Fig. 5 Correlation between QR and maintenance rate for stable and unstable fractures. The better the quality of reduction, the higher the probability of fracture reduction maintenance. This is further increased if fracture is stable

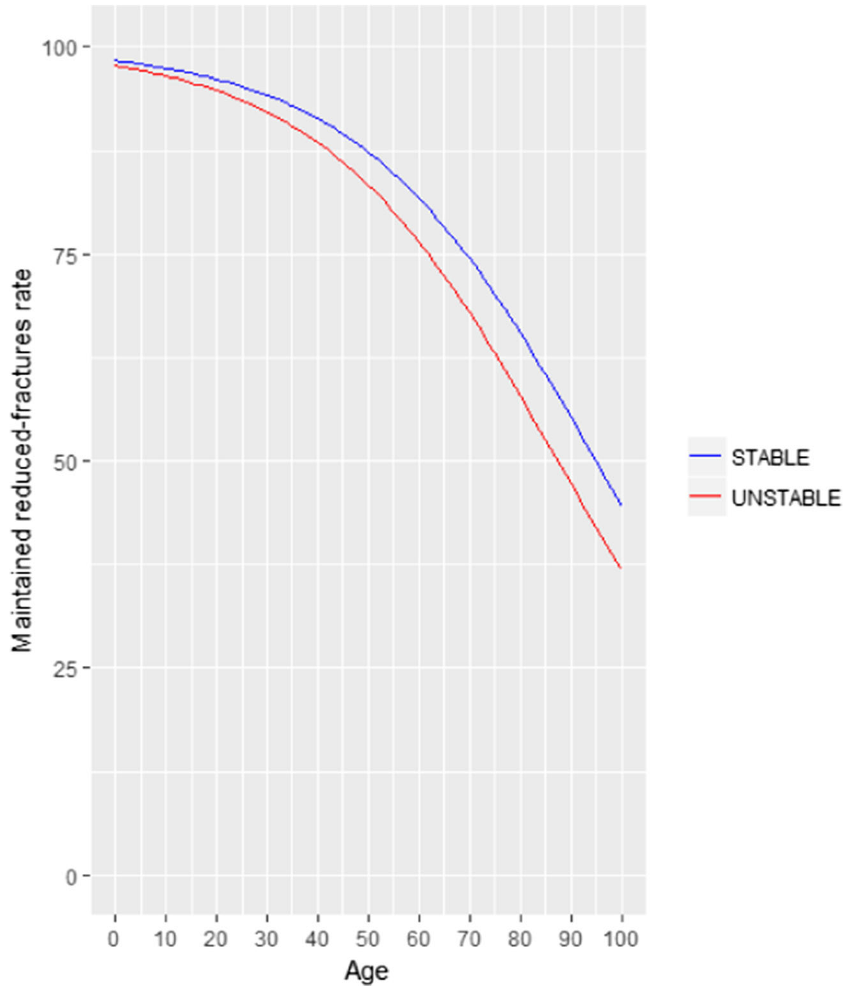

Fig. 6 Correlation between age and maintenance rate for stable and unstable fractures. The older the patient, the higher the risk of loss of reduction. This risk further increases with fracture instability

(AEC). At final radiological examination, these values averaged 9.1 mm for RL, 20.4° for RI, and − 2.3° for VT in group A and 8.1 mm, 19.5°, and − 2.4° in group B respectively. In order to adjust for the selection bias between the two groups we fitted an ANCOVA model for each radiological parameter measured at the end of treatment and introduced baseline (post-reduction) values as a covariate together with age, AO fracture classification, cast index, and quality of reduction (QR). Each model showed no significant difference between the two groups ($p > 0.05$ for each model). The mean estimated differences (computed through the ANCOVA models) in the deterioration of radiographic parameters during cast immobilization between group A and group B were 0.8 mm for RL, 0.4° for RI, and 0.9° for VT (Fig. 7).

Discussion

The aim of this study was to investigate the ability of locking prono-supination (by extending the cast above the elbow) to maintain bone alignment when distal radius fractures (DRFs) are managed conservatively. In our study, 73 patients were treated with a BEC, as opposed to 224 treated with an AEC. This considerable difference in group size is explained by individual clinician's preference about the type of treatment to administer, depending upon fracture and patients' characteristics. In all age subgroups, AEC was used in about two thirds of patients, whereas BEC was used in the remaining one third. In the > 90 years age group, half of patients were treated with AEC and half with BEC (Fig. 4). No relationship was found between cast length and risk of loss of reduction. Statistically significant factors predicting such risk were age, stability, and quality of reduction. These findings suggest that cast type does not play a significant role in preventing secondary displacement after manual reduction. Conversely, the maintenance of good results in conservative treatment seems to be mostly related to the inherent stability of the fracture and the age of the patient [1, 20–22]. In a study involving 125 patients aged > 50 years, Sakai et al. found a significant association between osteoporosis and risk of secondary displacement [23]. In the past, Pool and other authors have shown that the type of immobilization does not influence the final result and our findings further support this concept [8–11]. In 2006, Bong et al. published a randomized trial comparing the

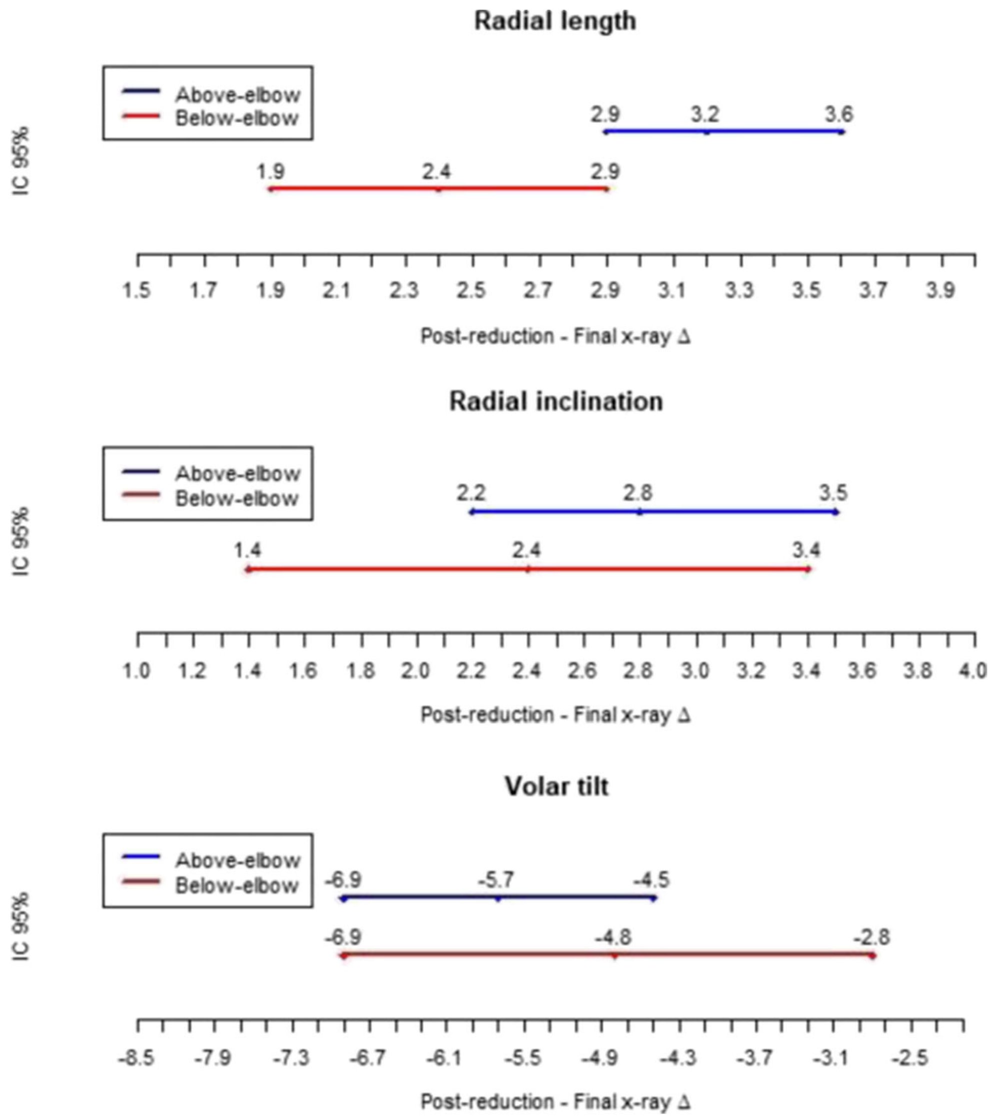

Fig. 7 IC 95% for mean calculated delta between post-reduction and end-treatment radiological parameters for above-elbow and below-elbow groups after adjustment for propensity score. Comparison between the values of the two groups is not significant ($p > 0.05$)

efficacy of an above- vs below-elbow cast ("sugar tong" vs short-arm radial gutter splint) in maintaining fracture reduction. They found no statistical difference between the two study groups and concluded that BEC was the best choice to immobilize distal radius fractures as it would be more tolerated by patients, being, at the same time, equally effective in maintaining fracture reduction when compared to a standard AEC [7]. The study was well designed although it lacked adequate follow-up, as its endpoint was fracture reduction maintenance at one week. This short-term follow-up could have missed some delayed displacements as it is known that these could occur long after one week post-manipulation [21]. It seems, after all, that the small amount of prono-supination allowed by casting the forearm leaving the elbow free is not able to exert a discernible influence on the likelihood of loss of reduction. Usually, secondary displacement of DRF occurs along the forearm long axis, when the distal fragment redisplaces dorsally following force vectors of the extensors when the dorsal cortex is not able to function as a buttress to hold it in place. This occurs when the dorsal cortex is comminuted and the distal fragment is not well seated (either because of a poor reduction manoeuvre or because of comminution of cortical and cancellous proximal bone) [24]. Alternatively, the distal fragment could simply further break apart, usually in poor-quality bone and older patients, disrupting bone joint surface and collapsing into the metaphysis. Age and stability have been considered as main independent predictors for secondary displacement by many investigators [21, 22, 25, 26], whereas, as proposed by Van der Linden and Ericson, more emphasis should be placed on proper technique of manipulation rather than technique of immobilization [9]. Restoring adequate cortex-to-cortex contact area is probably the crucial point. In our study, we assessed the quality of reduction according to investigators' subjective judgment on post-reduction radiographs. We are aware that this could render the variable not reproducible and could undermine its validity, but despite that, we found a strong, statistically significant relationship with secondary displacement risk. Another limitation of this study is that it was retrospective and not randomized. Furthermore, we referred to Graham's criteria to define the maintenance of reduction, but such definition could rely on the set of criteria used; thus, the percentage of well-healed or malunited fractures may vary accordingly, eventually altering the results. For this reason, we also analyzed how the radiographic parameters (radial length, radial inclination, and volar tilt) changed over time in order to provide an objective measurement. We found that the mean expected loss of the radiographic parameters over time for a given fracture (same AO type and same stability) does not differ significantly either depending on whether the patient was treated with an AEC or BEC (p value = 0.0083). Although our data were limited by the type of study, related selection bias was normalized through appropriate statistical analysis. Our results confirmed that age, stability, and quality of reduction were the main risk factors for secondary displacement in DRFs. Optimal fracture realignment and restoration of anatomic parameters played a key role in maintaining reduction. No significant difference was found between above- and below-elbow casts in maintaining reduction of manipulated distal radial fractures in adults.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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