Design of spinal brace shape classification

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Theodoros B. Grivas et al.

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

Scoliosis and Spinal Disorders, 2016, **DOI:** 10.1186/s13013-016-0102-y

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

Fabio Zaina et al.,

European journal of physical and rehabilitation medicine · February 2014

Anatomical Classification	Construction of the Envelope	Mechanism of Action	Plane of action	Brace Map Classification	Opening	Main indication	Initial Hours of prescription	Rigidity	Material
A	CE	MA	P					R	
L: LSO	S: Symmetric	T: Three Point	3D: 3-dimensional	PRLST3D	posterior	single and double curves	full time/part time	R: Rigid	polyethylene
L: LSO	A: Asymmetric	T: Three Point	Fr: Frontal	CRLATFr	anterior	single lumbar, thoracolumbar, thoracic curves	night time	R: Rigid	polyethylene
T: TLSO	A: Asymmetric	T: Three Point	3D: 3-dimensional	CRTAT3D	anterior	single and double curves	full time	R: Rigid	polyethylene
T: TLSO	A: Asymmetric	T: Three Point	FH: Frontal Horizontal	CRTATFH	posterior	single and double curves	full time	R: Rigid	polypropylene and aluminium
T: TLSO	A: Asymmetric	T: Three Point	3D: 3-dimensional	CVTAT3D	anterior	single and double curves	full time/part time	V: Very rigid	polymetacrylate and radioluscent duralumin
C: CTLSO	A: Asymmetric	E: Elongation	FH: Frontal Horizontal	CRCAEFH	posterior	single and double curves	full time/part time	R: Rigid	polyethylene, alumin and steel
L: LSO	A: Asymmetric	T: Three Point	3D: 3-dimensional	CRLAT3D	anterior	single lumbar/thoracolumbar curves	full time	R: Rigid	polyethylene
T: TLSO	A: Asymmetric	T: Three Point	Fr: Frontal	CRTATFr	anterior	single and double curves	night time	R: Rigid	polyethylene
L: LSO	A: Asymmetric	T: Three Point	Fr: Frontal	CRLATFr	anterior	single and double curves	full time/part time	R: Rigid	polyethylene
T: TLSO	S: Symmetric	P: Push	3D: 3-dimensional	CVTSP3D	anterior	single and double curves	full time	V: Very rigid	copolyester ± radioluscent duralumin
T: TLSO	A: Asymmetric	M: Movement	3D: 3-dimensional	PETAM3D	NA	single and double curves	full time	E: Elastic	elasthic tissue
L: LSO	S: Symmetric	T: Three Point	Sa: Sagittal	PRLSTSa	posterior	single and double curves	full time	R: Rigid	polyethylene
T: TLSO	A: Asymmetric	T: Three Point	3D: 3-dimensional	PLTAT3D	NA	single and double curves	full time/part time	L: Low Rigidity	soft plastic and metallic connections
T: TLSO	A: Asymmetric	T: Three Point	FH: Frontal Horizontal	CRTATFH	anterior	single and double curves	full time/part time	R: Rigid	polyethylene

MINERVA COPYRIGHT

First steps of new scoliosis brace classification were done in San Francisco 2019 (coordinator Stefano Negrini)

Classificatory items

- Overall action 92%
- Rigidity 92%
- Anatomy 92%
- Planes 85%
- Construction 88%
  - Valves 82%
  - Closure 93%

	Family name	Name	Level
1	Aulisa	Angelo Gabriele	1
2	Cerny	Pavel	1
3	McAviney	Jeb	1
4	Mills	Andrew	1
5	Negrini	Stefano	1
6	De Mauroy	Jean Claude	1
7	Bulat Würsching	Suncica	2
8	Hresko	Timothy	2
9	Kotwicki	Tomasz	2
10	Labelle	Hubert	2
11	Lein	Grigorii	2
12	Maloney	Emery	2
13	Marcotte	Louise	2
14	Matthews	Martin	2
15	Price	Nigel	2
16	Roye	Benjamin	2
17	Stikeleather	Luke	2
18	Vitale	Michael G	2
19	Wong	Man Sang	2
20	Wood	Grant	2
21	Wynne	James	2
22	Zaina	Fabio	2
23	Rigo	Manuel	2
24	Grivas	Theodoros B	AB
25	Lebel	Andrea	AB
26	Parent	Eric	AB
27	O'Brien	Joe	AB
28	Hanscom	David	AB

Overall action 55%

A. Elongation
B. Movement
C. Three points
D. Push-up
E. Bending
F. Detorsion

		Aulisa	Cerny	De Mauroy	McAviney	Mills	Negrini	
1	83%		Traction	Translation Vertical axis	Postural Elongation	Pull	Traction	Milwaukee
1	83%	MOV	Movement	Multiplanar 3 points	Movement Spinal Coupling		Movement	SpineCor
1	83%	PUSH	Push-up		Push Up	Push	Push-up	Sforzesco
1	83%	3P	3 points		3 Point pressure	3P (coupled)	Three points	Multiple
5	67%		Hypercorrection	Planar 3 points	Bending		Three points postural (Hypercorrection)	Charleston/Providence
6	33%		Detorsion	Translation + Derotation				Multiple
7	17%	3P/MOV						PASB
7	17%				Sagittal			TLI
7	17%					Pad-Relieve		
7	17%					Active Self correction		

Rigidity 58%

A. Very rigid
B. Rigid
C. Elastic

		Aulisa	Cerny	De Mauroy	McAviney	Negrini
1	100%	Rigid	Rigid	Rigid	Rigid	Rigid
1	100%	Elastic	Elastic	Tissue	Flexible	Soft elastic
2	80%		Very rigid	High Rigidity	Super Rigid	Very rigid
3	40%		Soft rigid			Soft anelastic
4	20%			Rigid +mobile piece		
4	20%				Semi Rigid	

Anatomy 100% vs Topography 65%

A. CTLSO
B. TLSO
C. LSO

		Aulisa (A)	Cerny (T)	De Mauroy (A)	McAviney (T)	Negrini (T)
1	80%		CTLSO	CTLSO	CTLSO	CTLSO
2	100%	TLSO	TLSO	TLSO	TLSO	TLSO
3	60%	LSO	LSO			LSO

Primary corrective plane 62%

A. Frontal
B. Horizontal
C. Sagittal

		Aulisa (P)	De Mauroy (A)	McAviney (A)	Mills (A)	Negrini (P)
1	100%	Frontal	Planar 3 points	Coronal	Translation	1D
2	80%	3D	Multiplanar 3 points		Translation Flexion Sagittal	3D
2	80%		Translation + Derotation	Coronal and transverse	Translation Flexion	2D
3	60%	Sagittal		Sagittal	Flexion	
4	20%		Translation Vertical axis			

Construction

Valves **100%**

- **Monovalve**
- **Bivalve**
- **Multisegmental**

Closure **100%**

- **Ventral**
- **Dorsal**
- **Lateral**

		Counts	Average	Aulisa	Cerny	De Mauroy	McAviney	Mills	Negrini	
7	**Construction**	**17%**	**5**	5						**Construction**
8	**Segmentation**	**17%**	**5**		5					**Construction**
9	**Valves**	**17%**	**5**						5	**Construction**
10	**Splints**	**17%**	**6**		6					**Construction**
11	**Closure**	**17%**	**7**		7					**Construction**

differences among experts L1

		Counts	Average	Aulisa	Cerny	De Mauroy	McAviney	Mills	Negrini	Parenthesis
1	**Action**	**83% (100%)**	**1**	1	1	1	1	(2)	1	Modifier
2	**Rigidity**	**83% (100%)**	**3,4**	6	2	2	5	(1)	2	Applied force
3	**Topography/anatomy**	**83% (100%)**	**4**	3	3	4	6	(5)	4	Treatable curves
4	**Planes/action**	**67% (83%)**	**3**	4		(1)	3	2	3	Combined
5	**Symmetry/Shape**	**67%**	**2,75**	2	4	3	2			
6	**Wearing Time**	**33%**	**6,5**				7	6		
7	**Construction**	**17%**	**5**	5						**Construction**
8	**Segmentation**	**17%**	**5**		5					**Construction**
9	**Valves**	**17%**	**5**			shape			5	**Construction**
10	**Splints, components**	**17%**	**6**		6					**Construction**
11	**Closure**	**17%**	**7**		7					**Construction**
12	**Applied force**	**17%**	**1**					1		**Action**
13	**Sagittal curves**	**17%**	**4**				4			**Action**
14	**Pressure**	**17%**	**8**		8					**Action**
15	**Growth modulation**	**17%**	**3**					3		**Tissue**
16	**Neuro+Muscle+Ligaments**	**17%**	**4**					4		**Tissue**
17	**Treatable curves**	**17%**	**5**					5		**Treatment**

design shape classification requirements should be

- **outside shape** classification in „first view“
- **universal use** for all types of different spinal orthoses
- **relevance**
- **unique** designation of each type

proposed parameters of important groups (outside shape)

CONTOUR („FLAG“ and „PADDLE“)

- ✓ **N**o **E**longation (NE)
- ✓ **L**ateral **F**lag (LF)
- ✓ **L**ateral **P**addle (LP)
- ✓ **C**ontralateral **P**addle (CP)
- ✓ **V**entral **F**lag (VF)
- ✓ **D**orsal **F**lag (DF)
- ✓ **V**entral **P**addle (VP)
- ✓ **D**orsal **P**addle (DP)

CUTS (segmentation) according to basic anatomic planes

- ✓ **N**o **C**uts (NC)
- ✓ One *Cut* (**O**ne **F**rontal, **O**ne **S**agittal, **O**ne **T**ransversal)
- ✓ Multi *Cut* (**M**ulti **F**rontal, **M**ulti **S**agittal, **M**ulti **T**ransversal)
- ✓ Semi *Cut* (**S**emi **F**rontal, **S**emi **S**agittal, **S**emi **T**ransversal)

SUPLEMENTS

- ✓ **N**o **S**upplements (NS)
- ✓ **R**igid **S**plint (RS)
- ✓ **F**lexible **S**plint (FS)
- ✓ **JO**int (hinge) (JO)
- ✓ **FR**ame (FR)
- ✓ **EL**astic (EL)
- ✓ **OT**her (OT)

OPENING (closing)

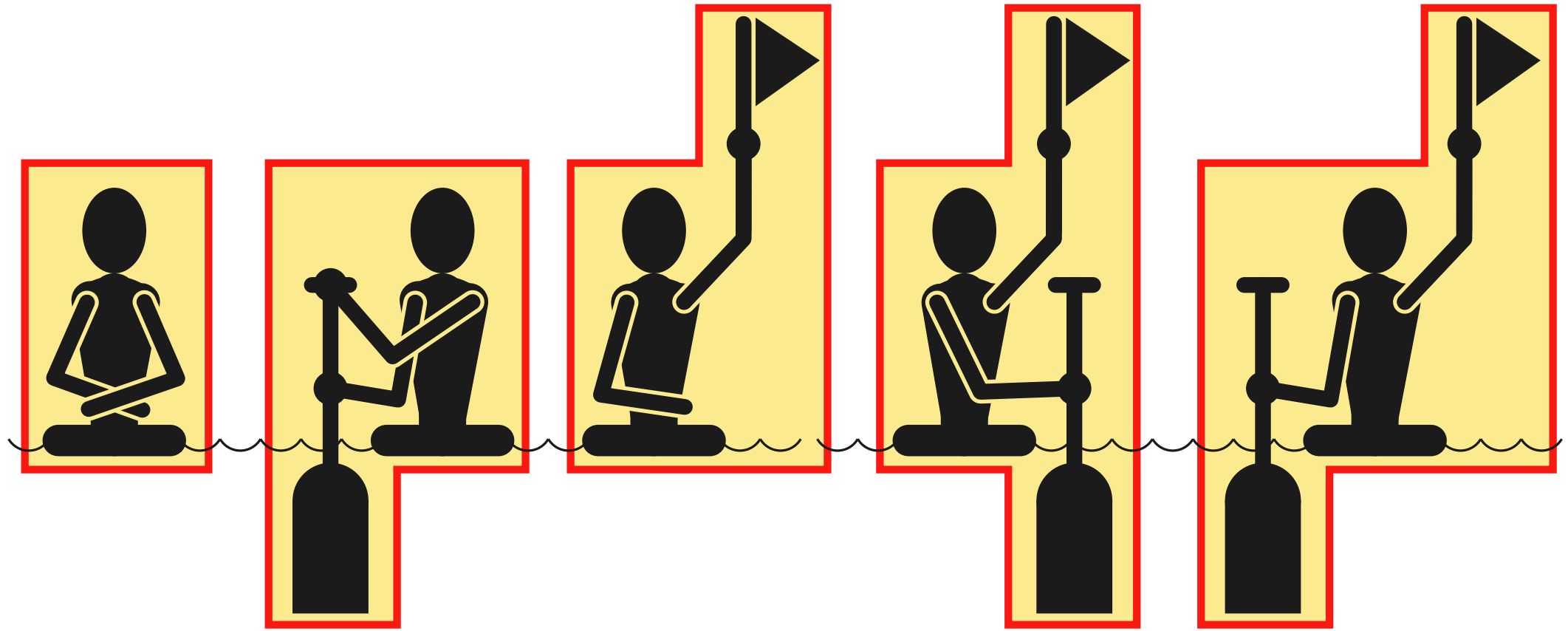
- ✓ **VE**ntral (VE)
- ✓ **DO**rsal (DO)
- ✓ **LA**teral (LA)

****

SYmmetry (SY)

ASymmetry (AS)

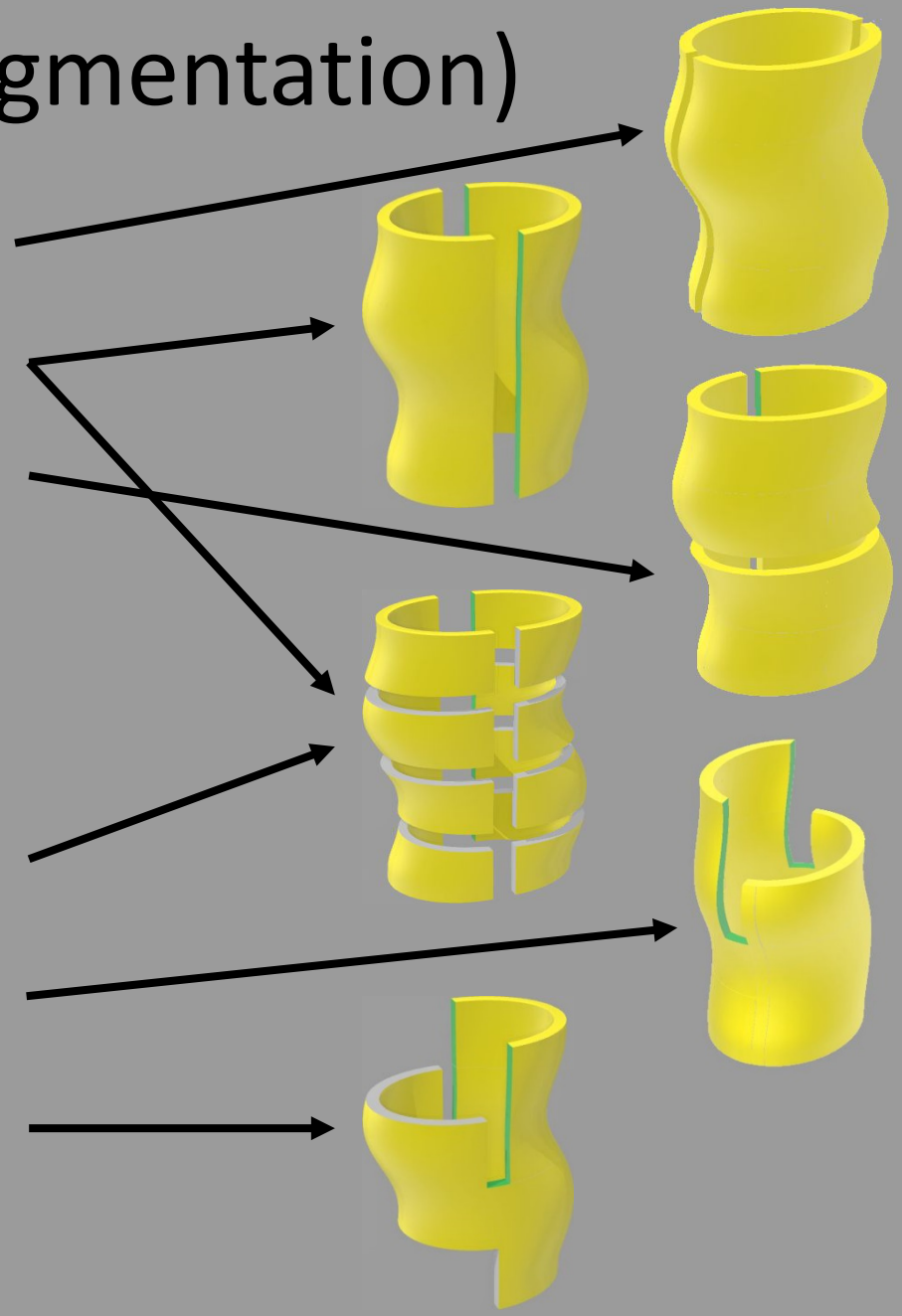
Flag and **Paddle** principles



No **E**longation	**L**ateral **P**addle	**L**ateral **F**lag	**L**ateral **F**lag + **L**ateral **P**addle	**L**ateral **F**lag + **C**ontralateral **P**addle
NE	**LP**	**LF**	**LF+LP**	**LF+CP**

Cut principles (segmentation)

One **F**rontal	(**OF**)
One **S**agittal	(**OS**)
One **T**ransversal	(**OT**)
Multi **F**rontal	(**MF**)
Multi **S**agittal	(**MS**)
Multi **T**ransversal	(**MT**)
Semi **F**rontal	(**SF**)
Semi **S**agittal	(**SS**)
Semi **T**ransversal	(**ST**)

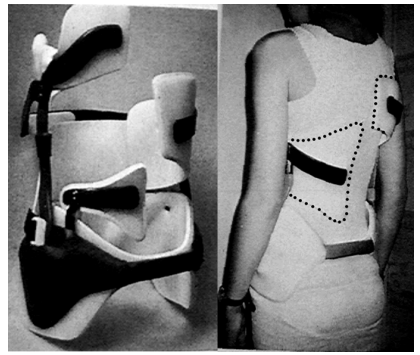


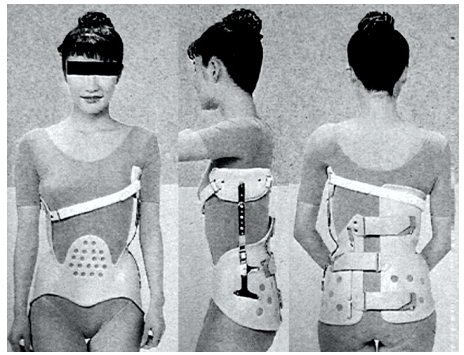
Supplements of construction

No **S**upplements (**NS**)

Rigid **S**plint (**RS**)

Flexible **S**plint (**FS**)





JOint (**JO**)

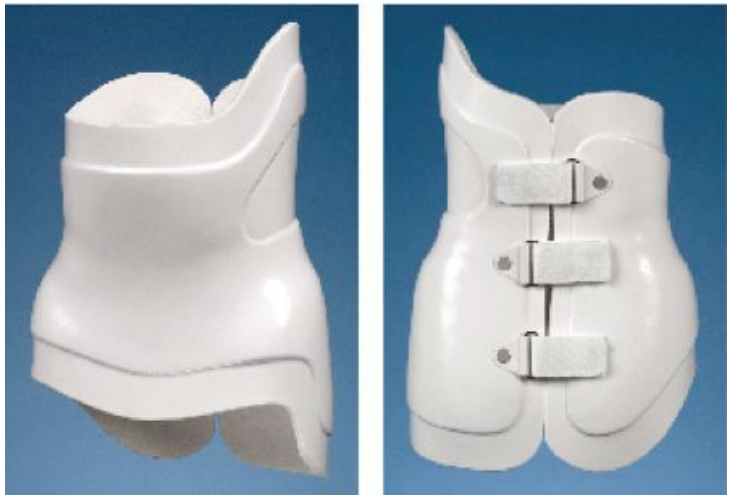
FRame (**FR**)

ELastic (**EL**)

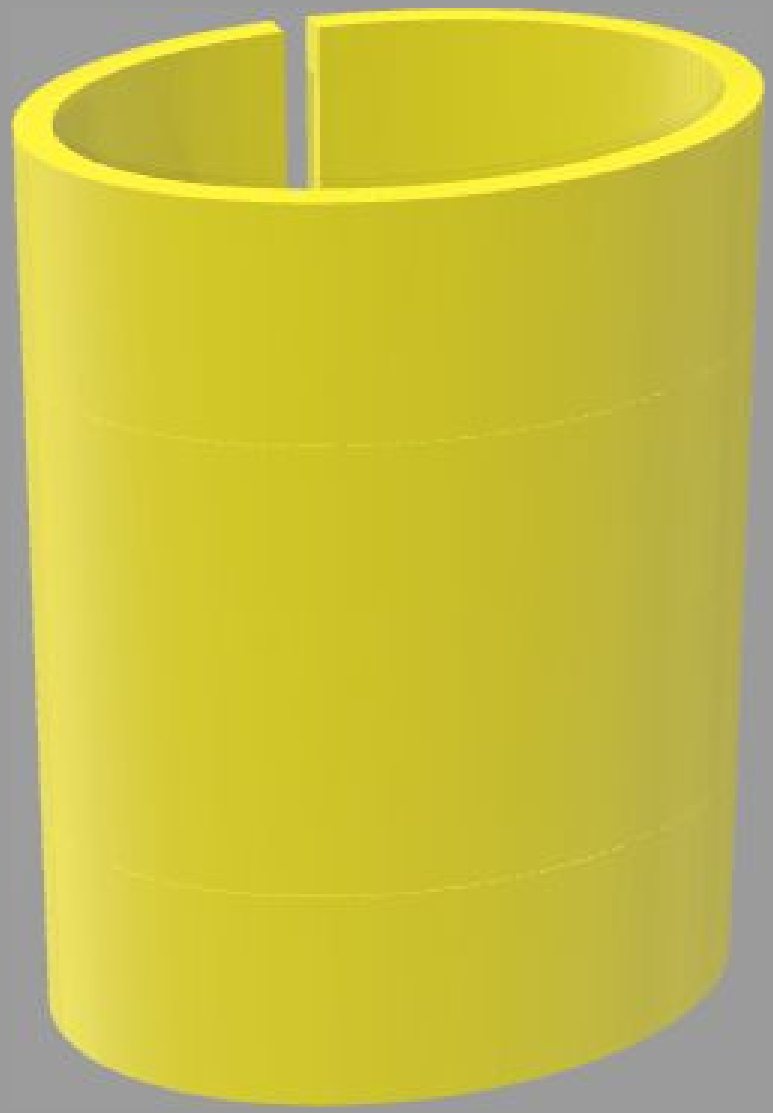
OTher (**OT**)

Opening (closing)

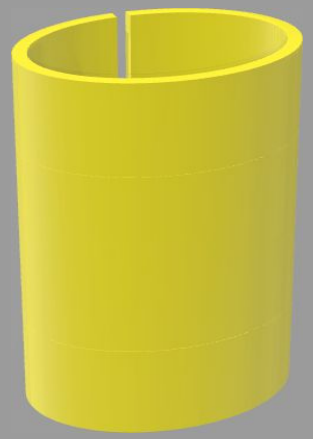
- **VE**ntral (**VE**)
- **DO**rsal (**DO**)
- **LA**teral (**LA**)



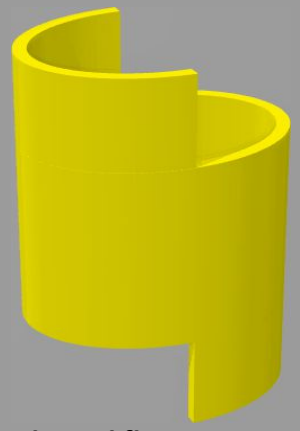
SYmmetry (**SY**) and **AS**ymmetry (**AS**)



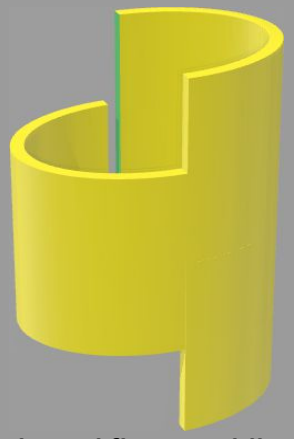
elongation, segmentation, supplements, opening, asymmetry



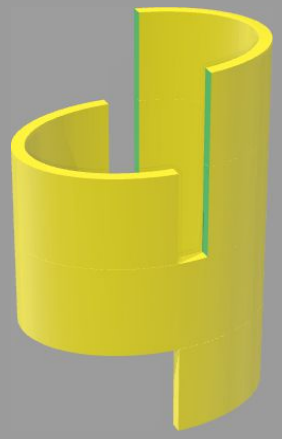
no elongation
no cuts
no supplements
ventral
symmetry



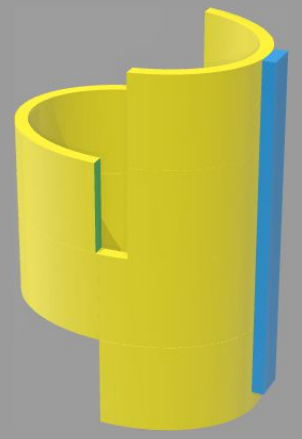
lateral flag + contra paddle
no cut
no supplement
ventral
symmetry



lateral flag + paddle
no cut
no supplement
ventral
symmetry



lateral flag + paddle
semi-sagittal
no supplement
ventral
symmetry

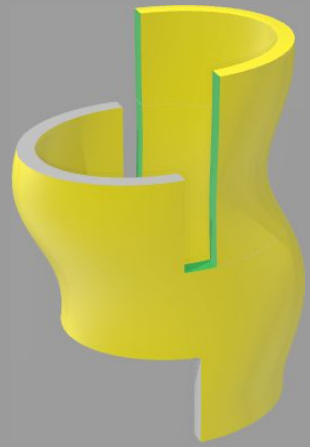


lateral flag + paddle
semi-sagittal
rigid splint
ventral
symmetry

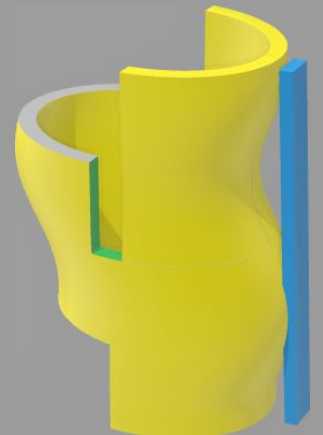
no elongation
no cuts
no supplements
ventral
asymmetry

lateral flag + contra paddle
no cut
no supplement
ventral
asymmetry

lateral flag + paddle
no cut
no supplement
ventral
asymmetry

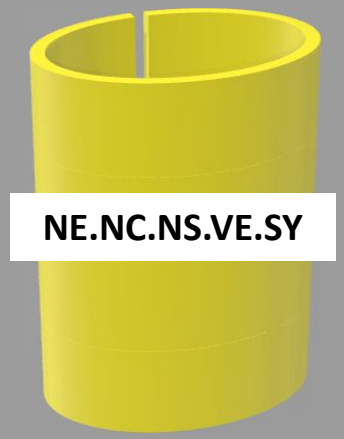


lateral flag + paddle
semi-sagittal
no supplement
ventral
asymmetry



lateral flag + paddle
semi-sagittal
rigid splint
ventral
asymmetry

elongation, segmentation, supplements, opening, asymmetry



NE.NC.NS.VE.SY

no elongation
no cuts
no supplements
ventral
symmetry

LF.NC.NS.VE.SY

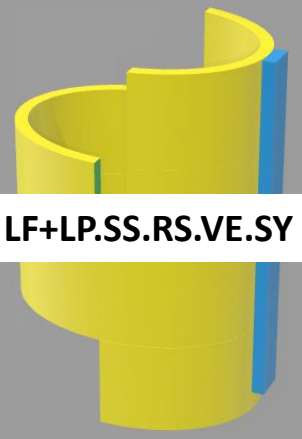
lateral flag + contra paddle
no cut
no supplement
ventral
symmetry

LF+LP.NC.NS.VE.SY

lateral flag + paddle
no cut
no supplement
ventral
symmetry

LF+LP.SS.NS.VE.SY

lateral flag + paddle
semi-sagittal
no supplement
ventral
symmetry



LF+LP.SS.RS.VE.SY

lateral flag + paddle
semi-sagittal
rigid splint
ventral
symmetry

NE.NC.NS.VE.AS

no elongation
no cuts
no supplements
ventral
asymmetry

LF.NC.NS.VE.AS

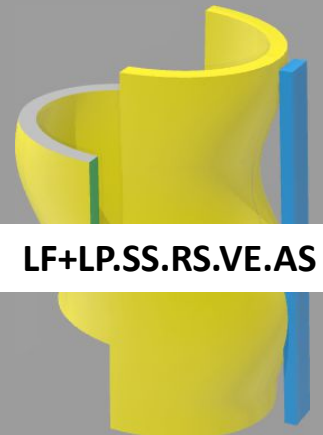
lateral flag + contra paddle
no cut
no supplement
ventral
asymmetry

LF+LP.NC.NS.VE.AS

lateral flag + paddle
no cut
no supplement
ventral
asymmetry

LF+LP.SS.NS.VE.AS

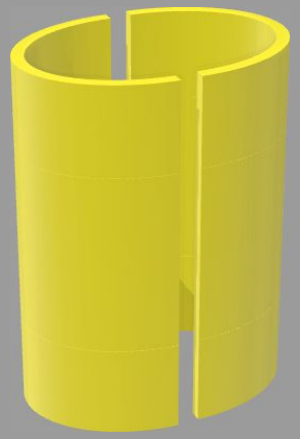
lateral flag + paddle
semi-sagittal
no supplement
ventral
asymmetry



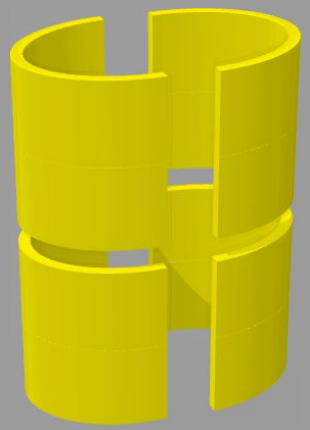
LF+LP.SS.RS.VE.AS

lateral flag + paddle
semi-sagittal
rigid splint
ventral
asymmetry

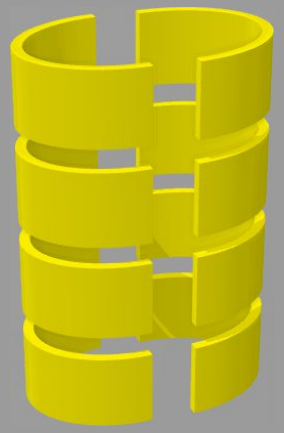
asymmetry, elongation, segmentation, components, opening



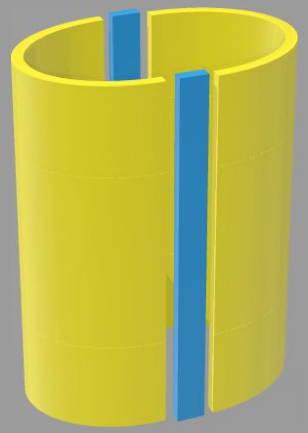
no elongation
one sagittal
no supplements
ventral
symmetry



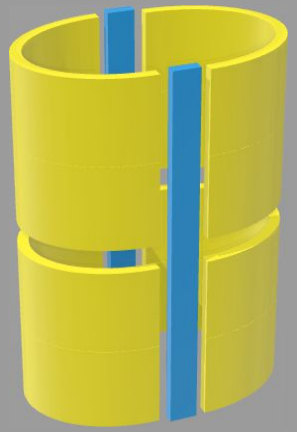
no elongation
one sag. + one trans.
no supplement
ventral
symmetry



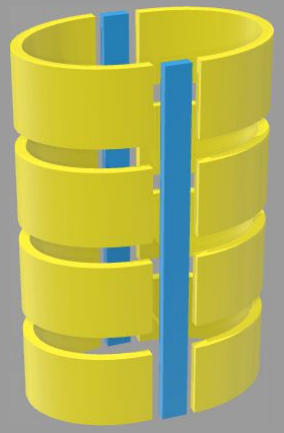
no elongation
one sag. + multi trans.
no supplement
ventral
symmetry



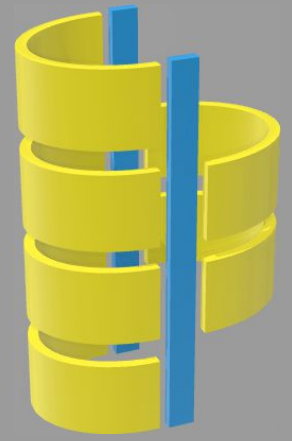
no elongation
one sagittal
rigid splint
ventral
symmetry



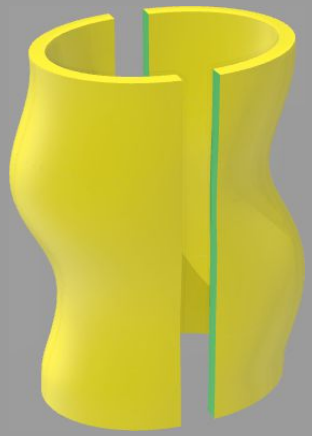
no elongation
one sag. + one trans.
rigid splint
ventral
symmetry



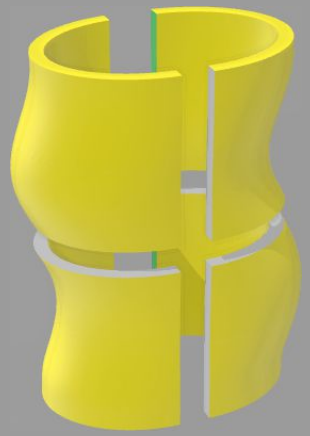
no elongation
one sag. + multi trans.
rigid splint
ventral
symmetry



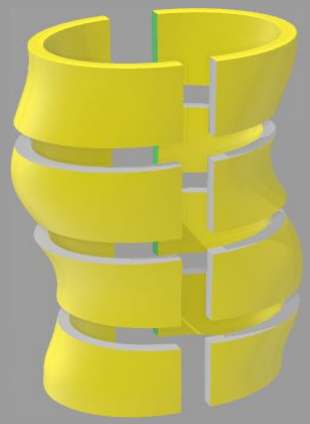
lateral flag + paddle
one sag. + multi trans.
rigid splint
ventral
symmetry



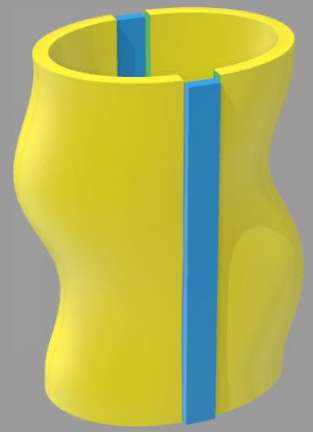
no elongation
one sagittal
no supplements
ventral
asymmetry



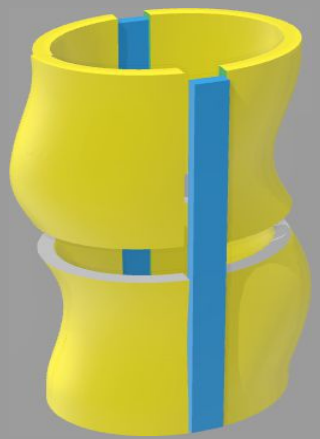
no elongation
one sag. + one trans.
no supplement
ventral
asymmetry



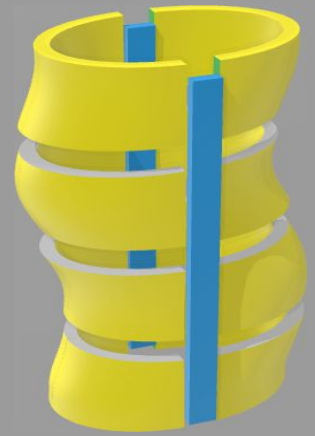
no elongation
one sag. + multi trans.
no supplement
ventral
asymmetry



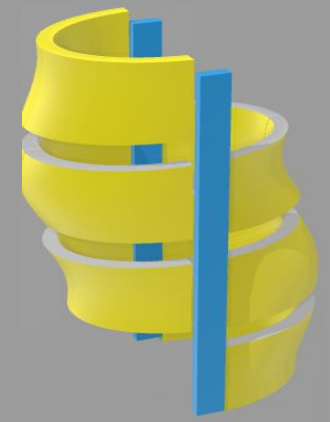
no elongation
one sagittal
rigid splint
ventral
asymmetry



no elongation
one sag. + one trans.
rigid splint
ventral
asymmetry



no elongation
one sag. + multi trans.
rigid splint
ventral
asymmetry

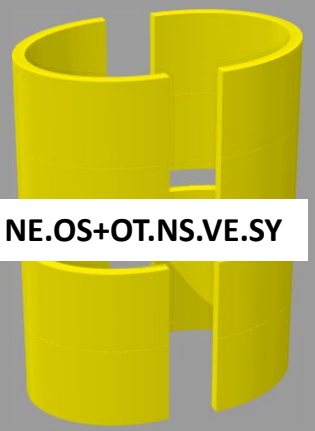


lateral flag + contra paddle
one sag. + multi trans.
rigid splint
ventral
asymmetry

asymmetry, elongation, segmentation, components, opening

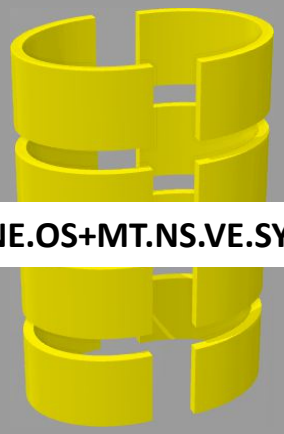
NE.OS.NS.VE.SY

no elongation
one sagittal
no supplements
ventral
symmetry



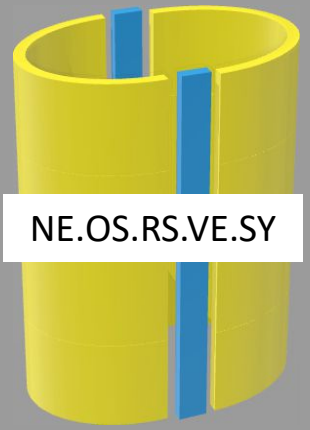
NE.OS+OT.NS.VE.SY

no elongation
one sag. + one trans.
no supplement
ventral
symmetry



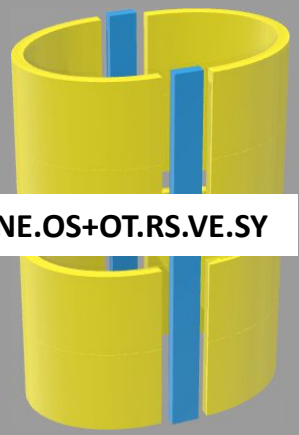
NE.OS+MT.NS.VE.SY

no elongation
one sag. + multi trans.
no supplement
ventral
symmetry



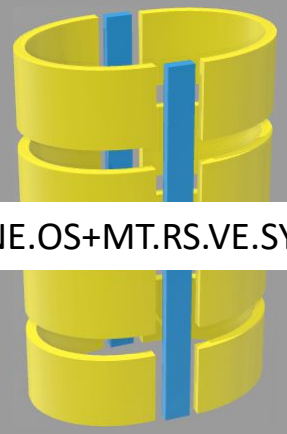
NE.OS.RS.VE.SY

no elongation
one sagittal
rigid splint
ventral
symmetry



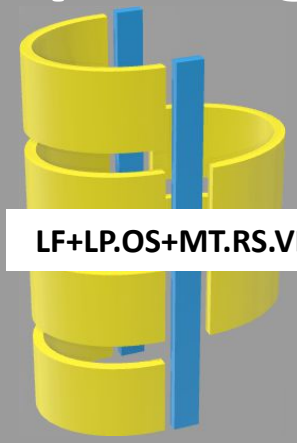
NE.OS+OT.RS.VE.SY

no elongation
one sag. + one trans.
rigid splint
ventral
symmetry



NE.OS+MT.RS.VE.SY

no elongation
one sag. + multi trans.
rigid splint
ventral
symmetry



LF+LP.OS+MT.RS.VE.SY

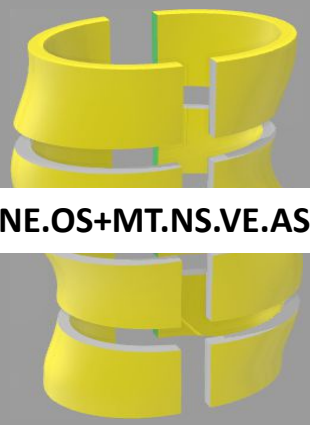
lateral flag + paddle
one sag. + multi trans.
rigid splint
ventral
symmetry

NE.OS.NS.VE.AS

no elongation
one sagittal
no supplements
ventral
asymmetry

NE.OS+OT.NS.VE.AS

no elongation
one sag. + one trans.
no supplement
ventral
asymmetry



NE.OS+MT.NS.VE.AS

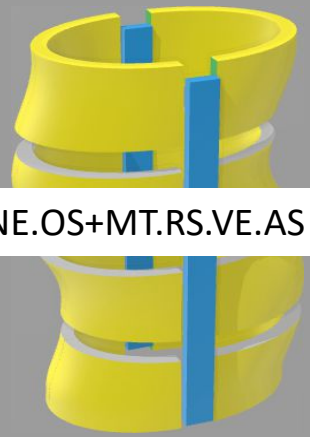
no elongation
one sag. + multi trans.
no supplement
ventral
asymmetry

NE.OS.RS.VE.AS

no elongation
one sagittal
rigid splint
ventral
asymmetry

NE.OS+OT.RS.VE.AS

no elongation
one sag. + one trans.
rigid splint
ventral
asymmetry



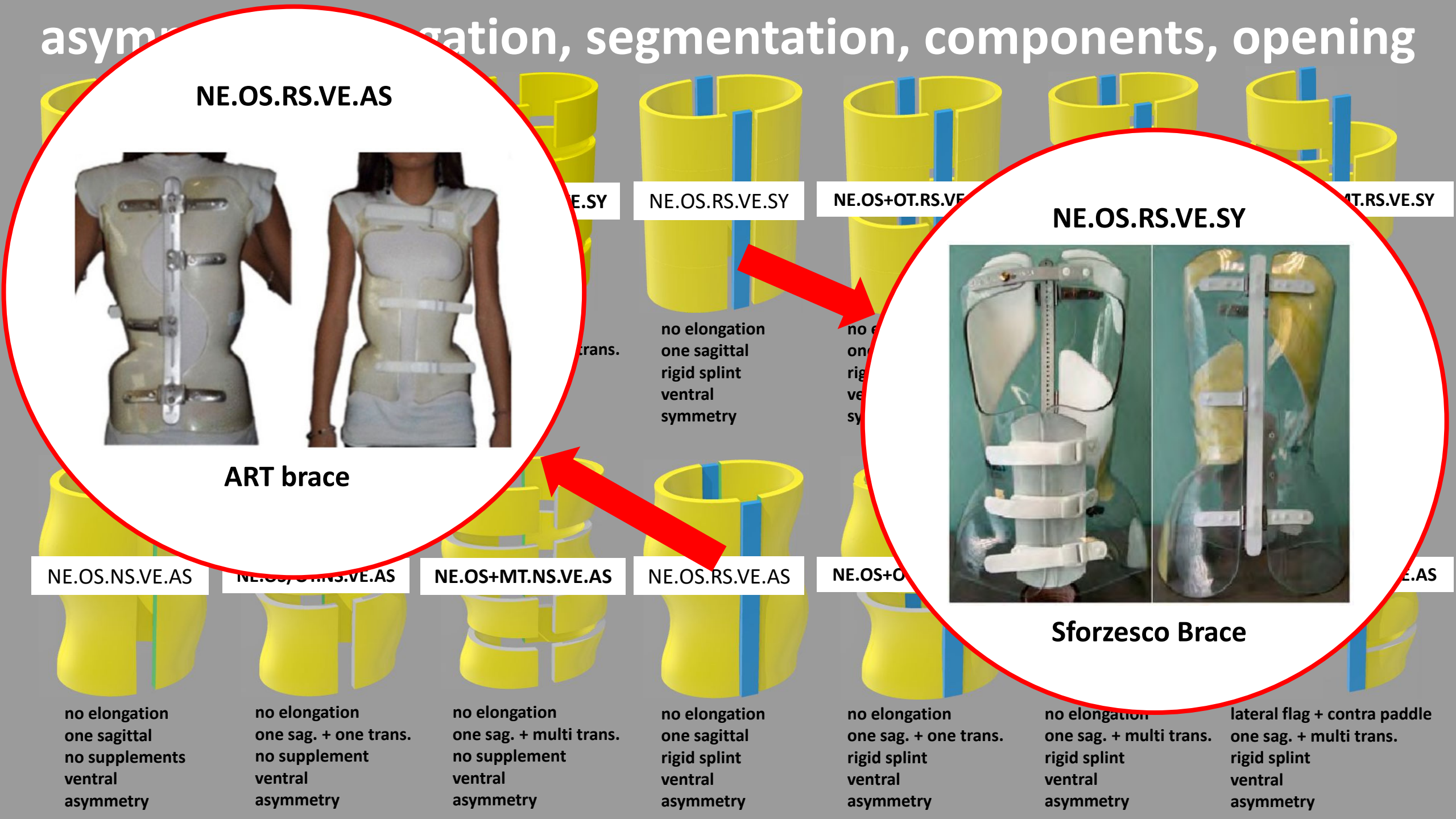
NE.OS+MT.RS.VE.AS

no elongation
one sag. + multi trans.
rigid splint
ventral
asymmetry

LF+CP.OS+MT.RS.VE.AS

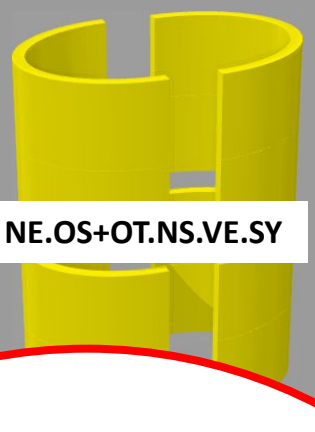
lateral flag + contra paddle
one sag. + multi trans.
rigid splint
ventral
asymmetry

asym gation, segmentation, components, opening

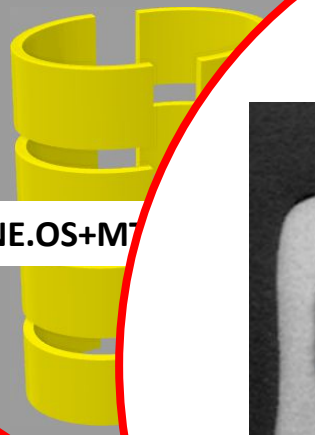


asymmetry, elongation, seg… components, opening

NE.OS.NS.VE.SY



NE.OS+OT.NS.VE.SY

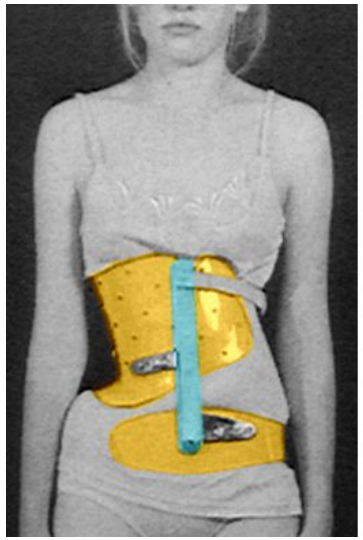


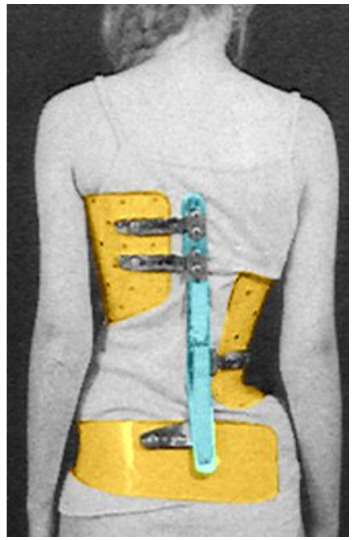
NE.OS+MT

no el…
or…

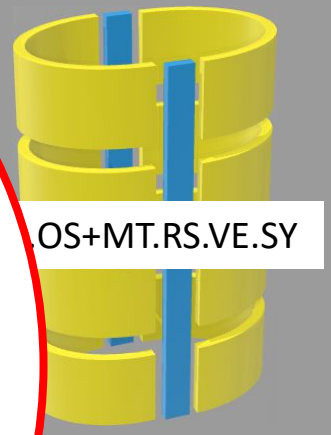
o elong…
sag.
…ple

LF+CP.OS+MT.RS.VE.AS



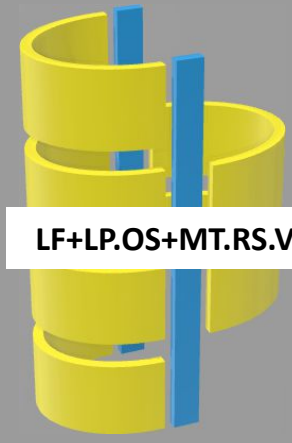


A Trois Valves Brace



OS+MT.RS.VE.SY

o elongation
one sag. + multi trans.
rigid splint
ventral
…mmetry



LF+LP.OS+MT.RS.VE.SY

lateral flag + paddle
one sag. + multi trans.
rigid splint
ventral
symmetry

NE.OS+MT.RS.VE.AS

…VE.AS

…gation
… sag. + multi trans.
…o supplement
ventral
asymmetry

NE.OS.RS.VE.AS

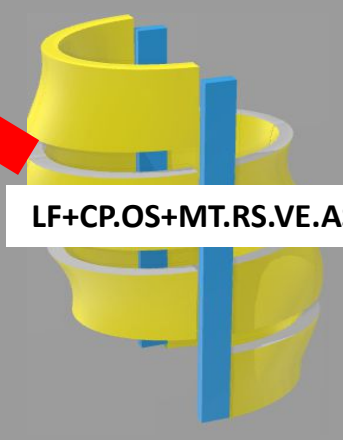
no elongation
one sagittal
rigid splint
ventral
asymmetry

NE.OS+OT.RS.VE.AS

no elongation
one sag. + one trans.
rigid splint
ventral
asymmetry

NE.OS+MT.RS.VE.AS

no elongation
one sag. + multi trans.
rigid splint
ventral
asymmetry



LF+CP.OS+MT.RS.VE.AS

lateral flag + contra paddle
one sag. + multi trans.
rigid splint
ventral
asymmetry

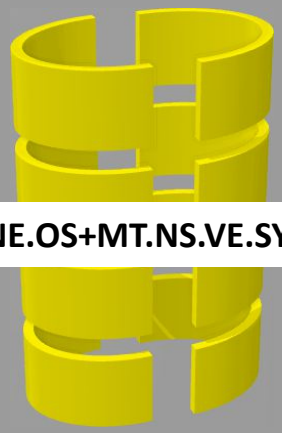
asymmetry, elongation, segmentation, comp…pening

NE.OS.NS.VE.SY

no elongation
one sagittal
no supplements
ventral
symmetry

NE.OS+OT.NS.VE.SY

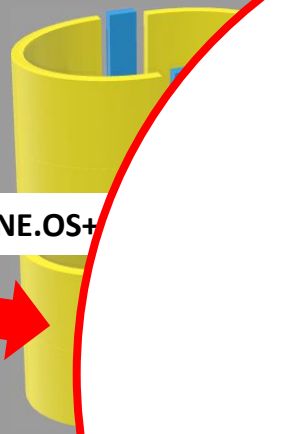
no elongation
…ne sag. + one trans.
…plement
ventra…
symmetry



NE.OS+MT.NS.VE.SY

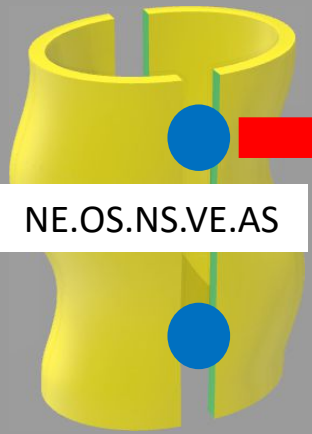
no elongation
one sag. +
no sup…
ver…

NE.OS.RS.VE.SY



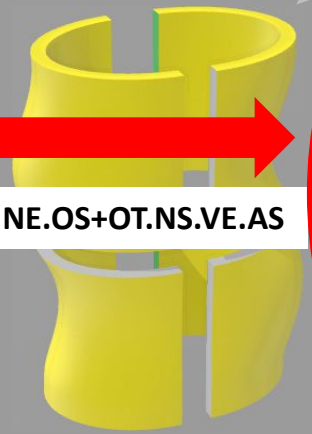
NE.OS+…

no e…
one s…
rigid sp…
…ntral
…metr…



NE.OS.NS.VE.AS

no elongation
one sagittal
no supplements
ventral
asymmetry



NE.OS+OT.NS.VE.AS

no elongation
one sag. + one trans.
no supplement
ventral
asymmetry

…
one…
no supp…
ventral
asymmetry

…S.VE.AS

…longation
…e sag. + one trans.
rigid splint
ventral
asymmetry

NE.OS+MT.RS.VE.AS

no elongation
one sag. + multi trans.
rigid splint
ventral
asymmetry

LF+CP.OS+MT.RS.VE.AS

lateral flag + contra paddle
one sag. + multi trans.
rigid splint
ventral
asymmetry

LP.NC.NS.VE.AS

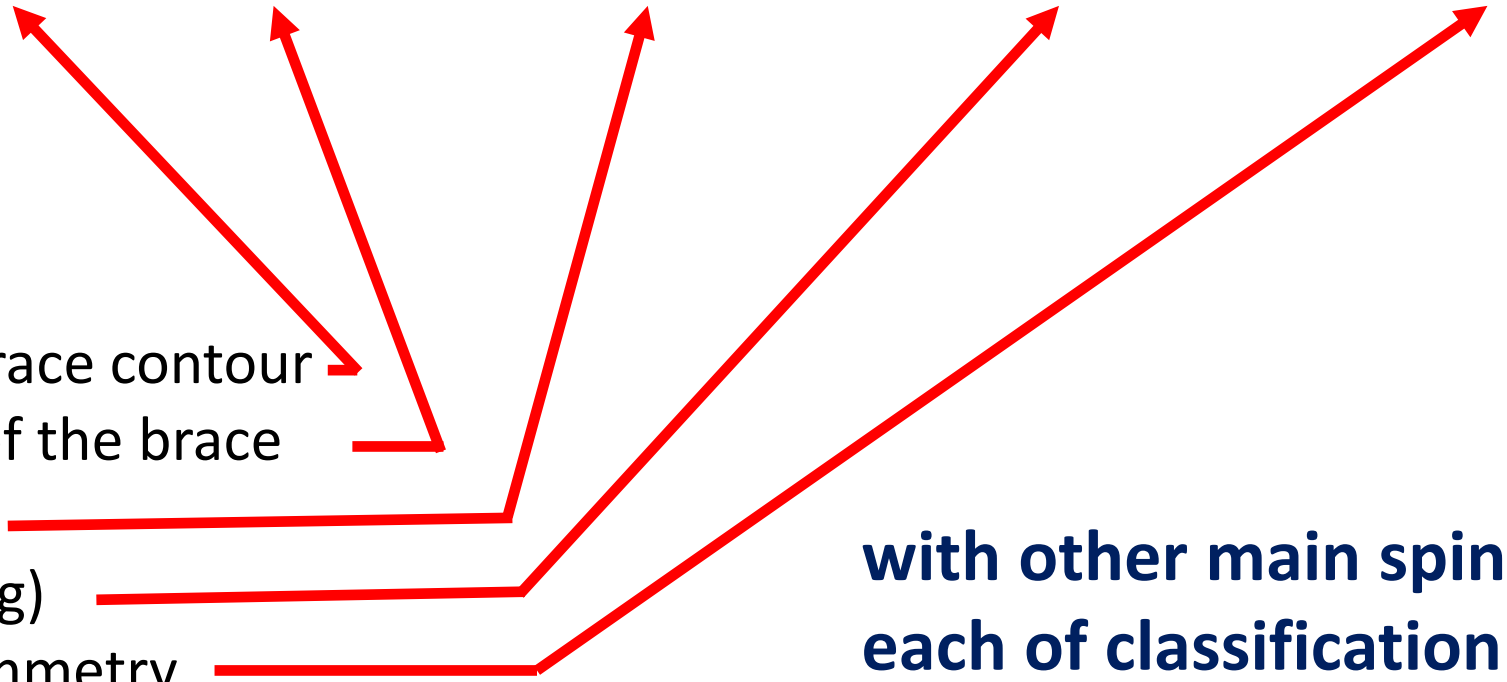
3D printed types

NE.OS+MT.OT.VE.SY

Green SunMedical Brace 2016

Final proposed formula for spinal brace shape classification:

Contour.Cuts.Supplements.Opening.Symmetry



Elongation of brace contour
Segmentation of the brace
Supplements
Opening (closing)
Symmetry/Asymmetry

with other main spinal brace criterion each of classification formula is unique

Example:

NE.MT+OS.RS.VE.AS

Elongation of brace contour
Segmentation of the brace
Supplements
Opening/Closing
Symmetry/Asymmetry

Thanks for your attention