

Supplementary Table S1. Hardware Failure Definitions Across Included Studies (n = 13)

Study (Year)	Arm	N	Hardware Failure Definition	HF Scope	Assessment Method	FU	HF Rate
Moussazadeh 2015	CAPS	44	Screw pullout on follow-up imaging; one case described as asymptomatic screw pull-out	Radiographic (any)	Follow-up X-ray	NR	2.3%
Kim 2017	CAPS	14	Screw loosening, pullout, or displacement on follow-up imaging	Radiographic (any)	Follow-up X-ray / CT	NR	0%
Barzilai 2019	CAPS	53	Screw fracture, peri-screw lucency, rod fracture on postoperative CT	Radiographic (any)	Postop CT	6–12 mo	7.5%
Massaad 2021	CAPS	69	Screw loosening, pullout, or failure; assessed on postoperative CT	Radiographic (any)	Postop CT	25.3 mo (median)	0%
Newman 2021	CAPS	44	Screw pullout, loosening, rod fracture, progressive kyphosis; included events requiring revision	Mixed (radiographic + symptomatic)	Routine imaging + clinical	12.9 mo (median)	9.1%
Patel 2021	CAPS / Ctrl	10 / 9	Construct failure identified on follow-up imaging; not further specified	Radiographic (any)	Follow-up imaging	NR	0% / 0%
Wagner 2021	CAPS	51	Screw loosening, screw breakage, rod fracture on follow-up imaging	Radiographic (any)	Follow-up X-ray / CT	8.5 mo (median)	11.8%
Cady-McCrea 2021	CAPS	8	Construct integrity assessed on follow-up imaging; any mechanical complication	Radiographic (any)	Follow-up imaging	4.9 mo (median)	0%
Feng 2022	CAPS / Ctrl	28 / 24	Screw loosening, rod breakage, cage displacement on follow-up X-ray/CT	Radiographic (any)	Follow-up X-ray / CT	12 mo	3.6% / 29.2%
Bardeesi 2025	CAPS	28	Construct failure on follow-up imaging; screw loosening, migration, or rod fracture	Radiographic (any)	Follow-up imaging	11 mo (median)	0%
Longo 2019	Control	58	Screw loosening, pullout, rod fracture on scheduled follow-up imaging	Radiographic (any)	Follow-up imaging	NR	13.8%
Kumar N 2021	Control	246	Broad radiographic: screw ploughing, loosening, cut-out, pull-out, breakage; cage subsidence/displacement/breakage; rod breakage; angular deformity >5°. Stratified into symptomatic (SF) vs asymptomatic (AsCF)	Radiographic (all failures, inclusive)	Routine imaging + clinical; competing risk analysis	5 mo (median to failure)	22.4%
Kumar N 2023	Control	200	Symptomatic implant complications only: new-onset pain, neurological	Symptomatic only	Clinical presentation	NR	≈2%

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			deficit, or ambulatory deterioration attributable to construct failure				

Abbreviations: CAPS = cement-augmented pedicle screw; Ctrl = conventional (non-augmented) control; HF = hardware failure; FU = follow-up duration; NR = not reported; SF = symptomatic failure; AsCF = asymptomatic construct failure; CT = computed tomography.

Note: The nearly elevenfold difference in HF rates between Kumar N 2021 (22.4%, broad radiographic definition) and Kumar N 2023 ($\approx 2\%$, symptomatic only) within the non-augmented control arm illustrates the critical impact of HF definition heterogeneity on reported outcomes. This definitional inconsistency is the primary driver of the considerable heterogeneity observed in the control-arm meta-analysis ($I^2 = 93.3\%$) and underscores the urgent need for a consensus, tiered HF reporting framework in metastatic spine surgery research.