**Appendix I.**

**Complications reported in the recent literature classified by incidence (common to extremely uncommon) and surgical technique (open, minimally invasive, hybrid).**

*Open procedures*

The OP group included 11,267 patients. The mean age was 52.06 ±13.09 years, mean follow-up was 3.52 ±1.47 years, mean EBL was 2,036.83±874.96 ml, mean number of fused level 8.56 ±2.59, mean operative time was 376.89 ±157.03 minutes.

* *Total complications:* IOC of 37.54% (CI 95%: 36.65-38.44)
* *Perioperative complications:* IOC of 26.49% (CI 95%: 25.68-27.32)
* *Major:* IOC of 10.90% (CI 95%: 10.33-11.49)
* Common (IOC >5.0%): none
* Uncommon (2%≤IOC≤5%): permanent/not full resolved neurological deficit (IOC: 2.26%), wound infection requiring debridement and/or reoperation (IOC: 2.00%).
* Very uncommon (0.5%≤IOC<2%): pulmonary embolism or thrombosis of major vessel (IOC: 0.76%), excessive bleeding (IOC 0.73%), instrumentation and/or graft failure requiring revision (IOC 0.59%) and unspecified pulmonary complications (IOC 0.50%).
* Extremely uncommon (IOC<0.5%): unspecified or requiring surgery complication (IOC 0.43%), wound hematoma or seroma requiring surgery (IOC 0.43%), death (IOC 0.33%), epidural hematoma (IOC 0.31%), pneumonia or lung infection (IOC 0.31%), cardiorespiratory or systemic complication (IOC 0.28%), congestive heart failure or unspecific cardiac (IOC 0.28%), pleural effusion or pneumothorax requiring intervention (IOC 0.26%), wound dehiscence requiring surgery (IOC 0.20%), sepsis (IOC 0.19%), vertebral compression fracture (IOC 0.18%), myocardial infarction/cardiac arrest (IOC 0.17%), stroke (IOC 0.17%), misplaced screw causing nerve related pain requiring reoperation (IOC 0.13%), respiratory distress syndrome or respiratory failure (IOC 0.11%), renal failure (IOC 0.10%), visual acuity change (IOC 0.07%), intraoperative vascular injury (IOC 0.06%), reintubation (IOC 0.05%), gastrointestinal complication (IOC 0.04%), incision abdominal hernia (IOC 0.03%), perioperative breakdown of L5S1 disc (IOC 0.02%), compartment syndrome (IOC 0.03%), pancreatitis (IOC 0.02%), transfusion reaction (IOC 0.02%), anaphylactic shock (IOC 0.01%), ischemia in extremities (IOC 0.01%), line-related infection (IOC 0.01%), painful rib remanent requiring excision (IOC 0.01%), pedicle or laminar fracture (IOC 0.01%), retroperitoneal hematoma (IOC 0.01%), subarachnoideal hemorrhage (IOC 0.01%) and visceral injury (IOC 0.01%)
* *Minor:* IOC of 15.59% (CI 95%: 14.93-16.28)
* Common (IOC >5.0%): none
* Uncommon (2%≤IOC≤5%): intraoperative dural tears (IOC: 3.30%), unspecified or other complication (IOC: 2.33%) and transient neurological deficit (IOC: 2.20%).
* Very uncommon (0.5%≤IOC<2%): wound infection (IOC: 1.26%), ileus/gastrointestinal complication (IOC: 1.22%), other intraoperative complication (IOC: 0.87%) and urinary tract infection (IOC: 0.86%).
* Extremely uncommon (IOC<0.5%): delirium (IOC: 0.43%), unspecified or miscellaneous infection (IOC: 0.35%), deep vein thrombosis (IOC: 0.34%), pleural effusion (IOC: 0.28%), cerebrospinal fluid leak (IOC: 0.28%), non-surgical wound healing complication (IOC: 0.26%), arrhythmia or tachycardia (IOC: 0.22%), other iatrogenic damage (IOC: 0.22%), miscellaneous cutaneous complication (IOC: 0.20%), non-surgical hematoma/seroma/bursa (IOC: 0.18%), reversible coagulopathy (IOC: 0.12%), instrumentation failure conservatively managed (IOC: 0.11%), fever of unknown origin (IOC: 0.11%), intraoperative revision (IOC: 0.11%), intraoperative subluxation or translation at surgical site (IOC: 0.10%), hypotension (IOC: 0.05%), pneumothorax (IOC: 0.04%), retained drain (IOC: 0.02%), intraoperative pedicle infraction (IOC: 0.01%) and symptomatic gallstones (IOC: 0.01%).
* *Late complications:* IOC of 11.05% (CI 95%: 10.48-11.65)
* Common (IOC >5.0%): none
* Uncommon (2%≤IOC≤5%): pseudoarthrosis (IOC: 3.31%) and instrumentation and/or graft failure requiring revision (IOC: 2.78%).
* Very uncommon (0.5%≤IOC<2%): adjacent segment degeneration (IOC 1.69%), proximal junctional kyphosis (IOC: 1.13%), unspecified revision (IOC: 0.73%) and symptomatic hardware (IOC: 0.60%).
* Extremely uncommon (IOC<0.5%): vertebral compression fracture (IOC 0.28%), late deep infection (IOC 0.18%), delayed neurological deficit (IOC 0.05%), superficial wound infection (IOC 0.09%), deformity progression (IOC 0.09%), hearing loss (IOC 0.04%), deep vein thrombosis (IOC 0.03%), other fracture (e.g. sacral, pelvic) (IOC 0.02%), iliac crest fracture or sacroiliac joint degeneration (IOC 0.02%), disc herniation (IOC 0.01%), pneumonia (IOC 0.01%) and seroma (IOC 0.01%).

*Hybrid procedures*

The hybrid group included 579 patients. The mean age was 64.99 ±3.33 years, mean follow-up was 2.23±0.53 years, mean EBL was 1,212.72 ±522.49 ml, mean number of fused level 5.83±1.08, mean operative time was 478.08 ±245.36 minutes.

* *Total complications:* IOC of 51.81% (CI 95%: 47.66-55.94)
* *Perioperative complications:* IOC of 36.44% (CI 95%: 32.54-40.53)
* *Major:* IOC of 14.68% (CI 95%: 11.95-17.89)
* Common (IOC >5.0%): unspecified or requiring surgery complication (IOC 6.74%).
* Uncommon (2%≤IOC≤5%): permanent/not full resolved neurological deficit (IOC: 2.42%).
* Very uncommon (0.5%≤IOC<2%): wound infection requiring debridement and/or reoperation (IOC: 1.21%), pleural effusion or pneumothorax requiring intervention (IOC 0.69%) and visceral injury (IOC 0.69%).
* Extremely uncommon (IOC<0.5%): cardiorespiratory or systemic complication (IOC 0.35%), congestive heart failure or unspecific cardiac (IOC 0.35%), excessive bleeding (IOC 0.35%), myocardial infarction/cardiac arrest (IOC 0.35%), pulmonary embolism or thrombosis of major vessel (IOC: 0.35%), sepsis (IOC 0.35%), wound dehiscence requiring surgery (IOC 0.35%), gastrointestinal complication (IOC 0.17%), incisional abdominal hernia (IOC 0.17%) and intraoperative vascular injury (IOC 0.17%).
* *Minor:* IOC of 21.76% (CI 95%: 18.51-25.39)
* Common (IOC >5.0%): unspecified or other complication (IOC 6.56%) and transient neurological deficit (IOC: 5.18%).
* Uncommon (2%≤IOC≤5%): unspecified or miscellaneous infection (IOC: 2.59%) and ileus/gastrointestinal complication (IOC: 2.42%).
* Very uncommon (0.5%≤IOC<2%): urinary tract infection (IOC: 1.04%), delirium (IOC: 0.69%), arrhythmia or tachycardia (IOC 0.69%) and hypotension (IOC: 0.69%).
* Extremely uncommon (IOC<0.5%): instrumentation failure conservatively managed (IOC: 0.35%), other intraoperative complication (IOC: 0.35%), pleural effusion (IOC: 0.35%), pulmonary congestion (IOC: 0.35%), intraoperative pedicle infraction (IOC: 0.17%), wound infection (IOC: 0.17%) and unspecific pulmonary complication (IOC: 0.17%).
* *Late complications:* IOC of 15.37% (CI 95%: 12.58-18.63)
* Common (IOC >5.0%): proximal junctional kyphosis (IOC: 8.12%).
* Uncommon (2%≤IOC≤5%): pseudoarthrosis (IOC 3.11%).
* Very uncommon (0.5%≤IOC<2%): instrumentation/graft failure (IOC: 1.55%), delayed neurological deficit (IOC: 1.21%) and adjacent segment degeneration (IOC: 0.86%).
* Extremely uncommon (IOC<0.5%): unspecified revision (IOC: 0.35%) and symptomatic hardware (IOC: 0.17%).

*MIS*

322 patients were assigned to MIS group. The mean age was 64.46 ±3.86 years, mean follow-up was 2.47 ±0.61 years, mean EBL was 355 ±264.36 ml, mean number of fused level 5.2 ±1.2, mean operative time was 332.38±114 minutes.

* *Total complications:* IOC of 38.20% (CI 95%: 32.91-43.77)
* *Perioperative complications:* IOC of 24.22% (CI 95%: 19.72-29.35)
* *Major:* IOC of 9.01% (CI 95%: 6.22-12.82)
* Common (IOC >5.0%): none
* Uncommon (2%≤IOC≤5%): permanent/not full resolved neurological deficit (IOC 2.48%).
* Very uncommon (0.5%≤IOC<2%): misplaced screw causing nerve related pain requiring reoperation (IOC 1.55%), wound infection requiring debridement and/or reoperation (IOC: 1.55%), wound dehiscence requiring surgery (IOC 1.55%), cerebellar hemorrhage (IOC 0.93%) and retroperitoneal hematoma (IOC 0.62%)
* Extremely uncommon (IOC<0.5%): visceral injury (IOC 0.31%).
* *Minor:* IOC of 15.22% (CI 95%: 11.57-19.72)
* Common (IOC >5.0%): transient neurological deficit (IOC: 9.32%).
* Uncommon (2%≤IOC≤5%): unspecified or other complication (IOC 4.97%).
* Very uncommon (0.5%≤IOC<2%): instrumentation failure conservatively managed (IOC: 0.93%).
* Extremely uncommon (IOC<0.5%): none
* *Late complications:* IOC of 13.98% (CI 95%: 10.48-18.36)
* Common (IOC >5.0%): pseudoarthrosis (IOC 5.59%).
* Uncommon (2%≤IOC≤5%): proximal junctional kyphosis (IOC 4.97%).
* Very uncommon (0.5%≤IOC<2%): instrumentation/graft failure (IOC 1.86%) and adjacent segment degeneration (IOC 0.93%)
* Extremely uncommon (IOC<0.5%): late deep infection (IOC 0.31%) and delayed neurological deficit (IOC 0.31%).

**Table 3:** Major perioperative incidence of complications (IOC) percentage with 95% confidence interval and classification according our scale in total study population, open procedures, hybrid procedures and minimally invasive surgery (MIS).

| **Major perioperative complications** | **Total study population** | **Open Procedures (OP)** | **Hybrid Procedures**  **(HP)** | **MIS** |
| --- | --- | --- | --- | --- |
| Neurological deficit (not transient, not full recovery, resolved with reoperation, or classified as ‘‘major’’) | Uncommon  2.28% (2.03-2.57) | Uncommon  2.26% (2.00-2.56) | Uncommon  2.42% (1.38-4.13) | Uncommon  2.48% (1.16-5.02) |
| Wound infection requiring debridement  and/or reoperation (especially deep | Uncommon  2.24% (1.99-2.52) | Uncommon  2.00% (1.75-2.28) | Very uncommon  1.21% (0.05-2.59) | Very uncommon  1.55% (0.57-3.79) |
| Unspecified or requiring surgery | Very uncommon  0.76% (0.62-0.94) | Extremely uncommon 0.47% (0.39-0.62) | Common  6.74% (4.90-9.19) |  |
| Pulmonary embolism or thrombosis of major vessel | Very uncommon  0.72% (0.58-0.89) | Very uncommon  0.76%(0.61-0.94) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Excessive bleeding | Very uncommon  0.69 (0.55-0.86) | Very uncommon  0.73% (0.58-0.91) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Instrumentation/graft failure (breakage, dislodgement, or resulting in inadequate correction) requiring revision | Very uncommon  0.55 (0.43-0.70) | Very uncommon  0.59% (0.46-0.75) |  |  |
| Unspecified pulmonary | Extremely uncommon  0.46% (0.35-0.60) | Very uncommon  0.50% (0.38-0.65) |  |  |
| Wound hematoma or seroma requiring surgery | Extremely uncommon  0.40% (0.30-0.53) | Extremely uncommon  0.43% (0.32-0.57) |  |  |
| Death | Extremely uncommon  0.30% (0.21-0.42) | Extremely uncommon  0.33% (0.24-0.46) |  |  |
| Epidural hematoma | Extremely uncommon  0.29% (0.21-0.41) | Extremely uncommon  0.31% (0.22-0.44) |  |  |
| Pneumonia/lung infection | Extremely uncommon  0.29% (0.21-0.41) | Extremely uncommon  0.31% (0.22-0.44) |  |  |
| Cardiorespiratory (non-pleural effusion) / systemic | Extremely uncommon  0.28% (0.20-0.40) | Extremely uncommon  0.28% (0.19-0.40) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Congestive heart failure or unspecified  cardiac, cardiocirculatory instability | Extremely uncommon  0.27% (0.19-0.38) | Extremely uncommon  0.28% (0.19-0.40) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Pleural effusion or pneumothorax (requiring intervention) | Extremely uncommon  0.27% (0.19-0.38) | Extremely uncommon  0.26% (0.18-0.38) | Very uncommon  0.69% (0.22-1.88) |  |
| Wound dehiscence requiring surgery | Extremely uncommon  0.25% (0.17-0.36) | Extremely uncommon  0.20% (0.13-0.31) | Extremely uncommon  0.35% (0.06-1.39) | Very uncommon  1.55% (0.57-3.79) |
| Sepsis | Extremely uncommon  0.19% (0.12-0.29) | Extremely uncommon  0.19% (0.12-0.29) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Myocardial infarction/cardiac arrest | Extremely uncommon  0.17% (0.11-0.27) | Extremely uncommon  0.17% (0.11-0.27) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Misplaced screw possibly causing nerve related pain (requiring reoperation) | Extremely uncommon  0.16% (0.10-0.25) | Extremely uncommon  0.13% (0.08-0.22) |  | Very uncommon  1.55% (0.57-3.79) |
| Stroke | Extremely uncommon  0.16% (0.10-0.25) | Extremely uncommon  0.17% (0.11-0.27) |  |  |
| Vertebral compression fracture | Extremely uncommon  0.16% (0.10-0.25) | Extremely uncommon  0.18% (0.11-0.28) |  |  |
| Respiratory distress syndrome/respiratory failure | Extremely uncommon  0.10% (0.05-0.18) | Extremely uncommon  0.11% (0.06-0.20) |  |  |
| Renal failure | Extremely uncommon  0.09% (0.05-0.17) | Extremely uncommon  0.10% (0.05-0.18) |  |  |
| Vascular injury (intraoperative) | Extremely uncommon  0.07% (0.03-0.14) | Extremely uncommon  0.06% (0.03-0.13) | Extremely uncommon  0.17% (0.01-1.11) |  |
| Visual acuity change | Extremely uncommon  0.07% (0.03-0.14) | Extremely uncommon  0.07% (0.03-0.14) |  |  |
| Gastrointestinal complication (bleeding, ischemia, Clostridium D. infection or other) | Extremely uncommon  0.05% (0.02-0.11) | Extremely uncommon  0.04% (0.01-0.10) | Extremely uncommon  0.17% (0.01-1.11) |  |
| Reintubation | Extremely uncommon  0.05% (0.02-0.11) | Extremely rare  0.05% (0.02-0.12) |  |  |
| Visceral injury | Extremely uncommon  0.05% (0.02-0.11) | Extremely uncommon  0.01% (0-0.06) | Very uncommon  0.69%(0.22-1.88) | Extremely uncommon  0.31% (0.02-1.99) |
| Incision abdominal hernia | Extremely uncommon  0.03% (0.01-0.09) | Extremely uncommon  0.03% (0.01-0.09) | Extremely uncommon  0.17% (0.01-1.11) |  |
| Breakdown of L5eS1 disc (perioperative not long-term) | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.02% (0-0.07) |  |  |
| Cerebellar hemorrhage | Extremely uncommon  0.02% (0-0.07) |  |  | Very uncommon  0.93% (0.24-2.93) |
| Compartment syndrome with or without shock (abdominal or extremity) | Extremely uncommon  0.02% (0.00-0.07) | Extremely uncommon  0.03% (0.01-0.09) |  |  |
| Pancreatitis | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.02% (0-0.07) |  |  |
| Retroperitoneal hematoma | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.01% (0-0.06) |  | Very uncommon  0.62% (0.11-2.47) |
| Trasfusion reaction | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.02% (0-0.07) |  |  |
| Anaphylatic shock | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| Ischemia in extremities | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| Line-related infection | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| Painful rib remnant requiring excision | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| Pedicle or laminar fracture (intraoperative) | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| Subarachnoideal hemorrhage | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| **Incidence of complication (IOC)** | **11.03% (10.48-11.60)** | **10.90% (10.33-11.49)** | **14.68% (11.95-17.89)** | **9.01% (6.22-12.82)** |

**Table 4:** Minor perioperative incidence of complications (IOC) percentage with 95% confidence interval and classification according our scale in total study population, open procedures, hybrid procedures and minimally invasive surgery (MIS).

| **Minor perioperative complications** | **Total study population** | **Open Procedures (OP)** | **Hybrid Procedures (HP)** | **MIS** |
| --- | --- | --- | --- | --- |
| An intraoperative Dural tear | Uncommon  3.06% (2.76-3.39) | Uncommon  3.30% (2.98-3.65) |  |  |
| Unspecified or other | Uncommon  2.57% (2.30-2.87) | Uncommon  2.33% (2.06-2.63) | Common  6.56% (4.74-8.97) | Uncommon  4.97% (2.97-8.11) |
| Transient neurological deficit (foot drop, brachial plexopathy, peroneal nerve palsy, radiculopathy, cauda equina, partial spinal cord injury, etc), or transient intraoperation | Uncommon  2.53% (2.26-2.83) | Uncommon  2.20% (1.94-2.49) | Common  5.18% (3.58-7.40) | Common  9.32% (6.48-13.17) |
| Ileus/gastrointestinal complication | Very uncommon  1.25% (1.06-1.47) | Very uncommon  1.22% (1.03-1.44) | Uncommon  2.42% (1.38-4.13) |  |
| Wound infection (medical/interventional  treatment) or superficial | Very uncommon  1.18% (1.00-1.39) | Very uncommon  1.26% (1.07-1.49) | Extremely uncommon  0.17% (0.01-1.11) |  |
| Urinary tract infection | Very uncommon  0.85% (0.70-1.03) | Very uncommon  0.86% (0.70-1.05) | Very uncommon  1.04% (0.42-2.36) |  |
| Other intraoperation | Very uncommon  0.82% (0.67-1.00) | Very uncommon  0.87% (0.71-1.06) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Delirium | Extremely uncommon  0.44% (0.33-0.58) | Extremely uncommon  0.43% (0.32-0.57) | Very uncommon  0.69% (0.22-1.88) |  |
| Unspecified or miscellaneous infection (eg,  yeast) | Extremely uncommon  0.44% (0.33-0.58) | Extremely uncommon  0.35% (0.25-0.48) | Uncommon  2.59% (1.51-4.34) |  |
| Deep vein thrombosis | Extremely uncommon  0.31% (0.22-0.43) | Extremely uncommon  0.34% (0.24-0.47) |  |  |
| Pleural effusion | Extremely uncommon  0.27% (0.19-0.38) | Extremely uncommon  0.28% (0.19-0.40) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Cerebrospinal fluid leak | Extremely uncommon  0.26% (0.18-0.37) | Extremely uncommon  0.28% (0.19-0.40) |  |  |
| Arrhythmia or tachycardia | Extremely uncommon  0.24% (0.16-0.35) | Extremely uncommon  0.22% (0.24-0.47) | Very uncommon  0.69% (0.22-1.88) |  |
| Wound healing complications (nonsurgical) | Extremely uncommon  0.24% (0.16-0.35) | Extremely uncommon  0.26% (0.18-0.38) |  |  |
| Other iatrogenic damage | Extremely uncommon  0.21% (0.14-0.31) | Extremely uncommon  0.22% (0.15-0.33) |  |  |
| Miscellaneous cutaneous complications | Extremely uncommon  0.18% (0.12-0.28) | Extremely uncommon  0.20% (0.13-0.31) |  |  |
| Hematoma, seroma, or bursa (no surgery) | Extremely uncommon  0.16% (0.10-0.25) | Extremely uncommon  0.18% (0.11-0.28) |  |  |
| Instrumentation failure (managed conservatively) | Extremely uncommon  0.14% (0.08-0.23) | Extremely uncommon  0.11% (0.06-0.20) | Extremely uncommon  0.35% (0.06-1.39) | Very uncommon  0.93% (0.24-2.93) |
| Reversible coagulopathy | Extremely uncommon  0.11% (0.06-0.19) | Extremely uncommon  0.12% (0.07-0.21) |  |  |
| Fever of unknown origin | Extremely uncommon  0.10% (0.05-0.17) | Extremely uncommon  0.11% (0.06-0.20) |  |  |
| Revision (intraoperative) | Extremely uncommon  0.10% (0.05-0.17) | Extremely uncommon  0.11% (0.06-0.20) |  |  |
| Subluxation or translation at surgical site (intraoperative) | Extremely uncommon  0.09% (0.05-0.17) | Extremely uncommon  0.10% (0.05-0.18) |  |  |
| Hypotension | Extremely uncommon  0.08% (0.04-0.15) | Extremely uncommon  0.05% (0.02-0.12) | Very uncommon  0.69% (0.22-1.88) |  |
| Pneumothorax | Extremely uncommon  0.03% (0.01-0.09) | Extremely uncommon  0.04% (0.01-0.10) |  |  |
| Pedicle infraction (intra) | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.17% (0.01-1.11) |  |
| Pulmonary congestion | Extremely uncommon  0.02% (0-0.07) |  | Extremely uncommon  0.35% (0.06-1.39) |  |
| Retained drain | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.02% (0-0.07) |  |  |
| Symptomatic gallstones | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| Unspecified pulmonary (resolved via simple measures) | Extremely uncommon  0.01% (0-0.06) |  | Extremely uncommon  0.17% (0.01-1.11) |  |
| **Incidence of complication (IOC)** | **15.88% (15.24-16.58)** | **15.59% (14.93-16.28)** | **21.76% (18.51-25.39)** | **15.22% (11.57-19.72)** |

**Table 5:** Incidence of late complications (IOC) percentage with 95% confidence interval and classification according our scale in total study population, open procedures, hybrid procedures and minimally invasive surgery (MIS).

| **Late complications** | **Total study population** | **Open Procedures (OP)** | **Hybrid Procedures**  **(HP)** | **MIS** |
| --- | --- | --- | --- | --- |
| Pseudoarthrosis | Uncommon  3.36% (3.05-3.70) | Uncommon  3.31% (2.99-3.66) | Uncommon  3.11% (1.91-4.97) | Common  5.59% (3.44-8.85) |
| Instrumentation/graft failure (breakage, dislodgement, screw loosening, or resulting in sagittal/coronal decompensation) | Uncommon  2.70% (2.42-3.01) | Uncommon  2.78% (2.49-3.10) | Very uncommon  1.55% (0.76-3.03) | Very uncommon  1.86% (0.76-4.21) |
| Adjacent segment degeneration | Very uncommon  1.63% (1.42-1.88) | Very uncommon  1.69% (1.46-1.95) | Very uncommon  0.86% (0.32-2.12) | Very uncommon  0.93% (0.24-2.93) |
| Proximal junctional kyphosis, especially requiring extension | Very uncommon  1.56% (1.35-1.80) | Very uncommon  1.13% (0.95-1.35) | Common  8.12% (6.09-10.73) | Uncommon  4.97% (2.96-8.11) |
| Unspecified revision | Very uncommon  0.73% (0.58-0.91) | Very uncommon  0.73% (0.58-0.91) | Extremely uncommon  0.35% (0.06-1.39) |  |
| Symptomatic screws/skin impingement / prominent hardware/painful graft possibly requiring removal | Very uncommon  0.57% (0.45-0.72) | Very uncommon  0.60% (0.47-0.77) | Extremely uncommon  0.17% (0.01-1.11) |  |
| Vertebral compression fracture | Extremely uncommon  0.25% (0.17-0.36) | Extremely uncommon  0.28% (0.19-0.40) |  |  |
| Late deep infection | Extremely uncommon  0.18% (0.11-0.27) | Extremely uncommon  0.18% (0.11-0.28) |  | Extremely uncommon  0.31% (0.02-1.99) |
| Delayed neurological deficit | Extremely uncommon  0.12% (0.07-0.20) | Extremely uncommon  0.05% (0.02-0.12) | Very uncommon  1.21% (0.53-2.59) | Extremely uncommon  0.31% (0.02-1.99) |
| Superficial wound infection or other wounds | Extremely uncommon  0.08% (0.04-0.15) | Extremely uncommon  0.09% (0.05-0.17) |  |  |
| Deformity progression | Extremely uncommon  0.08% (0.04-0.15) | Extremely uncommon  0.09% (0.05-0.17) |  |  |
| Hearing loss | Extremely uncommon  0.04% (0.01-0.10) | Extremely uncommon  0.04% (0.01-0.10) |  |  |
| Other fracture (eg, sacral, pelvic) | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.02% (0-0.07) |  |  |
| Iliac stress fracture or sacroiliac joint degeneration | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.02% (0-0.07) |  |  |
| Deep vein thrombosis | Extremely uncommon  0.02% (0-0.07) | Extremely uncommon  0.03% (0.01-0.09) |  |  |
| Disc herniation | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| Pneumonia | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| Seroma | Extremely uncommon  0.01% (0-0.06) | Extremely uncommon  0.01% (0-0.06) |  |  |
| **Incidence of complication (IOC)** | **11.05% (9.70-10.79)** | **11.05% (10.48-11.62)** | **15.37% (12.58-18.63)** | **13.98% (10.48-18.36)** |

**Appendix II:   
Complications reported in the recent literature classified by type of osteotomies (3CO versus non-3CO)**

1,390 patients for 3CO versus 1,590 patients for non-3CO were analyzed. For the two categories the mean ages were respectively 46.34 ±14.10 and 53.13 ±12.17 years, mean follow-up was 3.53±1.62 and 3.80±1.44 years, mean EBL was 2,232 ±1,033.4 ml and 1,824.97 ±631.68, mean number of fused level 8.15 ±3.17 and 7.76 ±2.23, mean operative time was 356.24 ±169.83 and 360.32 ±161.35 minutes respectively.

**Table 6:** Major perioperative incidence of complications (IOC) percentage with 95% confidence interval and classification according our scale in three-column osteotomies (3CO) and non-three-column osteotomies (non-3CO).

| **Major perioperative complications** | **3CO** | **non-3CO** |
| --- | --- | --- |
| Neurological deficit (not transient, not full recovery, resolved with reoperation, or classified as ‘‘major’’) | Uncommon  2.66% (1.91-3.69) | Very uncommon  1.45% (0.94-2.20) |
| Wound infection requiring debridement  and/or reoperation (especially deep | Very uncommon  1.58% (1.02-2.42) | Uncommon  3.90% (3.03-5.00) |
| Vertebral compression fracture | Very uncommon  1.15% (0.68-1.90) | Extremely uncommon  0.19% (0.05-0.60) |
| Pleural effusion or pneumothorax (requiring intervention) | Very uncommon  0.86% (0.47-1.54) | Extremely uncommon  0.06% (0-0.40) |
| Pneumonia/lung infection | Very uncommon  0.72% (0.37-1.37) | Extremely uncommon  0.19% (0.05-0.60) |
| Pulmonary embolism or thrombosis of major vessel | Very uncommon  0.72% (0.37-1.37) | Very uncommon  0.82% (0.46-1.44) |
| Epidural hematoma | Very uncommon  0.58% (0.27-1.18) | Very uncommon  0.57% (0.28-1.12) |
| Wound hematoma or seroma | Very uncommon  0.50% (0.22-1.08) | Extremely uncommon  0.44% (0.19-0.95) |
| Excessive bleeding | Extremely uncommon  0.43% (0.17-0.99) |  |
| Unspecified pulmonary | Extremely uncommon  0.43% (0.17-0.99) | Extremely uncommon  0.38% (0.16-0.87) |
| Renal failure | Extremely uncommon  0.36% (0.13-0.89) | Extremely uncommon  0.06% (0-0.40) |
| Compartment syndrome with or without shock (abdominal or extremity) | Extremely uncommon  0.22% (0.06-0.69) |  |
| Instrumentation/graft failure (breakage, dislodgement, or resulting in inadequate correction) requiring revision | Extremely uncommon  0.22% (0.06-0.69) | Very uncommon  0.94% (0.55-1.59) |
| Respiratory distress syndrome/respiratory failure | Extremely uncommon  0.22% (0.06-0.69) | Extremely uncommon  0.19% (0.05-0.60) |
| Visual acuity change | Extremely uncommon  0.22% (0.06-0.69) | Extremely uncommon  0.06% (0-0.40) |
| Congestive heart failure or unspecified  cardiac | Extremely uncommon  0.14% (0.02-0.57) |  |
| Myocardial infarction/cardiac arrest | Extremely uncommon  0.14% (0.02-0.57) | Extremely uncommon  0.13% (0.02-0.51) |
| Misplaced screw possibly causing nerve related pain (requiring reoperation) | Extremely uncommon  0.14% (0.02-0.57) | Extremely uncommon  0.38% (0.16-0.87) |
| Death | Extremely uncommon  0.14% (0.02-0.57) | Extremely uncommon  0.13% (0.02-0.51) |
| Vascular injury (intraoperative | Extremely uncommon  0.14% (0.02-0.57) | Extremely uncommon  0.06% (0-0.40) |
| Gastrointestinal complication (bleeding, ischemia, Clostridium D. infection or other) | Extremely uncommon  0.07% (0-0.46) | Extremely uncommon  0.13% (0.02-0.51) |
| Sepsis | Extremely uncommon  0.07% (0-0.46) | Extremely uncommon  0.06% (0-0.40) |
| Stroke | Extremely uncommon  0.07% (0-0.46) |  |
| Anaphylactic shock |  | Extremely uncommon  0.06% (0-0.40) |
| Breakdown of L5eS1 disc (perioperative not long-term) |  | Extremely uncommon  0.13% (0.02-0.51) |
| Cardiorespiratory (non-pleural effusion) / systemic |  | Very uncommon  1.01% (0.60-1.67) |
| Incision abdominal hernia (reoperation) |  | Extremely uncommon  0.19% (0.05-0.60) |
| Line-related infection |  | Extremely rare (0.06%) |
| Painful rib remnant requiring excision |  | Extremely uncommon  0.06% (0-0.40) |
| Pancreatitis |  | Extremely uncommon  0.13% (0.02-0.51) |
| Retroperitoneal hematoma |  | Extremely uncommon  0.06% (0-0.40) |
| Subarachnoideal hemorrhage |  | Extremely uncommon  0.06% (0-0.40) |
| Wound dehiscence requiring surgery |  | Extremely uncommon  0.19% (0.05-0.60) |

**Table 7:** Minor perioperative incidence of complications (IOC) percentage with 95% confidence interval and classification according our scale in three-column osteotomies (3CO) and non-three-column osteotomies (non-3CO).

| **Minor perioperative complications** | **3CO** | **Non-3CO** |
| --- | --- | --- |
| An intraoperative Dural tear | Common  5.32% (4.23-6.67) | Uncommon  3.02% (2.26-4.02) |
| Transient neurological deficit (foot drop, brachial plexopathy, peroneal nerve palsy, radiculopathy, cauda equina, partial spinal cord injury, etc), on transient intraoperation | Uncommon  4.68% (3.66-5.96) | Uncommon  2.83% (2.09-3.80) |
| Ileus/gastrointestinal complication | Uncommon  2.30% (1.60-3.27) | Uncommon  3.14% (2.36-4.15) |
| Unspecified or other | Uncommon  2.01% (1.36-2.93) | Uncommon  2.96% (2.21-3.95) |
| Wound infection (medical/interventional treatment) or superficial | Very uncommon  1.30% (0.79-2.08) | Very uncommon  1.51% (0.99-2.27) |
| Subluxation or translation at surgical site (intraoperative) | Very uncommon  0.79% (0.42-1.46) |  |
| Deep vein thrombosis | Very uncommon  0.72% (0.237-1.37) | Very uncommon  0.75% (0.41-1.35) |
| Cerebrospinal fluid leak | Very uncommon  0.50% (0.22-1.08) | Extremely uncommon  0.25% (0.08-0.68) |
| Arrhythmia or tachycardia | Extremely uncommon  0.43% (0.17-0.99) | Extremely uncommon  0.13% (0.02-0.51) |
| Delirium | Extremely uncommon  0.43% (0.17-0.99) | Very uncommon  0.94% (0.55-1.59) |
| Hypotension | Extremely uncommon  0.36% (0.13-0.89) |  |
| Other intraoperation | Extremely uncommon  0.22% (0.06-0.69) | Extremely uncommon  0.06% (0-0.40) |
| Reversible coagulopathy | Extremely uncommon  0.14% (0.02-0.57) | Extremely uncommon  0.06% (0-0.40) |
| Pneumothorax | Extremely uncommon  0.07% (0-0.46) | Extremely uncommon  0.13% (0.02-0.51) |
| Wound healing complications (nonsurgical) | Extremely uncommon  0.07% (0-0.46) | Extremely uncommon  0.06% (0-0.40) |
| Hematoma, seroma, or bursa (no surgery) |  | Extremely uncommon  0.06% (0-0.40) |
| Pleural effusion |  | Extremely uncommon  0.25% (0.08-0.68) |
| Symptomatic gallstones |  | Extremely uncommon  0.06% (0-0.40) |
| Unspecified or miscellaneous infection (eg, yeast) |  | Extremely uncommon  0.13% (0.02-0.51) |
| Urinary tract infection |  | Uncommon  2.51% (1.83-3.45) |

**Table 8:** Late complications’ incidence percentage with 95% confidence interval and classification according our scale in three-column osteotomies (3CO) and non-three-column osteotomies (non-3CO).

|  |  |  |
| --- | --- | --- |
| **Late complications** | **3CO** | **Non-3CO** |
| Pseudoarthrosis | Uncommon  2.73% (1.96-3.77) | Uncommon  2.70% (1.98-3.65) |
| Instrumentation/graft failure (breakage,  dislodgement, screw loosening, or resulting in sagittal/coronal decompensation) | Very uncommon  1.72% (1.14-2.60) | Very uncommon  1.76% (1.19-2.57) |
| Proximal junctional kyphosis, especially  requiring extension | Very uncommon  1.44% (0.91-2.26) | Very uncommon  1.64% (1.10-2.43) |
| Adjacent segment degeneration | Extremely uncommon  0.43% (0.17-0.99) | Very uncommon  1.51% (0.99-2.27) |
| Vertebral compression fracture | Extremely uncommon  0.43% (0.17-0.99) | Extremely uncommon  0.25% (0.08-0.69) |
| Symptomatic screws/skin impingement/  prominent hardware/painful graft possibly  requiring removal | Extremely uncommon  0.29% (0.09-0.79) | Very uncommon  1.32% (0.84-2.05) |
| Late deep infection | Extremely uncommon  0.14% (0.02-0.57) | Extremely uncommon  0.13% (0.02-0.51) |
| Iliac stress fracture or sacroiliac joint  degeneration |  | Extremely uncommon  0.06% (0-0.40) |
| Other fracture (eg, sacral, pelvic) |  | Extremely uncommon  0.13% (0.02-0.51) |
| Unspecified revision |  | Extremely uncommon  0.13% (0.02-0.51) |

**Appendix III. Summary of source articles.**

| **Authors and year** | **LOE** | **Study design** | **Patients**  **(\*)** |  | **Surgery** | **Etyology** | **Deformity plane** | **Mean age** | **Mean FU**  **(years)** | **EBL**  **(ml)** | **Mean N° fused level** | **Operative Time (min)** | **N°**  **compl.** | **C.R.** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Acosta FL et al. 2011. [[15](#_ENREF_15)] | IV | R | 21  (6) | Open: P, A/P | Mixed (10 PSO) | Sc, AS, U | S, C | 77, ±2.0 | 3.4 ±1.4 | - | 10±3.8 | 415±253 | 35 | 1.67 |
| Anand N e al. 2010 [[29](#_ENREF_29)] | IV | R | 28 | MIS | LLIF / AxiaLIF + PSF | Sc | C | 67.7 (22-81) | 2 | 241 + 231 | 4,8  (3-8) | 232+248 | 23 | 0.82 |
| Anand N e al. 2013 [[28](#_ENREF_28)] | IV | R | 71  (6) | MIS | LLIF / AxiaLIF + PSF | Sc, Ps | S, C | 64 (24-60) | 3.3  (2-5) | 412 / 314 + 357 | - | 237 | 16 | 0.23 |
| Anand N e al. 2014 [[26](#_ENREF_26)] | IV | R | 46  (4) | MIS | LLIF/ AxiaLIF + PSF | Sc, Ps | S, C | 67 (22-81) | 2  (2-6) | - | 5.6  (3-15) | - | 18 | 0.39 |
| Anand N e al. 2014 [[27](#_ENREF_27)] | IV | R | 50 | MIS | LLIF / AxiaLIF + PSF | Sc | C | 61 (20-85) | 2  (2-6.4) | 613 / 763 | 7  (4-15) | 416.5 | 23 | 0.46 |
| Arun R et al. 2011 [[32](#_ENREF_32)] | III | R cohort | 31 | Open: P | Mixed (12 PSO) | AS | S | 54.7 (40-74) | 5  (2-10) | - | - | 420  (240-540) | 16 | 0.52 |
| Berven SH et al. 2007 [[33](#_ENREF_33)] | IV | R | 38 | Open: P, A/P, A | Non-3CO | Sc | S, C | 64  (40-82) | 4.6 (3.3-4.9) | - | - | - | 24 | 0.63 |
| Bess S et al. 2007 [[34](#_ENREF_34)] | III | R cohort | 56 | Open: P, A/P | - | Sc, PS, PT, Cong | S, C | 49  (30-78) | 3.6  (2-9) | - | > 12 | - | 23 | 0.41 |
| Bess S et al. 2013[[35](#_ENREF_35)] | II | P cohort | 279 | Open: P, A/P | Mixed | Sc | S, C | 57 | 2.4 | - | 12 | - | 304 | 1.09 |
| Bezer M. et al. 2007 [[36](#_ENREF_36)] | IV | R | 16 | Open: P | 3CO (PSO) | Inf | S | 51  (27-65) | 9  (6-12) | 2780 (830-6300) | - | - | 2 | 0.13 |
| Bhagat S. et al. 2013 [[16](#_ENREF_16)] | IV | R | 48 | Open: P, A/P | Mixed (8 PSO, 2 VCR) | Sc | S, C | 64  (31-86) | 3 (2-5) | - | 10.8  (4-23) | - | 27 | 0.56 |
| Boachie-Adjei O et al. 2006 [[37](#_ENREF_37)] | IV | R | 24  (17) | Open: P, A/P | 3CO (PSO) | PS, PT, AS, Deg, Cong | S | 48  (31-74) | 4  (2-8.2) | 2700 (420-6700) | - | 304  (180-480) | 17 | 0.71 |
| Boachie-Adjei O et al. 2007 [[38](#_ENREF_38)] | IV | R | 10 | Open: A, A/P | Non-3CO | Sc | S, C | 60.6 | 5.2  (3.2-8.5) | - | - | - | 3 | 0.3 |
| Bourghli A et al. 2015 [[39](#_ENREF_39)] | IV | R | 10 | Open: P | 3CO  (COWO) | PT | S | 36.6±7.5 | 2.6±0.4 | 1390 (1000-2100) | - | 255 (210-360) | 3 | 0.3 |
| Bridwell KH et al. 2009 [[40](#_ENREF_40)] | II | P matched cohort | 85 | - | Mixed | Sc | C | 60 | >2 | - | - | - | 31 | 0.36 |
| Brodano GB et al. 2013 [[41](#_ENREF_41)] | IV | R | 20  (11) | Open: P | Non-3CO | Sc | C | 55.3 (40-74) | 2.5 | - | 10.3 | - | 15 | 0.75 |
| Buchowski JM et al. 2007 [[42](#_ENREF_42)] | IV | R | 108  (32) | Open: P, A/P | 3CO (PSO) | Sc, Deg, PT, PS, AS, Cong | S | 54.8 ± 14 | - | - | - | - | 12 | 0.11 |
| Caputo AM et al. 2013 [[43](#_ENREF_43)] | IV | R | 30  (15) | Hybrid | LLIF + PSF  (11 ALIF) | Sc | S, C | 65.9 (53-76) | 1.9 | - | 6.3  (4-9) | - | 8 | 0.27 |
| Chang CW et al. 2005 [[44](#_ENREF_44)] | IV | R | 26 | Open: P | 3CO (ALO) | Ost | - | 71.5 (65-81) | 3.2  (2.1-6.1) | 717 (310-963) | - | 137  (105-186) | 2 | 0.08 |
| Chang CW et al. 2005 [[45](#_ENREF_45)] | III | R cohort | 66  51 | Open: P | Non-3CO  3CO | AS | S | 34.8 (17-55) | 3.6  (2.1-5.3) | 1101  1915 | -  - | 183  218 | 27  17 | 0.41  0.33 |
| Chang KW et al. 2008 [[46](#_ENREF_46)] | IV | R | 83  (25) | Open: P | 3CO (COWO) | PS, PT, AS, Deg | S | 66.1 (52-76) | 3.5 (2-5) | 3340 (2519-7160) | - | 245  (191-313) | 45 | 0.54 |
| Charosky S et al. 2012 [[18](#_ENREF_18)] | IV | R | 306 | Open: P, A/P , A | Mixed (27 PSO) | Sc | S, C | 63  (50-83) | 4.5  (1-2.5) | - | 7 | - | 175 | 0.57 |
| Chen Z et al. 2011 [[47](#_ENREF_47)] | III | R cohort | 71 | Open: P, A/P , A | Non-3CO | Sc | S, C | 42.9 ± 12.2 | 2 | 1680.6 | 10.2 | 230.6 | 20 | 0.28 |
| Cho KJ et al. 2005 [[48](#_ENREF_48)] | III | R cohort | 41  30 | Open: P, A/P, A | 41 PSO  30 Non-3CO | Sc, PS, PT, AS, Deg | S, C | 54.5 ± 11.7  40.1 ± 11 | 4,6 ±  2.83  3.8 ± 1.48 | 2617  1395 | - | 726  780 | 24  14 | 0.59  0.47 |
| Cho KJ et al. 2007[[49](#_ENREF_49)] | IV | R | 47 | Open: P | Non-3CO | Sc | S,C | 66.6 ± 5.5 | 3.8 ± 1.7 | 2106 ± 1083 | 4.7±2.2 | 197.4 ± 60.7 | 32 | 0.68 |
| Cho KJ et al. 2008 [[50](#_ENREF_50)] | IV | R | 50 | Open: P | Non-3CO | Sc | S, C | 65.5 ± 5.1 | 4.3 ± 1.9 | 2245 | 4.8 | 210.5 | 33 | 0.66 |
| Cho SK et al. 2012 [[20](#_ENREF_20)] | III | R cohort | 250 (124) | Open: P | Mixed (39 PSO, 6 VCR) | Sc | S, C | 51.4 | 3.6 ± 1.4 | 1236.5 | 11.4 | 435 | 128 | 0.51 |
| Cho SK et al. 2012[[51](#_ENREF_51)] | III | R cohort | 166  (166) | Open | Mixed (42 PSO, 2 VCR) | Sc, PS, PT, AS, Deg, Cong, U | S, C | 53.8 | 3.5  (2-7) | - | ≥6 | - | 124 | 0.75 |
| Daubs MD et al. 2007 [[21](#_ENREF_21)] | IV | R | 46 | Open: P, A/P | Mixed (19 PSO) | Cong, U, Sc, AS | S, C | 66.8 ± 6.2 | 4.2 ± 2.5 | 2056 ± 1336 | 9.1 ±3.2 | 605 ± 213 | 44 | 0.96 |
| Deukmedjian AR et al. 2013 [[52](#_ENREF_52)] | IV | R | 27 | Hybrid | LLIF / ACR+ PSF / OSF | SC | S, C | 61 | 1.5 | - | - | - | 4 | 0.15 |
| Deviren V et al. 2008 [[53](#_ENREF_53)] | IV | R | 15 | Open: A | Non-3CO | Sc | S,C | 37.5 (25-59) | 3.9 | - | - | - | 6 | 0.40 |
| El-Sharkavwi MM et al. 2001 [[54](#_ENREF_54)] | II | P cohort | 37  43 | Open: P, A | Non-3CO  (ACP)  3CO (PSO) | PT | S | 35.6 ± 9.4  34.2 ± 9.9 | 2.89  2.89 | 1071.6±544.7  1107.4±366.2 | -  - | 165.3 ± 46.7  149.2 ± 30.2 | 6  4 | 0.16  0.09 |
| Finocchiaro FM et al. 2012 [[55](#_ENREF_55)] | IV | R | 62  (20) | Open: P | Mixed (16 PSO) | Deg, Sc, PS | S | 59±8.3 | 6.4  (1-10) | - | - | - | 12 | 0.19 |
| Fu L et al. 2014 [[56](#_ENREF_56)] | III | R cohort | 84  (31) | Open: P, A/P | Mixed | Sc | S, C | 68.6 ± 8 | >2 | - | 7.5 | - | 93 | 1.11 |
| Gavaskar AS et al. 2011 [[57](#_ENREF_57)] | IV | P | 52 | Open: P | 3CO (PSO) | PT, U, Cong, Inf | S | 25  (18-33) | 2.6  (2-4) | 1100 (900-1700) | 5 (4-6) | 160 (140-205) | 22 | 0.42 |
| Hamilton DK et al. 2016 [[58](#_ENREF_58)] | III | R case control | 63  63  63 | MIS  Hybrid  Open |  | U | - | 60.4 (19-84)  61.2 (22-83)  55.3 (18-80) | 2.8 (1.8-5.4)  2.7 (1.8-4.3)  2.4 (1.8-3.8) | 578.3  1563.4  1379 | 5.4  7.3  7.3 | 438.4  657.8  378.6 | 20  34  38 | 0.33  0.54  0.60 |
| Hassanzedah H et al. 2013 [[59](#_ENREF_59)] | IV | R | 51  (45) | Open: P | 3CO (36PSO, 13 VCR, 2 PSO+ VCR) | U | S, C | 68  (60-81) | >2 | 3900 (620-8000) | - | 522  (330-685) | 29 | 0.57 |
| Hsieh MK et al. 2015 [[60](#_ENREF_60)] | IV | R | 110 | Open: P, A/P | Non-3CO | Sc | S, C | 61.5 | 4.4  (2.2-8) | 2575 (200-6500) | - | 398  (210-753) | 18 | 0.16 |
| Hyun SJ et al. 2010 [[61](#_ENREF_61)] | IV | R | 13  (2) | Open: P | 3CO (PSO) | PT, PS, Deg | S | 59  (44-70) | 6.1  (3.4-9.5) | 2984 (1000-5500) | 5.8  (4-10) | 385  (275-550) | 22 | 1.69 |
| Hyun SJ et al. 2014 [[62](#_ENREF_62)] | III | R case control | 132 | Open: P | 3CO  (PSO / VCR) | U | S, C | 49 | 6.75  (2-16) | - | 12.8 | - | 52 | 0.39 |
| Ikenaga M et al. 2007 [[63](#_ENREF_63)] | IV | R | 67 | Open: P | 3CO (PSO) | PT, Cong, Deg | S | 68.8 (28-81) | 3.8 (2-14) | 1988 (274-10975) | - | 277  (155-435) | 43 | 0.64 |
| Jang JS et al. 2007 [[64](#_ENREF_64)] | III | P | 107 | Hybrid | LLIF + PSF / OSF | Sc | C | 68 (45-87) | - | 50-100 | 4.4  (1/9) | 178 | 37 | 0.35 |
| Jang JS et al. 2009 [[65](#_ENREF_65)] | IV | R | 19  (19) | Open: P + A | Non-3CO | PS | S | 62  (49-74) | 2.6  (2-3,1) | - | - | - | 4 | 0.21 |
| Ji X et al. 2015 [[66](#_ENREF_66)] | IV | R | 21 | Open: P + A | Non-3CO | Deg | S | 64.5 (50-74) | 2.7  (2-3.7) | 1800 (850-2500) | - | 320  (230-490) | 5 | 0.24 |
| Hyun SJ et al. 2014 [[62](#_ENREF_62)] | IV | R | 112  (41) | Open: P | 48 3CO  64 Non-3CO | Deg, PS,Sc, U | S, C | 53.1 ± 12.7  52.3 ± 12.4 | 3.9±1.2  3.5±1.4 | -  - | 11.6 ± 4.2  9.1± 6.3 | -  - | 11  18 | 0.23  0.28 |
| Kasliwal MK et al. 2012 [[67](#_ENREF_67)] | III | R matched cohort | 60  (30) | Open: P, A/P | Mixed (6 3CO) | Sc | S,C | 64 | 2 | 1715.5 | 10.1 | 522 | 38 | 0.63 |
| Khajavi K et al. 2014 [[68](#_ENREF_68)] | III | P | 21  (8) | MIS | LLIF + PSF | Sc | S, C | 70.1 (48-79) | 2 (1-3) | 68 (25-150) | 3.3 | 218  (100-360) | 9 | 0.43 |
| Kim HJ et al. 2014 [[69](#_ENREF_69)] | IV | R | 198  (100) | Open: P | Mixed | Sc | S, C | 61.5 | 2.5  (2-3.2) | 1917 | 11.8 | 400.5 | 158 | 0.8 |
| Kim KT et al. 2007 [[70](#_ENREF_70)] | IV | R | 12  (12) | Open: P, A/P | Mixed (6 PSO) | AS | S | 42.8 (32-58) | 4.3  (2.9-9) | - | - | - | 7 | 0.58 |
| Kim KT et al. 2012 [[71](#_ENREF_71)] | IV | R | 140 | Open: P | 3CO (PSO) | AS, PS, PT, Cong, Inf | S, C | 43.4 | 8  (5-12.5) | 1515.6 | - | 377.7 | 24 | 0.17 |
| Kim YB et al. 2008 [[72](#_ENREF_72)] | IV | R cohort | 48 | Open: P, A/P | Non-3CO | Sc | S, C | 49.6 (22-77) | 3.7  (2-10) | - | - | - | 19 | 0.4 |
| Kim YJ et al. 2007 [[73](#_ENREF_73)] | IV | R | 35  (11) | Open: P, A/P | 3CO (PSO) | Deg, Sc, U, PS, PT | S | 53.1 (21.0-77.9) | 5.8  (5-7.6) | - | 11.7  (5-17) | - | 25 | 0.71 |
| Koller H et al. 2016 [[74](#_ENREF_74)] | IV | R | 488  (46) | Open: P, A/P, A | Non-3CO | Sc | S, C | 51±12 | 3.3±1.9 | - | 7.4 ± 3 | - | 223 | 0.46 |
| La Maida GA et al. 2015 [[75](#_ENREF_75)] | III | R cohort | 59  13 | Open: P | Non-3CO  3CO | Sc | S, C | 60.7 ± 10.2 | 2.5 | -  - | -  - | 340  492 | 12  12 | 0.20  0.92 |
| Lenke LG et al. 2010 [[76](#_ENREF_76)] | IV | R | 16  (8) | Open: A/P | 3CO (VCR) | Sc, U | S, C | 43.5 (18-73) | 2.2 | 1691 (500-3100) | - | - | 7 | 0.44 |
| Liu X et al. 2015 [[77](#_ENREF_77)] | IV | R | 13  16 | Open: P | 3CO  (mVCR)  3CO  (COWO) | PT, In, Cong | S, C | 33.5  26.5 | 2.5  2.5 | 960±120  2600±1600 | -  - | 400±60  470±90 | 0  7 | 0  0.44 |
| Lu G et al. 2015 [[78](#_ENREF_78)] | IV | R | 11 | Open: P | 3CO  (VCR) | In | S, C | 29.8 ± 10.3 | 3.6  (2.1-5) | 2604.5±439.6 | - | 432.7 ± 97.7 | 4 | 0.36 |
| Mehdian H et al. 2015 [[79](#_ENREF_79)] | IV | P | 10 | Open: P | 3CO  (VYO) | U | S | 60 (51-68) | 3 (2-5.7) | 1287 ±350 | - | 220 ± 24 | 2 | 0.20 |
| Mesfin A et al. 2015 [[22](#_ENREF_22)] | IV | R | 14  (7) | Open: P, A/P | Mixed  (2 PSO, 1 VCR) | Sc | S, C | 67 (40.5-81.9) | 3.3 | 2996 (1300-5200) | 10.5  (7-17) | 496.5 (280-690) | 50 | 3.57 |
| Ohtori S et al. 2012 [[80](#_ENREF_80)] | IV | R | 20  (6) | Open: P, A/P | Non-3CO | Deg, Sc, PS | S, C | 66 ±7.0 | 3.4  (3-4) | - | 5.9  (4-9) | - | 5 | 0.25 |
| Okuda S et al. 2012 [[81](#_ENREF_81)] | III | R cohort | 26  14 | Open: A, P | Non-3CO  3CO (PSO) | Ost | S | 74  (60-80)  73  (62-80) | 4.17  (1-8.3)  4.17  (1-8.3) | 1472 (230-7420)  1581 (400-5650) | -  - | 354 (210-585)  436 (195-700) | 17  15 | 0.65  1.07 |
| O'Shaughnessy BA et al. 2009 [[82](#_ENREF_82)] | IV | R | 15  (13) | Open: P | 3CO (14 PSO, 1 VCR) | AS, PS, Sc, PT | S | 56  (36-81) | 3.5  (2-6.25) | - | - | - | 16 | 1.07 |
| Park P et al. 2015 [[83](#_ENREF_83)] | III | R | 43  62 | MIS  Hybrid | MISTLIF / LLIF / AxiaLIF + PSF  LLIF + OSF | U | S | 61 ±14.7  60.7 ±12.1 | 3.2 ± 1.1  2,6 ± 0,7 | 552,4 ± 460.1  1651.1 ± 1287.8 | 5.1±2.7  6.9±3.3 | 452.4 ± 212.2  708.5 ± 271.9 | 14  41 | 0.33  0.66 |
| Park P et al. 2016 [[84](#_ENREF_84)] | IV | R | 42 | Hybrid | MISTLIF / LLIF / + PSF/OSF | U | S, C | 70.3 ± 4.9 | 2.7 | 507.7 ± 537.3 | 5.0±2.8 | - | 19 | 0.45 |
| Park P et al. 2016 [[85](#_ENREF_85)] | IV | R | 77 | Hybrid | MISTLIF / LLIF / AxiaLIF + PSF/OSF | U | S, C | 63.3 | 2.9 | - | 5.9 | - | 45 | 0.58 |
| Park YS et al. 2014 [[86](#_ENREF_86)] | IV | R | 24 | Open: P | Mixed (23 PSO) | AS | S | 38  (30-67) | 2.5  (1.2-5.6) | - | - | - | 2 | 0.08 |
| Passias PG et al. 2016 [[87](#_ENREF_87)] | IV | R | 334 | Open | Mixed | U | S, C | 57.2 ± 15.1 | 2 | 1847.2± 1752.8 | 11.8 | 390.6 ±  130.8 | 76 | 0.23 |
| Peelle MW et al. 2007 [[88](#_ENREF_88)] | IV | R | 30 | Open: P, A/P | Non-3CO | Sc | S,C | 40  (20-66) | 3.3  (2-7.3) | - | - | - | 4 | 0.13 |
| Phillips FM et al. 2013 [[89](#_ENREF_89)] | III | P cohort | 107 | Hybrid | LLIF + PSF/OSF | Sc | S, C | 68  (45-87) | >2 | - | - | - | 50 | 0.47 |
| Qian BP et al. 2011 [[90](#_ENREF_90)] | IV | R | 7 | Open: A/P | 3CO (PSO) | AS | S | 41.7 (29-52) | 3.2  (2-4.9) | 2600 (1400-5000) | - | 460  (360-600) | 0 | 0 |
| Rose PS et al. 2009 [[91](#_ENREF_91)] | II | P matched cohort | 68 | Open: P, A/P | Non-3CO | Sc | S, C | 38.3 ± 13 | 3 (2-6) | 928 | - | 444 | 10 | 0.15 |
| Sansur CS et al. 2011 [[5](#_ENREF_5)] | IV | R | 4980  (1007) | Open: P, A, A/P | Mixed | Sc | S, C | 54.1 | - | - | - | - | 669 | 0.13 |
| Scheer JK et al 2015 [[92](#_ENREF_92)] | IV | R | 32  (4) | Hybrid | LLIF / TLIF / ALIF + OSF | Sc | S, C | 65.5 ±10,2 | 1.5±1.3 | - | - | - | 15 | 0.47 |
| Schmitt PJ et al. 2016 [[93](#_ENREF_93)] | IV | R | 172  (111) | Open: P, A/P | Mixed  (47 3CO) | Cong, Deg, PS, Sc, U, PT | S, C | 61.8 ± 13.4 | 3.7±1.4 | - | 9 ± 2.8 | - | 159 | 0.92 |
| Smith JS et al. 2011[[94](#_ENREF_94)] | IV | R | 587  (410) | Open: P, A, A/P | Mixed (215 PSO, 18 VCR, 19 ACD) | PS, Inf, Deg, Cong, U | S | 58 | - | - | - | - | 171 | 0.3 |
| Smith JS et al. 2016 [[7](#_ENREF_7)] | III | P | 291 | Open: P, A/P | Mixed | U | S, C | 56.2 ±  15.2 | 2.1 | 1800 | 11.1 ±  4.5 | 612 | 469 | 1.61 |
| Strom RG et al. 2016 [[95](#_ENREF_95)] | III | R | 32  60 | Hybrid  Open: P | LLIF + TLIF / OSF / Non3CO  Non3CO / 3CO (17 PSO) | U | S, C | 66±8  69±9 | 2.3+-1.5  2.1±1.3 | 1129 ± 850  1833 ± 1325 | ≥5  ≥5 | 404±60  304±65 | 47  133 | 1.47  2.22 |
| Suk SI et al. 2005 [[96](#_ENREF_96)] | IV | R | 21 | Open: P | 3CO (VCR) | Sc, PT, Inf | S, C | 45.5 (25-69) | 4.4  (2-6) | 2810 (320-5460) | 4.5  (2-8) | 280  (190-405) | 5 | 0.24 |
| Toyone T. Et al. 2012 [[97](#_ENREF_97)] | IV | P | 14 | Open: P | 3CO (PSO) | Sc | S, C | 67 (45-76) | 2.7  (2-3.5) | 1090 (700-2900) | - | 310  (254-375) | 4 | 0.29 |
| Tsai TH et al. 2011 [[98](#_ENREF_98)] | III | P cohort | 58 | Open: P | Mixed | Sc | S, C | 68.9 ± 8.5 | 3.2 ± 0.9 | 1598±1006 | 5.3±1.7 | 432  ± 102 | 59 | 1.02 |
| Wang H et al. 2016 [[99](#_ENREF_99)] | IV | R | 35 | Open: P | 3CO (VCR) | In, U | S, C | 37.8 ±12.8 | 3.8 ± 2.8 | - | 10.3 | - | 9 | 0.26 |
| Wang Y et al. 2008 [[100](#_ENREF_100)] | IV | R | 13 | Open: P | 3CO (VCR) | Sc | S, C | 31 (20.5-43.2) | 2.5  (2-3.3) | 2412 (1800-3200) | 7.7  (7-12) | 266  (208-350) | 4 | 0.31 |
| Wang Y et al. 2009 [[101](#_ENREF_101)] | IV | R | 8 | Open: P | 3CO (VCR) | Inf | S | 26.2 (19-32) | 2.6  (1.8-4.2) | 2933 (2000-6000) | 7  (6-11) | 285  (246-400) | 1 | 0.13 |
| Wang Y et al. 2010 [[102](#_ENREF_102)] | IV | P | 8 | Open: P | 3CO (PSO) | AS | S | 34.5 | 1.6 ± 0.5 | 2200 (1600-3860) | - | 236  (198-310) | 2 | 0.25 |
| Weistroffer JK et al. 2008 [[103](#_ENREF_103)] | IV | R | 50 | Open: P, A/P | Non-3CO | Sc, AS, Cong | S, C | 54  (18-72) | 9.7  (5-26) | - | >8 | - | 69 | 1.38 |
| Wu CH et al. 2008 [[104](#_ENREF_104)] | IV | R | 26 | Open: P | Non-3CO | Sc | S, C | 64.2 (51-77) | 3 (2-6) | 1678±829 | - | 360±64 | 4 | 0.15 |
| Xu H et al. 2015 [[105](#_ENREF_105)] | III | R cohort | 60 | Open: P | 3CO (PSO) | AS | S | 30.9 (21-65) | 2.7  (2-6.2) | 1721 | - | 514 | 28 | 0.47 |
| Yagi M et al. 2014 [[106](#_ENREF_106)] | IV | R | 57 | Open: A/P | Non-3CO | Sc | C | 53.8 ±10.2 | 4.8 ± 2.4 | 2034 ±716.2 | 7  (4-10) | 432 ±66 | 11 | 0.19 |
| Yagi M et al. 2013 [[107](#_ENREF_107)] | III | R case control | 66 | Open: A/P | Non-3CO | Sc | S, C | 56.5 (31-79) | 5.1  (2-11) | 2850 | 10.4 | 471 | 19 | 0.29 |
| Yagi M et al. 2016 [[108](#_ENREF_108)] | IV | R | 15 | Open: P | 3CO  (PSO) | PS, Deg | S, C | 66.2 ± 6.6 | 2.2  (1.5-3.5) | - | - | - | 3 | 0.2 |
| Yang BP et al. 2006 [[109](#_ENREF_109)] | IV | R | 35  (34) | Open: P | 3CO (PSO) | Sc, PS, PT, AS | S | 57.4 | 2 | 5800 (1200-11500) | - | 948  (408-2088) | 32 | 0.91 |
| Zeng Y et al. 2013 [[110](#_ENREF_110)] | III | R cohort | 19  23  39 | Open: P | 3CO (PSO)  3CO (AOPC)  3CO (VCR) | PS, PT, In, Cong | S | 38.5  38.5  38.5 | 2.6  2.6  2.6 | 1370  2300  2710 | -  -  - | 222  282  366 | 4  6  15 | 0.21  0.26  0.38 |
| Zhang HQ et al. 2014[[111](#_ENREF_111)] | IV | R | 9 | Open: P | 3CO (PSO) | AS | S | 41.4 (35-51) | 3.3  (2-5.7) | 3311±523.1 | - | 402.8 ± 50.3 | 7 | 0.78 |
| Zhang XS et al. 2010 [[112](#_ENREF_112)] | IV | R | 5  (3) | Open: P | 3CO (VCR) | PT | S, C | 36  (22-59) | 2 | 1362 (870-2570) | - | 265  (220-408) | 2 | 0.4 |
| Zhu Z et al. 2012 [[113](#_ENREF_113)] | III | R cohort | 31  19 | Open: P | 3CO (PSO)  Non-3CO | AS | S | 36  (22-54)  27  (21-40) | 2.6  (2-4.3)  2.8  (2-4.7) | 1740 (100-3100)  950 (600-1560) | 5.1 (4-6)  5.3 (5-6) | -  - | 5  8 | 0.16  0.42 |
| Zimmerm RM et al. 2010 [[114](#_ENREF_114)] | IV | P | 35 | Open: P, A/P | Non-3CO | Sc | S | 56.3 | 4.1±1.5 | 2735±1928 | 10±2.8 | 519 ±160 | 26 | 0.74 |

**Appendix III:** Studies selected according the inclusion and exclusion criteria. A: anterior approach; ACR: anterior column realignment; ALIF: anterior lumbar interbody fusion; ALO: apical lordosating osteotomy; AOPC: anterior opening-posterior closing; AS: ankylosing spondylitis; AxiaLIF: axial lumbar interbody fusion; A/P: combined anterior-posterior approach; C: coronal; Cong: other congenital/inherited conditions; COWO: closing-opening wedge osteotomy; Deg: degenerative; EBL: estimated blood loss; FU: follow-up; In: infectious; LOE: level of evidence; LLIF: lateral lumbar interbody fusion; MIS: minimally invasive surgery; MISTLIF: minimally invasive surgery transforaminal lumbar interbody fusion; mVCR: modified vertebral column resection; OSF: open screws fixation; Ost: osteoporotic; P: posterior approach; PS: postsurgical/iatrogenic; PSF: percutaneous segmental fixation; PSO: pedicle subtraction osteotomy; PT: post traumatic scoliosis; S: sagittal; Sc: scoliosis (idiopathic, degenerative, cong., neuromuscular); U: unspecified or other coronal and/or sagittal imbalance; VCR: vertebral column resection; 3CO: three-column osteotomy; (\*): revision surgery.