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SCIENTIFIC ARTICLE

A new radiographic view of the scaphotrapeziotrapezoid joint—a cadaveric study

Arthur Turow [1,2] · Joideep Phadnis [2,3] · Gregory I. Bain [1,2]

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Abstract

Background The scaphotrapeziotrapezoid joint (STTJ) has a complex osseous and ligamentous anatomy. Precise radiographic assessment is paramount when assessing osteoarthritic, post-traumatic, or post-operative patients. There has been no described technique to image the STTJ without any wrist movement, unobscured by the rest of the carpus. The aim of this study was to define an optimal radiographic method to assess the STTJ while maintaining the wrist in neutral position.

Methods Computer tomography 3-D reconstructions of three uninjured wrists were initially used to determine an approximate beam angle. Serial radiographs of 12 cadaveric wrists were taken. The forearms were positioned in varying degrees of pronation and supination. The beam angle was concurrently adjusted to varying degrees of caudal tilt. From the images obtained, we assessed if the adjacent carpus obscured the view of the STTJ.

Results Optimal STTJ imaging was in the semi-pronated wrist position with the X-ray beam tilted caudal. We found that the STTJ was best visualized at 48° supination from a fully pronated wrist and a caudal beam angle of 22°.

Conclusions The described wrist and beam orientation can aid in achieving an unobstructed view of the STTJ with little technical effort. This can aid in imaging ambulatory patients where symptoms prevent using other imaging techniques as well as patients in the operating room where imaging timing can be critical.

Keywords STT joint · Scaphotrapeziotrapezoid joint · Imaging · X-ray · Scaphoid

Introduction

The scaphotrapeziotrapezoid joint (STTJ) is a multi-facet articulation, formed by the distal, triangular-shaped articular surface of the scaphoid, the trapezium, and the trapezoid [1]. The trapezoid articulates with the adjacent trapezium and capitate. Routine PA radiographs usually show the scaphoid in a slightly flexed profile with its distal articular surface obscured by the concave trapezium and trapezoid articulations [2, 3]. A dedicated STTJ view could aid to better visualize the joint in acute trauma or in degenerative conditions.

Plain X-ray assessment has been limited to standard posterior-anterior (PA), lateral, semi-pronated, and ulnar deviation views as used for evaluating scaphoid pathology. Several studies have used these standard views, namely PA radiographs, to identify the severity of osteoarthritis [4–6]; however, PA radiographs have been shown to have a low sensitivity for the detection of pathology [7].

Morimoto and colleagues [8] have developed the scaphoid axial view for kinematic evaluation of the STTJ, placing the wrist in 45° of supination in order to evaluate trapezio-trapezoid inclination. The International Wrist Investigators' Workshop [9] has suggested a similar view with the addition of some ulnar deviation. Both views isolate the STTJ but fail to achieve a clear depiction of the scapho-trapezial articulation. More recent studies have focused on improving those techniques. Wollstein and colleagues [3] described a STTJ view, where the wrist is placed in full ulnar deviation and maximal extension. Their technique achieved good visualization of the

✉ Arthur Turow
arthur.turow@health.sa.gov.au

1 Flinders University of South Australia, Adelaide, Australia

2 Brighton & Sussex University Hospitals, Brighton, UK

3 Department of Orthopaedic Surgery, Flinders Medical Centre, Flinders Drive, Bedford Park, Adelaide, South Australia 5042, Australia

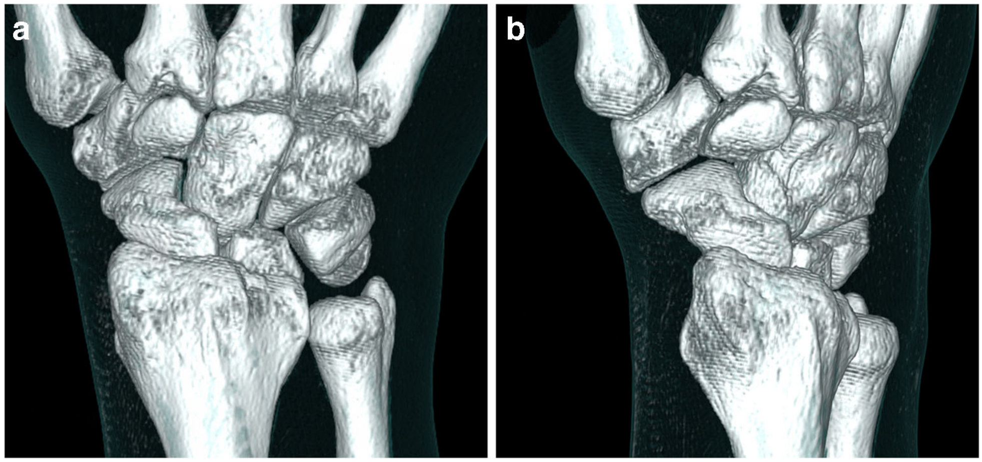

Fig. 1 3-D reconstruction of one of the CTs used for initial orientation assessment: **a** dorsal view of a normal wrist in neutral position; **b** after 40° coronal and 10° axial rotation, the STTJ can be seen unobscured from the trapezium and trapezoid

trapezio-trapezoid joint, at the expense of an unobstructed visualization of the distal scaphoid. A recent study has modified the STTJ view described by Wollstein [3] by imaging the wrist in 45° pronation in order to evaluate post-operative STTJ osteoarthritis following scaphoid fracture screw fixations [4]. This modified view still showed some overlap with the trapezium. DeGeorge and colleagues [10] added thumb abduction at 40° of forearm pronation and maximal wrist ulnar deviation. Thumb abduction allowed the authors to get a better, yet still incomplete, scapho-trapezial-trapezoid identification with preservation of the trapezio-trapezoid articulation.

Patients presenting with STTJ pathology frequently are not able to achieve full wrist extension, ulnar deviation, or thumb movement due to pain, especially where concurrent wrist pathology is present. Similarly, trauma or post-operative patients are usually unable to achieve a full range of motion.

The aim of this study was to achieve ideal STTJ visualization using serial radiographs while maintaining the wrist in neutral position. The results could then be used for trauma, surgical patients, or those with osteoarthritis.

Materials and methods

Sample preparation

Twelve embalmed adult cadaveric upper limbs were supplied by the Department for Anatomy & Histology at Flinders University, South Australia. Ethics approval was granted from the Southern Adelaide Clinical Human Research Ethics Committee (Approval SAC HREC EC00188). Twelve cadaveric right upper limbs of six males and six females (mean age 81; range 57–95) were studied. Each specimen was embalmed in a neutral wrist position.

Imaging

Initial assessment included review of pre-existing computed tomography (CT) 3-D reconstructions. 3-D data of three patients presenting to our department with normal CT findings were assessed using the RadiAnt DICOM Viewer™. This was to streamline radiographic imaging of the cadaveric specimens. CT scans were reviewed by two investigators, an orthopedic surgical trainee and a fellowship-trained orthopedic

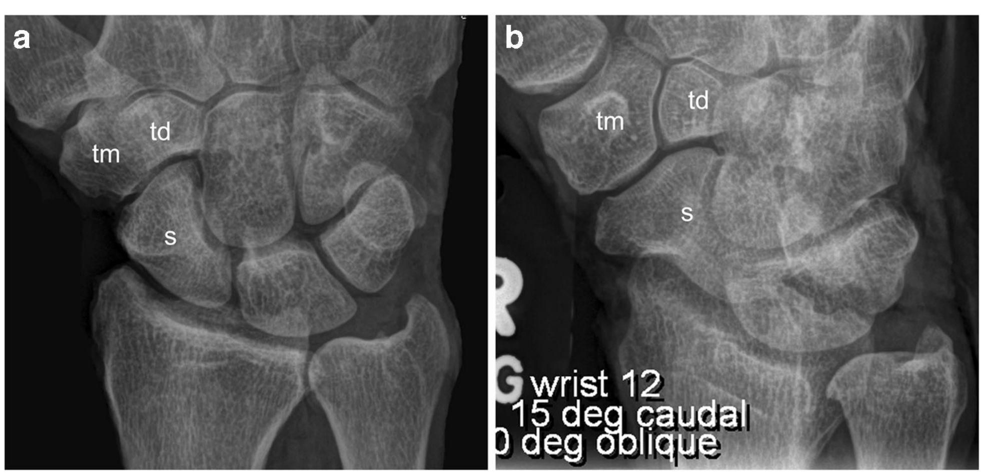

Fig. 2 X-rays of a right cadaveric wrist taken in: **a** standard PA view, demonstrating trapezium [tm], trapezoid [td] and scaphoid [s] overlap; **b** supination 40° and 15° caudal beam tilt showing an unobstructed STTJ

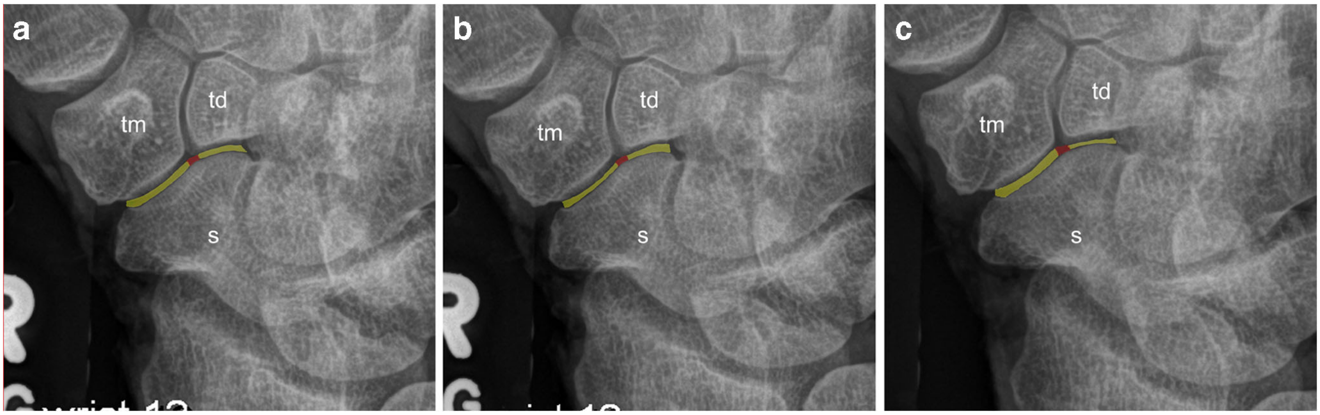

Fig. 3 Effect of wrist positioning on STTJ visualization. X-rays of the same cadaveric wrist as in Fig. 2. All three radiographs were taken in 15° of caudal beam angulation. **a** The chosen image for this specimen was 40° of supination. The scapho-trapezial and scapho-trapezoid articulations are of similar widths and continue across the tm/td joint. **b** 35° and **c** 45° of supination demonstrate joint-width discrepancies indicative of persistent rotation. Unobscured joint spaces are highlighted in *yellow*. The continuation of those spaces across the tm/td joint is in *red*. Trapezium [tm], trapezoid [td], and scaphoid [s]

surgeon. The angle for best beam placement was determined by rotating from the neutral, anterior reconstruction positions (Fig. 1a) until a uniform, clear space was seen across the STTJ (Fig. 1b). Rotation angles were recorded for each CT series and averages were calculated. This revealed that the STT joint was positioned at an angle 40° oblique to the coronal and 20° caudal to the axial plane of the forearm.

Each embalmed upper limb was secured on an imaging table. Initial wrist placement was in line with routine PA wrist radiographs: full pronation, palm in contact with imaging receptor, 100 cm from the X-ray tube [11]. The X-ray beam was limited to caudal and cranial tilt only. Supination and pronation were achieved by changing placement of the wrist on the imaging table with the aid of positioning blocks. The placement of the wrists was confirmed using a digital accelerometer placed across the diaphyses of the radius and the ulna 5 cm proximal to the wrist joint. The starting position was 40° of forearm supination and 20° of caudal beam orientation as determined by the initial CT assessment. Serial X-rays were taken in 2° increments of beam tilt and 5° of forearm rotation.

Table 1 Optimal positioning for visualization of the STTJ. Supination and caudal beam tilt angles are listed in degrees. Osteoarthritis (OA) was recorded in binary format

Wrist	Age	Sex	OA	Forearm supination	Caudal tilt
1	79	M	No	55	25
2	90	F	Yes	45	20
3	67	M	No	45	30
4	91	F	Yes	55	30
5	75	M	No	45	15
6	88	F	No	50	20
7	95	M	Yes	45	30
8	83	F	Yes	50	25
9	83	M	Yes	55	15
10	79	F	Yes	45	18
11	57	M	No	40	15
12	88	F	No	48	15
Mean				**48**	**22**
STD				**4.9**	**6.2**

Image assessment

The scapho-trapezial and the scapho-trapezoid joint spaces were assessed separately. The primary end-point was STTJ clear space between the scaphoid and the trapezio-trapezoid complex (Fig. 2). Three parameters were used to assess quality of that clear space: (1) any narrowing or obliteration along the distal scaphoid, (2) width uniformity of the scapho-trapezial and of the scapho-trapezoid joint spaces, and (3) joint space continuity across trapezium and trapezoid. In cases of clear-space obliteration and discontinuity or differing widths of clear-spaces at the trapezium or trapezoid (Fig. 3b, c), the forearm position and beam orientation were adjusted. Imaging of the STTJ was deemed satisfactory when the scapho-trapezial and the scapho-trapezoid joint spaces were uniform in width and when these spaces were continuous with each other (Fig. 2). Osteoarthritis was assessed according to the modified Eaton and Glickle classification [4, 7]. As the primary aim was to determine joint space uniformity in different wrist position, rather than the degree of joint degeneration, osteoarthritis was recorded in binary format. Each image was reviewed separately for joint space quality and presence or absence of osteoarthritis by the same investigators who also had assessed the initial CT scans. Any discrepancies were reassessed until consensus was reached. Differences in forearm and beam-angle orientations between samples were analyzed using the Mann–Whitney U test. A result was considered statistically significant when the p value was less than 0.05.

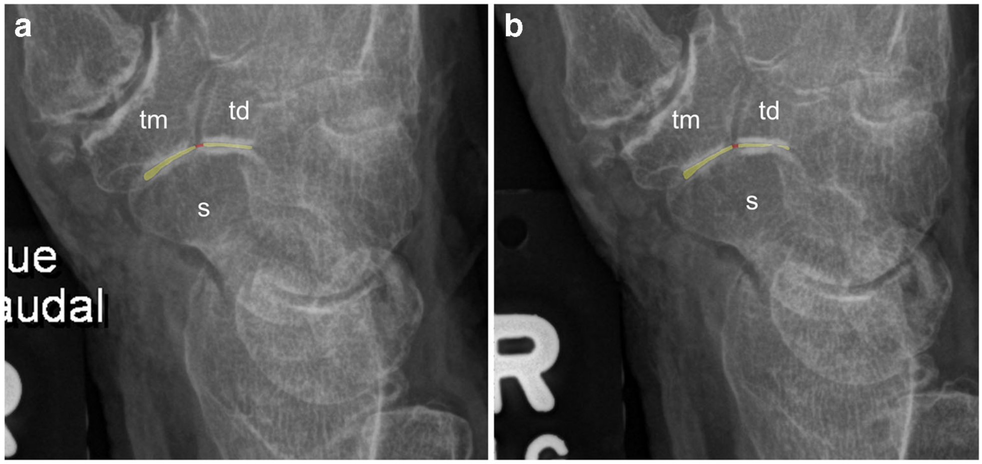

Fig. 4 Example X-ray of a wrist with advanced STTJ and concurrent carpometacarpal osteoarthritis. **a** The chosen image for this specimen was 40° of wrist supination and 20° caudal beam angle. The STTJ is in continuity. **b** 15° of beam angle resulted in joint discontinuity at the scapho-trapezoid joint. Unobscured joint spaces are highlighted in *yellow*. The continuation of those spaces across the tm/td joint is in *red*. Trapezium [tm], trapezoid [td], and scaphoid [s]

Results

A summary of the results is presented in Table 1. Osteoarthritis of the STTJ was present in 50% of the specimens (Fig. 4). All of those specimens had concurrent base of thumb osteoarthritis.

In order to achieve an unobscured view of the STTJ, the mean angles measured were: supination 48° (range 45–55°; STD 4.9) and a caudal beam angle 22° (range 15–30°; STD 6.2) from the initial wrist position (Fig. 5). There were no significant differences in forearm rotation ($p = 0.70$) or beam tilt ($p = 0.82$) between males and females. Equally, angular parameters were statistically similar in osteoarthritic and non-osteoarthritic specimens (forearm rotation: $p = 0.82$; beam tilt: $p = 0.48$).

Discussion

The described wrist and beam orientations can aid in obtaining an unobstructed radiograph of the STTJ. Our STTJ view can be easily reproduced during surgical procedures as well as in an ambulatory setting. Most modern outpatient X-ray machines can be orientated in at least one axis of rotation. This

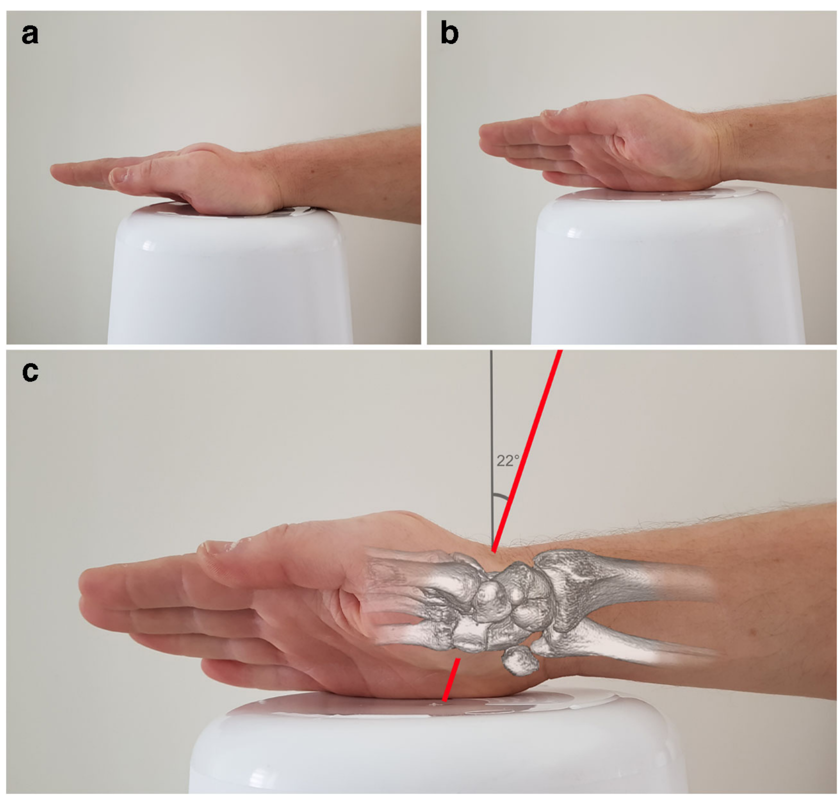

Fig. 5 Serial positioning of the wrist for imaging; the *red line* indicates X-ray beam direction. **a** Full pronation position with palm-down for routine PA radiographs; **b** supination of 48° from the starting position; **c** Caudal orientation of the XR beam to 22° while maintaining a neutral wrist position

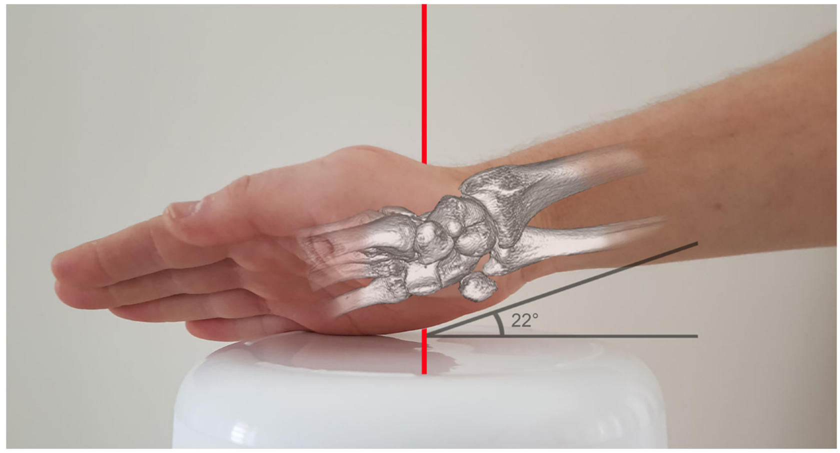

Fig. 6 Alternative wrist position to achieve the describe STTJ view: Supination of 48° from the fully pronated position and forearm elevation to 22°. The wrist is maintained in a neutral position and the X-ray beam (*red*) is perpendicular to the operating table

allows wrists to be imaged flat on the imaging table while only adjusting supination from the standard posterior-anterior position, avoiding calibration of the X-ray beam in several axes. This allows for more efficient and reliable imaging, even in situations where patients' symptoms would not allow any movement of the wrist or thumb (Fig. 5).

The standard PA view of the wrist has been the mainstay of STTJ imaging [12]; however, this view is not ideal due to substantial overlap of carpal bones, preventing clear visualization of the dome-shaped STTJ. The PA oblique view, as proposed by International Wrist Investigators' Workshop [9], can unfold the STTJ to a degree, but it still suffers from joint-space obliteration and discontinuity. In this study, we identified a radiographic view that avoids these difficulties and allows for clear imaging of the STTJ. Wollstein and colleagues [3] described an alternative STTJ view; however, this view depended on mobilizing the wrist into extremes of extension and ulnar deviation. A modified oblique pronation view of Wollstein's view was described as part of a percutaneous transtrapezial scaphoid fixation cohort study [4]. That view also required wrist mobilization to 45° of flexion and ulnar deviation. Our view has the advantage that the wrist can be kept in a neutral position with no required movement at either the wrist or carpal joints. It is able to achieve an unobstructed view of the distal scaphoid with no overlap with the trapezium or trapezoid. As an additional benefit, the trapezio-trapezoid joint can also be visualized with little bony overlap (Fig. 2). This can be useful when assessing scaphotrapezium-trapezoid fusion outcomes [13, 14].

Adequate imaging of the STTJ is paramount in scaphoid fracture fixation. There is evidence to suggest that screw placement through the distal pole of the scaphoid can lead to STTJ osteoarthritis [4, 15, 16]. Screw prominence, in particular when placed in a proximal to distal direction, needs to be assessed to avoid STTJ damage. Recent use of both volar [17, 18] and dorsal [19] plates for comminuted or non-united fractures, makes intra- and post-operative STTJ imaging even more important. Intra-operative fluoroscopy frequently depends on small adjustments, while holding a fracture reduced or while placing implants. With the described view, patients' wrists can be placed palm-down on the fluoroscopy intensifier. Supination and elevation of the forearm (Fig. 6) achieves our described view while maintaining the wrist and carpus in a fixed position.

The limitations of our study include sampling bias and the use of embalmed specimens. However, the rather uniform distribution of pronation and beam angles across genders and in wrists with STTJ osteoarthritis is reassuring. Usage of embalmed cadavers could predispose to measurement errors due to potential tissue distortion as part of the embalmment process. By not relying on ligamentotaxis or articular movements when obtaining X-rays, such errors were kept to a minimum. Furthermore, usage of a digital accelerometer across the specimens and incremental adjustments of the beam angle tilt allowed reproducible and accurate specimen positioning. Finally, as the starting pronation and beam angulations were derived from the CT analysis, not all wrist positions were tested. A future study could evaluate the unfolding of the STTJ from the standard, fully pronated PA to our described wrist position. This could allow for a more detailed analysis of the effects of pronation and beam orientation on the STT joint space. An inter-observer analysis of all variants of the STTJ view when compared to standard PA and PA oblique radiographs could further define the value of dedicated STTJ imaging in osteoarthritis assessment and its classification.

Conclusions

Precise imaging techniques of the wrist play an important role in evaluating the complex osseous and ligamentous anatomy of the wrist. Our described radiographic view achieves an unobstructed view of the STTJ with little technical effort. It can be used for ambulatory patients where wrist or thumb movement is prohibitive due to pain or in the theatre setting where accurate imaging is frequently time-critical.

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Compliance with ethical standards

Conflict of interest None.

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