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REVIEW ARTICLE

The classification of scoliosis braces developed by SOSORT with SRS, ISPO, and POSNA and approved by ESPRM

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Abstract

Purpose Studies have shown that bracing is an effective treatment for patients with idiopathic scoliosis. According to the current classification, almost all braces fall in the thoracolumbosacral orthosis (TLSO) category. Consequently, the generalization of scientific results is either impossible or misleading. This study aims to produce a classification of the brace types.

Methods Four scientific societies (SOSORT, SRS, ISPO, and POSNA) invited all their members to be part of the study. Six level 1 experts developed the initial classifications. At a consensus meeting with 26 other experts and societies' officials, thematic analysis and general discussion allowed to define the classification (minimum 80% agreement). The classification was applied to the braces published in the literature and officially approved by the 4 scientific societies and by ESPRM.

Results The classification is based on the following classificatory items: anatomy (CTLSO, TLSO, LSO), rigidity (very rigid, rigid, elastic), primary corrective plane (frontal, sagittal, transverse, frontal & sagittal, frontal & transverse, sagittal & transverse, three-dimensional), construction—valves (monocot, bivalve, multisegmented), construction—closure (dorsal, lateral, ventral), and primary action (bending, detorsion, elongation, movement, push-up, three points). The experts developed a definition for each item and were able to classify the 15 published braces into nine groups.

Conclusion The classification is based on the best current expertise (the lowest level of evidence). Experts recognize that this is the first edition and will change with future understanding and research. The broad application of this classification could have value for brace research, education, clinical practice, and growth in this field.

Keywords Idiopathic scoliosis · Brace · Classification

Introduction

Scoliosis is a three-dimensional deformity of the spine and the trunk [1], and it is diagnosed when there is a radiographic curvature with a Cobb angle greater than 10° [2]. Additionally, the international Society On Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) suggests observing all children with a rib prominence on the Adams forward bending test during growth, regardless of the curve's severity [1]. Adolescent (diagnosis after age 10) idiopathic (unknown etiology) scoliosis (AIS) is the most common type [3]. Scoliosis treatments include observation, physiotherapeutic scoliosis specific exercises (PSSE), bracing, and surgery [1].

Studies have shown that brace treatment for AIS is effective [4, 5]. Nevertheless, there are substantial differences in results published in the literature [1]. These could explain the conflicting expert opinions in the past [6], even in the face of positive results coming from a prospective observational study (also called benchmarking controlled trial—a standard for health research [7]) conducted in the nineties by members of the Scoliosis Research Society (SRS) [8]. Two main factors could explain the published literature differences: technical skill (brace type and construction quality)

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Extended author information available on the last page of the article and human influence (patients' adherence to hours prescribed and wearing the brace correctly). Different groups found considerable differences in patients' adherence to the bracing prescription [9, 10], while technical factors have not been studied as well, with very few comparisons among braces [11–13]. It is common knowledge that the same brace is built differently by different orthotists, but no research exists on the topic. Experts agree about how to manage braced patients [14, 15], but not on the biomechanics of the correction [16]. Consequently, we are now in a situation where all braces are acceptable provided that the prescriber (physician) and the designer and fabricator (orthotist) are experts on that brace [15].

One of the factors impairing research and leading to clinical confusion in the field is the absence of a classification to understand differences and commonalities among braces. The only existing classification is common to all other orthoses, which is to classify braces according to the anatomical joints held underneath the brace—in the spine, these are the trunk regions. Unfortunately, according to this classification, almost all braces for spinal deformities fall in the thoracolumbosacral orthosis (TLSO) category, without other differentiations included. As a result, clinicians cannot generalize research results on one brace to another with the same biomechanical action. Even worse, we could be inaccurately generalizing data on one brace to another brace with different biomechanical actions. All that we know is their names, related to geography (Boston, Charleston, Lyon, Milwaukee, Providence, Wilmington, Sforzesco), their developers (Cheneau, Cheneau Rigo System), some of their features (ART—asymmetrical rigid three-dimensional, DDB—dynamic derotation brace, PASB—progressive action short brace, TriaC—three C, comfort, control, and cosmetics, TLI—THORACO-LUMBAR LORDOTIC INTERVENTION) or other (SpineCor).

Since its start, SOSORT has developed a series of consensus papers to increase knowledge in the field [15–17]. In 2017, SOSORT started a process about braces nomenclature that continued in 2018 with the decision to focus on the absence of a valuable brace classification system. Unfortunately, this classification attempt failed (see Appendix 1 for more details). During the final consensus meeting, SOSORT decided to change the approach and use a different procedure based on expert opinion. This paper aims to report the results of this expert consensus to produce a classification of the brace types that will better describe and compare braces in future research.

Methods

We conducted a qualitative study based on an expert consensus process (Appendix 2). SOSORT initiated the process and invited other Spine societies to join. The SRS, through its Non-Operative Committee, the International Society of Prosthetics and Orthotics (ISPO), and the Pediatric Orthopedic Society of North America (POSNA), agreed to participate in the exercise. SOSORT invited all members of the 4 scientific societies to participate in the consensus. Participants were to categorize themselves as a Level 1 or 2 expert in bracing according to specific criteria listed in Table 1.

We asked Level 1 experts to describe a classification system if they had already developed one. We developed a Classification Description Sheet by piloting, and we used it to standardize the collection of the classifications and facilitate their comparisons. We invited all Level 1 and 2 experts to participate in the consensus meeting with SOSORT Executive and Advisory Board members and official representatives nominated by the participating scientific societies. Three weeks before the meeting, participants received all the materials, including a report of commonalities and differences in the experts' classification according to a thematic analysis performed by the coordinator (SN).

During the consensus, the different classification systems were presented, and the coordinator showed the thematic analysis and comparison among these classifications. After a general discussion, anonymous voting procedures performed with Socrative software (www.socrative.com) allowed us to define the classification items, their names, and the classification options for each item. The level of agreement required to accept each concept was 80%. The names and classification options required a simple majority, with a second vote

Table 1 Level of expertise required to be qualified as Level 1 or 2 experts during this consensus procedure

Expertise	Bracing prescriptions	Experience with different types	Scientific exposure
Level 1	500 braces/year, for at least 15 years	Three different types of braces, for at least two years	Attendance at 10 scoliosis specific international meetings in the last 15 years
Level 2	200 braces/year, for at least ten years	Not required	Attendance at 5 scoliosis specific international meetings in the last ten years

To be qualified at a specific level of expertise, all criteria had to be met for the two most popular options if no option reached 50% during the first vote.

After the consensus meeting, the authors explained the classification items and classified all braces with published results [18]. Finally, the promoting scientific societies invited other scientific societies to support the classification.

Results

The paper's six primary authors (SN, AGA, PC, JCdM, JMA, and AM) were all Level 1 experts and developed the initial classifications. The consensus meeting included 26 Level 1 or 2 participants, with 16 other Level 1 and 2 experts providing relevant input to the process. All 42 participants were a member of one of the involved scientific societies (32 SOSORT, 20 SRS, 7 POSNA, 6 ISPO); moreover, there were four members each from ESPRM, Eurospine, International Research Society on Spinal Disorders (IRSSD), International Society for the Study of the Lumbar Spine (ISSLS), North American Spine Society (NASS).

The thematic analysis identified some basic concepts that were common among the developers' classifications, and the developers' priority scores allowed us to calculate a median score for each of them (Table 2). To facilitate the consensus meeting, the coordinator provisionally defined each of these concepts. The thematic concept of "action," "rigidity," and "topography-anatomy" reached a complete agreement among proposers (100%). The concepts with more than one proposer had 83% ("plane"), 67% ("symmetry-shape"), and 33% ("wearing time" and "construction") agreement, respectively. All the other concepts had no agreement.

During the consensus meeting, the experts accepted all the concepts with at least 50% agreement, except for one. They finally decided that the concept "symmetry-shape" was inappropriate since all braces for scoliosis are asymmetrical. "Construction" was split into two sub-items: "valves" and "closure." Participants rejected all the concepts below 50% ("wearing time," "tissue," and "treatment"). Finally, participants gave each concept its final name and defined the classification options (Table 3).

Table 4 reports the definition of the terms used in the classification. There was a consensus that these definitions had to be intuitive because of the current lack of precise knowledge of most braces' biomechanical effects on the trunk and spine [16]. The primary authors' expertise provided these definitions, and the other experts' consensus formally accepted them.

Finally, Table 5 presents the classification of the braces currently used and published. Participants in the consensus

Table 2 Classifications proposed and concordance (with percent agreement and median score) found with the thematic analysis

Proposal of the developers						%A	MP	Thematic concept
AGA	PC	JCDM	JMA	AM	SN			
1. Action*	1. Biomechanical action	1. Mechanism of action	1. Action	2. Corrective action	1. Biomechanical action	100	1	Action
	8. Pressure		4. Sagittal curves	1. Applied force				
6. Rigidity	2. Rigidity	2. Rigidity	5. Rigidity	1. Applied force	2. Rigidity	100	2	Rigidity
3. Anatomy	3. Topography	4. Anatomy	6. Topography	5. Treatable curves	4. Topography	100	4	Topography-anatomy
4. Plane	–	1. Mechanism of action	3. Main plane of action	–	3. Planes	83	3	Plane
2. Shape	4. Shape	3. Symmetry	2. Symmetry	–	–	67	2	Symmetry-shape
–	–	–	7. Wearing time	6. Wearing time	–	33	6	Wearing Time
-	5. Segmentation	–	–	–	5. Valves	33	6	Construction
	6. Splints							
	7. Closure							
–	–	–	–	3. Growth modulation	–		3	Tissue
				4. Nerves Muscles Ligaments				
–	–	–	–	5. Treatable curves	–		5	Treatment

The numbers indicate the order of the importance of the classification concept provided by each developer

AGA Angelo Gabriele Aulisa, *PC* Pavel Cerny, *JCDM*: Jean Claude De Mauroy, *JMA* Jeb McAviney, *AM* Andrew Mills, *SN* Stefano Negrini, *%A* percent of agreement, *MP*: median priority

*The concept "action" includes more than one classification item for three proposers

Table 3 Results from the consensus meeting with the final classification item names and options (bold)

Thematic concept	Final classification item	Classification options	Agreement	
			Item (%)	Options (%)
Action	Primary action	Bending	92	55
		Detorsion		
		longation		
		Movement		
		Push-up		
		Three points		
Rigidity	Rigidity	Very rigid	92	58
		Rigid		
		Elastic		
Topography-anatomy	Anatomy	CTLSO	92	100
		TLSO		
		LSO		
Planes/action	Primary corrective plane	Frontal	85	62
		Sagittal		
		Transverse		
		Frontal & Sagittal		
		Frontal & Transverse		
		Sagittal & Transverse		
		Three-dimensional		
Construction	Construction		88	
	– Valves	**Monocot**	82	100
		Bivalve		
		Multisegmented		
	– Closure	Dorsal	93	100
		Lateral		
		Ventral		

The consensus rejected the thematic concept "symmetry-shape" (agreement < 50%)

provided the classification of each brace with this order of priority: (1) the developer, (2) a researcher on that brace, and (3) a Level 1 expert currently using/building that brace.

After the process concluded, the European Society of Physical and Rehabilitation Medicine accepted to support the classification.

Discussion

This paper reports on the consensus procedure developed with worldwide experts to define the first brace classification going beyond their given names. It is the extended effort of the Brace Classification Study Group formed some years ago by SOSORT which resulted in the Brace classification part one, Atlas and definitions, (https://www.sosort.org/bibliography/#guidelines). The overall aim of developing a classification system is to increase knowledge and allow better research in the field. The main limitation of this study is that the classification and corresponding definitions used are intuitive and based on expertise and consensus. Nevertheless, the experts recognized that this was unavoidable due to the current research knowledge, with a paucity of biomechanical data on specific braces, comparative studies of braces, etc. The authors and supporting scientific societies recognized the need during this first classification to start with such a consensus procedure hoping that will lead to something better in the future. The paper also has some strengths. The qualitative methodology of this study is appropriate since it followed all the classical stages of Consensus development. The experts were required to satisfy very demanding criteria and were gathered worldwide using the leading scientific societies on scoliosis and other spinal deformities. All the primary scientific societies focused on scoliosis care have been involved. Without any prior consultation, the experts showed good agreement before the consensus meeting, demonstrating a common understanding in the field. The consensus agreement was higher than the minimum required, and this showed the experts' commonalities. Nevertheless, there was complete agreement that this classification is only a starting point for research and future evolution.

Table 4 The definitions of the terms used in the brace classification system

Term	Definition
Primary action	The overall primary mechanism of action of the brace. The terms used do not describe an exclusive biomechanical action but the prevalent one*
Bending	Braces with a global action of bending the trunk toward curve correction (in the direction of its convexity), mainly in the coronal/frontal plane
Detorsion	Braces with global action on the whole spine through mutual derotation of different trunk regions, mainly in the transverse (horizontal or axial) plane
Elongation	Braces with a global action in elongation/decompression of the trunk and spine achieved through distraction effect of cervical component, mainly along the vertical axis
Movement	Braces that guide the active movement of the patient through specific constraints
Push-up	Braces with a global action of elongation and localized detorsion of the spine achieved through three-dimensional compression of the trunk's pathological prominences in a caudo-cranial direction
Three points	Braces with one or more triplets of corrective pressure forces on the curves to be corrected. They can be on a single plane or multiplanar. They are located one on the apex and the other two above and below
Rigidity	The overall rigidity of the whole brace's structure. It depends on the material type, its thickness, and the brace design and construction*
Very rigid	Braces with (almost) full trunk coverage requiring hinges (or similar) to allow opening due to material rigidity
Rigid	Braces of thermoplastic rigid material that can be deformed (opens without hinges if monocot) and multisegmented braces with uncovered areas of the trunk
Elastic	Braces of elastic or (semi-) flexible plastic or multiple materials allowing movement of the trunk and spine
Anatomy	Regions of the spine (joint levels) where the orthosis is located. According to the mechanisms of action, they can also control curves in more cranial spine regions
CTLSO	Cervico-thoraco-lumbo-sacral orthosis
TLSO	Thoraco-lumbo-sacral orthosis
LSO	Lumbo-sacral orthosis
Primary corrective plane	Main plane of action of the brace. In the case of two planes, the appropriate terms are combined
Frontal	Braces with primary action in the coronal/frontal plane to bring vertebral bodies toward the spinal midline
Transverse	Braces with primary action in the transverse/horizontal/axial plane to rotate the vertebral bodies toward the spinal midline
Sagittal	Braces with primary action on the sagittal plane, normalizing the physiological curvature of lumbar lordosis and/or thoracic kyphosis
Three-dimensional	Braces with direct action in all three planes at the same time
Valves	Pieces of material connected to form the brace
Monocot	Rigid braces built in one single shell
Bivalve	Rigid braces built in two connected shells
Multisegmented	Rigid braces built in more than two connected pieces and elastic braces
Closure	Location of the opening to don/doff the brace. In the case of more than one closure, the two appropriate terms are combined
Ventral	Braces with anterior closure
Dorsal	Braces with posterior closure
Lateral	Braces with side closure

Participants accepted that the definitions are intuitive because of the current lack of precise knowledge of most braces' biomechanical effects on the trunk and spine [16]. The primary authors' expertise provided these definitions, and the other experts' consensus formally accepted them

*By definition, all braces act on the trunk three-dimensionally. Consequently, each action or corrective plane of braces must be considered the primary, not exclusive

In all fields of medicine, classifications are essential and lead to improved mutual understanding and communication among researchers and clinicians. A classic example is the World Health Organization classification family, including the International Classification of Diseases (ICD) (https://www.who.int/standards/classifications/classification-of-diseases) used worldwide for more than a century to compare Health Systems, and the International Classification of Functioning, Disability, and Health (ICF) (https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health) used as a common understanding framework in medicine, rehabilitation,

Table 5 Classification of the braces currently available and published [18]

Anatomy	Rigidity	Primary action	Primary corrective plane	Construction	Closure	Brace name
TLSO	Very rigid	Detorsion	Frontal & Sagittal	Bivalve	Ventral	ART
		Push-up	Three-dimensional	Bivalve	Ventral	Sforzesco
	Rigid	Bending	Frontal	Monocot	Ventral	Charleston
						Providence
		Detorsion	Three-dimensional	Monocot	Ventral	Chêneau
						Dynamic derotating
						Rigo-Chêneau System
		Push-up	Three-dimensional	Bivalve	Ventral	Sibilla
		Three-point	Frontal	Monocot	Ventral	Wilmington
			Frontal & transverse	Monocot	Dorsal	Boston
			Sagittal	Monocot	Dorsal	TLI
			Three-dimensional	Multisegmented	Ventral	Lyon
	Elastic	Movement	Frontal & transverse	Multisegmented	Lateral	TriaC
			Three-dimensional	Multisegmented	Frontal	Spinecor
CTLSO	Rigid	Elongation	Frontal & sagittal	Multisegmented	Dorsal	Milwaukee
LSO	Rigid	Detorsion	Frontal & transverse	Monocot	Ventral	PASB

Participants in the consensus provided the classification of each brace with this order of priority: (1) the developer, (2) a researcher on that brace, and (3) a Level 1 expert currently using/building that brace

ART Asymmetric rigid three-dimensional; *PASB* progressive action short brace, *TLI* thoracolumbar lordotic intervention; *TriaC* three C, comfort, control, and cosmetics

education, and other areas. In the field of spinal disorders, we could cite for their the importance of the Pfirrmann grading system [19], the Modic changes of Magnetic Resonance Imaging [20], and the NASS lumbar disc nomenclature project [21]. Finally, in the field of spinal deformity, the Ponseti classification is still valid in the non-operative treatment of scoliosis [1], or the Lenke Classification for surgical recommendations in AIS [22] or the Schwab-SRS Classification for adult scoliosis [23]. Classifications are fundamental as a basis for research and the growth of a specific field.

The non-operative field of scoliosis treatment is currently growing after years of stagnation [24]. The birth of SOSORT in the years 2004/5 and its consensus papers created a basis of understanding and reinvigorated research on non-operative treatment [15–17]. The final push came from the Weinstein/Dolan BrAIST study in 2014 that reinforced the efficacy of bracing [4] after years of doubt [6]. SOSORT and the SRS Non-Operative Committee regularly collaborate and establish new criteria for standardizing research studies in the field [25]. The development of this brace classification is a natural evolution of this collaboration.

In clinics, practical knowledge of bracing has evolved and improved over time. The Boston brace in 2021 shares some qualities of the 1970 version but incorporates three-dimensional principles in design, with one derivative of this brace being the Dynamic Derotation Brace [26]. The Chêneau brace has evolved to Rigo-Chêneau [27]. A new class of braces was born with the Sforzesco [28], followed by the ART brace [29]. The very rigid plastic braces are comparable to casts [30] and expanded the indications into curve magnitudes that were previously treated surgically [5, 31, 32]. These evolutions complement a better understanding of the importance of a treating team surrounding the patient, including a physician, an orthotist, and a physiotherapist [33]. Progress in bracing includes monitors [9], CAD/CAM technologies, and three-dimensional printing [34]. Also, imaging has changed with the EOS system [35], and ultrasound technology is probably opening a new era in conservative treatment [36]. In this context, a brace classification system could advance the field from individualism to shared understanding and better science.

Scoliosis braces are still handcrafted products [37], where experience, continuous application, and even intuition have the most crucial role [15]. Still, it is more the art of medicine than the science behind it. Bracing results depend on the skills of the orthotist in design and fabrication, the physician in prescribing and checking the brace, the patient in adherence to treatment, and the team (physiotherapist included) in empowering the patient and family [15]. Research on bracing is increasingly looking into factors like in-brace results, wear-time dose, sagittal balance, rotational control, three-dimensional results, the rigidity of the material, prognostic factors, quality of life in adulthood, growth plate modulation, overall brace balance, and other areas. A brace classification improves communication in research by adding standardization of treatment descriptions which will promote reproducibility of results without jeopardizing the art inherent in bracing.

The primary actions are descriptions by the developers of the main corrective principles each brace follows. Nevertheless, we have to recognize that it is not so simple. Most of the braces follow more than one principle. Some orthotists could build one type of brace following a principle different from that devised by the developer and reported here. In individual cases, the developers themselves add features to their braces to search different primary actions according to individual's needs [38]. All these possibilities support the use of a brace classification system. Ideally, all the authors of research papers should classify the brace they used, specifying the primary intended action. By detailing which items from the classification each brace represents, it will be possible to identify characteristics most closely related to outcomes.

Some of the experts suggested that primary actions could be considered from different perspectives, mainly biomechanical. For example, in such a case, mechanical elongation action on the spine would include the two primary actions, "traction" and "push-up," where the difference would lie on the cranial or caudal starting point, respectively. There was a consensus that these two primary actions are different in bracing since cranial pulling eliminates the sagittal physiological curves, while caudal pushing can be three-dimensional. CAD/CAM technology introduced other biomechanical correction possibilities, like lateral drift, that one expert proposed in this classification. The consensus did not introduce these terms as distinctive of one specific current class of braces, even though we could have evolutions in the future. A discussion arose around the primary action "detorsion," considered biomechanically very similar to the three-point pressure used in many brace designs. Detorsion is ultimately constituted by two coupled three-point pressure systems applied in the transverse plane. There was a consensus to keep the distinction because some braces mainly use a single three-point system different from the detorsion concept. Another interesting discussion was if a detorsion primary action would necessarily imply a three-dimensional primary corrective plane. Experts agreed that there is a distinction between the planes where correction is sought (e.g., frontal and sagittal) and how to achieve this correction (detorsion).

The definition of rigidity was another difficult task. There was consensus that rigidity was a factor to consider and that it depends not only on the strength of the material. Orthotists can use different materials to achieve specific rigidity, like polycarbonate for very rigid, polyethylene for rigid, and copolymers with EVA or textile for elastic. However, many other physical factors influence rigidity, like material thickness and brace building through three-dimensional spatial shaping, reinforcements, cuts, and segmentation. A thin, deeply curved shell can have higher rigidity than a flat or shallowly shaped area of thicker material. In some designs, the rigidity increases due to changes in the material orientation angle, with the need to find solutions to allow the patient to don/doff a monocot brace. Consequently, there was consensus that the distinction between rigid and very rigid is still subjective and that this classification should serve as a stimulus for further research on the topic. It is also possible to distinguish between elastic (stretching, elongation possible) and inelastic (impossible to stretch) material [39, 40]. The first has also been defined as dynamic elastomeric fabric orthoses [41, 42], used in idiopathic and secondary scoliosis. Again, these distinctions could be developed in future editions of this classification.

The other classification items are anatomy, primary corrective plane, and construction. Experts discussed symmetry, widely used to distinguish some braces from others, but finally decided that braces to treat scoliosis cannot be symmetric and that the distinction was not useful. Other proposed items, like wearing hours and treatable curves, were excluded because they were not specific to describe braces, while influenced tissues had neither agreement nor enough research to justify their use.

This common terminology could be used as a standard reference when performing research. We can expect biomechanical studies, finite element modeling, and benchmarking studies to compare the different brace classes. Education would be simplified by the classification, allowing proper comparison and descriptions of the essential features of each brace. When it comes to practical applications, reimbursement systems could go beyond given names with implications for third-party payers, orthotists, and patients. Orthotists who are used to one given name brace could check if their application corresponds to the primary action intended by the brace developer; they could also approach another brace to verify another primary action. These are only simple examples, but we could probably expect more than this.

Conclusion

This is the first edition of a brace classification that we expect to change with better understanding and more research in the future. It is based on expertise more than evidence, but we also must recognize that expertise is the first step of the pyramid of evidence when no better research data are available. Moreover, this expertise is shared worldwide among some of the best brace experts. The involvement and support of the leading scientific societies in the field should guarantee its dissemination. We can expect that the broad application of the classification could have great value for research, education, practice, and the overall growth of conservative approaches to spinal deformities.

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