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Braces for conservative idiopathic scoliosis
Ortezele în tratamentul conservativ al scoliozelor idiopatice

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Abstract

Idiopathic scoliosis is the most common form of deviation of the spine. Many articles suggest that these deviations have an unfavorable prognosis in adulthood if left untreated in childhood, altering the quality of life by causing back pain, compromising the pulmonary and heart functions, leading to psychosocial consequences and reducing life expectancy. Non-surgical methods are designed to stop the progression and ideally correct any existing axial deviation. The application of orthoses to this effect pre-dates the era of evidence-based medicine. Numerous studies have been conducted, but they use varied inclusion criteria and objectives, distinct braces and wearing periods and associations with other therapeutic methods. In light of all these factors, the results are often contradictory. The meta-analyses of the last five years have shown that orthotics is the most effective non-surgical therapeutic method and that evidence supports bracing over observation. The current concern is focused on the development of the most efficient type of orthoses and increased compliance.

Keywords: spinal orthoses, evidence, scoliosis.

Rezumat

Scolioza idiopatică este cea mai frecventă formă de deviaţie a coloanei. Multe articole sugerează că aceste devieri netratate la copil prezintă un prognostic nefavorabil la vârsta adultă, modificând calitatea vieţii prin dureri de spate, compromiterea funcţiei pulmonare, cardiace, consecinţe psihosociale şi scăderea duratei de viaţă. Metodele non-chirurgicale au rolul de a opri evoluţia spre progresie şi în mod ideal de a corecta deviaţia axială existentă. Aplicarea ortezelor cu acest scop pre-datează era medicinii bazate pe dovezi. Există numeroase studii, dar cu criterii de includere şi obiective foarte variate, orteze şi perioade de purtare diferite, precum şi asocierea cu alte mijloace terapeutice. Prin prisma acestora rezultatele obţinute sunt frecvent contradictorii. Metaanalizele din ultimele 5 ani au arătat că ortezarea reprezintă cea mai eficientă metodă terapeutică non-chirurgicală şi că evidenţele sunt în favoarea ortezării şi nu doar a urmăririi bolnavului. Preocuparea actuală se focusează asupra dezvoltării tipului de orteză cea mai eficientă şi creşterea complianţei.

Cuvinte cheie: orteze spinale, evidenţe, scolioze.

Introduction

Scoliosis is a three-dimensional spine deformity characterized by the lateral deviation of the vertebrae in the anterior plane (De Smet et al., 1984; Stokes et al., 1987).

The Scoliosis Research Society (SRS) defines idiopathic scoliosis in adolescents as a deviation that exceeds 11 degrees (***, 2000).

Smaller curvatures present a lower risk of progression (Rogala et al., 1978).

In approximately 20% of cases, scoliosis is secondary to a primary pathology, whereas in 80% of cases, it is idiopathic in nature. In general, 10% of these cases require conservative treatment and 0.1-0.3% of them require surgical treatment. Idiopathic scoliosis progression is more common in female adolescents. The male-female ratio is set at 1.3:1 for any Cobb angle between 10 and 20 degrees, 5.4:1 for any angle between 20 and 30 degrees and 7:1 for angles wider than 30 degrees (Negrini et al., 2012).

According to SRS reports, 2-3% of children under 16 years of age present a curvature of 10 degrees or less and only 0.3-0.5% present a curvature of 20 degrees or more. The scoliosis prevalence rate is considered to be 1-3% (Stokes & Luk, 2013).

Ponseti's classification consists of four major types of scoliosis: dorsal scoliosis, lumbar scoliosis, thoracolumbar scoliosis and S-shaped scoliosis. This is the traditional classification, still used for conservative treatment and pre-operative classification purposes (Ponseti & Friedman, 1950).

The primary objectives of the conservative treatment of idiopathic scoliosis can be divided into two groups: morphological objectives and functional ones. The former have an esthetic relevance, whereas the two together

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determine the patient's quality of life and emotional well-being as well as prevent disability.

The objectives of the conservative treatment of idiopathic scoliosis include:

1. the cessation of the curve progression or its reduction;

2. the prevention or treatment of respiratory dysfunction;

3. the prevention or treatment of spinal pain syndromes;

4. the improvement of the aesthetics by correcting the posture.

Two highly effective correction methods set themselves apart from the conservative treatment methods. They are bracing and specific kinetotherapy. Other physiotherapy methods have proved their effectiveness in correcting the functional aspects, but cannot correct or stop the curve progression.

There is debate on the angles that require bracing, as well as on the corresponding types of spinal braces to be used. Specific kinetotherapy is recommended for all types of scoliosis and regardless of the deviation (Fusco et al., 2011; Negrini et al., 2008).

Spinal orthoses are external devices attached to the trunk with the purpose of stopping curve progression and correcting the deviation. Orthoses are made of fabrics and/or elastic bands. Evidence on their efficiency is clear (Negrini et al., 2012; Stokes et al., 2013).

The mechanism of action of orthoses is very complex: they promote neuro-motor reorganization through external and proprioceptive forces. On a biomechanical level, there are three manufacturing principles that must be met simultaneously:

1. *The pressure principle* - the pressure exerted by the brace on the trunk equals the sum of the forces acting on the surface. Therefore, the force acting at the level of the tegument will be indirectly proportional to the area of application.

2. *The equilibrium principle* - the sum of the resulting forces must be zero. In practice, the most frequently applied system is the 3-point pressure system, which occurs when a primary force is applied between two additional forces heading in opposite directions with the sum of all three forces equaling zero.

3. *The lever arm principle* - the distance from the point of application of the pressure force to the joint is directly proportional to the moment arm and indirectly proportional to the force necessary to generate a torsion force at the level of the joint. This principle justifies the use of metal or plastic bars in the manufacture of spinal orthoses. The torsion force increases proportionally to the bar length.

There is still ongoing debate on the recommended bracing time and duration as well as on the recommended brace angulation. According to the SRS, the best results are obtained in situations where the following criteria are met: the patient is at least 10 years of age at the time of bracing, the Risser sign is 0 to 2, the primary angle is 25 to 40 degrees and there is no prior treatment. Additionally, in the case of female patients, the orthotic treatment must be initiated in the premenarchal period or one year after the first menstrual period (Richards et al., 2005).

The opinions formulated by the authors are similar, but also refer to a number of other therapy methods. These indications can be found in the table below (Table I):

Table I

The authors' recommended treatment methods according to Risser sign and Cobb angle.

Risser sign	Cobb angle	Recommended methods
0 or 1	0-20	Observation, kinetotherapy
0 or 1	20 to 40	Corset, kinetotherapy
2 or 3	0 to 30	Observation, kinetotherapy
2 or 3	30 to 40	Corset, kinetotherapy
0 to 3	40 to 50	Corset, kinetotherapy, surgical treatment
0 to 4	≥ 50	Surgical treatment

Treatment guides do not recommend one type of spinal orthosis over another. They recommend the use of a rigid orthosis which has proved its effectiveness and has been used before.

Here are some details on the most common types of spinal orthoses, as well as some manufacturing principles and the obtained results:

1. *The Chêneau brace*

This brace was designed by Dr. Jacques Chêneau sometime around the 60's. The results from a first patient were registered in 1972 and officially presented in Bratislava in 1979. The Chêneau brace is a rigid brace with two main mechanisms of action:

a) *The passive mechanism*: convex to concave tissue transfer (the 3-point pressure system), elongation and unloading, derotation of the thorax, flexion;

b) *The active mechanism*: vertebral growth acting as a corrective factor, asymmetrically guided respiratory movements of the rib-cage, repositioning of the spatial arrangement of the trunk muscles, anti-gravitational effect (Kotwicki & Chêneau, 2008).

In 25% of cases, the treatment ended in a correction of the scoliosis, whereas in 23% of cases, it ended in its stabilization ($p<0.05$). The Chêneau brace is designed not only to stabilize and stop the scoliosis progression, but also to correct the curvature in some cases (Zaborowska-Sapeta et al., 2011).

There are also a number of braces based on the Chêneau brace (Bulthuis et al., 2008; De Mauroy et al., 2011; De Smet et al., 1984):

2. *The Rigo Chêneau brace*

This brace was developed by Rigo Manuel in the early 90's. It uses the concepts of equilibrium/disequilibrium at the point of transition and the counter-inclination at L4/L5 level. The Cobb angle correction of the main curvature is considered to be set at 53.7%. In patients with a single long dorsal curvature, the Cobb angle correction is set at 76.7%, 55.9% in axial rotation cases, respectively. This brace is recommended for patients presenting with mild to moderate juvenile scoliosis (Rigo et al., 2010; Rigo & Gallo, 2009).

3. *The Chêneau Light brace*

This brace was invented by Hans Rudolf Weiss in 2005. The advantage of this new bracing system is that the brace is available immediately and it can be both adjusted and modified very easily. The estimated Cobb angle correction is 16.4 degrees, with the value varying depending on

the anatomical level and the type of scoliosis (Weiss & Werkmann, 2010).

4. *The Gensingen brace*

Developed by the same team, this brace is a derivative of the Chêneau Light one. However, it uses the Computer Aided Design/Computer Aided Manufacturing technology. The Gensingen brace™ is used with curvature patterns a Chêneau light™ brace is not suitable for, as well as for curvatures exceeding 50 degrees (Weiss & Werkmann, 2010).

5. *The Lyonnaise (Lyon) brace*

Created by Pierre Stagna in 1947, this is an adjustable rigid brace with no neck ring. The treatment is based on two principles: an initial rigid cast is meant to stretch the deep ligaments before the application of the Lyon brace. This brace is mainly recommended for patients between 11 and 15 years of age. Its use in younger patients is not recommended for it can cause tubular deformations of the thorax. The Cobb angle correction is considered to be set at 12% in dorsal scoliosis cases and 10% in double scoliosis cases. A simultaneous corrective action on kyphosis has also been noticed (De Mauroy et al., 2011; Zaina et al., 2014).

6. *The Dynamic Derotating Brace (DDB)*

It was described as a modified Boston brace in Greece in 1982. It is recommended for the treatment of high apex curves, where the apex is at D5 level or further at cranial level (Grivas et al., 2010).

Published data indicate an average Cobb angle correction of 49.54% which can decrease to 44.1% after an observation period of 2 years (Zaina et al., 2014).

7. *The TriaC brace*

The TriaC brace was designed by Dr. Albert Gerrit Veldhuizen in the Netherlands. The name derives from the three C's – Comfort, Control and Cosmesis. The TriaC orthosis has a flexible coupling module which connects a thoracic part and a lumbar one. It exerts a transversal force, which consists of a progressive anterior force and a posterior one along with the associated rotation. There is no hip deviation in the sagittal plane, which allows flexibility without affecting the correction forces during movement (Veldhuizen et al., 2002).

An immediate correction of 22% for the primary curve and 35% for the secondary one can be noticed. The results remain unchanged even after a period of 1.6 years (Bulthuis et al., 2008).

8. *The Sforzesco brace*

This brace was developed by Stefano Negrini and his collaborators in Milan, Italy in 2004. It is based on the SPoRT concept - Symmetric, Patient-Oriented, Rigid, Three-Dimensional, Active. The Sforzesco brace combines characteristics of the Risser cast and the Lyon, Chêneau-Sibilla and Milwaukee braces. Its main action is to push the scoliosis upward from the pelvis, so as to deflex, derotate and restore the sagittal plane. Reported results show a level of effectiveness superior to that of the Lyon brace after a treatment period of 6 months (Negrini et al., 2006; Negrini & Marchini, 2007).

9. *The Progressive Action Short Brace (PASB)*

The Progressive Action Short Brace (PASB) has been used for the treatment of thoracolumbar and lumbar idiopathic curves. It is an original custom-made thoracolumbar-sacral orthosis (TLSO) designed by Dr. Lorenzo Aulisa in Italy. The device works based on the principle that a constrained spine dynamics can achieve correction of a curve by inverting the abnormal load distribution during growth. The forces exerted to correct the deformity include elongation, lateral flexion and derotation. In a transversal plane, these forces form an asymmetric ellipse. Overall, curve correction was achieved in up to 94% of patients, whereas curve stabilization was achieved in 6% of cases (Aulisa et al., 2009; Zaina et al., 2014).

10. *The Boston brace*

This brace is the most commonly used for the treatment of thoracolumbar scoliosis in North America. It was developed by John Hall and William Miller at Boston Children's Hospital in 1972. Miller and Hall tried to shorten the manufacturing process by developing a personalized mold model and six prefabricated models based on the cast device previously fitted for the Milwaukee braces. The manufacturing costs and time were reduced significantly. The Boston brace is symmetrical and features a posterior opening which incorporates the apex supports passively loading the curves. An opening is cut out in the thoracic support to allow the active transfer/exchange of the trunk and improve ventilation. Similarly to the Milwaukee brace, the Boston brace initially determined the correction of lumbar lordosis, which, in theory, allowed an improved correction of the pathological curve. Braces usually correct lumbar lordosis by 15 degrees with the purpose of lowering the risk of hypokyphosis. At the present moment, most braces are ordered following the body scan and CAD-CAM (Computer Aided Design/Computer Aided Manufacturing). Results: in 49% of cases, no curve modifications were registered; in 43% of cases, an improvement could be noticed; in 11% of cases, surgery was performed during that period of time with 1% of these patients undergoing surgery during the clinical observation period (Zaina et al., 2014; Emans, 1984).

11. *The Charleston brace*

Made by Frederick Reed and Ralph Hooper in Charleston, South Carolina in 1972, it was developed for patients who refused to wear a brace full-time. It is based on the principle derived from the Heuter-Vokmann one, where asymmetrical vertebral loading can affect bone growth. The orthosis is symmetrical and has an anterior opening as well as selective points of contact, allowing better correction than the other thoraco-lumbar-sacral orthoses. It is the best choice in cases of pathological lumbar, thoracic or thoracolumbar scoliosis. Studies have demonstrated that this orthosis can stabilize or improve scoliosis progression in 84% of cases (Lee et al., 2012).

12. *The Milwaukee brace*

Developed by Walter Blount and Albert Schmidt in Milwaukee, Wisconsin around 1945, it was initially used for the postoperative immobilization of neuro-muscular scoliosis. On account of the transformations in fashion trends and the psychological and emotional impact of wearing a large cervical thoracolumbar CTLSO, this brace has limited or overdue prescriptions. It is still used for the treatment of Scheuermann kyphosis and large pathological

thoracic curves. It is a symmetrical device with a posterior opening and enables curve correction through both passive and active mechanisms. Thoracic or axillary belts correct the curve passively and directly while the molds/supports at neck level or the lateral ones correct it actively. This active method of muscle correction has proved ineffective in scoliosis patients, but effective in kyphosis ones. Initially, the support/corset was made of leather, but the material was then replaced with thermoplastic ones resistant to high and low temperatures and easier and cheaper to process (cost-benefit ratio). According to Lonstein and Winter, 22% of a group of 1,020 patients whose treatment included these braces underwent surgery, this rate being higher in the case of patients with curvatures exceeding 30 degrees and a Risser sign of 0 or 1. The main problems with this type of orthosis lie in its compliance and low acceptability, the two justifying its limited use at night (Zaina et al., 2014; Lonstein & Winter, 1994; Maruyama et al., 2008).

Other braces are mainly used in North America, but the results of studies are inconstant or unclear. These braces include the Providence brace, the SpineCor brace and the Wilmington brace (Zaina et al., 2014).

The efficiency and monitoring of bracing in scoliosis patients

Evidence on bracing and kinetotherapy for conservative scoliosis treatment is clear. Randomized prospective studies, inclusion and efficiency criteria and monitoring methods raise various difficulties in conducting studies. There is insufficient data to perform a comparison between braces. The SRS recommends the use of that brace that has delivered the best results. Current data does not recommend the use of flexible braces made exclusively of fabrics for the treatment of scoliosis (Zaina et al., 2014).

Compliance to the orthotic treatment is usually low. It has been noticed that there is an almost linear connection between the therapeutic success of a brace and the amount of time it is worn for over a period of 24 hours. The best results were associated with patients who wore the brace for over 17.6 hours out of 24 (Weinstein et al., 2013).

The wearing period can be monitored by recording the infrared radiation using a sensor installed directly on the corset. This temperature sensor records the temperature values close to the patient's body temperature. Whenever these values are lower, it does not record anything. The recorded data is then downloaded using a software reader (Zaina et al., 2014).

Conclusions

1. Braces reduce the need for surgery as well as the aesthetic impact of the deformity in patients suffering from idiopathic scoliosis.

2. There are studies revealing the efficiency of braces in stopping curve progression and correcting deviations.

3. Bracing is only used for scoliosis treatment in cases where the curvature exceeds 15±5 degrees or progressive factors can be identified.

4. It is recommended that the scoliosis treatment uses the corset the team is most experienced with.

5. The brace should be worn for a minimum 17-18 hours daily. It has been noticed that there is an almost linear connection between the therapeutic success of a brace and the wearing period.

6. Orthotic treatment is recommended until skeletal maturity or cessation of the curve progression is achieved. Individual experience is also relevant.

7. The wearing period is to be reduced gradually.

8. The efficiency of the corset is monitored objectively through instant infrared imaging.

9. The bracing method does not replace specific kinetotherapy. It complements it. Kinetotherapy programs may or may not include bracing.

Conflicts of interest

Nothing to declare.

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