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# Subtalar arthroereisis for the treatment of the symptomatic paediatric flexible pes planus: a systematic review

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- Subtalar arthroereisis has a controversial history and has previously been associated with high failure rates and excessive complications.
- A database search for outcomes of arthroereisis for the treatment of symptomatic paediatric flexible pes planus provided 24 articles which were included in this review, with a total of 2550 feet operated on.
- Post-operative patient-reported outcome measures recorded marked improvement. Patient satisfaction was reported as excellent in 79.9%, and poor in 5.3%. All radiological measurements demonstrated improvement towards the normal range following arthroereisis, as did hindfoot valgus, supination, dorsiflexion and Viladot grade.
- Complications were reported in 7.1% of cases, with a reoperation rate of 3.1%.
- Arthroereisis as a treatment for symptomatic paediatric flexible pes planus produces favourable outcomes and high patient satisfaction rates with a reasonable risk profile. There is still a great deal of negativity and literature highlighting the complications and failures of arthroereisis, especially for older implants.
- The biggest flaws in the collective literature are the lack of high-quality prospective studies, a paucity of long-term data and the heterogeneity of utilized outcome measures between studies.

**Keywords:** arthroereisis; flatfoot; flexible; paediatric; pes planus

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## Introduction

Pes planus occurs as a result of loss of the medial longitudinal arch, abduction of the forefoot and excessive subtalar eversion. It can broadly be categorized as rigid or flexible. The rigid form is usually pathological,[1] often caused by genetic, neurological, inflammatory, rheumatological, traumatic or osseous abnormalities.[2] Flexible pes planus has no single identifiable cause and is often asymptomatic.[1–3] It can become painful and may require orthopaedic or podiatric intervention. Common treatment modalities include rest, physiotherapy, orthotics and anti-inflammatories.[1,3–5] Surgery is uncommon unless pain persists in spite of non-surgical management.[3–5] Surgical options include soft tissue procedures, realignment osteotomies and non-fusion motion-limiting techniques.[1,2,5–8] Fusion of selected joints in the foot is not recommended in paediatric patients unless associated with a neuromuscular pathology.[1,4]

Subtalar arthroereisis is a recognized non-fusion surgical treatment for symptomatic paediatric flexible pes planus. Arthroereisis (also arthroreisis, arthrorhisis or arthrorisis) derives from Greek, translated as to prop up or support a joint.[9] The procedure involves correcting the excessive eversion and maintaining the subtalar joint in a more neutral position using an implant inserted into the sinus tarsi or adjacent to it. The technique was first described by Chambers in 1946.[10] Subtalar arthroereisis became popular in the 1970s but has since fallen in and out of fashion. A survey of American Orthopedic Foot & Ankle Society (AOFAS) members conducted by Shah et al in 2013 found that subtalar arthroereisis is still performed by many practitioners. However, many had ceased performing the procedure, with high failure rates quoted as the primary reason.[11]

**Table 1.** Description of radiological measurements relevant to pes planus

| Measurement | Description | Normal range |
|---|---|---|
| Talonavicular coverage angle | The angle formed between a line connecting the edges of the articular surface of the talus and the articular surface of the navicular | 0° to 7° |
| Antero-posterior talar–1st metatarsal angle | The angle formed from a line through the mid-axis of the talus and the long axis of the 1st metatarsal | 3° to 11° |
| Lateral talar–1st metatarsal angle (Meary's angle) | The angle formed from the bisection of the long axis of the talus and the 1st metatarsal | 2° to 10° |
| Calcaneal inclination | The angle formed between a line from the plantar surface of the calcaneus to the inferior distal articular surface and the transverse plan | 13° to 23° |
| Talar declination | The angle formed between a line drawn along the long axis of the talus and the transverse plane | 18° to 24° |
| Lateral talocalcaneal angle | The angle formed between a line bisecting the talus and a line from the plantar surface of the calcaneus to the inferior distal articular surface | 25° to 45° |
| Moreau-Costa-Bartani angle | The angle formed between a line from the inferior posterior calcaneal tuberosity to the inferior border of the talonavicular joint and a line from the medial sesamoid to the inferior border of the talonavicular joint | 115° to 125° |
| Antero-posterior talocalcaneal angle (Kite's angle) | The angle formed by a line bisecting the head and neck of the talus and a line along the lateral surface of the calcaneus | 15° to 27° |
| Cyma line | A line drawn along the talonavicular joint and calcaneocuboid joint | Smooth double curve |

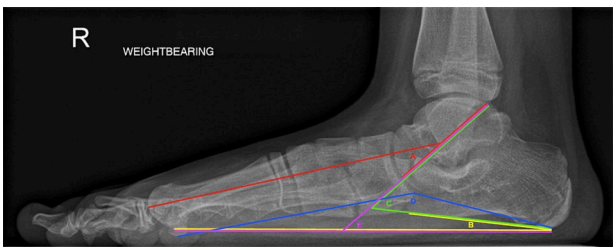


**Fig. 1** Radiological measurements from a weight-bearing lateral foot radiograph. Lateral talar 1st metatarsal angle: red (A); Calcaneal inclination: yellow (B); Lateral talocalcaneal angle: green (C); Moreau-Costa-Bartani angle: blue (D); Talar declination; pink (E).

There are two techniques for subtalar arthroereisis: (1) Insertion of an implant directly into the sinus tarsi to prevent it collapsing down.[12–24] (2) Screw insertion into the lateral side of either the talus[25] or calcaneus[17,19,26–35] while the foot is corrected to a neutral position; the screw head abuts the subtalar joint, preventing eversion. The implants are commonly made of metal or resorbable poly-L-lactic acid (PLLA).

Routine radiological imaging is not essential,[3,36] but can be helpful in excluding other pathologies and for surgical planning. Radiographs should always include weight-bearing antero-posterior (AP), lateral and oblique views of the foot and ankle.[3] Multiple measurements can be performed on plain radiographs to quantify midfoot and forefoot abduction, the loss of the longitudinal arch and hindfoot valgus (Table 1, Fig. 1 and Fig. 2). Cross-sectional imaging can also be utilized to further investigate for conditions such as degenerative changes, tarsal coalitions, tendinopathies or an accessory navicular.[2]

A previous review by Metcalfe et al found many studies reporting improvements in radiological outcomes and high satisfaction rates among patients. They acknowledge there is a lack of evidence for the indications of arthroereisis

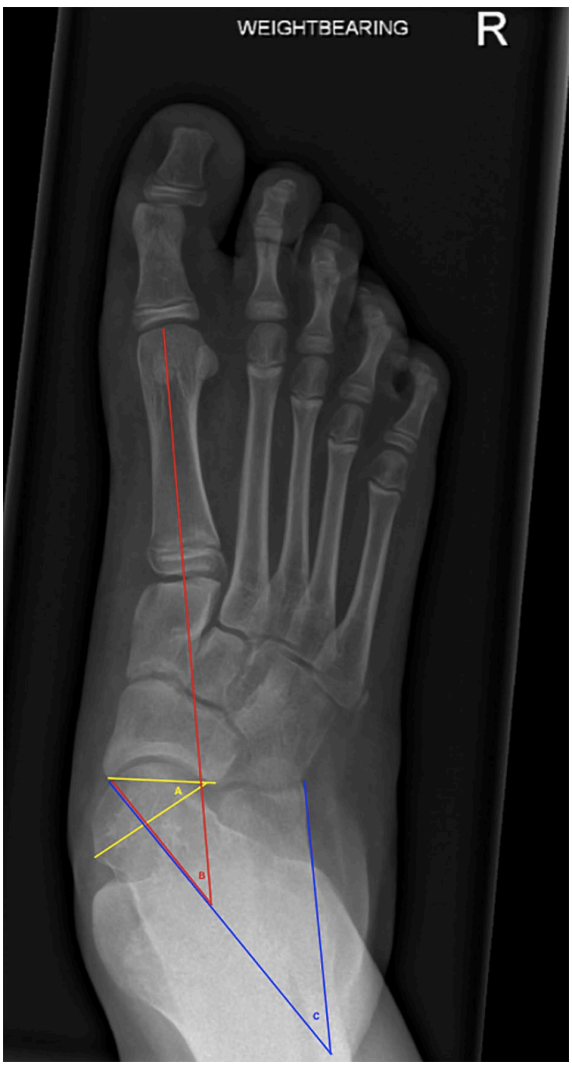


**Fig. 2** Radiological measurements from a weight-bearing antero-posterior (AP) foot radiograph. Talonavicular coverage angle: yellow (A); AP talar 1st metatarsal angle: red (B); AP talocalcaneal angle: blue (C).

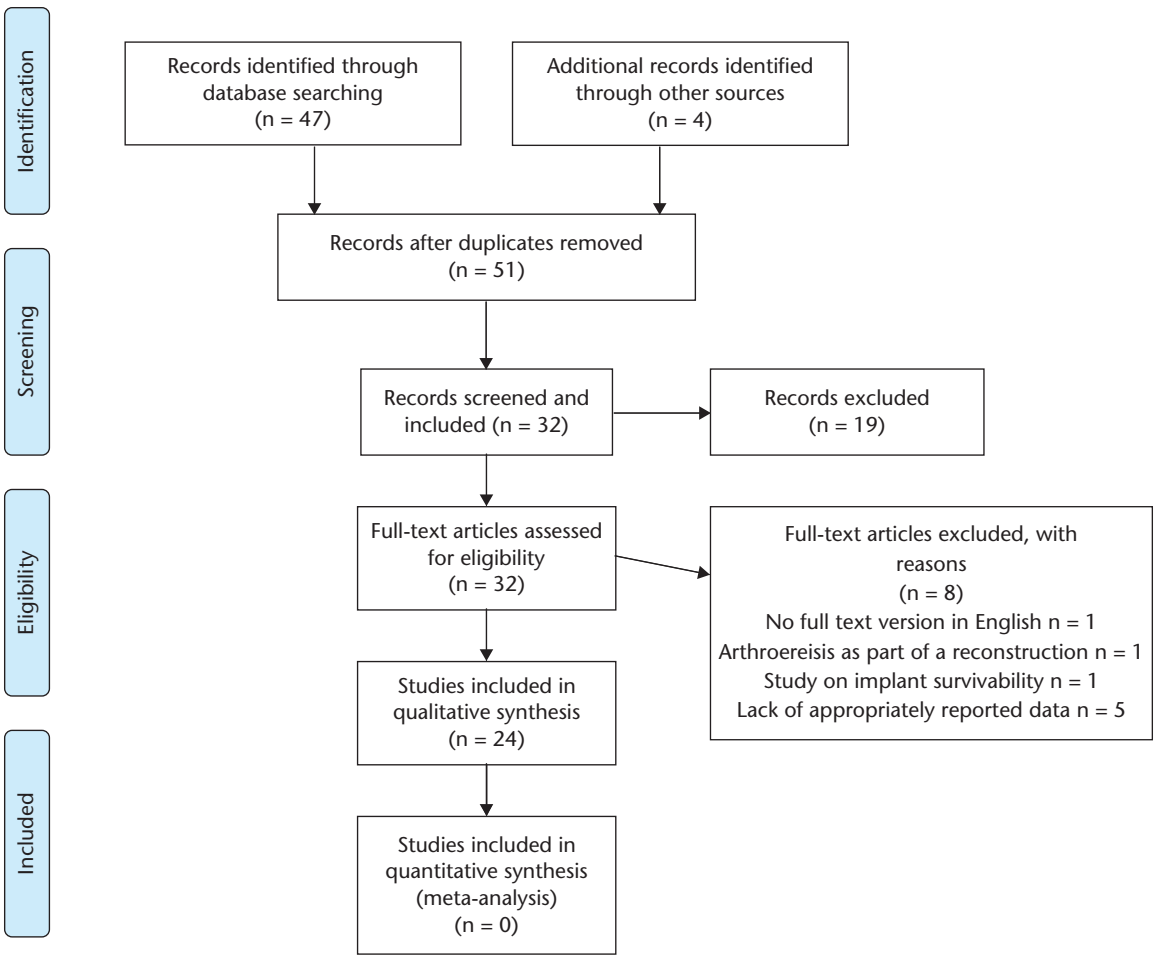


**Fig. 3** PRISMA flow diagram for the results of the search strategy.

***Source***: Reproduced from Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. *PLoS Med* 6(6): e1000097. doi:10.1371/journal.pmed1000097.

and studies they included lacked standardization and did not use disease-specific validated outcome tools.[37]

Although the technique is over 80 years old, there are still a lot of questions regarding the effectiveness of this procedure. The aim of this systematic review is to assess the outcomes of arthroereisis for the treatment of symptomatic paediatric flexible pes planus. Radiological, clinical and kinematic outcomes will be examined, as well as the reporting of complications of the procedure.

## Method

This systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

### *Search strategy*

A search was conducted using the online Cochrane Library, EMBASE, CINAHL, Medline and PubMed databases, using the following terms: subtalar[All Fields] AND arthroereisis[All Fields] AND (pediatric[All Fields] OR paediatric[All Fields]). The search was repeated using various alternative spellings for arthroereisis. No limitations were placed on gender, date or language. All results up until 1 June 2020 were included. References and bibliographies of all articles were reviewed to identify possible further relevant articles (see Fig. 3: PRISMA flow chart).

All articles were assessed against the following inclusion criteria:

- Primary subtalar arthroereisis for symptomatic paediatric flexible pes planus
- Prospective or retrospective studies

Exclusion criteria were as follows:

- Subtalar arthroereisis was not the primary intervention
- Studies including adults where data for paediatric patients was not readily separable

**Table 2.** Articles included in this study

| Author | Year | Journal | Study design | Level of evidence |
|---|---|---|---|---|
| Giannini et al[12] | 2001 | *Journal of Bone and Joint Surgery* | Retrospective case series | IV |
| Jerosch et al[26] | 2009 | *Foot and Ankle Surgery* | Retrospective case series | IV |
| Scharer et al[13] | 2010 | *Foot and Ankle Specialist* | Retrospective case series | IV |
| Kellerman et al[25] | 2011 | *Archives of Orthopaedic and Trauma Surgery* | Prospective case series | IV |
| Pavone et al[27] | 2013 | *Journal of Foot and Ankle Surgery* | Retrospective case series | IV |
| Richter et al[28] | 2013 | *Foot and Ankle Surgery* | Prospective case series | IV |
| De Pellegrin et al[29] | 2014 | *Journal of Children's Orthopaedics* | Retrospective case series | IV |
| Chong et al[14] | 2015 | *Journal of Paediatric Orthopaedics* | Prospective, non-randomized comparative | IIB |
| Martinelli et al[15] | 2018 | *Journal of Paediatric Orthopaedics* | Retrospective case series | IV |
| Cao et al[16] | 2017 | *Orthopaedic Surgery* | Retrospective case series | IV |
| Das et al[30] | 2017 | *Journal of Taibah University Medical Sciences* | Prospective case series | IV |
| Giannini et al[31] | 2017 | *Journal of Foot and Ankle Surgery* | Retrospective case series | IV |
| Arbab et al[32] | 2018 | *Zeitschrift für Orthopädie und Unfallchirurgie* | Retrospective case series | IV |
| Caravaggi et al[17] | 2018 | *Gait and Posture* | Prospective, non-randomized comparative | IIB |
| Memeo et al[19] | 2019 | *Journal of Foot and Ankle Surgery* | Retrospective, non-randomized comparative | III |
| De Bot et al[20] | 2019 | *Foot and Ankle Specialist* | Retrospective case series | IV |
| Ruiz-Picazo et al[21] | 2019 | *Advances in Orthopaedics* | Retrospective case series | IV |
| Megremis & Megremis[22] | 2019 | *Journal of Foot and Ankle Surgery* | Retrospective case series | IV |
| Papamerkouriou et al[23] | 2019 | *Cureus* | Prospective case series | IV |
| Hagen et al[33] | 2019 | *Clinical Biomechanics* | Prospective case series | IV |
| Bernasconi et al[24] | 2020 | *Orthopaedics and Traumatology* | Retrospective comparative | IV |
| Indino et al[18] | 2020 | *Foot and Ankle Surgery* | Retrospective case series | IV |
| Kubo et al[34] | 2020 | *Journal of Orthopaedic Science* | Retrospective comparative | IV |
| Franz et al[35] | 2020 | *Foot and Ankle Surgery* | Prospective case-control | III |

- Pathology other than flexible pes planus (e.g. tarsal coalition, neurogenic pes planus)
- Lack of reported meaningful radiological, kinematic or clinical outcomes
- Review articles or case reports
- No full text in the English language or easily translatable format

### *Data extraction*

All articles included underwent detailed review with the following data set assessed: number of patients, number of feet operated on, gender of patients, mean age of patients, age range of patients, implant details, concurrent procedures, post-operative care, follow-up, radiological outcomes, kinematic outcomes, clinical outcomes, complications, implant removal and loss of correction.

### *Assessment of methodological quality*

Methodological quality of articles was assessed using an abridged Downs and Black's criteria.[38] Fifteen criteria are assessed, with positive results scoring one mark and negative results scoring zero. The articles were independently assessed by two of the authors (CS and JB), with the senior author (MK) settling any disagreement. The level of evidence was also determined.

## Results

### *Search results*

Forty-seven articles were identified through the database search. Reviewing references identified four further articles. Application of the inclusion criteria resulted in 32 eligible articles. Eight studies were removed due to the exclusion criteria (no full text or translation in the English language $n = 1$; no results published in an interpretable format $n = 2$; no comparable pre-operative data available $n = 3$; focus on implant survivability instead of outcome $n = 1$; arthroereisis performed as part of a reconstruction $n = 1$), resulting in 24 studies being included in the final review (Fig. 3). The details of the included studies are shown in Table 2.

### *Methodological quality*

The results of the Downs and Black criteria for the 24 studies are displayed in Table 3. Three studies scored 11 out of 15[12,14,15], six studies scored 12 out of 15 [13,17,19,23,32,35], 10 studies scored 13 out of 15[18,20–22,24–26,28,29,33] and five studies scored 14 out of 15.[16,27,30,31,34] Five studies failed to specify any exclusion criteria.[12,13,23,26,29] Four studies failed to disclose sufficient detail of the surgical intervention so that an external group could repeat their methods.[14,17,19,35]

### *Study characteristics*

The 24 studies consist of five prospective case series,[23,25,28,30,33] 13 retrospective case series,[12,13,15,16,18,20–22,26,27,29,31,32], three prospective non-randomized comparative studies[14,17,35] and three retrospective non-randomized comparative studies.[19,24,34] A total of 2550 feet of at least 1399 patients were operated on (Memeo et al did not include number of participants, only the number of feet operated on). All studies stated the inclusion criteria were flexible pes planus with symptoms of pain or fatigue. Failure

**Table 3.** Downs and Black score of methodological quality for included studies. Y = positive result; N = negative result; ? = indeterminate result (counted as negative)

| Author | Objective described | Outcome described | Exclusion criteria described | Intervention described | Main findings reported | Adverse events | Random variability | Probability values | Representative sample invited to participate | Representative sample included | Lack of data dredging | Use of appropriate statistic | Accurate outcome measure | Confounders accounted for | Power calculation | Number of criteria met |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Giannini et al, 2001[12] | Y | Y | N | Y | Y | Y | Y | Y | ? | ? | Y | Y | Y | Y | N | 11 |
| Jerosch et al 2009[26] | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | 13 |
| Scharer et al, 2010[13] | Y | Y | N | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | N | 12 |
| Kellerman et al, 2011[25] | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | N | 13 |
| Pavone et al, 2013[27] | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | 14 |
| Richter et al, 2013[28] | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | N | 13 |
| De Pellegrin et al, 2014[29] | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | 13 |
| Chong et al, 2015[14] | Y | Y | Y | N | Y | Y | N | Y | Y | Y | Y | Y | N | Y | N | 11 |
| Martinelli et al, 2018[15] | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | N | Y | N | Y | N | 11 |
| Cao et al, 2017[16] | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | 14 |
| Das et al, 2017[30] | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | 14 |
| Giannini et al, 2017[31] | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | 14 |
| Arbab et al, 2018[32] | Y | Y | Y | Y | Y | Y | N | N | Y | Y | Y | Y | Y | Y | N | 12 |
| Caravaggi et al, 2018[17] | Y | Y | Y | N | Y | N | Y | Y | Y | Y | Y | Y | Y | Y | N | 12 |
| Memeo et al, 2019[10] | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | N | 12 |
| De Bot et al, 2019[20] | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | N | Y | Y | 13 |
| Ruiz-Picazo et al, 2019[21] | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | N | 13 |
| Megremis & Megremis, 2019[22] | N | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | 13 |
| Papamerkouriou et al, 2019[23] | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | N | 12 |
| Hagen et al, 2019[33] | Y | Y | Y | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | N | 13 |
| Bernasconi et al, 2020[24] | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | N | 13 |
| Indino et al, 2020[18] | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | Y | N | Y | Y | 13 |
| Kubo et al, 2020[34] | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | N | 14 |
| Franz et al, 2020[35] | Y | Y | Y | N | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | N | 12 |

of conservative measures was only a requirement of 13 studies.[13,14,16,18,20,22–25,27,30,32,33] Richter et al included their treatment algorithm, based on the age of the patient, evidence of tibialis posterior insufficiency and the talo-1st metatarsal index, as described by Hamel et al.[39] The age of patients ranged from 5 to 17 years, with a mean of 11.62 years. Six studies did not include details of patient gender,[12,14,17,23,34,35] but the remaining 18 studies included 915 males and 640 females.

Poly-L-lactic acid implants were used in four studies,[12,17,19,31] with the remainder utilizing either titanium alloy or stainless steel. Thirteen studies inserted the implants into the sinus tarsi,[12,13,15-24,40] 12 into the calcaneus[17,19,26–35] and one into the talus.[25] Caravaggi et al and Memeo et al performed comparative studies with treatment groups receiving an implant into either the sinus tarsi or calcaneum; both sets of data were analysed individually in this review. A concomitant procedure to increase dorsiflexion was performed in 536 feet, whether a percutaneous tendo-Achilles (TA) lengthening, open TA lengthening, gastrocnemius slide or recession. Sixteen patients had an accessory navicular excised. Fourteen patients had a concomitant spring ligament reconstruction. Ten studies routinely removed implants[16,20,21,23,25–30] after a minimum period of 18 months, at skeletal maturity or using the formula: planned removal/months post op = (age in years x 2) plus 6. The average follow-up period was 30.9 months. One study did not explicitly say how long they followed up their patients.[27] These findings are summarized in Table 4.

A variety of radiological, kinematic and clinical outcomes were used across the 24 studies, with poor homogeneity among them. The results of the studies have been summarized in Tables 5a, 5b and 5c. Radiological normal values are derived from the work by Lamm et al.[41] There was an improvement of all outcome parameters investigated. Patient satisfaction was reported by four studies[16,25,31,32] from 231 patients, with 79.9% rating excellent, 14.9% good or fair and 5.2% poor. One hundred and eighty-one complications were reported out of the 2550 operated feet, of which 78 required surgical intervention, giving an incidence of 7.1% and 3.1% respectively. The commonest causes for revision surgery were implant-related, including breakage, migration and inadequate correction. Pain was responsible for 29 of the 78 revision procedures.

## Discussion

The aim of this systematic review was to assess the outcomes of arthroereisis for the treatment of the symptomatic paediatric flexible pes planus. This review identified 24 studies (18 case series and six comparative studies) with overall moderate methodological quality. We excluded five studies due to lack of meaningful data: whether not collected, analysed or presented in a format which permitted analysis of their findings (e.g. lack of reporting pre-operative data).[42–46] Due to the heterogeneity of the studies it was not possible to meaningfully pool the data for meta-analysis.

Overall, results appear encouraging for the use of arthroereisis in the treatment of paediatric flexible pes planus. Improvement in radiological, kinematic and clinical outcome scores were fairly consistent between studies. There was a lack of standardization across the studies with regard to outcome measures utilized. Three studies did not measure any radiological outcome.[15,33,35] Only ten studies measured any form of kinematics[12,14,15,23–26,30,33,35] and only eight studies utilized patient-reported outcomes.[14–16,21–23,28,30]

Patient-reported outcome scores all showed marked improvement (Table 5c). Five different foot and ankle-specific scoring systems were used by eight studies, with no single measure being used by more than three different studies. Indino et al and Bernasconi et al only recorded post-operative scores so both sets of results were excluded. Pain, as assessed by a visual analogue scale in two studies,[16,17] improved from 5.5 pre-operatively to 1.4 post-operatively. Patient satisfaction was recorded in four studies,[16,25,31,32] and was generally high, with 79.9% rating the procedure as excellent and only 5.2% as poor.

Averaged radiological measurements all showed improvement towards the recognized normal range. The post-operative AP talar calcaneal angle, AP talar first metatarsal angle, lateral talar first metatarsal angle and calcaneal incidence normalized. The lateral talar calcaneal joint angle was found to lie in the normal range post-operatively; however, it was within normal limits pre-operatively as well. The other radiological markers all showed improvement towards a normal value.

Kinematic measurements also improved, with an average reduction in hindfoot valgus of 8.1°. There was improvement in supination, dorsiflexion and Viladot grade to near normal values. One study did not measure the hindfoot valgus angle pre-operatively, yet reported that there was an improvement of 4° post-operatively.[14] A second study only measured the degree of hindfoot post-operatively, without any pre-operative values as a comparator.[15] The data from both these studies with regard to hindfoot position were not included. Two studies did not quantify the degree of hindfoot valgus or forefoot abduction, instead purely basing this on the clinician's judgement during physical examination.[27,29] These clinical opinions were analysed separately to quantified measurements, as their validity is harder to ensure, but both of these studies reported a post-operative improvement. It must be noted that radiological and kinematic improvements only demonstrate that arthroereisis corrects the

**Table 4.** Study data extracted from included articles in this review

| Author | No of patients | No of feet | Male: Female | Mean age at surgery | Age range | Implant manufacturer | Implant placement | Implant material | Bioreso-rbable | Concomitant procedures | Postoperative mobilization | Mean follow up / months | Routine implant removal | Timing of implant removal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Giannini et al[12] | 21 | 21 | | | 8–15 | Stryker | ST | PLLA | Y | TA = 6, AN = 12 | WB 3/52 | 48 | N | |
| Jerosch et al[26] | 18 | 21 | 13:5 | 11.9 | 8–14 | | C | SS/Ti | N | TA = 5 | FWB | 31 | Y | SM |
| Scharer et al[13] | 39 | 68 | 24:15 | 12.0 | 6–16 | MBA | ST | Ti | N | TA = 18, AN = 4 | | 24 | N | |
| Kellerman et al[25] | 25 | 43 | 18:7 | 10.0 | 7–14 | Bonestar | T | SS/Ti | N | None | FWB | 9 | Y | F |
| Pavone et al[27] | 242 | 410 | 157:85 | 11.0 | 7–14 | Synthes | C | SS | N | TA = 18 | FWB | | Y | 36/12 |
| Richter et al[28] | 18 | 31 | 8:10 | 10.6 | 8–12 | | C | SS/Ti | N | TA = 25 | PWB 6/52 | 24 | Y | 24/12 |
| De Pellegrin et al[29] | 485 | 732 | 267:218 | 11.5 | 5–17 | Synthes | C | SS | N | | PWB 5/7 | 54 | Y | 37/12 |
| Chong et al[14] | 7 | 13 | | 12.8 | 8–17 | Vilex | ST | Ti | N | None | WC 3/52 | 12.9 | N | |
| Martinelli et al[15] | 49 | 98 | 30:19 | 10.7 | 7–14 | Tournier | ST | Ti | N | TA = 12 | WC 2/52 | 59 | N | |
| Cao et al[16] | 20 | 27 | 12:8 | 12.1 | 7–16 | Integra | ST | Ti + P | N | | WB 12/52 | 28.1 | Y | SM |
| Das et al[30] | 15 | 25 | 10:5 | 12.5 | | | C | SS/Ti | N | TA = 7 | FWB | 54 | Y | 36/12 |
| Giannini et al[31] | 44 | 88 | 31:13 | 11.7 | 8–14 | Lima | C | PLLA | Y | TA = 24 | WC 2/52 | 48 | N | |
| Arbab et al[32] | 41 | 73 | 23:18 | 11.8 | 9–14 | | C | SS | N | | | 30.6 | N | |
| Caravaggi et al[17] | 13 | 13 | | 11.3 | | | ST/C | PLLA | Y | | | 12.5 | N | |
| Indino et al[18] | 56 | 112 | 34:22 | | | Tornier; BRM | ST | Ti | N | None | WC 2/52 | 40 | N | |
| Memeo et al[19] | | 402 | | 13.4 | 8–16 | | ST/C | PLLA/Ti | Y/N | TA = 327 | NWB 2/52 | 30.6 | N | |
| De Bot et al[20] | 16 | 26 | 10:6 | 12.5 | 10–15 | Integra | ST | Ti + P | N | TA = 20, SL = 14 | NWB 4/52, WC 4/52 | 47 | Y | 34/12 |
| Ruiz-Picazo et al[21] | 16 | 32 | 13:3 | 9.0 | 7–11 | | ST | Ti | N | None | | 12 | Y | SM |
| Megremis & Megremis[22] | 14 | 28 | 10:4 | 10.7 | 8–14 | Integra | ST | Ti | N | TA = 28 | NWB 2/52, WC 2/52 | 35 | N | |
| Papamerkouriou et al[23] | 6 | 12 | | 11.05 | 6–15 | Integra | ST | Ti + P | N | None | WC 4/52 | 6 | Y | 18/12 |
| Hagen et al[33] | 14 | 27 | 12:2 | 12.38 | | Synthes | C | SS | N | | | 1 | N | |
| Bernasconi et al[24] | 31 | 62 | 22:19 | 10.5 | 8–15 | Stryker | ST | SS | N | | FWB after 2/7 | 62.5 | N | |
| Kubo et al[34] | 50 | 95 | | 11.3 | 5–15 | | C | | N | TA = 35 | FWB | 35.8 | N | |
| Franz et al[35] | 39 | 78 | | 11.3 | | | C | SS | N | TA = 11 | | 6 | N | |

*Notes*. ST = sinus tarsi; C = calcaneum; T = talus; PLLA = poly-L-lactic acid; SS = stainless steel; Ti = titanium alloy; P = ultra high molecular weight polyethylene; TA = tendo-Achilles or triceps surae soft tissue procedure; AN = accessory navicular excision; SL = spring ligament reconstruction; FWB = full weight-bearing; PWB = partial weight-bearing; WB = walking boot; WC = walking cast; /52 = weeks; SM = skeletal maturity; F = formula (age in years x2)+6 = months; M = months.

**Table 5a.** Pre- and post-operative radiological outcomes

| Outcome | MCB | LTCJ | CI | LT1M | APT1M | APTN | APTC | TD |
|---|---|---|---|---|---|---|---|---|
| Studies | 8 | 7 | 13 | 16 | 4 | 4 | 8 | 7 |
| No of feet | 1736 | 434 | 2017 | 703 | 99 | 176 | 1122 | 1736 |
| Pre-op mean | 145.3° | 42.4° | 12.2° | 17.1° | 22.2° | 21.3° | 31.2° | 40.1° |
| Post-op mean | 129.2° | 36.4° | 15.7° | 7.4° | 9.1° | 12.5° | 24.5° | 27.2° |
| Difference | –16.1° | –6.0° | +3.5° | +9.7° | –13.1° | –8.8° | –6.6° | –12.9° |
| Normal range | 115–125° | 25–45° | 13–23° | 2–10° | 3–11° | 0–7° | 15–27° | 18–24° |

*Notes*. Values in the normal range are denoted by underlined bold text. MCB = Moreau-Costa-Bertini angle; LTCJ = lateral talar calcaneal joint angle; CI = calcaneal inclination; LT1M = lateral talar 1st metatarsal angle; APT1M = anterior-posterior talar 1st metatarsal angle; APTN = anterior-posterior talar navicular angle; APTC = anterior-posterior talar calcaneal angle; TD = talar declination.

**Table 5b.** Pre- and post-operative kinematic outcomes

| Outcome | Hindfoot valgus (M) | Hindfoot valgus (C) | Forefoot abduction (C) | Subtalar supination | Dorsiflexion | Viladot grade |
|---|---|---|---|---|---|---|
| Studies | 4 | 2 | 2 | 1 | 3 | 3 |
| No of feet | 112 | 1142 | 1142 | 25 | 67 | 130 |
| Pre-op mean | 11.9° | 100.0% | 65.2% | 6.7° | 11.3° | 2.7 |
| Post-op mean | 3.9° | 1.0% | 3.1% | 14.5° | 16.4° | 0.6 |
| Difference | –8.1° | 99.0% | 62.1% | +7.8° | +5.1° | –2.1 |

*Notes*. (M) = measured value; (C) = clinical opinion.

**Table 5c.** Pre- and post-operative clinical outcomes

| Outcome | VAS | VAS-FA | MOXFQ | AOFAS | OAFQC -P | OAFQC -S | OAFQC -E | OAFQC -F |
|---|---|---|---|---|---|---|---|---|
| Studies | 3 | 2 | 1 | 3 | 3 | 3 | 3 | 2 |
| No. of feet | 53 | 56 | 12 | 52 | 155 | 155 | 155 | 130 |
| Pre-op mean | 5.5 | 70.3 | 55.3 | 57.6 | 66.9 | 86.1 | 83.6 | 69.9 |
| Post-op mean | 1.4 | 85.1 | 34.3 | 80.4 | 72.8 | 90.0 | 90.9 | 80.7 |
| Difference | –4.1 | 14.9 | –21.0 | +22.6 | +5.9 | +3.9 | +7.2 | +10.9 |

*Notes*. VAS = visual analogue scale [of pain]; VAS-FA = visual analogue scale foot and ankle; MOXFQ = Manchester-Oxford foot questionnaire; AOFAS = American Orthopaedic foot and ankle score; OAFQC = Oxford ankle foot questionnaire for children; -P = physical; -S = school and play; - E = emotional; -F = footwear.

deformity associated with pes planus; they do not infer a good outcome in terms of pain alleviation and symptom reduction.

Franz et al investigated pedobarographic changes following subtalar arthroereisis in 39 patients, using 24 normal feet as a control. Their study found that the post-operative contact area of the medial and lateral midfoot normalized and was comparable to the control group. Force-time-integral (FTI), a measure of load distribution independent of body weight, was found to improve in the forefoot with greater lateral distribution. The FTI under the hallux was found to have normalized compared to the controls.[35] This lateral load shift was also found by Papamerkouriou et al, albeit in a study of only six patients.[23]

Complication rates for the 2550 feet were 7.1%, with 3.1% requiring further surgery. Complications not requiring surgery included soft tissue irritation/pain ($n$ = 42), malcorrection ($n$ = 27), peroneal contractures ($n$ = 19), wound infections ($n$ = 10), 4th metatarsal stress fractures ($n$ = 3) and screw loosening ($n$ = 2). The commonest reason for revision surgery was exchange or adjustment for broken, migrated, inappropriately sized or incorrectly positioned implants ($n$ = 48) followed by pain ($n$ = 29). Where pain was the cause for surgery, no other reason could be identified, but the symptoms were severe enough to warrant exchange or removal of the implant. Two studies stated that the pain symptoms were ameliorated following the intervention,[14,15] but a third study did not mention whether there was any improvement.[27] One study found two patients had ongoing significant pain following implant removal, whereas symptoms improved in the 12 other patients.[24]

Addressing tendo-Achilles or gastrocnemius tightness were the most common concurrent procedures occurring during arthroereisis in this review, with 536 performed. In adult studies, acquired pes planus with tendo-Achilles contracture increases the mean valgus hindfoot alignment moment arm, tibiocalcaneal angle and talo-1st metatarsal angle.[47] It can be inferred that an uncorrected equinus deformity may contribute to the failure of a pes planus correction. Tendo-Achilles contracture must be addressed with a lengthening procedure.[48] The previously high failure rate of arthroereisis may be due to the fact that this significance had not been fully appreciated.

Metcalfe et al published a review of arthroereisis for paediatric flexible pes planus in 2011.[37] Their exclusion criteria were a little more relaxed than those used in this review, and included studies we discounted. They provide

a very detailed history of the individual devices used and the problems encountered with each. They conclude that arthroereisis represents a minimally invasive technique with a fast rehabilitation time for paediatric pes planus, and the simplicity of the procedure should not belie its corrective power. Studies were predominately heterogeneous and low level, examining a diverse array of radiological and kinematic outcomes, but lack utilization of validated outcome tools.[37]

A review by Tan et al in 2020 also investigated the use of arthroereisis in paediatric pes planus. They concluded that arthroereisis is effective in reducing symptoms and deformity. Their review could be criticized for including patients aged up to 21 years and also studies treating rigid pes planus.[49] Patient age at time of surgery appears to play an important factor, with 9 to 12 years thought to be optimal. Younger patients are at higher risk of recurrence and older patients have less successful outcomes, likely due to the reduced ability of the foot to remodel.[34] Rigid pes planus is also considered a contraindication to arthroereisis as a primary intervention.[29,50]

Since Metcalfe et al's review, Pavone et al, De Pellegrin et al, and Memeo et al have published three large series with 410,[27] 732,[29] and 402[19] feet respectively. Pavone et al primarily used radiological outcomes and a visual analogue scale to rate patient satisfaction. They also noted the clinical presence of heel valgus, forefoot abduction and talar protrusion, but failed to mention whether any standardization was used. They also did not use any patient-reported outcome measures as an objective measure of function and residual symptoms.[27] De Pellegrin et al presented the largest series, and outcomes were based on radiological measures and subjective clinical findings. They judged a good outcome based on four criteria: radiological improvement, lack of complications, normal foot function and the lack of further surgery.[29] They did not use validated patient-reported outcome tools. Memeo et al published their work more recently, retrospectively comparing outcomes between a sinus tarsi implant and a calcaneal implant. Again, radiological outcomes were primarily analysed along with subjective clinical parameters.[19]

It was not possible to sub-analyse the studies to compare the effectiveness of different implants due to study heterogeneity. Caravaggi et al performed a prospective comparative study using two types of PLLA resorbable arthroereisis implants: the endo-orthotic implant inserted into the sinus tarsi, and the calcaneo-stop screwed into the lateral calcaneus. They operated on 13 patients with bilateral pes planus; the calcaneo-stop inserted into the right foot and the endo-orthotic implant inserted into the left foot. Both implants performed well in restoring alignment of the hindfoot, but the endo-orthotic implant was more effective in restoring frontal-plane joint mobility. They reported no complications.[17] Memeo et al performed a retrospective comparative study using a PLLA sinus tarsi implant or a stainless steel screw in the calcaneum. Their numbers were much higher, with approximately 200 feet in each study arm. They concluded both methods provide satisfactory clinical and morphological correction, with no significant differences between the two techniques.[19]

Historically, arthroereisis has been much maligned due to alleged poor outcomes and high complication rates.[11] Chong et al performed a prospective comparative study of arthroereisis and Evans lateral column lengthening. They concluded 'both methods of surgical correction of the painful flexible flatfoot yielded significant improvements, both objectively and subjectively. Neither method yielded outcomes that were superior to the other'. The patient groups were small, with 13 feet in the arthroereisis group and 11 in the lateral column lengthening group, but they found a greater improvement in Oxford ankle–foot questionnaire scores in the arthroereisis group and complication rates were equal, with 2 occurring in each group.[14]

Complications following arthroereisis have been well documented in the literature, albeit mainly in adult patients. Needleman reported complication rates as high as 46% in adult patients using the Maxwell-Brancheau arthroereisis (MBA) subtalar implant. The primary complaint was of sinus tarsi pain (39%), yet clinical outcomes and patient satisfaction scored highly among the patients in his study and the majority of symptoms resolved following removal of the implant.[51] There is a lack of information regarding complications in paediatric patients following arthroereisis. It cannot be inferred that complications experienced by the adult population would be as common or as severe in the paediatric population and further research would be welcomed.

A talar neck fracture has been described in two case reports.[52,53] Kumar and Clough reported a 17-year-old male sustaining a talar neck fracture after a fall from a horse three years following insertion of a Talar-Fit screw implant (Osteomed, Addison, TX, USA) into the sinus tarsi. The fracture was managed non-operatively and healed within four months. It is believed the implant acted as a stress riser across the talar neck as the force of the fall was transmitted through the talus. Corpuz et al presented a 19-year-old female who sustained a talar neck stress fracture 10 years after insertion of an MBA implant (Integra LifeScience, NJ, USA) into the sinus tarsi. The fracture displaced during implant removal and required fixation, with a large bony defect found in the talar neck. It is believed that initial implant malpositioning was responsible for this.[53] Both talar neck fractures occurred following the use of a metallic screw implant placed in the sinus tarsi. In this review, of the studies that inserted metallic implants into the sinus tarsi, only Cao et al[16] planned for routine removal, with three studies not routinely removing them.[13–15] Three 4th

metatarsal stress fractures were reported in one study in this review, which were managed non-operatively; there were no talar neck fractures.

In 1998, Rockett et al reported an adolescent patient who developed bilateral talar intra-osseous ganglion cysts two years following bilateral subtalar arthroereisis peg (STA-peg) insertion (Wright Medical Technology, Arlington, TN).[54] The STA-peg is a high molecular weight polyethylene blocking implant that supports the lateral facet of the talus and prevents its anterior translation. Rockett et al noted the implant was loose, worn and associated with degenerative changes of the talus where it had been in contact with the implant. It was postulated that repeated minor trauma caused by contact between the STA-peg and the talus was responsible for formation of the cyst.[54] The STA-peg implant has also been associated with extensive synovitis in two patients reported by Scher et al in 2007. Both patients presented two years following surgery with pain and limited mobility. Histology results demonstrated sclerotic synovium with chronic granulomatous reaction to refractile polyethylene shards.[55]

Mosca stated in 2010 that there is no consensus on the indication of arthroereisis, complication rates ranged from 3.5–30% and that lateral column lengthening with an extra-articular calcaneal osteotomy is the procedure of choice.[3] A 2017 review of lateral column lengthening performed on 156 paediatric flat feet (146 for idiopathic pes planus) found that the overall complication rate was 17.5% with a revision rate of 12.3%, most commonly for deformity recurrence.[56] Calcaneal osteotomies also are not without risk, with wound complications quoted as high as 28% and infection rates of 20%; although these have improved since minimally invasive techniques has become more popular.[57]

There are limitations to this review. There is a clear lack of high-level, high-quality, long-term evidence. Only one study in this review compared arthroereisis to lateral column lengthening, which some consider to be the current gold standard procedure.[3] Many of the studies had small sample sizes, although three studies had reasonable numbers.[19,27,29] There is a lack of standardization of outcome measures across the studies, with a diverse array of radiological, clinical and kinematic outcomes being analysed. The majority of studies were performed retrospectively and any analysis on post-operative outcomes is only as good as the pre-operative data collection. This is likely to be responsible for radiological parameters being used as outcomes in the majority of studies. The mean follow-up time across the studies in this review is 37.1 months (average range 9–59 months). Following up paediatric patients on a long-term basis is challenging. As patients reach maturity they come under the remit of adult services should they encounter any complications from childhood surgery. Feedback to the original paediatric surgeon is not guaranteed unless they are particularly diligent at maintaining the records of their outcomes, or the patient starts litigation.

## Conclusion

This review found that arthroereisis as a treatment for symptomatic paediatric flexible pes planus produces favourable outcomes and high patient satisfaction rates with a reasonable risk profile. The studies included in this review are primarily case series, with six comparative studies. The average age at the time of surgery was 11.62 years (range 5–17 years), within the ideal age range of 9–12 years. The overall complication rate was 7.1% with further surgery required in 3.1% of cases. There is still a great deal of negativity and literature highlighting the complications and failures of arthroereisis, especially for older implants. Compared to arthroereisis, 'established' surgical procedures for flexible pes planus are not without risk either, include more complicated, lengthier interventions and have a longer rehabilitation period. With increasing development and use of resorbable implants, the need for a second procedure to remove the implant, and the pain attributed to it in some cases, should hopefully be negated. The biggest flaws in the collective literature are the lack of high-quality prospective studies, a paucity of long-term data and heterogeneity of utilized outcome measures between studies. These factors need to be addressed to truly evaluate whether arthroereisis is an effective treatment for symptomatic paediatric flexible pes planus.

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## REFERENCES


1. **Carr JB II, Yang S, Lather LA.** Pediatric pes planus: a state-of-the-art review. *Pediatrics* 2016;137:e20151230.

2. **Dare DM, Dodwell ER.** Pediatric flatfoot: cause, epidemiology, assessment, and treatment. *Curr Opin Pediatr* 2014;26:93–100.

3. **Mosca VS.** Flexible flatfoot in children and adolescents. *J Child Orthop* 2010;4:107–121.

4. **Sheikh Taha AM, Feldman DS.** Painful flexible flatfoot. *Foot Ankle Clin* 2015;20:693–704.

5. **Bouchard M, Mosca VS.** Flatfoot deformity in children and adolescents: surgical indications and management. *J Am Acad Orthop Surg* 2014;22:623–632.

6. **Walters JL, Mendicino SS.** Flexible adult flatfoot: soft tissue procedures. *Clin Podiatr Med Surg* 2014;31:349–355.

7. **Peterson KS, Overley BD Jr, Beideman TC.** Osteotomies for the flexible adult acquired flatfoot disorder. *Clin Podiatr Med Surg* 2015;32:389–403.

8. **Toullec E.** Adult flatfoot. *Orthop Traumatol Surg Res* 2015;101:S11–S17.

9. **Medical Dictionary.** *Arthroereisis*. The Free Dictionary. https://medical-dictionary.thefreedictionary.com/arthroereisis (date last accessed 5 July 2018).

10. **Chambers EF.** An operation for the correction of flexible flat feet of adolescents. *West J Surg Obstet Gynecol* 1946;54:77–86.

11. **Shah NS, Needleman RL, Bokhari O, Buzas D.** 2013 subtalar arthroereisis survey: the current practice patterns of members of the AOFAS. *Foot Ankle Spec* 2015;8:180–185.

12. **Giannini S, Ceccarelli F, Benedetti MG, Catani F, Faldini C.** Surgical treatment of flexible flatfoot in children: a four-year follow-up study. *J Bone Joint Surg Am* 2001;83-A:73–79.

13. **Scharer BM, Black BE, Sockrider N.** Treatment of painful pediatric flatfoot with Maxwell-Brancheau subtalar arthroereisis implant a retrospective radiographic review. *Foot Ankle Spec* 2010;3:67–72.

14. **Chong DY, Macwilliams BA, Hennessey TA, Teske N, Stevens PM.** Prospective comparison of subtalar arthroereisis with lateral column lengthening for painful flatfeet. *J Pediatr Orthop B* 2015;24:345–353.

15. **Martinelli N, Bianchi A, Martinkevich P, et al.** Return to sport activities after subtalar arthroereisis for correction of pediatric flexible flatfoot. *J Pediatr Orthop B* 2018;27:82–87.

16. **Cao L, Miao XD, Wu YP, Zhang XF, Zhang Q.** Therapeutic outcomes of Kalix II in treating juvenile flexible flatfoot. *Orthop Surg* 2017;9:20–27.

17. **Caravaggi P, Lullini G, Berti L, Giannini S, Leardini A.** Functional evaluation of bilateral subtalar arthroereisis for the correction of flexible flatfoot in children: 1-year follow-up. *Gait Posture* 2018;64:152–158.

18. **Indino C, Villafañe JH, D'Ambrosi R, et al.** Effectiveness of subtalar arthroereisis with endorthesis for pediatric flexible flat foot: a retrospective cross-sectional study with final follow up at skeletal maturity. *Foot Ankle Surg* 2020;26:98–104.

19. **Memeo A, Verdoni F, Rossi L, Ferrari E, Panuccio E, Pedretti L.** Flexible juvenile flat foot surgical correction: a comparison between two techniques after ten years' experience. *J Foot Ankle Surg* 2019;58:203–207.

20. **de Bot RTAL, Stevens J, Hermus JPS, Staal HM, van Rhijn LW, Witlox AM.** Clinical and radiological outcomes of subtalar Kalix II arthroereisis for a symptomatic pediatric flexible flatfoot. *Foot Ankle Spec* 2019;1938640019892062.

21. **Ruiz-Picazo D, Jiménez-Ortega P, Doñate-Pérez F, Gaspar-Aparicio N, García-Martín V, Ramírez-Villaescusa J, et al.** Radiographic and functional results following subtalar arthroereisis in pediatric flexible flatfoot. *Adv Orthop* 2019;2019:5061934.

22. **Megremis P, Megremis O.** Arthroereisis for symptomatic flexible flatfoot deformity in young children: radiological assessment and short-term follow-up. *J Foot Ankle Surg* 2019;58:904–915.

23. **Papamerkouriou Y-M, Rajan R, Chaudhry S, Kodumuri P, Evans H, Kerr M.** Prospective early clinical, radiological, and kinematic pedobarographic analysis following subtalar arthroereises for paediatric pes planovalgus. *Cureus* 2019;11:e6309.

24. **Bernasconi A, Iervolino C, D'Alterio R, Lintz F, Patel S, Sadile F.** Midterm assessment of subtalar arthroereisis for correction of flexible flatfeet in children. *Orthop Traumatol Surg Res* 2020;106:185–191.

25. **Kellermann P, Roth S, Gion K, Boda K, Tóth K.** Calcaneo-stop procedure for paediatric flexible flatfoot. *Arch Orthop Trauma Surg* 2011;131:1363–1367.

26. **Jerosch J, Schunck J, Abdel-Aziz H.** The stop screw technique: a simple and reliable method in treating flexible flatfoot in children. *Foot Ankle Surg* 2009;15:174–178.

27. **Pavone V, Costarella L, Testa G, Conte G, Riccioli M, Sessa G.** Calcaneo-stop procedure in the treatment of the juvenile symptomatic flatfoot. *J Foot Ankle Surg* 2013;52:444–447.

28. **Richter M, Zech S.** Arthrorisis with calcaneostop screw in children corrects Talo-1st Metatarsal-Index (TMT-Index). *Foot Ankle Surg* 2013;19:91–95.

29. **De Pellegrin M, Moharamzadeh D, Strobl WM, Biedermann R, Tschauner C, Wirth T.** Subtalar extra-articular screw arthroereisis (SESA) for the treatment of flexible flatfoot in children. *J Child Orthop* 2014;8:479–487.

30. **Das SP, Das PB, Ganesh S, Sahu MC.** Effectiveness of surgically treated symptomatic plano-valgus deformity by the calcaneo stop procedure according to radiological, functional and gait parameters. *J Taibah Univ Med Sci* 2017;12:102–109.

31. **Giannini S, Cadossi M, Mazzotti A, et al.** Bioabsorbable calcaneo-stop implant for the treatment of flexible flatfoot: a retrospective cohort study at a minimum follow-up of 4 years. *J Foot Ankle Surg* 2017;56:776–782.

32. **Arbab D, Frank D, Bouillon B, Lüring C, Wingenfeld C, Abbara-Czardybon M.** Subtalare screw arthroereisis for the treatment of symptomatic, flexible pes planovalgus. *Z Orthop Unfall* 2018;156:93–99.

33. **Hagen L, Kostakev M, Pape JP, Peterlein CD.** Are there benefits of a 2D gait analysis in the evaluation of the subtalar extra-articular screw arthroereisis? Short-term investigation in children. *Clin Biomech (Bristol, Avon)* 2019;63:73–78.

34. **Kubo H, Lipp C, Hufeland M, et al.** Outcome after subtalar screw arthroereisis in children with flexible flatfoot depends on time of treatment: midterm results of 95 cases. *J Orthop Sci* 2020;25:497–502.

35. **Franz A, Herz D, Raabe J, Seeberger U, Bollmann C.** Pedobarographic outcome after subtalar screw arthroereisis in flexible juvenile flatfoot. *Foot Ankle Surg* 2020;S1268-7731(20)30083-7.

36. **Banwell HA, Paris ME, Mackintosh S, Williams CM.** Paediatric flexible flat foot: how are we measuring it and are we getting it right? A systematic review. *J Foot Ankle Res* 2018;11:21.

**37. Metcalfe SA, Bowling FL, Reeves ND.** Subtalar joint arthroereisis in the management of pediatric flexible flatfoot: a critical review of the literature. *Foot Ankle Int* 2011;32:1127–1139.

**38. Downs SH, Black N.** The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 1998;52:377–384.

**39. Hamel J, Kinast C.** Der TMT-Index zur radiologischen Quantifizierung von Planovalgus-Deformitäten. *Fuss Sprunggelenk* 2006;4:221–226.

**40. Black BR, Chong R, Potter HG.** Cartilage imaging in sports medicine. *Sports Med Arthrosc Rev* 2009;17:68–80.

**41. Lamm BM, Stasko PA, Gesheff MG, Bhave A.** Normal foot and ankle radiographic angles, measurements, and reference points. *J Foot Ankle Surg* 2016;55: 991–998.

**42. Faldini C, Mazzotti A, Panciera A, et al.** Patient-perceived outcomes after subtalar arthroereisis with bioabsorbable implants for flexible flatfoot in growing age: a 4-year follow-up study. *Eur J Orthop Surg Traumatol* 2018;28:707–712.

**43. Jay RM, Din N.** Correcting pediatric flatfoot with subtalar arthroereisis and gastrocnemius recession: a retrospective study. *Foot Ankle Spec* 2013;6:101–107.

**44. Roth S, Sestan B, Tudor A, Ostojic Z, Sasso A, Durbesic A.** Minimally invasive calcaneo-stop method for idiopathic, flexible pes planovalgus in children. *Foot Ankle Int* 2007;28:991–995.

**45. Koning PM, Heesterbeek P, De Visser E.** Patients and methods. *J Am Podiatr Med Assoc* 2009;34:72–77.

**46. Nelson SC, Haycock DM, Little ER.** Flexible flatfoot treatment with arthroereisis: radiographic improvement and child health survey analysis. *J Foot Ankle Surg* 2004;43: 144–155.

**47. Arangio G, Rogman A, Reed JF III.** Hindfoot alignment valgus moment arm increases in adult flatfoot with Achilles tendon contracture. *Foot Ankle Int* 2009;30: 1078–1082.

**48. Mosca VS.** Calcaneal lengthening for valgus deformity of the hindfoot: results in children who had severe, symptomatic flatfoot and skewfoot. *J Bone Joint Surg Am* 1995;77:500–512.

**49. Tan JHI, Tan SHS, Lim AKS, Hui JH.** The outcomes of subtalar arthroereisis in pes planus: a systemic review and meta-analysis. *Arch Orthop Trauma Surg* 2020.

**50. Faldini C, Mazzotti A, Panciera A, Perna F, Stefanini N, Giannini S.** Bioabsorbable implants for subtalar arthroereisis in pediatric flatfoot. *Musculoskeletal Surgery* 2018;102:11–19.

**51. Needleman RL.** A surgical approach for flexible flatfeet in adults including a subtalar arthroereisis with the MBA sinus tarsi implant. *Foot Ankle Int* 2006;27:9–18.

**52. Kumar V, Clough TM.** Talar neck fracture-a rare but important complication following subtalar arthroereisis. *Foot (Edinb)* 2014;24:169–171.

**53. Corpuz M, Shofler D, Labovitz J, Hodor L, Yu K.** Fracture of the talus as a complication of subtalar arthroereisis. *J Foot Ankle Surg* 2012;51:91–94.

**54. Rockett AK, Mangum G, Mendicino SS.** Bilateral intraosseous cystic formation in the talus: a complication of subtalar arthroeresis. *J Foot Ankle Surg* 1998;37.

**55. Scher DM, Bansal M, Handler-Matasar S, Bohne WH, Green DW.** Extensive implant reaction in failed subtalar joint arthroereisis: report of two cases. *HSS J* 2007;3:177–181.

**56. Kumar S, Sonanis SV.** Lateral column lengthening for adolescent idiopathic pes planovalgus deformity: systematic review. *J Orthop* 2017;14:571–576.

**57. Kendal AR, Khalid A, Ball T, Rogers M, Cooke P, Sharp R.** Complications of minimally invasive calcaneal osteotomy versus open osteotomy. *Foot Ankle Int* 2015;36: 685–690.