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PII: S1268-7731(19)30016-5
DOI: https://doi.org/10.1016/j.fas.2019.01.007
Reference: FAS 1266

To appear in: *Foot and Ankle Surgery*

Received date: 16 November 2018
Revised date: 20 December 2018
Accepted date: 23 January 2019

Please cite this article as: Choi JY, Hong WH, Suh JS, Han JH, Lee DJ, Lee YJ, The long-term structural effect of orthoses for pediatric flexible flat foot: A systematic review, *Foot and Ankle Surgery* (2019), https://doi.org/10.1016/j.fas.2019.01.007

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The long-term structural effect of orthoses for pediatric flexible flat foot: A systematic review

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Highlights

- ▶ There is no strong evidence that the long-term use of orthoses improved the structural problem of pediatric flexible flat foot (PFFF).
- ▶ This finding could be attributed to the natural history of PFFF

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- ▶ Randomized controlled trials and prospective cohort studies could not prove the estimated effects of orthoses.
- ▶ Case series revealed that positive long-term effects could be achieved using orthoses.

Abstract

Background: We aimed to evaluate the structural effects of the long-term use of orthoses for pediatric flexible flat foot (PFFF) using an algorithmic approach and a structured critical framework to assess the methodological quality of reported studies.

Methods: A comprehensive literature search using five databases, namely MEDLINE, the Cochrane Library, Scopus, the Web of Science, and EMBASE, was performed for pertinent articles published before March 30, 2018. Studies with quantitative data on the effects of the long-term use of orthoses for PFFF were included. The search strategy was adapted as appropriate for all other databases searched considering the differences in indexing terms and search syntax for each database.

Results: Randomized controlled trials and prospective cohort studies could not prove the estimated effects of orthoses on the medial longitudinal arch. They revealed that flexible flat feet in young children slowly improved with growth, regardless of the type of footwear used. However, three of four case series studies revealed that positive long-term effects could be achieved using orthoses.

Conclusion: There is no strong evidence that the long-term use of orthoses improved the structural problem of PFFF.

Keywords: pediatric, flexible flat foot, orthoses, insole, structural change

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1. Introduction

Pediatric flexible flat foot (PFFF) is a relatively frequently encountered condition [1]. At birth, a normal infant has a plantar flexed ankle, an adducted forefoot, and an inverted hindfoot because of its position in the maternal uterus. When the child begins to stand, a physiological flat foot with the hindfoot valgus position develops because of the flexibility of the joints. As flexibility and subcutaneous fat decrease after the age of 3-4 years, a medial longitudinal arch begins to form, and the arch is formed by 10 years of age [1,2]. However, Harris and Beath [3] revealed that the physiological flat foot remains in 23% of adults. Staheli et al. [4] reported that 4% of physiological flat foot cases persisted after the age of 10 years. More recently, Bordin [5] reported that 16.4% of children aged 10 years on an average had flat feet, although they were frequently unknown because of the absence of symptoms.

PFFF is associated with pain and potential disability, and it can lead to severe pes plano valgus deformity in adults, thereby leading to surgical treatments. Therefore, several conservative treatment methods, from intrinsic muscle exercises to orthoses, including insoles or specially designed shoes, have been introduced [6]. However, the structural effects of orthoses use remain unclear because the normal physiological maturation of the medial longitudinal arch cannot be ruled out.

A previous systematic review by MacKenzie et al. [7] concluded that there was no evidence to indicate that orthopedic footwear, wedges, or foot orthoses immediately improved radiographical parameters in children with flexible flat foot. However, they also mentioned that, over time, radiographical parameters and foot posture with all interventions improved. Since most included studies did not include a control group, it was unable to make a concrete conclusion. A Cochrane review [8] revealed that there was limited evidence for practitioners regarding the efficacy of non-surgical

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interventions in children with flexible flat foot. Most of these systematic reviews contained various types of studies revealing immediate change or the effect with relatively short-term uses of orthoses. Therefore, determining how PFFF deformity would change following the long-term use of orthoses based on previous systematic reviews remains difficult.

This study aimed to evaluate the effects of the long-term use of orthoses for PFFF using an algorithmic approach and a structured critical framework to assess the methodological quality of reported studies. We assumed that pediatric feet could be influenced by external structural supports, such as orthotic treatment before the physeal closure (under age of 13-15 years).

2. Materials and methods

To precisely judge the effect of orthoses on structural changes, a comparison of the parameters related to radiography or gross appearance of untreated or other conservative treatments was necessary. Regarding the definition of 'long'-term, various studies have defined the duration of long-term use with their own reasons (1 year [9,10], 18 months [11], or 2 years [12-14]). Thus, we defined the long-term use of orthoses as a continuous use of orthoses for >2 years in this review.

2.1. Inclusion criteria

The inclusion criteria for this review were based on the PICOT (Population/Patient Problem, Intervention, Comparison, Outcome, and Time) format of study design questions. Studies were included in our systematic review if they met all of the following three inclusion criteria: (1) original studies with the aim of evaluating the effects of the long-term use of orthoses for PFFF by an algorithmic approach; (2) studies providing data on radiographs, gross foot posture, ankle range of motion

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(ROM), or reduced pain; and (3) studies involving human beings. If the data from the same or a similar population were published in more than one study, the most complete and relevant study was chosen for analysis.

2.2. Exclusion criteria

Studies were excluded according to the following criteria: (1) animal studies; (2) reviews, comment, editorial, conference abstract or paper, letter, and note; (3) studies without the number of cases and controls or clear grouping numbers; (4) cases of immediate effect or a relatively short-term intervention period of less than two years; and (5) analysis of an individual case.

2.3. Search strategy

In March 2018, a comprehensive literature search of electronic databases, including Medline, EMBASE, the Cochrane Database, the Web of Science, and Scopus, was performed. Of the core databases for medical and health science, Medline, EMBASE, and the Cochrane library were selected. As PFFF is a core condition that targets pediatrics, the Web of Science and Scopus databases were chosen because of matched study intervention and population. No restrictions were imposed in terms of the publication language, time, or status. In terms of the time period, the search did not restrict the publication date because we aimed to maximize the number of potential studies included. Electronic database searches used both free text words and Medical Subject Headings (MeSH). The search strategy was adapted as appropriate for all other databases searched (Appendix), considering the differences in indexing terms and search syntax for each database. The goal of the search strategy was to retrieve all relevant articles related to the topic. We identified further relevant studies by reviewing the reference lists of the studies identified in our initial search strategies.

Studies designed as clinical randomized controlled trials (RCTs) and non-RCTs, including cohort studies and case series that compared foot orthoses with conservative

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treatment using core components of PFFF, were searched. These include studies that a) used the following key terms: “flat foot,” “pes planus,” “pes plano valgus,” “pronate foot,” “hyperpronate foot,” “acquired flatfoot,” “foot deformities,” “acquired flatfoot deformity,” “conservative treatment,” “pediatric, juvenile,” “adolescent,” “orthosis,” “foot orthoses,” “orthopedic equipment,” “orthotic device,” “footwear,” “insole,” and “arch support” or b) highlighted a long-term use of the orthoses studied.

Also, studies that reported at least one of the primary outcomes, including radiographical parameters and gross appearance changes, were searched. Secondary outcomes included ankle ROM and degree of pain. These studies were chosen because of their association with the effects of orthotic devices and because a pilot search of the literature identified these as the most frequently reported and best-studied areas in PFFF treatment.

2.4. Study selection

The inclusion of all studies was independently decided by two reviewers based on predefined inclusion and exclusion criteria. Discrepancies were resolved by discussion among the reviewers. Any disagreements unresolved by discussion were referred to a third author to achieve a consensus. Study selection included two screening levels. The two reviewers independently screened the titles and abstracts of identified studies. The investigators retrieved articles of any citation identified by the reviewers for full-text review. The reviewers then assessed the reports to ensure that they met the inclusion criteria detailed below.

2.5. Data extraction

Two reviewers independently identified potential studies and extracted detailed information from each included article using a predefined form. The extracted data included information about demographic characteristics, including the first author’s name, the year of publication, the country where the study was performed, study

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design, the total number of participants, mean age, modes of intervention, duration of orthoses application, and study outcomes.

For the effects of orthoses, the measurement of outcomes varied among the studies. The following changes related to the effects of orthoses were extracted from the studies: (1) lateral radiographical parameters – talocalcaneal angle, talo-1st metatarsal angle, talo-horizontal angle, and calcaneal pitch angle; (2) anteroposterior (AP) radiographical parameters – talocalcaneal angle; (3) arch index calculation; (4) proportion of pes planus; (5) foot abduction/adduction; (6) resting calcaneal stance position (RCSP); (7) ankle ROM; and (8) pain.

2.6. Assessment of methodological quality

Two quality assessment tools based on the study designs were used to verify the quality of each retrieved article. Three reviewers independently assessed the methodological qualities of each study using the following quality assessment tools: (1) the Cochrane Collaboration's Risk of Bias (ROB) for randomized controlled trial (RCT) studies [15] and (2) the Study Quality Assessment (QA) Tools developed by National Institute for Health (NIH) for other study designs [16]. To ensure high quality of the reviewed articles, the QA tools chosen differed depending on the study designs. For example, for RCT studies, reviewers used the Cochrane Collaboration's ROB. For observational cohort, cross-sectional studies and case-control studies, reviewers used the QA and validity with the NIH tools, which are powerful to evaluate methodological flaws in non-RCTs and observational study methods. The quality appraisal or assessment tools used were dependent on study designs.

Three assessors rated each study, reaching consensus by majority in the instance of dispute. Scoring system was as 2=yes; 1=cannot determine, not applicable or not reported; 0=no. A total score was graded as excellent (75~100%), good (50~75%), fair (25~50%) and poor (0~25%). Any discrepancies were addressed by a joint re-evaluation of the original article by the fourth author.

3. Results

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3.1. Identification of studies

Figure 1 shows a flow diagram of the study selection as recommended by Preferred Reporting Items for Systematic Reviews and Meta-Analyses [17]. A total of 43 studies were completely assessed for eligibility. Of 43 studies, 10, 13, and 10 studies were excluded for reasons of immediate change, relatively short-term follow-up study for <2 years, and review articles for orthoses treatment of PFFF, respectively. Two more articles were excluded for insufficient information, such as no mention of the duration of orthoses application [18] or the lack of detailed description of orthoses [19]. We sent an e-mail to the respective corresponding authors to request the information for clarification; however, we did not get a response. Finally, eight studies were included for this systematic review [12-14,20-24].

3.2 Study characteristics

A total of 959 participants were included in the eight studies. The reason for the small number of studies would be the difficulty of continuous follow-up for a long time because most of the patients were asymptomatic.

Two studies [21,22], with 143 participants, were RCTs. Six studies [12-14,20,23,24], including two prospective cohort studies [20,23] and four case series [12-14,24], had 816 participants with PFFF. Four of the eight studies did not use a control group or another intervention to compare the intervention effect. The characteristics of the studies and their participants are shown in Table 1. Table 2 shows the result of the QA of each study. Two included prospective studies scored 15 (good) [23] and 14 (good) [20] of 24 while the case series studies scored excellent [12-14] except Bordelon (13/18, good) [24].

The duration of orthoses application, modes of intervention or control, and outcome evaluation method are demonstrated in Table 3. The study by Riccio et al. [23] was

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the only study to evaluate the difference between a simple therapeutic exercise and orthoses. Radiographical evaluations were performed in six studies (Table 4), but statistical comparisons with control groups were conducted in only two studies. Both studies showed no statistical differences between the intervention and the control groups. Non-radiographical evaluations are presented in Table 5. Riccio et al. [23] used Viladot type [25] with arch index calculation using podoscopic footprints, and Gould et al. [20] calculated the proportion of pes planus or hyperpronation after treatment. In the two recent studies, RCSP was used to judge the effect of the long-term use of orthoses. Bok et al. [13] demonstrated a significant increase in RCSP after the use of custom-made rigid foot orthosis for 2 years, and Lee et al. [14] also reported increases in RCSP in both preschool and school-aged children without a statistical comparison.

The conclusions of all included studies are summarized in Table 6. RCTs and prospective cohort studies could not prove the estimated effects of orthotic treatment on the medial longitudinal arch. These studies also concluded that flexible flat feet in young children slowly improved with growth, regardless of the type of footwear worn. However, three of the four case series studies revealed that positive long-term effects could be achieved. Since none of the studies included a control group, the normal physiological maturation of the arch could not be ruled out.

4. Discussion

Comparing previous systematic reviews [7,8] which included five studies with a follow-up duration of more than 2 years, three new studies including one RCT were included in this review. The reason of the small number of studies was that a long-term continuous follow-up study was difficult since most of the PFFF patients were asymptomatic or could become asymptomatic regardless of orthoses application.

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Unlike the findings of MacKenzie et al. [7], there is no strong evidence that the long-term use of these orthoses improves the structural problem of PFFF. Historically, several reports revealed the immediate change due to orthoses for PFFF. Leung et al. [26] reported that the modified University of California Biomechanics Laboratory (UCBL) shoe insert significantly affected the orientation and movement of the subtalar, ankle, and knee joints. They also revealed that these immediate changes reduced the degree and duration of abnormal pronation during stance via biomechanical gait evaluation. In contrast, Penneau et al. [27] showed no significant immediate radiological change between barefoot and various types of orthoses. Recently, Aboutirabi et al. [28] reported a significantly decreased center of pressure displacement and an increased percentage of gait symmetry and walking speed after the use of regular shoes with a functional foot orthosis compared to the use of medical shoes. Using a three-dimensional moment analysis, Jafarnezhadgero et al. [29] showed that foot orthoses could decrease the ankle evertor moment, knee and hip abductor moment, and hip flexor moment in the dominant lower limb.

Regarding the effects of short-term use of orthoses for <2 years, Bleck and Berzins [30] demonstrated the clinical and radiological improvements after the use of Helfet heel seat or UCBL shoe insert. They revealed that the duration of orthoses application varied from 13 to 19 months. More recently, Ahn et al. [31] reported that the use of a talus control foot orthoses more significantly improved the calcaneal pitch and RCSP than the rigid foot orthoses with 12 months of follow-up. In both groups, all of the radiological parameters changed toward the corrective direction.

Although several studies have been conducted, practitioners who consider orthoses treatment for PFFF always face this question: does this really change the foot shape to the normal? However, these immediate and short-term follow-up studies are unable to provide an accurate answer. It is meaningful that our review can provide an answer to this question.

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Interestingly, the patients in the RCTs [21,22] and the prospective cohort studies [20,23] were very young. If the patient is too young, there is a possibility that the orthoses would be applied even for the physiological flat foot, which could be improved spontaneously. Therefore, we think that orthoses should be applied from the age when the normal physiological flat foot is diminished (around 10 years of age) to the age when the growth of the foot ends (around 13-15 years of age). In this review, the patients' mean age was over 10 years in only one study [13].

We believe that radiological evaluations can most effectively reveal the structural change. However, only a few reports used radiographs as an evaluation tool. Furthermore, no studies using hindfoot alignment radiographs of Saltzman and el-Khoury [32] were found, even with the immediate or short-term follow-ups. Since a valgus deviation of the hindfoot alignment is an important patho-anatomical factor of the flat foot deformity, changes in the hindfoot alignment must be evaluated in studies that focus on the long-term effects of orthoses. Additionally, there was also no report evaluating talo-1st metatarsal angle and talonavicular coverage angle on foot AP radiographs. Since the flatfoot is a combination of sagittal, coronal, and axial deformity [33], measuring these angles is also very important to figure out the effectiveness more precisely [34].

Despite long-term use of the orthoses not having an effect on structural change, previous reports showed that these orthoses can reduce the pain and improve the functional ability of patients with PFFF. In this review, only Mereday et al. [12] evaluated the long-term effect on pain reduction of the orthoses for PFFF. They found that six out of ten participants with complaints of pain before wearing UCBL foot orthoses were all pain-free after 2 years of orthosis use. Lee et al. [10] also reported that the short-term use of custom-molded foot orthoses significantly improved foot pain and balancing ability after 3 months of follow-up. In contrast, Whitford and Esterman [9] tried to demonstrate and compare the effect of custom-made orthoses

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and ready-made prefabricated orthoses by focusing on gross motor skills, self-perception, exercise efficiency, and pain compared to no intervention. Although they did not compare radiological structural changes, they concluded that there was no evidence to justify the use of in-shoe orthoses for treating flexible excess foot pronation in children. However, the measurement of pain is subjective and hard to validate because these may depend on the parental personality [21] and the cost of the treatments while the functional ability can be assessed with dynamic gait analysis [29].

As with any research, this systematic review had some limitations. While the systematic search of the literature identified a modest body of evidence, there were concerns with the methodological quality. The areas of concern included the sample size and sampling techniques, diagnostic criteria, development, administration of intervention and its parameters, and the lack of psychometrically robust outcome measures. Given that half of the included studies were case series, the generalizability of the findings for these studies was limited. Because of the diversity of the outcome measures used and the heterogeneity of the interventions, a direct comparison of results between the studies was not possible.

5. Conclusions

In conclusion, we are not able to recommend the use of orthoses as it did not bring about structural changes in patients with PFFF. However, most of the studies in this review used various forms of foot orthoses as conservative treatment. Due to the deficiency of related studies, heterogeneity, and low methodological quality of the studies within this review, definite conclusions could not be made. Medical practitioners should be aware of the deficiency of studies with good quality evidence while they decide on the long-term use of orthoses for the management for PFFF.

Future recommendations for research include studies with longer term follow-up of

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>3 years and comparison with an untreated control group. The age to start the orthoses application also needs to be considered very carefully as mentioned above. In addition, we strongly suggest the evaluation of the changes in the hindfoot alignment using objective methods, such as the hindfoot alignment view by Saltzman and el-Khoury [32].

Acknowledgement

This research was supported by a grant of the Medical Research Information Center (MedRIC) of the National Research Foundation through the Ministry of Science and ICT (2018R1A6A6040880), Republic of Korea

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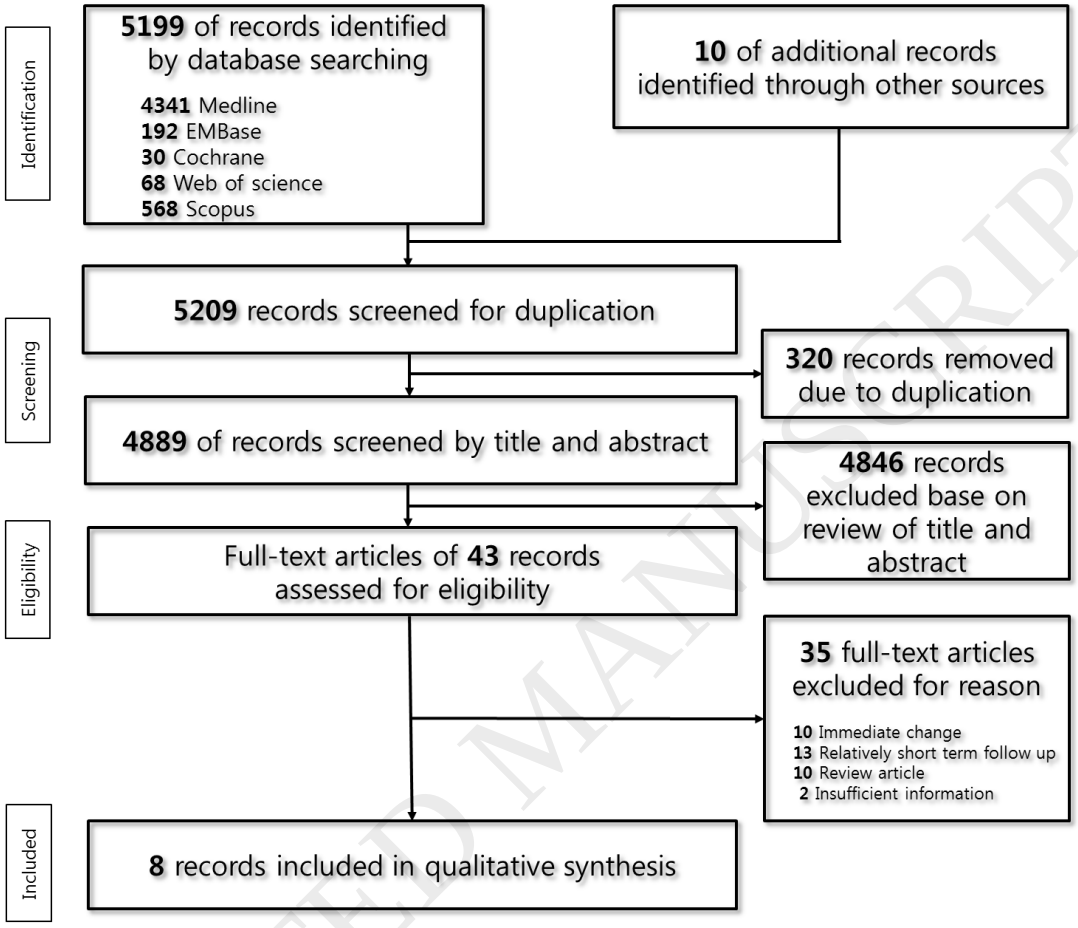
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Figure Legends

Figure 1.

A flow diagram of the study selection as recommended by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.



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Table 1. Study characteristics of eight studies analyzed in this review

Reference, Country	Study Design (Level of evidence)	Total number of Participants	Mean age	Gender (male : female)	Inclusion criteria	Outcome evaluation method
Wenger et al [21], United States (1989)	RCT (1)	98 (180 feet)	29.3±13.6 months	1:0.63	1-6 years old children with flexible flat foot Diagnosed by pediatricians, then referred to the institution	Radiographs (barefoot)
Kanatli et al [22], Turkey (2016)	RCT (1)	45	39.5 months (range, 17-72 months)	1:0.36	Pain free moderate flexible flat foot	Radiographs (uncertain)
Riccio et al [23], Italy (2009)	Prospective cohort study (2)	637 (1274 feet)	3.4±0.55 years (I) 2.6±0.52 years (C)	1:0.63 (I) 1:0.54 (C)	Flexible flat foot	Gross foot posture
*Gould et al [20],	Prospective cohort study	52	Not given (range,11~14	1:0.93	Clinically normal children, Beginner walker	Radiographs (uncertain)

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United States (1989)	(2)		months)			Gross foot posture
Mereday et al [12], United States (1972)	Case series (4)	10 (20 feet)	91.2 months (range, 3.5~12.5 years)	1:0.67	Flexible pes planus Non-rigid eversion deformity of the foot during stance Full range of passive ST motion	Radiographs (barefoot) Gross foot posture Pain
†Bordelon [24], United States (1980)	Case series (4)	12 (24 feet)	44.42±13.85 months (range, 31~76 months)	Not given	Idiopathic hypermobile flat foot	Radiographs (with orthoses) Gross foot posture Ankle ROM
Bok et al [13], South Korea (2014)	Case series (4)	39	10.3 years (range, 6~14 years)	1:1.17	Flexible flat foot RCSP >4^{o} + 1 abnormal radiological finding (APTCA >30^{o}, LTTCA>45^{o}, LTTMA>4^{o}, CPA<20^{o})	Radiographs (uncertain) Gross foot posture

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Lee et al [14], South Korea (2017)	Case series (4)	66	5.0±2.7 years	1:1	Aged under 13 years old children with pain free flexible flat foot	Gross foot posture

RCT, randomized controlled trials; I, intervention; C, control

*The findings at 5 years old was shown only. †The result was re-calculated for data with the orthoses application time of more than 24 months.

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Table 2. The result of quality assessment of each study.

Overall quality assessment												
Randomized controlled trial (assessed with the Cochrane collaboration's ROB)												
	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias					
Wenger et al [21]	High risk	Unclear	High risk	Low risk	High risk	Low risk	High risk					
Kanatli et al [22]	High risk	Unclear	High risk	Low risk	Low risk	Low risk	Low risk					
Prospective Cohort study (assess with NIH tool)												
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12 Score
Riccio et al [23]	2	2	0	2	0	2	2	0	1	1	1	2 15/24

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Gould et al [20]	2	2	2	2	0	2	2	0	0	1	1	0	14/24

Case series (assessed with NIH tool)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Score
										15/18
Mereday et al [12]	2	2	1	2	2	0	2	0	2	13/18
Bordelon [24]	0	2	2	2	2	0	2	1	2	15/18
										16/18
Bok et al [13]	2	1	2	1	1	2	2	2	2	
Lee et al [14]	2	2	1	2	2	2	1	1	2	

ROB, risk of bias; NIH, national institutes of health

The 3 assessors rated each study, reaching consensus by majority in the instance of dispute

Scoring system: 2=yes; 1= cannot determine, not applicable or not reported; 0=no

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Table 3. Duration of orthoses application, mode of intervention or control and outcome evaluation method of each study.

References	Duration of Orthoses application	Mode of Intervention	Mode of Control
Wenger et al [21]	36.8±5.04 months	I1. Corrective orthopaedic shoes (54) I2. Helfet Heel Cup (49) I3. UCBL (38)	Standard-last leather shoes (39)
Kanatli et al [22]	34.6±10.9 months	Custom made orthopaedic shoes with 0.5-0.9 cm longitudinal arch supports and 3-4mm heel wedges (21) Shoes were renewed every 6 month	Untreated (24)
Riccio et al [23]	2.75±0.63 years (I) 2.66±0.61 years (C)	Simple therapeutic exercise at least 2 hours per week - Flexibility, muscle strengthening, proprioception & postural balance (600)	Double planed plantar insole inclined both in medio-lateral & anteroposterior directions (674)
Gould et al [20]	4 years	I1. Straight last shoe + arch cookies (10) I2. Orthopaedic shoes with Thomas heel, long counter, solid shank and 0.312cm inside heel wedge (7) I3. Orthopaedic shoes with Thomas heel, long counter, solid shank and 0.312cm inside heel wedge + supplemental thin long arch	Straight last shoe (25)

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		support (7)	
Mereday et al [12]	2 years	UCBL fabricated shoe insert (20)	None
†Bordelon [24]	33.83 months	1/8 inch polyprolene fabricated insert + leather shoes with a long counter, steel shank and Thomas heel (24)	None
Bok et al [13]	24 months	Custom made rigid foot orthosis with the inverted technique (39)	None
Lee et al [14]	24 months	Custom made rigid foot orthosis on the basis of inverted technique with lateral long flanges (66) Subjects were recommended to wear for more than 8 hours per day.	None

I, intervention; C, control; ( ), number of cases; ST, subtalar; UCBL, University of California Biomechanics Laboratory; RCSP, resting calcaneal stance position; APTCA, anteroposterior talocalcaneal angle; LTTCA, lateral talocalcaneal angle; LTTMA, lateral talometatarsal angle; CPA, calcaneal pitch angle

†The result was re-calculated for data with the orthoses application time of more than 24 months.

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Table 4. Result of radiographic evaluation from each study.

References	**Lateral Talocalcaneal angle**		**Lateral Talo-1st MT angle**		**Lateral Talo-horizontal angle**		**Lateral Calcaneal pitch angle**		**Anterior Talocalcaneal angle**	
	Changes	*P*-value	Changes	*P*-value	Changes	*P*-value	Changes	*P*-value	Changes	*P*-value
Wenger et al [21]	I1. -7.36º I2. -6.65 º I3. -6.64 º C. -4.5 º	> 0.5	I1. -6.80º I2. -6.65 º I3. -6.64 º C. -5.78 º	> 0.5	I1. -6.47º I2. -5.47 º I3. -6.62 º C. -5.48 º	> 0.4				
Kanatli et al [22]	I. -0.34º C. -0.2 º	0.24	I. -0.45º C. -0.46º	0.72	I. -0.17º C. -0.13º	0.09	I. +0.6º C.+0.27 º	0.18	I. -0.13º C. -0.19º	0.19
*Gould et al [20]	I1. -6.8º (Rt) I1. -6.5º (Lt)									

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	I2. -3.6° (Rt) I2. -5.0° (Lt) I3. -5.7° (Rt) I3. -12.3° (Lt) C. -3.5° (Rt) C. -4.7° (Lt)									
Mereday et al [12]	-2.1° (in 11 feet)		-2.1° (in 4 feet)							
†Bordelon [24]			-9.12°							
Bok et al [13]	+0.3°	>0.05	-7.4°	<0.05			+4.4°	<0.05	-8.8°	<0.05

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		(compared to initial)		(compared to initial)				(compared to initial)		(compared to initial)

MT, metatarsal; I, intervention; C, control; N/A, not applicable

*The findings at 5 years old was shown only.

† The result was re-calculated for data with the orthoses application time of more than 24 months.

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Table 5. Result of non-radiographic evaluation from each study.

References	Gross foot posture	Range of motion	Pain
Riccio et al [23]	Arch index calculation using podoscopic footprints Viladot type [22] III → normal I. 91.2% C. 54% Viladot type II → normal I. 98.1% C. 89%		
*Gould et al [20]	Proportion of pes planus after treatment 25% (I1), 28.6% (I2), 40% (I3), 40% (C) Proportion of hyperpronation after treatment 75% (I1), 85% (I2), 80% (I3), 79% (C)		
Mereday et al [12]	Neither calcaneal eversion angle nor arch height established a definite trend which would demonstrate permanent effects upon the unsupported foot. (Exact measurements not given)		6 out of 10 participants who complained of pain before wearing UCBL foot orthoses,

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			were all pain free after 2 years of orthoses use.
†Bordelon [24]	Changes in foot adduction : -3.44° (in 16 feet) Changes in foot abduction : -2.81° (in 16 feet)	Changes in ankle dorsiflexion : -4.06° (in 16 feet)	
Bok et al [13]	Changes in RCSP : +6.1° → $P < 0.05$ (compared to initial)		
Lee et al [14]	Changes in RCSP Overall +3° (Rt), +3.2° (Lt) Preschool age +3.3° (Rt), +3.4° (Lt) School age +1.6° (Rt), +2° (Lt)		

I, intervention; C, control; RCSP, resting calcaneal stance position

*The findings at 5 years old was shown only.

† The result was re-calculated for data with the orthoses application time of more than 24 months.

Table 6. Conclusions of all studies.

References	Conclusions
Wenger et al [21] (1989)	Flexible flatfoot in young children slowly improves with growth. An intensive treatment with corrective shoes or inserts for a three year period does not alter

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	the natural history.
Kanatli et al [22] (2016)	Corrective shoes for flexible flatfoot were found not effective on development of foot arches. If the final diagnose is flexible flatfoot with moderate deformity, avoid unnecessary treatment with shoes, since they do not have the estimated effect of the medial longitudinal arch.
Riccio et al [23] (2009)	The rehabilitative approach seems to be more effective.
Gould et al [19] (1989)	Neutral arches developed regardless of the footwear worn but was developed faster during the first 2 years with 'Straight last shoe + arch cookies'. Thereafter, arch development proceeded approximately equally regardless of the type of footwear worn.
Mereday et al [12] (1972)	1, Protracted insert wear eliminated symptoms of local pain in the anterior tibial muscles and diffuse pain. 2. Some improvement in gait was shown as demonstrated by more even shoe wear while

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	inserts were worn.
Bordelon [24] (1980)	The hypermobile flatfoot of a child can be corrected by correcting the osseous structures to a neutral positionand maintaining in this position with a custom molded insert.
Bok et al [13] (2014)	Rigid foot orthosis with the inverted technique can be effective devices for treating flexible flat foot in children over 6 years old.
Lee et al [14] (2017)	Corrective insoles had an additional beneficial effect for flexible flatfoot in children younger than 13 years.

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