NEUROSURGICAL FOCUS

SUPPLEMENTAL MATERIAL

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Supplemental material

Evaluating robotic pedicle screw placement against conventional modalities: a systematic review and network meta-analysis

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Supplemental Table 1. Features of Included Studies

Reference	Study Type	Study Type (remove column for final version)	Language	Treatment (versus control)	Robot Type	Study Population								Pedicle screws per case mean (SD)		Pedicle screws (total)		Quality Assessment (non-RCT)
						Patients (n)		Age (mean, median*, (SD), [range])		Sex (female (%))		Body mass index (mean, median* (SD)) kg/m2						
						Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	NOS
Cannestra, 2014[4]	Retro	trt1=robot, trt2=fh	English	Robot-assisted (RBA)	Unidentifed	51	51							5.5	5.3			9
Du et al., 2020[73]	Retro	robot vs o-arm	English	RBA	Tinavi	136	166	58.6 (9.9)	60.1 (10.3)	62 (46)	80 (48)	22.5 (4.3)	23.2 (3.9)	5.6 (1.5)	5.5 (1.3)	760	908	8
Fan et al., 2018[7]	Retro	trt 1 = robotic, trt 2 = ct navigation, trt 3 = drill guide	English	RBA	Renaissance Mazor Robotics	83	109	61.6 (9.1)	63.9 (8.4)	48 (58)	65 (60)			12.2 (2.5)	11.7 (2.7)			9
Fan, et al., 2017[6]	Retro	trt1=robot, trt2=oarm	English	RBA	SpineAssist Mazor Robotics	39	51	60.6 (7.9)	65.1 (8.0)	20 (51)	31 (61)	22.9 (4.7)	24.8 (3.5)			176	234	9
Feng et al., 2019[9]	RCT	trt1=robot, trt2=FH	English	RBA	TiRobot	40	40	67.55 (6.5)	67.88 (7.34)	28 (70)	27 (67.5)	24.94 (4.52)	25.55 (3.46)			202	225	
Han et al., 2019[11]	RCT	trt1=robot, trt2=FH	English	RBA	TiRobot	115	119	54.6 (12.4)	56.1 (13.4)	60 (52)	61 (51)	25.7 (4.1)	24.9 (2.9)			532	584	
Hyun et al., 2017[14]	RCT	trt1=robot, trt2=conventional fluoroscopy	English	RBA	Renaissance Mazor Robotics	30	30	66.5 (8.1)	66.8 (8.9)	21 (70)	22 (73)	24.7 (2.6)	25.8 (3.3)	4.3	4.7	130	140	
Kantelhardt et al., 2011[19]	Retro	trt1=robot assist, trt2=conventional fluoroscopy	English	RBA	SpineAssist Mazor Robotics	55	57	62.8 [24-86]	63.4 [16-85]	30 (55)	30 (53)	27.1	26.6			250	286	9
Keric et al., 2016[20]	Retro	trt1=robot assist, trt2=conventional fluoroscopy	English	RBA	Renaissance Mazor Robotics	66	24	72.3* (11.1) [38-87]	68* (11.23) [31-84]	30 (45)	11 (46)					41	121	9
Khan et al., 2019[21]	Retro	trt1=rba, trt2=ctnav	English	RBA	MAZOR X	50	49	59.3 (11.7)	58.1 (10.5)	31 (62)	24 (48.9)	30.7 (5.1)	32.1 (5.9)			190	165	8
Kim et al., 2015[76]	RCT	trt1=mazor robot, trt2=FH	English	RBA	MAZOR X	20	20	64.4 (11.9)	64.7 (8.6)	9 (45)	12 (60)	25.3 (2.9)	28.7 (10.2)			80	80	
Kim et al., 2016[78]	RCT	trt1=robot, trt2=conventional fh	English	RBA	Renaissance Mazor Robotics	37	41	65.4 (10.4)	66.0 (8.6)	18 (50)	19 (45)	25.9	25.3			158	172	
Kim et al., 2018[22]	RCT	trt1=robot, trt2=fh	English	RBA	Renaissance Mazor Robotics	37	41	65.4 (10.4)	66.0 (8.6)	18 (49)	19 (45)	25.9	25.3					
Laudato et al., 2014[28]	Retro	trt1=robot assist, trt2=conventional fluoroscopy	English	RBA	MAZOR X	11	48									64	314	9
Laudato et al., 2018[29]	Retro	radiological study, trt 1 =	English	RBA	MAZOR X	11	25	65	63							64	191	9

		robotic assistance, trt 2 = o-arm, trt 3 = freehand																
Lieberman et al., 2012[32]	Cadaver	trial, trt1=robot, trt2=FH	English	RBA	SpineAssist Mazor Robotics	10	2									197	37	
Lonjon et al., 2015[36]	Prospective	trt1=robot, trt2=FH	English	RBA	ROSA MedTech	10	10	63.4 (11)	63.4 (11)	6 (60)	6 (60)	27.8 (4.0)	27.3 (5.6)			40	50	8
Mao, et al., 2020[37]	Retro	trt1=robot, trt2=oarm	English	RBA	MAZOR X	39	46	59.5 (12.4)	59.6 (13.7)	25 (64)	31 (67)					318	347	9
Molliqaj et al., 2017[39]	Retro	trt1=robot assist, trt2=conventional fluoroscopy	English	RBA	SpineAssist Mazor Robotics	98	71	58.3 (12.8)	54.4 (17.0)	48 (49)	35 (49)			4.47 (2.18)	6.21 (2.87)	439	441	9
Ringel et al., 2012[46]	RCT	trt1=spineassist robot, trt2=FH	English	RBA	SpineAssist Mazor Robotics	30	30	68*	67*	16 (53)	18 (60)	26*	28*			146	152	
Roser et al., 2013[47]	Prospective	trt1=robot, trt2=nav	English	RBA	SpineAssist Mazor Robotics	18	9									72	36	
Schatlo et al., 2014[49]	Retro	Retro study, trt1=robot, tr2=fluoroscopy	English	RBA	SpineAssist Mazor Robotics	55	40	52* [27-83]	58* [23-82]	29 (52.7)	28 (70)	24.7 (3.7)	28.0 (6.1)	4.3 (2.3)	4.9 (2.4)	241	163	9
Schizas et al., 2012[50]	Prospective	Trt1 = robot, trt2 = freehand	English	RBA	Unidentifed	11	23									64	64	9
Solomiichuk et al., 2017[57]	Retro	trt1=robot, trt2=conventional	English	RBA	SpineAssist Mazor Robotics	35	35	63.7 (10.6)	62.2 (11.1)	14 (40)	12 (34)			5.5 (2.1)	6.1 (2.3)	192	214	9
Tian et al., 2017[75]	RCT	trt1=robot, trt2=fluoroscopy	English	RBA	TiRobot	23	17									102	88	
Zahrawi, 2014[74]	Retro	trt1=robot, trt2=fh	English	RBA	Unidentifed	52	70							5.8	6	253	383	9
Boon Tow et al., 2015[3]	Prospective	trt1=o_arm, trt2=FH	English	O-Arm		19	19	60 (11.25)	62 (18.07)	13 (68)	6 (32)					76	76	8
Chen, et al., 2019[5]	Retro	trt1=O-arm navigation, trt2=conventional open-TLIF under C-arm fluoroscopy	English	O-Arm		21	24	52.67 (10.18)	51.71 (6.82)	9 (43)	13 (54)					84	96	8
Houten et al., 2012[13]	Retro	trt1=oarm, trt2=FH	English	O-Arm		52	42									205	141	9
Jin et al., 2016[17]	Retro	trt1=oarm, trt2=FH	English	O-Arm		13	19	14.8 [11-22]	15.3 [12-27]	8 (62)	10 (53)					92	121	9
Jing, et al., 2019[18]	Retro	trt 1=o-arm, trt2=freehand	English	O-Arm		35	25	54.80 (17.63)	53.04 (18.66)	18 (51)	12 (48)	24.73 (3.27)	24.08 (4.85)			191	150	9
Knafo et al., 2018[23]	Retro	trt1=oarm, trt2=carm	English	O-Arm		123	75	64.3 [27-88]	63.9 [26-87]	65 (53)	43 (57)					663	324	9

Liu et al., 2016[33]	Case-control	trt1=o--arm, trt2=FH	English	O-Arm		46	92	15.6 (3.4)	14.0 (2.2)	34 (74)	64 (70)					344	712	9
Liu et al., 2017[34]	Retro	trt1=oarm, trt2=FH	Chinese	O-Arm		18	23									122	136	8
Liu, Wang, et al., 2017[35]	Prospective	trt1=oarm, trt2=carm	English	O-Arm		30	23	41.6 (17.9)	43.2 (14.2)	11 (37)	8 (35)					208	156	8
Ohba et al., 2016[42]	Retro	trt1=oarm, trt2=FH	English	O-Arm		19	9	67 (14.1)	58.8 (22.1)	10 (53)	2 (22)	21.8 (6.7)	23.5 (3.9)			122	72	8
Peng, et al., 2019[43]	Retro	trt 1=o-arm, trt2=conventional	English	O-Arm		18	22	55.61 (9.29)	56.59 (7.13)	13 (72)	17 (77)					72	88	9
Sclafani et al., 2011[52]	Retro	trt1=o-arm, trt2=c-arm	English	O-Arm		4	6									22	24	9
Shin et al., 2012[55]	Retro	trt1=oarm, trt2=FH	English	O-Arm		24	45	57.7 [39-76]	59.4 [33-72]	14 (58)	24 (53)					106	204	9
Shin et al., 2015[54]	RCT	trt1=o-arm, trt2+conventional fluoroscopy	English	O-Arm		20	20	55.3 [28-75]	57.5 [30-72]	9 (45)	8 (40)					124	138	
Silbermann et al., 2011[56]	Comparison	trt1=o-arm, trt2=FH	English	O-Arm		37	30	64.41	60.1	16 (43)	15 (50)					187	150	8
Tabaraee et al., 2013[58]	Cadaver	trt1=oarm, trt2=carm	English	O-Arm		4	4							80	80			
Tajsic et al., 2018[59]	Retro	trt1=O-arm, trt2=conventional	English	O-Arm		27	93	50 [18-84]	58 [19-80]	29 (50)	43 (46)					162	504	8
Urbanski et al., 2018[64]	Retro	trt1=O-arm navigation, trt2=conventional freehand	English	O-Arm		27	22	20 [11-45]	24 [12-48]	22 (81)	19 (86)					451	384	8
Verma et al., 2016[65]	Retro	trt1=oarm, trt2=carm	English	O-Arm		278	309	27.67* [6-63]	28.9* [4-71]	62 (22)	76 (25)					1720	2173	9
Wang, et al., 2019[66]	Retro	trt1=O-arm navigation, trt2=conventional freehand	English	O-Arm		20	21	72.15 (5.58)	72.57 (6.41)	11 (55)	9 (43)					160	168	9
Yang, et al., 2020[68]	Retro	trt 1=o-arm, trt2=freehand	English	O-Arm		36	36	48.7 (9.7)	49.3 (11.2)	11 (31)	13 (36)					180	172	9
Zhang et al., 2019[71]	Prospective	trt1=o_arm, trt2=FH	English	O-Arm		50	50	54.6 (11.1)	55.6 (12.8)	33 (66)	29 (58)	25.6 (3.9)	25.3 (3.1)			100	100	9
Zhao, et al., 2018[72]	Retro	trt1=O-arm navigation, trt2=conventional freehand	English	O-Arm		27	27	14.2 (2.3)	14.8 (2.1)	19 (70)	18 (67)					484	478	9
Amiot et al., 2000[1]	Comparison using pro- and Retro data	trt1=computer-assisted, trt2=conventional	English	3D CT navigation		50	100	50.7 (13.7)	47.3 (12.7)					5.28	5.44	294	544	7

Arand et al., 2001[2]	Prospective	trt1=computer aided CT, trt2=conventional	German	3D CT navigation												72	86	8
Gruetzner et al., 2004[10]	Comparison using pro- and Retro data	trt1=3D imaging, trt2=CT	English	3D CT navigation		24	27	46.7 [20-76]	40.6	10 (42)	6 (22)	27.7 (3.4)	26.6 (3.7)			114	112	9
Han et al., 2010[12]	RCT	comparison, trt1=3D, trt2=conventional	English	3D CT navigation		22	20									92	84	
Huang et al., 2009[77]	Comparison		Chinese	3D CT navigation		21	21	*[24-64] total*		*13 (31) total*						104	98	9
Ishikawa et al., 2010[15]	Retro	trt1=3D FN, trt2=conventional	English	3D CT navigation		32	30	59.3 (9.8)	59.9 (18.3)	12 (38)	14 (47)					150	126	9
Ito et al., 2007[16]	Retro	trt1=3d navigation, trt2=conventional	English	3D CT navigation		5	5	57 [29-70]	58 [51-67]	4 (80)	5 (100)					25	27	9
Kotani et al., 2003[25]	Comparison using pro- and Retro data	trt1=computer assisted, trt2=conventional	English	3D CT navigation		17	180	42 [6-83]	N/A	10 (59)	N/A					78	669	9
Kotani et al., 2007[26]	Retro	trt1=computeer assisted, trt2=conventional	English	3D CT navigation		20	25	13 [6-18]	16 [6-18]	*37 (82) total*						57	81	9
Kotani et al., 2014[24]	Retro		English	3D CT navigation		32	29									416	222	7
Laine et al., 2000[27]	RCT	trt1=computer assisted, trt2=conventional	English	3D CT navigation		41	50	54 (16) [22-82]	53 (14) [22-77]					5.3	5.5	219	277	
Lekovic et al., 2007[31]	Retro	trt1=iso-C-arm 3D, trt2=fluoroscopy	English	3D CT navigation		12	25									94	183	9
Lee et al., 2007[30]	Comparison	trt1=CT-3D, trt2=fluoro	English	3D CT navigation		9	19									45	63	8
Liu et al., 2005[35]	Comparison	trt1=CT-baseed nav, trt2=x-ray fluoro	English	3D CT navigation												155	133	8
Liu et al., 2010[33]	Prospective	trt1=3D-C-arm, trt2=CT	English	3D CT navigation		29	29	40.6 [16-88]	48 [21-72]	8 (28)	10 (34)					140	159	8

Nakashima et al., 2009[40]	Retro	trt1=3D, trt2=conventional	English	3D CT navigation				63.2 [52-84]		17 (25)						150	150	9
Nottmeier et al., 2009[41]	Retro	trt1=3D, trt2=O/Carm	English	3D CT navigation		140	80									637	314	9
Rajasekaran et al., 2007[44]	RCT	trt1=Iso-C, trt2=FH	English	3D CT navigation		17	16	19.6 (9.3) [10-52]	15.4 (4.3) [11-19]	11 (65)	12 (75)					242	236	
Richter et al., 2005[45]	Prospective	trt1=computeer-assisted nav, trt2=conventional	English	3D CT navigation		32	20	58.4 [30-76]	54.5 [29-69]							167	93	9
Sakai et al., 2008[48]	Retro	trt1=Ct nav, trt2=FH	English	3D CT navigation		20	20	14.5 (3.1) [5-20]	15.1 (1.7) [15-22]	18 (90)	14 (70)					264	214	9
Schnake et al., 2004[51]	Retro	trt1=CT-based, trt2=conventional	German	3D CT navigation		56	41	*[16-80] total*		*42 (49) total*						211	113	9
Seller et al., 2005[53]	Prospective	trt1=computer-assisted CAOS, trt2=conventional	German	3D CT navigation		*16*										36	24	9
Tian et al., 2006[62]	Comparison	trt1=iso-C 3d nav, trt2=CT-based nav/C-arm	Chinese	3D CT navigation												187	145	9
Tian et al., 2013[60]	Cadaver	trt1=iso-c 3D, trt2=CT	English	3D CT navigation		8	8	*Adult cadavers*								80	80	
Tormenti et al., 2010[63]	Retro	trt1=XLIF, trt2=PLIF	English	3D CT navigation				60 [48-69]	61 [48-81]							164	211	9
Wood & Mannion, 2011[67]	Comparison	trt1=3D fluoro, trt2=CT merged w/ fluoro	English	3D CT navigation		43	24	53 [28-76]	53 [22-78]	21 (49)	16 (67)					186	110	9
Yu et al., 2008[69]	RCT	trt1=3d nav, trt2=traditional	Chinese	3D CT navigation		*401*												
Fu et al., 2007[9]	Retro	trt1=CTnav, trt2=fuoro	English	CT navigation		11	13									76	74	9
Merloz et al., 2007[38]	Clinical trial	trt1=nav, trt2=conventional	English	2D CT navigation		26	26	30.8 [17-64]	38.6 [18-67]	12 (46)	8 (31)					140	138	9

Table 1.

Abbreviations utilized: RCT = Randomized controlled trial. Tr1 = Treatment 1. Tr2 = Treatment 2. Retro = Retrospective study. Studies were included for analysis if they reported total number of screws or patients. All superscripted references are in reference to supplemental references below.

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Supplemental Table 2							
Author, year	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Feng et al., 2019[8]	Low	Low	High	Low	Low	Low	Low
Han et al., 2019[11]	Low	Low	High	Low	Low	Low	Low
Hyun et al., 2017[14]	Low	Low	High	Unclear	Low	Low	Low
Kim et al., 2015[76]	Low	Low	High	Low	Low	Low	Low
Kim et al., 2017[78]	Low	Low	High	Low	Low	Low	Low
Kim et al., 2018[22]	Low	Low	High	Low	Low	Low	Low
Lieberman et al., 2012[32]	Low	Low	High	Low	Low	Low	Low
Ringel et al., 2012[46]	Unclear	Unclear	High	Low	Low	Low	Low
Roser et al., 2013[47]	Unclear	Unclear	High	Unclear	Low	Low	Low
Tian et al., 2017[75]	Low	Low	High	Low	Low	Low	Low
Shin et al., 2015[54]	Low	Low	High	Low	Low	Low	Low
Laine et al., 2000[27]	Low	Unclear	High	Low	Low	Low	Low
Rajasekaran et al., 2007[44]	Low	Unclear	High	Unclear	Low	Low	Low
Yu et al., 2008[69]	Unclear	Unclear	High	Low	Low	Low	Low

*Superscript indicates references from Supplemental References accompanying Supplemental Table 1.