Influence Of Stepwise Removal Of UHMWPE Sublaminar Wires On Segmental Stability In Long Segment Instrumentation For Early Onset Scoliosis Correction

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Introduction: Growth-guidance or self-lengthening rod systems are an alternative to subcutaneous growing rods for the surgical treatment of early onset scoliosis (EOS). Growth-guidance systems are especially suitable for neuromuscular EOS patients, who often suffer from significant comorbidities, as the number of subsequent operative procedures is drastically decreased. We propose the use of ultra-high molecular weight polyethylene (UHMWPE) sublaminar wires in a growth-guidance system for EOS. In this concept, continued longitudinal growth is facilitated by sliding of the UHMWPE wires along a correctional rod. We have previously shown that such instrumentation did not adversely affect spinal growth over a 24 week period in an immature sheep model (Roth). However, sublaminar wire passage requires flaval ligament sectioning and thus subperiosteal exposure, which may lead to interlaminar bone formation with subsequent possible growth limitation. In order to preserve as much growth as possible in EOS patients, it becomes apparent that nonsegmental sublaminar wire constructs would be preferential over segmental constructs. Due to the substantially higher fatigue strength in UHMWPE sublaminar wires as compared to metal wires, segmental instrumentation with sublaminar wires is no longer necessary to maintain instrumentation integrity over the long term. However, sufficient number of levels should be instrumented in order to provide adequate spinal stabilization and deformity correction. In this in vitro biomechanical study, we study the influence of sequentially removing sublaminar wires, thereby attaining different nonsegmental sublaminar wire constructs, on the range of motion (ROM) in porcine thoracic spine segments. Our objective is to find the optimum number of consecutive construct end levels instrumented with UHMWPE sublaminar wires in order to attain a careful balance between allowing maximum growth and providing adequate fixation.

Methods: Nine porcine thoracic spines (T7-T14) were cleaned of all soft tissue and musculature while preserving ligaments and approximately 4 cm of ribs on both sides. A custom made four-point bending setup (figure 1) was used to test each specimen in flexion/extension (FE), side bending (SB), and axial rotation (AR) up to a ±4 Nm peak moment. All spines were tested in seven conditions. First, the uninstrumented spine was tested in all three loading directions. Subsequently fully segmental instrumentation was introduced in each spine. Dual pedicle screws were placed at T13. The flaval ligament was sectioned from T12/T13 to T7/T8 and 4mm wide woven UHMWPE sublaminar wires were passed sublaminarly at levels T8-T12. Dual cobalt-chromium (4.75mm diameter) rods with an approximate length of 18cm were placed and fixed using standard set screws at the pedicle screws. UHMWPE sublaminar wires were then secured using a double-loop sliding knot, which was tensioned to approximately 300 N and subsequently reinforced using multiple square knots as described previously.
All wires were tied and tensioned in the same order, starting with level T12. The spine was kept in neutral position using a custom made rig during instrumentation introduction. The spine instrumented with UHMWE sublaminar wires was tested in each loading direction, and subsequently the sublaminar wires at the most caudal level were removed using a scalpel. This stepwise removal and testing process was repeated until no sublaminar wires remained and five conditions with varying number of consecutive levels instrumented with UHMWPE sublaminar wires had been tested. The rods were then removed and the uninstrumented spine was tested again to test for mechanical property changes caused by soft tissue degradation or moisture loss which may occur during the total required test time. Spines were regularly sprayed using saline to keep prevent moisture loss. The seven different conditions and the test order are illustrated schematically in figure 2.

**Results:** Total ROM was 49° for both flexion/extension (FE) and side bending (SB) in the uninstrumented condition. Full segmental instrumentation led to a decrease in total ROM by approximately 70% for both FE and SB (ROM of 13° and 15° respectively). The stepwise removal of sublaminar wires at the most caudal level only led to a substantial and statistically significant rise in ROM for both FE and SB when the number of consecutively instrumented levels was decreased from two to one levels (condition 5 vs. 6). In axial rotation (AR), the total ROM was only 14° in the uninstrumented condition. Full segmental instrumentation only led to 20% decrease in total ROM in AR. Due to the limited ROM in AR, the porcine spine seems to be a suboptimal model to test instrumentation efficacy for rotational correction. Test time did not influence mechanical tissue properties as no significant differences between conditions 1 and 7 were found. Results for FE are shown in figure 3. In both FE and SB, the contribution of each disc is approximately equal in the uninstrumented conditions. In all instrumented conditions, gradual motion transition at the upper instrumented level was observed; the contribution of the upper instrumented level (T8-T9) towards the total ROM was statistically significantly greater than all other levels. In SB, an even more gradual transition can be observed, with statistically significant differences in ROM between all three upper instrumented levels (T8-T9, T9-T10, T10-T11).

**Discussion:** In this study we aimed to determine the optimal number of consecutive end levels instrumented with UHMWPE sublaminar wires for application in a non-segmental growth-guidance system to treat EOS. Based on results in both FE and SB, it appears that the optimal number of consecutive end levels instrumented with UHMWPE is two. Instrumenting more consecutive end levels with UHMWPE sublaminar wires does not seem to be beneficial in terms of providing additional spinal stabilization. However, growth needs to be anticipated for EOS patients. Dependent on the patients’ age and expected remaining growth, extra rod length or perhaps an extra end level should be instrumented so that two end levels always remain instrumented even in the case that UHMWPE at the most distal or proximal slide off of the rod.

**Significance:** New nonsegmental spinal instrumentation configurations, which vary from the traditional segmental manner, are explored using novel UHMWPE sublaminar wires for the treatment of early onset scoliosis.
Figure 1. Four point bending test setup used to apply pure moment loads
Figure 2. Overview of the seven instrumentation configurations tested. UHMWPE sublaminar wires are sequentially removed from the caudal to cranial end, while pedicle screws remain in place.

Figure 3. Total ROM in FE for the seven tested conditions. Significant differences (P<0.05) are denoted using asterisks.