Introduction

Polyaxial pedicle screws offer advantages over monoaxial pedicle screws in terms of positioning. Little information is available on the mechanical performance of new designs of polyaxial pedicle screws. The present study examined the static properties of 5 different polyaxial screws in compression-bending, tension-bending and torsion and fatigue behaviour in compression-bending following the ASTM F 1717 guidelines in a corpectomy model.

Materials and Methods

Five titanium alloy polyaxial pedicle screw systems were mechanically tested following ASTM F1717 guidelines in compression-bending (figure 1), tension-bending and torsion and compression bending fatigue at 75 % and 50 % stress levels. The 5 systems examined were: Moss Miami, Synergy Open System, Synergy Closed System, Tenor and XIA. Each manufacturer provided implants for 30, single level constructs for a PMMA corpectomy model. A qualified spinal surgeon assembled all constructs. Tightening torque of the polyaxial mechanism was recorded for each screw using a calibrated digital torque wrench. Each construct was photographed before and after mechanical testing. Mechanical testing was performed using an MTS 858 Biaxial Testing Machine using the testing jigs recommended in ASTM F1717 [1]. Each static test was repeated on 5 separate constructs for each screw system. Load and displacement data and mode of failure were recorded. The load at 2 % offset (N), stiffness (N/mm), ultimate displacement limit and ultimate load limit were determined for compression-bending and tension-bending and torque at 2 % offset (Nm), torsional stiffness (Nm/degree) for the torsional testing. Compression—bending fatigue was carried out at 37 °C in saline at 5 Hz for each system. The number of cycles and mode of failure were recorded. A test was considered run out at 5 million cycles. Data for each testing procedure was analyzed using a one-way ANOVA. A sample from each system was embedded in PMMA following mechanical testing and sectioned to examine the mode of failure at the polyaxial mechanism. Fractured components (screws, rods or saddles) were examined optically and under SEM to study the fracture surface.

Results

No screw shaft failures were observed in any of the static testing. Figure 2 presents a summary of typical load versus displacement curves for the compression-bending testing. The curves reveal failure by slippage of the polyaxial mechanism in the Moss Miami, Synergy Open, Synergy Closed and XIA systems. This mechanism produced a characteristic reduction in load during displacement. The Tenor system did not present this failure mode in compression or tension bending. Torsional data did not reveal any great differences between systems.

Cross sectional analysis of embedded sections of the 5 different systems revealed the different ways of achieving a polyaxial mechanism and the nature of failure or slip (Figure 3). The Tenor system did not demonstrate a slip of the polyaxial mechanism in compression-bending or tension-bending.

Discussion

Similar mechanical behaviour was observed in terms of mechanism of failure and static testing for all systems except the Tenor, which did not slip in compression-bending or tension-bending. All systems demonstrated similar stiffness in the initial part of the load versus displacement curves (figure 2). Cross sectional analysis of the failed systems provided an insight into the polyaxial mechanism employed by each design as well as the mode of failure (figure 3) with slippage occurring at the screw head. Fatigue analysis at 75% compression bending stress revealed a variety of failure modes and significant differences between systems.

REFERENCES

1. Static and fatigue for spinal implant constructs in a corpectomy model, ASTM F1717.