#### **Supplementary files**

1. Figures (Supplementary Figure 1- Supplementary Figure 26)

Supplementary Figure 1. Risk of bias summary of included studies.

Supplementary Figure 2. Risk of bias of included studies.

Supplementary Figure 3. Orthbot compared with Free-Hand on perfect pedicle screw insertion. Supplementary Figure 4. Renaissance compared with Free-Hand on perfect pedicle screw insertion. Supplementary Figure 5. ROSA compared with Free-Hand on perfect pedicle screw insertion. Supplementary Figure 6. SpineAssist compared with Free-Hand on perfect pedicle screw insertion. Supplementary Figure 7. TiRobot compared with Free-Hand on perfect pedicle screw insertion. Supplementary Figure 8. Subgroup analysis of perfect pedicle screw insertion. Supplementary Figure 9. Orthbot compared with Free-Hand on clinically acceptable pedicle. Supplementary Figure 10. Renaissance compared with Free-Hand on clinically acceptable pedicle. Supplementary Figure 11. ROSA compared with Free-Hand on clinically acceptable pedicle. Supplementary Figure 12. SpineAssist compared with Free-Hand on clinically acceptable pedicle. Supplementary Figure 13. TiRobot compared with Free-Hand on clinically acceptable pedicle. Supplementary Figure 14. Subgroup analysis of clinically acceptable pedicle. Supplementary Figure 15. Sensitivity analysis of overall complications during comparison between the robot-assisted technique versus the conventional freehand technique (excluding Zahrawi 2014). Supplementary Figure 16. Subgroup analysis of screw misplacement rate. Supplementary Figure 17. Contour-enhanced funnel plot of radiation exposure time. Supplementary Figure 18. Subgroup analysis of radiation exposure time. Supplementary Figure 19. Contour-enhanced funnel plot of radiation dosage. Supplementary Figure 20. Subgroup analysis of radiation dosage. Supplementary Figure 21. Pooled analysis of operative time. Supplementary Figure 22. Contour-enhanced funnel plot of operative time. Supplementary Figure 23. Subgroup analysis of operative time. Supplementary Figure 24. Pooled analysis of per screw time. Supplementary Figure 25. Subgroup analysis of perfect pedicle screw insertion in patients with metastases, tumor and infectious diseases of the spine.

Supplementary Figure 26. Subgroup analysis of clinically acceptable pedicle screw insertion in patients with metastases and infectious diseases of the spine.

2. Tables (Supplementary Table 1- Supplementary Table 6)

Supplementary Table 1. Search strategy.

Supplementary Table 2. Inclusion/exclusion criteria of literature.

Supplementary Table 3. Risk of bias table.

Supplementary Table 4. Newcastle-Ottawa quality assessment scale.

Supplementary Table 5. Scores of the Newcastle-Ottawa quality assessment scale for 16 cohort studies.

Supplementary Table 6. Characteristics of the included trials and participants.



Supplementary Figure 1. Risk of bias summary of included studies.



#### Supplementary Figure 2. Risk of bias of included studies.

Study	Orth Yes	bot No	Free-l Yes	Hand No							Oo wit	dds Ra th 95%	atio CI	Weight (%)
Li 2020	29	3	39	11		0		-			- 2.73 [	0.70,	10.67]	100.00
Overall						_					2.73 [	0.70,	10.67]	
Heteroge	neity:	<b>T</b> <sup>2</sup> =	0.00, I	<sup>2</sup> = .%	, H <sup>2</sup> = .									
Test of $\theta_i$	= θ <sub>j</sub> : 0	Q(0)	= -0.00	), p =	•									
Test of θ	= 0: z	= 1.	44, p =	0.15										
							1	2	4	8	_			
Random-e	ffects	REN	/L mod	del										

# Supplementary Figure 3. Orthbot compared with Free-Hand on perfect pedicle screw insertion.

# Supplementary Figure 4. Renaissance compared with Free-Hand on perfect pedicle screw

#### insertion.

	Renais	sance	Free-l	Hand						0	dds Ra	tio	Weight
Study	Yes	No	Yes	No						wi	th 95%	CI	(%)
Kim 2015	76	4	73	7		 			_	1.82 [	0.51,	6.49]	14.47
Hyun 2017	127	3	133	7						2.23 [	0.56,	8.81]	13.26
Kim 2016	148	10	158	14		 -				1.31 [	0.57,	3.04]	20.61
Keric 2016	268	73	43	78						- 6.66 [	4.23,	10.48]	27.00
Zhang 2021	250	17	251	37		—				2.17 [	1.19,	3.95]	24.65
Overall						-				2.59 [	1.34,	5.02]	
Heterogeneit	y: τ <sup>2</sup> = 0	.37, I <sup>2</sup>	= 70.8	38%, H	$H^2 = 3.43$								
Test of $\theta_i = \theta_i$	: Q(4) =	16.81	l, p = (	0.00									
Test of $\theta = 0$ :	z = 2.82	2, p =	0.00										
						1	2	4	8	-			

#### Supplementary Figure 5. ROSA compared with Free-Hand on perfect pedicle screw insertion.



# Supplementary Figure 6. SpineAssist compared with Free-Hand on perfect pedicle screw

#### insertion.

	SpineA	ssist	Free	-Hand					O	dds Ra	atio	Weight
Study	Yes	No	Yes	No					wit	h 95%	CI	(%)
Kantelhardt 2011	226	24	251	35		-			1.31 [	0.76,	2.28]	12.02
Ringel 2012	82	64	103	49		-			0.61 [	0.38,	0.98]	14.18
Lieberman 2012	130	67	20	17		-			1.65 [	0.81,	3.36]	8.65
Schizas 2012	51	13	53	11		_	<u> </u>		0.81 [	0.33,	1.98]	6.19
Roser 2013	71	1	39	1			-		— 1.82 [	0.11,	29.91]	0.78
Laudato 2014	50	14	221	93		-			1.50 [	0.79,	2.85]	9.96
Schatlo 2014	204	40	130	33		-			1.29 [	0.78,	2.16]	13.05
Molliqaj 2017	366	73	335	106					1.59 [	1.14,	2.21]	18.99
Solomiichuk 2017	129	63	136	78		-	-		1.17 [	0.78,	1.77]	16.17
Overall							•		1.20 [	0.94,	1.55]	
Heterogeneity: $\tau^2$ =	= 0.06, I	<sup>2</sup> = 42	.56%,	$H^2 = 1.74$								
Test of $\theta_i = \theta_j$ : Q(8	) = 12.82	2, p =	0.12									
Test of $\theta = 0$ : z = 1	.45, p =	0.15										
					1/8	1/2	2	8				
Dondom offecto DE	MI mod											

	TiRo	obot	Free-	Hand		Odds Ratio	Weight
Study	Yes	No	Yes	No		with 95% CI	(%)
Tian 2017	99	3	81	7	2.85	[ 0.71, 11.38	2.48
Han 2019	507	25	503	81		[ 2.05, 5.20	21.93
Zhang 2019	85	15	71	25	2.00	[ 0.98, 4.07	9.32
Fan 2019	163	23	124	80		[ 2.72, 7.68	] 17.60
Mao 2019	220	14	244	34	2.19	[ 1.14, 4.19	11.28
Chen 2020	340	38	589	197		[ 2.06, 4.34	34.27
Feng 2019	199	3	206	19	6.12	[ 1.78, 21.00	3.12
Overall					◆ 3.12	[ 2.51, 3.88	]
Heterogeneit	у: т <sup>2</sup> =	0.00	$ ,  ^2 = 0$	0. <mark>00</mark> %,	$H^2 = 1.00$		
Test of $\theta_i = \theta_j$	: Q(6)	= 5.9	98, p =	0.43			
Test of $\theta = 0$ :	z = 10	0.24,	p = 0.	00			
					1 2 4 8 16		
Random-effec	ts REI	ML m	odel				

# Supplementary Figure 7. TiRobot compared with Free-Hand on perfect pedicle screw insertion.

### Supplementary Figure 8. Subgroup analysis of perfect pedicle screw insertion.

					Oc	lds Ra	atio	
Study	K				wit	h 95%	5 CI	P-value
Treats								
Orthbot	1		•		-2.73 [	0.70,	10.67]	0.150
Renaissance	5				2.59 [	1.34,	5.02]	0.005
ROSA	1		•		2.10 [	0.52,	8.52]	0.301
SpineAssist	9		<b>⊹</b> ⊷		1.20 [	0.94,	1.55]	0.146
TiRobot	7			•	3.12 [	2.51,	3.88]	0.000
Test of group differences:	Q <sub>b</sub> (4) = 32.20, p = 0.00							
Indications								
Cervical spine	1		-	•	4.57 [	2.72,	7.68]	0.000
Degenerative scoliosis	1		i —	-	2.99 [	2.06,	4.34]	0.000
NA	2		<b></b>		1.57 [	0.97,	2.52]	0.064
Thoracic and lumbar spin	e 19				1.86 [	1.36,	2.53]	0.000
Test of group differences:	Q <sub>b</sub> (3) = 12.92, p = 0.00		1					
Images								
C-arm	8			•—	3.09 [	2.49,	3.83]	0.000
CT	15				1.58 [	1.13,	2.20]	0.007
Test of group differences:	Q <sub>b</sub> (1) = 11.00, p = 0.00							
Operation methods								
Cervical spinal surgery	1		-	•	4.57 [	2.72,	7.68]	0.000
NA	10			_	2.22 [	1.46,	3.37]	0.000
PLIF	7				1.86 [	1.22,	2.83]	0.004
PLIF and TLIF	2	•	1		0.88 [	0.42,	1.87]	0.745
TLIF	3			-	2.10 [	1.33,	3.31]	0.001
Test of group differences:	Q <sub>b</sub> (4) = 13.96, p = 0.01							
Overall			•		1.98 [	1.51,	2.59]	0.000
Heterogeneity: $\tau^2 = 0.28$ ,	$I^2 = 74.28\%, H^2 = 3.89$							
Test of $\theta_i = \theta_j$ : Q(22) = 92	.99, p = 0.00				_			
		1/2	1 2	4 8				
Random-effects REML mo	del							

CT: computed tomography; PLIF: Posterior lumbar interbody fusion; TLIF: Transforaminal lumbar

interbody fusion.

#### Supplementary Figure 9. Orthbot compared with Free-Hand on clinically acceptable pedicle.



	Renais	sance	e Free-	Hand					Odds Ratio Weight
Study	Yes	No	Yes	No					with 95% CI (%)
Kim 2015	80	0	79	1	_				- 3.04 [ 0.12, 75.69] 2.15
Hyun 2017	130	0	138	2					-4.71 [ 0.22, 99.06] 2.39
Kim 2016	157	1	171	1				-	0.92 [ 0.06, 14.80] 2.87
Keric 2016	307	34	89	32			-		3.25 [ 1.90, 5.56] 76.90
Zhang 2021	263	4	279	9		_			2.12 [ 0.65, 6.97] 15.68
Overall							•		2.95 [ 1.84, 4.73]
Heterogenei	ty: т <sup>2</sup> = 0	.00, I	<sup>2</sup> = 0.0	0%, H <sup>2</sup> = 1.00					
Test of $\theta_i = \theta_i$	j: Q(4) =	: 1.19	, p = 0	.88					
Test of $\theta = 0$	: z = 4.5	0, p =	0.00						
					1/16	1/2	4	32	_

# Supplementary Figure 10. Renaissance compared with Free-Hand on clinically acceptable pedicle.

ROSA Free-Hand Study Yes No Yes No		Odds Ratio Weight with 95% Cl (%)
Lonjon 2016 35 1 46 4		- 3.04 [ 0.33, 28.44] 100.00
Overall		- 3.04 [ 0.33, 28.44]
Heterogeneity: $\tau^2 = 0.00$ , $I^2 = .\%$ , $H^2 = .$		
Test of $\theta_i = \theta_j$ : Q(0) = 0.00, p = .		
Test of $\theta$ = 0: z = 0.98, p = 0.33		_
	1/2 1 2 4 8 16	_
Random-effects REML model		

# Supplementary Figure 11. ROSA compared with Free-Hand on clinically acceptable pedicle.

	Spine/	Assist	Free-l	Hand		Odds Ratio	Weight
Study	Yes	No	Yes	No		with 95% CI	(%)
Kantelhardt 2011	236	14	262	24		1.54 [ 0.78, 3.05]	15.24
Ringel 2012	122	24	141	11		0.40 [ 0.19, 0.84]	13.81
Lieberman 2012	182	15	32	5		1.90 [ 0.64, 5.58]	8.94
Schizas 2012	61	3	59	5		1.72 [ 0.39, 7.54]	5.60
Roser 2013	71	1	40	0		-0.59 [ 0.02, 14.78]	1.39
Laudato 2014	60	4	294	20	<b>_</b>	1.02 [ 0.34, 3.09]	8.62
Schatlo 2014	223	21	142	21		1.57 [ 0.83, 2.98]	16.13
Molliqaj 2017	425	14	421	20		1.44 [ 0.72, 2.89]	14.95
Solomiichuk 2017	172	20	197	17		0.74 [ 0.38, 1.46]	15.32
Overall					-	1.11 [ 0.75, 1.64]	
Heterogeneity: $\tau^2$ =	0.14, I	<sup>2</sup> = 4 <sup>2</sup>	1.97%,	$H^2 = 1.72$			
Test of $\theta_i = \theta_j$ : Q(8)	= 12.5	4, p =	0.13				
Test of $\theta = 0$ : $z = 0$ .	52, p =	0.61					
					1/32 1/8 1/2 2 8	_	
Random-effects REM	ML mod	del					

# Supplementary Figure 12. SpineAssist compared with Free-Hand on clinically acceptable pedicle.

Study	TiRo Yes	bot No	Free-I Yes	Hand No							Odds Ra with 95%	CI	Weight (%)
	100	0	07				1			0.5		07.071	0.04
Tian 2017	102	0	87	1		-				- 3.5	1 [ 0.14,	87.37]	2.21
Han 2019	525	7	546	38				_	-	5.2	2[2.31,	11.79]	34.33
Zhang 2019	98	2	94	2			+			1.0	4 [ 0.14,	7.55]	5.82
Fan 2019	184	2	186	18					<u> </u>	8.9	0[2.04,	38.92]	10.48
Mao 2019	230	4	264	14			-	-		3.0	5[0.99,	9.39]	18.01
Chen 2020	373	5	725	61				-	_	6.2	8 [ 2.50,	15.75]	26.93
Feng 2019	202	0	224	1			-	•		- 2.7	1[0.11,	66.80]	2.22
Overall								٠		4.6	8 [ 2.91,	7.55]	
Heterogeneit	у: т <sup>2</sup> =	0.00	$  _{1}^{2} = 0$	0.00%,	$H^2 = 1.00$								
Test of $\theta_i = \theta_j$	: Q(6)	= 4.	10, p =	0.66									
Test of $\theta = 0$ :	z = 6.	.34, p	0.0 = 0.0	0									
						1/8	1	8	6	4			
Random-effec	ts REI	ML m	odel										

# Supplementary Figure 13. TiRobot compared with Free-Hand on clinically acceptable pedicle.

Supi	olementarv	Figure	14. Subgro	oup analysi	s of clinically	acceptable	pedicle.

						Odds Ratio	
Study	K					with 95% Cl	P-value
Treats				1			
Orthbot	1						0.681
Renaissance	5					2.95 [ 1.84, 4.73]	0.000
ROSA	1			•		- 3.04 [ 0.33, 28.44]	0.329
SpineAssist	9		-	<b>•</b>		1.11 [ 0.75, 1.64]	0.606
TiRobot	7			-	-	4.68 [ 2.91, 7.55]	0.000
Test of group differences:	Q <sub>b</sub> (4) = 23.12, p = 0.00						
Indications							
Cervical spine	1			i —	•	— 8.90 [ 2.04, 38.92]	0.004
Degenerative scoliosis	1			. —	•	6.28 [ 2.50, 15.75]	0.000
NA	2		-	•		1.40 [ 0.65, 3.04]	0.391
Thoracic and lumbar spin	e 19					1.69 [ 1.12, 2.54]	0.012
Test of group differences:	Q <sub>b</sub> (3) = 11.28, p = 0.01						
Images							
C-arm	8			-	-	4.60 [ 2.88, 7.33]	0.000
СТ	15			•		1.38 [ 0.94, 2.03]	0.104
Test of group differences:	Q <sub>b</sub> (1) = 15.12, p = 0.00						
Operation methods							
Cervical spinal surgery	1			. —	•	— 8.90 [ 2.04, 38.92]	0.004
NA	10					2.23 [ 1.46, 3.41]	0.000
PLIF	7		-	 		1.95 [ 0.84, 4.51]	0.118
PLIF and TLIF	2	-	•	1		0.79 [ 0.21, 2.99]	0.729
TLIF	3			•	_	2.45 [ 1.00, 6.00]	0.050
Test of group differences:	Q <sub>b</sub> (4) = 5.85, p = 0.21						
Overall				•		1.92 [ 1.31, 2.81]	0.001
Heterogeneity: $\tau^2 = 0.40$ ,	l <sup>2</sup> = 58.21%, H <sup>2</sup> = 2.39						
Test of $\theta_i = \theta_j$ : Q(22) = 49	.39, p = 0.00						
		1/8	1/2	2	8	32	
Random-effects REML mo	del						

CT: computed tomography; PLIF: Posterior lumbar interbody fusion; TLIF: Transforaminal lumbar

interbody fusion.

Supplementary Figure 15. Sensitivity analysis of overall complications during comparison between the robot-assisted technique versus the conventional freehand technique (excluding Zahrawi 2014).

#### Weight Robot-assisted Free-Hand Odds Ratio with 95% CI Study Yes No Yes No (%) Kantelhardt 2011 24 142 85 95 -0.19 [ 0.11, 0.32] 29.77 Ringel 2012 1 0 30 3.10 [ 0.12, 79.23] 2.20 29 Schatlo 2014 2 0.35 [ 0.03, 4.02] 1 54 38 3.75 Cannestra 2014 1 50 4 47 0.23 [ 0.03, 2.18] 4.42 Keric 2016 21 320 15 106 0.46 [ 0.23, 0.93] 23.57 Kim 2016 0 37 1 40 0.36 [ 0.01, 9.11] 2.21 Solomiichuk 2017 5 30 9 26 0.48 [ 0.14, 1.62] 12.06 Fan 2019 7 0.14 [ 0.02, 1.18] 1 60 59 4.80 Chen 2020 1 30 2 64 1.07 [ 0.09, 12.23] 3.74 Zhang 2021 6 33 10 32 0.58 [ 0.19, 1.79] 13.47 0.36 [ 0.22, 0.58] Overall Heterogeneity: $\tau^2 = 0.14$ , $I^2 = 26.01\%$ , $H^2 = 1.35$ Test of $\theta_i = \theta_j$ : Q(9) = 9.99, p = 0.35 Test of $\theta$ = 0: z = -4.10, p = 0.00 1/64 1/4 4 64

Supplementary	Figure	16. Subgroup	analysis of screw	misplacement rate.
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Supplementary Figure 17. Contour-enhanced funnel plot of radiation exposure time.

### Supplementary Figure 18. Subgroup analysis of radiation exposure time.

					Ν	lean Diff		
Study	К				W	ith 95% (		P-value
Treats								
NA	1				-33.10 [	-38.11,	-28.09]	0.000
Orthbot	1		+		-1.71 [	-4.78,	1.36]	0.275
Renaissance	2				-5.18 [	-14.12,	3.77]	0.257
ROSA	1				49.80 [	44.55,	55.05]	0.000
SpineAssist	4	-			-2.20 [	-25.47,	21.07]	0.853
TiRobot	3				10.96 [	4.27,	17.65]	0.001
Test of group differences: $Q_{b}$	(5) = 522.68, p = 0.00							
Indications								
NA	2	+			-32.61 [	-35.72,	-29.50]	0.000
Thoracic and lumbar spine	10				9.85 [	-1.05,	20.75]	0.077
Test of group differences: $Q_{b}$	(1) = 53.89, p = 0.00							
Images								
C-arm	4		•		21.29 [	1.58,	41.00]	0.034
СТ	7				-3.48 [	-15.55,	8.60]	0.573
NA	1		i i		-33.10 [	-38.11,	-28.09]	0.000
Test of group differences: $Q_b$	(2) = 43.21, p = 0.00							
Operation methods								
NA	7				-5.79 [	-20.20,	8.62]	0.431
PLIF	2				-8.64 [	-18.17,	0.89]	0.076
TLIF	3				24.90 [	-0.61,	50.41]	0.056
Test of group differences: $Q_{b}$	(2) = 5.85, p = 0.05							
Overall					2.45 [	-10.61,	15.51]	0.713
Heterogeneity: $\tau^2 = 501.02$ , l	<sup>2</sup> = 99.51%, H <sup>2</sup> = 204.02							
Test of $\theta_i = \theta_j$ : Q(11) = 920.8	5, p = 0.00							
•		-50	0	50				
			~	50				

Random-effects REML model

CT: computed tomography; PLIF: Posterior lumbar interbody fusion; TLIF: Transforaminal lumbar

interbody fusion.



Supplementary Figure 19. Contour-enhanced funnel plot of radiation dosage.

Supplementary	Figure 20.	Subgroup	analysis of r	adiation dosa	σe.
Supplementaly	riguite 20.	Subgroup	analy 515 01 1	autation uosa	ge.

					N	lean Diff		
Study	к				wi	th 95% (		P-value
Treats								
Renaissance	1			+	-0.14 [	-0.19,	-0.09]	0.000
SpineAssist	4				-4.05 [	-9.47,	1.37]	0.143
TiRobot	4				-28.89 [	-45.86,	-11.91]	0.001
Test of group differences: Q	<sub>b</sub> (2) = 13.01, p = 0.00							
Indications								
NA	1		-	•-	-9.90 [	-11.58,	-8.22]	0.000
Thoracic and lumbar spine	8	-	•		-15.00 [	-27.76,	-2.25]	0.021
Test of group differences: Q	<sub>b</sub> (1) = 0.60, p = 0.44							
Images								
C-arm	4				-28.89 [	-45.86,	-11.91]	0.001
CT	5				-3.21 [	-7.63,	1.21]	0.155
Test of group differences: Q	<sub>b</sub> (1) = 8.24, p = 0.00							
Operation methods								
NA	4		•		16.38 [	-37.52,	4.76]	0.129
PLIF	3			_ <b>_</b>	-1.77 [	-6.59,	3.04]	0.470
TLIF	2				-29.61 [	-40.86,	-18.36]	0.000
Test of group differences: Q	<sub>b</sub> (2) = 20.76, p = 0.00							
Overall					-14.38 [	-25.62,	-3.13]	0.012
Heterogeneity: $\tau^2 = 288.00$ ,	$I^2 = 100.00\%, H^2 = 27585.80$							
Test of $\theta_i = \theta_i$ : Q(8) = 462.20	0, p = 0.00			1				
		-40	-20		-			
		-40	-20	0				

Random-effects REML model

CT: computed tomography; PLIF: Posterior lumbar interbody fusion; TLIF: Transforaminal lumbar

interbody fusion.

	R	obot-assi	sted		Free-Ha	nd	Mean Diff. Weigh
Study	Ν	Mean	SD	Ν	Mean	SD	with 95% Cl (%)
Kantelhardt 2011	55	59.1	1	57	52.9	1	6.20 [ 5.83, 6.57] 7.96
Lieberman 2012	10	243	64.8	2	376.2	183	-133.20 [ -261.38, -5.02] 0.99
Schatlo 2014	55	205	44	40	189	39	16.00 [ -1.10, 33.10] 7.07
Keric 2016	66	218.8	85.4	24	202.6	80	
Kim 2016	37	220.1	55.9	41	189.8	45.1	30.30 [ 7.85, 52.75] 6.54
Hyun 2017	30	208.5	66.7	30	208.5	62.5	0.00 [ -32.71, 32.71] 5.45
Lonjon 2016	10	186	21	10	112	29	- 74.00 [ 51.81, 96.19] 6.57
Solomiichuk 2017	35	226.1	78.8	35	264.1	124.3	-38.00 [ -86.76, 10.76] 3.94
Tian 2017	23	138.9	46.6	17	118.2	40.6	
Fan 2019	61	220	88.33	66	210	88.33	10.00 [ -20.75, 40.75] 5.66
Feng 2019	40	111.6	33	40	114.6	26.4	-3.00 [ -16.10, 10.10] 7.41
Han 2019	115	149.5	50.8	119	138	48.6	11.50 [ -1.24, 24.24] 7.44
Zhang 2019	50	184.7	54.3	50	117.8	36.9	66.90 [ 48.70, 85.10] 6.97
Mao 2019	57	161.3	56	59	144.7	46.2	16.60 [ -2.06, 35.26] 6.92
Chen 2020	31	283.1	30.8	66	291.9	40	-8.80 [ -24.74, 7.14] 7.18
Li 2020	7	289	87	10	266	92	23.00 [ -63.96, 109.96] 1.88
Zhang 2021	39	189.23	32.96	42	199.05	36.41	-9.82 [ -24.98, 5.34] 7.24
Overall							♦ 13.77 [ 0.14, 27.39]
Heterogeneity: $\tau^2 =$	607.2	4, I <sup>2</sup> = 91	.73%, H	l <sup>2</sup> = 12	2.10		
Test of $\theta_i = \theta_j$ : Q(16)	6) = 10	5.04, p =	0.00				
Test of $\theta = 0$ : $z = 1$ .	.98, p :	= 0.05					
						-3	
Random-effects RFI	ML mo	del				-01	

# Supplementary Figure 21. Pooled analysis of operative time.



Supplementary Figure 22. Contour-enhanced funnel plot of operative time.

### Supplementary Figure 23. Subgroup analysis of operative time.

						N	lean Diff.		
Study	К					W	ith 95% C		P-value
Treats									
Orthbot	1			_		- 23.00 [	-63.96,	109.96]	0.604
Renaissance	4					7.89 [	-12.83,	28.61]	0.455
ROSA	1				-	74.00 [	51.81,	96.19]	0.000
SpineAssist	4				-	-6.13 [	-36.88,	24.63]	0.696
TiRobot	7				-	15.99 [	-2.97,	34.95]	0.098
Test of group differences: Q	,(4) = 26.15, p = 0.00								
Indications									
Cervical spine	1				- <b> </b>	10.00 [	-20.75,	40.75]	0.524
Degenerative scoliosis	1				-	-8.80 [	-24.74,	7.14]	0.279
NA	1	-		•		-133.20 [	-261.38,	-5.02]	0.042
Thoracic and lumbar spine	10					23.44 [	4.61,	42.27]	0.015
Thoracic and lumbar spine	4				•	6.20 [	5.83,	6.57]	0.000
Test of group differences: Q	,(4) = 11.23, p = 0.02								
Images									
C-arm	8					23.18 [	1.70,	44.67]	0.034
СТ	9				-	5.35 [	-6.40,	17.10]	0.372
Test of group differences: Q	,(1) = 2.04, p = 0.15								
Operation methods									
Cervical spinal surgery	1				- <b> </b>	10.00 [	-20.75,	40.75]	0.524
NA	6				+	5.30 [	-9.31,	19.90]	0.477
PLIF	6				+	3.28 [	-11.16,	17.72]	0.656
PLIF and TLIF	1				•	6.20 [	5.83,	6.57]	0.000
TLIF	3					52.25 [	16.75,	87.76]	0.004
Test of group differences: Q	(4) = 6.69, p = 0.15								
Overall					•	13.77 [	0.14,	27.39]	0.048
Heterogeneity: $\tau^2 = 607.24$ ,	<sup>2</sup> = 91.73%, H <sup>2</sup> = 12.10								
Test of $\theta_i = \theta_j$ : Q(16) = 105.0	94, p = 0.00								
		-300	-200	-100	0 1	- 00			
Random-effects REML mode	l								

CT: computed tomography; PLIF: Posterior lumbar interbody fusion; TLIF: Transforaminal lumbar interbody fusion.

# Supplementary Figure 24. Pooled analysis of per screw time.

	Ro	oot-assi	sted	F	ree-Ha	nd					Mean Diff.	Weight
Study	Ν	Mean	SD	Ν	Mean	SD					with 95% CI	(%)
Lieberman 2012	197	4.05	1.08	37	6.27	3.05					-2.22 [ -2.77, -1.67]	49.24
Feng 2019	202	5.48	1.37	225	5.69	1.29				-	-0.21 [ -0.46, 0.04]	50.76
Overall											<del>-1.20</del> [ -3.17, 0.77]	
Heterogeneity: T <sup>2</sup>	= 1.97,	l <sup>2</sup> = 97.	.66%,	$H^{2} = 4$	2.73							
Test of $\theta_i = \theta_j$ : Q(1	) = 42.	73, p =	0.00									
Test of $\theta = 0$ : z = -	1.19, p	o = 0.23										
						-	3	-2	-1	C	)	
Random-effects RE	EML mo	odel										

### Supplementary Figure 25. Subgroup analysis of perfect pedicle screw insertion in patients with

#### metastases, tumor and infectious diseases of the spine.

	Robot-as	ssiste	I Free-	Hand		Odds Ratio	Weight
Study	Yes	No	Yes	No		with 95% CI	(%)
Others							
Kantelhardt 2011	226	24	251	35		1.31 [ 0.76, 2.28]	5.33
Ringel 2012	82	64	103	49		0.61 [ 0.38, 0.98]	5.67
Lieberman 2012	130	67	20	17		1.65 [ 0.81, 3.36]	4.64
Schizas 2012	51	13	53	11		0.81 [ 0.33, 1.98]	3.92
Roser 2013	71	1	39	1 -		- 1.82 [ 0.11, 29.91]	0.82
Laudato 2014	50	14	221	93		1.50 [ 0.79, 2.85]	4.94
Schatlo 2014	204	40	130	33		1.29 [ 0.78, 2.16]	5.50
Kim 2015	76	4	73	7		1.82 [ 0.51, 6.49]	2.72
Hyun 2017	127	3	133	7		2.23 [ 0.56, 8.81]	2.46
Kim 2016	148	10	158	14		1.31 [ 0.57, 3.04]	4.11
Keric 2016	268	73	43	78		6.66 [ 4.23, 10.48]	5.74
Zhang 2021	250	17	251	37		2.17 [ 1.19, 3.95]	5.12
Lonjon 2016	33	3	42	8		2.10 [ 0.52, 8.52]	2.40
Tian 2017	99	3	81	7		2.85 [ 0.71, 11.38]	2.44
Han 2019	507	25	503	81		3.27 [ 2.05, 5.20]	5.69
Zhang 2019	85	15	71	25		2.00 [ 0.98, 4.07]	4.63
Fan 2019	163	23	124	80		4.57 [ 2.72, 7.68]	5.47
Mao 2019	220	14	244	34		2.19 [ 1.14, 4.19]	4.91
Chen 2020	340	38	589	197		2.99 [ 2.06, 4.34]	6.06
Feng 2019	199	3	206	19		6.12 [ 1.78, 21.00]	2.81
Li 2020	29	3	39	11		2.73 [ 0.70, 10.67]	2.49
Heterogeneity: $\tau^2 = 0.30$ , $I^2 = 72.33\%$ , $H^2 = 3.61$					•	2.08 [ 1.55, 2.79]	
Test of $\theta_i = \theta_j$ : Q(20) = 83.19, p = 0.00							
Metastases and infectious diseases of the spine							
Molliqaj 2017	366	73	335	106	-	1.59 [ 1.14, 2.21]	6.21
Solomiichuk 2017	129	63	136	78	-	1.17 [ 0.78, 1.77]	5.92
Heterogeneity: τ <sup>2</sup> = 0.01, I <sup>2</sup> = 19.68%, H <sup>2</sup> = 1.25					•	1.40 [ 1.05, 1.87]	
Test of $\theta_i = \theta_i$ : Q(1) = 1.25, p = 0.26							
Overall					•	1.98 [ 1.51, 2.59]	
Heterogeneity: T = 0.28, I = 74.28%, H = 3.89							
Test of $\theta_i = \theta_i$ : Q(22) = 92.99, p = 0.00							
Test of group differences: $Q_{\rm b}(1) = 3.51$ , p = 0.06							
				1/	8 1/2 2 8	_	

Supplementary Figure 26. Subgroup analysis of clinically acceptable pedicle screw insertion in patients with metastases and infectious diseases of the spine.

	Robot-a:	ssiste	f Free	-Hand		Odds Ratio	Weight
Study	Yes	No	Yes	No		with 95% CI	(%)
Others							
Kantelhardt 2011	236	14	262	24		1.54 [ 0.78, 3.05]	7.33
Ringel 2012	122	24	141	11		0.40 [ 0.19, 0.84]	6.97
Lieberman 2012	182	15	32	5	-+ <b></b>	1.90 [ 0.64, 5.58]	5.42
Schizas 2012	61	3	59	5		1.72 [ 0.39, 7.54]	3.94
Roser 2013	71	1	40	0 -		0.59 [ 0.02, 14.78]	1.22
Laudato 2014	60	4	294	20		1.02 [ 0.34, 3.09]	5.29
Schatlo 2014	223	21	142	21	-+	1.57 [ 0.83, 2.98]	7.53
Kim 2015	80	0	79	1		3.04 [ 0.12, 75.69]	1.23
Hyun 2017	130	0	138	2		- 4.71 [ 0.22, 99.06]	1.35
Kim 2016	157	1	171	1		0.92 [ 0.06, 14.80]	1.57
Keric 2016	307	34	89	32		3.25 [ 1.90, 5.56]	8.04
Zhang 2021	263	4	279	9		2.12 [ 0.65, 6.97]	4.96
Lonjon 2016	35	1	46	4		3.04 [ 0.33, 28.44]	2.23
Tian 2017	102	0	87	1		- 3.51 [ 0.14, 87.37]	1.23
Han 2019	525	7	546	38		5.22 [ 2.31, 11.79]	6.66
Zhang 2019	98	2	94	2		1.04 [ 0.14, 7.55]	2.68
Fan 2019	184	2	186	18		8.90 [ 2.04, 38.92]	3.94
Mao 2019	230	4	264	14		3.05 [ 0.99, 9.39]	5.22
Chen 2020	373	5	725	61		6.28 [ 2.50, 15.75]	6.15
Feng 2019	202	0	224	1		2.71 [ 0.11, 66.80]	1.23
Li 2020	32	0	49	1		1.97 [ 0.08, 49.85]	1.22
Heterogeneity: $\tau^2 = 0.39$ , $I^2 = 54.60\%$ , $H^2 = 2.20$					•	2.13 [ 1.41, 3.22]	
Test of $\theta_i$ = $\theta_j$ : Q(20) = 40.92, p = 0.00							
Metastases and infectious diseases of the spine							
Molliqaj 2017	425	14	421	20		1.44 [ 0.72, 2.89]	7.25
Solomiichuk 2017	172	20	197	17		0.74 [ 0.38, 1.46]	7.35
Heterogeneity: $\tau^2 = 0.10$ , $I^2 = 44.29\%$ , $H^2 = 1.80$					🔶 🔶	1.03 [ 0.54, 1.97]	
Test of $\theta_i$ = $\theta_i$ : Q(1) = 1.80, p = 0.18							
Overall					•	1.92 [ 1.31, 2.81]	
Heterogeneity: τ <sup>2</sup> = 0.40, I <sup>2</sup> = 58.21%, H <sup>2</sup> = 2.39							
Test of $\theta_1 = \theta_1$ : Q(22) = 49.39, p = 0.00							
Test of group differences: $Q_h(1) = 3.43$ , p = 0.06							
				1/	32 1/4 2 16	_	

# Supplementary Table 1. Search strategy

Database	Search strategy
Pubmed	#1 "Spine"[MeSH Terms] OR "Vertebral Column"[All Fields] OR "Vertebral Columns"[All Fields] OR
	"Spinal Column"[All Fields] OR "Spinal Columns"[All Fields] OR "Spine"[All Fields] OR "Vertebra"[All
	Fields] OR "Vertebrae"[All Fields]
	#2 "Robotics"[MeSH Terms] OR "robot"[All Fields] OR "robotics"[All Fields] OR" robotic"[All Fields]
	#3 #1 AND #2
Embase	#1 "Vertebral Column"[All Fields] OR "Vertebral Columns"[All Fields] OR "Spinal Column"[All Fields]
	OR "Spinal Columns" [All Fields] OR "Spine" [All Fields] OR "Vertebra" [All Fields] OR "Vertebrae" [All
	Fields]
	#2 "robot"[All Fields] OR "robotics"[All Fields] OR" robotic "[All Fields]
	#3 #1 AND #2
Cochrane library	#1 "Vertebral Column"[TI,AB,KW] OR "Vertebral Columns"[TI,AB,KW] OR "Spinal
	Column"[TI,AB,KW] OR "Spinal Columns"[TI,AB,KW] OR "Spine"[TI,AB,KW] OR
	"Vertebra"[TI,AB,KW] OR "Vertebrae"[TI,AB,KW]
	#2 "robot"[TI,AB,KW] OR "robotics"[TI,AB,KW] OR" robotic"[TI,AB,KW]
	#3 #1 AND #2

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# Supplementary Table 2. Inclusion/exclusion criteria of literature.

PICOS	Inclusion	Exclusion
Р	patients with spinal disorders that underwent pedicle screw placement were included in our study	Patients younger than 18 years old.
Ι	<ol> <li>patients in the case- or experimental group received robotic-assisted pedicle screw implantation surgery;</li> <li>No limit on sample size.</li> </ol>	Other types of minimally invasive technique were excluded.
С	patients in the control groups underwent conventional freehand approach.	Did not differentiate between single-level and multilevel surgery were
		not eligible.
0	1) Primary outcomes including accuracy of pedicle-screw placement, proximal joint violation, and complications.	Relevant outcomes were missing.
	2) Secondary outcome included radiation time, radiation exposure and surgical time.	
S	RCTs, prospective cohort studies,	1) Articles without peer-reviewed or unpublished;
	and retrospective comparative studies in our analysis.	2) Studies that were repeatedly published or had qualitative outcomes;
		3) Quasi-experimental studies and crossover studies.

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# Supplementary Table 3. Risk of bias table.

1	Random sequence generation (selection bias)
2	Allocation concealment (selection bias)
3	Blinding of participants and personnel (performance bias)
4	Blinding of outcome assessment (detection bias)
5	Incomplete outcome data (attrition bias)
6	Selective reporting (reporting bias)
7	Other bias

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#### Supplementary Table 4. Newcastle-Ottawa quality assessment scale.

Selection
1. Representativeness of the exposed cohort
a) Truly representative of the average(describe) in the community.
b) Somewhat representative of the average in the community.
c) Selected group of the users eg. Nurses, volunteers.
d)No description of the derivation of the cohort.
2. Selection of the non exposed cohort
a) Drawn from the same community as the exposed cohort.
b) Drawn from a different source.
c) No description of the derivation of the non exposed cohort.
3. Ascertainment of exposure
a) Secure record (eg. Surgical records).
b) Structured interview.
c) Written self report.
d) No description.
3. Demonstration that outcome of interest was not present at start of study
a) Yes.
d) No.
Comparability
3. Comparability of the cohorts on the basis of the design or analysis
a) Study controls for(select the most important factor).
b) Study controls for any additional factor (This criteria could be modified to indicate specific control for a second important factor).
Outcome
1. Assessment of outcome

a) Independent blind assessment.
b) Record linkage.
c) Self report.
a) No description.
2. Was follow up long enough for outcomes to occur
a) Yes (select an adequate follow up period for outcome of interest).
b) No.
3. Adequacy of follow up of cohorts
a) Complete follow up-all subjects accounted for.
b) Subjects lost to follow up unlikely to introduce bias.
c) Follow up rate <10% and no description of those lost.
d) No statement.

Study	Selection	Comparability	Outcome	Total		
Kantelhardt 2011	***	**	***	*******       ******       ******       ******       ******       ******       ******       ******       ******       ******       ******		
Lieberman 2012	***	*	***			
Schizas 2012	***	*	***			
Cannestra 2014	***	*	**			
Laudato 2014	****	**	***			
Schatlo 2014	***	*	***			
Zahrawi 2014	*	-	**			
Lonjon 2016	***	**	***			
Keric 2016	***	*	***			
Molliqaj 2017	****	**	***			
Solomiichuk 2017	****	**	***	*******		
Archavlis 2018	****	**	***	*******		
Mao 2019	****	**	***	*******		
Zhang 2019	***	**	***	******		
Chen 2020	****	**	***	******		
Zhang 2021	****	**	***	*******		

Supplementary Table 5. Scores of the Newcastle-Ottawa quality assessment scale for 16 cohort studies.

Number	Studies	Country	Type Age (yr)		Male/ Female		Total no. of	Pedicle	Robot type	Indications	The evaluation criteria of accuracy	Images	s Screw	Clinical outcome	
			of					patient	screws					accuracy	
			study	RA	FH	RA	FH								
1	Kantelhardt 2011	Germany	RCS	62.8	63.4	25/30	27/30	RA: 55	RA: 250	SpineAssist (Mazor)	Spinal fusion in the thoracic and	Category A, fully contained within the pedicle; category	CT	CT 2mm	Revision of screws, duration of hospitalizations, infections, CSF fistula, Adverse
								FH: 57	FH: 286		lumbar spine	B, a breach less than 2 mm; category C, a breach of 2 to			events, time for surgery, opioid administration.
												4 mm; and category D, a breach greater than 4 mm.			
2	Lieberman 2012	USA	RCCS	NA	NA	NA	NA	RA: 10	RA: 197	SpineAssist (Mazor)	Cadaveric Spine	Category A, fully contained within the pedicle; category	CT	CT 2 mm	Radiation level, fluoroscopy time, and procedure time.
								FH: 2	FH: 37			B, a breach less than 2 mm; category C, a breach of 2 to			
												4 mm; and category D, a breach greater than 4 mm.			
3	Ringel 2012	Germany	RCT	68	67	14/16	12/18	RA: 30	RA: 146	SpineAssist (Mazor)	Mono- or bi-segmental lumbar or	Gertzbein and Robbins scale	CT	CT 2mm	Postoperative screw revision, hospitalization, radiation exposure, and duration of
								FH: 30	FH: 152		lumbosacral stabilization				surgery.
4	Schizas 2012	Switzerland	PCS	65	66	6/5	11/12	RA: 11	RA: 64	SpineAssist (Mazor)	Vertebral fracture, spinal stenosis,	Grade A = completely in; Grade B = $< 2$ mm breach;	CT	CT 2mm	Complications, screw revisions., radiation doses, duration of radiation.
								FH: 23	FH: 64		degenerative disc disease	Grade $C = 2-4$ mm breach; Grade $D = > 4$ mm breach			
5	Roser 2013	Germany	RCT	NA	NA	NA	NA	RA: 18	RA: 72	SpineAssist (Mazor)	Monosegmental degenerative	Gertzbein and Robbins	CT	CT 2mm	Radiation dosage, radiation time.
								FH: 10	FH: 40		lumbar instability				
6	Cannestra 2014	USA	RCS	NA	NA	NA	NA	RA: 51	RA: 280	NA	Degenerative spine	NA	NA	NA	Complications, radiation exposure.
								FH: 51	FH: 270						
7	Laudato 2014	Switzerland	RCS	NA	NA	NA	NA	RA: 11	RA: 64	SpineAssist (Mazor)	NA	Grade A = completely in; Grade B = $< 2$ mm breach;	СТ	CT 2mm	Complications, screw revision.
								FH: 48	FH: 314			Grade $C = 2-4$ mm breach; Grade $D = > 4$ mm breach			
8	Schatlo 2014	Germany	RCS	52	58	26/29	12/28	RA: 55	RA: 55	SpineAssist (Mazor)	Degenerative spine disease	Gertzbein and Robbins scale	СТ	CT 2mm	Screw revision, complication, opioid administration, blood loss, duration of operation,
								FH: 40	FH: 40						length of stay.
9	Zahrawi 2014	USA	RCS	NA	NA	NA	NA	RA: 52	RA: 253	Renaissance (Mazor)	Degenerative spine disease	NA	СТ	CT 2 mm	Postoperative complication rates, revisions surgery, length of stay, duration of surgery,
								FH: 70	FH: 383						ODI, blood loss, screw implantation time.
10	Kim 2015	South Korea	RCT	64.4	64.7	11/9	12/8	RA: 20	RA: 80	Renaissance (Mazor)	Lumbar spinal stenosis	Gertzbein and Robbins scale	СТ	CT 2mm	None.
								FH: 20	FH: 80						
11	Lonjon 2016	France	RCS	63.4	63.4	4/6	4/6	RA: 10	RA: 40	ROSA	Degenerative lumbar disease	Gertzbein and Robbins scale	C-arm	CT 2mm	Duration of surgery, time in the operating room, total dose of radiation, radiation
								FH: 10	FH: 50						exposure, instrumentation level.
12	Keric 2016	Germany	RCS	72.3	68	36/30	13/11	RA: 66	RA: 341	Renaissance (Mazor)	Pyogenic spondylodiscitis of the	Screws entirely in the bone were graded 0, encroachment	СТ	CT 2mm	Postoperative hospitalization, pain, screw revisions, quality of life, ODI.
								FH: 24	FH: 121		lumbar and thoracic spine	of the cortical bone grade 1, deviation of less than 3 mm			
												grade 2, deviation from 3 to 6 mm grade 3, and deviation			
												of more than 6 mm grade 4			
13	Kim 2016	South Korea	RCT	65.4	66.0	19/18	22/19	RA: 37	RA: 158	Renaissance (Mazor)	Lumbar spinal stenosis	Gertzbein and Robbins scale	СТ	CT 2mm	Duration of surgery, complications, radiation exposure, time to return to ambulation.
14		C d V	DOT		(( )	0/21	0/22	FH: 41	FH: 172				CTT.	CT 2	
14	Hyun 2017	South Korea	RCI	66.5	66.8	9/21	8/ 22	KA: 30	RA: 130	Renaissance (Mazor)	Degenerative lumbar disease	Gertzbein and Kobbins scale	CT	CT 2mm	Postoperative screw revision, hospitalization, radiation exposure, pain, quality of life
15	Molligai 2017	Gormony	PCS	59.2	54.4	50/ 48	26/25	PA: 08	PA: 420	SpineAssist (Mazor)	Decenerative traume and tumor	Cortzhoir and Polhing goals	СТ	CT 2mm	Complications.
15	womqaj 2017	Germany	RCS	56.5	54.4	50/ 40	50/55	FH: 71	FH: 441	Spinerssist (Wazur)	begenerative, trauma and tumor	Seizeen and Robbins Searc		CT 2mm	complications, serew revisions.
16	Solomiichuk	Switzerland	RCS	63.7	62.2	21/14	23/12	RA: 35	RA: 192	SpineAssist (Mazor)	Metastatic spine disease	Gertzbein and Robbins scale	СТ	CT 2mm	Complications, radiation exposure, radiation time, surgicalsite infection.
	2017							FH: 35	FH: 214						

### Supplementary Table 6. Characteristics of the included trials and participants.

17	Tian 2017	China	RCT	NA	NA	NA	NA	RA: 23	RA: 102	TiRobot	Lumbar vertebral fracture, lumbar	Gertzbein and Robbins scale	C-arm	CT 2mm	Duration of operation.
								FH: 17	FH: 88	(TINAVI)	spondylolisthesis				
18	Archavlis 2018	Germany	RCS	51	49	22/36	32/40	RA: 58	RA: 116	Renaissance (Mazor)	Degenerative spondylolisthetic	NA	СТ	CT	Facet joint violation.
								FH: 72	FH: 144		stenosis grades I and II and				
											degenerative disease				
19	Han 2019	China	RCT	54.6	56.1	55/60	58/61	RA:115	RA: 532	TiRobot	Degenerative and trauma	Gertzbein and Robbins scale	C-arm	CT 2mm	Duration of surgery, length of hospital stay, proximal joint violation, and revision
								FH:119	FH: 584	(TINAVI)					surgery.
20	Mao 2019	China	PCS	55.1	59.2	18/39	25/34	RA:57	RA: 234	TiRobot	Degenerative lumbar disease	Gertzbein and Robbins scale	C-arm	CT 2mm	Operation time, blood loss, radiation time, radiation dosage, postoperative
								FH:59	FH: 278	(TINAVI)					hospitalization, adverse events, revisions.
21	Fan 2019	China	RCT	49	49.5	31/18	39/27	RA:61	RA: 186	TiRobot	Cervical spinal disease	Gertzbein and Robbins scale	C-arm	CT	Duration of surgery, blood loss, postoperative length of stay, and surgery related
								FH:66	FH: 204	(TINAVI)					complications.
22	Feng 2019	China	RCT	67.55	67.88	12/28	13/27	RA:40	RA: 202	TiRobot	Degenerative lumbar disease with	Gertzbein and Robbins scale	C-arm	CT 2mm	Operative time, pedicle screw placement time, radiation exposure to the medical team,
								FH:40	FH: 225	(TINAVI)	osteoporosis				and intraoperative blood loss were recorded
23	Zhang 2019	China	PCS	54.6	55.6	17/33	21/29	RA: 50	RA: 100	TiRobot	Lumbar degenerative disease	Gertzbein and Robbins scale	C-arm	CT 2mm	Facet-joint violation, pedicle, surgical time, intraoperative blood loss, length of stay,
								FH: 50	FH: 96	(TINAVI)					revision surgery, radiation exposure.
24	Chen 2020	China	RCS	69.8	69.3	12/19	25/41	RA: 31	RA: 378	TiRobot	Adult degenerative scoliosis	Gertzbein and Robbins scale	C-arm	CT 2mm	Operative time, intraoperative blood loss, length of stay, adverse events, revisions.
								FH: 66	FH: 786	(TINAVI)					
25	Li 2020	China	RCT	47.4	49.9	3/4	4/6	RA: 7	RA: 32	Orthbot	Degenerative lumbar disc disease	Gertzbein and Robbins scale	CT	CT 1 mm	operation time, blood loss, radiation time (radiation time per case and per screw),
								FH: 10	FH: 50		or lumbar spinal stenosis				length of stay, and screw-related complications.
26	Zhang 2021	China	RCS	65.95	66.86	21/18	22/20	RA: 39	RA: 32	Renaissance (Mazor)	Patients underwent lumbar	Gertzbein and Robbins scale	CT	NA	Operative time, intraoperative blood loss, intraoperative fluoroscopy time,
								FH: 42	FH: 50		surgery before, and needed				complications.
											revision surgery				

RA: robot-assisted; FH: free hand; RCT: randomized controlled trial; RCS: retrospective cohort study; PCS: prospective cohort study; RCCS: retrospective cohort study. CT: computed tomography. Gertzbein and Robbins scale: Screw position was classified within the pedicle (group A), cortical breach of less than 2 mm (group B), cortical breach of 4 mm or more but less than 6 mm (group C), cortical breach of 6 mm or more (group E).