A report for
Universitätsklinikum Schleswig-Holstein/Campus Kiel
on shared decision making
for hip dysplasia

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LIST OF ABBREVIATIONS

AAOS	American Academy of Orthopaedic Surgeons
AOR	Anterior open reduction
AVN	Avascular necrosis
AWMF	Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften
CDSR	Cochrane Database of Systematic Reviews
CI	Confidence interval
CRD	Centre for Reviews and Dissemination
DARE	Database of Abstracts of Reviews of Effects
F	Femoral osteotomy
FAQ	Frequently asked question
G-I-N	Guidelines International Network
HTA	Health technology assessment
KSR	Kleijnen Systematic Reviews
MA	Meta-analysis
MG	Mittelmeier-Graf
MRI	Magenetic resonance imaging
n	Number of events
N	Number of patients
N/A	Not applicable
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
OR	Odds ratio
OS	Ossific nucleus
P	Pelvic osteotomy
PICOS	Participants, intervention, comparators, outcomes and study design
RCT	Randomised controlled trial
RD	Risk difference
RR	Risk ratio
SD	Standard deviation
SDM	Shared decision making
SR	Systematic review
SWMD	Standardised weighted mean difference

1. PROJECT OBJECTIVE

A key aim of the research project “Making SDM a reality” is to create interactive websites to inform patients as part of shared decision making (SDM).

To support this, Kleijnen Systematic Reviews (KSR) Ltd has prepared an evidence report with a synthesis of the literature underpinning the supporting evidence table of the relevant treatment options.

The topic of this evidence report is treatment of hip dysplasia of new-borns and toddlers.

2. METHODS

2.1 INCLUSION CRITERIA

The research question underpinning the literature searches for this topic was developed in conjunction with clinical departments at Universitätsklinikum Schleswig-Holstein/Campus Kiel. The question was framed in terms of participants, intervention, comparators, outcomes and study design (PICOS), see Table 1.

As detailed below, literature searches were carried out using a stepwise approach to identify relevant studies according to study design. In the first step, searches aimed to identify relevant systematic reviews and guidelines. For this project, no further searches were conducted as relevant results were extracted from the identified literature.

Table 1: Inclusion criteria for searches

PICOS	
Patient population	Congenital hip dysplasia or developmental dysplasia of the hip, diagnosed in the first weeks (approx. up to 5) of a new-born or alternatively later in children. Excluded those with spastic paralysis or other malformations
Intervention/Comparators	• Watchful waiting (maturation without treatment) • Hip abduction braces (hips are restricted in movement via braces) • Hip spica cast (hips fixed in place with a plaster or fibreglass cast) • Traction (overhead or longitudinal extension of the legs while in bed) • Closed reduction (hips are repositioned manually) • Open reduction (hips are repositioned in surgical procedure)
Outcomes	• Acceptability/adherence • Intervention duration • Functionality • Pain • Need for operation • Side effects • Impact on daily life
Study design	Systematic reviews (SR)/meta-analyses (MA) of randomised controlled trials (RCTs), or of studies of lower evidence levels (non-randomised/observational studies), if needed. If no SRs/MAs are available, respective primary studies have to systematically searched
MA = meta-analysis; PICOS = participants, intervention, comparators, outcomes and study design; RCT = randomised controlled trial; SR = systematic review	

In consultation with the commissioner, questions frequently asked by patients in conjunction with outcomes identified in the literature were developed into an evidence table outline.

2.2 FREQUENTLY ASKED QUESTIONS

The following research questions were identified as frequently asked questions (FAQs):

1) What does the treatment involve?
   a) Description of the interventions

b) Duration of the interventions
c) Which treatment is medically appropriate for the child?

2) What does the child get out of the treatment?
   a) Where the hip needs to get to (normalisation), what can happen if this cannot be achieved, and what would happen with an undetected/untreated/wrongly treated hip dysplasia?
   b) How is the treatment for the child?
   c) Can the child be completely cured?

3) What is the risk of complications or further procedures?
   a) Risk of necrosis
   b) Risk of needing to (re-)operate
   c) Other side effects

4) How does the treatment impact daily life of child and carer?
   a) Is the treatment wearing for the child?
   b) What are the challenges in implementation of treatment at home, and treatment adherence?
   c) How long will the child have to spend in hospital?

2.3 LITERATURE SEARCHES

Literature searches were carried out to identify relevant systematic reviews and guidelines on hip dysplasia. As relevant reviews and guidelines were retrieved, it was not necessary to conduct additional searches for primary studies.

The search strategies were developed specifically for each database and the keywords adapted according to the configuration of each database. Searches were limited by date range for systematic reviews and guidelines to 2012-2019. Where appropriate, searches were limited to remove animal studies. Searches were not limited by language or publication status.

2.4 SEARCH SOURCES

Systematic reviews and guidelines

The following systematic review specific databases were searched from 2012 to January 2019:

- KSR Evidence (Internet): up to 2019/01/17 (https://ksrevidence.com/)
- Cochrane Database of Systematic Reviews (CDSR) (Wiley): issue 1 of 12, January 2019
- Database of Abstracts of Reviews of Effects (DARE) (https://www.crd.york.ac.uk/CRDWeb/): up to April 2015
- Health Technology Assessment (HTA) database (https://www.crd.york.ac.uk/CRDWeb/): up to October 2016
- Epistemonikos (Internet) (https://www.epistemonikos.org/): up to 2019/01/17

The following guidelines resources were searched from 2012 to present:

- Guidelines International Network (G-I-N) (Internet): up to 2019/01/16 (http://www.g-i-n.net/library/international-guidelines-library)
- NICE Evidence (Internet): up to 2019/01/16 (www.evidence.nhs.uk/)
- ECRI Institute Guidelines Trust (Internet): up to 2019/01/16 (https://guidelines.ecri.org/)

Full details of all search strategies are presented in Appendix 1.

Handling of citations

Identified references from the bibliographic database searches were downloaded into EndNote bibliographic management software for further assessment and handling.

Supplementary searches

Internet searches were performed to add more qualitative patient-related information to inform the more narrative FAQs.

2.5 METHODS OF STUDY SELECTION, QUALITY ASSESSMENT AND DATA EXTRACTION

Literature searches

Literature searches were conducted on 16 and 17 January 2019 to identify evidence to inform questions (FAQs) and to answer these FAQs focusing on systematic reviews, meta-analyses and evidence-based guidelines.

For this evidence report, searches for systematic reviews and guidelines were supplemented by targeted web searches to find information for the more narrative aspects of the FAQs.

Study selection

Two reviewers independently screened the title and abstract of each record identified by the search and determined the potential relevance of each record. For potentially relevant records, the full paper was obtained, independently checked, and inclusion criteria applied. Any disagreements were resolved through discussion.

An evidence hierarchy was used to select the most appropriate study(ies) to populate the evidence tables. Where more than one study could provide evidence, the most relevant studies were selected using the following criteria: recency (most recent preferred), quality (highest quality preferred), representativeness (populations which were representative of the general target population were preferred). Where there were gaps in the evidence (no systematic review or guideline available), as described before, relevant randomised controlled trials (RCTs) would have been searched for and extracted, and where no RCTs would have been identified, observational studies would have been employed.

Data extraction

For each study, data were extracted by one reviewer and checked by another. Any disagreements were resolved by consensus.

3. RESULTS

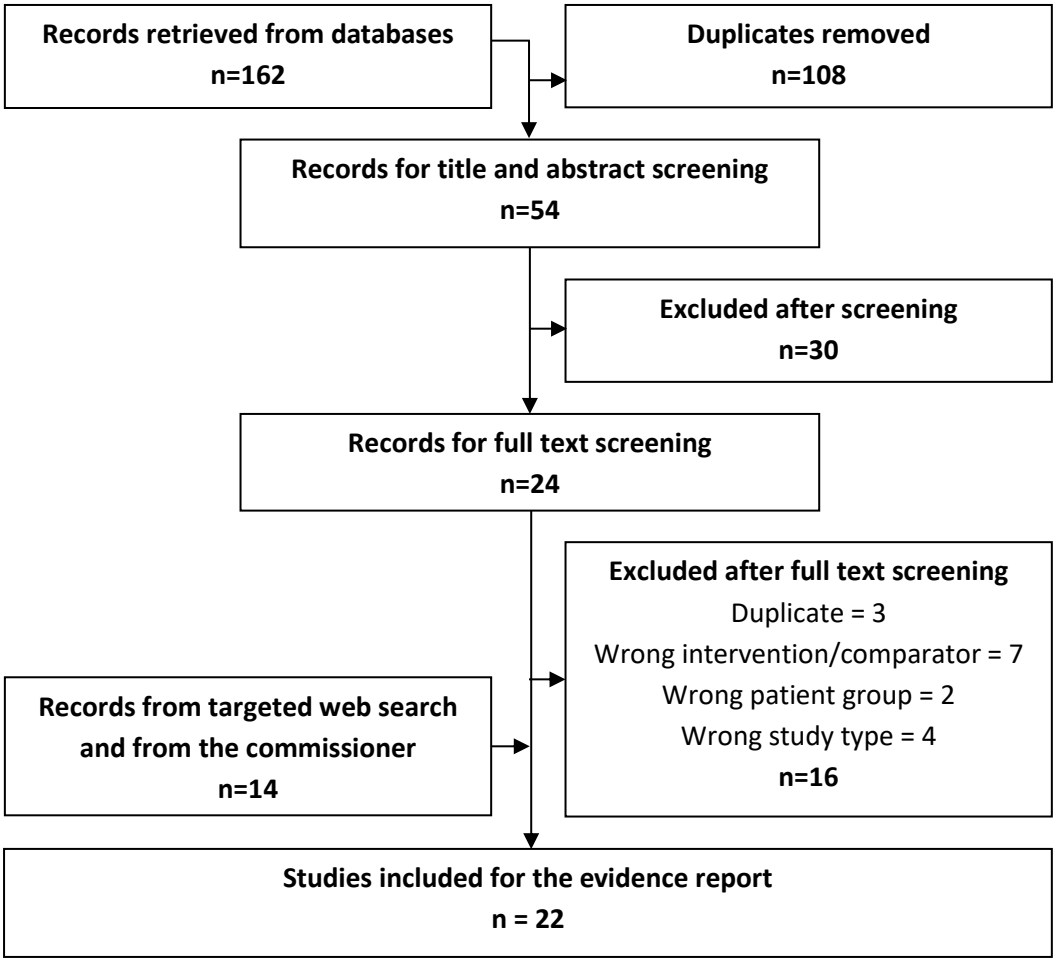
3.1 LITERATURE SEARCH RESULTS AND INCLUSION ASSESSMENT

After de-duplication, a total of 54 records were retrieved from literature searches. Titles and abstracts were screened by two reviewers. Full papers were obtained for 24 records. After further review, 16 records were excluded. Thus, eight records were initially selected for this report, please see Table 2.

In addition, the commissioner elucidated the importance of two additional references and targeted internet searches were also performed and retrieved another 12 records which were used to inform the more narrative aspects of the FAQs.

A summary of the study selection process according to a modified PRISMA flow chart is reported in Figure 1.

Figure 1: Study selection process



3.2 OVERVIEW OF THE EVIDENCE

Table 2: Evidence sources

Study ID	Evidence type	What does the treatment involve?	What does the child get out of the treatment?	What is the risk of complications or further procedures?	How does the treatment impact daily life?
Records from database search					
AAOS American Academy of Orthopaedic Surgeons 2014[1]	Guideline	Qualitative	Quantitative	Quantitative	None
Akilapa 2014[2]	SR	None	None	Quantitative	None
Kothari 2016[3]	SR	None	Quantitative	Quantitative	None
Li 2018[4]	SR	None	None	Quantitative	Quantitative
Novais 2016[5]	SR	None	None	Quantitative	None
Park 2018[6]	SR	None	None	Quantitative	None
Wang 2016[7]	SR	None	None	Quantitative	None
Williams 2017[8]	RCT	Qualitative	None	None	Qualitative
Record from commissioner					
Biedermann 2018[9]	Real world evidence	Quantitative	Quantitative	None	None
Shorter 2013[10]	SR – screening programmes	Qualitative	Qualitative	Qualitative	None
Records from targeted web search					
Barakat 2017[11]	Clinical study	Qualitative	None	None	None
Hefti 2015[12]	Practice handbook	Qualitative	None	None	None
Hipdysplasia.org[13]	Patient information website	Qualitative	Qualitative	None	Qualitative
Hipdysplasia.org video[14]	Patient information video	None	Qualitative	None	None
Kinderhueftdysplasie.de[15]	Patient information website	Qualitative	None	None	Qualitative
Omeroglu 2018[16]	Review	Qualitative	None	None	None
Paediatric Orthopaedic Service, East Kent Hospitals University[17]	Patient leaflet	None	None	None	Qualitative

Study ID	Evidence type	What does the treatment involve?	What does the child get out of the treatment?	What is the risk of complications or further procedures?	How does the treatment impact daily life?
Robben 2017[18]	Clinician training website	None	Qualitative	None	None
Shaw 2016[19]	Clinical report	Qualitative	None	None	None
Walton 2018[20]	Protocol	Qualitative	None	None	None
Weinstein 2004[21]	Review	Qualitative	None	None	None
Yang 2019[22]	Review	Qualitative	None	Qualitative	None
Records used for background					
Brand 2013[23]	Review	None	None	None	None
Dwan 2017[24]	Protocol	None	None	None	None
Graf 2004[25]	Review	Qualitative	None	None	None
Karnik 2007[26]	Review	None	None	None	None
McKay[27]	Review	None	None	None	None
Tönnis 1976[28]	Review	None	None	None	None
Waddell 2016[29]	SR	Qualitative	None	None	None

AAOS = American Academy of Orthopaedic Surgeons; MA = meta-analysis; none = results for this FAQ not available or was not used as it was down prioritised due to higher quality or newer; qualitative = qualitative results available/used; quantitative = quantitative results available/used; RCT = randomised controlled trial; SR = systematic review

FAQ 1: What does the treatment involve?

Developmental dysplasia of the hip (DDH) is a condition where the "ball and socket" joint of the hip does not properly form in babies and young children. Treatments to alleviate these problems involve repositioning, stabilisation, and (late) maturation of the affected hip.

a) Description of the interventions

Table 3 list the available interventions. Whilst treatments are described separately, it is important to recognise that they are often provided in combination either sequentially or in parallel. A non-exhaustive list of devices is available in Appendix 3. Treatments suggested depend on the degree of hip dysplasia, which has been classified by Graf into different types (see section 1c and Appendix 2 for details).

Table 3: Conservative treatments

Term	Definition	Usage
Watchful waiting	Maturation without treatment. This solely consists of regular monitoring while the hip is left to mature without intervention.	Watchful waiting may be recommended when an immature hip of type IIa or IIc is detected on the ultrasound scan, the femoral head is not dislocated and does not therefore need to be reduced.[30]
Hip abduction braces	A device in the form of brace or harness that is fitted to limit the movement of the legs and allow the formation of the hip. It is also called a dynamic splint. Amongst the available hip abduction braces, the Pavlik harness has been traditionally used for infants up to six months.[16] This type of brace is no longer used at the University Hospital of Kiel and is therefore not included in this report.	This form of intervention may be successful for dysplastic hips up to Graf III. If the reduction is not successful within a certain time frame, a different treatment may be employed. [30]
Hip spica cast	A device which assists fixing the hip in place. Spica casts may be made of plaster or fibreglass.	This therapy can be implemented alone, and is also recommended after a closed or open reduction[13]
Traction	This is either done overhead or longitudinally. A procedure in which the ligaments are stretched. Traction/extension requires bedrest during the treatment. In the literature little difference is made between overhead and longitudinal traction.	The aim of this is the preparation of the ligaments prior to a surgical or other intervention. Please note that use of longitudinal traction / overhead extension is a contentious issue[13], the evidence found pointed to no evidence of benefits[4] or harm,[6] a new systematic review and meta-analysis on

Term	Definition	Usage
		the role of pre-reduction hip traction is underway[20]
Closed reduction	This is a minimally invasive procedure where the hip is placed into position. A health care professional physically manipulates the femoral head back into the socket. General anaesthesia is required.[21,11]	This intervention may be performed for children between six and 18 months old or those children who failed to be stabilised with reduction braces or other means (e.g. maturation or splints following braces).
Open reduction	This is an invasive procedure where the hip is placed into position. The hip joint may be cleared of any tissue that obstructs the head of the femur before placing the femoral head into the socket. Osteotomy, where the bone is cut and realigned to allow the formation of the hip into position, can be part of an open reduction.[13] An adductor tenotomy (cutting of the adductor tendon) can also be performed to increase angle of abduction.[21,11]	The intervention is followed by immobilizing the hips in a hip spica cast[22,13] This is done so the tendons do not pull the hip back out of place after the procedure. While the hip stabilises in the spica cast the tendons will adjust to their new position and length. The older the child and the more the hip is out of place the higher the need for the procedure to be an open rather than a closed reduction as the tendons would be keeping the hip tighter in the "wrong" position and would need help to let go. Open reduction with osteotomy is only performed on children more than 18 months old as the bone needs to be mature and formed enough to be able to be surgically shaped.

b) Duration of the interventions

Biedermann 2018[9] has collected data on hip dysplasia cases in Austria. They found that the median time to reaching a normal hip stage for the age of the child very much depends on the severity of the dysplasia but ranges from a median of 6 to 17 weeks (see Table 4). The grading system used is based on the Graf system which is described in section 1c and in Appendix 2.

Table 4: Median time until reaching grade I as a function of grade

Grade at baseline classification	Total, n	Censored, n	Median time until grade I, weeks (95% CI; IQR)
IIa+	1751	58	6 (5.9 to 6.1; 6 to 9)
IIa-	30	8	6 (4.5 to 7.5; 5 to 9)
IIb	8	1	7 (3.5 to 10.5; 4 to 16)
IIc	176	28	10 (9.0 to 11.0; 7 to 13)
III	18	5	15 (12.2 to 17.8; 11 to 21)
IV	8	1	17 (6.7 to 27.3; 12 to 27)
Overall	1991	101	6 (5.9 to 6.1; 6 to 9)

From Biedermann 2018[9]
CI = confidence interval; IQR = interquartile range

The treatment received depended on the Grade of hip dysplasia at baseline:

- After a median time of six weeks (95% CI 5.9 to 6.1), Grade IIa+ hips reached full maturation to Grade I hips, independent of treatment.

  Type IIc and IId hips were analysed as one subgroup (n = 182; 7% of the patient population). These were generally treated in abduction with a Tübinger orthosis. The hips reached normality (type I) after a median time of ten weeks (95% CI 9.0 to 11.0).

- Surgical interventions (closed and open reduction) were needed in approximately 10% of patients with DDH; this corresponds to previously published data

Biedermann 2018[9] presented the deterioration patterns for 125 of the 28,092 neonates (0.4%) comparing baseline diagnosis with highest Graf grade given at any time point in an Austrian cohort (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). Authors report that all the hips which had deteriorated did recover after treatment. However, given the study design it is not possible to ascertain whether these would have resolved spontaneously. Moreover, the specific setting in which the study was carried out does not exclude the possibility of DDH cases that were part of this cohort but were treated outside the study.

Table 5: Descriptive statistics for deterioration following initial screening

Highest grade given at any time point	Grade at baseline classification							
	I	IIa+	IIa-	IIb	IIc	III	IV	Total
IIa+	31	N/A						31
IIa-	2	23	N/A					25
IIb	3	6	0	N/A				9
IIc	11	36	4	0	N/A			51
III	0	5	0	0	1	N/A		6
IV	1	0	0	0	2	0	N/A	3
Total	48	70	4	0	3	0	0	125

From Biedermann 2018[9]
N/A = not applicable

Watchful waiting

Duration depends on the development of the hip and the age of the child. Approximately 90% of new-borns with early stage hip dysplasia (Graf type IIa) do not develop hip dysplasia.[18]

Hip abduction braces

Hip abduction braces will need to stay on the child for a period lasting between two weeks and several months, depending on severity of the dysplasia and age of the child. Longer treatment periods will often be required when the children are older and/or when treatment initiation is delayed. This is elucidated by the fact that when hip dysplasia is identified (and treated) before eight weeks of age, the efficacy of non-surgical interventions is increased.[8]

Hip spica cast

A spica cast will typically be in place for three to six months after closed or open reduction.[13] Duration depends on the age of the child, the degree of hip dysplasia and the invasiveness of the intervention.

Traction (preceding closed reduction)

Li 2018[4] reported on length of hospital stay with closed reduction with or without preceding traction (combining numbers from overhead or longitudinal traction in 276 patients). Traction would take place in hospital, so that would add considerable time to the hospital stay as evidenced below with an average of five days total for closed reduction without traction and almost 16 days for closed reduction preceded by traction. I.e. traction accounts for approximately 11 days. See Table 5 below.

Table 6: Length of hospital stay (mean number of days) after closed reduction

Traction	No traction
15.6 (SD 7.2)	5.0 (SD 2.2)
P<0.001	

From Li 2018[4]
SD = standard deviation

Closed and open reduction

No information was available on procedure duration, but the hospital stay following closed reduction without preceding traction was approximately 5 days (see table 4).[4] Following closed or open reduction the hips will be immobilized with a spica cast for six to eight weeks,[13] however it can

be a duration of up to 6 months.[13] After the spica cast a slightly more flexible hip abduction brace possibly with an added bar might be employed.[13]

c) Which treatment is medically appropriate for the child?

Graf has proposed a classification for hip dysplasia depending on the degree of dysplasia or dislocation.[25] This is classification has been adopted internationally and constitutes a critical tool in assessing the degree of dysplasia and recommended treatment. This classification is described in Appendix 2. A decision-making approach based on age, degree of dysplasia as described by Graf[25], clinical stability of the hip and actual progression needs to be employed when opting for the most appropriate intervention. A clinical summary of the general recommendations is reported in Appendix 2, a plain language summary is presented below.

A suspected hip dysplasia is measured with ultrasound (sometimes also x-ray; however, x-ray would not show the cartilaginous structures). Clinicians use the Graf scheme to describe the severity of the dysplasia (see Appendix 2). The types mentioned in the Graf scheme are very much dependent on the alpha angle, a measurement of how well formed or how deep the hip socket is. Subtype is somewhat dependent on the beta angle which reflects the femoral head cartilaginous coverage (subtypes Ia and Ib). The subtype also depends on the age of the child (subtypes IIa, IIa+ IIa- IIb at similar angles/development but at ages approximately four, six, 10, and 13 weeks). In type IIc the socket is more severely deficient, Type D is dislocated, Type III is also dislocated and parts of the soft tissue is moved upwards (subtypes IIIa and IIIb), Type IV is severely dislocated.[18]

Watchful waiting

If the infant presents early with a very mild dysplasia, watchful waiting might be employed.

Hip abduction braces

If the infant presents with a hip up to a stable type IIc hip, hip abduction braces would be employed.

Hip spica cast

This is employed for a hip unstable type IIc, possibly also for hips type III-IV. It would almost always be employed after traction, closed reduction and open reduction.

Traction

Might be employed for a type D (dislocated) hip, possibly also for types III-IV Hip dislocation can be reduced by in-line traction and external rotation, with an assistant sometimes pushing on the femoral head or pulling the femur laterally to assist reduction.[29]

Closed reduction

Would likely be employed for a type D (dislocated) hip, also likely for types III-IV

Open reduction

Might be employed for hips type III, but more likely for type IV

FAQ 1: EVIDENCE SUMMARY

What are the treatment options?

Watchful waiting: Regular monitoring while the hip is left to mature without intervention.

Hip abduction braces: Legs movement is restricted. It is suitable for young infants and milder forms of dysplasia.

Hip spica cast: Legs movement is fully blocked. This can be implemented alone or following abduction braces, a manual/closed reduction or surgical intervention.

Traction: Legs are gently stretched support reposition of femoral head. Traction is often followed by another intervention like e.g. a hip spica cast for stabilisation and late maturation or to prepare a closed reduction.

Closed reduction: A minimally invasive intervention. The hip is forcefully placed into position. It may be appropriate for children aged between six and 18 months. Often followed by a hip spica cast to stabilise the joint

Open reduction: Invasive procedure where the hip is placed into position. It can include osteotomy where the bone is shaped as required. It is feasible after 18 months of age.

FAQ 2: What does the child get out of the treatment?

Focus here is on where the hip needs to get to, what can happen if this cannot be achieved, and what would happen with an undetected/untreated/wrongly treated hip dysplasia?

In the developed child, the femoral head needs to fit securely in the socket of the hip. If a hip is dysplastic and is not treated, it can lead to pain, a waddling walk, a decrease in strength, early osteoarthritis and other hip deformities.[13]

Watchful waiting

For a lot of infants with a mildly under-developed hip, the hip development catches up on its own.

Hip abduction braces, Hip spica cast, Closed and open reduction

As there is universal hip dysplasia screening in Germany, it is likely that your child's hip dysplasia is in the early stages and can be treated successfully with hip abduction braces. See FAQ 2c below for success rates. About 90% of children with abnormal hips suffer from moderate/early hip dysplasia (IIa hips) that may be become normal within 6 or so weeks with appropriate treatment like hip abduction braces or sometimes even without treatment. More severely diseased patients might need longer or more intense/invasive treatment like closed and open reduction. However, if hip abduction braces fail to achieve normal development of the hip, then treatment is intensified, method depending on the stage of the hip. If it is dislocated, closed reduction can be employed (likely followed by a hip spica cast) or traction and/or open reduction followed by a hip spica cast. The hip spica cast fixes the child's hips in the optimal healthy hip position (rather than the more flexible movement allowed by a hip abduction brace).

Traction

Sometimes traction is used before surgery, see Table 6 for influence on success/failure rates with and without traction. Please note that use of traction is a contentious issue, the evidence found pointed to no evidence of benefits[4] or harm[6], a new systematic review and meta-analysis on the role of pre-reduction hip traction is underway.[20]

Table 7: Effect of traction on failure rate of subsequent closed reduction (in patients with hip dysplasia detected between 6-24 months of age)

	Groups	N	Failure of reduction n (%)	χ^2	P-value
Overall	Traction	314	29 (9.2)	1.621[b]	0.203
	No traction	126	7 (5.6)		
Tönnis grade II	Traction	132	6 (4.5)	-	1.000[a]
	No traction	70	3 (4.3)		
Tönnis grade III - IV	Traction	182	23 (12.6)	1.285[b]	0.257
	No traction	56	4 (7.1)		

From Li 2018[4], Table 2
Tönnis grades describe severity of osteoarthritis of the hip (0 no sign of osteoarthritis–3)[28]
[a] Fisher's exact test
[b] Chi square test
N = number of patients; n = number of events

a) How is the treatment for the child?

It is unclear in how far treatment causes pain in new-born babies. Pain associated with hip dysplasia can only be reported by children at older ages. However, it is plausible that the lowest level interventions like hip abduction braces are less invasive and less limiting than more invasive treatments and might also cause less pain.

Watchful waiting

Not applicable, no intervention is employed.

Hip abduction braces

There should be no pain and most hip abduction braces are well padded, so they are not uncomfortable to the child. Some specific braces can cause trouble (see more under FAQ 3 for side effects).

Hip spica cast

There should be no pain but there can be some discomfort. This very much depends on the ability to keep the hip spica cast dry, especially on the inside, as there can be chafing of the skin.[13] It is not unusual to have to be in the cast for three to six months, so it has to be changed on a regular basis to allow for the child's growth.[13]

Traction

As this treatment requires bedrest, it will be boring for the child.

Closed and open reduction

Both closed and open reductions require general anaesthesia during the procedure. There will be some pain following but this should be manageable with pain medication for a little while. Following the procedure, the child will be in a hip spica cast.

b) Can the child be completely cured?

A child with severe hip dysplasia (Graf types III and IV) can be completely cured (see Table 4 in FAQ1). However, this is wholly dependent on adhering to the treatment prescribed. In the Biedermann study, children with type IIa+ hip dysplasia reached full maturation to type I hips after a median time of six weeks (95% CI 5.9 to 6.1), independent of treatment.[9]

Watchful waiting

Shorter 2013[10] was a Cochrane review of screening programmes for developmental dysplasia of the hip in new-born infants. It included some commentary on watchful waiting.

Where infants are clinically detected as having unstable but not dislocated hips, or are detected on ultrasound to have mild hip dysplasia, there is evidence that delaying treatment by two to eight weeks reduces the need for treatment without a significant increase in late diagnosed dysplasia or surgery. However, the confidence interval around the late diagnosis of DDH was very large including both significant benefit and significant harm (RR 0.57, 95% CI: 0.18 to 1.86).[10] Furthermore, this evidence is based on a study in Norway where the screening procedures may have been different to those in Germany.

Hip abduction braces

The study by Biedermann et al. further reported that Type IIc and IId hips (analysed as one subgroup of n = 182; 7% of the patient population) were generally treated in abduction with a Tübinger orthosis. The hips reached normality (type I) after a median time of ten weeks (95% CI 9.0 to 11.0).[9]

However, while abduction braces might be effective in the majority of children with hip dysplasia, very mild cases might be over-treated.[10]

Additional observational evidence from 2002 reported the success rates comparing different hip abduction braces (Craig, Pavlik and von Rosen) to no treatment. Ten of 37 (27%) of Graf III hips which had initially received no splint required a plaster or an operation after six to 12 months. In contrast, 10 of the 97 hips (about 10%) initially treated with a splint required later further treatment. Of this group, however, 92 of these hips had been initially diagnosed as category III and five at category IV.[31] All patients with Graf IV received prior splints.

Closed/Open reduction

No evidence was identified on how likely patients would completely recover following reduction. However, Biedermann et al. report that surgical interventions (closed and open reduction) were needed in approximately 10% of all patients with DDH; a number that corresponds to previously published data. It is also stated that “All the hips in our study that deteriorated recovered after being treated in our institution”. [9]

FAQ 2: EVIDENCE SUMMARY

What does the child get out of the treatment?

Watchful waiting: Hip development can occur naturally for infants with an under-developed hip. Pain associated with hip dysplasia usually does not occur until the early teenage years.

Hip abduction braces: In most/mild cases of hip dysplasia, hip abduction braces can be utilised to promote development of the hip. In general, braces should not be uncomfortable for the child.

Hip spica cast: The hip spica cast fixes the child's hips in the optimal healthy hip position. When the hip is dislocated a cast can be fitted after open/ closed reduction. It is not unusual to have to be in the cast for three to six months, so it has to be changed on a regular basis to allow for the child's growth

Traction: Use of traction is a contentious issue but no evidence was found suggesting either positive benefit or negative harm. New research on effectiveness will soon be published. Prolonged traction can be associated with boredom.

Closed and open reduction: Reductions (open or closed) are a form of treatment intensification when abduction braces fail to promote adequate development of the hip. Procedures involve general anaesthetic and some post-operative pain which can be managed via medication.

Overview: During hip dysplasia treatment, the child's hip is helped to grow into the right shape and position. This is usually not painful for the child, even though splints can look restrictive. However, by following treatment protocols, the child's hip can be completely normalised, whereas the consequences of not following or delaying the treatment can be the need for a more restrictive and/or more invasive treatment which might take longer to finish.

FAQ 3: What is the risk of complications or further procedures?

a) What is the risk of necrosis?

Avascular necrosis (AVN) is a potentially severe complication that may result from the interventions on hip dysplasia. Its exact originating cause (aetiology) is still unknown. The vascular compression and pressure on the femoral head have been accepted as the key triggers, the consequences of AVN are the permanent disruption to the hip development leading to abnormal gait, leg length discrepancy and pathologies of the degenerative joint.[6] Recently, the monitoring of the perfusion of the femoral head with new magnetic resonance imaging (MRI) techniques has been promising in the prevention of AVN.[22] For the purposes of this review evidence relating to the terms avascular necrosis and osteonecrosis have been treated interchangeably.

This review has identified six studies: Akilapa 2014,[2] Li 2018,[4] Novais 2016,[5] Park 2018,[6] Wang 2016,[7] Kothari 2016,[3] whose objective was the assessment on the risk of AVN depending on the form of the intervention or when the intervention was carried out.

Watchful waiting

Not applicable, no treatment is employed

Hip abduction braces and Hip spica cast

The AAOS guideline 2014[1] reports that treatment of all forms for hip dysplasia have been associated with varying rates of avascular necrosis. The AAOS guideline also reported on an old 1988 study comparing the Von Rosen splint (a type of hip abduction braces) and the Frejka pillow (a softer option than the hip abduction braces with less restriction of movement) in 1100 children, showing a risk ratio of 0.0426 (0.056, 3.255), i.e. no significant difference between the two treatments. However, no absolute numbers were presented. We found no evidence for the risk with a hip spica cast alone, but the risk with hip spica cast is included in the risk associated with traction, closed and open reduction.

Traction

Li 2018[4] reports on a systematic review to analyse the effect of traction previous to closed reduction on the incidence of AVN with late-detected developmental hip dysplasia. All included studies were retrospective. No statistically significant difference was reported between the traction and no-traction groups in the incidence of AVN (OR 0.76; 95% CI 0.45 to 1.30, p=0.32). Authors note how the method of traction varied across hospitals and that Tönnis grades III and IV were more likely to undergo treatment compared with grades I and II.[4] Some studies assess severity only by use of a Tonnis grade which is based on degree of osteoarthritis. It is not directly comparable with the GRAF method.

The article published by Park 2018[6] describes a systematic review and is also aimed at the evaluation on the effect of traction prior to a closed reduction. The review excluded studies that included subluxations (severe dysplasia) unless these had been analysed separately. The seven included studies were all observational. The age at the time of the intervention ranged from 1 to 55 months. No statistically significant difference resulted from the analysis between both groups (risk ratio (RR) 0.86; 95% CI 0.52 to 1.40, p=0.536). Outstanding critical factors that need further research are age, traction method, severity of dislocation and secondary procedure.[6] The results from both Li 2018[4] and Park 2018[6] are reported in

Table 8.

Table 8: Risk of AVN between traction and no traction prior to closed reduction

Study	Parameter	Traction vs. No Traction
Li 2018[4]	OR (95% CI)	0.76 (0.45 to 1.30), p=0.32 showing no clear difference in risk
Park 2018[6]	RR (95% CI)	0.86 (0.52 to 1.40), p=0.54 showing no clear difference in risk
From: Li 2018[4] and Park 2018[6] AVN = avascular necrosis; CI = confidence interval; OR = odds ratio; RR = risk ratio		

Closed and open reduction

The systematic review Novais 2016[5] aimed to establish the difference in risk for AVN depending on age for both open and closed reduction as well as the risk resulting from a medial or an anterior open reduction. The review excluded studies that included patient who underwent open reduction with concomitant pelvic osteotomy. Manual closed reduction was included with or without adductor tenotomy. This review found no association between the time of the intervention or a medial versus anterior surgical approach. The results illustrating the risk depending on hips reduced at or after 12 months and those reduced earlier are reported in Table 9. Consequently, this review provides no rationale to support delaying the intervention based on the potential AVN risk. The authors highlighted that many of the studies were nonrandomized Level III or IV observational studies of inconsistent quality.[5]

Table 9: Risk of AVN between reduction before or after 12 months of age

Subgroup	12 months vs. earlier OR (95% CI)
Closed reduction	1.1 (0.4 to 3.2) p=0.9 showing no clear difference in risk
Open reduction	1.1 (0.7 to 1.9) p=0.7 showing no clear difference in risk
From: Novais 2016[5] CI = confidence interval; OR = odds ratio	

The systematic review authored by Wang et al 2016[7] studied the association between AVN and a closed or open reduction. The review included patients younger than three years old and who had been treated with a closed or open reduction after a failed treatment with Pavlik harness or who had been first seen after the age of six months. The findings of the meta-analysis suggest that open reduction is a risk factor for an increased incidence of AVN (all grades) compared with closed reduction. Pooled ratios are reported in

Table 10. Authors point at the differences in the results and unstable heterogeneity as potential limitations to their findings.[7] It must be noted that though the Pavlik harness is part of the history of these patients, it is not a differential factor between the study groups.

Table 10: Risk of AVN between open reduction and closed reduction

Subgroup	Open reduction vs. closed reduction OR (95% CI)
All grades AVN	2.26 (1.21 to 4.22) favouring closed reduction
AVN grades II-IV	2.46 (0.93 to 6.51) favouring closed reduction

From: Wang 2016[7]
AVN = avascular necrosis; CI = confidence interval; OR = odds ratio

Open reduction

The systematic review reported by Kothari 2016[3] was undertaken to ascertain a range of outcomes after surgical intervention, amongst them AVN, in children who had been diagnosed with hip dislocation or subluxation (severe forms of dysplasia) and intervened via anterior open reduction. The difference in risk was evaluated for the addition of pelvic and/or femoral osteotomy. Their findings support open reduction with concomitant pelvic osteotomy as the most appropriate option for all outcomes including AVN. Taken in conjunction with Table 7 in FAQ2 it seems that that clinical and radiological outcomes are not necessarily linked to the risk of AVN as one treatment gives you lower risk but also lower chance of a good radiological and clinical outcome. The results on the odds ratio of AVN for the different interventions have been captured in Table 11. The authors highlight that the included studies were not randomised and the mean age of the anterior open reduction was younger than the other groups which may be interpreted as a sign of bias.

Table 11: Risk of AVN between surgical interventions

Results given as OR (95 % CI)					
AOR versus AOR/P	**AOR versus AOR/F**	**AOR versus AOR/F/P**	**AOR/P versus AOR/F**	**AOR/P versus AOR/F/P**	**AOR/F versus AOR/F/P**
0.21 (0.07–0.72), p = 0.004	0.21 (0.06–0.78), p = 0.014	0.15 (0.045–0.48), p < 0.001*	0.95 (0.48–1.91), p = 0.856	0.68 (0.46–1.00), p = 0.052	0.71, (0.36–1.39), p = 0.345

Based on Kothari 2016[3], Table 5
* Level of significance adjusted to α < 0.003
AOR = anterior open reduction; AVN = avascular necrosis; CI = confidence intervals; F = femoral osteotomy; OR = odds ratio; P = pelvic osteotomy

The article published by Akilapa 2014[2] provides the details of a systematic review aimed at establishing the long-term outcomes of the medial open reduction for hip dysplasia. It excluded studies where patients had additional femoral or pelvic osteotomies. The median reported rate was 21.9% (range 5-43%). Authors of the included studies assessed age at surgery as a prognostic factor for AVN. However, the different correlations did not allow establishing an optimal age for intervention. All selected studies were retrospective.[2]

b) What is the risk of needing to (re-)operate?

Three reviews studied the risk of the children undergoing further surgery depending on the form of the procedure: Akilapa 2014[2], Kothari 2016[3], and Wang 2016[7].

Watchful waiting

No evidence was identified from the selected literature. However, there remains potential that watchful waiting might result in missed/incomplete maturation.

Hip abduction braces

The risk of needing an operation after hip abduction braces was briefly mentioned in FAQ 2 to elucidate the success rate of hip abduction braces. As shown below and in FAQ 2, only low-quality evidence was available, but that does point to a relatively low risk (1 out of 54 treated hips, in a range of 0-2%). See table 12.

Table 12: Comparison of risk of operation at 6-12 months after treatment with hip abduction braces

Craig splint N = 28 vs. no treatment N = 37	**von Rosen splint N = 26 vs. no treatment N = 37**
Craig splint n = 1 (3.6%) vs. no treatment n = 2 (5.4%); RD= -0.02 (-0.02, -0.02) favouring Craig splint over no treatment	von Rosen splint n = 0 (0%) vs. no treatment = 2 (5.4%); RD= -0.05 (-0.13, 0.02) favouring von Rosen splint over no treatment
Overall favouring von Rosen splint over Craig splint over no treatment	
From AAOS 2014[1], Table 43. Based on Low strength evidence (GRADE) from Wilkinson 2002[31]. Results from 134 hips in 96 children with Graf type-III or type-IV dysplasia: 28 affected hips in 22 children with the Craig splint, 43 hips in 30 children with the Pavlik harness, and 26 hips in 16 children with the von Rosen splint. A total of 37 affected hips in 28 children were not splinted. All children were less than three months of age at referral. Pavlik numbers have been subtracted due to exclusion for high risk this side effect. N = number of hips; n = number of hips needing operation; RD = risk difference	

Hip spica cast

No evidence found for hip spica cast alone, but the risk with closed and open reduction would include the risk with hip spica cast, as the vast majority of children will be in a hip spica cast after reduction, closed or open.

Traction

No evidence found for traction alone

Closed and open reduction

The rate of secondary operations in children who had undergone medial open reduction as reported by Akilapa 2014[2] ranged from 11 to 50%. The indications included re-dislocation, residual subluxation, residual dysplasia, deformed femoral heads and osteoarthritis. Older patients at the time of surgery were more likely to have additional operations. The included study reported higher rate of needing an operation in children who had reductions over the age of 12 months compared to those who had reduction under the age of 12 months.[2]

A statistically significant difference favouring open reduction over closed reduction was reported by Wang 2016[7] (OR 0.30; 95% CI 0.15 to 0.60). This is likely to be clinically relevant. Critically, in three of the included studies by this review the reduction was delayed, as patients were older than 13 months, and the likelihood of further surgery showed an increase. Additionally, the majority of patients in the open surgery cohort were patients who had suffered from the failure of a previous closed reduction. The review notes how younger children had a lower risk for both AVN and further surgery. However determining the preferred treatment for children aged 18 to 36 months remains unclear.[7]

The risk of further procedures in children that had been intervened via anterior open reduction and pelvic and/or femoral osteotomy was evaluated by Kothari 2016[3]. The findings reported a higher risk resulted from open reduction alone and open reduction with femoral osteotomy compared with both of the other groups. No statistically significant difference was observed in the open reduction and pelvic osteotomy group compared with open reduction and double osteotomy. As with the AVN risk, the risk of further procedures seems to not tally with the chance of a good radiological or clinical outcome, perhaps the risk of further procedures has to do with the higher AVN risk. Authors conclude that anterior open reduction alone causes an unacceptable high risk of further procedure.[3] The pooled odds ratios illustrating these findings are contained in Table 13.

Table 13: Risk of further procedures needed after surgical interventions

Results given as OR (95% CI)					
AOR versus AOR/P	**AOR versus AOR/F**	**AOR versus AOR/F/P**	**AOR/P versus AOR/F**	**AOR/P versus AOR/F/P**	**AOR/F versus AOR/F/P**
10.13 (3.47–29.59), p < 0.001*	3.02 (0.99–9.24), p = 0.078	14.51 (4.14–50.86), p < 0.001*	0.30 (0.15–0.58), p < 0.001*	1.43 (0.60–3.45), p = 0.415	4.80 (1.89–12.21), p < 0.001

From Kothari 2016[3], Table 5
* Level of significance adjusted to α < 0.003
AOR = anterior open reduction; CI = confidence intervals; F = femoral osteotomy; OR = odds ratio; P = pelvic osteotomy

c) Other side effects

Risk of osteoporosis: A health technology assessment (HTA) in 2017[8] reported on results of interviews with parents of children with hip dysplasia. The HTA reported that treatment in infancy was essential to preventing problems in later life, including osteoarthritis. However, this was a qualitative outcome, and not something they measured quantitatively.

Impacts on daily life are reported in FAQ 4.

FAQ 3: EVIDENCE SUMMARY

What are the risks of complications or further procedures?

Watchful waiting: The prime risk of watchful waiting is the potential reduction in effectiveness of delayed or deferred treatment

Hip abduction braces: No specific risks were found in regard of hip abduction braces, nor any significant differences between different types of brace.

Hip spica cast: No specific risks (including the need for further surgery) were found in regard of hip spica casts used in isolation of other treatments.

Traction: Studies evaluating the risks of avascular necrosis found no clear differences associated with traction as opposed to no traction. No evidence was found in regard of the need for surgical intervention required after traction.

Closed and open reduction: One review found no association between the time of the intervention or a medial versus anterior surgical approach. This suggests no rationale for delaying procedures based on potential risks of avascular necrosis. A systematic review which compared open vs closed reduction concluded that there was less risk of avascular necrosis with closed reduction. However another review suggested that open reduction with concomitant pelvic osteotomy was the most appropriate option for a range of outcomes including risks of avascular necrosis. The rate of secondary operations in children who had undergone medial open reduction ranged from 11 to 50%. The indications included re-dislocation, residual subluxation, residual dysplasia, deformed femoral heads and osteoarthritis. The study which provided this evidence also suggested that the need for re-operation was greater when children were originally operated on after 12 months of age compared to younger ages. A further study suggested that re-operation was more likely with closed reduction compared to open reduction. Addition of femoral osteotomy to open reduction was found to reduce the risk of further operations when compared to open reduction alone. Indeed the study concluded conclude that anterior open reduction alone causes an unacceptable high risk of further procedure

Overview: The risk of AVN and a (possibly secondary) operation varies depending on the time when treatment is initiated (i.e. the age of the child) and the choice of the initial procedure. A number of studies have evaluated the difference in risk resulting from the choice of surgical procedure. However, the broad range of variables and risk of bias from the primary evidence impedes establishing a specific form of intervention as dominant over other. On the other hand, the age of the child and the time of treatment initiation have been reported as determining factors on the subsequent risk of AVN and need for further surgery.

Later risk of osteoarthritis seems lower with earlier treatment start, although no firm numbers are available on this.

Taken together, the various risks of complications seem to favour earlier treatment start.

Not treating an unhealthy hip comes at the risk of pain and osteoarthritis (starting in teenage years) as well as potentially severely impacted gait (starting at walking age).

FAQ 4: How does the treatment impact daily life of child and carer?

a) Is the treatment wearing for the child? What are the challenges in implementation of treatment at home, and treatment adherence?

Evidence was found for hip spica cast and to a lesser degree hip abduction braces. The vast difference between the two is that the hip spica cast does not come off all the while it is employed impacting cleanliness to a much higher degree than would the implementation of hip abduction braces. Hip abduction braces would however still impact the positions of the child, such as car seat, choice of pram, breast feeding etc.

Watchful waiting

Not applicable, no intervention is employed

Traction

Traction will impact the child and the parents, as it takes place in hospital and the child needs to stay in bed for the duration. This impacts time of carers, feeding and nappy change. The child may also become bored. No specific change is required to the home from the traction alone, however, since traction is usually followed by hip spica cast, the impact of that intervention would subsequently apply.

Closed and open reduction

Closed and open reduction would impact the child during the procedure, but in itself less so the daily life after that. However, since closed or open reduction is usually followed by hip spica cast, the impact of that intervention would subsequently apply.

Hip abduction braces and hip spica cast

Williams 2017[8] reports important feedback from parents on the impact of treatment from a randomised controlled trial comparing the benefits (or otherwise) associated with delay to surgery for children aged 12 weeks to 13 months. Although this trial suffered from poor recruitment of patients due to lack of suitable patients, feedback from the 14 parents (nine with early treatment and five with delayed treatment) offers some insight into impact of a hip abduction braces or a spica cast on daily life.

Patients were randomised to two groups; those who had early treatment and those whose treatment was delayed until two to four weeks following the appearance of the ossific nucleus (ON). It is worth noting that patients in this trial all underwent surgery but carers reported aspects of daily life that were influenced by use of traction and/or casts as part of treatment. Furthermore, the patient group consists of patients aged between three and 13 months who have either presented late (aged >3 months) or have previously failed treatment with a hip abduction brace (aged 2 – 12 weeks). Whilst this is a different population to that identified in the rest of this review, it is felt that some of the reported treatment impacts are likely to be of some relevance. It should be noted, however, that effects may be more serious/severe for the patients and carers in this trial than might be anticipated for those diagnosed earlier.

No material differences were evidenced between alternative treatments. However, important daily life impacts have been reported for children being treated for hip dysplasia.

Hygiene (nappies and washing)

Interviews with parents, reported by Williams 2017[8], revealed particular problems of looking after a child for a minimum of 12 weeks in a waist–ankle hip spica plaster cast. These included concerns

over fragility of the cast, especially if exposed to moisture; personal hygiene and bathing were significant and common themes. Nappies must be changed very frequently - two to three per hour, day and night, to prevent the plaster becoming wet and soiled. This is important to prevent the child developing sores under the plaster and to stop the plaster from smelling. If the plaster does become wet, kitchen paper can be used to dry the inside of the plaster, or leave nappies off for short periods. Parents often use baby wipes as these do not soak the plaster. In the event of sores developing, creams can be used but talc should not be. The gap between skin and spica cast opening can be sealed off with waterproof tape to keep the inside clean and dry, particularly around the nappy area when bathing.[13]

Clothing

Clothing needs to be larger than would otherwise be the case in order to accommodate the hip spica cast.

Feeding

Frequent smaller meals may prevent bloating which might make the plaster uncomfortable to wear. Care should also be taken so that food residue does not fall into the plaster which might cause irritation. Fluid intake should be increased to prevent constipation.

Playtime

Beanbags/bouncy chairs are helpful in positioning the child to allow them to play.

Anaesthesia and multiple surgeries

Daily life will be disrupted as a result of surgical procedures. Open reduction, femoral osteotomy[17] can involve three operations under general anaesthetic. The first involves injection of dye into the hip joint and an x-ray (arthrogram). Surgery will then proceed with a cut in the groin to enable the surgeon to free all the tight structures that are stopping the femoral head fitting in the socket correctly. At the end of surgery, a hip spica plaster will be applied. Operation two (six to eight weeks later) involves removal of the hip spica plaster. It is usually necessary to rotate the leg bone (femoral osteotomy) at this stage and this is held in place with metal pins and plate (external fixator). A further hip spica plaster is then applied. Operation three (12 to 14 weeks later) involves removal of the new hip spica plaster; a further arthrogram is performed to check the hip position is satisfactory. The metal pins and plate are then removed.

Positioning

Positioning should be changed frequently to prevent pressure sores.

Equipment

The child will not be able to use a normal narrow pram, car seat, and high chair with a spica cast, and even with a brace, it can be beneficial to use equipment with extra space for legs in a wide angle. Please see kinderhueftdysplasie.de[15] for links to hip abduction and cast friendly equipment in Germany.

Psychological/emotional impact

When interviewed, parents in the study reported by Williams 2017[8], described treatment as an "emotional rollercoaster" and some felt that the child's condition and/or treatment was regarded as detrimental to their own mental well-being.

Employment and leave

Interviews with parents, reported by Williams 2017[8], revealed high levels of employment-related costs which might be incurred as a result of treatment for developmental dysplasia of the hip. Much will depend on the specific circumstances of parents in relation to employment type, employer policies and access to informal care e.g. through extended family networks. Parental and annual leave are often required to support and care for the child during key treatment phases. In some instances, employment opportunities (e.g. promotion) might be compromised as a result of prolonged or frequent periods of leave.

Childcare requirements

Often periods of informal or paid childcare are required when parents have work commitments or sometimes respite requirements.

Out of pocket expenses

Extra equipment might be required e.g. car seats need to be appropriate to manage any casts (low sided). There are also likely to be travel, accommodation and subsistence costs associated with hospital visits.

Familial relationships

Interviews with parents, reported by Williams 2017[8], revealed that relationships were sometimes strained within the family as a result of increased stress and worry.

Carer physical health

Some physical health detriment was reported in parents interviewed in the study reported by Williams 2017[8]. For some, moving and handling their child with the weight and awkwardness of the cast contributed to shoulder and/or back pain.

b) How long will the child have to spend in hospital?

Watchful waiting

Not applicable, no intervention is employed

Hip abduction braces

Not applicable, the braces would be given at a visit, not requiring hospital stay

Hip spica cast

No evidence was found on the hospital length of stay for application of a hip spica cast. However, it would usually be applied as part of another intervention such as traction, and/or closed or open reduction.

Closed reduction and traction

Li 2018[4] reported on length of hospital stay with closed reduction with or without preceding traction (combining numbers from overhead or longitudinal traction in 276 patients). Traction would take place in hospital, so that would add considerable time to the hospital stay as evidenced in Table 5 of FAQ 1 with an average of five days total for closed reduction without traction and almost 16 days for closed reduction preceded by traction, i.e. approximately 11 days for traction alone.

Open reduction

No evidence was found on the hospital length of stay for open reduction, but presumably a mean of at least 5 days, since that was the mean length of hospital stay for closed reduction without preceding traction.[4]

FAQ 4: EVIDENCE SUMMARY

How does the treatment impact my daily life and that of my child?

Watchful waiting: There are no implications with watchful waiting

Hip abduction braces: Many of the issues relating to a hip spica cast also apply to hip abduction braces. However, unlike a hip spica cast, braces can be given outside of a hospital setting.

Hip spica cast: Hip dysplasia treatment will affect the child's ability to move about, but most children find a way to get about even with a cast. As it is very important to keep the inside of the cast clean, there is a large burden on carers to change nappies very often, heavy lifting due to the extra weight of the cast, and the costs associated with special equipment (strollers, car seat, extra amount of nappies, extra amount of wet wipes for cleaning, special clothes etc.), time spent in transport to, from and in hospital.

Traction: Traction is undertaken in hospital and can become boring. Additional care time will be needed for feeding and nappy change.

Closed and open reduction: Daily life is largely unaffected after the procedure, unless other treatments are deployed like hip spica casts. Daily life will be disrupted due to hospital attendance as would be the case for most other surgical procedures.

Overview: Caring for a child during hip dysplasia treatment will impact the daily life and of the carer in many ways from having to change nappies very frequently to lifting a child who is much heavier than usual because of a cast.

Caring for a child in hip dysplasia treatment is a lot of work, but it is doable, and it is important for the child's hip health the rest of the child's life.

3.3 ASSESSMENT OF THE CLINICAL REVIEW EVIDENCE

Table 14 provides an overview of the key clinical evidence sources used in this review to answer the FAQs.

Table 14: Overview of key clinical evidence sources answering the FAQs

Study ID	Participants	Interventions	Outcomes	Study Design	Quality of evidence
AAOS American Academy of Orthopaedic Surgeons 2014[1]	Birth-6 months	Diagnosis and treatment	Detection and non-operative management of paediatric developmental dysplasia of the hip in infants up to six months of age	Guidelines	High quality review identifying low to moderate quality evidence
Akilapa 2014[2]	Not extracted	Medial vs anterior open reduction	Avascular necrosis risk	SR (Observational)	Review of moderate quality evidence (1996-2012))
Biedermann 2018[9]	Neonates who were screened within six weeks after birth	Hip screening and classification of hip dysplasia, treatment for hip dysplasia	Time to normal hip, first operations on the hip, radiological signs of avascular necrosis	Real world evidence	Low quality evidence of effectiveness, main focus incidence
Kothari 2016[3]	Age range [12 months-6 years]	Open reduction vs (Open reduction with pelvic/femoral osteotomy)	Avascular necrosis incidence; clinical outcome; radiological outcome; further procedures	SR (Observational)	The main limitation of the review was that the literature identified comprised retrospective studies of mixed quality with inherent bias.
Li 2018[4]	6-24 months	Traction vs No traction	Osteonecrosis	SR (Observational)	Rigorous review but based on observational studies

Study ID	Participants	Interventions	Outcomes	Study Design	Quality of evidence
Novais 2016[5]	Unclear	Timing: Age (as a prognostic factor); medial vs anterior reduction	Osteonecrosis	SR (Observational)	The majority of the studies including in this meta-analysis were rated as being of poor methodologic quality.
Park 2018[6]	Age range [1.5-55] months	Traction vs No traction	Avascular necrosis incidence	SR (Observational)	There was insufficient evidence to determine efficacy of different interventions.
Shorter 2013[10]	Maximum of 23,530	Screening	Incidence of late diagnosed DDH (> eight weeks of age diagnosed by either clinical examination, ultrasound or x-ray) for which either medical or surgical intervention was required.	SR of Randomised, quasi-randomised controlled trials and cluster randomised trials comparing the effectiveness of different types of screening programme.	Main limitation is focus on screening rather than intervention. Furthermore, screening processes (i.e. screening tests and timing) may not reflect German practice. Subsequent interventions were rarely described. Studies were substantially underpowered to detect significant differences in the uncommon event of late detected DDH or surgery. Quality of the evidence based on GRADE was not used.

Study ID	Participants	Interventions	Outcomes	Study Design	Quality of evidence
Wang 2016[7]	Birth-3 years	Open vs closed reduction	Avascular necrosis incidence	SR (Observational)	Review based on observational studies that identified largely unexplained effects.
Williams 2017[8]	[12 weeks-13 months]	Timing: Delayed vs Early surgery	Avascular necrosis incidence	RCT	The major limitation is that the study closed without recruiting a sufficient number of patients to answer the trial question.
RCT = randomized controlled trial; SR = systematic review					

4. DISCUSSION

4.1 STRENGTHS, LIMITATIONS AND UNCERTAINTIES

This report was primarily developed based on evidence from systematic reviews and guidelines.

German and European guidelines were intended to be prioritized. However, no European and only a 2002 consensus-based guideline by the Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften (AWMF) were found. Therefore the results from the American 2014 guideline[1] were used. The AWMF is currently preparing an updated evidence-based guideline on hip dysplasia. However, it is not yet available.

This report is also based on some primary literature and web-based ley language guidance, as many of the impacts on daily life outcomes are not yet covered by the clinical literature.

Overall, evidence for the topic of hip dysplasia has been sparse, though, particularly with regards to choice of type of hip abduction braces. Presented in this report is the available evidence. General information was used from two protocols Walton 2018,[20] and Dwan 2017.[24] One[20] is elucidating the use of traction, which seems to be a debated treatment, and the other[24] looking into the choice of hip abduction brace, which is equally debated with the convenient Pavlik harness still widely used though it has a relatively high risk of avascular necrosis.

The overarching results from all four frequently asked questions seem to be that treatment should be started as early as possible. It will be inconvenient, but by starting early the risk of needing more invasive interventions like closed reduction or surgical intervention and subsequent hip spica cast might be reduced, while the chance of a complete normalisation of the hip is good. Not treating an unhealthy hip comes at the risk of pain and osteoarthritis already from the teenage years and in extreme cases severely impacted gait starting at walking age.

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APPENDIX 1: SEARCH STRATEGIES

Cochrane Database of Systematic Reviews (Wiley) - Issue 1 of 12, January 2019
Date searched: 16/01/2019
Records found: 1 (protocol)

ID	Search	Hits
#1	MeSH descriptor: [Hip Dislocation, Congenital] explode all trees	72
#2	(hip or hips) NEAR/3 (dislocat* OR dysplas* OR displace* OR sublux* OR sub-lux*):ti,ab,kw	385
#3	(congenital* OR developmental):ti,ab,kw	10463
#4	#2 AND #3	128
#5	(DDH OR CDH) AND (hip or hips or femur* or acetabul*):ti,ab,kw	33
#6	#1 OR #4 OR #5 Cochrane Library publication date Between Jan 2012 and Jan 2019 in Cochrane Reviews, Cochrane Protocols	1

CRD Databases
https://www.crd.york.ac.uk/CRDWeb/
Date searched: 16.1.19
Records found: DARE - 4; HTA - 1

1 MeSH DESCRIPTOR Hip Dislocation, Congenital EXPLODE ALL TREES 26
2 (((hip or hips) AND (congenital or developmental) AND (dislocat* OR dysplas* OR displace* OR sublux* OR sub-lux*))) 34
3 (((DDH OR CDH) AND (hip or hips or femur* or acetabul*))) 11
4 * IN DARE, HTA FROM 2012 TO 2019 28158
5 #1 OR #2 OR #3 35
6 #4 AND #5 5

KSR Evidence (Internet): 2012-2019/01/17
https://ksrevidence.com/
Limited 2012-2019
Searched 17.1.19

#	Query	Results
1	hip or hips in All text	1441
2	dislocat* OR dysplas* OR displace* OR sublux* in All text	1006
3	congenital* OR developmental in All text	1855
4	#1 and #2 and #3	18
5	CDH OR DDH in All text	28
6	#1 and #5	11
7	#4 or #6	18

Epistemonikos (Internet): 2012-2019/01/17
Searched 17.1.19
https://www.epistemonikos.org/en/
Limited 2012-2019

Limited to systematic reviews, Cochrane SRs omitted.
(title:((title:((hip OR hips) AND (dislocat* OR dysplas* OR displace* OR sublux* OR sub-lux*)) OR abstract:((hip OR hips) AND (dislocat* OR dysplas* OR displace* OR sublux* OR sub-lux*)))) OR abstract:((title:((hip OR hips) AND (dislocat* OR dysplas* OR displace* OR sublux* OR sub-lux*)) OR

abstract:((hip OR hips) AND (dislocat* OR dysplas* OR displace* OR sublux* OR sub-lux*))))) AND (title:((congenital* OR developmental)) OR abstract:((congenital* OR developmental)))
Retrieved 31 records

Guidelines International Network
https://www.g-i-n.net/library/international-guidelines-library
2012-16.1.19

Search Terms	Records Retrieved
Hip dysplasia	5
Developmental dysplasia	4 (retrieved in previous search)
Congenital hip	1 (retrieved in previous search)
DDH or CDH	0
Total	5

National Institute for Health and Care Excellence (NICE): Guidelines
Searched 16.1.19
https://www.nice.org.uk/

Searched for guidance under hip conditions:
No relevant results

NICE Evidence
Searched 16.1.19
https://www.evidence.nhs.uk/

Guidance 58 records
Systematic Reviews 23 records
Screened and exported 22 records to Endnote – excluded records obviously not relevant

ECRI Guidelines Trust (Internet): up to 2019/01/16
Searched 16.1.19
https://guidelines.ecri.org/

searched hip dysplasia

4 records retrieved (duplicates from other resources no need to screen)

APPENDIX 2: GRAF CLASSIFICATION SYSTEM

Table 15: Graf classification system explaining the hip types

Graf	Sonographic hip type	Bony roof	Ossific rim	Cartilage rim	Alpha angle
Ia	Mature	Good	Sharp	Long and narrow, extends far over femoral head	>60
Ib	Mature	Good	Usually blunt	Short and broad, but covers femoral head	>60
IIa	Physiological delay in ossification > 3months (physiological immature but stable hips)	Deficient	Rounded	Covers femoral head	50 - 59
IIb	Physiological delay in ossification > 3months (inherently stable)	Deficient	Rounded	Covers femoral head	50 - 59
IIc	On point of dislocation (unstable, requires immediate treatment)	Deficient	Rounded or flat	Covers femoral head	43 - 49
IId	On point of dislocation	Severely deficient	Rounded or flat	Compressed	43 - 49
IIIa	Dislocated (subluxation)	Poor	Flat	Displaced upwards and echo poor	<43
IIIb	Dislocated (subluxation)	Poor	Flat	Displaced upwards and more reflective than femoral head	<43
IV	Dislocated (complete)	Poor	Flat	Interposed	<43

Reference: Karnik 2007[26]. More detailed information on the classification system is taken from Robben 201715 (http://www.radiologyassistant.nl/en/p54ba2c50995c5/developmental-dysplasia-of-the-hip-ultrasound.html), which also contains helpful figures and explanations. This covers Type IIa+ (still within acceptable limits for age) and Type IIa- (at risk to develop dysplasia).

Table 16: Summary of recommendations according to hip sonographic type

Phase	Graf Type	Recommendation	Alternative
Degreening (stable, "dysplastic" joints)	Stable IIc Special status: Unstable IIc in the new-born	Reduction orthosis [hip abduction braces] such as: Mittelmeier-Graf straddle bandage (MG) (Size I-III) Treatment trial with MG straddle bandage for 4 weeks see above	Reduction orthosis (hip abduction braces) such as: Splints, Bernau, Fettweisorthese, Hilgenreiner optimal splint, etc.
Retention (formerly dislocated, reduced and/or unstable joints)	Unstable IIc Exception: Unstable IIc in new-born, see post-maturity phase	Seat-squat plaster [hip spica cast] (for 4 weeks)	Retention orthosis [hip abduction braces permitting less movement]: plaster, Fettweisorthese, Düsseldorf harness etc.
Reduction	III–IV	Overhead extension	Reduction Orthosis [hip

Phase	Graf Type	Recommendation	Alternative
("Dislocated" joints)	Type D	[traction] or manual closed reduction. Differential Therapeutic Decision: Sonography	abduction braces permitting less movement]: Hanausek, Düsseldorfer harness; Fettweisorthese etc.
Reference: Graf 2004[25], modified with [text] to unify to wording in the rest of the report. This table excludes watchful waiting for the mildest forms (IIa) and those solely apt for the most severe forms			

APPENDIX 3: TABLES OF MORE IN DEPTH INFORMATION

Table 17: Description of devices employed towards conservative interventions

Form of intervention	Device
Spreading treatment / reduction	Tübinger Hüftbeugeschiene/Tübinger Spreizschiene (Coxaflex, Lörracher Bewegungsschiene, Correctio Beugeschiene); Mittelmeier-Graf-Schiene (a.k.a. Idealspreizhose, Mittelmeier-Graf (MG)-Spreizhose); Becker / Becker-Mittelmeier Spreizhose; Bernau; Hanausek Repositionsorthese; von Rosen splint; Erlanger Beuge-Spreiz Orthese; Hilgenreiner Optimalschienen
Retention/reduction depending on use of bar	Hoffman-Daimler Spreizschiene
Retention / immobilization	Düsseldorfer harness; Fettweisorthese
Longitudinal traction / overhead extension	Unnamed; Bryant's
Based on kinderhueftdysplasie.de[15] and hipdysplasia.org[13]	

Radiological (majority of reported studies using Severin score) and clinical outcomes (Based on 15 studies: 13 using the McKay score,[27] 1 using a modified score, and 1 using the Iowa Hip Score[23]) of open reductions with or without concomitant pelvic and/or femoral osteotomy were compared in a meta-analysis from 2016 (based on 18 studies: 17 cohort studies, 1 case series; Quality assessment based on Centre of Evidence Based Medicine case study appraisal tool. Included studies fulfilled between 4 and 9 of 10 quality questions (mean 6.8)).[3] Open reduction alone was associated with a higher odds of a satisfactory radiological result compared with open reduction with both pelvic and femoral osteotomies. Similarly, this review reported increased odds of a satisfactory clinical outcome for open reduction versus reduction with pelvic and/or femoral osteotomy.

Table 18: Difference in radiological and clinical outcomes between surgical interventions

	Results given as OR (95% CI)					
Parameter	**AOR versus AOR/P**	**AOR versus AOR/F**	**AOR versus AOR/F/P**	**AOR/P versus AOR/F**	**AOR/P versus AOR/F/P**	**AOR/F versus AOR/F/P**
Radiological outcome	4.38 (1.04–18.55), p = 0.029	1.76 (0.15–20.51), p = 0.539	6.83 (1.63–28.63), p = 0.001	0.40 (0.05–3.08), p = 0.713	1.56 (1.02–2.38), p = 0.044	3.88 (0.51–29.5), p = 0.220
Clinical outcome	19.07 (1.15–316.02), p = 0.001	117.00 (4.35–3139.68), p = 0.003	19.33 (1.18–318.01), p = 0.001	6.21 (0.85–45.64), p = 0.101	1.02 (0.63–1.64), p = 1.000	0.16 (0.02–1.19), p =0.102
From Kothari 2016[3], table 5 AOR = anterior open reduction; CI = confidence intervals; F = femoral osteotomy; OR = odds ratio; P = pelvic						

	Results given as OR (95% CI)					
Parameter	**AOR versus AOR/P**	**AOR versus AOR/F**	**AOR versus AOR/F/P**	**AOR/P versus AOR/F**	**AOR/P versus AOR/F/P**	**AOR/F versus AOR/F/P**
osteotomy						

Low quality evidence from 2002 was identified, but success rates from a study comparing different hip abduction braces to no treatment found that 10 of 37 (27%) children with no treatment needed hip spica cast after six to 12 months, while children in a hip abduction brace, the number was 17 of 97 (18%).[31,1] Success rates with hip abduction braces seem to have improved since then, see Table 4.

Treatment with the von Rosen splint had overall better outcomes than those treated with the Craig splint, those with no treatment or those treated with Pavlik harness (which is excluded here for side effect reasons).[31,1]

An older study from 1988 compared the von Rosen splint to the Frejka pillow and found the von Rosen splint to have a relatively lower incidence of treatment failure.[31,1]

Table 19: Comparison of outcomes between various splint treatments

Outcomes	Results	
	Craig splint N = 28 vs. no treatment N = 37	**von Rosen splint N = 26 vs. no treatment N = 37**
Mean (+/-) improvement on ultrasound between 1st exam and 12-20 weeks	SWMD= 0.14 (-0.20, 0.44)	SWMD= -0.64 (-1.20, 0.02)
Acetabular angle ≥ 28 degrees at 6-12 months (radiograph)	RD= -0.07 (-0.29, 0.16)	RD= -0.27 (-0.46, -0.09) favouring von Rosen splint over no treatment
C/B ratio >.75 at 6-12 months (radiograph)	RD= 0.08 (-0.16, 0.33)	RD= 0.05 (-0.20, 0.30)
Moderately dysplastic or worse hips at 6-12 months (radiograph)	RD= -0.02 (-0.20, 0.16)	RD= -0.16 (-0.28, -0.04) favouring von Rosen splint over no treatment
Further treatment (Plaster) at 6-12 months	Craig splint: n = 3 (10.7%) vs. no treatment n = 8 (21.6%) RD= -0.11 (-0.11, -0.11) favouring Craig splint over no treatment	von Rosen splint n = 0 (0%) vs. no treatment n = 8 (21.6%) RD= -0.22 (-0.35, -0.08) favouring von Rosen splint over no treatment
Further treatment (Operation) at 6-12 months	Craig splint n = 1 vs. no treatment n = 2 RD= -0.02 (-0.02, -0.02) favouring Craig splint over no treatment	von Rosen splint n = 0 vs. no treatment n = 2 RD= -0.05 (-0.13, 0.02) favouring von Rosen splint over no treatment
	Overall favouring von Rosen splint over Craig splint over no treatment	
	von Rosen splint N = 180 vs. Frejka pillow N = 920	
Treatment failure, follow up to walking age	von Rosen splint n = 1 (0.6%) vs Frejka pillow n = 55 (6.0%); RR=0.09 (0.013, 0.667) Favouring von Rosen splint over Frejka pillow	
Traction and plastering at 3 years	RR=0.100 (0.014, 0.721) Favouring von Rosen splint over Frejka pillow	

From AAOS 2014[1], Table 43 and 46. Based on low strength of evidence (GRADE) from Heikkila 1988[32] and Wilkinson 2002[31]. Results from 134 hips in 96 children with Graf type-III or type-IV dysplasia: 28 affected hips in 22 children with the Craig splint, 43 hips in 30 children with the Pavlik harness, and 26 hips in 16 children with the von Rosen splint. A total of 37 affected hips in 28 children was not splinted. All children were less than three months of age at referral. Pavlik numbers have been subtracted due to exclusion for high risk of AVN.

#hips = number of hips; AVN = avascular necrosis; GRADE = Grading of Recommendations Assessment, Development and Evaluation; N = number of patients for the von Rosen splint vs Frejka pillow comparison, number of hips in the Craig splint vs von Rosen splint vs no treatment comparison; n = number of events; RD = risk difference; SWMD = standardised weighted mean difference