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# Biomechanical comparison: stability of lateral-approach anterior lumbar interbody fusion and lateral fixation compared with anterior-approach anterior lumbar interbody fusion and posterior fixation in the lower lumbar spine

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*Object.* The stability of lateral lumbar interbody graft–augmented fusion and supplementary lateral plate fixation in human cadavers has not been determined. The purpose of this study was to investigate the immediate biomechanical stabilities of the following: 1) femoral ring allograft (FRA)–augmented anterior lumbar interbody fusion (ALIF) after left lateral discectomy combined with additional lateral MACS HMA plate and screw fixation; and 2) ALIF combined with posterior transpedicular fixation after anterior discectomy.

*Methods.* Sixteen human lumbosacral spines were loaded with six modes of motion. The intervertebral motion was measured using a video-based motion-capturing system. The range of motion (ROM) and the neutral zone (NZ) in each loading mode were compared with a maximum of 7.5 Nm.

The ROM values for both stand-alone ALIF approaches were similar to those of the intact spine, whereas NZ measurements were higher in most loading modes. No significant intergroup differences were found. The ROM and NZ values for lateral fixation in all modes were significantly lower than those of intact spine, except when NZ was measured in lateral bending. All ROM and NZ values for transpedicular fixation were significantly lower than those for stand-alone anterior ALIF. Transpedicular fixation conferred better stabilization than lateral fixation in flexion, extension, and lateral bending modes.

*Conclusions.* Neither approach to stand-alone FRA-augmented ALIF provided sufficient stabilization, but supplementary instrumentation conferred significant stabilization. The MACS HMA plate and screw fixation system, although inferior to posterior transpedicular fixation, provided adequate stability compared with the intact spine and can serve as a sound alternative to supplementary spinal stabilization.

Key Words • **anterior lumbar interbody fusion** • **anterior approach** • **lateral approach** • **biomechanical stability**

Anterior lumbar interbody fusion allows direct removal of dysfunctional intervertebral discs and improves fusion-related stability. The procedure also avoids posterior paraspinal muscle trauma, postoperative epidural scarring, and perineural fibrosis, and it reduces operative time and blood loss. The goals of ALIF include solid interbody arthrodesis, restoration and preservation of intervertebral disc height, reestablishment of sagittal and coronal alignment, and decompression of central neural and foraminal elements by intervertebral distraction. The procedure involves radical discectomy and meticulous preparation of the bone endplates, the placement of precisely sized structural implants (filled with cancellous iliac autograft) into and around the implants, and the maintenance of tight anular tension. Anterior lumbar interbody fusion can be performed via anterior or lateral approaches. The lateral approach has some anatomical advantages. It may, with minimal retraction and dissection, decrease injuries to the nerve roots, abdominal viscera, hypogastric plexus, and great vessels. The lateral approach can also preserve the anterior anulus fibrosus and ALL from a biomechanical viewpoint.

Various types of interbody implants, including bone autograft, allograft, and a variety of cages, have been developed for interbody fusion.[1–3,14,17,26] Recent clinical results involving threaded titanium cages have been favorable;[13,26] however, radiographic assessment of bone incorporation into these metallic cages has become a significant limitation. The FRA has been used as a "biological" cage that permits restoration of the anterior column. Clinically the use of the FRA and posterior instrumentation has been associated with fusion rates as high as 94% and, based on radiographic studies, is not accompanied by allograft resorption.[9]

Nonetheless, the authors of several clinical studies have shown that the immediate stabilization provided by stand-

*Abbreviations used in this paper:* ALIF = anterior lumbar interbody fusion; ALL = anterior longitudinal ligament; BMD = bone mineral density; DSH = disc space height; FRA = femoral ring allograft; NZ = neutral zone; ROM = range of motion; SD = standard deviation; VB = vertebral body.

alone ALIF supplemented with a metallic, carbon fiber cage or allograft materials is still unsatisfactory.[17,18,23,24,30] In other biomechanical studies cage-assisted stand-alone interbody fusion has not been shown to stabilize the spine, regardless of the cage design and insertion trajectory.[15,16,21,29] Therefore, supplementary posterior support, such as that provided by transpedicular or translaminar screw fixation, is necessary to achieve adequate stabilization. In addition, supplementary posterior fixation is needed in the presence of degenerative spondylolisthesis or segmental instability. The authors of many biomechanical studies have reported that supplementary posterior fixation results in a significant stabilizing effect in all modes of loading.[6,16,22,25,29,32]

Although additional posterior transpedicular fixation after ALIF has been reported to achieve the most rigid construct and to provide a high fusion rate, it requires a second surgical field as well as paraspinal muscle dissection, and it is associated with other significant risks. The MACS HMA Anterior Fixation System (Aesculap, San Francisco, CA) is traditionally used at sites in which there is thoracolumbar junction disease. Because of its low-profile construct and ease of use, the MACS HMA system was used in this study for supplementary lateral fixation after ALIF.

The lateral placement of an allograft bone dowel into the interbody space and supplementary lateral fixation in the same operative field would be advantageous if these procedures could provide acute stability similar to that conferred by posterior transpedicular fixation; however, the effect of lateral FRA-assisted interbody fusion and supplementary lateral plate/screw fixation on stability has not been determined in the human cadaveric model. Therefore, the purpose of this study was to compare the immediate biomechanical stabilities of ALIF in two forms: 1) supplemented with an FRA and lateral MACS HMA plate/screw fixation performed after left lateral discectomy; and 2) supplemented with posterior transpedicular fixation performed after anterior discectomy (Fig. 1).

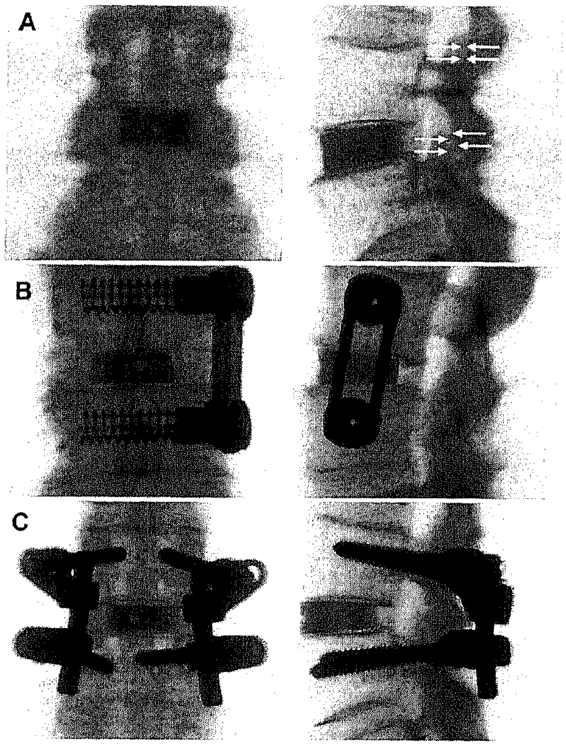

FIG. 1. Anteroposterior and lateral radiographs demonstrating features of ALIF after application of an FRA and two different supplementary fixation systems. A: Stand-alone ALIF resulted in increased intervertebral space and distracted facet joints compared with upper facet joints *(arrows)*. B: Additional lateral fixation with MACS HMA plate/screw instrumentation. C: Additional posterior transpedicular screw fixation with a TiMX system.

## Materials and Methods

### *Cadaveric Specimen Preparation*

Sixteen human cadaveric lumbosacral spine specimens (L2–S1) were obtained from Science Care Anatomical (Phoenix, AZ). The mean age of the six male and 10 female specimens was 72 ± 11 years (± SD) (range 45–90 years). Anteroposterior and lateral radiographs of the specimens were scrutinized to exclude osseous abnormalities, and BMD measurements were obtained using dual-energy x-ray absorptiometry (Hologic QDR 4500A; Hologic, Inc., Waltham, MA). The mean BMD values (± SD) of the ALIF performed via the left lateral discectomy approach and via the anterior discectomy approach were 0.803 ± 0.07 and 0.804 ± 0.13 $g/cm^2$, respectively. No significant intergroup differences in age or BMD existed. For biomechanical testing en bloc specimens were stored at −20°C until thawed at room temperature overnight and were kept moist during all procedures. The attached musculature was removed, with care taken to preserve the joint capsules, ligaments, discs, and bone structures.

### *Experimental Protocol*

The 16 specimens were divided into two groups of eight specimens each. Eight specimens were tested for each implant type; in each group, four specimens were assessed at the L3–4 level and four specimens were tested at the L4–5 level. All specimens underwent FRA-augmented ALIF. The MACS HMA screw/plate fixation system was placed after left lateral discectomy and ALIF, whereas the posterior transpedicular fixation was performed after ALIF via anterior discectomy. The implants were as follows: 1) MACS HMA screw and plate system (Aesculap); and 2) TiMX posterior transpedicular system (DePuy AcroMed, Cleveland, OH).

After radical discectomy, a space was created by preparing the upper and lower vertebral endplates with curettes and taps to expose the osseous endplates. Before FRA insertion, the graft was filled with autologous iliac crest cancellous bone. The size of the FRA was determined so as to create a tight anulus (that is, a height of 9–13 mm) after its insertion. After the insertion of an adequate FRA, the residual disc space was filled tightly with iliac crest cancellous autograft. Each of eight specimens underwent anterior insertion of the FRA followed by posterior placement of the TiMX transpedicular system. In the remaining eight specimens undergoing left lateral FRA-augmented fusion, the MACS HMA screw/plate fixation system was placed via a left lateral approach. The additional implants were applied according to the manufacturers' guidelines. Twelve-mm-diameter and 38-mm-long polyaxial screws were used in the MACS HMA instrumentation. The pedicle screws and rods used for additional fixation in the posterior TiMX transpedicular system were 6.25 mm in diameter and between 45 and 50 mm in length.

### *Fixation and Biomechanical Testing*

For each specimen, L-2 and S-1 vertebrae were cast into two potting fixtures with polymethylmethacrylate and polyester resin, respectively. The potting fixtures for L-2 and S-1 were then attached to the upper and lower spine-loading fixtures of a biomechanical loading frame, respectively (MTS 858; Materials Testing Systems, Eden

Prairie, MN). Six modes of motion—flexion, extension, right/left lateral bending, and right/left axial rotation—were applied with a loading rate of 0.1 Nm/second up to 7.5 Nm. Three infrared reflective markers were placed on the superior and inferior vertebrae of the surgically treated levels, and the vertebral motion was measured using a video-based motion-capturing system (MacReflex; Qualisys Medical AB, Gottenburg, Sweden). To approximate the upright standing condition of the tissues of the specimen (for example, to let the spine disc be restored to its normal height), before each mode of loading, the specimens were preloaded with 200 N of axial compression, and the compressive load was then removed. To stabilize the viscoelastic effect, each mode of testing was performed three times, but only the results of the third test were used. The six modes of loading were applied to each specimen in the following order: 1) the intact spine (16 specimens); 2) after destabilization by anterior or lateral discectomy and preparation of osseous endplates (eight specimens); 3) after FRA-augmented ALIF (eight specimens); and 4) after left lateral MACS HMA plate/screw fixation (eight specimens) or after posterior TiMX transpedicular fixation (eight specimens). The ROM and NZ of each mode of loading were determined.

*Statistical Analysis*

The mean ROM and NZ values for each specimen group were determined and normalized to the corresponding values obtained from the intact spine. Range of motion is the maximum displacement under the maximum applied load; NZ is the difference between the original position and the displacement of the spine after the load force is removed. Normalization was performed by dividing the ROM or NZ values by those of the intact spine. Because the number of specimens in each treatment group was small and the data could not be assumed to be normally distributed, nonparametric statistical methods were used to ascertain the statistically significant intergroup differences. Paired comparisons were made between different treatment groups by using Wilcoxon paired tests. Statistical significance was established at a probability value of 0.05. Values are presented as the means ± SDs.

## Results

The mean ROM and NZ values for all specimens are shown in Table 1. Those for individual specimens were normalized to those of the intact spine as shown in Figs. 2 and 3, respectively.

*Postdiscectomy Measurements*

Statistical analysis revealed that both lateral and anterior discectomy significantly destabilized the spine in all modes of motion ($p < 0.05$) (Figs. 2 and 3). For lateral discectomy, mean ROM values were 204 ± 76, 137 ± 55, 202 ± 89, and 147 ± 24% in flexion, extension, lateral bending, and axial rotation, respectively; mean NZ values were 418 ± 411% in flexion, 226 ± 227% in extension, 642 ± 861% in lateral bending, and 272 ± 162% in axial rotation. For anterior discectomy, mean ROM values were 204 ± 99, 148 ± 50, 162 ± 35, and 172 ± 59% in flexion, extension, lateral bending, and axial rotation, respectively; mean values of NZ were 302 ± 227, 262 ± 229, 338 ± 203, and 293 ± 158% in flexion, extension, lateral bending, and axial rotation, respectively. Neither ROM nor NZ values associated with anterior discectomy were significantly different in any loading mode from the corresponding values associated with lateral discectomy.

*Stand-Alone ALIF*

Compared with discectomy, FRA-augmented ALIF provided some additional stabilization. For lateral ALIF, the ROM values were 83 ± 33, 92 ± 68, 116 ± 56, and 80 ± 45% in flexion, extension, lateral bending, and axial rotation, respectively; the NZ values were 156 ± 261% in flexion, 121 ± 118% in extension, 181 ± 117% in lateral bending, and 199 ± 237% in axial rotation. According to ROM values obtained in all loading modes, ALIF conferred greater stability than did lateral discectomy (Fig. 2). The NZ values showed significant differences ($p < 0.05$) in flexion only (Fig. 3). Lateral ALIF reduced the ROM values to below those of the intact spine without statistical significance in flexion, extension, and axial rotation; however, in lateral bending, lateral ALIF only restored the value of ROM to approximately that of the intact spine, and the values of NZ were not significantly less than those of the intact spine in any loading mode.

For anterior ALIF, the ROM values were 114 ± 57, 98 ± 48, 91 ± 38, and 93 ± 57% in flexion, extension, lateral bending, and axial rotation, respectively; the NZ values were 176 ± 108% in flexion, 166 ± 197% in extension, 153 ± 162% in lateral bending, and 148 ± 107% in axial rotation (Figs. 2 and 3). Compared with anterior discectomy, anterior ALIF provided stabilization in terms of ROM in all loading modes and, in terms of NZ, in flexion and lateral bending modes ($p < 0.05$); however, ROM values were not significantly different from those of the intact spine in any mode. All NZ values were greater than those of the intact spine. Neither ROM nor NZ values of anterior ALIF were significantly different from the corresponding values of lateral ALIF in any loading mode.

*Supplementary Instrumentation*

Supplementary instrumentation provided additional stabilization. After application of the left lateral MACS HMA plate and screw system, mean ROM values were 37 ± 16, 66 ± 28, 54 ± 26, and 50 ± 32% in flexion, extension, lateral bending, and axial rotation, respectively; mean NZ values were 41 ± 19% in flexion, 48 ± 32% in extension, 74 ± 53% in lateral bending, and 80 ± 66% in axial rotation (Figs. 2 and 3). Compared with the lateral stand-alone ALIF, ROM values were lower in all loading modes, significantly so in flexion and lateral bending. The mean NZ measurement after left lateral MACS HMA plate/screw fixation was significantly lower in the lateral bending mode only. The ROM and NZ values in all loading modes were significantly lower than those of the intact spine, except for the NZ in lateral bending.

After application of the posterior TiMX transpedicular fixation system, the ROM values were 16 ± 26, 18 ± 7, 28 ± 22, and 23 ± 25% in flexion, extension, lateral bending, and axial rotation, respectively; the NZ values were 17 ± 18, 13 ± 13, 28 ± 34, and 31 ± 41% in flexion, extension, lateral bending, and axial rotation, respectively (Figs. 2 and 3). All ROM and NZ values were significantly lower ($p < 0.05$) than those associated with both anterior ALIF and the intact spine. Additionally, based on ROM and NZ results, posterior TiMX transpedicular fixation provided better stabilization in flexion, extension, and lateral bending than did lateral MACS HMA fixation.

## Discussion

*Anterior Lumbar Interbody Fusion*

Anterior lumbar interbody fusion is a stability-inducing

TABLE 1
*Summary of ROM and NZ values obtained in all treatment groups*

| Approach | ROM/NZ Value (°)* Flexion | Extension | Lat Bending | Axial Rotation |
|---|---|---|---|---|
| lat group | | | | |
| intact | 2.94 ± 0.78/0.48 ± 0.51 | 3.18 ± 1.98/0.45 ± 0.36 | 7.86 ± 4.47/0.81 ± 0.87 | 3.80 ± 2.78/0.92 ± 1.49 |
| discectomy | 5.81 ± 2.16/1.42 ± 1.23 | 3.88 ± 2.15/0.62 ± 0.34 | 14.04 ± 7.02/2.34 ± 2.34 | 5.65 ± 3.89/1.94 ± 2.85 |
| ALIF | 2.37 ± 1.14/0.35 ± 0.37 | 2.23 ± 1.05/0.43 ± 0.36 | 7.62 ± 3.43/0.85 ± 0.45 | 2.72 ± 1.75/0.70 ± 0.80 |
| HMA fixation | 1.28 ± 0.70/0.25 ± 0.2 | 1.91 ± 0.99/0.24 ± 0.20 | 2.98 ± 1.35/0.35 ± 0.25 | 1.57 ± 0.99/0.27 ± 0.22 |
| ant group | | | | |
| intact | 4.82 ± 2.36/0.92 ± 1.09 | 3.77 ± 1.92/0.85 ± 0.62 | 8.50 ± 2.30/0.94 ± 0.54 | 4.54 ± 2.05/0.82 ± 0.61 |
| discectomy | 9.64 ± 3.92/2.05 ± 1.37 | 5.02 ± 2.23/2.01 ± 1.56 | 13.18 ± 6.07/2.33 ± 1.28 | 7.97 ± 4.89/2.12 ± 1.39 |
| ALIF | 4.81 ± 1.79/1.03 ± 0.55 | 3.36 ± 1.58/1.00 ± 0.75 | 7.85 ± 3.58/1.00 ± 0.82 | 4.59 ± 3.23/1.20 ± 1.09 |
| TiMX fixation | 0.71 ± 0.96/0.10 ± 0.11 | 0.80 ± 0.63/0.11 ± 0.14 | 2.50 ± 1.89/0.27 ± 0.39 | 1.16 ± 1.52/0.26 ± 0.39 |

* All data are presented as the means ± SDs.

fusion method used to treat painful degenerative disc disease, spondylolisthesis, segmental instability, and the failed–back surgery syndrome in the lower lumbar spine. The intervertebral surface is highly vascular, and the grafts have a wide contact area in the weight-bearing axis of the spine. Interbody fusion permits high load transmission through the anterior column and restores DSH and segmental lordosis. The restoration of DSH and the reduction of any deformities are the major advantages of interbody fusion methods, and postoperative preservation of these states is important in reducing pain and enhancing clinical outcome. Successful interbody fusion provides stable axial support without implant subsidence or graft collapse and reduces the postoperative segmental mobility, permitting better graft incorporation. Chen and colleagues[4] have indicated that the restoration of DSH via ALIF could significantly increase both the neural foraminal volume by approximately 20% and the neural foraminal area by approximately 30% at degenerative L4–5 and L–S1 levels.

### *Stand-Alone ALIF*

The compressive strength of a structural implant determines its ability to preserve DSH distraction, anular tension, and the reduction of any deformity. Failure of the structural implants before incorporation leads to the loss of DSH, segmental instability, and eventually pseudarthrosis. During the last 10 years, the development of metallic and carbon fiber interbody cages has resulted in the popularization of cage-assisted lumbar interbody fusion.

In several biomechanical studies, however, investigators have demonstrated that structural implant–augmented stand-alone ALIF does not stabilize the spine despite the various types of implants and insertional directions.[7,15,16,21] Some biomechanical studies of cage- or FRA-assisted ALIF in human cadaveric specimens have been reported.[6,21,25,29] These studies have shown that, after implant insertion, specimen motion was generally less than that of the intact spine; however, in extension, motion was approximately equal to that of the intact spine, which indicates that implants do not stabilize the spine in extension mode. Tsantrizos, et al.,[29] studied five different cages (I/F, BAK, TIS, SynCage, and ScrewCage) and reported that these devices did not reduce the NZ below that of the intact spine. They also claimed that the BAK and TIS cages caused the greatest increase in the NZ in flexion–extension and lateral bending. They proposed that the increase in the NZ is indicative of potential initial segmental instability, concluding that stand-alone cages reduced ROM effectively but that an increased NZ indicated the presence of micromotion at the cage–endplate interface.

The FRA is known to be superior to a tricortical iliac crest autograft because of its higher compressive strength, although some disadvantages, such as graft resorption and delayed graft incorporation, have been reported.[8,31] Until now, few clinical and biomechanical studies have been conducted to assess stand-alone FRA-augmented ALIF.[1,9,10] Glazer, et al.,[6] reported that the stand-alone FRA-assisted ALIF did not provide stability in extension, but the addition of anterolateral instrumentation resolved this problem. In several clinical studies investigators have reported that the fusion rate was higher when FRA-augmented ALIF was performed in conjunction with additional fixations.[8,11,27] In the present study, radical discectomy and preparation of osseous endplates were performed, an FRA was filled with autologous iliac cancellous bone, and the residual disc space was filled tightly with iliac cancellous autograft after the insertion of an adequate FRA. This procedure may make the interbody fusion more stable. Alternatively, the channel discectomy made by reaming the interbody space for the insertion of horizontal cylinder (screw)–type cages usually does not completely remove the disc and cartilaginous material from the disc space. The remaining soft materials may decrease the intersegmental spinal stability and interfere with fusion.

When stand-alone FRA-augmented ALIF was performed after left lateral discectomy, the ROM and NZ values were slightly lower in flexion and extension modes than those obtained after anterior-approach ALIF; however, no significant intergroup differences were found. As a result, decreased stability in extension seems to be partially affected by the removal of the ALL and the anterior anulus. In the lumbar spine, the facet joints primarily limit extension and axial rotation. During extension, the inferior articular processes slide downward onto the superior articular processes, and, in turn, this movement is blocked by impaction against the lamina below. If significant interbody distraction has occurred during ALIF, the distance between the inferior facet of the upper vertebra and superior facet of the lower vertebra will be increased and cannot limit extension (Fig. 1A). Nydegger and colleagues[20] have suggested that the lack of stabilization in extension is caused by facet distraction secondary to overall intervertebral distraction. Although the ALL and anterior anulus limit this spinal extension, their proximity to the instantaneous axes of rotation implies that their main effect is not on extension. The benefit of an intact ALL has been recognized in axial rotation. The intact ALL provides an anchor anterior to both the posterior longitudinal ligament and posterior elements that offers more resistance to axial rotation. In this study we have also shown that the axial rotation ROM demonstrated in lateral ALIF–treated specimens was slightly lower than that in anterior ALIF–treated specimens.

*Surgery-Related Considerations*

Anterior lumbar interbody fusion can be performed via an anterior or lateral approach. The anterior approach allows the surgeon's trajectory to pass in front of the intervertebral spaces, and it can also be performed endoscopically. This procedure, however, involves a wide dissection and retraction of various important structures such as the abdominal viscera, the great vessels including the abdominal aorta, inferior vena cava, and iliac vessels, the ureter, and the hypogastric sympathetic plexus. The ALL is also sacrificed. Alternatively, the lateral approach, including the endoscopic procedure, has some anatomical advantages. It allows access to the lateral disc area, requiring minimal dissection and retraction of these important structures. It also has some biomechanical advantages because it preserves the ALL and the anterior part of the anulus fibrosus. These structures may be as important as facet joints in spinal extension and axial rotation. It has been argued that a BAK cage or an FRA bone dowel insertion performed via a lateral endoscopic retroperitoneal approach resulted in fewer clinical complications than the traditional open transperitoneal anterior approach—that is, there was no implant migration, significant subsidence, or pseudarthrosis at levels above the lumbosacral junction.[19] The large bulk of the psoas muscle containing lumbosacral nerve roots may need to be mobilized laterally when performing lateral ALIF in which additional instrumentation must be placed. Care must be taken to avoid the ureter and the genitofemoral nerve on the psoas muscle. The left psoas muscles can be dissected meticulously at the site of muscle origin and should be retracted laterally. In a procedure involving the lateral-approach ALIF and placement of additional instrumentation, ligation and transection of segmental vessels are also required to obtain enough space for the lateral screw/plate fixation and to prevent lumbar and lumbosacral plexus injuries. Exposure of the lateral surface of the L-4 and L-5 VBs is technically more difficult than that of the L-3 and L-4 VBs. This is because exposure of the left lateral aspect of the L-5 VB requires ligation of the ascending iliolumbar vein (which is usually located at the lateral aspect of the L-5 VB) and mobilization of the great vessels at or near the iliac bifurcation. The lateral surface of the L-5 VB is also narrower and more convex than that of the other lumbar vertebrae. At this level, proper placement of the HMA screw is sometimes difficult because of a high-lying iliac crest. This approach cannot be performed below the L4–5 level because of the height of the iliac crest.

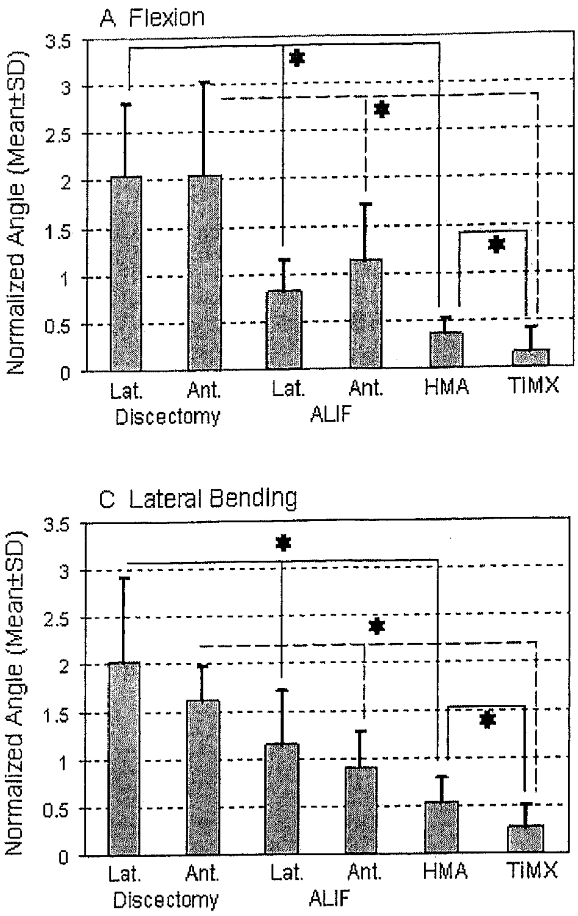


FIG. 2. Graphs. Normalized ROM values (means ± SDs) obtained in spine specimens after lateral and anterior discectomy, lateral and anterior ALIF, and placement of additional instrumentation. *p < 0.05.

In this study, the MACS HMA screw/plate system was used for supplementary lateral fixation after ALIF. This system has a low-profile construct and polyaxial mechanism. One VB can be fixed using only one MACS HMA screw, and the screw can be used monocortically.

*Effect of Supplementary Instrumentation*

The effect of supplementary instrumentation on stabilization of the interbody structural implants is clear: it enhances segmental stability and increases the stiffness of ALIF with any type of implant. Segmental intervertebral stability can lead to successful fusion, and the increased stiffness in compression load could prevent graft collapse or implant subsidence. Early results of autograft- or allograft-assisted ALIF without supplementary instrumentation have been associated with lower rates of clinical success and fusion.[5,28,29] In one study of stand-alone autograft- or allograft-assisted ALIF, the disc heights measured at the last follow-up examination were narrower than at baseline in approximately half of the patients.[5] The authors even suggested that loss of distraction is a normal postoperative event and that postprocedure disc space distraction is tem-

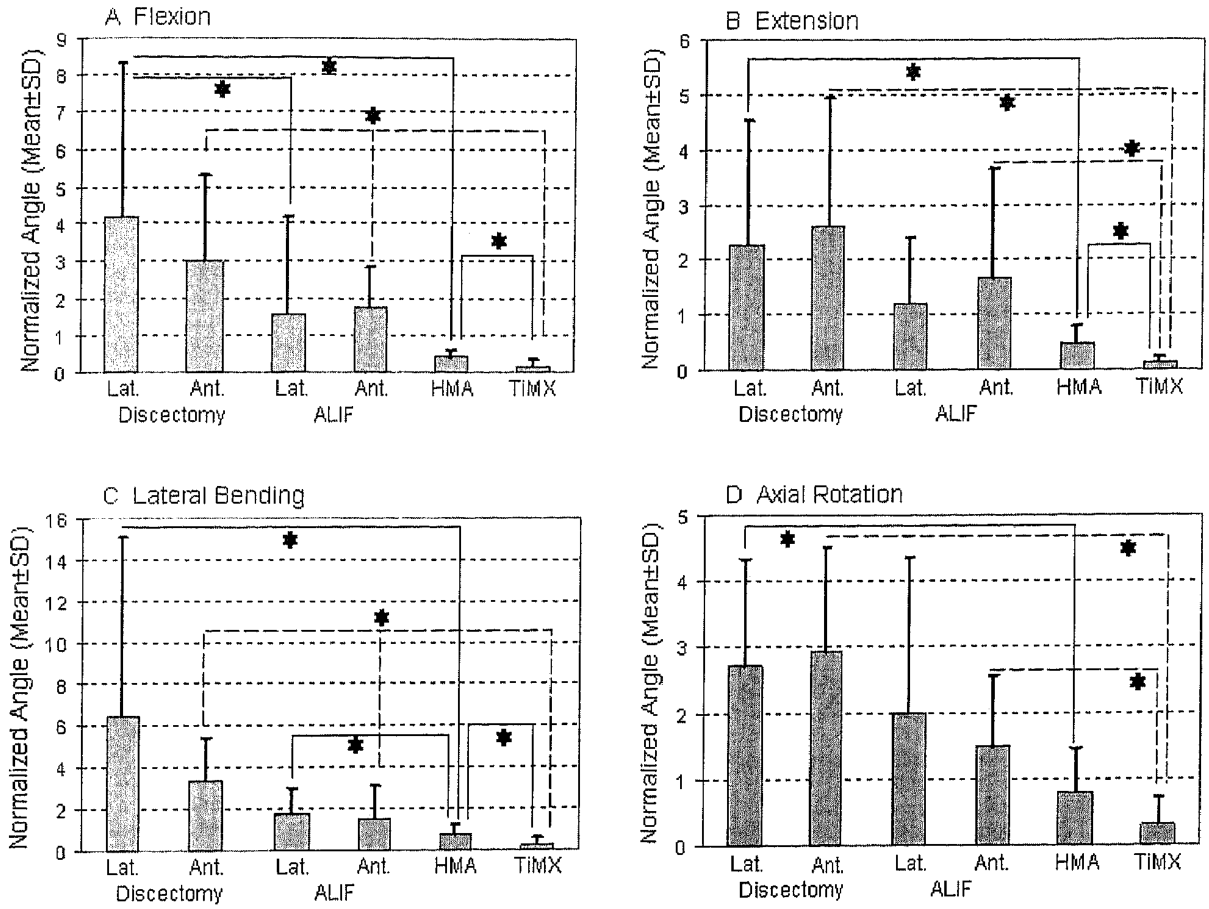


FIG. 3. Normalized NZ values (means ±SDs) obtained in spine specimens after lateral and anterior discectomy, lateral and anterior ALIF, and placement of additional instrumentation. *$p < 0.05$.

porary when ALIF has been performed. This result confirmed that autograft- or allograft-assisted interbody fusion without supplementary fixation could not maintain disc space and neural foraminal distraction. Kumar, et al.,[12] also reported that stand-alone FRA-augmented ALIF fusion was achieved in 66% of patients, and intervertebral distraction was maintained in only 59%. Maintaining intervertebral distraction is important because it promotes anterior load sharing, increases the amount of space for nerve roots, and prevents a flat-back syndrome.[17]

In this study, because the ROM and NZ values for lateral MACS HMA fixation in all loading modes were significantly lower than those for the intact spine, except for NZ in lateral bending, it could be concluded that this system restored biomechanical stabilities compared with the intact spine. Although posterior TiMX transpedicular fixation yielded better stabilization in flexion, extension, and bending modes in terms of both ROM and the NZ, supplementary lateral MACS HMA plate/screw fixation after ALIF also provided significant additional stability compared with the intact spine in most loading modes. Therefore, this procedure can maintain segmental spinal stability, although it did not achieve the same stability as posterior transpedicular fixation.

Cadaveric studies have certain limitations. Most of our cadaveric specimens were obtained in elderly patients, and because motion decreases with age, the mean BMD value of the specimens in this study was below the normal value found in younger patients undergoing this surgical procedure. Although the ROM and NZ values were normalized to those of the intact spine, the results may translate into lower biomechanical stability in a young healthy population because BMD influences the primary stability of screw fixation. It also should be considered that motion was evaluated without muscular assistance and that our data were derived from pure movements applied to only L3–4 or L4–5. Therefore, the clinical application of this study should be considered with caution.

## Conclusions

The anterior- and lateral-approach stand-alone FRA-augmented ALIF did not provide sufficient stabilization in this human cadaveric lumbosacral spine study. Application of two different supplementary instrumentations yielded significant additional stabilization in most loading modes. Based on our ROM and NZ values, MACS HMA plate/screw fixation after ALIF provided greater biomechanical stability than that measured in the intact spine. The MACS HMA plate/screw system, although inferior to the posterior transpedicular fixation, provides adequate stability compared with the intact spine and can serve as a sound alternative to supplementary spinal stabilization.

### Disclosure

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