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ORIGINAL ARTICLE • WRIST - IMAGING

Distal radius fluoroscopic skyline view: extension–supination versus flexion–supination

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Abstract

The aim of our study was to compare the vertical fluoroscopic view of the wrist in extension and supination (ES) to the view in flexion and supination (FS) and determine which of the two views allowed the best visualization of four selected anatomical landmarks SDLR (radial styloid, dorsal radius cortex, Lister's tubercle and distal radioulnar joint). Our case series included 50 patients who had suffered a distal radius fracture and undergone an open reduction and internal fixation procedure with a volar locking plate. For each case, two fluoroscopic views were taken: ES (wrist extension and supination) (group I) and FS (wrist flexion and supination) (group II). Ten observers had to recognize the SDLR anatomical landmarks on 100 fluoroscopic skyline views (time 1) and 15 days later (time 2). The rate of recognition of the four anatomical landmarks was 78% in group I and 66% in group II ($p < 0.001$). The concordance rate of recognition of the four anatomical landmarks was mediocre ($\kappa = 0.411$). In conclusion, the vertical fluoroscopic skyline view in wrist extension and supination seems to be the most adequate view to assess the quality of the fracture reduction, the distal radioulnar joint and the length of the screws in open reduction and internal fixation of distal radius fractures with volar locking plates.

Keywords Skyline · Dorsal tangential view · Distal radius

Introduction

During intraoperative evaluation of distal radius fractures treated by open reduction and internal fixation using palmar locking plates, the antero-posterior and lateral views are not sufficient to determine the quality of the fracture reduction, the aspect of the distal radioulnar joint and the screws length [1]. Some authors used four selected anatomical landmarks (SDLR), the radius styloid, the entirety of the dorsal radius cortex, the Lister's tubercle, and the distal radioulnar joint to compare different fluoroscopic views [1].

The aim of this study was to compare the vertical skyline fluoroscopic view in extension and supination (ES) to the skyline vertical fluoroscopic view in flexion and supination (FS) to determine which one provided the best visualization of the four anatomical landmarks SDLR.

The main hypothesis of this study was that the skyline fluoroscopic vertical view in ES allowed a better recognition of the four anatomical landmarks SDRS than the fluoroscopic vertical view in FS, according to the blinded assessment of 10 observers. The secondary hypothesis of the study was that the reproducibility of the recognition was good.

Materials and methods

Regarding the materials, we included all the clinical files from our patients who had suffered a distal radius fracture and had undergone an open reduction and external fixation procedure with a locking volar plate between June 26, 2017 and October 10, 2017. Out of a total of 124 cases, we excluded from the study the data from the patients who had had either an intraoperative skyline view in wrist extension and supination or a skyline view in wrist flexion and

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supination (Fig. 1). Out of the remaining 99 cases, two blinded observers presenting a level of expertise III [2] excluded the patients whose ES and FS fluoroscopic views did not provide a complete visualization of the four anatomical landmarks SDLR [1]. Our case series consisted eventually of 50 patients presenting two fluoroscopic skyline views, in ES (group I) and in FS (group II).

The method consisted to randomize and to present 100 relevant fluoroscopic skyline views of 50 patients to the attention of 10 blinded observers. The level of expertise of the observers was III [2]. Each one of the 10 observers had to recognize a maximal number of the above-described anatomical landmarks SDLR (from 0 to 4) in each one of the 100 fluoroscopic skyline views (time 1). Fifteen days later, in order to test the reproducibility of the recognition, the same group of blinded observers had to undertake the same process (time 2). To avoid the biases, the above-mentioned 100 fluoroscopic views were presented to the observers on time 2 after randomization in order to create an apparently new case series (Fig. 2).

Having assumed that the two groups were comparable, the statistical analysis was conducted and aimed at comparing the values of a qualitative variable (number of anatomical landmarks recognized from 0 to 4) and finding a concordance between group I and II, and between time 1 and time 2. To compare group I and II, a mixed ordinal logistic regression model was used with a significance threshold set at $p < 0.05$. To compare time 1 and 2, a Kappa coefficient was used. The concordance rate was very high when Kappa was included between 0.81 and 1.00, strong when $0.61 < \text{Kappa} < 0.80$, moderate when $041 < \text{Kappa} < 0.60$ and low when $0.21 < \text{Kappa} < 0.40$, and no concordance was found when $\text{Kappa} < 0.21$.

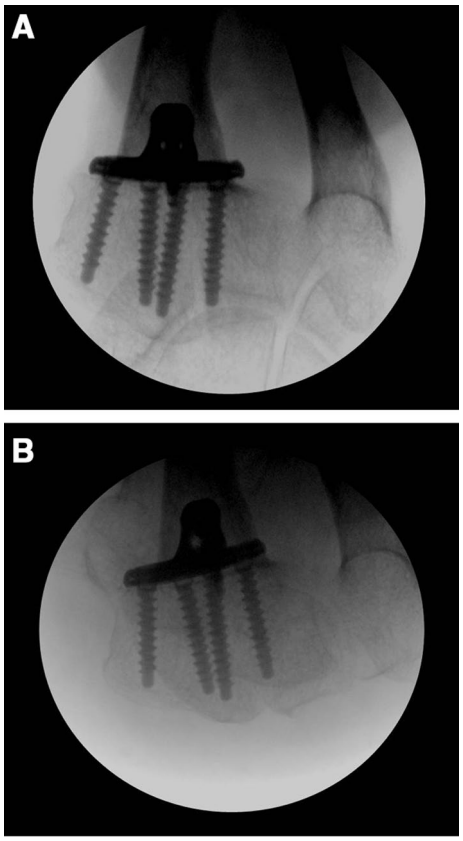

Fig. 2 Vertical skyline fluoroscopic view for the same patient. **a** Extension and supination: the four anatomical landmarks SDRL are visible. **b** Flexion and supination: only three anatomical landmarks SDRL are visible, and the Lister's tubercle is not visible

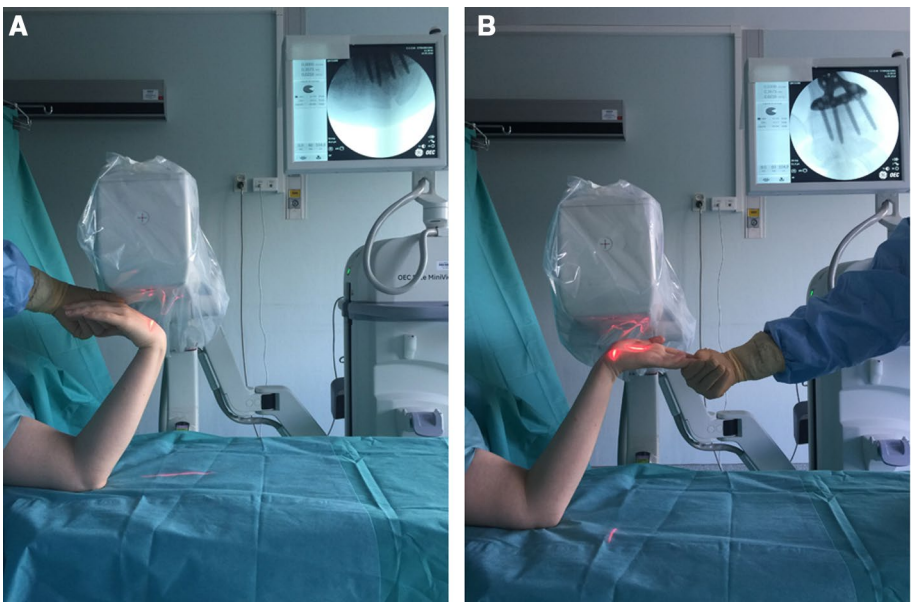

Fig. 1 Positioning of a skyline vertical fluoroscopic view. **a** Extension and supination. **b** Flexion and supination

Table 1 Results of a study comparing the visibility of four selected anatomical landmarks on a skyline view in extension and pronation and a skyline view in flexion and supination assessed by 10 blinded observers (time 1)

Obs (*N*)	Obs 1		Obs 2		Obs 3		Obs 4		Obs 5		Obs 6		Obs 7		Obs 8		Obs 9		Obs 10	
Obs level[a] (1–5)	2		2		2		2		2		3		3		3		3		5	
Skyline (EP/FS)	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS
SDLR (0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)
Patient (*N*)																				
1	2	4	2	4	2	4	2	4	1	2	2	4	3	3	4	4	2	3	4	4
2	4	4	3	3	4	4	4	4	4	3	4	2	4	3	4	4	3	3	4	4
3	4	4	3	3	3	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
4	4	4	4	3	4	3	4	4	4	3	4	4	4	4	4	4	4	4	4	4
5	3	3	2	3	3	3	4	4	2	3	4	3	4	3	4	4	4	4	4	4
6	3	3	2	3	3	4	4	4	4	2	4	4	4	3	4	4	4	3	4	4
7	4	4	3	3	4	4	4	4	3	2	4	3	4	4	4	4	4	4	3	4
8	4	4	4	4	4	4	4	4	2	1	4	2	4	3	4	4	4	1	4	3
9	4	3	3	3	3	3	4	3	3	1	4	3	3	3	4	4	4	3	3	3
10	3	3	3	3	3	3	4	3	4	3	4	4	4	4	4	4	4	4	4	3
11	2	4	2	3	3	3	4	4	2	3	4	4	4	4	4	4	3	4	2	4
12	4	4	4	3	3	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
13	4	4	4	3	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4
14	3	2	3	1	4	4	4	1	3	1	4	1	3	2	4	1	4	0	4	3
15	4	2	4	1	4	3	4	2	4	1	4	2	4	3	4	4	4	3	4	3
16	4	3	3	3	4	4	4	2	2	2	4	3	4	4	4	4	4	4	4	4
17	4	3	3	3	4	3	4	3	3	4	4	3	4	3	4	4	4	4	4	3
18	4	4	3	3	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
19	4	4	3	2	3	3	4	4	4	1	4	4	4	2	4	4	3	2	4	4
20	4	4	4	3	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4
21	4	4	3	3	4	4	4	3	4	3	4	4	4	2	4	4	4	4	4	4
22	4	4	3	3	4	4	4	4	4	3	4	4	4	3	4	4	4	2	4	4
23	4	4	4	4	4	4	4	4	4	1	4	4	4	3	4	4	4	2	4	4
24	4	4	3	3	3	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4
25	4	3	3	3	4	4	4	4	4	1	4	4	4	3	4	4	4	1	4	4
26	4	4	4	4	4	3	4	4	4	3	4	4	4	4	4	4	4	4	4	4
27	4	2	3	3	4	3	4	3	4	2	4	4	4	4	4	4	4	1	4	4
28	4	4	4	4	4	2	4	4	3	2	4	4	4	4	4	4	4	2	4	4
29	4	4	4	3	4	4	4	4	3	3	4	4	4	4	4	4	4	4	4	4
30	4	4	3	3	4	4	4	4	4	3	4	4	4	3	4	4	4	4	4	4
31	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4

Table 1 (continued)

Obs (*N*)	Obs 1		Obs 2		Obs 3		Obs 4		Obs 5		Obs 6		Obs 7		Obs 8		Obs 9		Obs 10	
Obs level[a] (1–5)	2		2		2		2		2		3		3		3		3		5	
Skyline (EP/FS)	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS
SDLR (0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)
Patient (*N*)																				
32	3	3	2	3	2	3	3	3	3	3	4	3	4	3	4	3	3	4	3	4
33	3	3	2	3	1	4	4	3	2	2	3	3	3	4	2	3	4	4	4	4
34	3	4	3	2	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4
35	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
36	4	3	4	3	4	2	4	4	3	2	4	2	4	3	4	4	4	3	3	4
37	3	3	4	3	3	2	4	3	4	3	4	4	4	4	4	4	4	4	4	4
38	3	4	2	3	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4
39	3	3	2	3	2	2	4	4	3	3	4	4	4	2	4	4	4	4	3	4
40	4	4	3	4	2	2	4	4	4	3	4	4	4	3	4	3	4	4	4	4
41	4	2	3	3	3	3	3	4	4	3	4	2	4	3	4	3	4	4	4	3
42	4	4	3	4	3	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
43	3	4	1	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4
44	4	3	2	3	3	3	3	4	2	4	4	4	4	4	4	4	4	3	4	4
45	4	4	4	4	4	4	3	4	3	4	3	4	3	4	4	4	3	4	4	4
46	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
47	4	4	3	3	4	4	4	3	3	3	4	4	4	4	4	4	4	4	4	4
48	4	4	3	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
49	3	1	2	3	4	3	4	3	4	4	4	3	4	4	4	4	4	2	4	4
50	4	3	3	4	4	4	4	4	3	4	4	4	4	3	4	4	4	4	4	4

Obs observer, *EP* extension pronation, *FS* flexion–supination, *SDLR* radius styloid, dorsal radius cortex, Lister's tubercle, distal radioulnar joint

[a]According to Tang JB, Giddins G. Why and how to report surgeons' levels of expertise. J Hand Surg Eur Vol. 2016;41:365–366

Table 2 Results of a case series comparing the identification of four anatomical landmarks on a skyline view in extension and pronation and on a skyline view in flexion and supination by 10 independent observers (time 2, 15 days after time 1)

Obs (*N*)	Obs 1		Obs 2		Obs 3		Obs 4		Obs 5		Obs 6		Obs 7		Obs 8		Obs 9		Obs 10	
Obs level[a] (1–5)	2		2		2		2		2		3		3		3		3		5	
Skyline (EP/FS)	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS
SDLR (0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)
Case (*N*)																				
1	4	4	3	4	4	4	0	4	2	4	4	4	4	4	1	4	0	4	1	4
2	4	1	4	3	4	4	4	4	4	3	4	4	4	3	4	4	2	4	4	4
3	3	4	3	3	4	4	4	4	3	4	4	4	4	4	2	4	4	4	4	4
4	4	3	4	4	4	3	4	4	4	3	4	4	4	4	4	4	4	3	4	4
5	3	3	3	3	4	1	1	3	3	3	4	2	4	4	4	4	4	4	3	4
6	3	3	3	4	2	4	3	1	4	3	4	4	4	3	4	4	4	4	4	4
7	4	4	4	4	4	4	3	4	4	3	4	4	4	4	4	4	4	4	4	4
8	4	4	4	4	4	4	4	3	4	4	4	3	4	2	4	2	4	4	4	4
9	4	3	4	3	3	4	4	2	4	4	4	2	3	3	4	3	4	3	4	3
10	3	3	4	4	4	3	4	3	4	4	4	3	4	3	3	3	4	4	4	3
11	2	4	3	4	4	4	4	4	3	4	4	4	4	4	3	4	4	3	3	4
12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
13	4	4	4	4	4	4	4	4	4	4	4	2	4	3	4	4	4	4	4	4
14	4	1	4	3	4	4	4	2	3	1	4	2	4	2	4	2	4	2	4	4
15	4	3	4	3	4	4	4	1	4	3	4	4	4	3	4	3	4	1	4	4
16	2	3	4	4	4	4	4	3	4	3	4	3	4	4	2	4	4	1	4	4
17	3	4	3	4	4	4	4	3	4	3	4	4	4	4	4	4	4	4	4	3
18	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
19	4	4	4	4	4	4	3	3	4	0	4	2	4	3	4	4	4	2	4	4
20	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
21	4	4	4	4	4	4	4	1	4	4	4	3	4	2	4	4	4	4	4	4
22	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4
23	4	4	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4
24	4	4	3	4	4	4	4	4	3	4	4	3	4	4	4	4	4	4	4	4
25	4	4	3	3	4	4	4	2	4	1	4	4	4	3	4	3	4	1	4	4
26	4	3	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	3
27	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	1	4	4
28	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4
29	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
30	4	4	3	3	3	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4
31	4	4	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Table 2 (continued)

Obs (*N*)	Obs 1		Obs 2		Obs 3		Obs 4		Obs 5		Obs 6		Obs 7		Obs 8		Obs 9		Obs 10	
Obs level[a] (1–5)	2		2		2		2		2		3		3		3		3		5	
Skyline (EP/FS)	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS	EP	FS
SDLR (0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)	(0–4)
Case (*N*)																				
32	2	4	2	4	3	3	3	2	3	3	4	4	4	4	4	4	4	1	3	3
33	4	4	3	3	3	3	4	4	3	3	4	4	3	4	2	4	4	3	4	4
34	3	4	3	4	3	4	4	4	4	4	4	4	4	3	4	4	4	3	4	4
35	3	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
36	4	4	3	3	3	4	4	4	3	3	4	3	4	2	4	4	4	4	4	4
37	3	3	3	3	3	4	3	3	3	3	4	4	3	4	4	4	4	4	4	4
38	3	3	2	4	2	3	3	4	4	4	4	4	3	4	3	4	4	4	4	4
39	3	3	2	3	3	3	4	4	4	4	4	4	4	3	3	4	4	3	4	4
40	3	4	3	4	4	4	4	4	4	3	4	4	4	3	4	4	4	3	4	4
41	4	3	3	3	3	4	3	2	4	3	4	3	4	3	4	3	4	1	3	1
42	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
43	3	4	2	4	3	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4
44	4	4	3	4	4	4	4	3	3	4	4	4	4	4	3	4	4	3	4	3
45	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4
46	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
47	3	4	3	3	4	4	4	1	3	3	4	4	4	4	4	4	4	3	4	4
48	4	4	3	4	4	4	4	4	4	3	4	4	4	4	4	4	4	3	4	4
49	3	3	3	3	3	4	4	3	4	2	4	4	4	4	4	4	4	1	4	1
50	4	3	4	4	4	4	4	2	4	4	4	4	4	3	4	4	4	2	4	4

Obs observer, *EP* extension–pronation, *FS* flexion–supination. *SDLR* radius styloid, dorsal radius cortex, Lister's tubercle and distal radioulnar joint

[a]According to Tang JB, Giddins G. Why and how to report surgeons' levels of expertise. J Hand Surg Eur Vol. 2016;41:365–366

Results

The rate of recognition of the four anatomical landmarks for all blinded observers was estimated at 78% in group I and 66% in group II. The difference was significant with a $p < 0.001$. The concordance rate of recognition of the four anatomical landmarks for all unbiased observers corresponded to a Kappa coefficient of 0.411, which showed a mediocre concordance.

Discussion

Among the complications of distal radius fracture fixation procedures with volar locking plates, the most common are the ruptures and the injuries to the finger extensor tendons [3]. Those complications are mainly due to the penetration of the screws through the dorsal cortex of the distal radius and/or into the distal radioulnar joint [4]. Many ultrasound scan views, tomographic and fluoroscopic views have been described to study these anatomical regions (Tables 1, 2).

Regarding the ultrasound scan, some authors have shown in a clinical postoperative study that there was no difference in the detection of the screws exceeding the dorsal radius cortex between the radiographic lateral view and the skyline radiographic view, being the ultrasonography scan the reference imaging technique [5]. Some other authors have shown in an experimental study that the use of the ultrasound scan as a reference imaging technique was not advisable since its sensitivity in detecting the screws exceeding the dorsal radius cortex was more than two times lower than the sensitivity of the skyline fluoroscopic view [6].

Regarding the CT scan, some authors have shown in a clinical study that the sensitivity of the fluoroscopic intraoperative skyline view was similar to the sensitivity of the postoperative CT scan [7]. Anyway, the CT scan is not always available as an imaging procedure, and the CT scan radiation dose is higher than the dose associated with fluoroscopy.

Regarding the fluoroscopy, some authors have shown in an experimental study that the sensitivity of detection of the screws exceeding the dorsal radius cortex in the lateral radiographic view decreased progressively when moving from radial to ulnar [8]. One of the explanations to this phenomenon could be the anatomical variability of the height of the Lister's tubercle [9]. Another reason could be the image overlapping of the Lister tubercle and the notch of the EPL tendon, which would limit the correct visualization of the screw penetrating the above-mentioned notch, increasing the risk of tendon injury [10].

In order to improve the sensitivity of the fluoroscopy, some authors have described more fluoroscopic views: the oblique view [11], the postero-anterior wrist pronation and supination view [12] and the skyline view [13]. In a study on a synthetic model, some authors estimated the dorsal protrusion of the screws at 1 mm, showing that the skyline view was more useful than the oblique view, the pronation view and the lateral standard view [10]. The skyline view can be performed with the image intensifier either in a horizontal [14] or a vertical position [5, 15]. It has then been proven that the vertical positioning, compared to the horizontal positioning, decreased the operative time and the contaminations of the operative field [16]. The skyline view can be performed either in wrist extension and pronation (ES) [17] or in flexion and supination (FS), with either a horizontal [18] or a vertical positioning of the image intensifier [19]. Some authors described some difficulties in performing the flexion skyline view when confronted with an important edema of the wrist [13].

The weaknesses of our study were the paucity of the data which limited the assessment of the inter-observer reproducibility and the mediocre intra-observer reproducibility. The strength of this study lied in the fact that the results of the statistical analysis were significantly in favor of the extension–supination view and that this is the only case series in the current literature testing and comparing multiple fluoroscopic skyline views and based on several anatomical landmarks.

The main hypothesis of our study was proved as the skyline vertical fluoroscopic view in extension and supination of the wrist was found to provide a better identification of the four anatomical landmarks SDLR than the skyline fluoroscopic view in flexion and supination. The secondary hypothesis was not proved since the reproducibility of the identification was mediocre.

In conclusion, in distal radius fracture fixation procedures with volar plates, the skyline vertical fluoroscopic view in wrist extension and supination seemed to provide the most accurate information to assess the quality of the reduction, the distal radioulnar joint and the length of the screws.

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Compliance with ethical standards

Conflict of interest Philippe Liverneaux has conflicts of interest with Newclip Technics, Argomedical, Zimmer Biomet and Biomodex. None of the other authors have conflicts of interest.

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