INTRODUCTION: Progression of the slip deformity in adults with isthmic spondylolisthesis has an incidence rate of 20% to 23%1,2. A review of the literature suggests that the progression of anterior slip is influenced by: (i) the extent of load-bearing deficiency of the intervertebral disc caused by disc degeneration, and (ii) the magnitude of the shear/compressive force ratio at the lumbosacral segment. While the importance of these factors has been noted in the clinical and biomechanical literature, their combined effect on slip progression has not been investigated.

The progression of slip is an important factor for clinical evaluation and choice of treatment method. Clinical studies have reported a solid fusion in 45% to 95% of all cases where posterolateral fusion using transpedicular instrumentation (PLF) was used3. Despite their three-column bony purchase, some studies indicate that there is continued potential for micro-motion with PLF, making complete fusion difficult to obtain and increasing the likelihood of implant failure. The combination of transpedicular instrumentation and an anterior interbody cage in a circumferential fusion (CF), in addition to allowing for anterior column support, increases the surface area for fusion without risk of neurological complications.4

Previous in vitro models of isthmic spondylolisthesis have included only the creation of a pars defect without producing the anterior displacement of the superior vertebra, which does not represent the in vivo instability seen with isthmic spondylolisthesis. No objective biomechanical data using human specimens exists on the stabilizing effects of PLF and CF on spinal segments with an unstable isthmic spondylolisthesis under realistic physiologic loads. Therefore, the goal of this study was twofold: (i) to create an in vitro model of unstable L5-S1 adult-onset isthmic spondylolisthesis, and (ii) to evaluate the biomechanical effectiveness of a PLF and CF to stabilize an unstable isthmic spondylolisthesis.

METHODS: Ten cadaveric lumbar spines (L1-S, mean age 58 yrs.) were used. Prior to testing, anterior-posterior and lateral plane radiographs and MRI were performed to rule out any bony and soft tissue abnormalities. Each specimen was mounted in the testing system such that the superior endplate of S1 was inclined to 45° from horizontal to simulate normal upright physiologic loading and resulting spondylolisthesis, after L5-S1 transpedicular instrumentation (PLF), and after L5-S1 transpedicular instrumentation and anterior interbody cage (CF). Flexion-extension motion (FE-ROM) was measured optoelectronically and slip at L5-S1 was measured using digital video-fluoroscopy. Data were analyzed using repeated measures ANOVA.

RESULTS: Through a combination of bilateral pars fracture and partial disectomy, a model of a grade I unstable isthmic spondylolisthesis was created. A strong positive correlation was seen between shear load and percentage slip ($R^2=0.71$, $p<0.01$). Spondylolisthesis slip under 800N follower preload was significantly smaller than under 800N vertical load ($p=0.036$) (Fig. 1). Without preload the L5-S1 FE-ROM was significantly larger with spondylolisthesis than intact ($p=0.002$). The application of a 400 N or 800 N follower preload to the spondylolisthetic spine reduced the instability seen without preload ($p=0.42$) (Fig. 2). PLF was able to prevent progression of slip under no preload and with 400 N and 800 N follower preloads. Slip under 400 N vertical preload was significantly smaller with PLF than with no instrumentation ($p=0.043$) and showed a trend toward decreasing slip under 800 N vertical load with PLF ($p=0.083$) (Fig. 1). When the amount of slip with PLF under 800 N follower preload was compared to the amount of slip with 800 N vertical preload, PLF showed a trend toward increasing slip under a vertical preload ($p=0.064$). PLF effectively reduced the L5-S1 FE-ROM instability seen with spondylolisthesis to less than intact without preload and with both a 400N and 400 N and 800 N vertical preload ($p<0.003$), while showing a trend toward decreasing the L5-S1 FE-ROM to less than intact under an 800 N vertical load ($p=0.066$) (Fig. 2).

CF was able to prevent progression of slip seen with spondylolisthesis under no preload and with both a 400N and 800 N follower preload (Fig. 1). When the amount of slip with CF under 800 N follower preload was compared to the amount of slip with 800 N vertical preload it was found that there was no significant difference between CF slip under follower and vertical preload ($p=0.865$). CF effectively reduced the L5-S1 FE-ROM instability seen with spondylolisthesis to less than intact without preload and with an 800 N follower preload and with both a 400 N and an 800 N vertical preload ($p=0.041$), while restoring L5-S1 FE-ROM to intact levels with a 400 N follower preload ($p=0.117$) (Fig. 2). There was no significant difference in the L5-S1 FE-ROM with PLF and CF for any preload ($p=0.275$).

DISCUSSION: With a combination of pars fracture and partial disectomy, the current model produced both a grade I anterior slip and an increase in the flexion-extension motion at L5-S1 when a combination of compressive and shear loads were applied. This makes the model a more realistic representation of in vivo isthmic spondylolisthesis than any previous model.

The decrease in slip and restoration of normal, intact motion seen with the application of a follower load demonstrates the stabilizing effect of the follower load, and further suggests that muscles may play an active and important role in stabilizing an unstable lumbar spine. The current study showed that PLF and CF decreased the L5-S1 instability seen with spondylolisthesis when subjected to both compressive and shear loading. Yet, further slip of L5 when subjected to a shear load at L5-S1 was only prevented with the inclusion of an interbody cage in circumferential fusion. While transpedicular instrumentation can effectively reduce range of motion in an unstable spondylolisthesis without effectively resisting further slip of L5, circumferential fusion can limit both the range of motion and further slip of L5. Therefore, a circumferential fusion may be a better biomechanical choice for the treatment of an unstable progressive isthmic spondylolisthesis.

REFERENCES: