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# BRACING IN ADOLESCENT IDIOPATHIC SCOLIOSIS

## *ADÖLESAN İDİOPATİK SKOLYOZDA KORSE TEDAVİSİ*

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**SUMMARY:**

Disagreements still continue among healthcare professionals concerning the effect and long-term problems of bracing, one of the non-operative treatments of scoliosis. The differences in the results of studies on the effect of bracing in the literature, unclear procedures of administration and the quality of such studies weakened the confidence in bracing. Moreover, the difficulty of identifying those who are suitable for bracing, the effects of various bracing concepts and the problems concerning the experience and administration skills of the implementers are also influencing factors in practice. The associations of surgical and conservative treatment groups are trying to construct a common algorithm to eliminate the confusion in this matter.

The common conclusion of the evidence-based, randomized controlled studies on the effect of bracing that have been published in recent years is that bracing is successful in adolescents, preferably Risser 2 and under, who are still in the process of maturation and whose spine has a curvature of 25-45°. They also stress the importance of high level of compliance and full-time use of braces for success. Using braces of a correct biomechanical design until the completion of maturation under the common surveillance of a physician and a technician can prevent curve progression and reduce the rate of surgery in scoliotic individuals.

It should also be taken into consideration that bracing can promise a stable and moving spine with no need for fusion even for some children and that it will contribute to well-being by reducing surgical costs and the rate of morbidity.

Key words: Adolescent idiopathic scoliosis, brace

**Level of evidence:** Review article, Level V

**ÖZET:**

Skolyozun nonoperatif tedavilerinden olan korsenin etkisi ve uzun dönemde ortaya çıkan sorunlara ilişkin sağlık profesyonelleri arasındaki fikir ayrılığı halen devam etmektedir. Literatürde korsenin etkisine ilişkin çalışmaların sonuçlarındaki farklılıklar, uygulama prosedürlerinin net olmaması ve araştırmaların kalitesi ise korseye olan inancı olumsuz etkilemiştir. Ayrıca korse için uygun olguların belirlenmesindeki zorluk yanında farklı korse konseptlerinin etkisi, uygulayıcıların deneyim ve uygulama becerisindeki sorunlar da pratikte etkilidir. Cerrahi ve konservatif tedavi gruplarının kuruluşları da bu konudaki karmaşayı ortadan kaldırmak adına ortak bir algoritma oluşturmaya çalışmaktadır.

Son yıllarda yayınlanan korse etkisi ile ilgili kanıt düzeyi yüksek randomize kontrollü çalışmaların ortak çıkarımı korsenin 25-45° eğrilikte, maturitesi devam eden, tercihen Risser 2 ve altındaki adölosanlarda başarılı olduğudur. Başarı için ayrıca kompliansı yüksek adölosanlar ve tam zamanlı korse kullanımının önemi de vurgulanmaktadır.

Doğru biyomekanik tasarımı olan, hekim ve teknikerin birlikte takip ettiği korsenin maturasyon tamamlanmasına dek kullanılması skolyotik bireyde eğrilik progresyonunu engeller ve cerrahi oranı azaltır. Korsenin, bir kısım çocuğa bile stabil ve hareketli, füzyon gerekmeyen bir omurga vadetmesi yanında cerrahi maliyet ve morbidite yönü ile de sağlayacağı katkı da unutulmamalıdır.

**Anahtar kelimeler:** Adölosan idiyopatik skolyoz, korse

**Kanıt düzeyi:** Derleme, Düzey V

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## INTRODUCTION:

Scoliosis is defined as a three dimensional spine deformity involving an axial rotation together with a lateral deviation in the vertebrae, but its etiology has not been clarified yet with 70-80 % of the cases identified as idiopathic scoliosis[30,42,56]. Idiopathic scoliosis is seen more in female and male adolescents aged 10-14 in their pubertal periods and curvatures of more than 20° occurring in girls at a rate of 1/5 are of more progressive nature[37,56].

According to the data of the National Scoliosis Foundation, an estimated 7 million people in United States, the reason for 600000 doctor visits in the USA is scoliosis and 30000 children are using braces and 38000 spinal fusion surgeries are being performed[20]. In adolescent children, scoliosis-related surgery takes the second place after appendicitis-related surgery and its annual cost is around 518 million dollars[57]. Considering the age group it affects, scoliosis is an important public health issue leading to various health, cosmetic, social and psychological problems associated with the deformity that occurs[60].

The purpose of operative and non-operative treatments in scoliosis is a pain-free and stable spine, a positive perception of the body and an active and high-quality life without any cosmetic worries. The prophylactic and non-operative treatments involve observation, bracing and exercising depending of the age of the adolescent and the angle of the scoliosis. The common opinion of the professionals working in both surgical and conservative treatment fields is that bracing should be used for girls with continuing maturation and preferably at their menarche and for children of Risser 0-2[20,37,47].

Success in treatment depends not only on bracing criteria but also on applying a pattern specific brace designed in line with the site and angle of the scoliosis to the patient following correct biomechanical rules for an adequate period of time. The brace should be worn for 20-22 hours daily especially in the period when growth is fast[37,47]. The bracing treatment should be continued until the maturity of the skeleton completes. When braces are being used, patients should be monitored by a physician specialized in this field, a physiotherapist and an experienced orthesis technician to make the necessary adjustments in time.

The generally accepted braces in scoliosis treatment are rigid thoraco-lumbo-sacral ortheses (TLSO) and very different bracing concepts are used today depending on the country in question. The purpose of bracing treatment is to prevent curve progression and to reduce the rate of surgery.

One of the hypotheses concerning the effect of bracing is that it provides mechanical support to the body as a passive delimiter as well as corrects the curvature by removing the body from the pressure area caused by the forces applied in the brace, thereby making an active component effect[15]. According to another hypothesis, braces enable neuromotor reorganization through their external corrective effect, delimiting movements and proprioceptive input[15]. The final goal is to modify the pathological spinal curve or to stop curve progression by means of the traction or external corrective forces applied in the brace.

There are still differing views on the efficacy of bracing treatment and the results of the studies on the issue are questionable[20,57]. The results of recent randomized controlled studies, however, have evidenced that braces prevent curve progression and reduce the rate of surgery when correct bracing protocols are followed[57].

The purpose of this review is to go through bracing algorithms, bracing-related problems of parents and patients and the results of studies on the efficacy of bracing to establish a common approach among the professionals.

## HISTORY OF BRACING:

A historical search shows that the longitudinal traction method was first used by Hippocrates in the 5th Century B.C. Galen, one of the students of Hippocrates, incorporated application of direct pressure to the brace with traction in the 2nd Century. The first really supporting brace was developed and used by Ambrose Paré (1510-1590). Towards the end of 1800s, Lewis Albert Sayre, the first orthopedic surgery professor in America, used the spinal traction method with a plastic brace to control spinal deformities[11, 22].

Utilization of XR in radiology around 1895 and achieving good quality spinal radiographies towards 1830s accelerated studies in this field. Hibbs, who introduced his surgical technique in 1910 with the first spinal fusion operation on a patient who developed gibbus due to tuberculosis, used it in scoliosis surgery in 1914[11]. He continued to implement the traction and bracing techniques he used for these patients preoperatively in the postoperative period to achieve fusion and to immobilize the spine.

In the beginning of the 20th Century, Lovett and Brewster used a full-time "turnbuckle" cast in scoliotic deformity. Risser modified this with a lighter and more functional model that better served the need of the patient. He also contributed to the identification of patients suitable for bracing with the classification known by his name, the Risser classification. Coming to 1950s, Ponseti and Friedman from Iowa University prepared surgical and non-operative guidelines for patients with adolescent idiopathic scoliosis (AIS). In this period when the natural course of idiopathic scoliosis and the risk factors for progression were better specified, surgeons came to know bracing treatment better and use it more often[11].

In 1946, Walter Blount used the first cervico-thoraco-lumbo-sacral-orthosis (CTLSO) for scoliosis, also known as the Milwaukee brace for postoperative immobilization following a scoliotic surgery. This brace was then started to be used for non-operative treatment of AIS[11,58]. Its pelvic part is custom made out of leather, its cervical part and anterior bar out of aluminum and its posterior bar out of rigid metal and pressure is created with the pads used in this brace (added pressure parts) (Fig.-1.a).

The Milwaukee orthosis was successful for thoracic and double-curve deformities. In its conventional model, the pelvic part of the brace was produced from prefabricated vitroten or polypropylene material. The cervical support in its original model was later modified due to the problems it caused in the tooth structure. After having been used in AIS for many years, this brace was abandoned in time for causing a decrease in lumbar lordosis of the users, having more passive effect and creating compliance problems in patients. Later, low-profile brace models made of lighter materials were developed, which had similar effect in controlling curve progression[11,27].

In 1969, Mac Ewen and associates from the Alfred Du Pond Institute developed the low-profile TLSO, which is known as the Wilmington brace and is still very popular today. For the production of this brace, which requires specific equipment and experience, measurements are taken using traction on a bed called the Risser Frame in supine position and a positive model is constructed from thermoplastic material. Still being used, this brace model is not recommended for high thoracic and rigid curves[11,27,48].

Modeling of braces showed changes in time in both Europe and the USA. The goal was to achieve a result that was effective and acceptable to the patient and that was able to exert pressure to the spine in three planes. The symmetrical Boston and Wilmington braces and the overcorrection-based Providence and Charleston Bending braces, which are intended for night use only, are used more widely in the USA today. The bracing technologies in Europe provide a wide spectrum of braces ranging from full-time symmetrical low-profile TLSO models such as Lyon, Sforsezco and Sibilla to asymmetrical models targeting more hypercorrection such as Cheneau, Rigo-System Cheneau and Genginsen. Braces that are custom produced using the Computer Aid Design Computer Aid Manufacture (CaDCaM) technology are used more widely[14]. The latest novelty in braces involves the manufacturing techniques using the 3D printer technology, which are visually more cosmetic, rendering more effective results, produced in a shorter time and less costly.

## BOSTON BRACE:

John Hall and orthotist William Miller from Boston Children's Hospital designed a low-profile TLSO in 1972. This brace, known as the Boston brace, is still one of the most widely used scoliosis braces. The major difference of this brace compared to the Wilmington brace that had been used until then is that it was not custom molded but prefabricated in different sizes that could be modified to suit the patient's deformity. Towards 1990s, the Boston group made some modifications in the brace in line with their experiences in order to achieve a better derotation of the spine and remodeled it for a variety of curves. The Boston brace allows standard symmetric model, lumbar and pelvic flexion and enables active and passive curve correction. While the apical pads used in the brace apply passive correction forces on the convex side, the open areas on the concave side allow active reduction[9-11] (Fig.-1.b).

It has been shown in studies that with its well-tolerated, standardized, low-profile features, the Boston brace, can produce, when used full-time, satisfactory results similar to those of the Wilmington brace in scoliotic individuals.

## CHARLESTON AND PROVIDENCE NIGHT BRACE:

Designed to keep the scoliotic curve under control and to increase compliance with the use of brace, the Charleston bending brace is meant to be used 8-10 hours at night. This affects the adolescent self-image positively, increases compliance and prevents conflicts associated with the use of brace between the family and the child. In an overcorrection position, the brace theoretically stretches soft tissues and reduces the load on the vertebral endplate on the concave side of the curve[19]. Unlike classical TLSO, the reduction forces in the brace, which is made of rigid plastic, are applied as sidebending (Fig.-1.c).

Another night brace is the Providence brace. Alongside overcorrection, derotational and lateral forces are employed in the design of this brace to bring the curve to midline.

Both of these braces are more successful in flexible, single thoracolumbal and lumbal curves. In their study where they compared these braces to the Boston brace, Katz et al. reported that results similar to those of full-time Boston braces could be obtained with the night braces in curves up to 35° and particularly in single curves[19,23].

## SPINECOR BRACE:

Developed by Charles Rivard and Christine Coillard in Montreal Saint-Justine hospital, the SpineCor brace is a dynamic non-rigid brace that was put into use after 1998. It is based on the hypothesis that the postural disorganization, muscular dysfunction and unsynchronized spinal growth that occur in scoliosis can be prevented with the controlled movements in the brace. The brace consists of a thermoplastic pelvic base, a cotton bolero and four corrective elastic bands in varying sizes (Fig.-1.d).

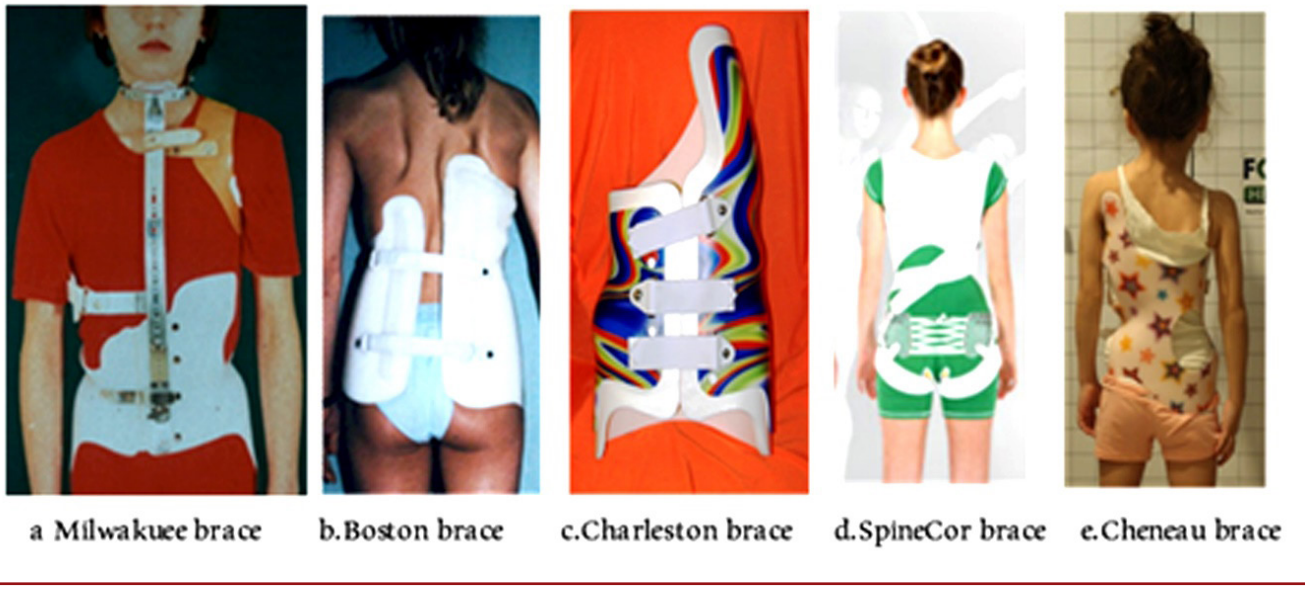


**Figure-1.** Scoliosis Brace models.

The bands are placed and stretched according to an algorithm taught to the clinician depending on the place of the curve. The non-rigid positioning of the brace under clothing is preferable for patients. It is recommended to use this brace full-time and until the skeletal maturity is completed as in other braces. The best results are reportedly obtained especially in small, single, structural thoracolumbal and lumbal curvatures[46]. However, determining the corrective movements, sufficient experience and problems arising from the user are important matters to be kept in mind. A retrospective study made by Gutman and associates indicates increased curve progression and risk of surgery in children using the SpineCor braces[16].

## CHENEAU AND CHENEAU DERIVED BRACES:

The thermoplastic Cheneau brace was developed by Dr. Jacques Cheneau and was given the name Cheneau-Toulouse-Munster Brace. The corrective principles in the brace are explained by both passive and active corrective mechanisms. Accordingly, the corrective effect on the scoliotic curve is described as transfer of tissues from the convex side to the concave side through passive correction and a three dimensional control through maximum correction of the curve. Removal of the load on the elongations and vertebras and derotation of the thorax are also possible. The active mechanisms include asymmetrical support with the effect of respiratory movements, repositioning of trunk muscles to restore physiological position and antigravity effect[25,58]. The correction pads in this brace, which is opened from the front, are not placed in symmetrical plastic cylinders as in the Boston brace and some other braces but are designed directly into a positive cast model. The first patient results of the brace were disclosed in 1972 and presented in Bratislava in 1979. The skill of the technician is very important in this brace that requires a three dimensional modeling depending on the site and degree of the curve based on the mold taken from the patient.

Apart from modeling, there have been developments also in the design and manufacturing of the scoliosis braces in line with recent advances in technology. High quality Cheneau model derivate braces of different types were developed using the CaD CaM modeling and the expert-based brace library.

The best known Cheneau derivative models are the Ortholution Rigo system Cheneau, Gensingen brace, Regnier Gmbh and Sanomed Orthopaedie models, which are widely used in European countries (Fig.-1.e). Their use is increasing also in America, Japan and Far East.

The results of many studies made with Cheneau brace models indicate that the brace is quite effective in controlling scoliotic curves. The studies on this subject are explained in more detail further on under the heading Brace Results and Brace-Related Studies.

The basic biomechanical rule in scoliosis braces is to normalize the deformed spine with overcorrective external forces applied through using the brace and to take control over the deviation. In a well-designed brace, the forces in the coronal, sagittal and transverse planes are generally controlled simultaneously. The iliac cristae are the contact points used to position the lumbar spine whereas the costae and sterna are good control points for thoracic spinal deformities. The flexible spine is brought under control with the moment effect that is based on the three-point principle in the coronal plane. The lateral forces applied to the apex of the convexity where the curve is are

balanced with contralateral forces under and above the apex. While the upper margin of the coronal plane is the axilla, its lower margins are the pelvis and the iliac cristae. The sternum, the upper point of the vertebra and the pelvis are taken as the basis for deviations in the sagittal plane. Normal lordosis and kyphosis control is achieved in this plane. For deformities in the transverse plane, forces from extra local pads to be applied from transverse processes are used to limit the increased rotation in sterna and costae in the thoracic area and in the axillary lumbal region[25].

After all, the external forces targeting to control the curve in three specific planes should be designed in a way that they will not cause other problems in the user while controlling the flexible spine (Fig.-1.e).

## AIS BRACE INDICATIONS:

It is still difficult to say that there is a consensus among health professionals about the use and outcomes of bracing in adolescent idiopathic scoliosis. Braces are more widely used and the set indication limits are more observed in the countries where bracing techniques are more developed and a health refund system is in place. Although the developments in surgical methods reached contemporary levels in our country, we cannot say the same for bracing practices, which can be considered as one of the conservative treatment methods. The orthesis technicians in Turkey are still not well acquainted with scoliosis and are not skilled enough at scoliosis bracing practices. Considering that the compensation allocated by the social security agency for a scoliosis brace in Turkey is around 70 USD, the reasons for the insufficiency of employing bracing and the unwillingness to use advanced technologies can be understood. This also makes the physicians who prescribe scoliosis braces lose their confidence in braces. Due to models that do not produce good results and do not satisfy users cosmetically, the physicians in our country seem to keep the brace indication range narrower than generally accepted limits.

The commonly agreed rule for the use of a trunk brace in AIS is being a growing immature child and having a curve between 25 and 40 degrees. The treatment options recommended according to the degree of scoliosis and the maturity of the child as also accepted by the Scoliosis Research Society (SRS) are given in the table below (Table-1)[47].

The conservative treatment report 2006 of the International Scientific Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT), Guidelines Committee stresses that each case has its own natural course and any conservative treatment should be planned in view of the individual condition of the patient. Observation is recommended in scoliosis less than 15° before the onset of maturity and use of a brace in immature individuals with scoliosis over 25° by also identifying the risk of progression. Part-time and full-time brace use as well as a rehabilitation program is recommended for adolescents of Risser 0-3 with a progression risk of 60 % and more[59] (Figure-2).

**Table-1.** Indication for treatment of the scoliosis curve

| Risser | Curve | Action |
|---|---|---|
| 0-1<br>0-1 | 0-20°<br>20-40° | Observe<br>Brace |
| 2-3<br>2-3 | 0-30°<br>30-40° | Observe<br>Brace |
| 0-3<br>0-4 | 40-50°<br>50-Higher >50° | Gray<br>Surgery |

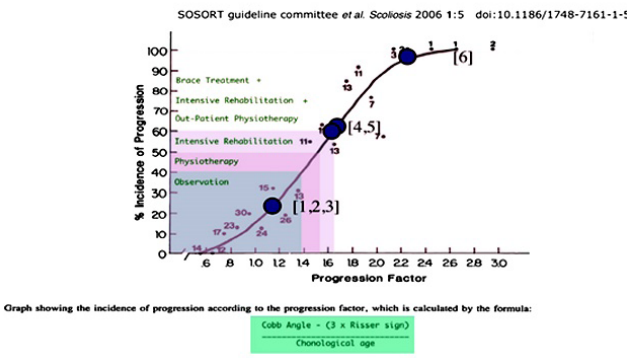


**Figure-2.** Sosort Guidelines committee 2006. (scoliosis progression and treatment protocols)

Despite the guidelines recommended by SRS and SOSORT, physicians seem to follow different indications in brace use in line with their own experiences. In the review they published, Richard et al. point out the differences in the ranges of indications in the clinical studies on braces. According to their review, as an optimal inclusion criterion, adolescents aged 10 and over, with Risser 0-2 and whose primary curve is 25-40°, and if a girl, who is in her pre-menarche period or not older than post-menarcheal year one are more suitable for a brace[18].

When deciding on a brace in AIS, the generally accepted criteria should be followed, but whenever broader indications are used for using braces in special cases, the patient specific conditions should be expressly disclosed. Considering the highly evidenced bracing results in recent years, it should be borne in mind that some professionals' approach to keep away from braces is also controversial for patients.

## BRACE PRESCRIPTION AND MANUFACTURING STANDARDS:

Even when acting on common grounds in brace indication in AIS, professionals have to find solutions to various problems that arise during bracing treatment. These include measurement and manufacturing techniques, correct design, implementation, duration of wearing, material-related problems, bodily changes in a growing child and the algorithms of monitoring and check-ups. A physician who prescribes a brace should try it on the patient after the technician finishes the brace. In Europe and America, some of the orthesis technicians have specialized in scoliosis; they can model one or more braces technically well and fit them on patients. Unfortunately, this is not the case for Turkey; we, as physicians do not have the same chance. Therefore, physicians should question the knowledge and experience of their technician with respect to braces and should hold themselves also responsible for the results.

In a successful bracing practice, besides selecting suitable patients, using standard braces that are biomechanically correctly designed and manufactured from appropriate material is also important. When readymade braces are to be used, a brace that is specific to the pattern of the scoliosis should be chosen and it should be modified to suit the patient. In custom made braces either using plaster molds or the new technology CaDCaM, the orthesis technician should be experienced enough to complete the design of the brace in the best way so that it fits the scoliosis site and apex, and the patient's body. Due to the problems in this area, SOSORT has developed standards and recommendations in its bracing guidelines for both physicians (MDs) prescribing braces and monitoring the conservative treatment and technicians (CPOs) manufacturing the braces. The aim is to increase the success of conservative treatment[38].

***According to these recommendations;***

The MD responsible for the treatment has to be experienced and should fulfill all these requirements: 1. training by a previous master (i.e. MD with at least 5 years of experience in bracing) for at least 2 years, 2. at least 2 years of continuous practice in scoliosis bracing, 3. prescription of at least 1 brace per working week (~45 per year) in the last 2 years, and 4. evaluation of at least 4 scoliosis patients per working week (~150 per year) in the last 2 years. Conservative treatment performed by physicians who have the above training and experience will reportedly be more successful.

The CPO should fulfill the following requirements; 1. working continuously with a master MD (i.e. a MD fulfilling recommendation 1 criteria) for at least 2 years, 2. at least 2 years of continuous practice in scoliosis bracing, and 3. construction of at least 2 braces per working week (~100 per year) in the last 2 years. It is stressed that trainings should be provided to CPOs so that they become qualified and skilled enough in terms of practice and experience[38].

Conservative treatment requires team work. The physician, CPO and therapist should implement a treatment program focusing on the best result for the patient in a interdisciplinary way by including also the patient and their family in the team. The education of CPOs in our country is obviously insufficient in this sense. These deficiencies can be eliminated through Category 1 and 2 completion trainings that are being carried out in many countries by the International Society of Prosthetics and Orthotics (ISPO). Completion of these trainings and practical works that are needed to catch international standards in also developing countries with the incentives of CPO vocational organizations and health administrators will certainly provide positive contributions to physicians' practices and patients.

## BRACE FITTING, CHECKING AND CONTROL:

A brace must be fitted to a patient in supine position, the legs in flexion from the hips and posterior tilting of the pelvis completed so that it fully fits the pelvis. The belts of the brace should be tightened in a way to allow a slight flexibility during active breathing in controlled-respiration and not to create any problems for daily activities of the patient. The middle ratcheting buckle is checked at the chondro-costal level. The tightening of the lower ratchet closure does not compress the abdomen, but stabilizes trochanters. Upper velcro closure must be tight enough to prevent the tingling in the upper limbs (Fig.-3).

When the brace is first fitted, the patient should be asked to sit and walk with the brace on for a certain period of time. Afterwards, it will be appropriate to take off the brace and check the whole body. After the last necessary adjustments are made for sites under excessive pressure and disturbing forces, the protocol for wearing, taking off and using the brace should be explained to the patient and their family in detail.

The child should be clinically observed in brace from the coronal and sagittal perspectives to see if the central sacral line (CSL) is aligned with the middle line and how the sagittal pattern is and photographic records should be taken to be kept for follow-up (Fig.-4).

Clinically, the height of the child in brace is measured, because the gain in height is an average of 1.58 cm due to the untwisting of the spine. This is an excellent clinical indicator of the effectiveness of the brace. In the sagittal plane, alignment of Tragus – Acromion - Trochanter - Ankles is checked[34].

After fitting the brace, frontal and sagittal XRs should be taken to examine the effect of the brace on scoliotic spine and necessary adjustments should be made. Different approaches

are seen in this matter in practice. Some physicians prefer to take XR immediately after the brace is fitted and some others 3-4 days later[34,60]. Yet, some implementers in Europe prefer to take XRs 4-6 weeks after the use rather than when it is first fitted. In this way, they allow sufficient time for the adaptation of the body to the brace and for cosmetic effect through proprioceptive input. It would be useful to place metal markers in plastic braces before taking XRs to better analyze the pressure points of the brace and to see if the axillary endpoint is at the right point in the brace. It should be checked, when necessary, whether there is any secondary upper thoracic and cervical deviation occurring due to high axillary endpoint and if there is, it should be corrected (Fig.-5).

**Figure-3.** Brace fitting

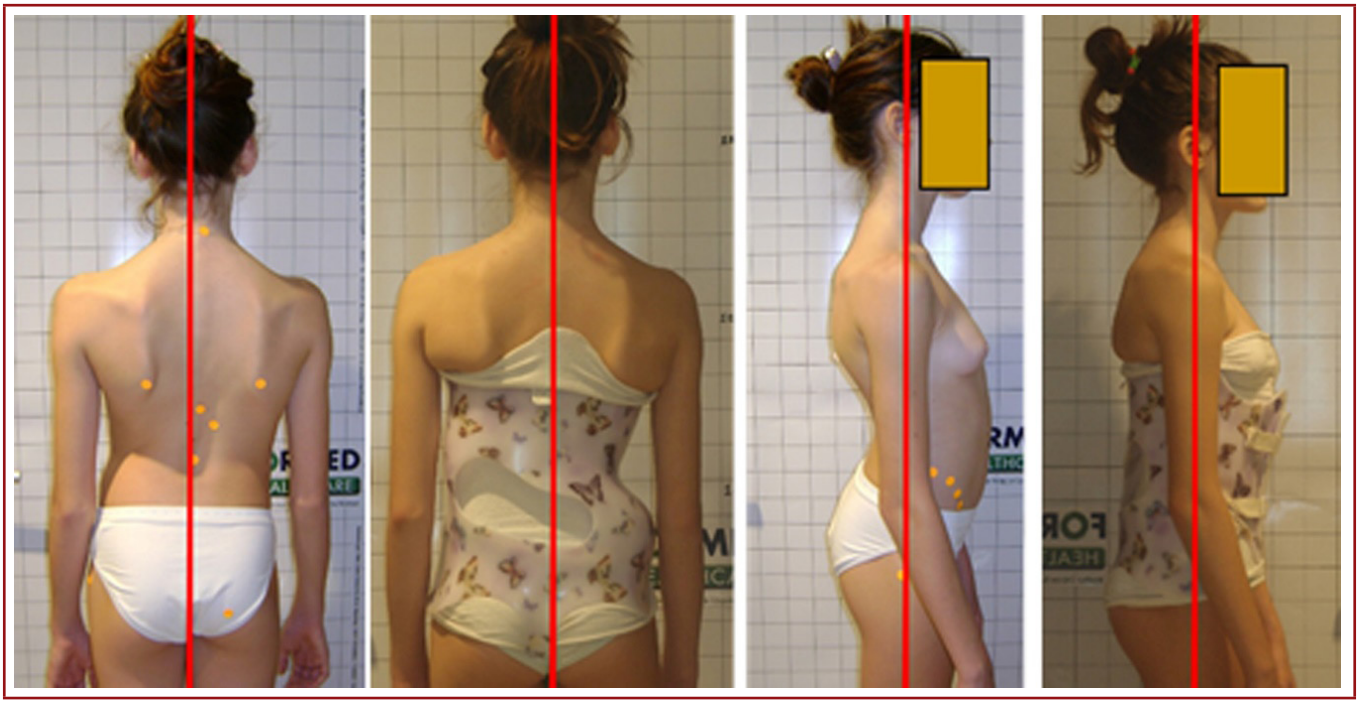

**Figure-4.** Brace checking and control

**Figure-5.** Xr control after 4-6 weeks

The first effect 4-6 weeks after the use of brace is the change in the cosmetic pattern of the body and its inclination towards the correct posture. The photographic and radiological images before the use of brace and 4-6 weeks after also affect the patient compliance positively. The results should be shown to the family and their child to enhance their motivation. Undesired problems arising in the body due to the brace should be eliminated and the child should be made comfortable in the brace.

A brace produces more successful results in flexible curvatures. The studies made on this subject mention that the first effect in the brace is a determinant for the success of the treatment[61].

Utmost care should be taken to protect children using braces from radiation in radiological follow-ups. Due to problems that may arise from x-rays in the breasts and other organs of growing children, professionals should consider low-dose radiation and use, when possible, topography or EOS low-dose systems. During bracing follow-ups, the child's height and weight should continuously be monitored and extra pads should be added, if necessary, for sufficient corrective forces to enable derotation. If the brace should be replaced in line with the physical changes in the child, the decision should be made according to the body measurements during follow-ups. Another issue is to replace ineffective or incorrect braces without delay.

Adolescents using braces should be checked by the physician in 4-6 month intervals after the first check-up and if there is no negative finding in physical examinations and Bunnel scoliometer measurements, frequent radiologic procedures should be avoided. The Tanner stages for the pubertal development of the child, and menarche and height gain in girls are important markers, which should be recorded in detail in check-ups.

## BRACE WEARING PROTOCOL AND MANNER OF USING A BRACE:

The protocol that is recommended in brace use and has been evidenced to be effective is full-time use of the brace, that is, not less than 20 hours a day, particularly in adolescents in their Risser 0-2 periods. Many studies have shown that the positive response derived from a brace is a dose-response[23,38,47,57]. Curve progression control and surgical treatment limit noticeably change in adolescents using their braces for 16 hours and longer[23,57].

Although continuing to use the brace half-time from Risser 2 until Risser 4 seems to produce positive results for the scoliotic curve and body cosmetics, there are no study results comparing the outcomes of children wearing and not wearing braces during this time. Families should be informed in detail about starting and continuing to use braces and to overcome the initial difficulties, the duration should be gradually increased until full-time use is secured. To improve the child's compliance, care should be taken to allow them flexibility for personal requests, school exams and special days.

When the brace is removed, performing personal hygiene, exercises and sporting activities is recommended.

Sporting activities are useful to relax the tension in the muscles, because the paraspinal muscles in particular are active when sporting and this protects the spine from collapsing.

## PATIENT COMPLIANCE AND OTHER BRACE PROBLEMS:

Using scoliosis braces causes some unwanted problems in adolescents, which may relate to appearance or material. These include dermatological problems, pain, abdominal cramps, intestinal complaints, sleeping problems and psychological and social problems[43]. One of the major problems regarding braces is patient compliance. The perception of the body and cosmetic concerns associated with both the scoliosis and brace bring about a very important problem for adolescents. This also adversely affects the child's relationships with their social environment, friends and parents. Braces that are defective, not suitable for the body or have become small may cause other asymmetries in the body, difference in the breasts, numbness in the arms due to axillary pressure, swelling in the arms or on the skin due to pressure, weakness and cramps in the muscles and deformities in the costae. Besides discomfort during sitting, lying and other daily activities, restrictions in using clothes affect the adolescent negatively. Since the child's perception of his/her body is negatively affected due to both scoliosis and brace, the physician and the family should provide professional support when necessary to protect the child's self-esteem. The results obtained from the brace partially decrease such negativities[44].

Some studies have shown that quality of life, body image, and emotional and social conditions are affected in especially children using braces full-time[7]. Some other studies report conversely that braces do not create a major problem on quality of life[54]. Ugwanali et al. have questioned quality of life in 214 subjects with adolescent scoliosis using the Quality of Life Measures Child Health Questionnaire and have shown that braces do not affect quality of life negatively[54]. In their BRAIST study, Schwieger et al. compared adolescents who used a brace for 6 hours or less with those who used one for 16 hours and longer using the Spinal Appearance Questionnaire and PedsQ, scale for quality of life in children, and they found no statistical difference between the two groups[52].

In a study where the emotional stress levels of families and their children were compared with respect to scoliotic deformity and brace use, it was shown that stress was associated more with body deformity. In a severe spinal deformity, a poor psychosocial outcome is said to be associated with the patient's age and the duration of using the brace[13].

## BRACE RESULTS AND BRACE-RELATED STUDIES:

Studies with long follow-up periods relating to the effect of braces on adolescent idiopathic scoliosis started to appear in the literature towards the end of 1970s with the Milwaukee brace in line with historical development of braces. The results of the nearly 5-year lasting follow-up study of Carr et al. on 133 patients with adolescent idiopathic scoliosis who used Milwaukee braces revealed that success was high and the need for surgical intervention dropped in children who had scoliosis of 40 degrees and less and who well responded to the brace in their first year[4]. The results of the study made by Loenstein and Winter on 524 patients using Milwaukee braces showed that the brace was successful in scoliotic curves of 20-29 degrees and the natural course remained unchanged beyond this angle range[29]. It was reported in another series with 111 patients using Milwaukee braces where the same authors also participated that the natural course of scoliosis did not change despite the use of braces[39]. Another important problem concerning a Milwaukee brace is the orthodontic problems it causes due to its neck ring[31,40]. It has also been shown to negatively affect the sagittal profile and increase hypokyphosis[21].

Following the results of 295 Boston brace users regarding the effect of this brace on scoliosis, which was published by the Boston brace developers in 1986, many studies were published on this subject between 1993 and 1998[55]. The results of 40 adolescents with idiopathic scoliosis who used Boston braces showed that the brace decreased the angle of scoliosis in the frontal plane, but it proved ineffective in three dimensional effect, especially in the rotation of the thoracic apical vertebrae and in spinal balance. Its negative effect in the segittal plane by noticeably decreasing thoracic kyphosis was noted in particular[26]. The common results of the studies on the use of Boston braces indicate that the brace produces successful results and reduce the need for surgery in appropriately selected patients in Risser <2 whose curve is 25-45 degrees when they wear them for a long time and their compliance is good[49,57]. As in other braces, the Boston brace produces better results when it is used longer than 12 hours a day[23].

The results of the studies made with the Providence and Charleston braces show that night braces are also effective in controlling the progression of scoliosis, they even produced similar results to those of full-time TLSO braces and controlled progression at a rate of 60-70%. Contrary to these results, other randomized controlled studies have evidenced that when the duration of wearing a brace increases, the success of the treatment also increases[3,23,35,53].

The Chenau and Chenau derivative braces, which are curve pattern derotation braces, are widely used in Europe. These braces are manufactured mostly using the CaD CaM technology in recent years. It has even become possible today to produce a brace without any need for other procedures after designing it owing to the CaD design 3D printer technology, which shows that this technique will be used more in the future for manufacturing braces. The results of the clinical study made by Maruyoma et al. on 33 adolescents of Risser <2 who used Cheneau braces demonstrated that 76 % curve stabilization could be achieved in these subjects who were

followed up until their skeletal maturity[32]. The studies on the Cheneau braces in the literature show that a Cheneau brace controls the sagittal plane as much as the frontal plane and makes a positive effect on the postural balance with its action on the trunk when standing and walking[41].

The results of the retrospective study of Rigo et al. on 105 patients with idiopathic scoliosis who had been treated with Cheneau braces indicate that Cheneau braces are effective in primary correction of scoliosis and can prevent the Cobb and distortion angles[45].

Braces conforming to correct biomechanical rules have been shown in the results of various researchers to be effective in Cobb angles less than 45 degrees in immature subjects with idiopathic scoliosis and to reduce their need for surgical fusion. Besides retrospective studies, the results of recent prospective studies involving long-term follow-ups have also demonstrated that braces prevent progression.

The results of the observation and multicenter study randomizing 242 subjects with idiopathic scoliosis as the brace treatment group of Weinstein et al. showed that the use braces decreased curve progression and lowered the surgical threshold and it proved to be a study supporting the confidence in braces[6].

Another argument about use of braces and its results is that scoliosis has its own natural course in each patient, therefore, scoliosis may not progress up to the surgical limit in a group of subjects who receive no treatment whatsoever. Sanders et al. have investigated the number needed to treat (NNT) to prevent one surgery in 126 patients with AIS who used Boston braces and whose length of use and compliance were monitored by way of heat sensors. They found in the end that compliance was important in using a brace, longer daily uses reduced the risk of progression that would necessitate surgery, but even when no brace is used, most of the patients did not reach surgical limits[49].

We see that the discussions on the role of braces in treatment and treatment criteria still continue. This is because a natural course for individual cases cannot be predicted as to in whom, why and to what extent scoliosis can progress. Another problem concerning researchers relates to the difficulties involved in long-term studies that can take into consideration many issues such as selection of subjects with the same natural course, ethical problems in randomization and brace compliance. The 662 studies in the meta-analysis made by Negrini et al. had varying results. Alongside the results suggesting that braces prevent progression, there are also study results stating that braces have no effect on quality of life. Authors who point out the problems in randomization for treatment in the studies made in this field also stress the importance of exploring the effects of braces, their side effects and compliance issues through long-term, well-planned prospective studies[36].

New, highly evidenced studies regarding the efficacy of braces in scoliosis show that correct and standard braces prevent the progression of scoliosis and reduce the incidence of surgery in subjects with adolescent idiopathic scoliosis when algorithms are strictly followed and braces are used full-time. Despite such evidences regarding the effect of braces, the child's compliance with brace use and psychosocial problems still remain to be overcome. The decision to use braces in children who have the option of a low-cost treatment to protect their spine from surgical fusion should not be left solely to their own initiative. Efforts should be made to prevent conflict between the family and their child due to use of brace and professional support should be sought when necessary. Adolescents can accuse their families in their later years of not insisting on the treatment despite the decision they had made in their adolescence under the influence of their psychosocial standing. For this reason, support should be provided to those parents who disagree with many decisions of adolescents for their own sake and who try to protect them from future problems as their own experiences dictate. It should be kept in mind that increased awareness of scoliosis and early diagnosis will improve the success of conservative treatment.

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