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Scoliosis and Spinal Disorders

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Brace Classification Study Group (BCSG): part one – definitions and atlas

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Abstract

Background: The current increase in types of scoliosis braces defined by a surname or a town makes scientific classification essential. Currently, it is a challenge to compare braces and specify the indications of each brace. A precise definition of the characteristics of current braces is needed. As such, the International Society for Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) mandated the Brace Classification Study Group (BCSG) to address the pertinent terminology and brace classification. As such, the following study represents the first part of the SOSORT consensus in addressing the definitions and providing a visual atlas of bracing.

Methods: After a short introduction on the braces, the aim of the BCSG is described and its policies/general consideration are outlined. The BSCG endeavor embraces the very important SOSORT – Scoliosis Research Society cooperation, the history of which is also briefly narrated. This report contains contributions from a multidisciplinary panel of 17 professionals who are part of the BCSG. The BCSG introduced several pertinent domains to characterize bracing systems. The domains are defined to allow for analysis of each brace system.

Results: A first approach to brace classification based on some of these proposed domains is presented. The BCSG has reached a consensus on 139 terms related to bracing and has provided over 120 figures to serve as an atlas for educational purposes.

Conclusions: This is the first clinical terminology tool for bracing related to scoliosis based on the current scientific evidence and formal multidisciplinary consensus. A visual atlas of various brace types is also provided.

Keywords: Scoliosis, Spine, Nomenclature, Brace, Classification, Terminology, Definition, Brace Classification Study Group, BCSG

Background

There are many different spinal orthoses used for non-surgical treatment of various types of spinal deformities [1–4]. Most clinicians use the term brace instead of spinal orthotic/orthosis and bracing as the action of treating a patient with a brace. The simplest classification of braces is based on the anatomical region where the orthosis acts: cervical (C), thoracic (T), lumbar (L) and sacral (S). Using this naming system, two main families of braces have been classically used: a) Cervical-Thoraco-Lumbo-Sacral Orthotics or CTLSO and b) Thoraco-Lumbo-Sacral Orthotics or TLSO [4].

The anatomical classification is clear and simple; however, it is hardly acceptable nowadays for two reasons. First of all, each group includes very different types of braces and a variety of principles or concepts to treat many different disorders. Consequently, the anatomical classification does not allow establishment of any clear similarity or difference between two braces classified into a same group. Secondly, some well-known concepts might reasonably be attributed to both groups. For example, the Boston brace, one of the most popular concepts to treat adolescent idiopathic scoliosis (IS) in North America, is commonly classified as TLSO but in some cases it can be built with a super-structure to act also on the cervical spine, and classified then as CTLSO [1].

A different classification was introduced by Negrini et al. [5] and presented during the annual meeting of the

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International Society for Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) in Athens in 2008, under the acronym BRACE MAP. BRACE MAP derives from the following terms: Building, Rigidity, Anatomical classification, Construction of the Envelope, Mechanism of action, and Plane of action. Each item was composed of two to seven classificatory elements defined using one or two letters in order to refer specifically to the characteristics of the brace throughout the classification (e.g. SpineCor was classified as CpETAM3, meaning Custom positioning, Elastic, TLS, Asymmetric, Movement principle and 3D correction). Of the 13 braces considered, BRACE MAP provided the ability to differentiate between all but two of the braces. This was the first comprehensive brace classification system. However, the same authors concluded that despite its utility in distinguishing between most of the existing braces, redefinition of this first proposal would be necessary through a consensus process.

Until now, 12 consensus papers have been published by the SOSORT [6–17], including a consensus on terminology that was used initially to form the basis of this work [14]. During the SOSORT annual meeting in Wiesbaden, Germany in May 2014, a consensus group was formed, chaired by Dr. Theodoros B. Grivas, to develop a new brace classification. The Brace Classification Study Group (BCSG) is composed of active SOSORT members and members from the Non-Operative Committee of the Scoliosis Research Society (SRS) (listed alphabetically in Table 1).

Table 1 Alphabetical listing of BCSG members

Aulissa Angelo Gabriele (Italy)
De Mauroy Jean Claude (France)
Diers Helmut (Germany)
Glassman Steve (US)
Grivas Theodoros B (Greece)
Hresko Timothy (US)
Kotwicki Tomasz (Poland)
Knott Patrick (US)
Maruyama Toru (Japan)
Negrini Stefano (Italy)
O'Brien Joe (US)
Price Nigel (US)
Rigo Manuel (Spain)
Stikeleather Luke (US)
Thometz John (US)
Wood Grant (US)
Wynne James (US)
Zaina Fabio (Italy)

Table 2 List of domains suggested by BCSG members

3D
2D Frontal
2D Horizontal
2D Sagittal
Aesthetics
Activities of Daily Living (ADL)
Anatomical Classification (C: CTLSO; T: TLSO; L: LSO)
Asymmetric
Building
Brace with Monitoring Device
Brace Wearing Monitor
CAD/CAM
Combined Frontal Horizontal
Combined Frontal Sagittal
Combined Horizontal Sagittal
Custom Made
Custom Position
Derotation
Driver
Elastic
Elongation
Long Brace
Mechanism of Action
Outcomes Related Words
Plane of Action
Plaster Mould
Prefabricated Envelop
Preliminary Plaster Cast
Pusher
Quality of Life (QoL)
Rib Hump
Rigid
Rigidity
Sagittal Plane Correction
Short Brace
Soft
Stopper
Symmetric
Three Point
Very Rigid

Aims

The charges of the BCSG include and address the following: the identification of all the relevant terms of characteristics of a brace for the non-operative treatment

Table 3 Timeline of the consensus process

Date	Consensus processing
2007	*Boston*- Beginning of the SOSORT – SRS cooperation
2010	Montreal - 8th SOSORT consensus on terminology
2014	*Wiesbaden* - A consensus group was formed, chaired by Dr. Theodoros B. Grivas, to develop a new brace classification (BCSG):
	Panel of 17 multidisciplinary experts: 7 surgeons, 6 non surgeons, 2 CPO, 1 Engineer, 1 Patient. (8 from North America, 8 from Europe and 1 from Japan)
	Initial draft list of 40 terms to define. Roundtable entitled "Braces: conceptual and technical approach to scoliosis"
2015	*Katowice* - Evidence from the SOSORT guidelines and literature (2 relevant papers from 1547 papers with search terms 'scoliosis' and 'brace')
	Elaboration of a secondary list of 139 provisional definitions arranged in a conceptual framework of 19 domains based on integration of research knowledge and clinical experience of the panel. Elaboration of an atlas to illustrate definitions.
2016	*Banff* - Final synthesis of the 139 definitions and illustration of 120 figures
2017	*Lyon* - Delphi Round-2 and Round-3 during the next Lyon SOSORT meeting

of spinal deformities, mainly IS, and the creation of a specific vocabulary with the definitions of these terms. Also the grouping of the braces according to their characteristics that is the anatomical region they cover, their function, the material of which they are made, the tolerance, the adaptability and the adherence to treatment (compliance) of the patients, the treated deformity, the monitoring, and the outcome measures to achieve unique identification of the characteristics of each existing brace according to the created terminology. Finally the aim was to plan the evaluation of the quality of outcomes according to each of the brace characteristics, with the ultimate aspiration to recognize the most suitable brace construction for each specific spinal deformity.

Fig. 2 Body cast for Infantile Scoliosis. Serial or Mehta casting

The identification and definition of terms of brace characteristics and creation of a vocabulary will facilitate the communication among the specialists using a common language. Additionally the classification and assessment of

Fig. 1 Preliminary plaster cast, example of the Lyon management: Reduction by plaster cast

Fig. 3 Plaster molds

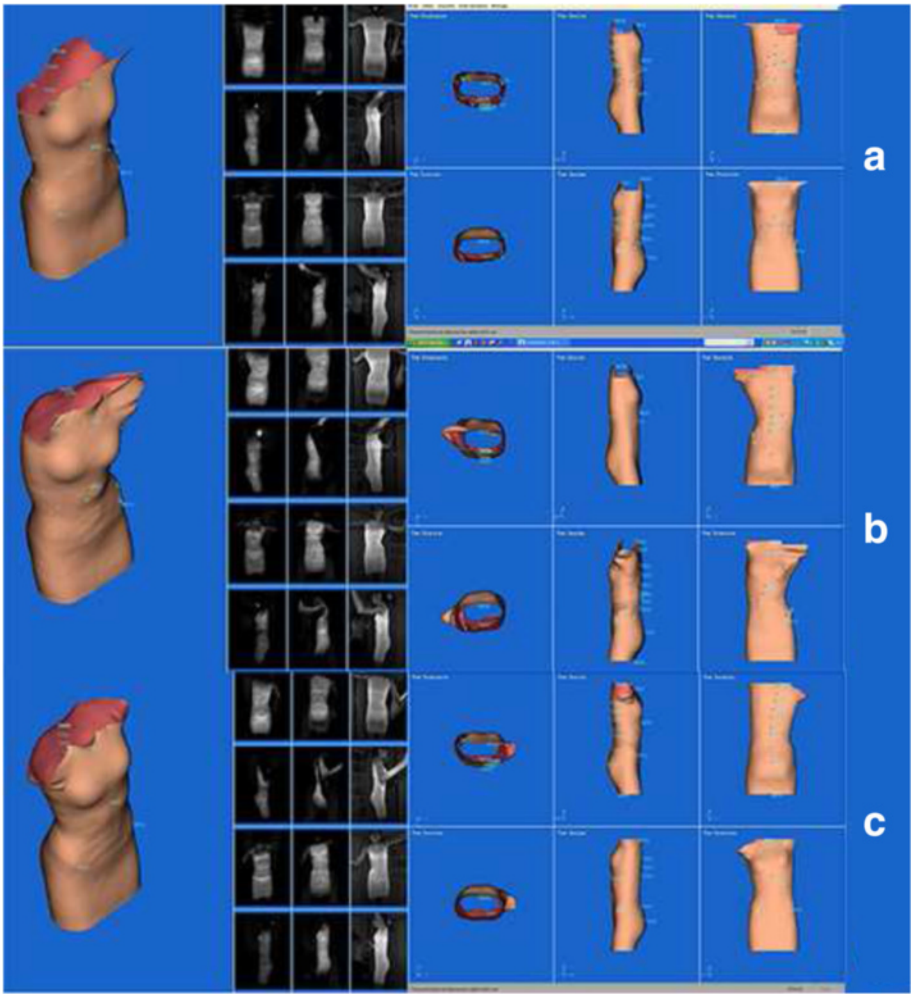

Fig. 4 Regional shape capture, from top to bottom: **a** for pelvis and shoulders, **b** for lumbar region, **c** for thoracic region

Fig. 5 Negative cast in plaster of Paris or resin

effectiveness of existing braces within each domain of classification, and the study of outcomes according to each of these characteristics will optimize the brace treatment for spinal deformities

The terms that were identified in the first meeting of the BCSG are illustrated in Table 2. The initial steps of the group were to complete the preliminary list with any unnoticed term, grouping them and providing a definition and a proper figure, if applicable, for each of them. An atlas to accompany the terminology was one of the aims.

This part of the work (i.e. definitions and atlas) represents part one of a two-part project. Part two of our consensus statement will address brace classification and will be entitled, "Brace Classification Study Group (BCSG): part two – classification"

Scope

Policies - general consideration

The BCSG members are all specialists involved in the non-operative treatment of IS comprised of orthopaedic

Fig. 6 Positive mold in polyurethane obtained by CAD/CAM carver

surgeons, rehabilitation doctors, certified prosthetist - orthotists (CPOs), physiotherapists specialized in non-operative scoliosis treatment, colleagues working on brace development, bio-engineers working on compliance monitoring electronics (gadgets), finite element study specialists related to braces application, etc. The acronym **BRACE MAP** was initially proposed at the 2008 SOSORT meeting and we resumed the six domains suggested [5]. However, the BCSG introduced 40 definitions for analysis as listed in Table 2. The first stage of this consensus has brought together the 139 definitions in 17 final domains.

Additionally, in a roundtable entitled "Braces: conceptual and technical approach to scoliosis", held at SOSORT 2014, the biomechanical presentation was reviewed. It was the first approach to brace classification based on some of the domains proposed by the BCSG (Additional file 1). The majority of the work was carried out online on the SOSORT website and every three months a draft text was forwarded to the panel for survey. The time-course of the consensus process is noted in Table 3.

BCSG and SOSORT - SRS co-operation

Many surgeons and members of the SRS have gradually abandoned the non-surgical treatment for IS. Although the effectiveness of bracing was proven by the SRS [18], the lack of classification does not facilitate the indication and the prescription. Cooperation between the two societies is essential. The collaboration between the SOSORT and the SRS started in 2007 during the SOSORT meeting in Boston, chaired by Joe O'Brien and was established by Dr. Theodoros B. Grivas during the SOSORT meeting in Athens, Greece in 2008. At that time Dr. George Thompson, who had great experience with the providence brace, served for two years as President of the SRS and he was invited to both the Boston and Athens SOSORT meetings. During the 2014 SOSORT meeting, a joint SOSORT-SRS consensus on 'Recommendations for Research Studies on Treatment of Idiopathic Scoliosis' was presented and published for the first time [17]. This report contains contributions from SOSORT and SRS members who are part of the BCSG and are listed in alphabetical order (Table 1).

Definitions

Brace fabrication

Preliminary plaster cast

Refers to the Lyon management in two steps: (1) reduction in asymmetric non-removable plaster cast and (2) contention by a more symmetrical removable brace (Fig. 1).

Body cast, serial casting (Mehta casting)

A non-removable plaster cast, which is usually applied to an infantile scoliosis patient while under anesthesia and suspended from the ground in a Risser frame. The cast surrounds the chest, abdomen, pelvis, and may also include the shoulders. It may be used to correct scoliosis in very young patients or for postoperative spinal mobilization (Fig. 2).

Plaster mold

The traditional method used to capture an impression of the trunk of a patient. A plaster or synthetic bandage is applied, which hardens and is removed from the patient. This plaster mold is used for the custom fabrication of the brace (Fig. 3).

Regional shape capture

A shape capture obtained by the superposition of three specifically corrected shape captures of the same patient: the pelvic area, lumbar area, and thoracic area. The

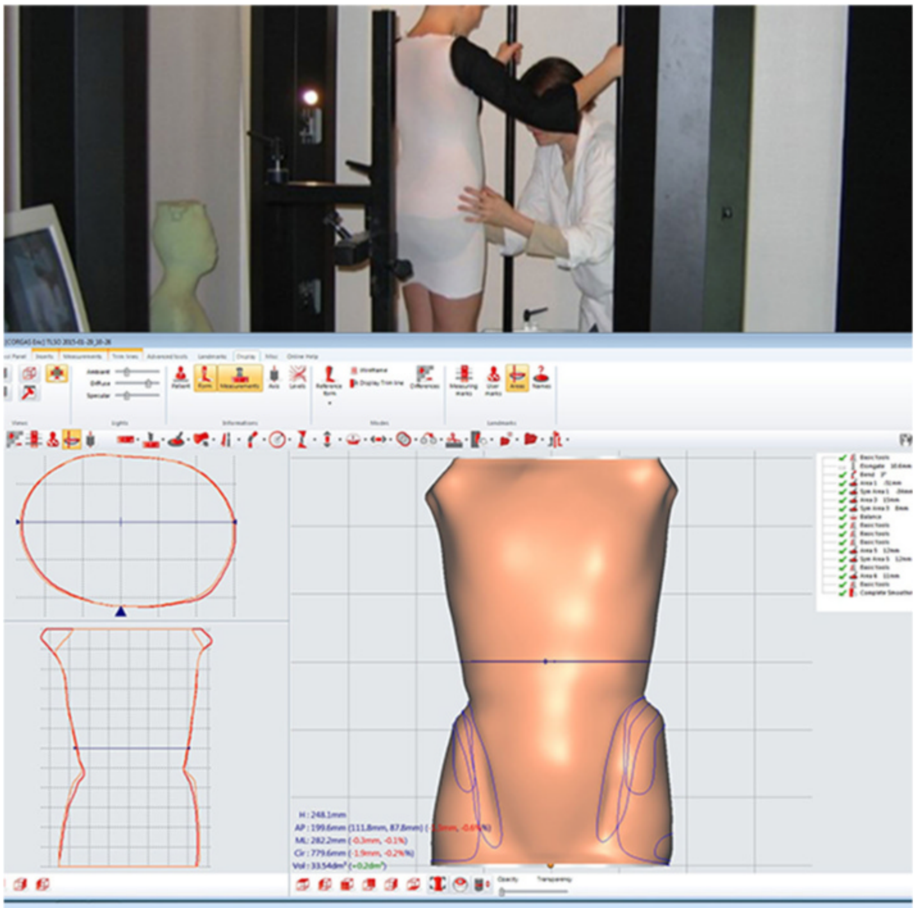

Fig. 7 CAD/CAM system with shape capture and shape processing

Fig. 8 Custom made positive mold

regional shape capture makes the sagittal plane normalization more accurate (Fig. 4).

Negative cast

The plaster or synthetic cast once it has been removed from the patient (Fig. 5).

Positive mold

A solid mold formed from filling the negative cast with plaster (Fig. 6).

CAD/CAM

The term is an acronym defined as “Computer-Aided Design/Computer-Aided Manufacturing.” The process of making a shape capture with 3D modeling tools and a milling machine for fabrication (Fig. 7).

Custom-made

The term refers to “made-to-measure” (UK). A brace fabricated from a custom mold and measurements of the patient’s trunk (Fig. 8).

Fig. 9 Prefabricated Boston Module

Fig. 10 Axilla extension of a brace

Fig. 11 TLSO scoliosis brace

Prefabricated envelope (Module)

A brace that is fabricated over a standardized body form instead of a specific patient. The prefabricated envelope is designed to fit a patient within a range of measurements (Fig. 9).

Axillary/axilla extension

The lateral section of a thermoplastic brace that extends upward under the arm, on the concave side of the

Fig. 12 Milling or carving machine

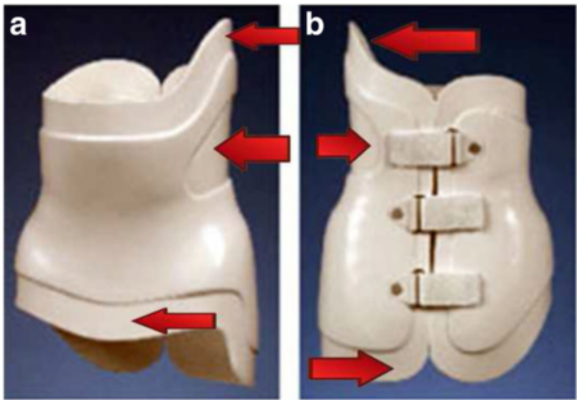

Fig. 13 Cloth gusset on a Boston brace: **a** antero-lateral view, **b** posterior view

thoracic curve, towards the level of the upper end plate of the vertebra. The function of the axillary extension is to apply a counterforce to the apex of the curve with a longer lever-arm (Fig. 10).

Scoliosis brace

A general term commonly used to describe a TLSO, LSO, or other spinal orthoses (Fig. 11).

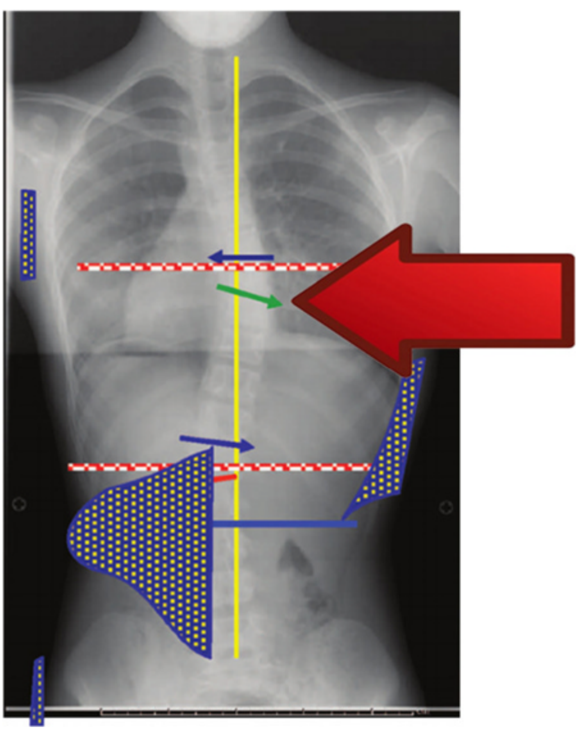

Fig. 14 Null point on the radiological apex of the curve at the red arrow level

Fig. 15 Trochanteric extension of a brace

Milling machine

A computer-aided manufacturing mill, also referred to as a carver (Fig. 12).

Cloth gusset

Elastic cloth affixed to a window or area of relief to provide a gradual transition between areas of pressure and relief, to provide limited pressure, or to maintain tension between the posterior and anterior parts of the brace (Fig. 13).

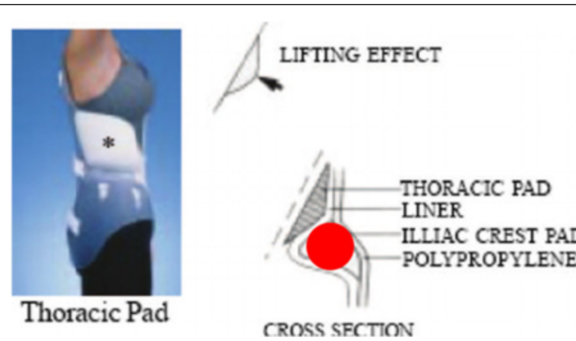

Fig. 16 Crest roll between lumbar pad and iliac crest

Fig. 17 Trim line of an asymmetrical polycarbonate brace

Fig. 18 Prefabricated Boston module

Null point
Radiographic term used to describe the apex of a curve based on standing radiograph (Fig. 14).

Trochanteric extension
A plastic extension covering the greater trochanter, generally placed on the side toward which L5 tilts. When needed, a pad is also used on the inner surface of the extension. It provides balance for the brace and avoids sideward tilting (decompensation) relative to the pelvis (Fig. 15).

Crest roll
The inward pressure between the iliac crest and the lower margin of the ribs. It prevents distal or proximal migration of the brace and aids in the positioning the pelvis (Fig. 16).

Construction of a brace

Trim line
The cut and finished edges of a spinal orthosis that allow the brace to fit and function comfortably and optimally (Fig. 17).

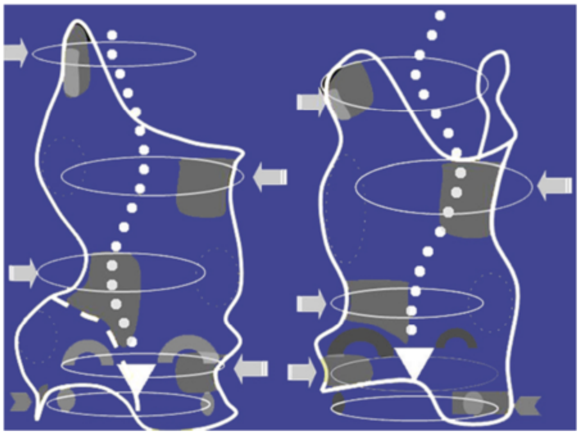

Fig. 19 Blueprints of a Chêneau type brace

Fig. 21 Expansion room in the concavity of the curve

Fig. 20 Brace windows of a Chêneau type brace

Fig. 22 Pelvic section of a Rigo Chêneau brace

Fig. 23 Hyper-corrected positive-cast

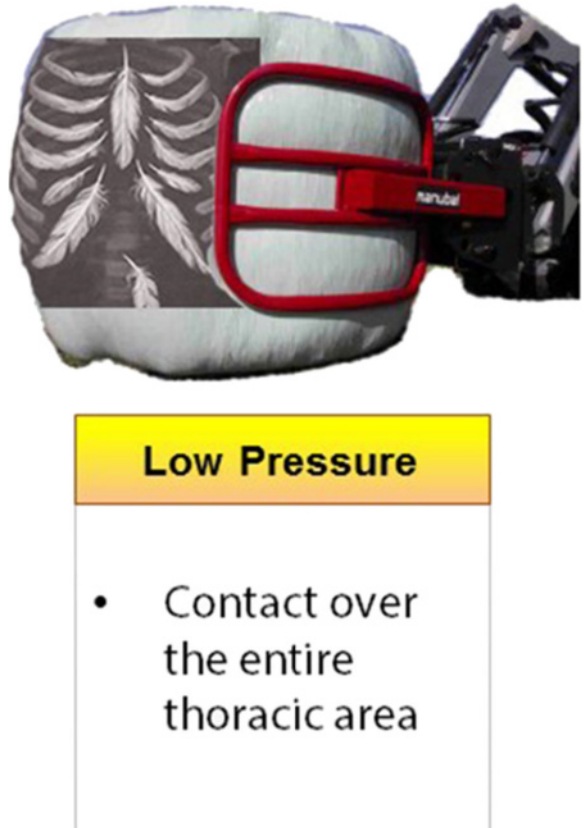

Fig. 25 Continuous contact without pad

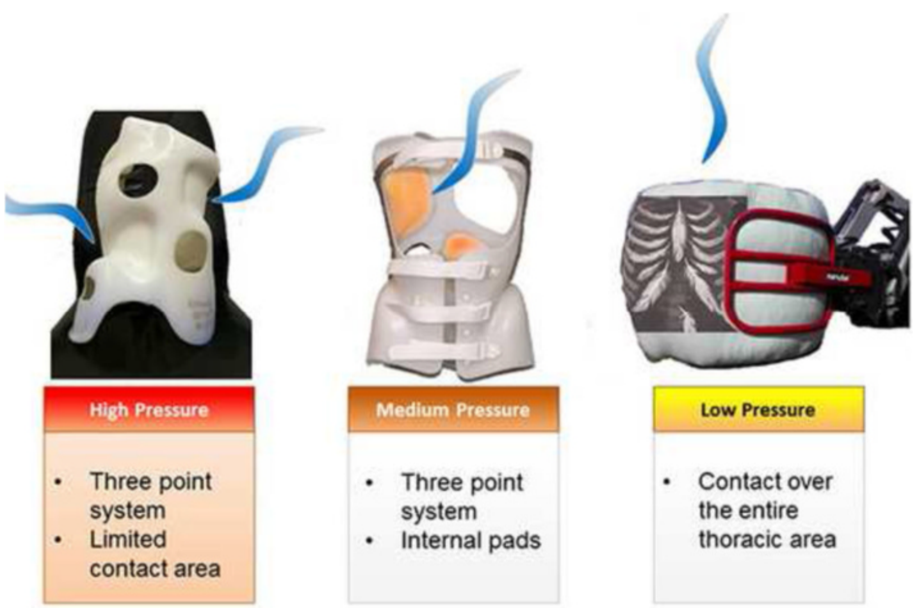

Fig. 24 Pressure points. Classification in high, medium and low contact

Fig. 26 Pads for medium contact

Module
A prefabricated brace that is customized to the individual patient's blueprint. They come in various sizes, which are fit and adapted to the patient for treatment of scoliosis (Fig. 18).

Blueprint
Determines the trim lines of the brace and also the position of corrective pads (Fig. 19).

Brace window
An opening cut out of the plastic of a brace. Used to provide pressure relief, extra flexibility, or a reduction in brace weight (Fig. 20).

Expansion room
A section of the brace that is built up and away from the patient's body. It provides room for the body to be pushed by the brace pads and allows the brace to achieve a greater degree of correction than just pressure with no expansion (Fig. 21).

Fig. 28 Thoracic pad in a Chêneau type brace

Pelvic section
The section of a scoliosis brace that covers the pelvis. Stabilizes and controls the pelvis and suspends the brace via the pelvic grip of the waist (Fig. 22).

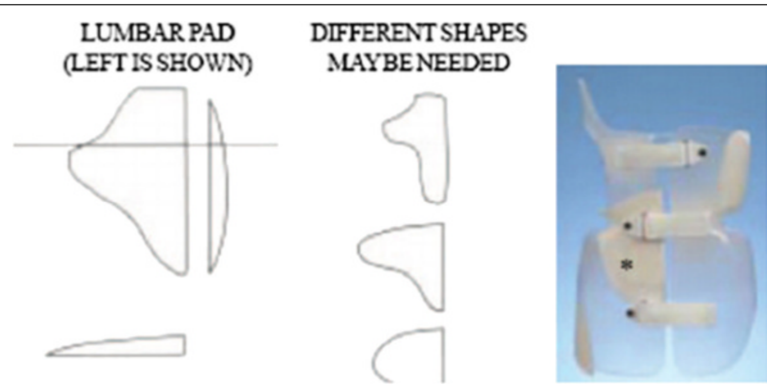

Fig. 27 Lumbar pad for a Boston brace

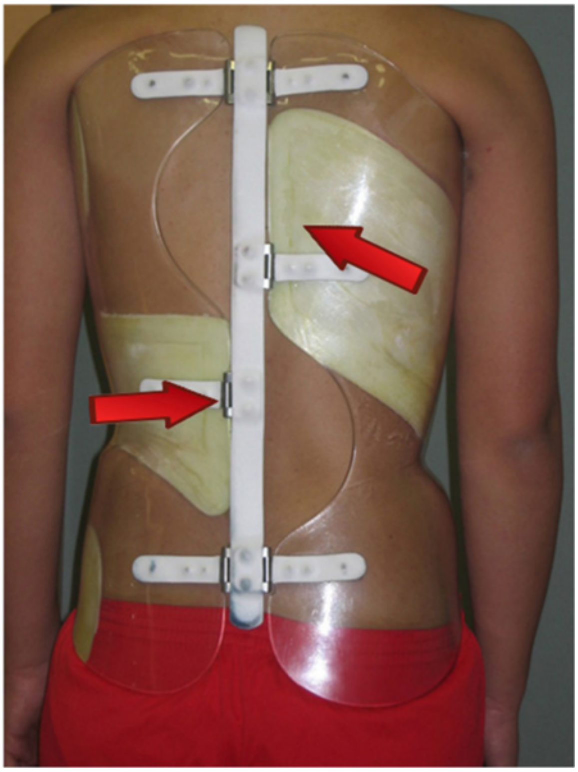

Fig. 29 Pushes along the red arrows in a Sforzesco brace

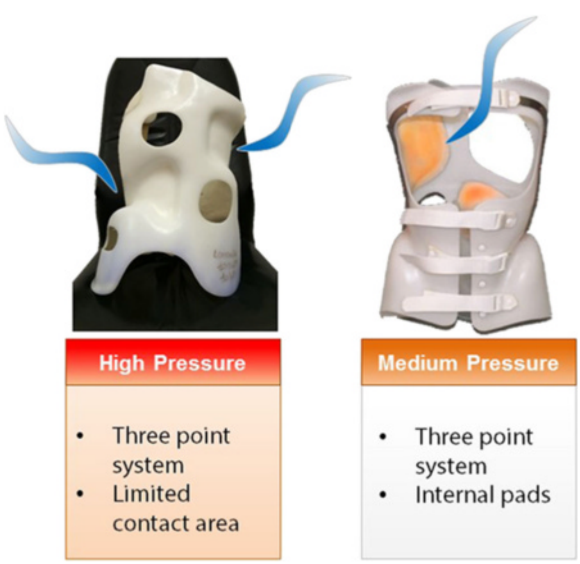

Fig. 30 High pressure contact in a Chêneau type brace

Hyper-corrected positive-cast

The modified positive cast of a Chêneau brace in which aggressively rectified pressure points and expansion rooms can be clearly observed (Fig. 23).

Contact

Pressure points

Points of the brace that correct the deformity via physical force. They are produced either during the modification of the mold (and therefore built directly into the plastic of the brace) or by added Pelite or Plastazote pads. The pressure is applied to the convex side of the curve or to the prominences of the scoliotic deformity. Common pads are the lumbar, thoracic, axilla and trochanter pads (Fig. 24).

Continuous Contact

The external surface of the brace is smooth. Motion within the brace (4D) is facilitated by the gliding (Fig. 25).

Pad contact

Contact with a pad and or pressure against the body (Fig. 26).

Lumbar pad

This is a corrective pad used in scoliosis braces, which is adapted to the convex side of the lumbar curve (Fig. 27).

Thoracic pad

This is a corrective pad used in scoliosis braces, which is adapted to the convex side of the thoracic curve (Fig. 28).

Push

The area of the brace providing the corrective forces to the trunk with the aim to reduce the trunk and spine deformity. A push can be developed by the envelope, added through plastic material inside the envelope, or a combination of the two (Fig. 29).

Driver

The material on the 3D concavities that prevents a hyper-correction of the curve. It changes the direction of the corrective forces, driving them up with the whole trunk. A driver is at the base of the push-up action of SPoRT braces.

Stop

Part of the brace that stops the movement of the body tissues, providing a counter-push in a 3-point system, whether three or bi-dimensional.

Escape

The area of the brace where the body can freely move in consequence of the corrective forces applied.

Fig. 31 Axillary clamp of the ARTbrace also called baby lift concept: **a** axillary clamp, **b** baby lift, **c** before bracing, **d** Under bracing, **e** Clinical picture before bracing, **f** Clinical picture in brace

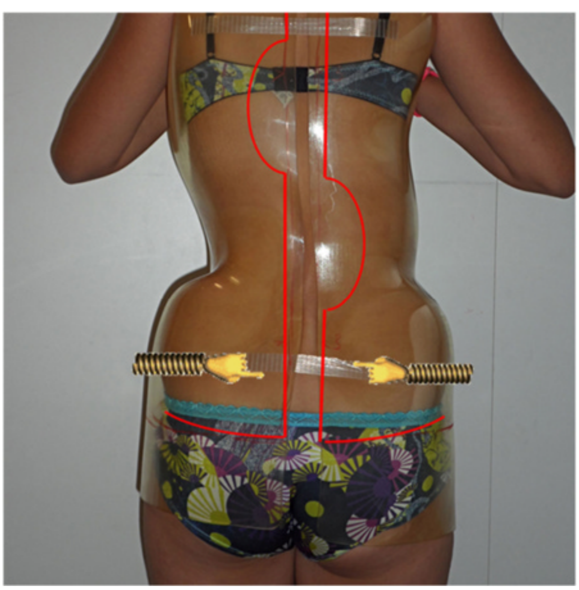

Fig. 32 Pelvic clamp of a polycarbonate brace

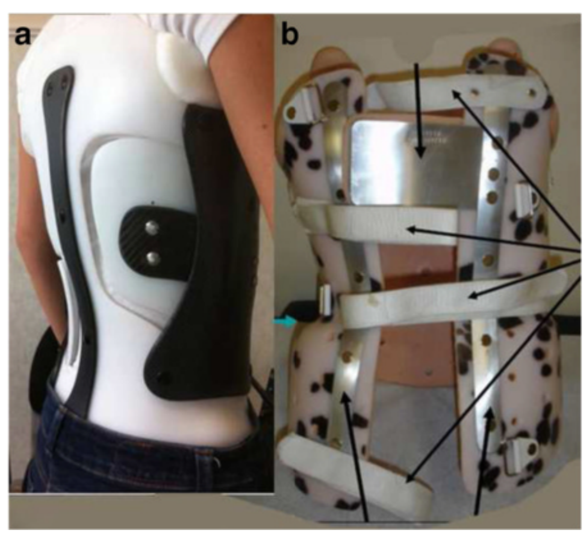

Fig. 33 Dynamic contact of: **a** a CMCR brace and **b** a DDB brace

Fig. 34 Non-contact or window in a TLSO brace

High pressure contact

Characteristic of the Chêneau brace. The external surface of the brace is not symmetrical or smooth (Fig. 30).

Axillary clamp

A section of the brace that wraps around the anterior and posterior axilla, allowing the application of derotational forces (Fig. 31).

Pelvic clamp

The arrangement of two sidepieces in the lower part of the brace. Untwisting is carried out from this fixed point (Fig. 32).

Dynamic contact

A principal of the Dynamic Derotation Brace. It may produce a derotational force or alter the neuro-motor response by constantly providing new somatosensory input to the patient.

For the Carbon brace, this mobility provides a permanent pressure, which varies depending on ribs and spine movements. The correction is obtained without spinal extension so that each respiratory movement takes part in a gradual return to dorsal kyphosis (Fig. 33).

Fig. 35 Expansion room in the thoracic concavity

NON contact, window

Cutting in the external surface of the brace. The opening does not allow for expansion, but reduces the weight of

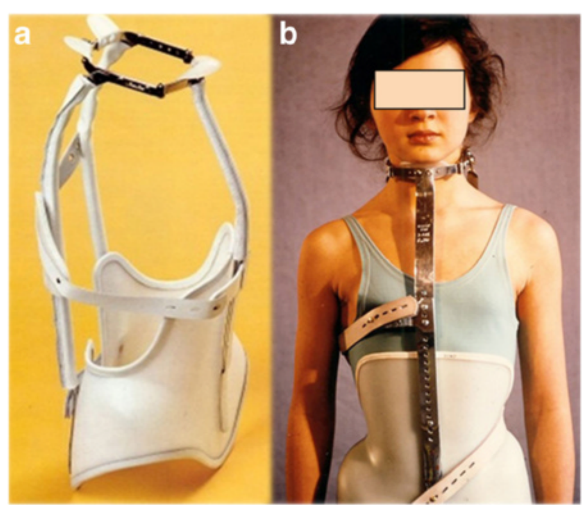

Fig. 36 Milwaukee brace (CTLSO): **a** Lateral view, **b** Anterior view on the child

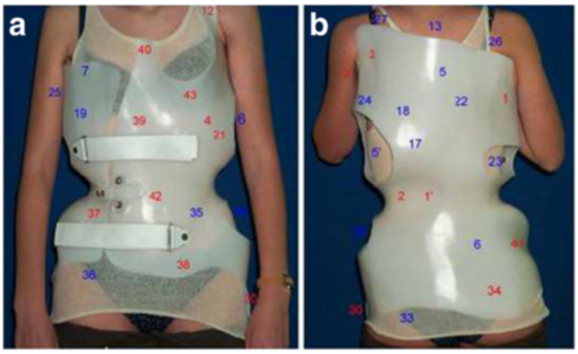

Fig. 37 Chêneau brace: multiple three point system: **a** Anterior view, **b** Posterior view [19]

the brace and increases the effect of the support zone (Fig. 34).

Expansion room

No cutting, but the external surface of the brace is no longer in contact, leaving room for movement in the opposite direction of the support zone (Fig. 35).

Brace types

Milwaukee brace

A CTLSO scoliosis brace used to treat the coronal plane curve of the cervical, thoracic, lumbar and sacral regions of the vertebral column. It consists of a contoured pelvic girdle attached by three uprights to an occipital pad and throat mold of the chin piece (Fig. 36).

Cheneau brace

A thermoplastic brace modeled on a hyper-corrected positive plaster cast of the patient. It follows the general correction principle of detorsion and sagittal plane normalization, which would affect correction of the coronal and transversal planes, resulting in some elongation of the spine, without any significant distraction force" (Fig. 37).

WCR (Wood Cheneau Rigo) brace

A thermoplastic TLSO, which is designed using the Rigo Classification of scoliosis and brace design. It follows the same principal as the Chêneau brace, and is handmade by Grant Wood. It is his personal version of the Chêneau-Rigo brace (Fig. 38).

Boston brace

A thermoplastic TLSO used to treat the coronal plane curve and transversal rotation of the thoracic, lumbar and sacral regions of the vertebral column. This brace can either be prefabricated or custom-made (Fig. 39).

Fig. 38 Wood Chêneau Rigo brace (WCR brace)

Night overcorrecting brace

A brace made with the principle of reverse bending or "over correcting" to treat the curve. An over correcting brace is very tall under a patient's arm, which pushes the patient too far to even stand up, and can only be worn at night (Fig. 40).

Sforzesco brace

A brace created by Stefano Negrini using the SPoRT concept of bracing (three-dimensional elongation). Due to its overall symmetry, the brace provides space over pathological depressions and pushes over elevations.

Fig. 39 Boston brace

Correction is reached through construction of the envelope, pushes, escapes, stops, and drivers (Fig. 41).

ARTbrace

A brace created by Jean Claude de Mauroy, ART stands for Asymmetrical, Rigid, Torsion brace. It is constructed with 2 rigid asymmetrical lateral pieces of polycarbonate connected posteriorly at the midline by a duraluminium bar. Both anterior and lower ratcheting buckles are rigid, the upper third is Velcro. The asymmetry is obtained by superposition of 3 regional specific molds (Fig. 42).

Fig. 40 Night overcorrecting brace

Fig. 41 Sforzesco brace

Dynamic Derotation Braces (DDBs)

A hard, custom-made, polyvinylchloride (PVC), underarm spinal orthoses, which opens at the back, equipped with specially designed blades set to produce a derotational force on the thorax and the trunk of the patient. There are three modules, the thoracic or thoraco-lumbar curve, the lumbar curve, and the double major curve pattern (Fig. 43).

Passive correction brace

A scoliosis brace that does not have space or windows for active correction of the spine. Correction is passive with the spine being pushed into the corrected position and then being held there by the tight fitting brace without the need for active muscular effort (Fig. 44).

Brace rigidity

Rigidity

An orthotic classification ranging from flexible, to semi rigid, to rigid, to high rigidity. It refers to the amount of bendability of the brace. Not to be confused with hardness (Fig. 45).

Elastic

A brace primarily composed of elastic straps (Spinecor brace) (Fig. 46).

Fig. 42 ARTbrace

High rigidity brace
A thermoplastic brace made with polymetacrylate or polycarbonate. This requires a posterior bar with hinges to open and close the brace (Sforzesco and Lyon braces) (Fig. 47).

Material
Polymetacrylate
A hard transparent thermoplastic, often used as a lightweight or shatter-resistant alternative to soda-lime glass. The old Lyon brace was made in polymetacrylate (Fig. 48).

Polycarbonate
A particular group of thermoplastic polymers that are easily worked, molded, and thermoformed. They have high temperature and impact resistance (Fig. 49).

Polypropylene (PP)
A semi-rigid thermoplastic used in a wide variety of applications. It is rugged and resistant to many chemical solvents, bases and acids. Polypropylene is the most common material used in the manufacture of scoliosis bracing, specifically for young scoliosis patients who require correction of their curves (Fig. 50).

Polyethylene (PE)
A common plastic which can vary greatly in flexibility and transparency depending on the density. Polyethylene is commonly used for adults and neurological scoliosis patients who require less correction and a more supportive or accommodative brace (Fig. 51).

Thermoforming
A manufacturing process where a plastic sheet is heated to a pliable forming temperature, formed to a specific shape in a mold, and trimmed to create a usable product (Fig. 52).

Vacuum thermoforming
A simplified version of thermoforming, whereby a sheet of plastic is heated to a forming temperature, stretched onto a single-surface mold, and forced against the mold by a vacuum. This is the standard process that orthotic technicians use to fabricate a custom made scoliosis brace (Fig. 53).

Plastazote
A lightweight polyethylene foam used for padding sensitive pressure points or used to increase pressures to the apexes of the scoliotic curves. It is thermoformable and self-adhesive at forming temperature (Fig. 54).

Skin protection garment
An undershirt used as an interface between the patient's body and the scoliosis brace, which reduces friction and irritation to the skin (Fig. 55).

Body anatomy/level-s coverage
Anatomical classification (CTLSO, TLSO, LSO)
CTLSO: a cervicothoracolumbosacral orthosis
TLSO: a thoracolumbosacral orthosis
LSO: a lumbosacral orthosis

Low profile
A brace that does not significantly protrude from the body (Fig. 56).

Short brace
A brace that extends from the sacrum to lower thoracic regions of the spine. It's usually classified as LSO or a low TLSO (Fig. 57).

Long brace
A brace that extends from the sacrum to the thoracic region of the spine, usually up to the axilla. This is usually classified as a TLSO (Fig. 58).

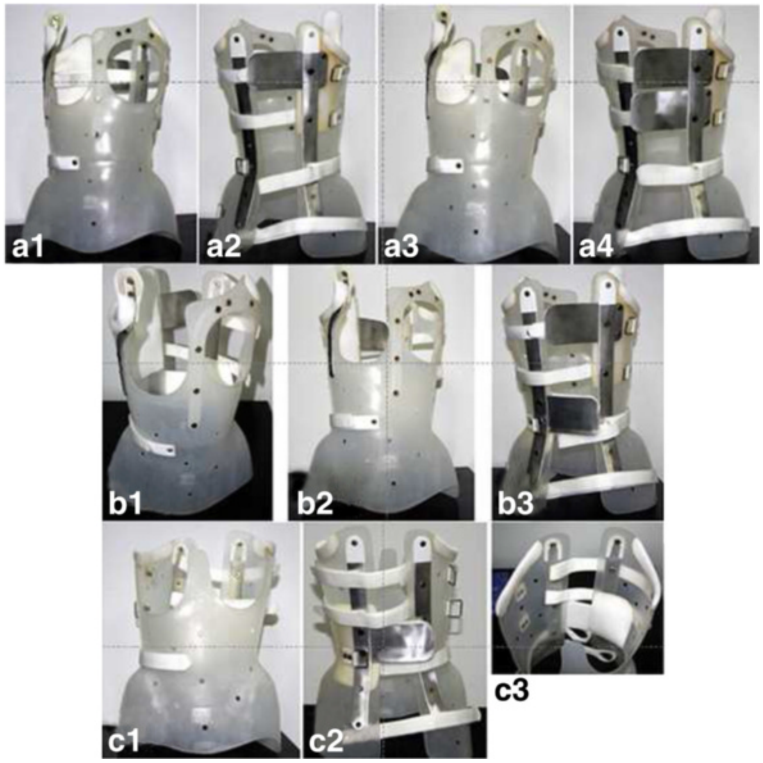

Fig. 43 Dynamic derotation brace: A1-4 for double major curves, B1-3 for thoracic curves, C1-3 for lumbar curves

Fig. 44 Passive correction TLSO brace

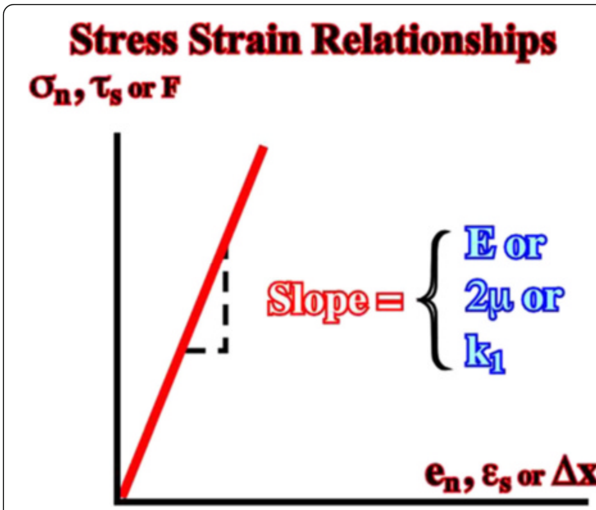

Fig. 45 Stress Strain Relationships: The constant E is Young's modulus and mu is the shear modulus or the modulus of rigidity

Fig. 46 Elastic brace: **a** antero-lateral view, **b** posterior view

Fig. 48 Lyon brace in polymethacrylate

Fig. 47 High Rigidity braces in polycarbonate

Fig. 49 Pieces of Polycarbonate

Fig. 51 Polyethylene: used for adults and neurological scoliosis patients

Fig. 50 Polypropylene: most common material used for scoliosis braces

Concave

A surface that curves inward. One of the objectives for scoliosis treatment would be to open the concave side of the scoliotic curve (i.e. to decrease the collapse of the spine) (Fig. 59).

Convex

A surface that curves outward. One of the objectives of a scoliosis brace is to apply a force to the convex side of the scoliotic curve (Fig. 60).

Fig. 52 Thermoforming of polymethacrylate

Fig. 53 Vacuum thermoforming

Fig. 55 Skin protection garment used between skin and brace

Scoliosis classification useful for bracing

3-curve scoliosis

Presents as one long thoracic curve with the apical vertebra around T9 to T10 or a thoracolumbar curve with the apical vertebra around T11. This long thoracic or thoracolumbar curve has two small compensatory curves, one cephalic and the other caudal (Fig. 61).

4-curve scoliosis

Presents as two main curves, one in the thoracic region and the other in the lumbar or low thoracolumbar region. These double curves have two small compensatory curves, one cephalic and the other caudal (Fig. 62).

Pelvic obliquity

Difference in the height of pelvis, possibly due do infrapelvic (LLD or contractures), intrapelvic (congenital bone abnormality), or suprapelvic scoliosis (Fig. 63).

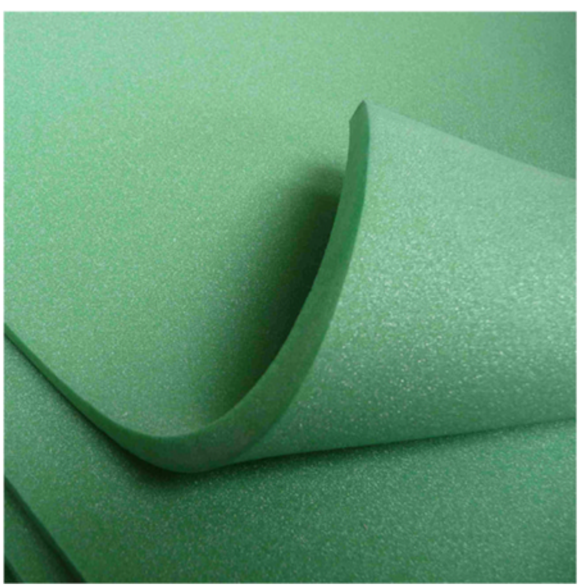

Fig. 54 Plastazote: thermoforming and self-adhesive

Fig. 56 Low profile brace

Fig. 57 Short detorsional brace

Anteversion

An abnormal position of the hemi-pelvis that is rotated and torsioned anteriorly therefore the anterior superior iliac spine is more prominent than usual. The contralateral hemi-pelvis would be in retroversion. Anteversion of the pelvis usually refers to forward flexion of the pelvis on the femoral heads which places the sacral plate in a more vertical position (Fig. 64).

Fig. 58 Long TLSO brace

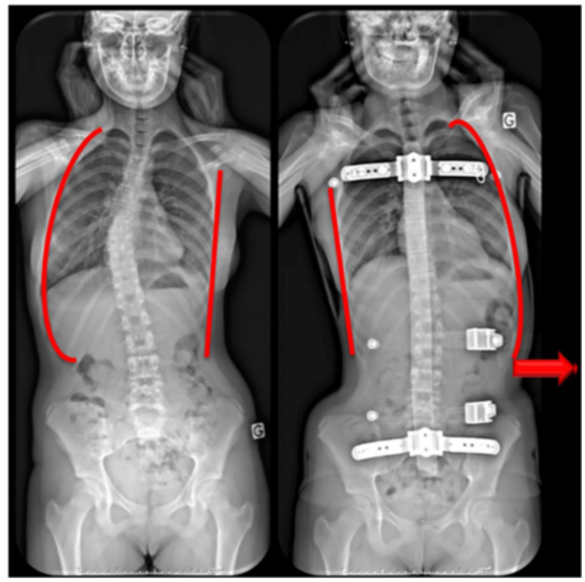

Fig. 59 Concave side opening of with brace

Retroversion

An abnormal position of the hemi-pelvis, which is rotated and torsioned posteriorly therefore the anterior superior iliac spine is less prominent than usual. The contralateral hemi-pelvis would be in anteversion (Fig. 65).

Iliac rotation

A situation of relative retroversion of the convex side of the lumbar curve and anteversion of the concave lumbar side (Fig. 66).

Compensatory curve

A curve, which can be structural or non-structural, above or below a major curve that tends to maintain normal body alignment. A compensatory curve is synonymous with the secondary curve (Fig. 67).

Flat back

The physical appearance of the back surface in the sagittal plane of the thoracic region being "flat," also called hypokyphosis (Fig. 68).

Flat back effect

An effect produced by a TLSO in which the design of the brace produces hypokyphosis (Fig. 69).

Major curve, primary curve

The largest structural curve, which is usually the first to appear (Fig. 70).

Minor curve, secondary curve

The smallest scoliotic curve, which is always more flexible than the major curve (Fig. 71).

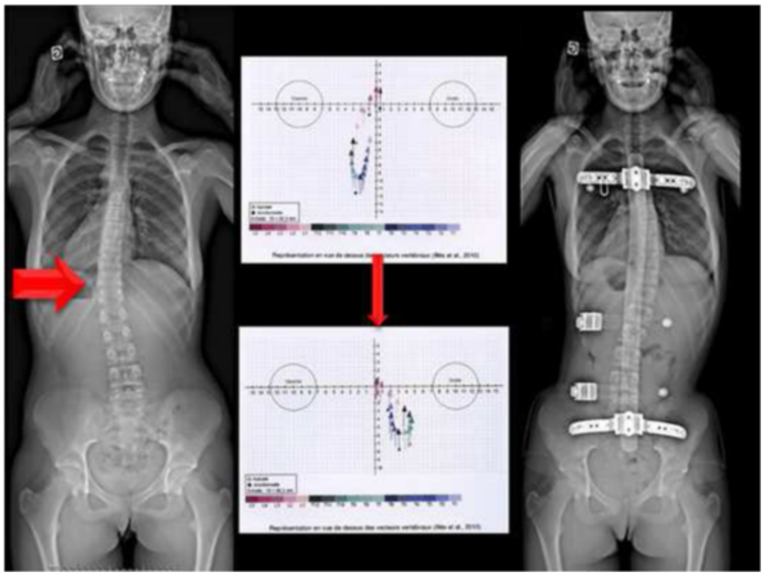

Fig. 60 Convex overcorrection and total inversion with high rigid brace

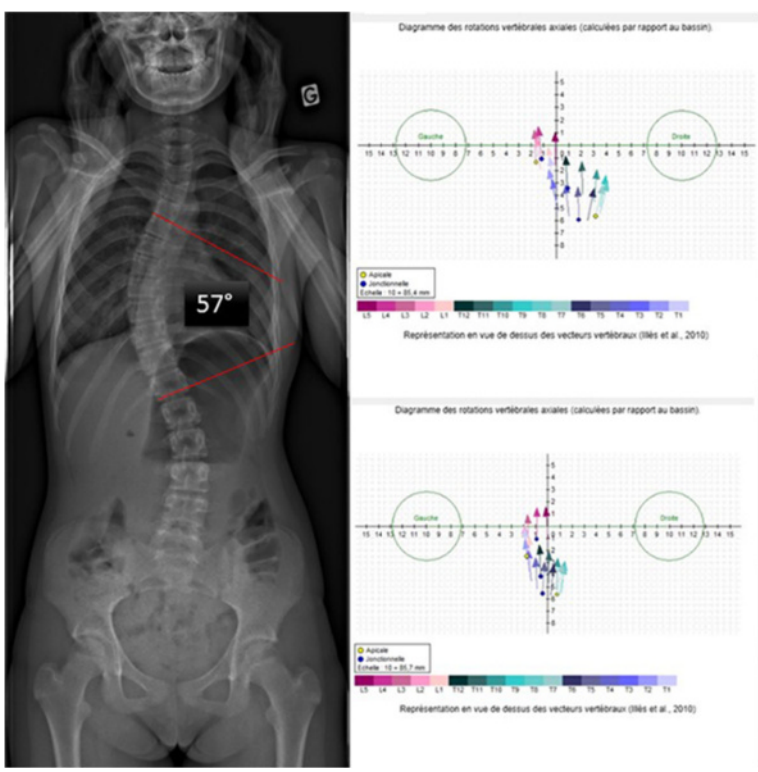

Fig. 61 3 curves scoliosis: Main thoracic curve with 2 minor compensatory curves

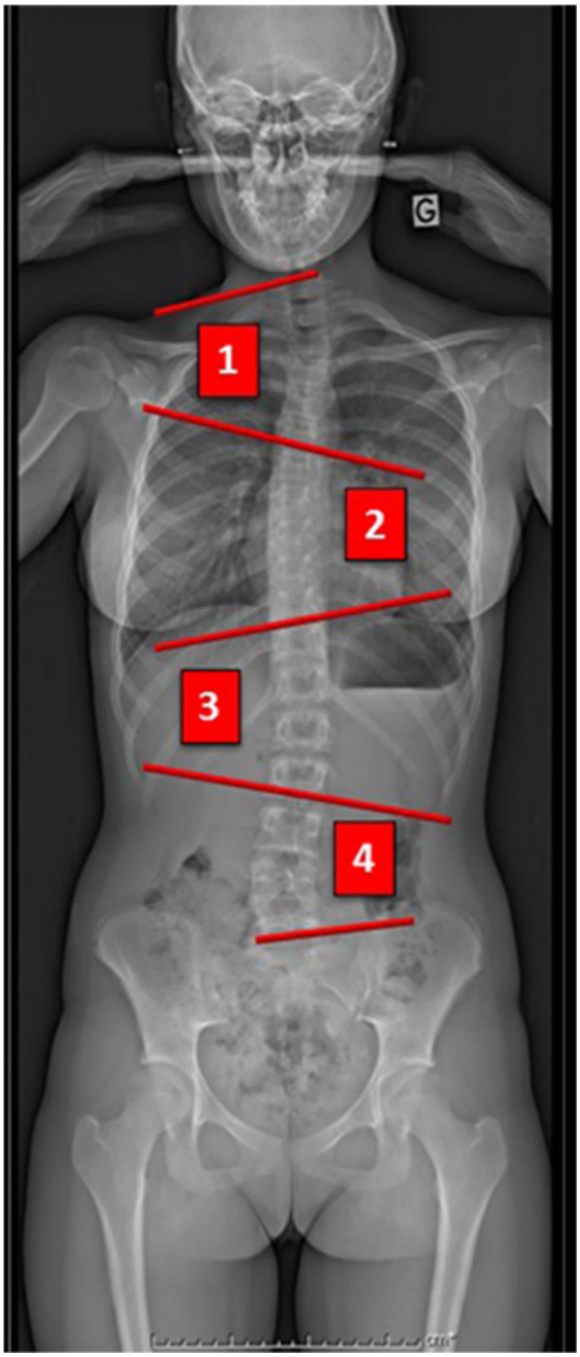

Fig. 62 4 curves scoliosis: 1. Upper thoracic curve, 2. Middle thoracic curve, 3. Thoraco-lumbar curve, 4. Lower lumbar curve

Apical vertebra
The most rotated vertebra in a curve; the most deviated vertebra from the vertical axis of the patient (Fig. 72).

Hyperkyphosis
A sagittal alignment of the thoracic spine in which there is more than the normal amount of kyphosis (Fig. 73).

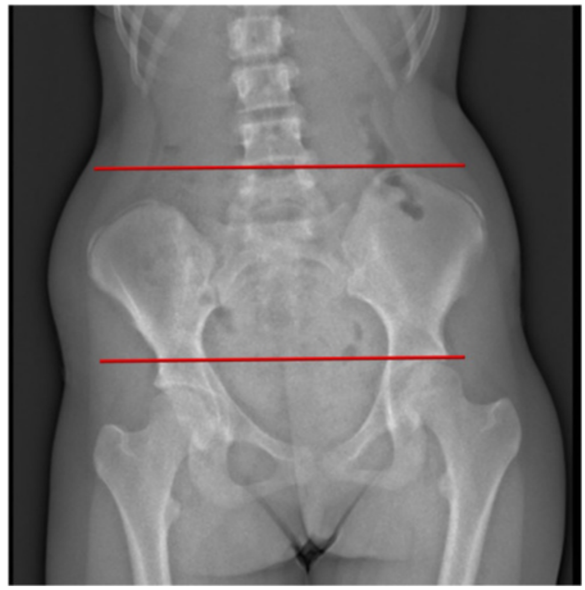

Fig. 63 Pelvic obliquity

Hypokyphosis
A sagittal alignment of the thoracic spine in which there is less than the normal amount of kyphosis, but it is not so severe as to be truly lordotic (Fig. 74).

Non-progressive curve or scoliosis
A scoliotic curve in which the Cobb angle does not increase 5° or more during a six-month period. Below 20°,

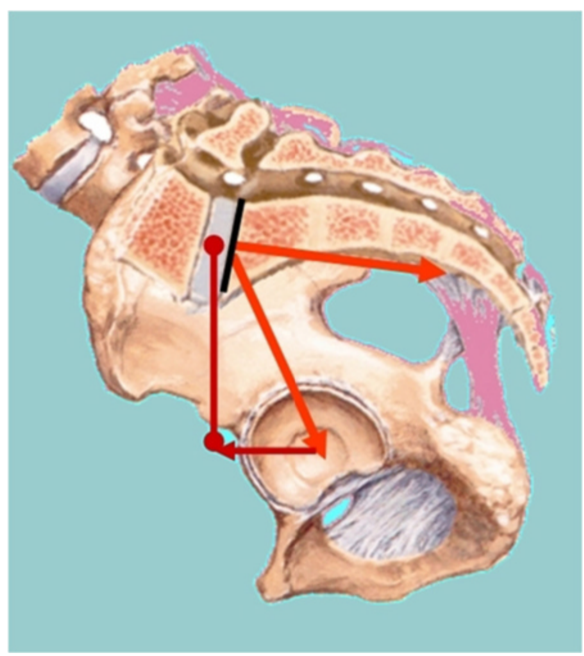

Fig. 64 Pelvic Anteversion

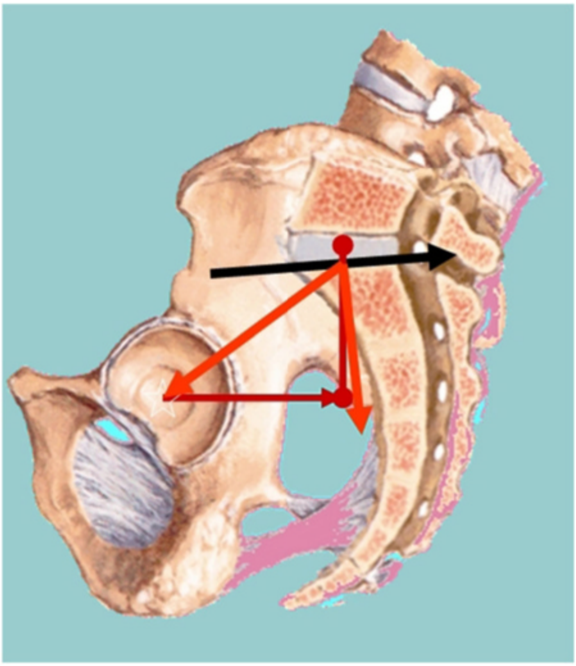

Fig. 65 Pelvic Retroversion

Fig. 66 Iliac rotation

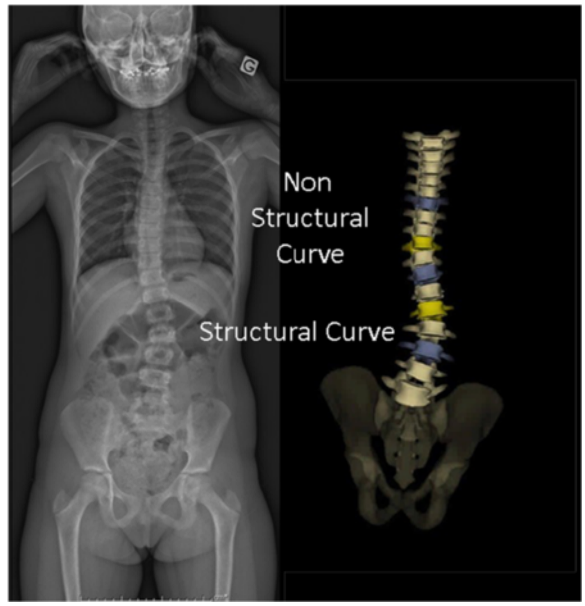

Fig. 67 Compensatory curve to maintain body alignment

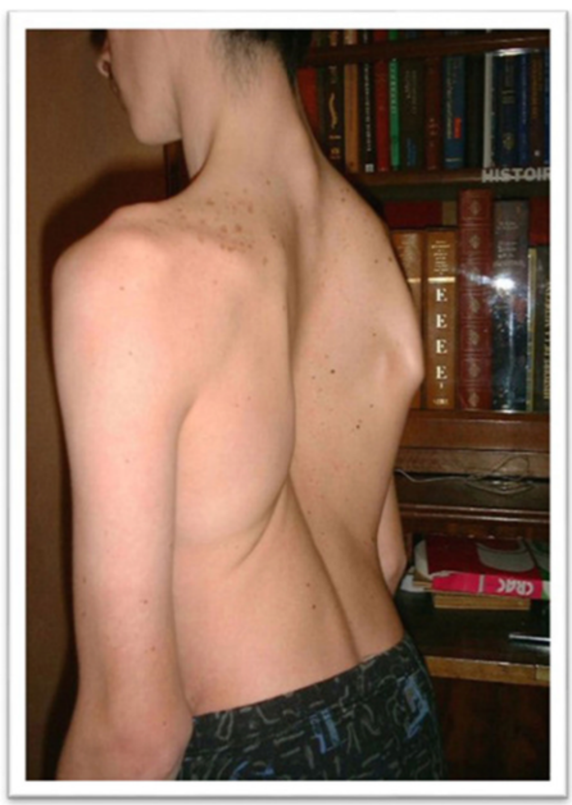

Fig. 68 Flat back with thoracic lordosis

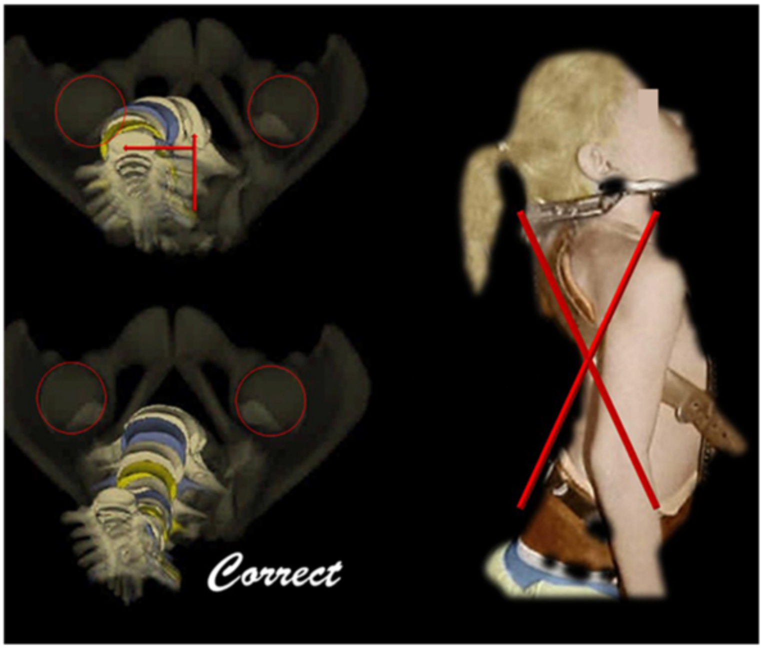

Fig. 69 Flat back effect during translation on the vertical axis

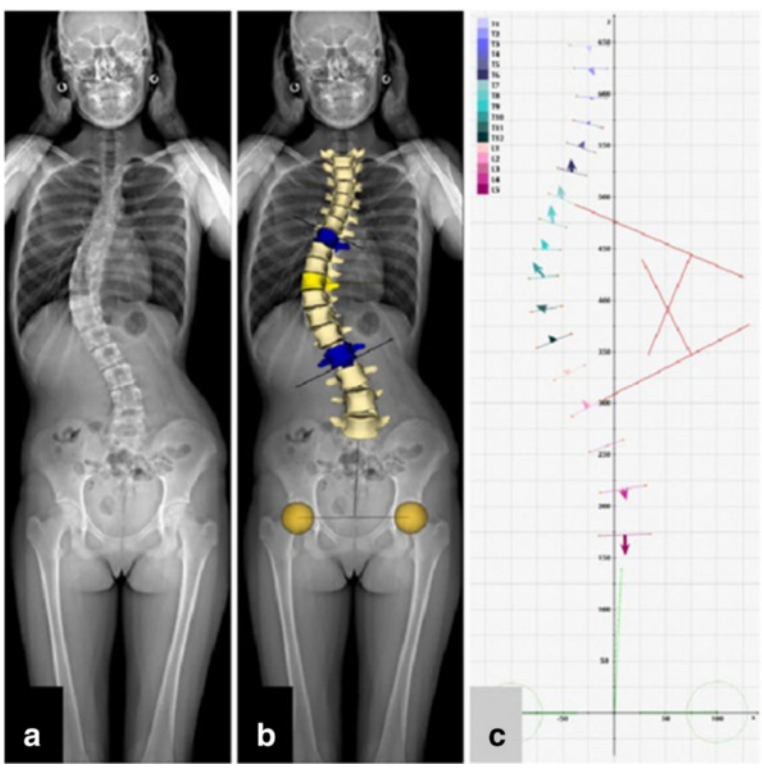

Fig. 70 Major or primary curve. **a** - Standard view, **b** - 3D recontructed view, **c** - Vectorial view

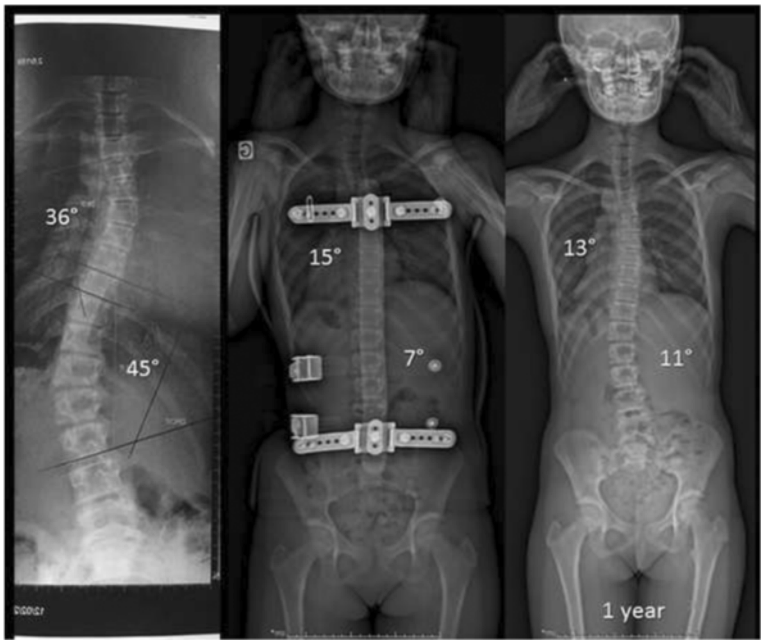

Fig. 71 Minor thoracic curve, in-brace correction and result after 1 year bracing

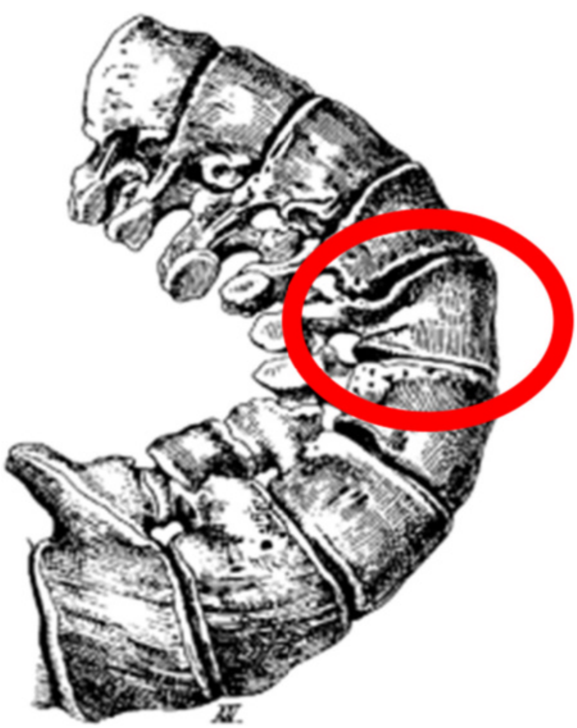

Fig. 72 Apical vertebra with maximal deformation

Fig. 73 Hyperkyphosis: regular thoracic

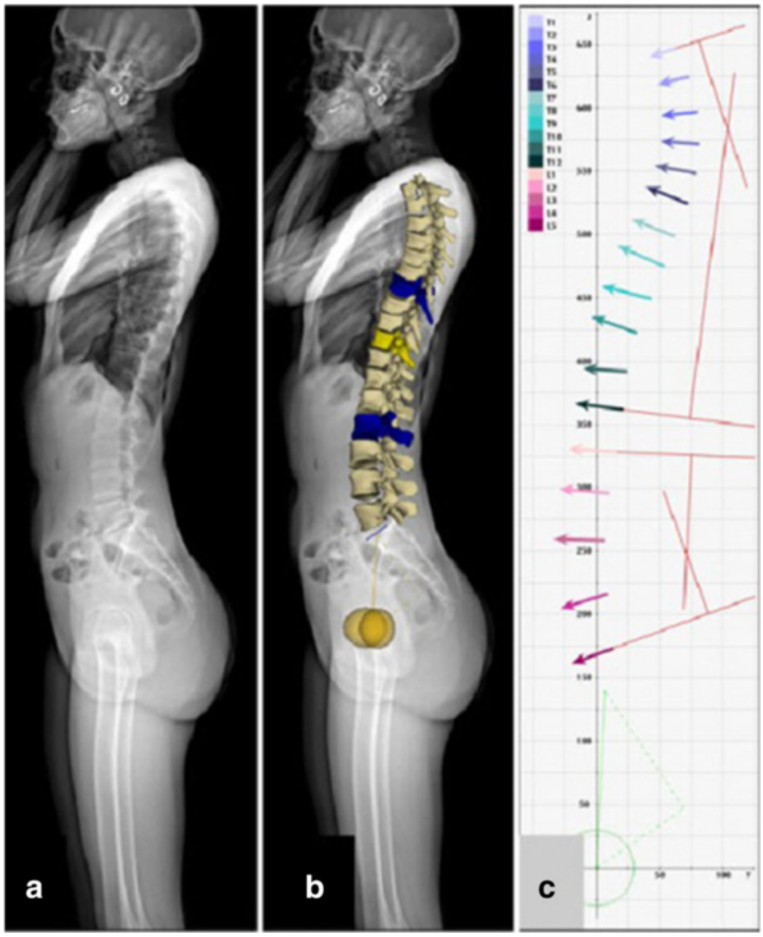

Fig. 74 Hypokyphosis. **a** - Standard view, **b** - 3D recontructed view, **c** - Vectorial view

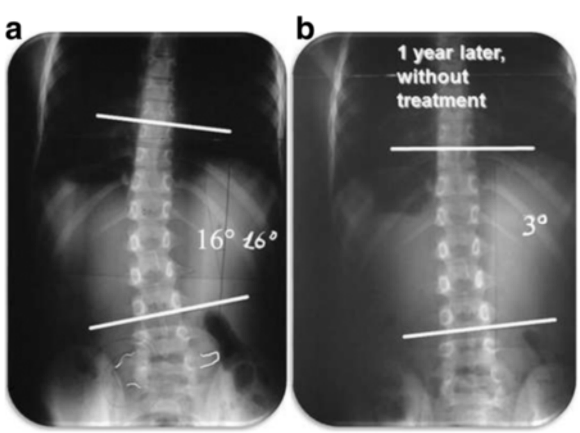

Fig. 75 Non progressive scoliosis usually seen before puberty: **a** Initial 16°, **b** One year after, without treatment 3°

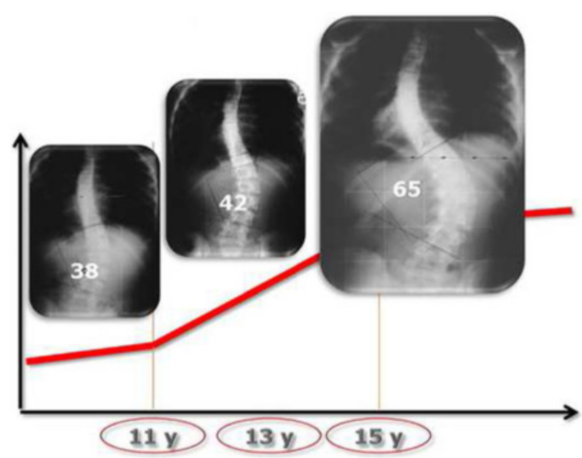

Fig. 76 Progressive curve during puberty: Duval-Beaupere's law

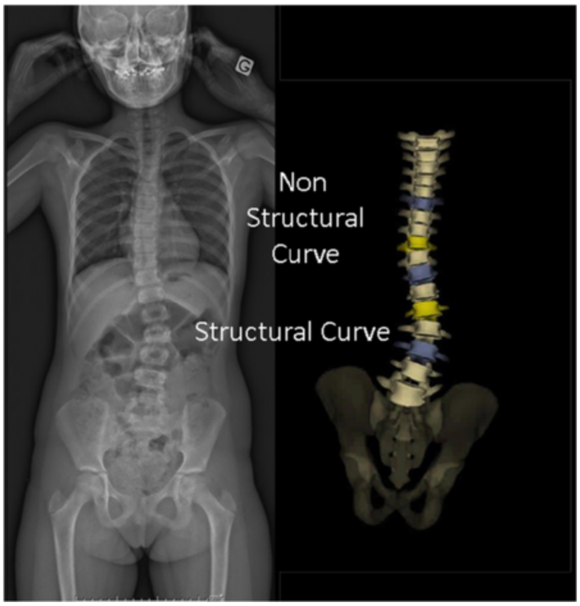

Fig. 77 Nonstructural thoracic curve: without rotation

most curves are non-progressive (chaotic scoliosis) (Fig. 75).

Progressive curve or scoliosis

A scoliotic curve in which the Cobb angle increases 5° or more during a six-month period. Progression is also considered to be a sustained increase if the Cobb angle increases by at least 10° (Fig. 76).

Fig. 78 First historical adjustable Lyon orthosis in leather and steel

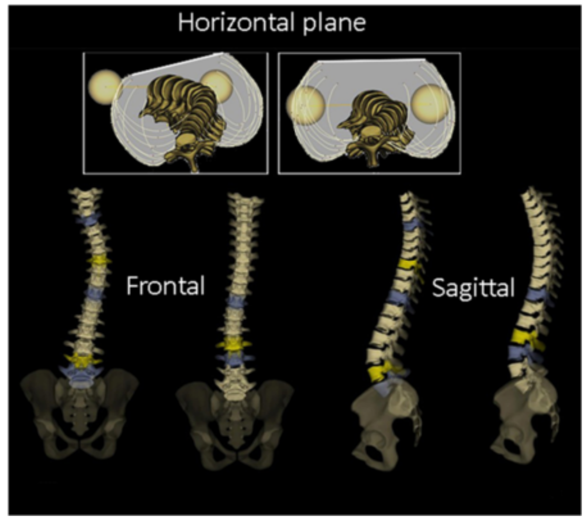

Fig. 79 3D radiological reconstruction

Non-structural curve

A spinal curvature above or below the structural, primary curve that is fully corrected during side bending or in lying position. Reflects a compensatory mechanism by the posture controlling system. Follows in development or regression to the primary structural curve (Fig. 77).

Fig. 80 Overcorrecting night and day brace

Fig. 81 Three points short Lyon brace

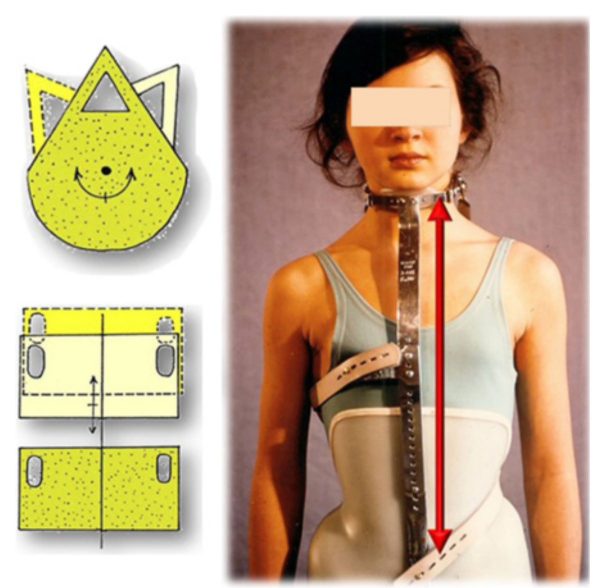

Fig. 82 Axial elongation: rotation and translation along the vertical axis

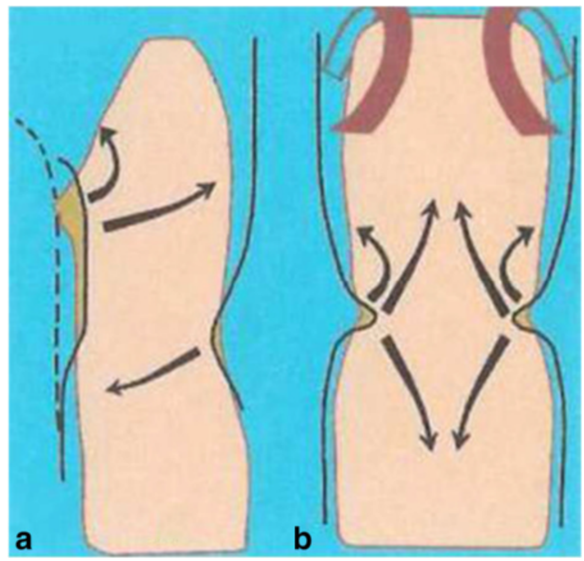

Fig. 83 Cherry stone effect: by Jacques Chêneau. The condition is however that no obstacle should block this correcting effect, like parts crossing over the shoulders. **a** - latero-lateral view, **b** - antero-posterior view

Brace function

Orthosis

An externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal system (Fig. 78).

3-D correction

The correction of the deformities in all three anatomical planes. This involves correction of the coronal plane deformities (i.e. thoracic and lumbar curves), transverse plane deformities (i.e. pelvic torsion and thoracic

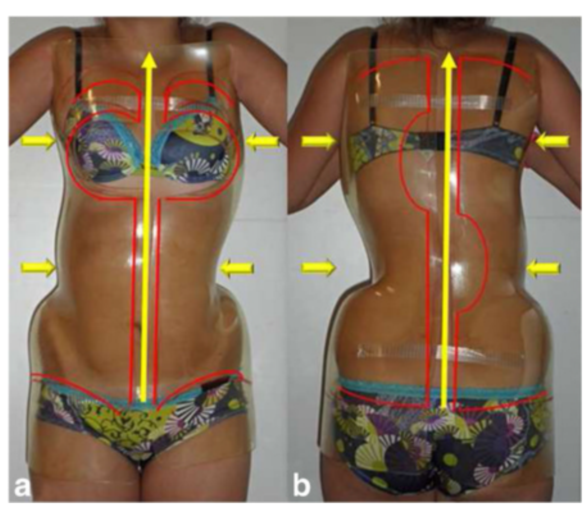

Fig. 84 Mayonnaise tube effect by Jean Claude de Mauroy. Tightening the two side pieces, the self-axial elongation is obtained. **a** - frontal view, **b** - back view

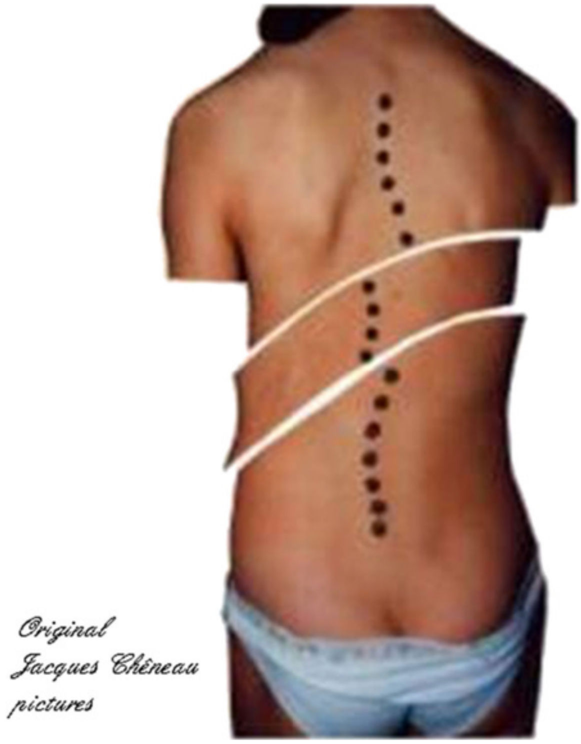

Fig. 85 Tissue transfer or translation by Jacques Chêneau

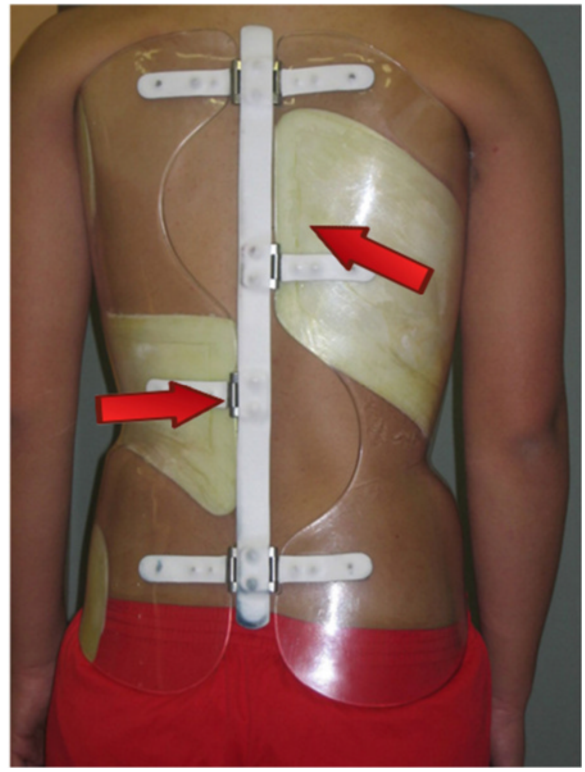

Fig. 87 Pushes on a Sforzesco brace

rotation) and sagittal plane deformities (i.e. hypokyphosis). The objective is that the correction occurs simultaneously in three planes of the space, as a unique movement called torsion and not plane-by-plane correction (Fig. 79).

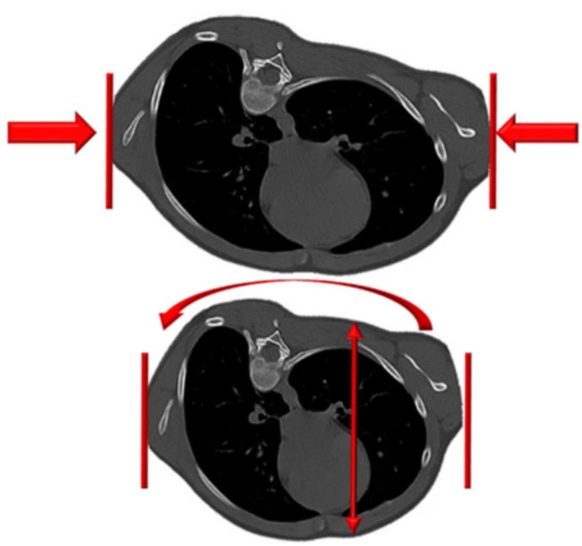

Fig. 86 Clamp effect by Jacques Chêneau

Overcorrecting

A brace with strong enough pressure to reverse a scoliotic curve (Fig. 80).

Mechanism of action

Three point pressure system

The correction of a scoliotic curve using three separate pressure points. This is achieved by one force applied in

Fig. 88 Three points system with counter forces for a congenital malformation

Fig. 89 Dynamic thrust in a CMCR

the center of the convex side of a curve, with two counter forces applied to each end of the contralateral side of the curve (Fig. 81).

Axial elongation

Motion along the vertical axis without trunk compression. The principle is to elongate the spine with the cervical collar. Another effect of axial elongation is disk decoaptation that favors the correction in the other plans (Fig. 82).

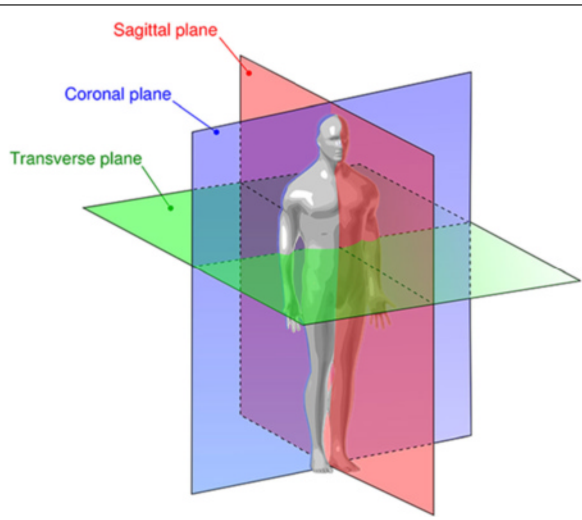

Fig. 90 Three planes of action

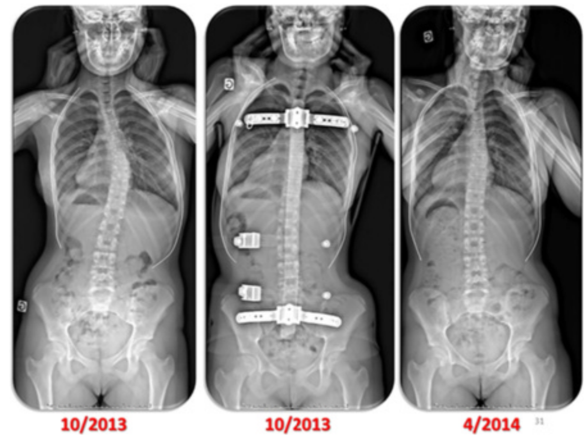

Fig. 91 Deflexion in the frontal plane

Cherry stone effect

As noted by Jacques Chêneau, a cherry stone effect is defined "When tissues on a trunk are laterally pressed, in whatever place it is, they migrate in the directions which remain free. If only the high and low openings of the brace are free, it is in these directions that the 'leakage' of tissues is made. It is the direction of the normal growth." (Fig. 83).

Mayonnaise tube effect

Similar to the cherry stone effect, but the pressure is laterally applied to the whole trunk with a higher pressure at the thoracolumbar junction. The result is a vertical stretching of the spine (ARTbrace) (Fig. 84).

Fig. 92 Bending effect in the thoracic area

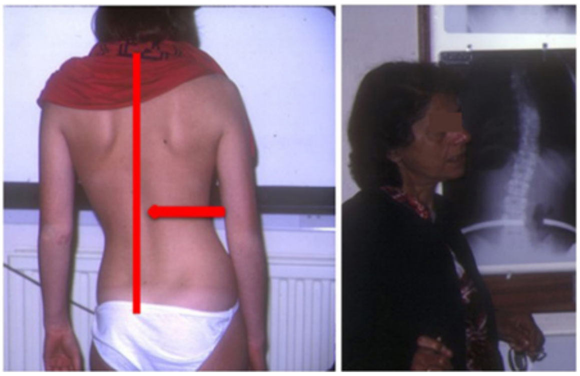

Fig. 93 Min Mehta explaining the 'side shift' with translation and extension

Tissue transfer pressure expansion, translation
According to Jacques Chêneau, this term is defined as "Tissue transfer by means of the complex pressures-expansions is much more elective. It consists in making migrate a tissue slide from humps towards concavities. Convex-concave wandering of a slice of tissues." (Fig. 85).

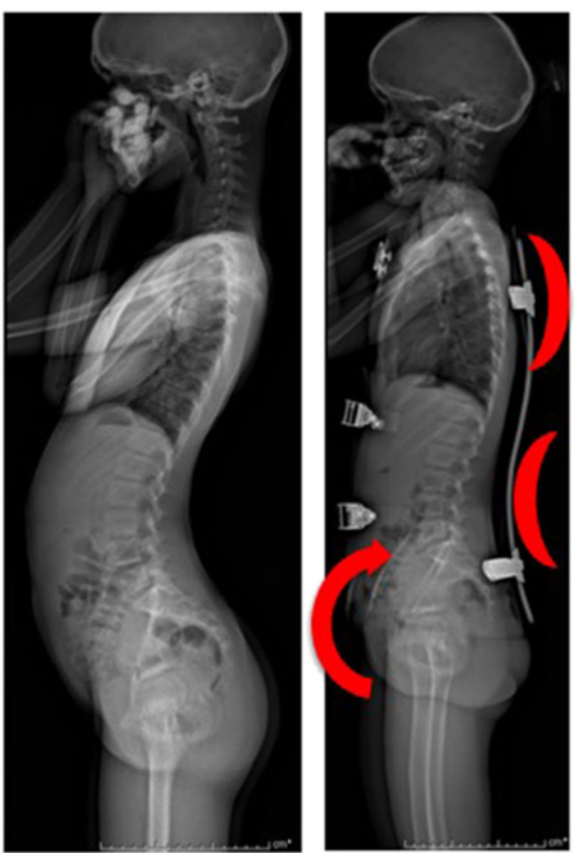

Fig. 94 Sagittal plane normalization with regional shape capture

Clamp effect on the greater diameter of thorax
As defined by Jacques Chêneau, this term reflects "Reducing the oblique diameter of the thorax being squeezed is accompanied by an increase in small diameter and expansion of the concavity. The brace takes in clamp this large diameter. Let us take care to spare very vast spaces for expansion of the smaller diameter. It extends from the sternum to the area of the concavity behind." (Fig. 86).

Pusher
A pushing force along the flanks. The possible actions at the flanks include:

- Shift: in the case of a low lumbar slope
- Stop: when there is a lumbar curve on the side opposite to the main slope
- Remodelling: to improve the aesthetics of a flattened flank (Fig. 87)

Counter-force
A force directly opposed to another force (e.g. a brace's corrective force against a scoliotic curve) (Fig. 88).

Thrust
A quick force delivered to a specific area (Fig. 89).

3D correction

Plane of action
The plane on which a brace produces an effect (coronal, sagittal, etc.) (Fig. 90).

2D frontal
Deflexion The action of straightening a scoliotic curve on the frontal plane.

A traditional Schroth Method term describing the straightening of a scoliotic curve (Fig. 91).

Bending effect
Lateral inclination of the trunk towards curve correction used for the upper thoracic region in most TLSO. Also, hyper-corrective position of the trunk in a night brace.

According to Jacques Chêneau, "One strongly presses from left towards right under the left armpit so that the spine bends towards the convexity. That carries out an inflection towards right, known as "bending". The patient thus inclined rectifies himself spontaneously with the following minutes." (Fig. 92).

Shift or shifting
Lateral displacement of a body part in the frontal plane used to obtain better curve correction or restore trunk balance (Fig. 93).

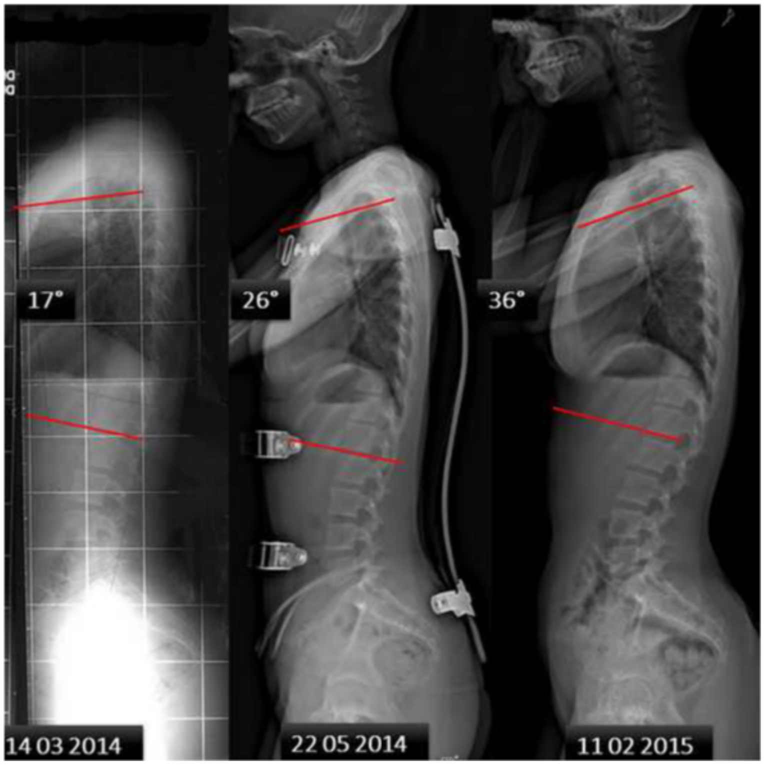

Fig. 95 Thoracic re-kyphotization with regional shape capture

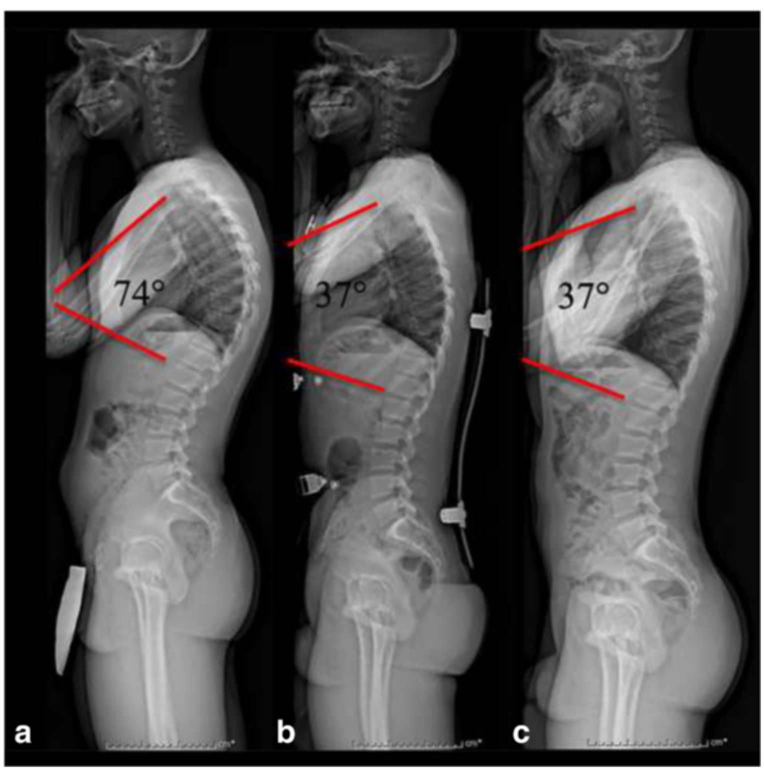

Fig. 96 Dekyphotization: **a** Initial hyperkyphosis 74°, **b** In-brace correction with physiological angulation of 37°, **c** End of Treatment without brace 37°

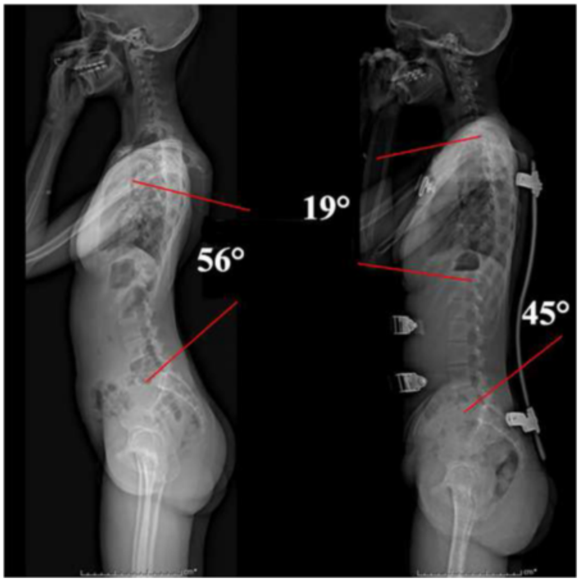

Fig. 97 Delordotization: from a thoracic lordosis to kyphosis under brace

2D sagittal

Sagittal plane normalization, sagittal plane correction Obtaining a normal physiological kyphotic curve in the thoracic region as well as normal physiological lordotic curve in the lumbar region, while maintaining the transition points of these regions (reharmonization after a Milwaukee brace) (Fig. 94).

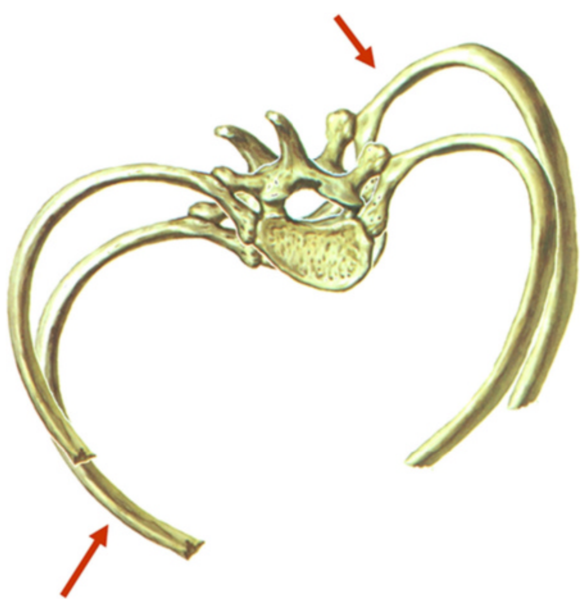

Fig. 98 Derotation: rotation on the vertical axis

Fig. 99 Global Detorsion in a modern sculpture. Arrows are showing the opposite directions of forces

Re-kyphosis Correction of the hypokyphosis by returning the vertebral column in the thoracic region to the normal physiological kyphosis of the sagittal plane (Fig. 95).

Dekyphotization The action of reduction of the kyphosis of the spine. Neologism: the act of correcting hyperkyphosis in a brace (Fig. 96).

Delordosization The action of reducing of the lordosis of the spine. Neologism: the act of correcting hyperlordosis in a brace (Fig. 97).

Fig. 100 Untwisting with soft tissue and concrete

2D horizontal

Derotation Reduction of the vertebral rotation in a scoliotic curve, either manually or with a brace. Derotational forces are applied to specific areas of the spine (Fig. 98).

Detorsion Correction of the torsional aspect of the vertebral column. Detorsional forces are a global action on the whole spine (Fig. 99).

Fig. 101 Alignment, but no balance

Untwisting The removal of twisting forces (Fig. 100).

3D

Alignment Arrangement or position in a straight line. Alignment doesn't mean balance (Fig. 101).

Balance Ability of human body to maintain center of gravity within the base of support to prevent falling. Jean Dubousset first introduced the concept of 'cone of balance', referring to a stable region of standing posture, deviating outside the cone poses challenges to balance mechanisms (Fig. 102).

Visual shape perception

Symmetric

Brace construction for symmetric (e.g. Scheuermann) and some asymmetric pathologies (Fig. 103).

Asymmetric

Regular pattern of corrective brace for idiopathic scoliosis. Enables selective application of pressures and unloading around the curve (Fig. 104).

Evaluation - outcome measure: 1 - Clinical

Rib hump

Scoliotic convexity. A protruding rotated aspect of rib cage. The prominence of the ribs best exhibited on forward bending (Fig. 105).

Double Rib Contour Sign (DRCS)

All lateral standing spinal radiographs in idiopathic scoliosis show a DRC sign of the thoracic cage, a radiographic expression of the rib hump. The outline of the convex ribs overlies the contour of the concave ribs. The rib-index is the ratio d1/d2. d1 is the distance between the posterior margin of the vertebral body and the most extended point of the most projecting rib contour. d2 is the distance between the posterior margin of the same vertebral body and the most protruding point of the least projecting rib contour (Fig. 106).

Rib Index

A measure of the transverse deformity of ribcage extracted from DRCS. RI is the ratio d1/d2. d1 is the distance between the posterior margin of the vertebral body and the most extended point of the most projecting rib contour. d2 is the distance between the posterior margin of the same vertebral body and the most protruding point of the least projecting rib contour (Fig. 107).

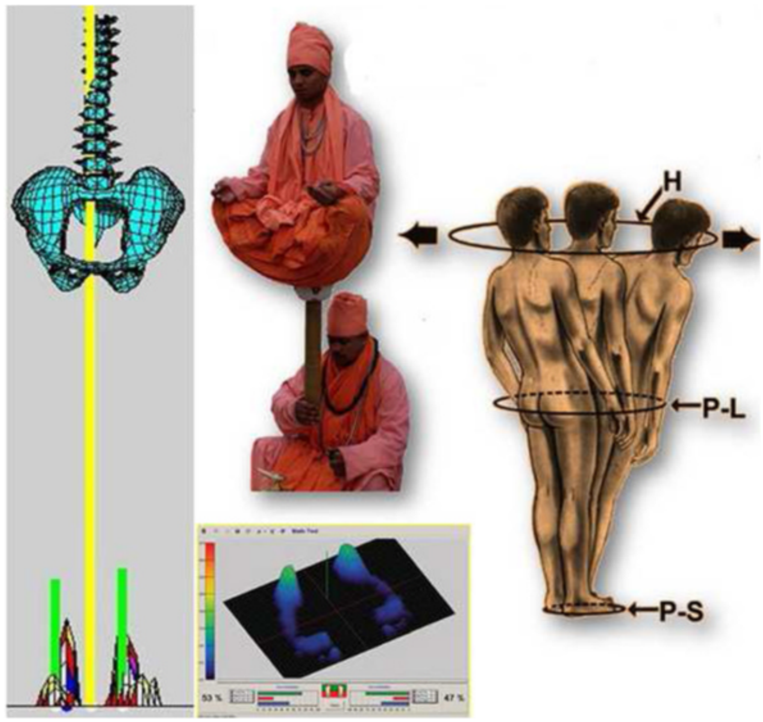

Fig. 102 Balance with the Dubousset's balance cone

POTSI index

A parameter to assess deformity in the coronal plane. Eight specific points at the surface of the patient's back are required. Ideal POTSI is zero, meaning full symmetry of the back surface. Normal values were reported to be below 27. The POTSI is very accurate in revealing any frontal plane asymmetry (Fig. 108).

ATSI index

A surface parameter describing frontal plane trunk asymmetry in scoliosis, equivalent of POTSI for the anterior trunk. Measurable on regular photography or surface topography scans. Ideal ATSI is zero, meaning full symmetry of the anterior trunk (Fig. 109).

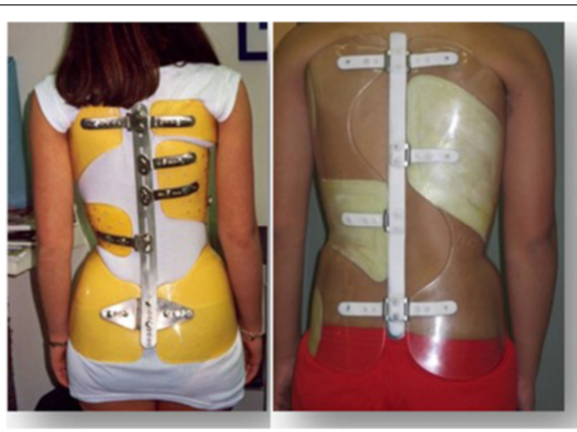

Fig. 103 Symmetrical Lyon and Sforzesco braces

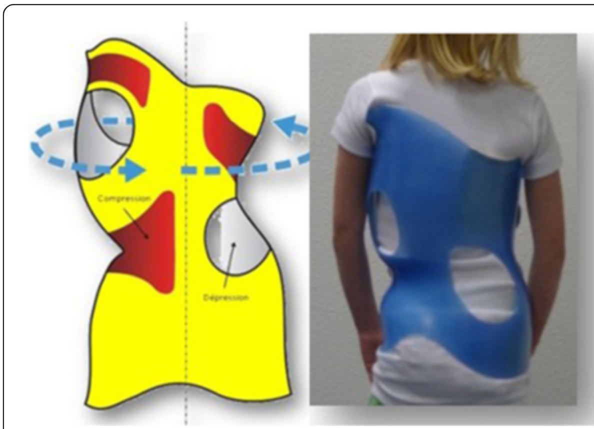

Fig. 104 Asymmetrical Chêneau brace

Fig. 105 Rib hump measurement with the scoliometer

Quality of Life (QoL)

A multidimensional construct composed of functional, physical, emotional, social and spiritual well-being (Fig. 110).

Activities of Daily Living (ADL) (brace, rehab)

The things normally done in daily living including any daily activity performed for self-care (eating, bathing, dressing, grooming), work, homemaking, and leisure.

Acceptability (brace)

Describes the patient's desire to remain compliant with the brace.

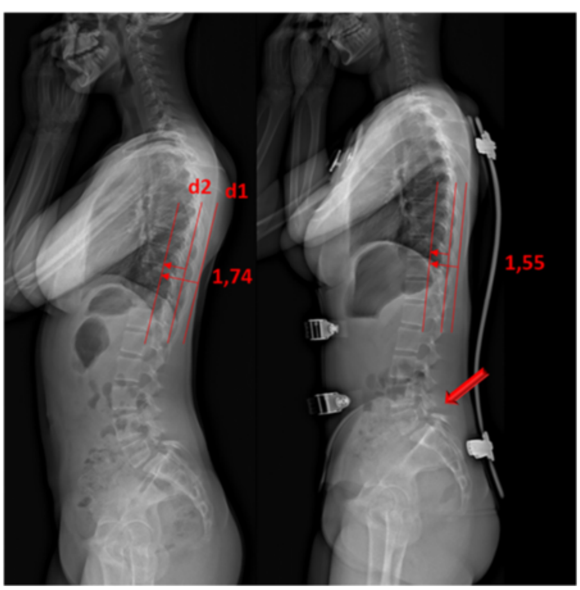

Fig. 106 Double rib contour sign of Grivas

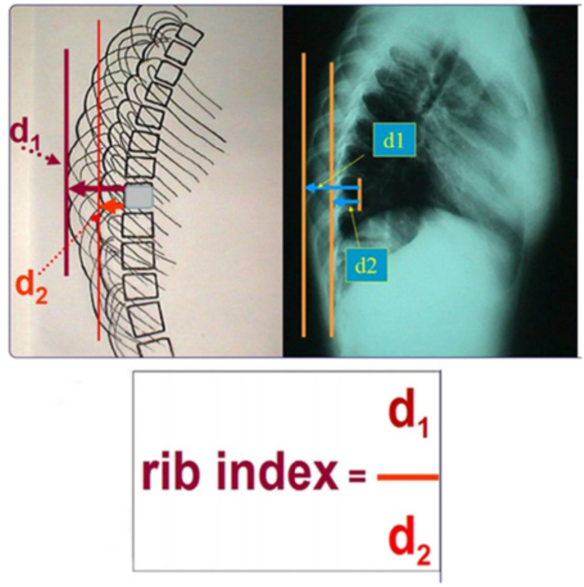

Fig. 107 Rib index: ratio of d1/d2

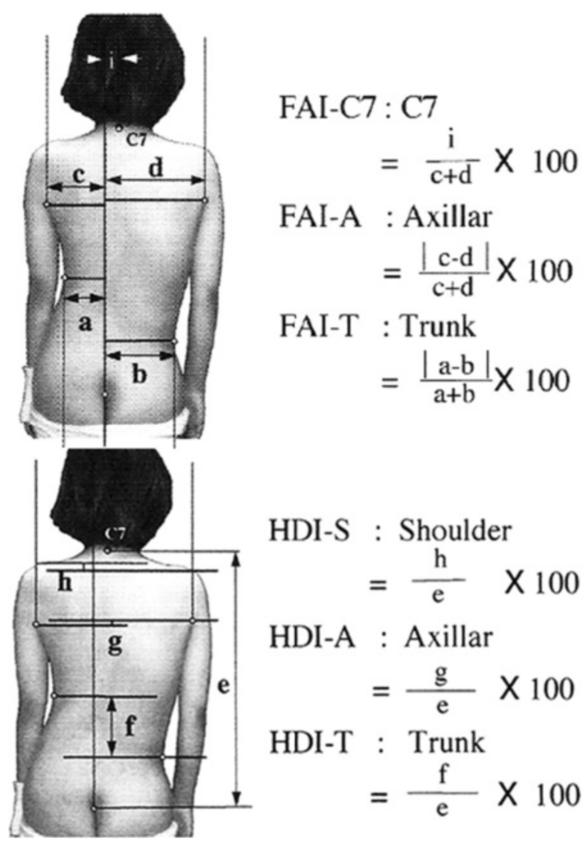

Fig. 108 POTSI Index

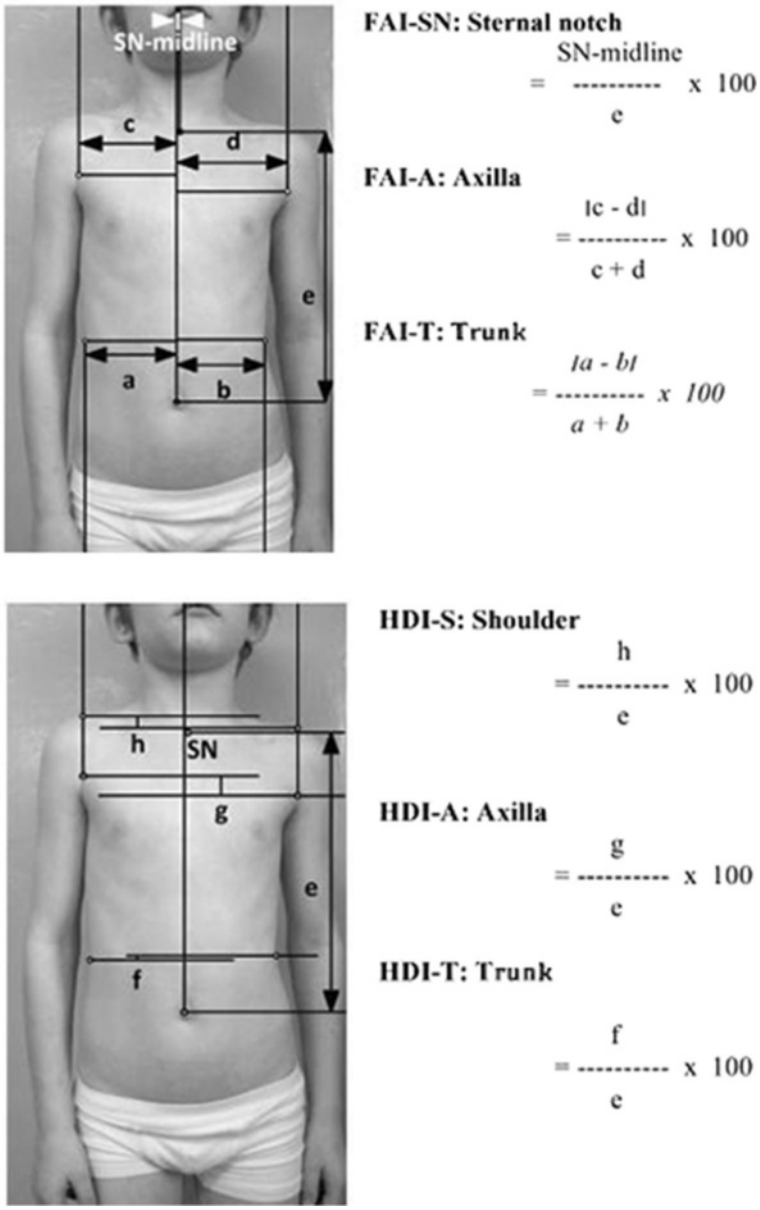

Fig. 109 ATSI Index

Adaptability (brace)

Describes the brace's ability to be modified to fit the patient.

Check (of a brace)

The process in which the new brace is tested for the interaction with the trunk of the patient in order to improve its efficacy and tolerance. It is the responsibility of the treating physician and is based on a strict collaboration between physician, orthotist, patient and family. Includes counselling to allow proper compliance.

Evaluation - outcome measure: 2 - Radiological

Microdose

New radiological standard for bracing. Twenty-five times less radiation than a full spine radiography (AP and lateral.) Contains the equivalent of a week of Earth's natural radiation (Fig. 111).

Severity index

Prognosis for minor scoliosis at first evaluation with Specificity and Sensibility near 100 % with EOS. The index takes into account 6 measures:

1. The apical axial rotation

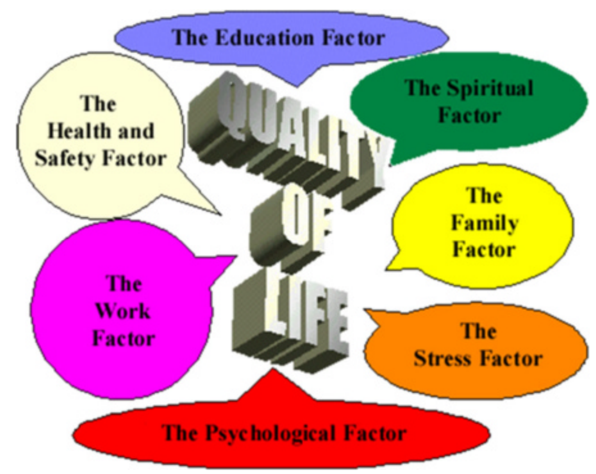

Fig. 110 Quality of Life: evaluation of all factors

2. The intervertebral rotation in the upper junctional zone
3. The intervertebral rotation in lower junction zone
4. The torsion index
5. The apical hypokyphosis index.
6. The 3D Cobb angle (Fig. 112)

Upper view

New radiological standard to appreciate alignment and balance in a brace (Fig. 113).

Global torsion index

Arithmetic average of the 17 segmental rotations of thoracic and lumbar vertebrae. This index quantifies the detorsion or untwisting (Fig. 114).

Evaluation - outcome measure: 3 - Bracing

Commitment to treatment

For the patient: the act of following procedure and wearing the brace.

For the treating team: the strong belief in treatment needed to allow patients to understand the importance of his or her treatment, a key element to achieve compliance, mainly in brace treatment.

Competence

The experience in a specific medical area necessary for making diagnoses, prescribing and/or applying a treatment, and following up with a patient. Adequacy and possession of required skill, knowledge, qualification, or capacity.

Compliance

The degree of concordance between the patient's behaviour and recommendations of health professionals. Often appears to be a characteristic of the patient. In reality, it can heavily depend on the behaviour of the treating team (Fig. 115).

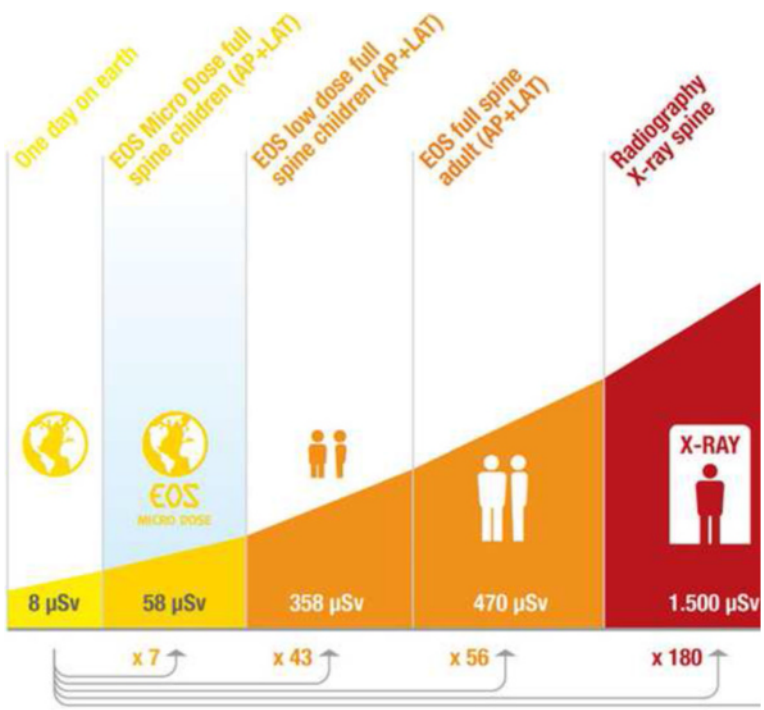

Fig. 111 Ultra-low dose of irradiation is equivalent at a week natural exposure (25 less irradiation)

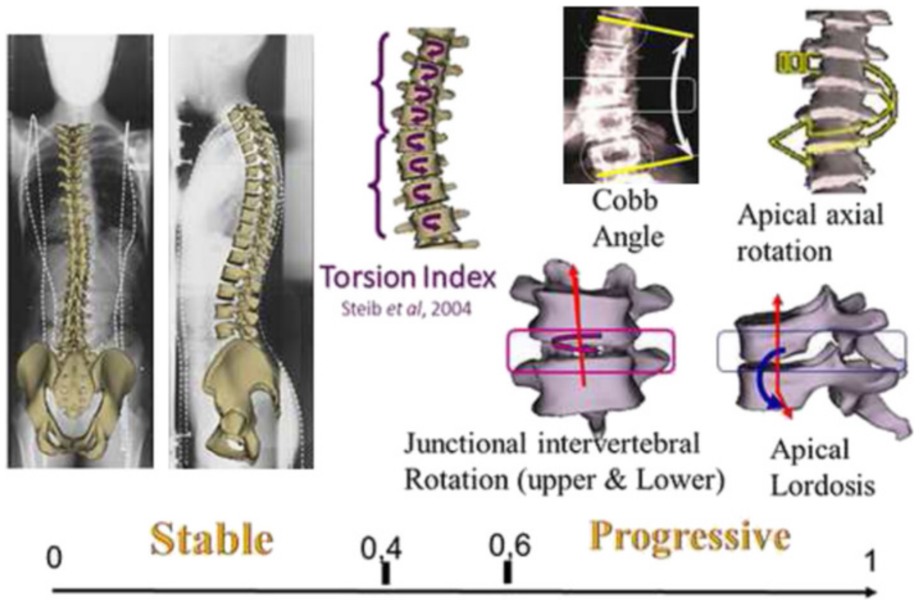

Fig. 112 Severity index of EOS system for mild idiopathic scoliosis prognosis at first evaluation

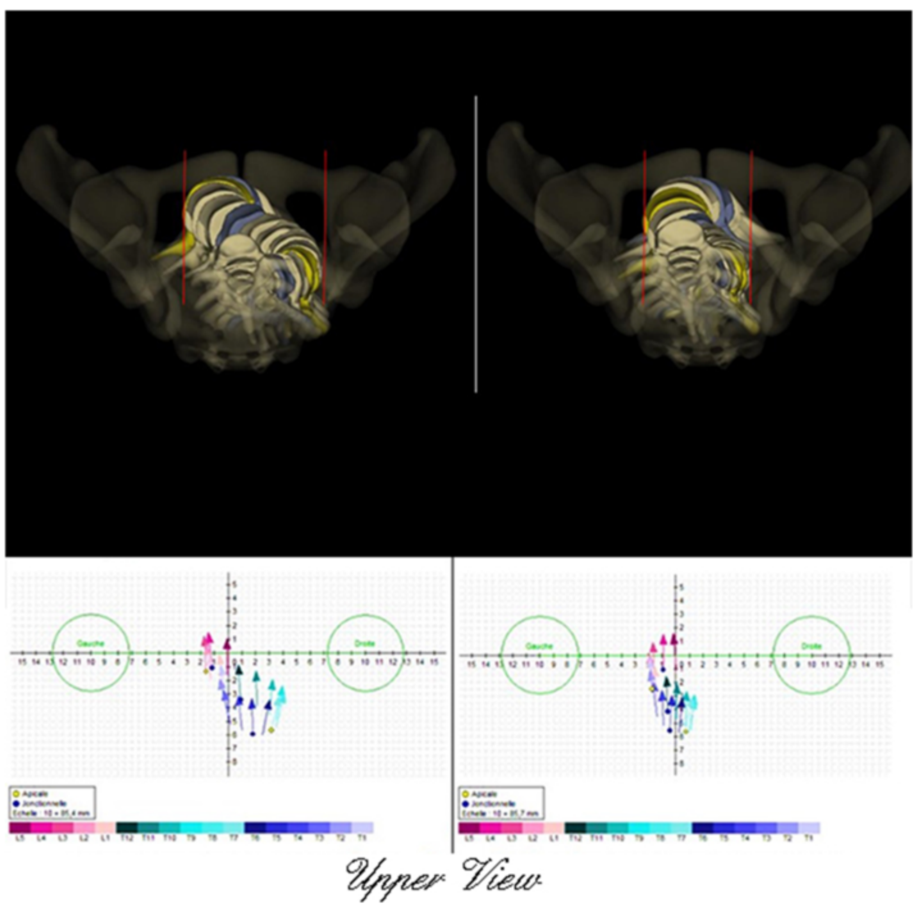

Fig. 113 Upper view or da Vinci view

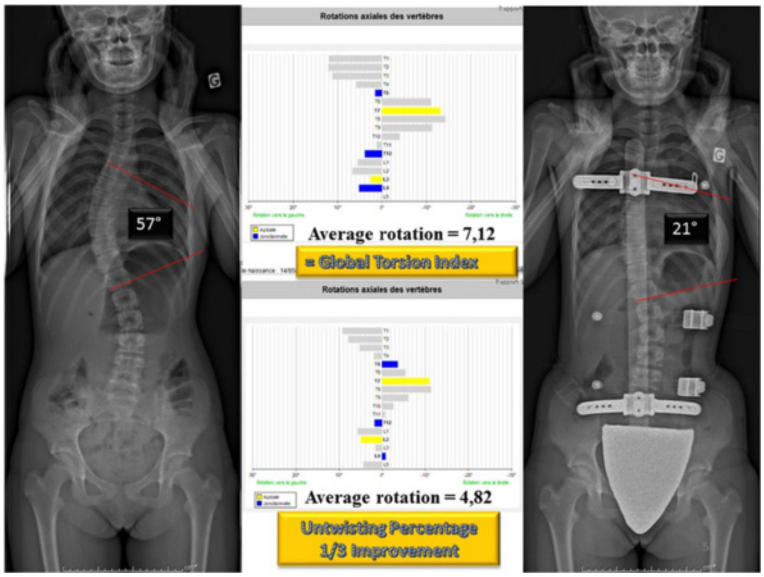

Fig. 114 Global torsion index: Average of all seventeen rotations before and in-brace

Monitorable brace
A brace which features a monitor device able to monitor compliance of brace wearing.

Thermobrace
Gadget incorporated into the brace for treatment compliance assessment using the body temperature of the wearer as a measurable parameter.

Correction (of a brace)
The correction of all measurable parameters in all three body planes (frontal, sagittal, transverse).

In-brace correction
The percentage of correction of all measurable parameters in all three body planes (frontal, sagittal, transverse) while wearing a Brace (Fig. 116).

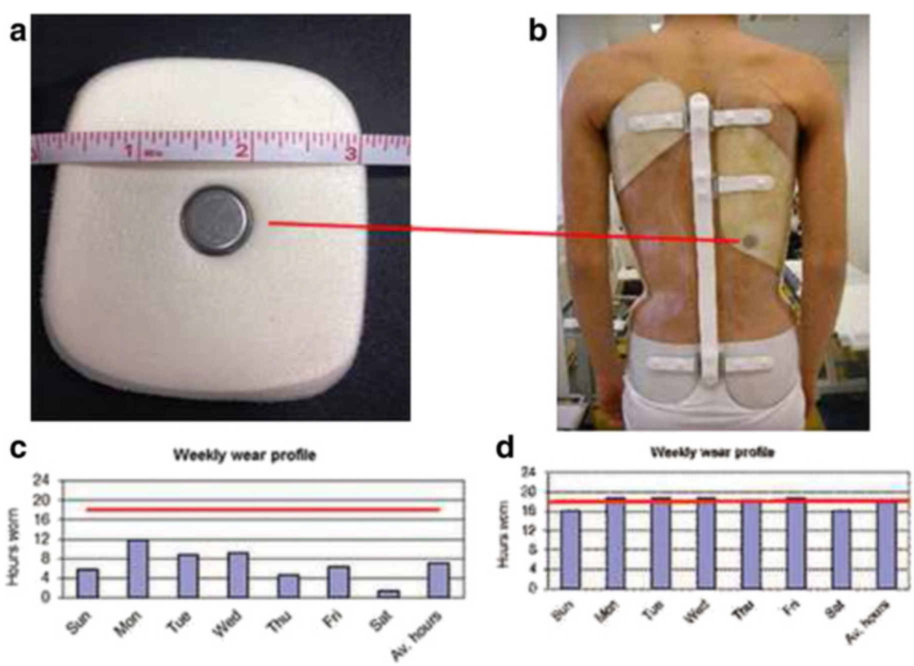

Fig. 115 Compliance: monitoring with **a** I-Button, **b** I-Button in a Sforzesco brace, **c** Low compliance, **d** High Compliance

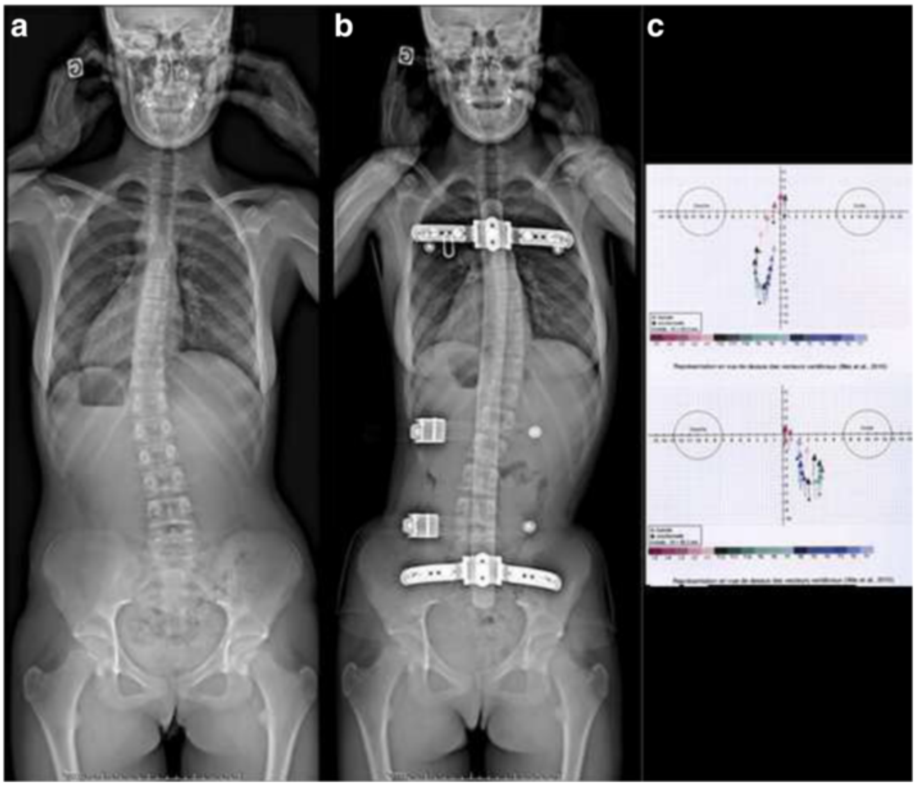

Fig. 116 In-brace correction: **a** Initial curve, **b** In-brace overcorrection, **c** Upper view of Vectorial detorsion

Improvement
A change equal or more than the amount of the measurement's reading error in an outcome's measure, Cobb angle more than or equal to 5°.

Cosmetic
Done to improve physical appearance. Also called cosmesis.

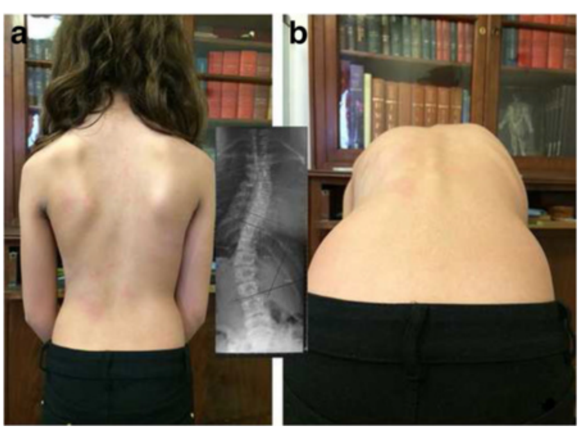

Fig. 117 Aesthetics or cosmetic, clinical outcome at brace weaning: **a** Clinical picture at removal of the brace, **b** Rib hump at the end of treatment

Aesthetics
Relating to a pleasing appearance, similar to cosmetic (Fig. 117).

Prescribed time of bracing

Dose-response (curve)
A range of bracing time over which response occurs. Bracing time lower than the threshold produce no response while those in excess of the threshold exert no additional response. The shape of the curve is usually hyperbolic when plotted with linear axes (Fig. 118).

Total time
24 h.

Full time
20–22 h.

Part time
18–14 h (Fig. 119).

Night time
Eight hours during night.

Fig. 118 Dose response curve: Rate of treatment success according to average hours of daily brace wear. (Adapted from BrAIST study, Weinstein)

Concertina effect hypothesis

According to this hypothesis, each time a brace is weaned the deformity gradually moves back from the maximal in-brace correction to the original out-of-brace situation. This reversal is due to a postural collapse that is correlated to the length of brace weaning and the rigidity (flexibility) of the spine (Fig. 120).

Health professionals

Orthotist

The professional for the production and application of Orthoses. "Orthotic care may include, but is not limited to, patient evaluation, orthosis design, fabrication, fitting and modification to treat a neuromusculoskeletal disorder or acquired condition" (ABCOP).

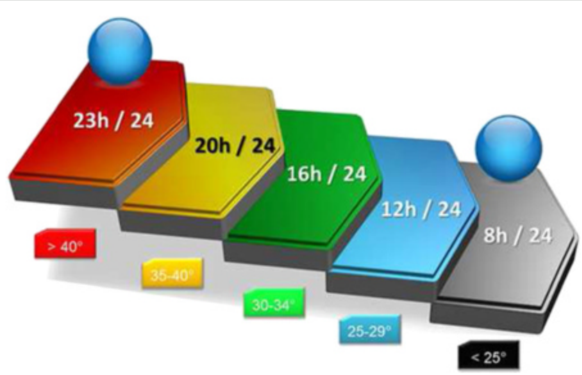

Fig. 119 Part-Time bracing according to initial angulation (Lyon brace protocol)

CPO

Certified Orthotic and Prosthetic professional (American Board of Certification (ABC)). The terminology is also presented in the additional file (Additional file 1) and it is completed; however, it may expand if necessary. Many terms are elaborated with related pictures.

Discussion

Many linguistic and imaging difficulties have been overcome in the creation of these definitions. The language was the first obstacle, for example in Europe 'molding' applies equally to molding cast and CAD/CAM. In the United States, 'molding' is specific of 'cast molding' and the term 'captures shape' is preferred for the CAD/CAM. As the term 'shape capture' is also understandable in Europe, we have retained this term. For the same term we had up to 4 different definitions. Some were eliminated, others combined. Many countries have no specific school for training orthotists who will now have consensual definitions. Radiologic imaging has made significant progress in recent years and has improved many illustrations. Recent advances in bracing with high rigidity, shape capture molding and new 3D assessment technologies have made necessary a more exhaustive classification. Given the importance of definitions, we had a two-stage process for bracing classification. The second stage will follow the more classical Delphi round 2 and round 3 procedure.

Conclusions

This is the first consensus statement by the BCSG addressing a standardized terminology related to bracing in patients with scoliosis. This work provides the foundation for future work addressing bracing

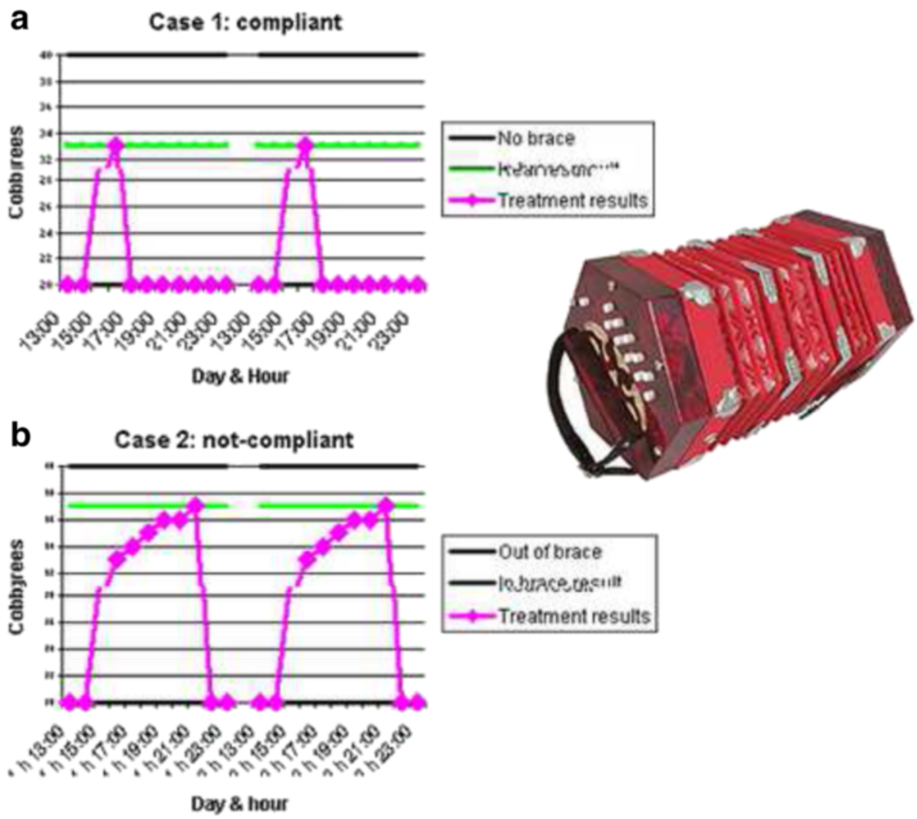

Fig. 120 Concertina effect: **a** In case 1 compliant, the loss without brace is lower than in case 2 non compliant (**b**)

classification. A visual atlas related to the bracing terminology is also provided. In this process, the BCSG has documented 17 distinct domains, ranging from fabrication to final outcome evaluation of bracing. Increasing awareness and understanding of current orthotic terminology and concepts will hopefully lead to more improved selection of ideal bracing and outcomes for the scoliotic patient.

Additional file

Additional file 1: Round table: Braces conceptual and technical approach to scoliosis: JC de Mauroy and N Price. The spreadsheet reproduces the Classification of the 6 most used braces in Europe according to 16 biomechanical parameters. (XLSX 658 kb)

Abbreviations

ADL: Activities of Daily Living; ATSI: Anterior Trunk Symmetry Index; BCSG: Brace Classification Study Group; BRACE MAP: Building, Rigidity, Anatomical classification, Construction of the Envelope, Mechanism of Action, Plane of action; CAD/CAM: Computer-Aided Design/Computer-Aided Manufacturing; CPO: Certified Prosthetic and Orthotic professional; CTLSO: Cervical-Thoraco-Lumbo-Sacral Orthotics; DRCS: Double Rib Contour Sign; IS: Idiopathic Scoliosis; LLD: Leg Length Discrepancy; LSO: lumbosacral orthosis; PE: Polyethylene; POTSI: Posterior Trunk Symmetry Index; PP: Polypropylene; QOL: Quality of life; TLSO: Thoraco-Lumbo-Sacral Orthotics

Acknowledgements

For three years, all BCSG work has been reported on-line on the SOSORT website. We would like to thank SOSORT members, who were encouraged to share their remarks and comments.

Availability of data and materials

Not applicable.

Authors' contributions

TG organized and chaired in the BSCG consensus, also contributed drafting the manuscript and the definitions of the terms in the terminology section. JCM participated in the BSCG, contributed drafting the manuscript and the definitions of the terms in the terminology section and contributed much of the iconography Grant Wood participated in the BSCG, also contributed drafting the manuscript and the definitions of the terms in the terminology section, he has also improved the English text's language. MR participated in the BSCG and contributed drafting the manuscript. MTH participated in the BSCG, contributed drafting some of the definitions of the terms in the terminology section. TK participated in the BSCG, also provided useful advice. SN participated in the BSCG, also contributed in the definitions of some terms in the terminology section. All authors read the final draft and gave their consent for publication.

Competing interest

TG reports no conflicts of interest concerning this article. JCM reports no conflicts of interest concerning this article. He is Co-inventor of the ARTbrace, (EP2878284). GW reports no conflicts of interest concerning this article. He is the manufacture of the WCR brace for scoliosis. MR reports no conflicts of interest concerning this article. He is the medical advisor of Ortholutions (Germany) and Align-Clinic (US). MTH reports no conflicts of interest concerning this article. The Children's Orthopaedic Surgery Foundation has received research funds from Boston Brace International. TK reports no conflicts of interest concerning this article. SN reports no conflicts of interest concerning this article. He does own stock of ISICO (Italian Scientific Spine Institute), is consultant for Medtronic and is consultant for Janssen Pharmaceuticals.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Not applicable.

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