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Surgery of the deformities in ankylosing spondylitis: our experience of lumbar osteotomies in 31 patients

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Abstract Corrective surgery for kyphotic deformities of the spine in ankylosing spondylitis is a major surgery for rare indications. The authors report 31 lumbar osteotomies. The goal is to correct the deformity through a posterior limited approach and to minimise the neurological risks. The modifications developed by the authors for monosegmental closing wedge osteotomies are explained. The posterior resection is rhomboid shaped with a bilateral lamina removal. An osteotomy is performed in a forwards direction on the lateral aspects of the vertebral body without bone resection. This osteoclasty allows progressive vertebral body compression. Pediclectomy is associated if the corresponding foramen at the osteotomy level becomes too narrow in the process of redressing the spine. The resection level is adjusted so that superior and inferior posterior arches come into contact with a good compression. The authors point out the risk of lateral translation. Before the osteotomy, the two adjacent vertebrae are implanted with 5-mm cylindrical pedicular screws, so that posterior fixation can be carried out at any

time. Posterior monobloc fixation allows for very great compression of the osteoclasty. The authors compare the results of their experiences in opening and closing osteotomy. They progressively changed their technique for closing osteotomies, because of published vascular complications and mechanical risks (instability and pseudarthrosis in opening osteotomies). Closing osteotomy also minimises the risk of stenosis with radicular compression or traction if an important correction is performed. The level of the osteotomy varied in this series, which had a correction rate of up to 75°. The choice of level depends on secondary effects on pelvic position and projection of the centre of gravity. The preferred procedure remains a monosegmental correction because it is faster and easier, with minimum bleeding. Short monobloc posterior fixation is sufficient to maintain reduction and to obtain stability from posterior compression.

Key words Ankylosing spondylitis · Wedge osteotomy · Opening osteotomy · Spinal osteotomy · Spinal kyphosis

Introduction

Corrective surgery for kyphotic deformities of the spine in ankylosing spondylitis involves a major operation. This sur-

gery has rare indications, despite the fact that the first procedures were described quite a long time ago (1941) [32] and that anaesthesiology has improved greatly since that time.

This surgery is mainly indicated in cases of severe deformities that lead to a serious handicap (difficulty in

walking, diminution of the visual field) after all preventive methods have proved ineffective. It is also indicated in active patients, since these deformities are severely disabling in everyday life.

There are many surgical procedures, but they are not unanimously accepted. Plurisegmental osteotomies are advocated by some, but the authors prefer a closing wedge procedure, because it is easier and less invasive than even a monosegmental opening osteotomy.

The goal is to correct the deformity through a limited posterior approach, minimising the neurological risks. The authors disagree on the best level for opening or closing osteotomies. Some of them prefer to perform the osteotomy as close as possible to the thoracolumbar hinge in order to prevent a parasitical effect on the pelvis; but this reasoning takes no account of the influence of the osteotomy on pelvic balance, on the posterior displacement of the upper segments and on the visual field direction. Other authors prefer to perform the osteotomy in the inferior part of the lumbar spine, because this has a more significant effect on the upper segment; but this motivation fails to take into account the secondary effect on the pelvis and the consequent flexion contracture of the hips. The authors present their experience of 31 lumbar osteotomies, they compare opening and closing osteotomies and explain their technique for monosegmental closing wedge osteotomy.

History

Smith-Petersen [32] was the first to describe a lumbar osteotomy for this kind of kyphosis. He performed a V-shaped trench from the facets straight to the laminae, removing the spinous process at that and the adjacent levels. Closure was achieved by elevating the inferior limbs. Healing was achieved with immobilisation in a plaster shell for 6 weeks, followed by use of a plaster jacket for 1 year. The best results were achieved when calcification of the anterior ligament was not too great.

La Chapelle [19] in 1946 modified the technique, adding a preceeding anterior approach in order to resect the ligament in case of its complete calcification.

Briggs et al. [4] conducted the osteotomy at the L3-L4 level in 1947, but performed a wider resection of the laminae, carried out a wide bilateral foraminotomy and resected a part of the adjacent pedicles. This procedure was therefore also an anterior opening osteotomy, obtained by direct pressure on the posterior arches.

Herbert [12], in 1959, performed a large rhomboid-shaped resection with opening of the foramen. When rupture of the anterior ligament was not achieved, he performed an anterior approach in order to excise it, as well as the disc. Healing was left to wearing a corset.

Wilson [40] in 1969 proposed changing lumbar osteotomy to a pelvic one.

Simmons [29, 30] in 1972 also precised the technique of lumbar osteotomy at the L3-L4 level, underneath the conus. This osteotomy removes the spinous process of L3, part of L2 and L4, the posterior arch of L3 and the inferior facets of L3. Closure is achieved either spontaneously or after overelevation of the inferior limbs. He then carried out an osteoclasty by rupture of the anterior ligament, and healing was left to the wearing of a Böhler corset for 3 months.

Puschel and Zielke [23], in 1982, described a polysegmental osteotomy at four to six levels. Osteosynthesis was achieved through transpedicular fixation at each level.

Thomassen [36], in 1985, described an osteotomy that removed a posterior wedge including the spinous processes, the posterior arch, and a wedge of the L2 body with a posterior base including the pedicles.

The extension of the lumbar spine was not obtained through an anterior opening, but through a posterior closing. This L2 osteotomy was associated with a transpedicular fixation from T12 to L4. The advantage of this closing osteotomy with a pediclectomy is that it avoids excess traction on the roots, and also avoids abdominal lesion by traction, particularly on the aorta.

Materials and methods

Between 1980 and 1994, 31 patients (26 male, 5 female) were treated in the orthopaedic department of the Pitié Hospital for kyphotic deformities of the spine that were due to ankylosing spondylitis.

Clinical study

The preoperative age of the patients ranged from 32 to 61 years (mean 43.5 years). Symptoms had developed over a period ranging from 6 to 42 years, with an average of 17 years. The indications for surgery were mainly:

1. Diminution of the visual field (29/31) and downward inclination of visual direction (30/31)
2. Walking difficulty (24/31), which was associated with hip flexion contracture in 14 patients
3. Diminution of breathing capacity (8/31)
4. Digestive troubles due to abdominal compression (3/31)

Global thoracolumbar kyphosis was the most common deformity (20/31). The average loss of height since the beginning of the kyphosis was 12 cm (range 6–19 cm). The occipital jib (31/31) was on average 26 cm (range 18–35 cm). The average cervical jib was 17 cm (range 15–33 cm).

Radiologic study

The sacroiliac joints were fused in all patients. Hips were found to be radiologically normal in 24 patients, 4 patients suffered arthritis with contracted hips in flexion, two of them bilateral. Three had previously undergone total hip replacement for flexed hips.

In 14 patients, clinical analysis of sagittal alignment was difficult because of associated flexion contracture of the hips.

The preoperative standing lateral radiographs were compared with the large global standing radiographs at the latest follow-up.

On global antero-posterior and lateral standing views, 6 patients had a scoliotic deformity with a wide radius, 28 had the typical aspect of patients with "bamboo spine". The anterior ligament

was calcified totally in 15 patients, only at the lumbar level in 13 [9], and was intact in 3. Lateral standing views were studied to assess hip flexion and the lateral aspect of the curvature, in particular to ascertain whether the curvature was a global thoracolumbar kyphosis systematically associated with a vertical sacrum (20 patients) or a double curvature with significant thoracic kyphosis and loss of lumbar lordosis (11 patients).

Extra spine study

Breathing capacity was decreased in 16 patients, and there was 1 patient with mixed respiratory insufficiency. Preoperative evoked potentials were studied in 11 patients, they were irregular in six cases (three associated with cervical stenosis, three with significant thoracic kyphosis). Electromyography was performed in ten patients; only two slight radicular involvements were noted.

Operative technique

The osteotomies (Tables 1, 2)

As a first stage, 19 opening osteotomies were performed: 1 at T12-L1 and 7 at L2-L3 (making a total of 8 "superior" osteotomies); 9 at L3-L4 and 2 at L4-L5 (totalling 11 "inferior" osteotomies).

As a second stage, 12 closing osteotomies were performed according to our technique: 1 at L1-L2 and 5 at L2-L3 (6 "superior" osteotomies in total); and 6 at L3-L4 (6 "inferior" osteotomies).

The opening osteotomies (n = 19)

The opening osteotomies were always performed at the discal level. A two-step procedure was used in six cases, involving an anterior approach with resection of the anterior ligament and a discectomy, followed by a posterior procedure comprising a posterior rhomboid shaped resection, correction and fixation using Roy-Camille pedicle screw plates.

A posterior approach alone was sufficient in 13 cases.

The closing osteotomies (n = 12)

Closing osteotomies were always performed through a posterior approach at the vertebral body level. The posterior resection was

rhomboid shaped. After removing the laminae, the resection level was adjusted to allow contact between the posterior arches with good compression. An osteotomy stroke was drawn in a forwards direction on the lateral aspects of the vertebral body. This procedure is not a bone resection, but a simple osteotomy. If necessary, a pediclectomy is performed; this is mandatory if the corresponding foramen, at the osteotomy level, becomes too narrow in the process of correcting the spine. No anterior bony resection is performed, but a pure osteoclasty with progressive vertebral body compression.

While the correction manoeuvres are made care must be taken not only of lateral translation but particularly of anterior slipping of the spine, provoked by an osteotomy stroke drawn too far forward.

This is why we first performed a pedicular implantation of the two adjacent vertebrae with 5-mm cylindrical screws. This allows for progressive stabilisation during the reduction manoeuvres, helping to avoid such translations.

These screws are used in the final monobloc fixation, which involves heavy posterior compression of the osteoclasty using "Domino" instrumentation. The first plates we used were classical Roy-Camille plates with a fixed distance between the holes. We now use an evolution of this system, which allows final adjustment by complementary posterior compression through the plates.

Closure of the osteotomies

Closure of the osteotomies was achieved spontaneously in 2 cases, by direct compression in 2, and in 27 cases by overelevation of the inferior limbs, facilitated by the orthopaedic table on which the patient was installed in prone position.

Fixation

Four of the first cases had no osteosynthesis. Posterior fixation was performed in 27 cases; long, semi-rigid fixations were used in 14 cases (early cases or cases with significant osteoporosis; Fig. 1). Short, rigid fixations, which give a maximum compression of the osteoclasty level, were used in 13 cases (Figs. 2-4).

The bony fragments of the resection were always used as a graft. A posterior iliac crest graft was necessary only in cases of reoperation.

The patients were postoperatively immobilised in a systematic 3-point brace. Twenty-four of the 31 patients had an average bed rest of 2 months. The average time taken to achieve fusion was 4.5 months (range 3-19 months).

Table 1 Opening osteotomies: curve type and level of operation

		Global kyphosis	Double curvature
T12-L1	1		1
L1-L1			
L2-L3	7	2	5
L3-L4	9	7	2
L4-L5	2	2	

Table 2 Closing osteotomies: curve type and level of operation

		Global kyphosis	Double curvature
T12-L1			
L1-L1	1	1	
L2-L3	5	1	4
L3-L4	6	6	
L4-L5			

Results

Morphological results

Opening osteotomies ($n =$ cases) achieved a mean correction was 41.05° : 25° at T12-L1 ($n = 1$), 46° at L2-L3 ($n = 7$), 41° at L3-L4 ($n = 9$) and 52° at L4-L5 ($n = 2$). Two cases of secondary displacement and one of non union led to three reoperations.

Closing osteotomies ($n = 12$) achieved a mean correction of 47.4° : 40° at L1-L2 ($n = 1$), 51° at L2-L3 ($n = 7$) and 43° at L3-L4 ($n = 4$).

Two secondary displacements, with a loss of 20° without any neurological involvement, did not need secondary surgery.

Fig. 1 Opening osteotomy: long, semi rigid fixation

Fig. 2 Opening osteotomy at the L3-L4 level: short, rigid fixation

Fig. 3 Posterior wedge osteotomy: short, rigid fixation

Fig. 4 Posterior wedge osteotomy: asymmetric, rigid fixation at the L2 level

The distribution of the operated levels in global kyphotic and double curvature deformities are given in Tables 1 and 2.

Peroperative problems

Four dural tears and five anterior translations of the caudal segment of the spine occurred, all of them after opening osteotomies.

A fracture of the anterior cortex of the vertebral body happened once, at the end of the reduction in a posterior osteoclasty, for a significant correction, without any further mechanical consequence.

In the opening osteotomies, the fixation was found to be solid in all but four cases. These were early cases, when long, semi-rigid fixation was used.

In one case, a closing osteotomy led to difficulties in fixation. The patient was old with poor bone quality; sudden changes of evoked potentials associated with peroperative medical problems, combined with fragile pedicles, led to the fixation being limited to a unilateral long, semi-rigid osteosynthesis.

Functional results

Opening osteotomies

Six patients out of the 19 who underwent opening osteotomies initially showed an excellent functional result. Six neurological complications occurred. They were transitory in two cases and led to minor functional sequelae in four. One patient developed postoperative paraplegia:

Fig. 5 Late posterior stenosis after opening osteotomy (8 years following surgery)

revision surgery was immediately performed with a laminectomy for decompression of an intraspinal haematoma. Neurological recovery in this patient has been complete.

One case of secondary spinal stenosis occurred in a patient who had undergone significant monosegmental correction at the L4-L5 level. This late complication (8 years after surgery) led to revision surgery consisting of a laminectomy and root decompression, with excellent final results (Fig. 5).

Three patients with inferior osteotomies developed an increase in hip contraction because of severe posterior tilt of the trunk, which disturbed the stability of the pelvis. They were all reoperated and had excellent final results.

Closing osteotomies

Six of the 12 patients who underwent closing osteotomies, had excellent initial results without any pain or correction

loss. There were three cases of transitory radicular involvement and one case of nonunion, which needed reoperation.

The two patients with secondary displacement had good final results in terms of walking, hip contraction and pain, but an insufficient improvement of visual field.

Discussion

The indications for corrective surgery in ankylosing spondylitis are not easy to define.

Opening or closing osteotomies?

In our experience, opening osteotomies performed through a posterior approach require precise rules.

In the early cases, an anterior approach was indicated only if the anterior ligament was not calcified. In the pres-

Fig. 6 Opening osteotomy: postoperative anterior venous compression

Fig. 7 Global lateral radiographs. Wedge osteotomy at the L2 level: posterior short, rigid fixation

ence of calcification, the opening at the disc level was considered as insufficient or difficult or impossible to achieve. We never attempted an anterior opening of the spine through a body fracture, which could lead to mechanical or neurological difficulties as reported in the literature [20]. We took a different attitude at the cervical level.

We progressively tended towards closing osteotomies. The reasons are based on the vascular risks reported in the literature [1, 3, 6, 19, 20] (Fig. 6) and the instability caused by the anterior opening in the coronal and sagittal planes or in rotation [1, 3, 6, 21, 22]. Furthermore, the risk of stenosis has been reported in the literature [10, 12, 13, 16, 21, 34, 36] as has radicular compression or traction in major corrections.

Analysis of the ossification of the anterior ligament serves no purpose in closing osteotomies and an additional anterior approach is never necessary.

We modified the classical technique of wedge osteotomy [18]. Our technique does not require any vertebral

Fig. 8 Global kyphosis: osteotomy angle analysis. The osteotomy angle ($\hat{e}$) is equal to the posterior balance angle of the superior segment ($\hat{f}$):

$$\left. \begin{array}{l} O_1C = O_2C = R \\ O_1A_1 = O_2A_2 = R \\ A_1C = A_2C \end{array} \right\} \Rightarrow \Delta O_1A_1C = \Delta O_2A_2C \Rightarrow \hat{C}_1 = \hat{C}_2$$

$$\left. \begin{array}{l} \hat{C}_1 - \hat{g} = \hat{e} \\ \hat{C}_2 - \hat{g} = \hat{f} \\ \hat{C}_1 = \hat{C}_2 \end{array} \right\} \Rightarrow \boxed{\hat{e} = \hat{f}}$$

(A_1CB initial aspect of spine, A_2CB aspect of spine after osteotomy, O_1 curve centre of arc A_1CB , O_2 curve centre of arc A_2C , R global curve radius of spine, e osteotomy angle, f balance angle)

body resection; it is only an osteoclasty of the vertebral body [36]. The resection of the posterior arch achieves an adjustment sufficient to control the extension correction and increase lateral stability. It also provides a good contact zone, which allows the healing of the posterior graft associated with compressive posterior plating.

The choice of this osteoclastic technique allows a very progressive and smooth compression, which makes the correction very precise and avoids anterior translation or lateral flexion.

The choice of osteotomy level

The level of the osteotomy was not the same in all our patients. A closing osteotomy at L2-L3 allows for a significant correction, up to 75°, but the choice must take account of secondary effects on the pelvis.

Fig. 9 Global kyphosis: posterior balance analysis. The posterior balance angle depends on the level of the osteotomy. The posterior balance of the superior segment could be equal for an upper level osteotomy (A2) or for a lower one (A3). For the same posterior balance, the osteotomy angle of an upper level osteotomy ($\hat{f}_1$) is greater than that of a lower level one ($\hat{f}_2$):

$$\left. \begin{aligned} \hat{e} &= \hat{f}_2 + \hat{h} \\ \hat{f}_1 &= \hat{e} + \hat{g} \end{aligned} \right\} \Rightarrow \hat{f}_1 = \hat{f}_2 + \hat{g} + \hat{h}$$

$$\hat{f}_1 - \hat{f}_2 = \hat{g} + \hat{h} \Rightarrow \boxed{\hat{f}_1 > \hat{f}_2}$$

(A1CDB initial aspect of spine, A2CDB aspect of spine after upper level osteotomy at C, A3CDB aspect of spine after lower level osteotomy at D, O1 curve centre of arc A1CDB, O2 curve centre of arc A2C, O3 curve centre of arc A3D, $\hat{f}_1$ balance angle of upper level osteotomy at C, $\hat{f}_2$ balance angle of lower level osteotomy at D)

An inferior osteotomy at L4 or L5 is more difficult, as the vertebra is more deeply situated, and it may lead to secondary balance problems of the pelvis. The decision must take into account not only technical but also geometric considerations.

Mostly, we performed superior osteotomies for global kyphotic deformities and inferior osteotomies for double curvatures in line with Roy-Camille's approach [24–26].

Some authors [27] postulate that osteotomy has a greater effect if it is done at the upper levels of lumbar spine. We studied the effect of osteotomies on global lateral radiographs (Fig. 7) and geometrically to compare the different levels and techniques by simulation. The osteotomy angle (e) is always equal to the posterior balance angle (f) of the superior segment of the trunk (Fig. 8). Geometric analysis (Fig. 9) shows that, whatever the os-

Fig. 10 Global kyphosis: visual direction analysis. Correction of visual direction ($\hat{e} - \hat{g}$) is equal to the osteotomy angle ($\hat{f}$):

$$\left. \begin{aligned} O_1A_1 = O_1C = R \\ O_2A_2 = O_2C = R \end{aligned} \right\} \Rightarrow \hat{a}_1 = \hat{a}_2 = \frac{180^\circ - \hat{h}}{2}$$

$$\left. \begin{aligned} \hat{C}_1 &= \hat{e} + \hat{a}_1 \\ \hat{C}_2 &= \hat{g} + \hat{a}_2 \\ \hat{a}_1 &= \hat{a}_2 \\ \hat{C}_1 - \hat{C}_2 &= \hat{f} \end{aligned} \right\} \Rightarrow \hat{C}_1 - \hat{C}_2 = \hat{e} - \hat{g} \Rightarrow \boxed{\hat{e} - \hat{g} = \hat{f}}$$

(A1CB initial aspect of spine, A2CB aspect of spine after osteotomy at C, O1 curve centre of arc A1CB, O2 curve centre of arc A2C, $\hat{f}$ osteotomy angle, e initial angle of visual direction by horizon, g angle of visual direction by horizon after osteotomy)

teotomy type (closing or opening), the posterior balance of the superior part of the trunk depends on the level of the osteotomy. If the osteotomy is done superiorly, the correcting angle at the osteotomy level must be greater than the angle required at the lower level for the same result (f).

The angular correction for the direction of the visual field depends on the correction angle of the osteotomy (Fig. 10). It can be shown geometrically (Figs. 11, 12) that the correction angle in the visual field is more important in superior osteotomies than in inferior osteotomy for the same posterior balance angle (f). So, posterior balance correction and visual field angular correction are two different concepts.

The effect on the pelvis, and especially on the position of the sacrum, which depends on hip contracture flexion, is not well described in the literature.

We observed three cases of increasing hip contraction after inferior osteotomy. This can be explained geometri-

Fig. 11 Global kyphosis: effect of osteotomy on visual direction for constant posterior balance. For the same posterior balance ($A2$ or $A3$), the osteotomy angle of an upper level osteotomy at C is greater than that of a lower one at D . As the size of correction of the visual direction is equal to the osteotomy angle (Fig. 10), the correction of visual direction of an upper level osteotomy at C ($\hat{a}_1 - \hat{a}_2$) is also greater than that of a lower one at D ($\hat{a}_1 - \hat{a}_3$). $A1CDB$ initial aspect of spine, $A2CDB$ aspect of spine after upper level osteotomy at C , $A3CDB$ aspect of spine after lower level osteotomy at D , $O1$ curve centre of arc $A1CDB$, $O2$ curve centre of arc $A2C$, $O3$ curve centre of arc $A3D$, $a1$ initial angle of visual direction by horizon, $a2$ angle of visual direction by horizon after upper level osteotomy at C , $a3$ angle of visual direction by horizon after lower level osteotomy at D)

cally (Figs. 13–16). The parasitic effect on the pelvis of a superior osteotomy is smaller than in cases of inferior osteotomy after posterior projection of the centre of gravity. If the projection of the centre of gravity remains anterior to the position of the coxofemoral joint, a residual flexion contracture of the hips is acceptable. When the retroprojection of the centre of gravity is too great to be corrected by the hips, the result can be an additional contraction. We observed this outcome after inferior osteotomies with an excessive correction of the centre of gravity.

This conclusion is particularly evident for double curvature osteotomies, where the increase in lumbar lordosis can lead to excessive retroprojection of the centre of gravity (Figs. 11–14). In our series, a superior osteotomy was preferred in cases of double curvature, while an inferior osteotomy was used in cases of global kyphotic deformity with a vertical sacrum, as we observed in 20 patients.

Fig. 12 Global kyphosis: centre of gravity analysis, initial aspect (AB initial aspect of spine, O spinal curve centre, BE initial aspect of thigh, EF initial aspect of leg, $C.G.$ body's centre of gravity)

Fusion and stabilisation

We found only one case of nonunion in opening osteotomies. This complication appeared in specific circumstances. A unilateral long, semi-rigid fixation was the most that could be performed, because of sudden medical perioperative problems; bone quality was poor and the patient was obese. An anterior and lateral displacement was noted, and the patient was successfully reoperated using an extensive rigid posterior plating.

Fig. 13 Global kyphosis: effect of upper osteotomy on body's centre of gravity (*A1CB* initial aspect of spine, *A2CB* aspect of spine after osteotomy, *C.G.* body's centre of gravity, *BE1* initial aspect of thigh, *BE2* aspect of thigh after upper level osteotomy, *E1F1* initial aspect of leg, *E2F2* aspect of leg after upper level osteotomy)

Monosegmental rather than polysegmental correction

Our approach has always been to perform monosegmental corrections, because this technique is less invasive. A correct choice for the level of osteotomy can avoid posture troubles associated with the correction. The only long-

Fig. 14 Global kyphosis: effect of lower level osteotomy on body's centre of gravity. Patient in global kyphosis with initial hip flexion (Fig. 12). If an osteotomy is carried out at the lumbar lower level (*D*) (Fig. 14), the retroprojection of body's centre of gravity will be greater than that of a lumbar upper level osteotomy at *C* (Fig. 13). If there is a possibility for reduction of hip flexion, whatever level of osteotomy, the retroprojection of the centre of gravity of the patient's body will induce necessary correction (Figs. 13, 14) (*ADB* aspect of spine after lower level osteotomy, *C.G.* body's centre of gravity, *BE* aspect of thigh after lower level osteotomy, *EF* aspect of leg after lower level osteotomy)

Fig. 15 Excessive posterior balance of spine (*ACB* aspect of spine after osteotomy, *BE* aspect of thigh after osteotomy, *EF* aspect of leg after osteotomy). If there is no possibility for adaptation of the hips, an undesired knee flexion will appear. This phenomenon will be greater in cases of lower level osteotomy than in upper level ones

term complication of monosegmental osteotomies was found in an opening osteotomy at the L4-L5 level. It led to a pelvic imbalance, hyperlordosis and a secondary spinal stenosis at this level 8 years after the correction. The posterior osteophyte protrusion required a complementary laminectomy.

Conclusion

The evolution of our technique [24–27] for monosegmental closing osteotomy led us to more reliable reductions through a surgery less invasive than plurisegmental techniques. It diminishes the risks of an anterior displacement and nonunion.

Fig. 16 A, B Effect of correction on sagittal balance: global analysis of curvatures and hip status on global lateral standing view

We also prefer monosegmental correction because of its rapidity and the low risk of radicular compression and mechanical problems.

Posterior plating is essential for final fixation and compression, but reduction is essentially obtained by a direct compression or over elevation of the limbs.

A short fixation is sufficient to maintain the reduction; the stability is given by posterior compression and by rigid fixation. The absence of a bony anterior gap gives better lateral stability and allows for a frontal correction if necessary.

The best level for the lumbar osteotomy depends on the deformity and on local conditions. Neither ossification of the anterior ligament nor the aspect of the discs have any influence on surgical strategy in posterior wedge osteotomies. Global standing views are essential for analysis of the global balance of the trunk. This global analysis of the deformities remains important especially because of the limits of adaptation possibilities in some cases. Hip flexion and position of the sacrum must be analysed to decide whether a superior or inferior osteotomy should be done.

Visual field adjustment and posterior balance of the trunk are two different concepts. We prefer to use a superior osteotomy in cases of double curvature kyphosis and an inferior osteotomy in cases of global kyphosis.

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