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Measurement of clavicular length and shortening after a midshaft clavicular fracture: Spatial digitization versus planar roentgen photogrammetry

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ABSTRACT

Purpose: Clavicular shortening after fracture is deemed prognostic for clinical outcome and is therefore generally assessed on radiographs. It is used for clinical decision making regarding operative or non-operative treatment in the first 2 weeks after trauma, although the reliability and accuracy of the measurements are unclear. This study aimed to assess the reliability of roentgen photogrammetry (2D) of clavicular length and shortening, and to compare these with 3D-spatial digitization measurements, obtained with an electromagnetic recording system (Flock of Birds). *Patients and methods*: Thirty-two participants with a consolidated non-operatively treated two or multi-fragmented dislocated midshaft clavicular fracture were analysed. Two observers measured clavicular lengths and absolute and proportional clavicular shortening on radiographs taken before and after fracture consolidation. The clavicular lengths were also measured with spatial digitization. Inter-observer agreement on the radiographic measurements was assessed using the Intraclass Correlation Coefficient (ICC). Agreement between the radiographic and spatial digitization measurements was assessed using a Bland–Altman plot. *Results*: The inter-observer agreement on clavicular length, and absolute and proportional shortening on trauma radiographs was almost perfect (ICC > 0.90), but moderate for absolute shortening after consolidation (ICC = 0.45). The Bland–Altman plot compared measurements of length on AP panorama radiographs with spatial digitization and showed that planar roentgen photogrammetry resulted in up to 37 mm longer and 34 mm shorter measurements than spatial digitization. *Conclusion*: Measurements of clavicular length on radiographs are highly reliable between observers, but may not reflect the actual length and shortening of the clavicle when compared to length measurements with spatial digitization. We recommend to use proportional shortening when measuring clavicular length or shortening on radiographs for clinical decision making.

1. Introduction

Non-operative treatment of displaced midshaft clavicular fractures may lead to mal-union and subsequent shortening of the clavicle (Andersen et al., 1987; Eskola et al., 1986; Hillen et al., 2010; Nordqvist and Petersson, 1994). Several studies suggested that conservative treatment of fractured clavicles with more than 15 mm shortening on the trauma radiograph may lead to unsatisfactory results, such as pain while lying on the affected side, subjectively decreased muscle strength or impaired range of motion, assumed to be caused by a change in the closed-chain mechanism of the shoulder (Eskola et al., 1986; Hill et al., 1997; Lazarides and Zafiropoulos, 2006), or even non-union (Canadian Orthopaedic Trauma Society, 2007; Wick et al., 2001). In clinical decision making, the choice between surgical fixation or non-operative treatment is not only based on the condition and wish of the patient, but also on the degree of shortening and displacement of the fractured clavicle. For the cases with more than 15 mm shortening, surgical fixation in the first two weeks after trauma is generally advocated (Canadian Orthopaedic Trauma Society, 2007; Stegeman et al., 2013). Therefore clavicular length and shortening must be measured in a reliable and valid manner.

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In current clinical practice, clavicular length and shortening are measured two-dimensionally on digital radiographs, with the fracture projected in one or two planes (frontal plane and a transverse plane tilted 15°–30° around the anteroposterior axis). Two notes of criticism about these clinically relevant measurements are in order: the accuracy of these measurements is questionable, because the use of different types of radiographs, different directions of the X-ray beam, and the conversion of three-dimensional (3D) to two-dimensional (2D) information, may lead to amplification and projection errors. The reliability and validity of clavicular length and shortening measurements on radiographs have been scarcely investigated. The other point of discussion is whether clavicular shortening should be expressed as an absolute measure (in mm). Since clavicular length varies between individuals, a certain amount of shortening may not have the same effect on the shoulder function in every patient (Smekal et al., 2008). For this reason, it may be more appropriate to express clavicular shortening as a proportional measure.

The 3D positions of predefined bony landmarks can be determined accurately and reliably with an electromagnetic tracking device (spatially digitized observations) (Meskers et al., 1999), from which bone lengths can be calculated. It may also be assumed that the 3D spatial digitization measurements reflect anatomic clavicular length more closely than 2D planar photogrammetry. In theory, spatial digitization is the best method to determine clavicular length. Currently, the agreement between measurements on radiographs and spatial digitization is not known.

This study aimed to determine the inter-observer reliability of measurements of clavicular length and absolute and proportional shortening on radiographs and to compare 2D planar roentgen photogrammetry of clavicular length with 3D spatial digitization. Furthermore, we evaluated an alternative method for calculating proportional shortening of consolidated clavicles on radiographs which accounts for inter-individual variation of clavicular length.

2. Patients and methods

This exploratory study was approved by the institutional Medical Ethics Review Committee and registered in the Dutch Trial Registry (NTR3167). The study was performed between December 2011 and April 2012.

2.1. Participants

For this exploratory study no sample size calculation was performed. Patients with a non-operatively treated two or multi-fragmented displaced midshaft clavicular fracture (type 2B1 or 2B2 according to the Robinson classification) (Robinson, 1998) that had consolidated within four months after trauma were selected from the medical databases 2006–2010 of the Leiden University Medical Centre and the Rijnland Hospital in The Netherlands. Patients were eligible for inclusion in the study if they were aged 18–60 years at time of fracture and had no associated injuries, pathological fracture, neurovascular injury, or previous acromioclavicular injury of either shoulder. Patients with non-union of the fractured clavicle were excluded. Candidates with a cardiovascular pacemaker were also excluded, since an electromagnetic field was used for the spatial digitization measurements. All 74 eligible patients were subsequently contacted by phone after having received written information. Of those, 32 patients were willing to participate in the study and visited the outpatient clinic for radiography and spatial digitization. Informed consent was obtained from each participant.

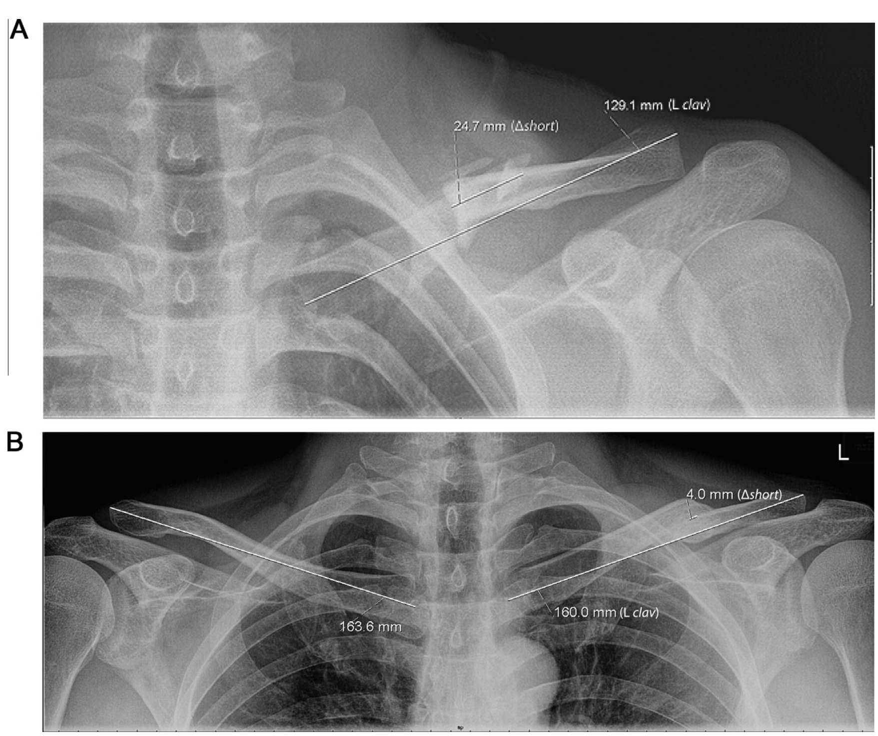

Fig. 1. Measurement of clavicular length and shortening after a midshaft fracture, on the anteroposterior trauma radiograph (A) and anteroposterior panorama radiograph (B)*. Fig. 1A: Clavicular length (L *clav*) is defined by the line connecting the middle of the medial border with the most lateral edge. Absolute shortening (Δ *short*) was calculated by connecting the cortical fragments along the axial line of the clavicle. The Clavicular Shortening Index (*CSI*) is defined as the absolute shortening divided by the length of the affected clavicle plus absolute shortening. For this case, the relative shortening is 24.7/(129.1 + 24.7) × 100 = 16.1%. Fig. 1B: Clavicular length (L *clav*) is defined by the line connecting the middle of the medial border with the most lateral edge. The length of the consolidated clavicle (L) in this example is 160.6 mm and the length of the contralateral clavicle (R) is 163.4 mm. Absolute shortening (Δ *short*) is defined as the axial distance between the cortical fragment ends. In this case, the absolute shortening is 4.0 mm. *A and B are from different patients.