

Supplementary File S1 - Additional Analyses and Sensitivity Results

Time Course and Individual Heterogeneity of Disability Recovery After Spine Surgery: A Secondary Analysis of the SPINEREG Cohort

Supplementary File S1 supports the main manuscript. Tables reproduce prespecified sensitivity, missingness, responder-sequence, and paired-change analyses from the frozen SPINEREG workflow; Table S8 reports standardized adjusted diagnosis trajectories used only for visualization in Figure 3A. The locked machine-readable counterparts are contained in Supplementary File S2 - Reproducibility Package.

Table S1. Observed ODI descriptives.

time	n	mean	sd	median	q1	q3
PRE	1392	46.841	16.401	46	35	60
6 months	837	23.179	18.885	20	8	35
12 months	970	21.676	19.164	17	6	33
24 months	661	20.162	19.084	14	6	32

Note. Values reproduced directly from the locked analysis outputs in the SPINEREG reproducibility package.

Table S2. Gaussian GEE sensitivity analysis.

estimate	se	ci low	ci high	p	term
46.841	0.439	45.979	47.702	<0.001	PRE
23.608	0.59	22.452	24.764	<0.001	6 months
22.22	0.578	21.087	23.353	<0.001	12 months
21.108	0.657	19.821	22.395	<0.001	24 months
-1.389	0.548	-2.464	-0.314	0.011	12 vs 6
-1.112	0.64	-2.366	0.143	0.082	24 vs 12
-2.5	0.656	-3.787	-1.214	<0.001	24 vs 6

Note. Values reproduced directly from the locked analysis outputs in the SPINEREG reproducibility package.

Table S3. Complete-case mixed-model sensitivity analysis.

estimate	se	ci low	ci high	p	term	complete case n	p holm
44.823	1.04	42.785	46.861	<0.001	PRE	254	
19.567	1.04	17.529	21.605	<0.001	6 months	254	
17.551	1.04	15.513	19.589	<0.001	12 months	254	

estimate	se	ci low	ci high	p	term	complete case n	p holm
18.248	1.04	16.21	20.286	<0.001	24 months	254	
-2.016	0.97	-3.918	-0.114	0.038	12 vs 6	254	0.113
0.697	0.97	-1.205	2.599	0.473	24 vs 12	254	0.473
-1.319	0.97	-3.221	0.583	0.174	24 vs 6	254	0.348

Note. Values reproduced directly from the locked analysis outputs in the SPINEREG reproducibility package.

Table S4. Baseline predictors of follow-up availability.

followup	predictor	beta	se	OR	OR ci low	OR ci high	p
6 months	Intercept	0.245	0.138	1.278	0.975	1.674	0.075
6 months	Baseline ODI	-0.003	0.004	0.997	0.99	1.004	0.425
6 months	Hb (g/dL)	0.049	0.049	1.05	0.954	1.155	0.317
6 months	Age (years)	-0.009	0.004	0.991	0.983	1	0.047
6 months	Female sex	-0.053	0.138	0.949	0.724	1.243	0.702
6 months	Deformity vs disc	0.571	0.175	1.77	1.256	2.493	0.001
6 months	Other back vs disc	0.09	0.126	1.094	0.854	1.402	0.475
6 months	ASA 2 vs 1	0.063	0.151	1.065	0.793	1.432	0.675
6 months	ASA 3 vs 1	0.072	0.236	1.074	0.677	1.705	0.761
12 months	Intercept	0.803	0.148	2.232	1.671	2.98	<0.001
12 months	Baseline ODI	-0.006	0.004	0.994	0.986	1.001	0.095
12 months	Hb (g/dL)	0.077	0.051	1.08	0.976	1.194	0.135
12 months	Age (years)	-0.002	0.005	0.998	0.989	1.007	0.655
12 months	Female sex	-0.002	0.146	0.998	0.749	1.33	0.990
12 months	Deformity vs disc	0.119	0.177	1.126	0.796	1.593	0.503
12 months	Other back vs disc	0.21	0.136	1.234	0.945	1.61	0.122
12 months	ASA 2 vs 1	-0.082	0.161	0.921	0.672	1.264	0.611
12 months	ASA 3 vs 1	-0.099	0.249	0.906	0.556	1.476	0.691
24 months	Intercept	-0.091	0.136	0.913	0.699	1.191	0.502
24 months	Baseline ODI	-0.001	0.004	0.999	0.992	1.006	0.810
24 months	Hb (g/dL)	0.017	0.048	1.017	0.925	1.119	0.721



followup	predictor	beta	se	OR	OR ci low	OR ci high	p
24 months	Age (years)	-0.018	0.004	0.982	0.973	0.99	<0.001
24 months	Female sex	-0.042	0.136	0.959	0.734	1.253	0.761
24 months	Deformity vs disc	-0.71	0.172	0.492	0.351	0.689	<0.001
24 months	Other back vs disc	0.071	0.125	1.074	0.84	1.372	0.571
24 months	ASA 2 vs 1	0.093	0.148	1.098	0.822	1.467	0.528
24 months	ASA 3 vs 1	0.055	0.234	1.056	0.668	1.67	0.815

Note. Values reproduced directly from the locked analysis outputs in the SPINEREG reproducibility package.

Table S5. Inverse-probability-weighted GEE sensitivity analysis.

estimate	se	ci low	ci high	p	term
46.841	0.439	45.979	47.702	<0.001	PRE
23.736	0.595	22.569	24.903	<0.001	6 months
22.583	0.589	21.427	23.738	<0.001	12 months
21.68	0.685	20.338	23.023	<0.001	24 months
-1.154	0.558	-2.247	-0.06	0.039	12 vs 6
-0.902	0.673	-2.22	0.416	0.180	24 vs 12
-2.056	0.685	-3.399	-0.713	0.003	24 vs 6

Note. Values reproduced directly from the locked analysis outputs in the SPINEREG reproducibility package.

Table S6. Complete-case responder sequences.

Response threshold	Sequence (6→12→24 months)	n	% of complete cases
≥30% reduction	000	19	7.5
≥30% reduction	001	10	3.9
≥30% reduction	010	10	3.9
≥30% reduction	011	22	8.7
≥30% reduction	100	9	3.5
≥30% reduction	101	7	2.8
≥30% reduction	110	15	5.9
≥30% reduction	111	162	63.8
≥12.7-point reduction	000	24	9.4
≥12.7-point reduction	001	11	4.3
≥12.7-point reduction	010	10	3.9
≥12.7-point reduction	011	22	8.7
≥12.7-point reduction	100	4	1.6
≥12.7-point reduction	101	6	2.4
≥12.7-point reduction	110	14	5.5
≥12.7-point reduction	111	163	64.2

Note. Sequence digits indicate threshold-defined responder status at 6, 12, and 24 months (1=responder; 0=non-responder) among the 254 participants with ODI observed at all three postoperative assessments. Leading zeros are retained explicitly.

Table S7. Paired postoperative changes.

contrast	n pairs	mean change	sd change	ci low	ci high	p	median change	q1	q3
12 vs 6	593	-1.315	13.215	-2.379	-0.252	0.016	-1	-9	4
24 vs 12	394	-0.165	12.905	-1.439	1.109	0.800	0	-6	4.75

contrast	n pairs	mean change	sd change	ci low	ci high	p	median change	q1	q3
24 vs 6	343	-1.338	12.57	-2.668	-0.008	0.049	-2	-8	4

Note. Values reproduced directly from the locked analysis outputs in the SPINEREG reproducibility package.

Table S8. Standardized adjusted postoperative ODI trajectories by diagnosis used in Figure 3A.

Diagnostic group	Months	Adjusted ODI	95% CI low	95% CI high
Spinal deformity	6	29.72	27.13	32.31
Spinal deformity	12	27.47	24.88	30.07
Spinal deformity	24	25.42	22.11	28.74
Disc disease	6	21.52	19.90	23.14
Disc disease	12	20.15	18.60	21.70
Disc disease	24	19.74	18.05	21.43
Other back surgery	6	23.51	21.79	25.23
Other back surgery	12	22.85	21.22	24.48
Other back surgery	24	22.71	20.89	24.54

Note. Values are model-based standardized marginal means, averaged over the cohort covariate distribution. They are presentation estimates for Figure 3A; diagnosis-specific inferential contrasts are reported in the main manuscript and frozen analysis outputs.

Data-integrity statement

The source workbook SHA-256 was

03c0f51af84bc4e8c2fbcf8deef52993d6abb14057a236928a9e47eb1daa4e3f. The uploaded raw XLSX and the XLSX contained in the repository ZIP were byte-identical. The raw workbook was not modified; all derived analysis files were created separately. The public workbook contained 1,392 patient rows and no explicit patient identifier, so a deterministic analysis-only row identifier was used.

Reproducibility

Supplementary File S2 - Reproducibility Package contains the frozen SAP, analysis-ready wide and long CSV files, checksum manifest, the complete primary analysis script, executed Jupyter notebook, machine-readable result tables, and publication figures. SPINEREG_secondary_analysis.py reproduces the locked statistical outputs; SPINEREG_publication_figures.py recreates the redesigned publication figures from those outputs and the analysis-ready data.