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Spinal Osteotomies in Spinal Deformity Surgery: Anatomical Classification, Indications, and Surgical Techniques

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Abstract:

Background: Spinal osteotomies are essential surgical techniques used for the correction of complex spinal deformities affecting the sagittal and coronal planes. These procedures aim to restore spinal alignment, improve functional outcomes, and enhance quality of life in patients with deformity-related imbalance. The choice of osteotomy depends on the severity and rigidity of the deformity, underlying pathology, and desired degree of correction. Various osteotomy techniques have evolved over time, ranging from limited posterior element resections to extensive vertebral column resections. The anatomical classification proposed by Schwab and colleagues provides a standardized framework for categorizing spinal osteotomies into six grades according to the extent of bony and soft tissue resection. This review highlights the principles, indications, anatomical classification, surgical approaches, and correction capabilities of the commonly used spinal osteotomy techniques, with emphasis on their role in the management of spinal deformities.

Keywords: Spinal osteotomy; Spinal deformity; Pedicle subtraction osteotomy; Vertebral column resection; Sagittal balance; Scoliosis; Schwab classification; Spinal alignment

Introduction:

In addition to evaluating direct indications for osteotomies based on radiographic alignment, assessing the etiology of the deformity may factor into the decision of surgical strategy**(1)**

De novo spinal deformities involve the sagittal plane to a more significant degree than the coronal plane. Therefore, realigning the sagittal plane is paramount , especially because of the sagittal plane impact on quality of life**(1)**

In patients presenting with hypolordosis and pelvic retroversion, shortening the posterior column by either Smith- Peterson or pedicle subtraction osteotomies, allows for correction in the sagittal plane so that the patient can assume a more physiological alignment **(2)**

In AIS patients, deformities often afflict the coronal plane. Even though HRQOLs are not highly correlated with coronal radiographic parameters, osteotomies are still indicated in curves that may progress (Cobb angle [30°in patients that are still growing or[45°in patients that have completed their growth) or cause the patient significant cosmetic distress]**(2)**

Anatomical classification of osteotomies

Background

The spectrum of surgical realignment techniques ranges from partial facetectomies to major resections such as corpectomies. Smith-Petersen, in 1945, described a superior facet osteotomy to intervene in the fused facets of rheumatoid arthritis**(1)**

In 1984, Heinig published his approach on a resection of the vertebral body which he called the ‘‘eggshell procedure,’’ more commonly known today as a trans pedicular decancellation **(3)**

Variations have led to the techniques of closing wedge osteotomy or pedicle subtraction osteotomy (PSO) ; a procedure he concluded that was reserved for treating more complex reconstructive problems like sharp angled deformities, traumatic deformity, tumors, and infection **(4)**

Until recently, there was no official classification categorizing these various types of osteotomies and group eponyms into a universal language **(4)**

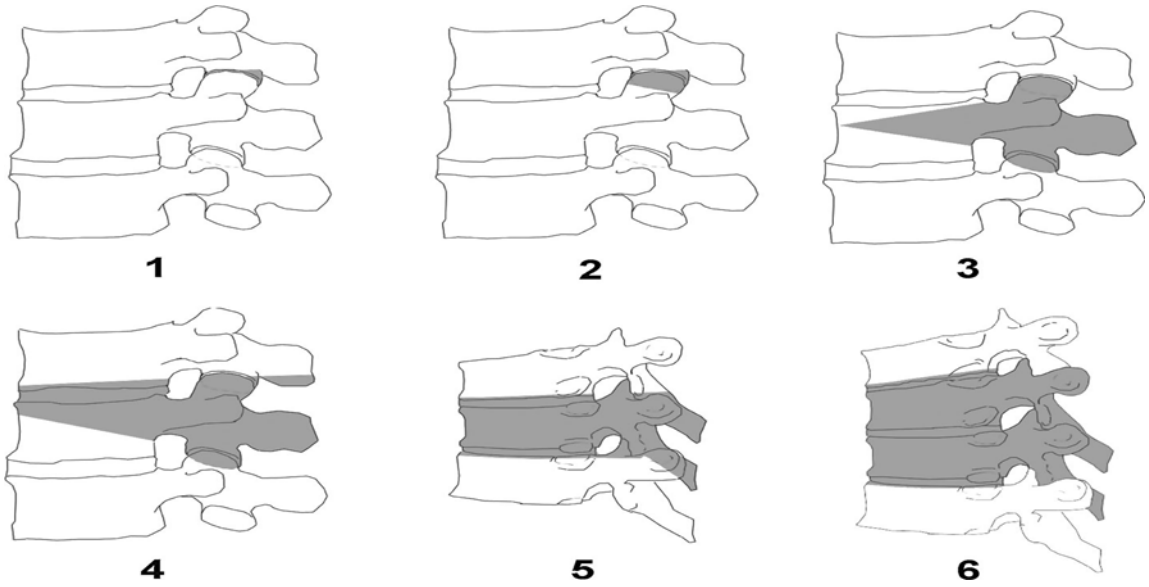

Figure 1 Osteotomy classification: grades 1–6 according to the anatomical resection

Classifying vertebral osteotomies

A systematic and anatomically based approach toward spinal osteotomies that is reliable and simple to learn is needed to facilitate communication, standardize outcomes research, and establish a framework upon which indications can be properly studied and described **(5)**

Schwab et al. proposed an anatomical classification that offers 6 grades of resection that reflect increasing degrees of destabilization and thus potential angular correction ability **(Figure 1) (6)**

Furthermore, to address the surgical approach, modifiers were added: P for posterior approach and A/P for combined anterior and posterior approach**(6)**

Grade1: Partial facet resection

A grade 1 osteotomy achieves the most modest deformity correction and encompasses techniques that resect the inferior facet and joint capsule like the Chevron osteotomy, extension osteotomy, and SPO. This is essentially a partial facetectomy without complete removal of the superior articular process and Smith-Petersen osteotomies fall into this category**(7)**

About 5°–10° of correction can be gained at each level of the grade1 osteotomy, which is approached from the posterior only (modifier P). If this osteotomy is utilized, the patient must have a non-fused anterior column due to the anterior lengthening that occurs **(7)**

Grade2: Complete facet resection

Like the grade1 osteotomy, the grade 2 osteotomy requires anterior column mobility and involves resection of the inferior facet.

However, a grade 2 osteotomy extends the resection to include both the inferior facet and superior

facet, along with their articulating processes, the ligamentum flavum , and potentially other posterior elements to include the lamina or spinous process **(8)**

Osteotomies like the Ponte procedure are only approached from the posterior, but other grade 2 osteotomies like the one described by Burgos et al. for pediatric thoracolumbar scoliosis involving an anterior soft tissue release with a posterior resection, would have a combined A/P modifier **(8)**

Again, it is important to distinguish between the inferior facet resection of a grade 1 osteotomy and the inferior and superior facet resection and removal of the respective articulating processes of a grade 2 osteotomy ; while both SPO and Ponte osteotomies involved facet resection, they differ in amount of bone removed and degrees of angulation achievable, and thus should be distinguished (Grade 1 vs. Grade 2) **(9)**

Grade 3: Partial body and pedicle resection

The grade 3 osteotomy extends the resection into the vertebral body, specifically a wedge resection with the posterior elements, while leaving the disks and a portion of cortex above and below the resection intact. Depending on the technique, grade 3 osteotomies can be approached posteriorly (P) or combined (A/P) **(6)**

There exist many published procedures that fall into this grade including the PSO, circumferential wedge bone resection, multilevel vertebral osteotomy by Suh et al. closing opening wedge osteotomy , and Pascal-Mousse lard's osteotomy are all grade 3 resections.**(10)**

Grade 4: Partial body, pedicle and disk resection

Disk removal characterizes a grade 4 osteotomy. This osteotomy resects slightly more than the grade 3 to include not only just the posterior vertebral body and posterior elements, but also an end plate and at least one adjacent disk; a grade 4 resection in the thoracic region would involve a concomitant rib resection**(6)**

The approach modifier for grade 4 is also P or A/P. Examples in the published literature include a modified eggshell procedure], and a technique which combines a modified SPO with removal of the superior disk and superior body to lessen stretching which could cause aortic or inferior vena cava obstruction **(6)**

Grade5: Complete body and disks resection

Grade 5 osteotomy involves total removal of a vertebral body, posterior elements, pedicles, as well as the adjacent disks; in the thoracic region, a grade 5 osteotomy is accompanied with a rib resection.

The approach is usually a posterior (P), but can actually be performed in a combined method as well (A/P). This osteotomy is also commonly known as a vertebral column resection (VCR) **(6)**

Grade 6: Multiple vertebral and disks resection

A grade 6 osteotomy expands upon the resection of a grade5 osteotomy to include several adjacent vertebrae, thus achieving the most coronal and sagittal plane correction of all the osteotomies; at the very least, this includes one complete vertebral body and a partial second vertebrae**(11)**

Congenital malformations can lead to partially developed vertebrae that may warrant a grade 6 osteotomy. In addition, tumors and infectious processes can lead to destruction of multiple adjacent vertebrae, also necessitating surgical treatment with a grade 6 osteotomy**(11)**

This anatomically based, graded scale classification system which also addresses the nuances of approach, attempts to include the majority of spinal osteotomy techniques, yet it is still simple enough to permit comparative analysis for future research in spinal deformity treatment**(6)**

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