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Review Article

Treatment of Spinal Deformities: Don't be « Glued » by the COBB Angle

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ABSTRACT

Despite the evaluation of any spinal deformity must be always done on Morphology, Pain, Function, Self- Image, Psychology, Quality of life…The evaluation of the Cobb angle is considered as the basis of such evaluation pre and post any eventual treatment. Despite its simplicity to use It really measure very incompletely only in 2D, the morphology of the spinal deformities because essentially the horizontal plane data is missing in most of the classification systems that are clearly 2D measurements, and practically it measure only the collapsing of the spine. The introduction of the horizontal plane data through the 3D reconstruction modern techniques with especially the view from the top with or without the vertebral vector technique bring a real 3D evaluation easier to address than the technique developed from the plane of maximum deformity that is not so friendly usable. Finally the goal of this paper was only to make the readers, the authors, the reviewers, the orthopedic surgeons, researchers, and the teachers, to be aware that the Unique Cobb angle measurement cannot remain the "Gold Standard" in the assessment of the spinal deformities as before as after any treatment.

INTRODUCTION

Despite the assessment of any spinal deformity has to be always done pre and post treatment on Anatomy, Morphology, Pain, Function, Self- Image, Psychology, Quality of life criteria's,…the measurement of the Cobb angle is considered as the basis of such evaluation .Many practitioner surgeons ect summarize the case with this only Cobb Angle. The purpose of this paper is to try to show that even for the pure morphology & anatomy aspect this Cobb angle must be revisited. The Radiological measurement of the spinal deformities on their frontal and sagittal projections is universally done with the Cobb angle, from 1948 [1]. It is the angle measured in degree between the 2 vertebral body plateau most tilted on the horizontal .This is used as for frontal or lateral projection of the spinal deformities. It is always required for almost all scientific publications. In fact it is a simple, reproducible, effective and reliable manner to do it, but in reality it is a partial very incomplete measurement as soon as we think 3Dimensions.

Why don't be glued on the cobb angle?

The X-rays are the shadows of the 3D reality: The AP and Lateral views of the body including the spine are only the projections on each plane of a 3D spine structure, the horizontal plane is missing. One cannot imagine an architect designing a house without the horizontal plane projection of the building. Subsequently, in reality when

considered in 3D this Cobb angle measure only the collapsing of the spine in the plane of the study.

All the classifications for scoliosis are actually mainly based upon the cobb angle: All are useful but incomplete*I.Ponseti/ B.Friedman (1950)* [2] based upon the localization of the curves according the Cobb angle , single or double, major or minor ,**Howard King (1983)*[3] where the concept of the stable vertebra appeared as well as the center sacral vertical line and the flexibility was taken into account .**Then the Larry Lenke classification appeared(2001*) [4] and became quite universal, It comes directly from the previous ones but important adjunctions have been made :The division between structural and not structural curve was important where the importance of the bending test was recognized , as well as the location of the apex of the curves. Subsequently a multitude of modifiers appeared, depending of the localization such as lumbar or sagittal modifiers. This was important to plan the surgical treatment and also compare more precisely similar aspects of the curves for prognostication, treatments, results, etc. *The more recent one *from Kariman Abelin Genevois & Pierre Roussouly (2018)* [5] is based on the sagittal projection essentially and on the apical axial rotation. In reality none of them use the horizontal plane references as the major concept of the 3D nature of the deformity to help for distinction of the various curves and their subsequent treatments.

Do not forget the lewis sayre experimentation (1877): [6] A dry mounted spine skeleton is attached to a rectangular wood frame thanks to elastic stitches attached t horizontally between the spinous processes of each vertebra and the lateral border of the rectangular frame. Then a flexible brass rod is introduced top to bottom in the spinal canal .When we push on the button located at the top of the rod we create a scoliosis thanks to the horizontal forces coming from the tension of the elastic stitches. Reversely when we pull on the button we put back the spine straight correcting completely the scoliosis .This confirm that the Cobb angle measure only in 3D the collapsing of the spine.

Finally for me a scoliosis is a succession of curves where torsion is the major component: explaining why the horizontal plane is determinant. This was well demonstrated when in 1978/80, we obtained thanks to Henry Graf & Jerome Hecquet (computer engineer) [7] a computer 3D reconstruction of a scoliotic spine coming from 2 orthogonal X- Rays projections (AP & Lateral) of a scoliotic patient . The view from the top demonstrate perfectly the "piling up" of the spinal engine, with its torsion and counter torsion, where the horizontal plane is in first line for evaluation.

Why for me, the horizontal plane is determinant for spinal deformities assessment?

The first evidence for me was the prognostication of the infantile idiopathic scoliosis: Thanks to the previous common work done on this group of children we were able to distinguish with the horizontal plane projection of the 3D reconstruction of these scoliotic curves the 3categories: Spontaneously resolving, Progressive benign, and Progressive malignant with a perfect reliability controlled in all the cases presented with the required follow up (Figure 1). Despite publication and presentation at the SRS meeting in Chicago (1980). Nobody understood and used it (but ourselves) in clinic because at that time the 3D has not entered the clinical practice.

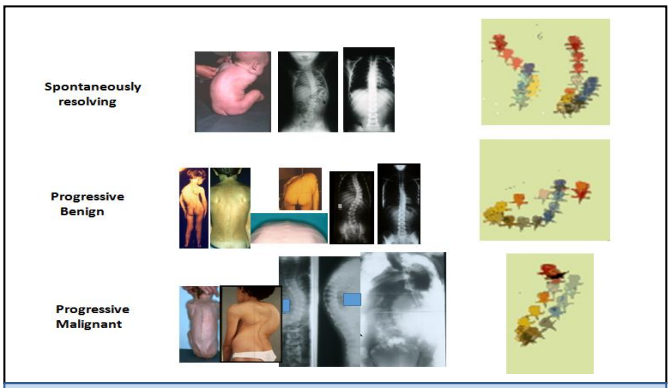


Figure 1: The view from the top of a 3D reconstruction distinguish clearly the3 categories about the prognostic: regressive spontaneously, progressive benign, progressive malignant.

The next evidences came from, many disorders not sufficiently understood even nowadays

The hyper-rotatory or paradoxical kyphosis: When we look upon a patient with a kyphoscoliosis, especially for thoracic or thoraco-lumbar localization, it is necessary to match the AP X-ray projection of the apex of the curve with the Lateral one .Sometimes this apex is one vertebra but sometimes only one Disc . When these apex coincide perfectly on the same level on both orthogonal projections it is the hyper-rotatory deformity. We called it paradoxical kyphosis because it looks kyphosis but in reality the vertebrae around this apex are in lordosis

from one vertebra to the other. The length of the anterior part (Vertebral Bodies)is longer than the posterior one (spinous processes, facets& laminae). When the rotation is measured we have here the maximum of axial rotation, sometimes 90° or more with the minimum of intervertebral rotation. In comparison with Scheuermann kyphosis where it is pure kyphosis without any axial rotation, at the apex the length of the anterior part (vertebral bodies) is shorter than the posterior one (post elements). This was demonstrated long time ago by René Perdriolle [8] on an anatomical specimens with meticulous measurements on the 3 planes of the vertebral bodies dimensions. It is easy to visualize it with the projection "view from the top" of such scoliotic spine on the horizontal plane. It is also the location of the maximum rigidity of the curve with the subsequent maximum of the structural deformities of the bony elements front and back and their consequences for the treatment.

The crankshaft phenomenon: [9] It is the biomechanical application, observed clinically, of this phenomenon occurring on a growing spine when an isolated posterior fusion of the curve lead to a recurrence of the deformity with the remaining anterior growth of the vertebral units on a still twisted spine . This is again demonstrated with the 3D reconstruction seen from the top clarifying perfectly the horizontal plane progressive deformity (Figure 2).

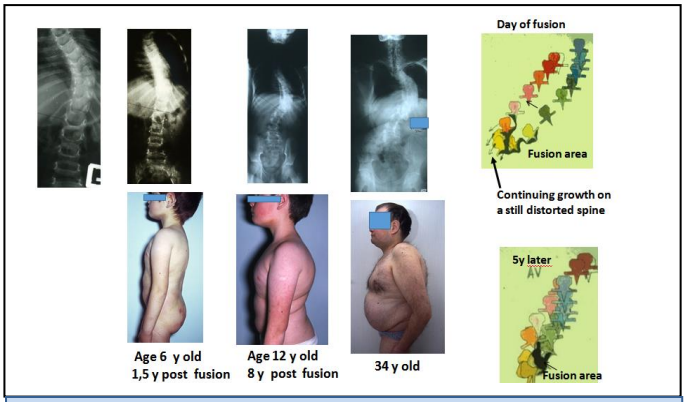
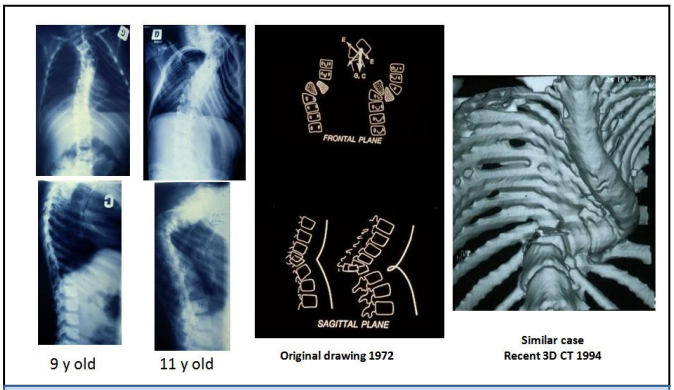


Figure 2: Evident aspect from the top reconstruction of the crankshaft phenomenon.

The rotatory dislocation phenomenon: With Mme Duval Beaupèrein 1972 [10], we observe this common deformity on 3 different etiologies of growing spine: Congenital, Dystrophic Idiopathic. It was the development of a kyphosis segment often acute in between 2 segments in lordosis (Figure 3). Each one of the lordosis segments rotating in an opposite direction. The progression was often very quick in a few months or years leading sometimes with neurological compromise with the generally excellent effect of the progressive continuous longitudinal axial traction giving the resolution of the neurological signs, without necessity to decompress the spinal cord. This was confirmed by the anterior approach of these conditions when we did the anterior fusion from the concave side of the kyphosis in order to fit properly the successive struts bone graft considered at that time necessary to get a good palisade anterior fusion .In the mean time we observed that these anterior struts where always oblique regarding the gravity axis on their frontal projection while perfectly vertical in their sagittal one. When a reverse way horizontal rotation occurs around only one unstable vertebra at any level of the spine, the same dislocation can occur. This is perfectly seen for example at the L3/L4 level in some degenerative spine, but it is also perfectly seen at any level of the spine with the denomination of.



Rotatory dislocation phenomenon

Figure 3: The rotatory dislocation mechanism:Kyphosis in between 2 lordosis segments.

The junctional kyphosis: We can detect this problem when we match the AP and Lateral projection of a scoliotic spine , when the apex of the lateral projection coincide with the junction in between 2 curves on the AP projections it is a junctional kyphosis. A structural scoliotic curve is defined by all successive vertebrae comprised between 2end vertebrae one proximal, one distal along the gravity line. These end vertebrae are with the minimum of axial rotation, the minimum of lateral deviation from the gravity line but the maximum of intervertebral rotation. The apex of the curve is represented by a vertebra or

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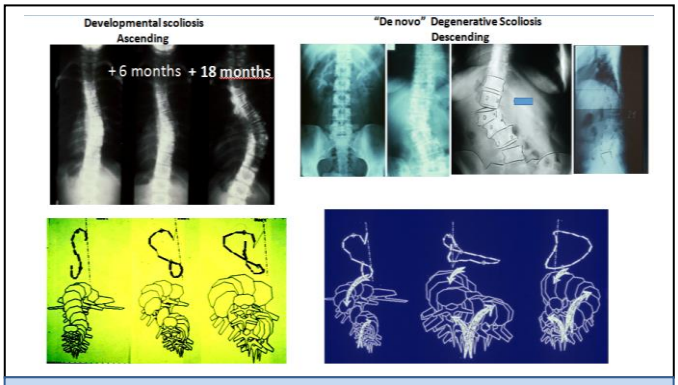
a disc with the maximum of axial rotation, a maximum of lateral deviation, and the most horizontal orientation in a standing position regarding the gravity line with also the minimum of intervertebral rotation. Subsequently the vertebra located at the junction in between 2 structural curves or even structural &compensatory is in a situation of possible instability in kyphosis. It is frequently seen in between the 2 curves of a double major thoracic and lumbar curve at the TL junction, it is also frequent at the upper thoracic area for the double thoracic curve, and it is a frequent mechanism of some PJK as in early onset or adolescent scoliosis as more frequently in adult spine surgery. It was amazing for me, in a recent paper (2019) [11] of a spine deformity journal, to see the picture of a severe PJK in an early onset idiopathic scoliosis treated with instrumentation, where despite presenting all evident X-Rays documents , neither authors neither reviewers have spoken about this evident kyphotic rotatory dislocation phenomenon (kyphosis in between 2 lordosis curves). All these pathologies are explained by the initiation of the deformity by a failure in the horizontal plane of the piling up of the vertebral units.

It explain also for me the 2 major categories of scoliosis: Ascending (or developmental) and Descending (or degenerative)



Evolution seen from the top

Figure 4: View from the top of the evolution of ascending and descending scoliosis, similar with torsion and counter torsion.

(Figure 4) Despite 2 different patho-anatomies they have only one way for biomechanical initiation: the failure into the horizontal plane. I called the first category Developmental or "Ascending" because it is the idiopathic type started in infancy or childhood and progressing during growth, secondary to probably a genetic neurological and hormonal disorder. When growth is completed as for bone as for soft tissues, the deformity is then submitted to only mechanical and metabolic disorders in relation with gravity and ageing on every biological tissues. When doing sequential 3D reconstructions including the view from, the top the horizontal plane implication in the evolution of the deformity became obvious, with torsion and counter torsion. During this evolution the common factor for the patient was to keep the best balance as possible on a static and dynamic point of view, with a horizontal vision thanks to the multiple ways of compensation of the body. In such conditions we understand that the Cobb angle only if it gives some measurement of the collapse of the spine is far away from a real 3D assessment. When we consider the second category the one I called "Descending" or degenerative, we know that for some of them, the "De Novo" group the deformity is starting in adult hood on a normal adult spine, the reason is a degenerative cascade at level of the disc and soft tissues structures (capsules ligaments aponeurosis, muscles,.. ect), with secondary bone dislocations and degenerative changes, associated with metabolic bone disorders. But for all of them the initiation was also an horizontal rotational failure ending with the same torsion and counter torsion phenomenon and a similar view from the Top.

WHAT ARE SOME OF THE NEGATIVE CONSEQUENCES TO BE GLUED TO THE COBB ANGLE?

The race to the best cobb angle is frequently not the best goal for assessing the treatment

Because we have observed that when the correction of the curve has reached 0° on the frontal projection, the sagittal one demonstrate quite always a loss sometimes significant of the kyphosis. This creates in the thoracic area a flat thorax no so harmonious cosmetic aspect of the body shape. On another hand especially at the upper thorax the excessive correction of the Cobb angle may lead to a shoulder asymmetry not so harmonious, but also can induce reactive pain or junctional problem at the cervical spine area. Finally this race for the best post op Cobb angle frequently drive to extend the length of the instrumentation, removing some flexible levels useful to bring compensation into the alignment. This bring the comment I like to say: The most important part of the spine after surgery for scoliosis is not the fused and instrumented one, but the unfused remaining mobile above and below .So, the words of

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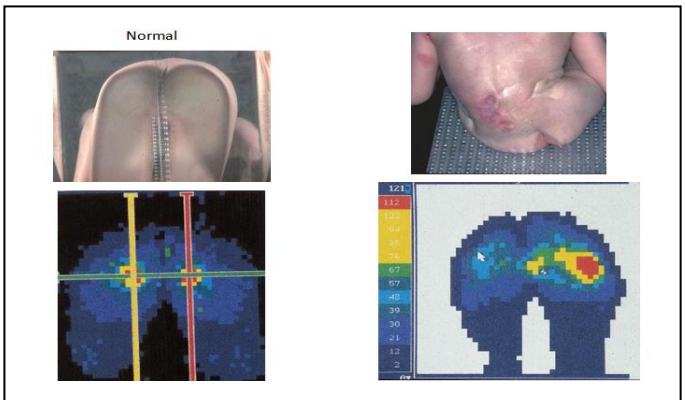
Alain Dimeglio telling that "The Maximum of correction is not always the Optimum" seems well up to date .When we look to the old results of the CD instrumentation we must recognize that despite a still remaining Cobb angle, when the 3D alignment was obtained with a well re -established harmony, with a good dynamic balance, the long lasting results must be expected. We come back to the basic philosophy of the CD principles: Balance and Harmony are more important than % of the Cobb angle correction! [12].

The assessment of pre-op and post-op neuro-muscular or congenital scoliosis with pelvic obliquity thanks to the only cobb angle is another example far from a 3D evaluation.

Despite all publications about this topic assess the results of the treatment with the change of the Cobb angle of the scoliosis in degree, as well as by the measurement of the projection of the pelvic inclination in the frontal plane relative to the orthogonal line of the gravity line also in degree. The same can be done for the sagittal plane projection. This information are still useful but to get a more practical, physiological, and reliable information it is recommended to measure in a functional sitting position the pressure from the body on a force plate located under the thighs and the buttocks. The modern technology, now, allow this easily. It is not invasive, reproducible and may be combined with dynamic situations. It can drive to the development of personalized sitting platform on the wheel chair, ect. This is only to convince you to not be "glued" with the only Cobb angle. 3D Buttocks pressure measurements are more useful to quantify the results (Figure 5).



Evaluation of pelvic obliquity with a force plate

Figure 5: Evaluation of pelvic obliquity correction with the pressure measurement under the buttocks of the patient.

MY PROPOSAL FOR A 3D ASSESSMENT OF SPINAL DEFORMITIES IN ORDER TO IMPROVE THE "ONLY COBB ANGLE" COMES FROM AN INTRODUCTION OF MORE HORIZONTAL PLANE DATA.

Static

From a long time , the CT scan give a transversal (Horizontal slice)at any level, from which many information can be measured (Rib hump, Spinal penetration index ect,) but to get a more complete information and real 3D reconstruction of the entire spine it is necessary to get multiple successive slices with 2 inconvenient : * Excessive radiation not compatible in a growing child or adolescent because the proven risk of late oncological disorders * the CT is done in lying position so removing the effect of gravity . It is why the development of EOS imaging device with low dose radiation and reliable 3D reconstruction of the entire skeleton in a standing functional position, was designed. From this a 3D piling up of the spinal skeleton is obtained similar & better than the initial one (1978) because we can really measure the horizontal plane data of each curve or vertebra, ; In order to make it more easy to use , and simplify it to be used in one glance the Vertebral vector technique was introduced by Tamaslles [13] and allow to distinguish more precisely the various deformities without using the Cobb angle. The principles and technique are fully explained in the reference [13]. For example among 301 cases of idiopathic scoliosis classified Lenke 1, when we look on their horizontal plane projection we can find 3 different categories .This play for choosing a different strategy for their surgical, correction The view from the top derived from the "cone of economy" concept is particularly useful to classify and compare the results on another aspect than the Cobb angle, more close to the reality of the alignment and balance of the patient (Figure 6). For a similar Cobb angle even on the frontal and lateral projections, the view from the top can be very different and correlate much better with the clinical situation of the patient. The prognostic for progression of mild scoliosis detected during childhood or at adolescent age is generally done with the Cobb measurements of successive X- rays. A severity index was developed in order to make the prognostic for progression at the first exam; thanks to a 3D reconstruction, and measurement of 7 items most coming from the horizontal

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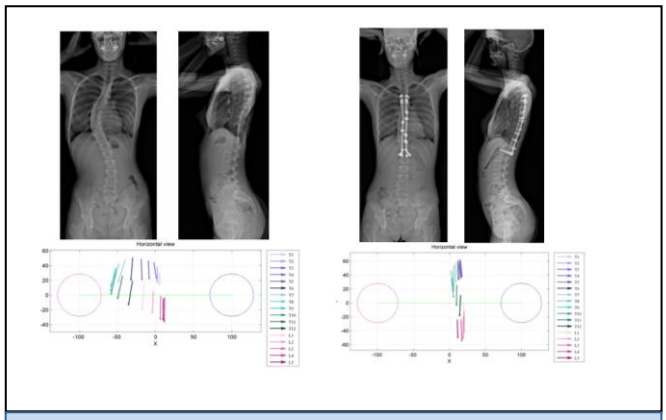
plane data, it is possible to detect the progressive or the stable cases in 85% of the cases with 89% reliability. Thanks to this 3D reconstruction of the spine and also the Thoracic cage we can analyze the result of the treatments surgical or orthotic and recognize the effect on the spine alignment but also the change in good or bad of the thoracic cage anatomy with their consequence on the respiratory function.



Vertebral Vectors : View from the Top
Figure 6: Vertebral vectors simplify and make the 3D measurement of the spinal deformities more accurate and visualize in a glance the 3D Aspect.

Dynamic and function

The global and local 3D mobility of the spine operated on or not is also a major component in the evaluation of the late results sometimes independent of the Cobb angle correction .Especially below the instrumented area the long time prognostic lies in the 3D mobility of the discs allowing a possible compensation as in the alignment as in the function .The best way in biomechanical labs is up to now with recording of the 3D movements with multiples cameras and anatomical reflective markers combined with the images coming from the 3D skeletal reconstruction. But for a pragmatic and simple evaluation during a regular clinic, the measurements with a chronometer of the time necessary to do the 3 to 4 classical tests is quite sufficient and perfectly reliable.

CONCLUSION

The goal of this paper was only to make the readers, the authors, the reviewers, the orthopedic surgeons, researchers, and the teachers, to be aware that the Unique Cobb angle measurement cannot remain the “Gold Standard” in the assessment of the spinal deformities as before as after any treatment.

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