**Supplemental Table 1.** Dimensional analysis of vertebral specimens used in a biomechanical study on the effect of cement augmentation and fenestrated pedicle screw design on pull-out strength.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Vertebral Specimen Designation** | **Spinal Level** | **Bone Mineral Density (g/cm2)** | **T Score** | **Pedicle Height** | **Body Width (widest dimension) (mm)** | **Body Height (tallest dimension) (mm)** |
| *528* | L1\* | 0.886 | -2.3 | 24 | 48 | 33 |
| L2\* | 0.939 | -2.5 | 22 | 48 | 35 |
| L3\* | 1.125 | -1.0 | 20 | 50 | 39 |
| L4\* | 1.018 | -1.9 | 18 | 55 | 40 |
| L5 | 0.992 | Nil | 20 | 55 | 39 |
| *529* | L1 | 1.218 | 0.8 | 23 | 45 | 31 |
| L2 | 1.323 | 0.7 | 20 | 51 | 35 |
| L3 | 1.431 | 1.2 | 23 | 50 | 37 |
| L4 | 1.643 | 2.9 | 24 | 58 | 38 |
| L5 | 1.306 | Nil | 25 | 60 | 40 |
| *466* | L1 | 1.218 | 0.8 | 24 | 54 | 31 |
| L2 | 1.416 | 1.4 | 25 | 50 | 35 |
| L3 | 1.407 | 1.1 | 25 | 58 | 35 |
| L4 | 1.138 | 1.5 | 20 | 55 | 35 |
| L5 | 1.376 | Nil | 24 | 57 | 35 |
| *481* | L1 | 1.016 | -0.7 | 26 | 52 | 37 |
| L2\* | 1.025 | -1.4 | 28 | 51 | 36 |
| L3 | 1.138 | -0.9 | 25 | 58 | 41 |
| L4\* | 1.067 | -1.0 | 27 | 58 | 40 |
| L5 | 1.019 | Nil | 26 | 58 | 40 |
| *527* | L1\*\* | 0.637 | -4.4 | 30 | 52 | 35 |
| L2\*\* | 0.625 | -5.1 | 30 | 55 | 36 |
| L3\*\* | 0.906 | -2.8 | 26 | 60 | 40 |
| L4\*\* | 0.811 | -3.6 | 25 | 61 | 41 |
| L5 | 0.81 | Nil | 26 | 65 | 46 |
| *463* | L1 | 1.225 | 0.8 | 24 | 50 | 31 |
| L2 | 1.424 | 1.4 | 25 | 48 | 32 |
| L3 | 1.592 | 2.4 | 23 | 57 | 37 |
| L4 | 1.564 | 2.4 | 24 | 58 | 38 |
| L5 | 1.539 | Nil | 26 | 58 | 38 |
| *530* | L1\* | 0.872 | -2.4 | 30 | 53 | 39 |
| L2\* | 0.993 | -2.1 | 28 | 56 | 42 |
| L3\* | 1.023 | -1.8 | 30 | 60 | 43 |
| L4\* | 0.983 | -2.1 | 30 | 60 | 45 |
| L5 | 0.972 | Nil | 27 | 63 | 46 |
| *464\** | L1\*\* | 0.711 | -3.0 | 20 | 40 | 28 |
| L2\*\* | 0.828 | -2.8 | 22 | 45 | 30 |
| L3\*\* | 0.842 | -.3.0 | 20 | 50 | 33 |
| L4\* | 0.895 | -2.2 | 20 | 50 | 37 |
| L5 | 0.847 | Nil | 18 | 58 | 38 |

*\* T score within -1.0 and -2.5 SD consistent with osteopenia*

*\*\* T score <-2.5 SD consistent with osteoporosis*

**Supplemental Table 2.** Dimensional Analysis of Cement Plumes within Augmented Vertebral Tests

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Screw Type** | **Cement Type** | **Vertebral Specimen**  **Designation** | **A/P Plume (mm)** | **Lateral Plume (mm)** | **Plume Distance from Tip (mm)** | **Plume Distance from Head (mm)** | **Distance from Tip to Anterior Cortex (mm)** | **Distance from Tip to Pedicle (mm)** | **Screw Insertion Angle (degrees)** |
| *Design 1* | hV | 530 - L1 | 16.92 | 16.29 | ‐1.42 | 27.22 | 14.38 | 29.91 | 16.7 |
| 530 - L2 | 15.26 | 16.82 | 0 | 30.61 | 14.39 | 27.33 | 15.5 |
| 530 - L3 | 16.44 | 14.73 | 0 | 29.27 | 14.17 | 29.06 | 10.8 |
| 528 - L4 | 13.63 | 12.73 | ‐1.9 | 30.22 | 4.42 | 29.9 | 21.1 |
| 529 - L5 | 16.36 | 13.83 | ‐1.43 | 28.14 | 6.82 | 26.6 | 15.6 |
| 528 - L1 | 17.23 | 16.22 | ‐3.82 | 25.83 | 8.42 | 26.34 | 13.9 |
| F20 | 530 - L4 | 10.93 | 11.93 | ‐3.29 | 31.75 | 8.92 | 31.87 | 16.5 |
| 530 - L5 | 22.91 | 17.28 | 2.46 | 23.01 | 7.13 | 32.14 | 14.8 |
| 529 - L1 | 13.05 | 11.67 | 0 | 31.99 | 2.21 | 30.22 | 13.6 |
| 529 - L2 | 14.72 | 14.34 | ‐4.58 | 29.04 | 5.00 | 25.66 | 8.2 |
| 529 - L3 | 15.75 | 19.14 | ‐5.18 | 28.45 | 6.31 | 29.53 | 13.1 |
| 529 - L4 | 16.49 | 14.46 | 0 | 29.02 | 7.44 | 28.34 | 21.3 |
| *Design 2* | hV | 528 - L2 | 16.50 | 13.25 | ‐4.23 | 24.40 | 8.38 | 27.46 | 16.2 |
| 528 - L3 | 13.50 | 13.42 | ‐2.56 | 26.63 | 10.17 | 25.04 | 33.9 |
| 527 - L4 | 14.95 | 17.51 | ‐4.8 | 25.68 | 9.67 | 29.2 | 13.6 |
| 481 - L5 | 13.33 | 16.77 | ‐4.43 | 24.98 | 7.08 | 27.18 | 30.2 |
| 481 - L1 | 16.26 | 17.31 | ‐2.73 | 29.38 | 6.15 | 27.43 | 16.3 |
| 481 - L2 | 13.61 | 12.32 | ‐4.99 | 27.65 | 7.76 | 26.81 | 16.2 |
| F20 | 528 - L5 | 10.26 | 10.68 | ‐5.06 | 29.64 | 5.36 | 30.42 | 29.1 |
| 527 - L1 | 14.13 | 15.83 | ‐3.1 | 26.83 | 9.95 | 27.23 | 24.9 |
| 527 - L2 | 12.93 | 18.40 | ‐4.69 | 26.99 | 12.25 | 25.24 | 17.2 |
| 527 - L3 | 16.33 | 15.04 | ‐3.09 | 25.52 | 8.23 | 29.38 | 19.7 |
| 481 - L4 | 14.74 | 11.94 | ‐3.62 | 26.12 | 6.04 | 31.49 | 23.2 |
| 527 - L5 | 10.63 | 8.02 | ‐4.88 | 29.84 | 16.96 | 24.45 | 21.1 |
| *Design 3* | hV | 481 - L3 | 20.95 | 15.16 | 0 | 22.55 | 12.25 | 23.57 | 19.8 |
| 466 - L4 | 12.36 | 12.35 | ‐9.32 | 23.18 | 3.19 | 23.75 | 20.3 |
| 466 - L5 | 16.58 | 11.89 | 3.31 | 30.55 | 7.59 | 21.45 | 23.7 |
| 464 - L1 | 18.88 | 13.09 | ‐5.82 | 21.27 | 4.73 | 18.48 | 16.4 |
| 464 - L2 | 18.83 | 16.31 | ‐4.96 | 21.02 | 5.07 | 22.52 | 25.2 |
| 464 - L3 | 21.58 | 15.70 | ‐4.49 | 19.89 | 4.96 | 25.12 | 19.9 |
| F20 | 466 - L1 | 19.62 | 11.10 | ‐2.52 | 22.44 | 6.50 | 20.41 | 15.4 |
| 466 - L2 | 12.36 | 13.51 | 0 | 31.77 | 4.46 | 20.75 | 21.0 |
| 466 - L3 | 18.15 | 18.76 | 6.47 | 33.2 | 10.66 | 16.19 | 16.0 |
| 464 - L4 | 17.48 | 19.65 | ‐2.4 | 24.82 | 8.35 | 22.71 | 18.5 |
| 464 - L5 | 20.86 | 15.31 | ‐1.22 | 19.59 | 13.29 | 22.27 | 29.8 |
| 463 - L1 | 13.32 | 14.78 | 0.72 | 32.06 | 7.48 | 19.44 | 14.8 |

**Supplemental Table 3.** Foam Blocks: Data from pull-out testing and geometric analysis of the cement plume

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Screw Type** | **Block Number** | **Test Pull-out Value (N)** | **Cement Type** | **A/P Plume Diameter (mm)** | **Lateral Plume Diameter (mm)** | **Plume Distance from Tip (mm)** | **Plume Distance from Head (mm)** |
| *Design 1* | F1 | 192.11 | hV | 18.22 | 19.89 | 0 | 28.13 |
| F8 | 183.40 | 18.06 | 18.94 | 0 | 28.18 |
| F15 | 130.55 | 15.23 | 17.88 | ‐2.88 | 28.21 |
| F22 | 210.08 | 17.34 | 17.71 | 0 | 29.5 |
| F29 | 209.20 | 16.74 | 17.4 | 0 | 29.08 |
| F36 | 109.20 | 19.01 | 18.36 | 0 | 27.65 |
| F2 | 149.60 | F20 | 16.97 | 16.65 | 0 | 29.53 |
| F9 | 166.13 | 10.31 | 14.44 | ‐7.03 | 29.45 |
| F16 | 238.01 | 15.1 | 16.28 | 0 | 29.88 |
| F23 | 168.15 | 10.8 | 14.88 | ‐5.78 | 29.89 |
| F30 | 179.20 | 18.79 | 21.54 | 0 | 26.44 |
| F37 | 277.57 | 17.26 | 21.54 | ‐1.89 | 27.13 |
| *Design 2* | F3 | 165.65 | hV | 15.53 | 18.65 | ‐4.8 | 24.92 |
| F10 | 200.66 | 15.98 | 20.73 | ‐4.48 | 25.49 |
| F17 | 213.62 | 14.87 | 17.77 | ‐5.84 | 25.99 |
| F24 | 174.29 | 15.21 | 19.71 | ‐4.66 | 25.45 |
| F31 | 212.79 | 14.9 | 16.6 | ‐4.94 | 26.34 |
| F38 | 166.06 | 17.37 | 19.24 | ‐3.85 | 24.48 |
| F4 | 156.84 | F20 | 13.11 | 15.07 | ‐6.87 | 25.66 |
| F11 | 152.59 | 16.33 | 18.35 | ‐5.7 | 24.59 |
| F18 | 125.72 | 15.08 | 14.98 | ‐4.55 | 25.93 |
| F25 | 147.68 | 16.57 | 18.46 | ‐4.92 | 24.33 |
| F32 | 157.21 | 15.83 | 18.05 | ‐4.4 | 25.31 |
| F39 | 167.60 | 15.45 | 16.36 | ‐5.3 | 25.68 |
| *Design 3* | F5 | 164.31 | hV | 13.28 | 18.00 | ‐11.25 | 21.97 |
| F12 | 180.48 | 18.76 | 18.37 | ‐6.12 | 21.28 |
| F19 | 153.01 | 10.9 | 16.04 | ‐11.26 | 23.71 |
| F26 | 184.49 | 18.49 | 19.61 | ‐6.4 | 21.51 |
| F33 | 222.53 | 14.05 | 20.13 | ‐11.05 | 20.97 |
| F40 | 170.32 | 19.97 | 19.5 | ‐5.01 | 20.84 |
| F6 | 140.02 | F20 | 11.02 | 16.51 | ‐13.41 | 21.21 |
| F13 | 177.26 | 10.61 | 15.8 | ‐13.3 | 22.29 |
| F20 | 144.93 | 19.52 | 17.78 | ‐5.95 | 20.51 |
| F27 | 204.99 | 21.64 | 19.27 | ‐4.56 | 19.52 |
| F34 | 202.68 | 12.05 | 17.37 | ‐12.62 | 21.14 |
| F41 | 139.08 | 18.4 | 15.61 | ‐4.79 | 21.68 |
| *Control* | FC7 | 40.34 |  | | | | |
| FC14 | 64.00 |
| FC21 | 74.50 |
| FC28 | 82.23 |
| FC35 | 57.50 |
| FC42 | 48.31 |

**Supplemental Table 4.** Vertebral Tests of Augmented and Non-augmented Control Screws

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Screw Type** | **Cement Type** | **Vertebral Specimen**  **Designation** | **Test Pull-out Value (N)** | ***Control Pull-out Value (N)*** |
| *Design 1* | hV | 530 - L1 | 834.39 | *869.17* |
| 530 - L2 | 1579.66 | *997.61* |
| 530 - L3 | 1340.28 | *1034.56* |
| 528 - L4 | 1507.22 | *1343.10* |
| 529 - L5 | 901.23 | *781.71* |
| 528 - L1 | 1606.56 | *906.55* |
| F20 | 530 - L4 | 1384.46 | *1214.28* |
| 530 - L5 | 1186.68 | *773.91* |
| 529 - L1 | 451.24 | *238.40* |
| 529 - L2 | 365.71 | *426.05* |
| 529 - L3 | 1001.07 | *365.72* |
| 529 - L4 | 947.31 | *362.09* |
| *Design 2* | hV | 528 - L2 | 1034.57 | *1042.91* |
| 528 - L3 | 2137.12 | *1009.61* |
| 527 - L4 | 1519.65 | *647.78* |
| 481 - L5 | 1534.64 | *1360.04* |
| 481 - L1 | 1643.56 | *901.73* |
| 481 - L2 | 1330.27 | *865.01* |
| F20 | 528 - L5 | 1969.38 | *1326.08* |
| 527 - L1 | 1493.67 | *542.09* |
| 527 - L2 | 1979.52 | *805.24* |
| 527 - L3 | 2341.64 | *999.92* |
| 481 - L4 | 1618.00 | *1225.03* |
| 527 - L5 | 1611.27 | *1647.24* |
| *Design 3* | hV | 481 - L3 | 1430.04 | *1007.50* |
| 466 - L4 | 2512.00 | *905.42* |
| 466 - L5 | 2171.00 | *976.31* |
| 464 - L1 | 391.54 | *366.63* |
| 464 - L2 | 798.77 | *430.75* |
| 464 - L3 | 1012.28 | *456.45* |
| F20 | 466 - L1 | 880.11 | *1162.68* |
| 466 - L2 | 1633.47 | *551.64* |
| 466 - L3 | 1259.00 | *453.60* |
| 464 - L4 | 397.09 | *579.71* |
| 464 - L5 | 846.52 | *419.97* |
| 463 - L1 | 1390.01 | *1171.86* |

**Supplemental Table 5.** Dimensional Analysis of Control Screws within Vertebral Tests

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Screw Type** | **Vertebral Specimen**  **Designation** | **Distance from Tip to Anterior Cortex (mm)** | **Distance from Tip to Pedicle (mm)** | **Screw Insertion Angle (Degrees)** |
| *Design 1* | 530 - L1 | 11.63 | 26.50 | 6.5 |
| 530 - L2 | 10.15 | 26.10 | 10.0 |
| 530 - L3 | 10.53 | 28.6 | 12.2 |
| 528 - L4 | 5.58 | 28.77 | 22.5 |
| 529 - L5 | 8.27 | 22.40 | 14.1 |
| 528 - L1 | 8.84 | 20.94 | 14.9 |
| 530 - L4 | 8.61 | 27.15 | 12.8 |
| 530 - L5 | 6.58 | 30.69 | 21.3 |
| 529 - L1 | 0 | 28.23 | 8.2 |
| 529 - L2 | 5.49 | 23.79 | 18.7 |
| 529 - L3 | 8.11 | 24.42 | 9.9 |
| 529 - L4 | 6.51 | 26.61 | 10.0 |
| *Design 2* | 528 - L2 | 9.71 | 24.49 | 19.5 |
| 528 - L3 | 8.32 | 24.93 | 22.3 |
| 527 - L4 | 9.87 | 26.45 | 16.1 |
| 481 - L5 | 6.18 | 27.27 | 24.1 |
| 481 - L1 | 7.59 | 23.03 | 19.4 |
| 481 - L2 | 6.95 | 30.36 | 15.9 |
| 528 - L5 | 3.65 | 30.73 | 28.2 |
| 527 - L1 | 9.42 | 23.49 | 24.3 |
| 527 - L2 | 10.61 | 24.33 | 14.7 |
| 527 - L3 | 8.68 | 26.94 | 26.9 |
| 481 - L4 | 6.54 | 28.9 | 15.2 |
| 527 - L5 | 8.51 | 26.12 | 22.9 |
| *Design 3* | 481 - L3 | 11.5 | 23.43 | 22.1 |
| 466 - L4 | 2.22 | 24.15 | 22.9 |
| 466 - L5 | 5.69 | 20.72 | 32.8 |
| 464 - L1 | 8.58 | 16.15 | 7.7 |
| 464 - L2 | 7.68 | 20.63 | 16.6 |
| 464 - L3 | 6.2 | 25.08 | 16.2 |
| 466 - L1 | 4.27 | 17.09 | 16.3 |
| 466 - L2 | 3.34 | 21.05 | 21.8 |
| 466 - L3 | 7.56 | 18.66 | 22.6 |
| 464 - L4 | 7.61 | 21.85 | 21.3 |
| 464 - L5 | 6.9 | 20.9 | 22.4 |
| 463 - L1 | 7.91 | 22.41 | 13.8 |