Treatment of Hip Dysplasia. 15 Years Hip Flexion Device of Tübingen.

Key words: congenital dysplasia of the hip – hip dysplasia – developmental dislocation of the hip (DDH) – congenital dislocation of the hip (CDH) – conservative treatment – Frekja pillow – hip flexion device  


Summary
A DDH is seen in 2 to 4% of all live births in Germany. If left untreated, in most cases this will lead to an early dysplasia arthritis of the hip. However, since the introduction of ultrasound the diagnosis and treatment of the immature infant hip is possible in the first days of life. The earlier treatment is initiated, the quicker and more reliable a normalization of the hip parameters is observed by ultrasound. For a fast development of the hip joints, the most important is to ensure the reliable maintenance of the “human position” (Salter), the foetal hip position. It is no longer the common hip abduction used up until now, but a reliable hip flexion of about 100 degrees together with a firmly adjustable average hip abduction (Tschauner 2001). This results in the centering of the hip head required which is the most important stimulus for the final maturing of the acetabulum. The superior effect of such hip flexion devices has been supported by comparative examinations (Tönnis) showing healing rates of 98%.

Epidemiology
Hip dysplasia is the most frequent of congenital dislocations. In German radiographic examinations hip dysplasia is diagnosed in 2 to 4% and manifest hip joint luxation in 0.2% of all newborn babies. Based upon a rate of 767,000 live births in 1999 (Federal Department for Statistics) this would give an annual rate of about 23,000 children with dysplasia and about 1,500 children with luxation. Unsuccessfully treated dysplasia will generally lead to coxarthrosis, while early diagnosis and treatment of hip dysplasia or luxation will in most cases lead to complete healing. For this reason early and consistent examination of the infant hip is of vital importance (Graf 2001).

Etiology of Hip Dysplasia
Salter presented a complex and sound analysis of the issues of genesis of hip dysplasia. He distinguishes pre- and postnatal influential factors.

Prenatal Influential Factors
In a study carried out together with genetecist W. Cox, Salter found that in 226 children, of whom one parent suffered from congenital hip luxation, the same disease was only observed in four children. All other 222 children had perfectly normal hips. For this reason the genetic factor alone cannot sufficiently explain the incidence of congenital hip luxation.

With his examination of twins in 1952, Idelberger successfully demonstrated that a concordance in terms of hip luxation can be diagnosed in 43 % of monozygotic twins but only in 2.8 % of dizygotic twins. Sexually determined incidence could be observed solely in congenital hip luxations, where 80 to 90 % of the children were girls but not in case of other defects of skeleton. Salter discovered that girls with hip luxation look more feminine while boys with hip luxation appear less masculine than others. Literature suggests that abnormality of the oestrogenic process is responsible for an increased laxity of the hip joint capsula.

Salter summarizes that familial hereditary factors are known in about 20% of the cases.
Postnatal Factors

In this connection the influence of (prenatal) birth anamnesis must be mentioned first: hip luxation is observed 10 times more often in pelvic presentation and 5 times more often in forceps delivery than in vertex presentation. Also, uterine narrowness will also increase the incidence of hip luxation, e.g. when diabetic mothers deliver big babies.

Some geographical and racial incidences could be clarified for example by the habits of carrying the children. The cradleboard ("Komsen") used by Northamerican Indians or the Lapplanders is a carrying board on which the infant is placed with legs extended/adducted in a similar fashion to that in the sackpillow formerly used in Saxonia and Italy. Hip luxation was found in 12.3% of the children where a cradleboard was used and in only 1.2% of the cases where it was not used. In extensive examinations in Africa, however, where mothers carry their children on their belly or back with the child’s hip in abducted position there were almost no cases of hip luxation.

Salters investigations show that when looking into the case history we have to put special attention on prenatal conditions and birth anamnesis. With regards to carrying habits there still is a need to give advice to the parents, especially as it comes to relieving the infants’s back, for example by the use of carrying shawls or rucksacs.

Pathomorphology, Biomechanics and Maturing Curve Development of the hip joint is genetically determined but also is subject to outer mechanical influences, such as breech presentation. Even minor „physiological“ forces such as the newborn’s kicking of feet in hip abduction (human posture) promotes contour differentiation of the acetabular roof. Tensile forces occur in unphysiologic postures such as hips in extended position/Lorenz position. If these tensile forces exceed a certain limit, tensile strain will build up at the interface between cartilage and bone, which will stop the initial processes and lead to metaphysial enchondral ossification. Growth comes to a stop! Without early intervention and biomechanical treatment it will lead to advanced hip dysplasia, or even the development of decentralization. Klisic (1989) put this development in the relevant terms „developmental dysplasia of the hip (DDH)", which according to current understanding should be used instead of „congenital dislocation of the hip (CDH)“. These biomechanically based conditions of growth of the infant’s hip joints were analyzed by Matthiessen (1993, 1997, 1999) in experimental examinations (Fig. 1, 2, 3).

Where there is quick growth during the first weeks of life, the „linear“ maturing process will develop according to the sonometric values of Graf (1995, 2000) beginning at an alpha-point of 50.8 degrees at the date of birth up to an alpha-point of 60 degrees at three months of age. By his statistical investigations (1995) Graf proved that the medium alpha-value in type-I hip joints is 64.4 degrees in the 3rd month of life. Through retrospective evaluation of untreated infants Tschauner (1994) succeeded in developing a maturing curve of the sonographic alpha-angle. This proved that the medium value of spontaneously maturing untreated hip joints reaches 59.7 degrees already at 4 weeks of age. Between 4 weeks and 16 weeks of age the medium values increase by only 4 degrees. At 4 months of age, a typical plateauing will begin between degrees 64 and 65 and continue to build up until 11 months of age (Fig. 4).

Mathematic calculation leads to a growth curve that conforms to an e-function and which describes all natural growth and decomposition processes (prototype: radioactive decomposition). The deeper cause for this function is that the change of size is always proportionate to the momentaneous value of this particular size. In other words, endogenously determined growth always orients around the target value. For this reason the growth of the alpha-angle is always proportionate to the distance from the target value. To achieve a target value predetermined by nature everything “small“ must grow faster than what is already “big“. In respect to acetabulum, that means the further the time distance of morphogenetic differentiation of

Fig. 1: Load distribution on completely (a) as well as partly (b,c) roofed ball joints. In case of incompletely roofed ball joints load maximum of cosine distribution (Pmax) is dislocated from the direction of force (R) towards acetabular convexity (Brinkmann et al., 1980).

Fig. 2: Structure of cosine distribution in an optimally developed hip of an eight week old infant. Load maximum (↑) is relocated towards the soft cartilagenous acetabular convexity. Resultant (R), femoral neck axis (S), hip head center (o). For graphical illustration of the biomechanical load, an “imaginary plane“ (E1) is constructed into the spheroid threedimensionally curved growth symphysis (cartilage-bone interface). The illustration shows that the newborn’s hip is very sensitive to exogenous mechanical forces so that post partum the physiologic flexion and abduction position must be conserved and promoted.
the acetabulum from the final differentiation, the faster growth must be. That also explains the phenomenon that in unilateral treatment of dysplasia, the displastic hip grows exponentially faster while the nondysplastic counter hip joint undergoes regular growth. Tönnis (1999) statistically proves this as well in his multicenter study.

Clinical Examination

During the first days of life the most obvious and often only diagnosis is instability. At this stage, the hip joint capsula is flaccid, the hip often dislocatable but not permanently dislocatable, usually with still no sign of abductive contracture. Barlow examined 9000 newborns in England and found that out of 60 one of them showed an instability in one or even both hip joints. 68% of those became stable within the first week and 88% by the end of the second month. 12% instable hips persisted in a group of children with primary instable hips, equalling 1.5‰. Salter derived from this that congenital flaxity of hip joint capsula and the sometimes resulting instability of the joint are the primary problem. This implicates the conclusion that capsular flaxity tends to spontaneous back-formation.

During the first weeks of life hip subluxations can be identified through targeted examination (Roser-Ortolani or Barlow signs), the majority of these luxations spontaneously resolving between two up to eight weeks of age. However, these luxations are important signs for instability and require careful sonographic as well as clinical examination and perhaps treatment.

Diagnosis of asymmetry of the femoral and buttock folds is of minor significance, whereas unilateral and bilateral distorsion of abduction due to an increase of abductor tone from about 4 weeks of age suggests hip luxation.

Photographic Methods

A diagnosis of hip dysplasia and hip luxation, as early as possible and if possible post partum, principally requires careful clinical and sonographical examination, as dysplasia can only be identified with photographic methods (Graf, 1980, 2000).

In 1996 sonographic screening was introduced and has ever since been used in Germany together with the early diagnosis program for pediatric diseases. The guidelines published by the Federal Medical Association (1996) stipulate that children with risk factors (positive family case history, breech presentation or other intra-uterine abnormal presentation, instable hip joints) should undergo a sonographic hip examination type 2 (“U2”) at the end of the first week of life and others a type “U 3” examination at 4 to 6 weeks of life. Graf (2001) points out that this is a politically based compromise solution. From the medical point of view the hip joint must be examined within the first 4 weeks after birth at the latest, in order to make sure that the joints requiring treatment can be adequately treated within the time slot of highest growth potential.

Radiographic examination is necessary at the end of every treatment of hip dysplasia (Tönnis, 1987) Radiography also is recommended in case of marginal sonographic diagnosis in order to determine definitive growth (Mattiesen, 1999) and later for all children with corresponding indications after the first year of life.
factory result. The orthosis must not restrict the infant, but allow for a flexion angle of more than 90 degrees and reliably exclude extension and abduction beyond a maximum of 50 degrees. In this hip posture the hip head is in central position, the hip musculature and joint capsula are relaxed and the neighbouring vessels that supply the hip head are not constricted. There is no longer the risk of hip head necrosis, if unwanted abduction can be prevented. This can best be achieved with a bar that prevents the thigh supports from slipping aside by their own weight. This mechanism was a frequent cause for hip head necrosis in orthoses that use the same principle as the Pavlik and the Hoffmann-Daimler harnesses, which still allow further uncontrolled spontaneous abduction.

A question frequently posed by the parents is, if the hip flexion joint will harm the child’s back. It is said that the final maturing process of the mainly cartilagenous acetabulum is very positively influenced and promoted by the counter pressure of a functionally effective and properly fitted orthosis, as it correctly places the hip head in the center of the acetabulum. By the infant’s spontaneous kicking and alternating movement of the long shoulder harnesses the child counteracts the development of kyphosis. Every mother will know that activity from pregnancy.

Comparison of different Orthoses

In a multicenter study from 20 clinics in Austria, Switzerland and Germany, Tönnis (1999) carried out a study comparing all commonly used methods of hip dysplasia and luxation treatment. The results of the infant hips which were treated with solely one orthosis alone were evaluated using Graf ultrasound. Tönnis compared the improvement of bony alpha-angle from the beginning to the end of treatment. Tables I and II are extracts from the Tönnis tables (1999). These concise versions do not show the initial angles that can be looked up in the original tables, nor the age of the infants at the beginning of treatment and the duration of treatment. But they give information on the number of treatments with every orthosis and the result on completion of treatment. Less good results are often due to basic misdiagnosis or the delayed commencement of the treatment, and sometimes due to improper use of the orthoses.

Biomechanical Principles of Treatment

Pathomorphologic conditions (Tschauner 2001) of decentralized, instable and retardedly-ossifying joints require different principles of treatment — with reposition, retention or maturing orthoses. In case of decentralized and instable joints a Fettweis plaster is often applied, and then treated the joint is treated with the orthoses indicated in Table I. Only the orthoses in 1 to 3 of Table I have additional hip abduction control and an adjustable spreader bar that prevents unwanted and often harmful excessive abduction. These orthoses are predominantly used as maturing orthoses, as well as retention orthoses in cases where the corresponding experience of the physician and compliance (acceptance) by the parents allows.
Complications

Hip head necrosis is the most severe of complications, which Tönnis discovered in one of his first examination series carried out in 1987. The statistics show that this complication (table IV) it was mostly observed in Graf hip type III or luxation degree II. Fortunately there were no reports of hip head necrosis in connection with the newer hip flexion orthoses (no. 1-3 of table I). From about 70,000 treatments with the Tübingen Hip Flexion Orthosis carried out between 1987 and 2000 there were no severe complications, and certainly no cases of hip head necrosis reported.

Tönnis also points out that some reposition obstacles such as excessively expanded ligamentum capitis femoris can only be identified in joint arthrography, because structures located medial to the hip head cannot be recognized in sonography.

Inexact fitting or application of the orthoses is another frequent cause for an unsatisfactory course of healing processes. Too big (excessively abducted) orthoses bear the risk of hip head necrosis, whereas too small orthoses may lead to reluxation of the hip head in dorsal direction. In any case it is absolutely imperative that the parents are familiarised with the treatment concept and have to be carefully instructed about how to use the orthosis. If they follow the instructions improper use detrimental to the childrens’ hip joints can be avoided using the corresponding “foolproof” ortheses.
Table I: Percentage of deviation degrees (see table III) of the alpha angle after treatment with different, predominantly abducting orthoses (Tönnis, 1999).

<table>
<thead>
<tr>
<th>Degrees of deviation</th>
<th>1</th>
<th>1.1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Number of Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Coxaflex harness</td>
<td>98.8</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
<td>85</td>
</tr>
<tr>
<td>2 Tübinger Hip</td>
<td>97.8</td>
<td>0.6</td>
<td>1.7</td>
<td></td>
<td></td>
<td>363</td>
</tr>
<tr>
<td>3 Lörracher Hip</td>
<td>76.2</td>
<td>23.8</td>
<td></td>
<td></td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>4 Fettweis Hip Subluxation Orthosis for Children</td>
<td>88.9</td>
<td>11.1</td>
<td></td>
<td></td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>5 Pavlik harness</td>
<td>95.5</td>
<td>4.5</td>
<td>11.1</td>
<td>4.2</td>
<td>1.4</td>
<td>72</td>
</tr>
</tbody>
</table>

Table II: Percentage of deviation degrees (see table III) of the alpha angle after treatment with different, predominantly abducting orthoses (Tönnis, 1999) and the Fettweis cast.

<table>
<thead>
<tr>
<th>Degrees of deviation</th>
<th>1</th>
<th>1.1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Number of Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 v.-Rosen-Orthosis</td>
<td>74.8</td>
<td>20.9</td>
<td>3.5</td>
<td>0.9</td>
<td></td>
<td>115</td>
</tr>
<tr>
<td>7 Abduction pants</td>
<td>93.1</td>
<td>1.0</td>
<td>5.7</td>
<td>0.2</td>
<td></td>
<td>592</td>
</tr>
<tr>
<td>8 Düsseldorfer spreader splint (DSS)</td>
<td>66.7</td>
<td>33.3</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>9 Fettweis cast, after wards DSS</td>
<td>94.1</td>
<td>5.9</td>
<td></td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>10 Fettweis cast, after wards Lorenz Orthosis</td>
<td>77.1</td>
<td>20.0</td>
<td>2.9</td>
<td></td>
<td></td>
<td>35</td>
</tr>
</tbody>
</table>

Fig. 7: Extract from an industrial brochure, which shows that the necessary hip flexion of beyond 90 degrees for treating hip dysplasia cannot be achieved with some products.
At what angles should treatment be given?

Longitudinal examinations of the alpha-angle in sonography were carried out and results presented by Casser (1992), Matthiessen (1999) and Tschauner (1993). In these examinations the control area always was within simple standard deviation and the therapeutic area within double the standard deviation. The curve shows that during the first 4 weeks of life growth and ossification speed of the acetabular roof are high, already slow down at the age of 12 weeks, until at the age of 16 weeks they no longer change significantly (see above and Graf, 2000).

This enormous maturing power is reflected in the clinical experience that in case of early treatment within the first weeks of life, irrespective of basic diagnosis, a very quick final maturing process can be observed. While Graf recommends treatment until a type I hip is achieved, in other words an alpha-angle of at least 60 degrees is reached, Tönnis refers to the examinations made by Casser and sees a need for treatment until achieving an angle normalization of up to 65°. In radiography Casser frequently discovered defects of acetabular convexity, if at the end of treatment an ultrasound showed the alpha-angle still to be between 60 and 65 degrees.

The acetabular roof (AC-) angle shown on the X-ray photo should be below 30 degrees at the age of 3 to 4 months and below 25 degrees at five months to two years of age (Tönnis and Brunken 1968). According to the stipulations of the working committee for hip dysplasia it is imperative that radiography is carried out at the end of every treatment (Tönnis, 1987). This radiography is used to compare with the initial diagnosis in case of later reoccurrence of hip head necrosis, a persisting defect of acetabular convexity or the more seldom reoccurrence of hip dysplasia. Patience is a key "factor" which must not be underestimated, neither by the physician nor the parents as it is a very important aspect for the success of dysplasia treatment.

Practice in the Treatment of Dysplasia

Advice to the Parents

The active cooperation of parents is of primary importance for the success of treatment. It is easier to attract parents to the therapy if they understand the principle of the treatment. Abduction treatment is regarding the hip joints a prolongation of the prenatal phase, in order to allow final maturing of the hips under equally favourable conditions. The first question generally refers to the duration of treatment. In cases of early treatment with the Tübingen hip flexion orthosis within the first 6 weeks of life, and subject to the diagnosis, it is largely correct to say that the duration of treatment will take about twice the present age of the child.

First Fitting with a Tübingen Hip Flexion Orthosis

As a rule the treating physician himself will fit the orthosis. In any case the physician must check the accurate fit of the orthosis, as is the case with all other orthopedic technical prescriptions. The orthosis comes with two illustrated instructions for use, one for the parents and – due to CE regulations – a second one for the orthopedic technician/physician, the latter describing the four necessary steps:

1. To apply the orthosis the shoulder harness is brought from behind, over the child’s head and fixed with the white snap locks on the shoulder harness (Fig. 8).
2. The baby’s thighs are placed in the thigh supports which are connected to the shoulder harness with beaded cords (Fig. 9).
3. Now the infant’s feet or buttocks are placed against the thigh supports which are connected to the shoulder harness with beaded cords (Fig. 9).
4. Finally the physician will adjust the spreader bar to the desired moderate abduction position (dependent on the infant’s age and the level of dysplasia, max. 50 degrees, fig. 11,12).

Table III: Normal and deviating degrees according to Tönnis (1999).

<table>
<thead>
<tr>
<th>Normal and deviating degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree 1  = normal value</td>
</tr>
<tr>
<td>Degree 1.1 = physiological immaturity</td>
</tr>
<tr>
<td>Degree 2  = light dysplasia (stable)</td>
</tr>
<tr>
<td>Degree 3  = severe dysplasia with decentralization (unstable)</td>
</tr>
<tr>
<td>Degree 4  = extreme dysplasia with luxation</td>
</tr>
</tbody>
</table>

Table IV: Percentage of hip head necroses in different methods of treatment (Tönnis, 1999).

<table>
<thead>
<tr>
<th>Method</th>
<th>Necrosis</th>
<th>Number of Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abduction pants</td>
<td>0.7</td>
<td>274</td>
</tr>
<tr>
<td>Pavlik harness</td>
<td>1.5</td>
<td>67</td>
</tr>
<tr>
<td>+ Abduction pants</td>
<td>5.0</td>
<td>238</td>
</tr>
<tr>
<td>Fettweis cast</td>
<td>2.7 up to 7.2</td>
<td>406</td>
</tr>
<tr>
<td>Fettweis and different orthoses</td>
<td>3.3 up to 20.0</td>
<td>200</td>
</tr>
<tr>
<td>Reposition of extension + orthoses</td>
<td>0</td>
<td>25</td>
</tr>
</tbody>
</table>
Follow-up Checks

Multilingual instructions are handed over to the parents describing in word and pictures every single step of how to pull the orthosis on and off. It may be necessary to point out that during treatment with the hip flexion joint it will be uncomfortable for the child to wear cloth diapers. The red snap locks to release the residual bead cord from the shoulder harness should only be opened by the physician. The next consultation should take place after 2 or 3 days, so that it is possible to discuss any questions the parents might have: In this consultation and every follow-up consultation – at intervals of four weeks – the orthopedic physician will adjust the size of the flexion hip joint and revise the local diagnostic findings on the hip joints. Through this the orthopedic physician becomes clear on the sonographic and local findings. During 15 years of use, the authors have not once detected an irritation of the hip joints.

Once the hip joints have completely matured, it will be necessary to take an X-ray photo of the pelvis (Tönnis, 1987) as already mentioned above. The next check-up date will be fixed as soon as the infant can walk on his/her own, or at 15 months of age at the latest. Later check-ups will take place before school age at the age of 5 and, if necessary, a short time before the end of the growth process. Only in suspect cases will X-ray photos be taken on these occasions. In case of retarded hip joints (“endogenous dysplasia”) or children with developing coxa valga et antetorta it will be necessary to carry out radiographic examinations later than at 5 years of age in order not to miss the right time for corrective operation, before school age and the closure of hypsiloid cartilage.

Indications for the Tübingen Hip Flexion Orthosis

During the first years this orthosis was used solely for stable hip joints or was recommended by Graf (Bernau, 1990; Malzer et al., 1992; Maronna 1993; Jüsten et al., 1997) for type II c. Meanwhile there are numerous reports from experienced therapists (Braukmann, Halbhübner, Matthiesen) who successfully used the hip flexion joint for the treatment of instable hip joints (up to type III a). But this information is not intended to tempt anybody to discard the proven methods of treatment for instable hip joints.

Fig. 8: To apply the orthosis the shoulder harness is brought from behind, over the child’s head and fixed with the white snap locks on the shoulder harness. The shoulder harness is covered with two, washable elasticated terry cloths.

Fig. 9: In the second step the child’s legs are placed in the thigh supports while the baby lies on his/her back with feet or ….

Fig. 10: … buttocks against the mother’s chest or stomach. Now the hands are free to place and fix the left and right beaded cords into the snap lock.
Résumé

Since the introduction of ultrasound by R. Graf, diagnosis and treatment of hip dysplasia, the most frequent congenital malformation of skeleton, is possible immediately after birth. This time winning factor is of decisive importance, because the high growth potential in the first 3 months of life can be taken advantage of for therapy. This could not be done before as ultrasonic was not yet available.


or use the Tübingen hip flexion orthosis unsolicitally. The use of this unproblematic orthosis for instable hip joints is reserved for special cases, which despite the profound experience of the therapist, demand very accurate and close control as well as excellent compliance (acceptance) on the part of the parents. The child must wear the orthosis for as long as instability persists; it should not be removed, even for short periods, e.g. as with the Pavlik harness or the Fettweis cast.

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Fig. 11: To adjust the spreader bar the left slide clamp is released. The spreader bar is adjusted into the desired moderate abduction position and the adjustment secured in place with the slide clamp. The adjusted abduction position remains unchanged during the time the child wears the orthosis.

Fig. 12: Generally the spreader bar will be adjusted while the baby lies on his/ her back, because the right moderate hip abduction (40 to 50 degrees) can best be evaluated in this position.

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