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META-ANALYSIS

Ponseti method compared with soft-tissue release for the management of clubfoot: A meta-analysis study

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Abstract

AIM: To compare the functional outcomes of patients who underwent open surgery *vs* Ponseti method for the management of idiopathic clubfoot and to determine whether correlations exist between functional outcome and radiographic measurements.

METHODS: A meta-analysis of the literature was conducted for studies concerning primary treatment of patients with idiopathic clubfoot. We searched PubMed Medline, EMBASE, and the Cochrane Library databases from January 1950 to October 2011. Meta-analyses were performed on outcomes from 12 studies. Pooled means, SDs, and sample sizes were either identified in the results or calculated based on the results of each study.

RESULTS: Overall, 835 treated idiopathic clubfeet in 516 patients were reviewed. The average follow-up was 15.7 years. Patients managed with Ponseti method did have a higher rate of excellent or good outcome than patients treated with open surgery (0.76 and 0.62, respectively), but not quite to the point of statistical significance (Q = 3.73, P = 0.053). Age at surgery was not correlated with the functional outcome for the surgically treated patients (r = -0.32, P = 0.68). A larger anteroposterior talocalcaneal angle was correlated with a higher rate of excellent or good outcomes (r = 0.80, P = 0.006). There were no other significant correlations between the functional and radiographic outcomes.

CONCLUSION: The Ponseti method should be considered the initial treatment of idiopathic clubfeet, and open surgery should be reserved for clubfeet that cannot be completely corrected.

Key words: Idiopathic clubfoot; Congenital talipes equinovarus; Ponseti method; Surgical release; Ponseti-Laaveg score

Core tip: This study analyzed a large cohort of patients with idiopathic clubfoot and presented differences in the functional and radiographic outcomes based on the management employed. Although no statistically significant difference was noted in the overall functional outcomes between patients managed with the Ponseti method or open surgery, patients treated with the Ponseti method had a higher rate of excellent or good outcomes. Serial manipulation and casting has been widely accepted as the initial treatment of idiopathic clubfeet, and soft-tissue release is reserved for clubfeet that cannot be completely corrected. A strict brace compliance remains the major challenge of the Ponseti method.

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INTRODUCTION

During the second half of the twentieth century, the primary treatment of idiopathic clubfoot has ranged from gentle manipulations to aggressive surgical treatment. Surgical management predominated because it was considered as a method that could obtain full and lasting correction. Over time and based on long-term follow-up studies surgeons realized that the results of surgical intervention are unpredictable[1-3]. Extensive soft-tissue releases can result in scarring which may lead to stiffness, recurrent deformity, and pain[4]. It was this observation along with the promising results of the Ponseti method[5,6] that shifted treatment of idiopathic clubfoot towards a more conservative approach consisting of manipulations and serial casting, and frequently minimal invasive surgery. Open surgery is usually reserved for more severe cases that failed serial casting. However, even in these cases, current surgical procedures are less aggressive than procedures performed three decades ago.

Although there are a plethora of studies that have assessed the functional and radiographic outcomes following different treatment protocols, there are only a few studies that directly compare open surgery and Ponseti method for the management of idiopathic clubfoot[1,7-9]. This can be mainly attributed to variable and simplistic grading systems for scoring the severity of the deformity as well as the differing evaluation systems for assessing outcomes. Only one study in the current literature prospectively compares surgical management and Ponseti method, but there are no prospective randomize controlled trials[7].

The present meta-analysis aims to address two topics. The main purpose is to compare the functional outcomes between patients undergoing open surgery *vs* Ponseti method for the treatment of idiopathic clubfoot. A secondary aim is to determine if functional outcomes and radiographic measurements correlate.

MATERIALS AND METHODS

Literature search

A meta-analysis of the literature was conducted for studies concerning management of patients with idiopathic clubfoot with either soft-tissue release or Ponseti method. The search was performed with use of the following electronic bibliographic databases: Medical Literature Analysis and Retrieval System online (PubMed Medline), Excerpta Medica Database (EMBASE), and The Cochrane Library. The medical subject headings or text words utilized included: "clubfoot", "congenital talipes equinovarus", "soft-tissue release", "surgery", and "Ponseti method". The bibliographies of the retrieved articles as well as the "related articles" option in PubMed Medline were also searched to assess for potentially inclusive papers that were missed by the initial search.

Criteria for eligibility

Since several methods and systems have been used to describe the functional and radiographic outcome of patients treated with open surgery or Ponseti method, we performed an initial search to identify the most commonly used functional scores and radiographic parameters. These included: Laaveg-Ponseti score (Figure 1)[5], anteroposterior talocalcaneal angle (TCA-AP), lateral talocalcaneal angle (TCA-LT), anteroposterior talus-first metatarsal angle (TMT-AP), lateral talus-first metatarsal angle (TMT-LT), anteroposterior calcaneus-fifth metatarsal angle (CMT-AP), lateral first-fifth metatarsal angle (MTT-LT), and talocalcaneal index (TCI) (Figure 2). The Laaveg-Ponseti score is a 100-point evaluation system with scores between 90 and 100 considered as excellent, 80 and 89 as good, 70 and 79 as moderate, and below 70 as poor. According to our initial search of the literature, this was the most commonly used functional score in patients who underwent soft-tissue release or Ponseti method from its description in 1980 until today. In contrast to other systems, it can be used to study the correlation between the functional outcome and radiographic measurements since it relies only on clinical aspects, not including any radiographic parameters[10].

Based on the initial search findings, studies selected for the analyses were original studies fulfilling the following eligibility criteria: (1) assess idiopathic clubfoot; (2) assess primary treatment of idiopathic clubfoot; (3) use the functional evaluation score of Laaveg-Ponseti; (4) use of at least three of the radiographic outcome measures found to be the most commonly used in the literature and described above; (5) evaluate more than ten feet; (6) evaluate human subjects; and (7) was published from January 1950 through October 2011.

Potentially inclusive papers were manually reviewed and were discussed among the authors, and a decision was made regarding inclusion. If there was any disagreement among authors regarding the inclusion of an article, the senior author made the final decision.

Extraction of data

Data were carefully extracted and computerized on the following variables from those published articles that meet our inclusion criteria: (1) radiographic findings at final follow-up (main outcome variable); (2) Laaveg-Ponseti score at final follow-up (main outcome variable); (3) time period during which the procedure was performed; (4) duration of follow-up; (5) number of patients/feet; (6) unilateral or bilateral involvement; (7) sex of the patient; (8) age at treatment; (9) level of evidence; (10) publication year; and (11) authors' names.

Statistical analysis

Due to the possibility of variation between studies, the more conservative, random-effects model was selected over a fixed-effects model. Random effects models account for both within-study and between-study variation and are more preferable when assessing observational studies. Pooled means, SDs, and sample sizes were either identified in the results of each study or calculated based

Category	Points
Satisfaction (20 points)	
I am	
(1) very satisfied with the end result	20
(2) satisfied with the end result	16
(3) neither satisfied nor unsatisfied with the end result	12
(4) unsatisfied with the end result	8
(5) very unsatisfied with the end result	4
Function (20 points)	
In my daily living, my club foot	
(1) does not limit my activities	20
(2) occasionally limits my strenuous activities	16
(3) neither satisfied nor unsatisfied with the end result	12
(4) usually limits my strenuous activities	8
(5) limits me in walking	4
Pain (30 points)	
My club foot	
(1) is never painful	30
(2) occasionally causes mild pain during strenuous activities	24
(3) usually is painful after strenuous activities only	18
(4) is occasionally painful during routine activities	12
(5) is painful during walking	6
Position of heel when standing (10 points)	
My club foot	
Heel varus, 0° or some heel valgus	10
Heel varus, 1°-5°	5
Heel varus, 6°-10°	3
Heel varus, greater than 10°	0
Passive motion (10 points)	
Dorsiflexion	1 point per 5°
Total varus-valgus motion of heel	1 point per 10°
Total anterior inversion-eversion of foot	1 point per 25°
Gait (10 points)	
Normal	6
Can toe-walk	2
Can heel-walk	2
Limp	-2
No heel-strike	-2
Abnormal toe-off	-2

Figure 1 Functional rating system for clubfoot. Reproduced from by Laaveg *et al*[5].

Figure 2 Radiographic parameters most commonly measured on plain films. Anteroposterior (A) and lateral (B) standing foot radiographs of a patient with clubfoot showing the anteroposterior talocalcaneal angle (a), anteroposterior calcaneus-fifth metatarsal angle (b), anteroposterior talus-first metatarsal angle (c), lateral talocalcaneal angle (d), lateral talus-first metatarsal angle (e), and lateral first-fifth metatarsal angle (f).

on the results. Effect sizes with 95%CI were calculated using the mean and SE for each study. Subgroup analyses were performed in order to compare the Ponseti method and surgical treatment studies on all outcome measures. Variability between treatment types was assessed with Cochran's Q statistic, which measures the presence or absence of heterogeneity between studies based on a χ^2 distribution. It is calculated as the weighted sum of squared differences between individual study effects and pooled effects across studies. The I^2 index was also calculated as a measure of the extent of heterogeneity between studies. Larger Q and I^2 values indicate

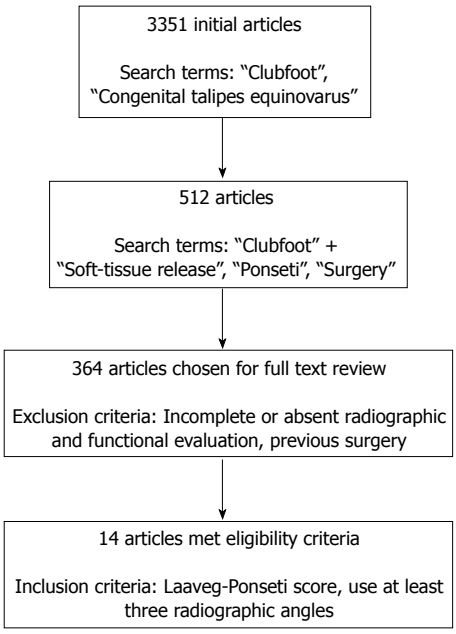

Figure 3 Flow chart summary of the literature.

greater variability. The number of feet with good or excellent outcomes on the Laaveg-Ponseti scale was also compared to the number of feet with poor or fair outcomes using event rates of successful outcomes rather than effect sizes.

Meta-analyses were performed using the Comprehensive Meta-Analysis software (2.0, Bio-Stat, Englewood, NJ, United States). A *P* value of 0.05 or less was considered as statistical significant.

RESULTS

Literature search

Based on the title and the abstract, the initial electronic search yielded 512 articles as potentially eligible. After obtaining the full text of 364 articles, a total of fourteen articles were found to fulfill the inclusion criteria[1,3,5,6,9-18]. Two studies were excluded because the measures were in terms of medians and ranges, and thus, effect sizes could not be calculated[9,18]. A flow chart summary of the literature search is shown in Figure 3.

Meta-analyses were performed on outcomes from 12 studies[1,3,5,6,10-17]. Nine studies evaluated functional and radiographic outcome following soft-tissue release, two studies after Ponseti method, and one study compared outcomes in patients who underwent Ponseti method or open surgery for the management of idiopathic clubfoot. Three studies were therapeutic level of evidence Ⅲ studies[1,3,13]. The rest of the studies were observational level of evidence Ⅳ case series[5,6,10-12,14-17].

In summary, 835 treated idiopathic clubfeet in 516 patients were reviewed. Among these patients, 369 patients (611 feet) were treated with soft-tissue release and 147 patients (224 feet) were managed with the Ponseti method. The male-to-female ratio was 2.5:1. The unilateral-to-bilateral involvement ratio was 1.25:1. The mean age at initiation of treatment was 8.8 ± 4.8 mo. The average follow-up was 15.7 ± 10.8 years. The minimum follow-up was one year and the maximum 42 years.

Functional outcome

At the final follow-up, functional outcomes, as measured with the Laaveg-Ponseti score, did not differ between patients treated with Ponseti method and patients treated with soft-tissue release (86.3 and 82.0, respectively, Q = 0.45, P = 0.50) (Table 1). However, when compared categorically, patients managed with Ponseti method did have a higher rate of excellent or good outcome than patients treated with open surgery (0.76 and 0.62, respectively), but not quite to the point of statistical significance (Q = 3.73, P = 0.053) (Figure 4, Table 1).

For all patients studied, a longer length of follow-up was correlated with worse functional outcomes (r = -0.82, P = 0.023). Age at surgery was not correlated with functional outcome for patients treated with open surgery (r = -0.32, P = 0.68).

Radiographic outcome

The radiographs taken at the time of the final follow-up did not show any significant differences between patients treated with manipulation and serial casting (Ponseti method) and patients treated with soft-tissue release regarding the TCA-AP (15.8° and 18.9°, respectively) (Q = 2.09, P = 0.15), TCA-LT (29.9° and 26.6°, respectively) (Q = 0.33, P = 0.57), TCI (45.7° and 46.1°, respectively) (Q = 0.002, P = 0.96), and the TMT-AP angles (0.96° and 6.04°, respectively) (Q = 0.55, P = 0.11) (Table 2).

Statistically significant differences were noted between patients managed with the Ponseti method and patients treated with open surgery in TMT-LT (5.51° and 12.08°, respectively) (Q = 10.74, P = 0.001), MTT-LT (15.4° and 25.2°, respectively) (Q = 10.48, P = 0.001), and CMT-AP angles (-6.49° and 3.86°, respectively) (Q = 16.12, P < 0.001) (Table 3).

Heterogeneity in outcomes

For the Laaveg-Ponseti score and all radiographic measurements, except TCA-LT, greater variability was recorded in patients who underwent open surgery compared with patients managed with the Ponseti method, as indicated by the higher Q values and I^2 values (Table 4).

Correlations between functional outcome and radiographic measurements

A larger TCA-AP angle was correlated with a higher rate of excellent or good outcomes (r = 0.80, P = 0.006). Functional outcomes were not significantly correlated with MTT-LT (r = -0.80, P = 0.20), TMT-AP (r = -0.80, P = 0.20), and TCA-AP (r = 0.70, P = 0.19) angles or the TCI (r = -0.30, P = 0.62) (Table 5).

DISCUSSION

Idiopathic clubfoot is a complex three dimensional deformity with an incidence of between 0.64 and 6.8 per

Table 1 Comparison of Laaveg-Ponseti score between patients treated with the Ponseti method and surgically managed patients

Studies	Level of evidence	Mean follow-up (yr)	Time period of procedure	Patients (*n*)	Feet (*n*)	Laaveg-Ponseti score mean (95%CI)	Excellent/good Laaveg-Ponseti rating rate (95%CI)
All Treatments				500	810	86.2 (84.2-88.2)	0.73 (0.67-0.78)
Ponseti method				147	224	86.3 (84.2-88.3)	0.76 (0.69-0.81)
Ippolito *et al*[1]	Ⅲ	19	1979-1984	32	49	85.4 (83.9-86.9)	0.78 (0.64-0.87)
Laaveg *et al*[5]	Ⅲ	18.8	1950-1967	70	104	87.5 (85.3-89.7)	0.74 (0.65-0.82)
Cooper *et al*[6]	Ⅳ	34	1950-1967	45	71	-	0.78 (0.63-0.88)
Soft-tissue release				353	586	82.0 (69.5-94.5)	0.62 (0.48-0.74)
Ippolito *et al*[1]	Ⅲ	25	1973-1977	32	47	74.7 (71.4-78.0)	0.43 (0.29-0.57)
Dobbs *et al*[3]	Ⅲ	31	1972-1979	45	73	65.3 (62.9-67.7)	0.33 (0.23-0.44)
Fridman *et al*[10]	Ⅳ	6.4	1986-2003	50	71	86.9 (84.1-89.6)	0.80 (0.69-0.88)
Schuh e *et al*[11]	Ⅳ	4.5	1986-2000	86	130	95.6 (94.0-97.2)	-
Singh *et al*[12]	Ⅳ	13.8	1980-1996	18	33	-	0.82 (0.65-0.92)
Prasad *et al*[13]	Ⅳ	-	-	30	50	-	0.58 (0.44-0.71)
Munshi *et al*[14]	Ⅲ	3.5	-	-	50	87.3 (83.1-91.5)	0.78 (0.65-0.87)
Herbsthofer *et al*[15]	Ⅳ	6.7	1984-1994	38	62	-	0.47 (0.35-0.59)
Abulsaad *et al*[16]	Ⅳ	3.9	2000-2004	54	70	-	0.69 (0.57-0.78)
Difference between treatments						Q = 0.45, P = 0.50	Q = 3.73, P = 0.053

Treatment type	Study	Year	Statistics					Event rate and 95%CI
			Event rate	Lower limit	Upper limit	*Z*	*P*	
Ponseti Method	Ippolito *et al*[1]	2003	0.78	0.64	0.87	3.62	< 0.001	
Ponseti Method	Cooper *et al*[6]	1995	0.78	0.63	0.88	3.49	< 0.001	
Ponseti Method	Laaveg *et al*[5]	1980	0.74	0.65	0.82	4.69	< 0.001	
Ponseti Method			**0.76**	**0.69**	**0.81**	**6.85**	**< 0.001**	
Soft Tissue Release	Ippolito *et al*[1]	2003	0.43	0.29	0.57	-1.02	0.31	
Soft Tissue Release	Singh *et al*[12]	2005	0.82	0.65	0.92	3.33	0.001	
Soft Tissue Release	Prasad *et al*[13]	2009	0.58	0.44	0.71	1.13	0.26	
Soft Tissue Release	Herbsthofer *et al*[15]	1998	0.47	0.35	0.59	-0.51	0.61	
Soft Tissue Release	Fridman *et al*[10]	2007	0.80	0.69	0.88	4.71	< 0.001	
Soft Tissue Release	Dobbs *et al*[3]	2006	0.33	0.23	0.44	-2.87	0.004	
Soft Tissue Release	Abulsaad *et al*[16]	2008	0.69	0.57	0.78	3.03	0.003	
Soft Tissue Release	Munshi *et al*[14]	2006	0.78	0.65	0.87	3.71	< 0.001	
Soft Tissue Release			**0.62**	**0.48**	**0.74**	**1.66**	**0.097**	
Combined			**0.73**	**0.67**	**0.78**	**6.78**	**< 0.001**	

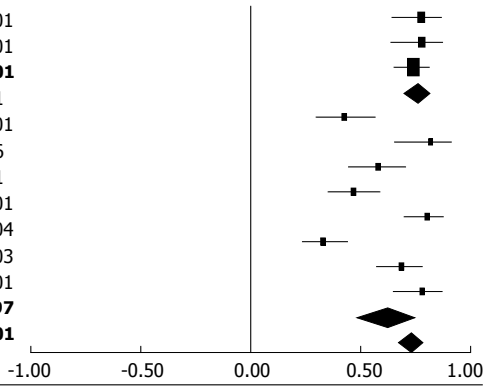

Figure 4 Success rate of Ponseti method *vs* soft-tissue release for clubfoot management based on Laaveg-Ponseti score.

1000 live births[19]. Pathogenesis of idiopathic clubfoot remains obscure, but there is increased evidence for a multifactorial etiologic model. Both genetic and environmental factors have been implicated. Muscle growth impairment[20,21], primary germ plasm defect in the talus[22], vascular anomalies[23-25], medial retraction fibrosis[26], and intrauterine factors[19], such as oligohydramnios, placental insufficiency, drugs, infective pathogens, and amniocentesis prior to the eleventh week[27], have been proposed as potential etiologic factors in the pathogenesis of idiopathic clubfoot. Studies have shown that the deformity has a heritable factor, but is not inherited in a simple autosomal dominant or recessive mendelian fashion[28-32]. Although there is no evidence to support sex linkage, males are affected more commonly than females in all ethnic groups. The reported male-to-female ratio is 2.5:1[33]. This is in accordance to our findings. The male-to-female ratio in 516 patients with idiopathic clubfoot reviewed in our study was 2.5:1. We also recorded a unilateral-to-bilateral involvement ratio of 1.25:1.

The success rates in different series are difficult to compare because of variation in severity of the deformity between study groups and, more importantly, absence of common assessment protocols. In the present meta-analysis, in an effort to use a "common language" between patients treated with open surgery or Ponseti method, we used the subjective assessment method published by Laaveg *et al*[5]. It is based on functionality, presence of pain, foot and ankle range of motion, and patient's satisfaction. In contrast to other systems, it can be used to study the correlation between the functional outcome and radiographic measurements since it relies only on clinical aspects, not including any radiographic parameters[15]. Although it may have been interesting to compare outcomes based on the degree of deformity prior to treatment, only five of the 12 studies included in this meta-analysis evaluated clubfeet at birth. Even in these few studies, the system used deferred, and a comparison in terms of severity of the deformity was not possible. It should also be noted that this study has the disadvantages

Table 2 Comparison of anteroposterior talocalcaneal angle, lateral talocalcaneal angle, and talocalcaneal index between patients treated with the Ponseti method and surgically managed patients

Studies	Patients	Feet	Talocalcaneal		
			AP mean (95%CI)	Lateral mean (95%CI)	Index mean (95%CI)
All treatments	430	655	16.2 (14.9-17.5)	26.9 (23.9-29.9)	46.0 (41.4-50.7)
Ponseti method	147	224	15.8 (14.5-17.2)	29.9 (19.3-40.5)	45.7 (33.4-58.0)
Ippolito *et al*[1]	32	49	16.1 (14.6-17.6)	38.8 (37.1-40.4)	54.9 (51.7-58.0)
Laaveg *et al*[5]	70	104	14.5 (12.8-16.2)	20.9 (19.8-22.0)	35.5 (33.5-37.5)
Cooper *et al*[6]	45	71	17.0 (15.1-18.9)	30.0 (28.4-31.6)	47.0 (43.5-50.5)
Soft-tissue release	283	431	18.9 (15.0-22.8)	26.6 (23.5-29.8)	46.1 (41.0-51.1)
Ippolito *et al*[1]	32	47	14.1 (12.2-16.0)	33.2 (30.7-35.7)	47.3 (42.9-51.7)
Dobbs *et al*[3]	45	73	12.8 (11.1-14.4)	23.3 (21.8-24.8)	36.1 (32.9-39.3)
Fridman *et al*[10]	50	71	20.8 (19.3-22.3)	22.5 (20.9-24.0)	43.3 (40.9-45.6)
Singh *et al*[12]	18	33	28.4 (27.0-29.8)	30.9 (29.2-32.6)	59.3 (56.2-62.4)
Prasad *et al*[13]	30	50	18.5 (16.2-20.8)	27.4 (24.6-30.1)	45.8 (43.3-48.4)
Herbsthofer *et al*[15]	38	62	16.1 (14.6-17.6)	23.0 (21.3-24.7)	39.1 (36.0-42.2)
Abulsaad *et al*[16]	54	70	16.4 (15.1-17.6)	21.4 (19.9-23.0)	42.2 (39.7-44.7)
Docquier *et al*[17]	16	25	24.3 (21.5-27.1)	32.2 (29.6-34.8)	56.5 (51.1-61.9)
Difference between treatment			$Q = 2.09$, $P = 0.15$	$Q = 0.33$, $P = 0.57$	$Q = 0.002$, $P = 0.96$

Table 3 Comparison of talus-1st metatarsal, 1st-5th metatarsal, and calcaneus-5th metatarsal angles between patients treated with the Ponseti method and surgically managed patients

Studies	Patients	Feet	Talus-1st metatarsal		1st-5th metatarsal	
			AP mean (95%CI)	Lateral mean (95%CI)	Lateral mean (95%CI)	AP mean (95%CI)
All treatments	516	655	1.27 (-0.23-2.77)	6.24 (5.00-7.48)	15.6 (16.7-17.9)	-5.11 (-6.83 - -3.40)
Ponseti method	147	224	0.96 (-0.59-2.51)	5.51 (4.20-6.82)	15.4 (14.7-16.1)	-6.49 (-8.33 - -4.65)
Ippolito *et al*[1]	32	49	0.94 (-1.01-2.89)	6.39 (4.40-8.38)	15.5 (14.2-16.7)	-6.8 (-9.20 - -4.40)
Laaveg *et al*[5]	70	104	-	-	14.7 (13.5-15.9)	-4.9 (-6.92 - -2.88)
Cooper *et al*[6]	45	71	1 (-1.56-3.56)	5 (3.60-6.40)	16 (14.8-17.2)	-8 (-10.33 - -5.67)
Soft-tissue release	283	431	6.04 (-0.06-12.13)	12.08 (8.38-15.79)	25.2 (19.3-31.0)	3.86 (-0.84 - 8.57)
Ippolito *et al*[1]	32	47	8.28 (5.97-10.59)	9.4 (6.69-12.11)	22.1 (20.3-23.9)	-0.62 (-3.04 - 1.80)
Dobbs *et al*[3]	45	73	15.95 (13.24-18.66)	7.68 (4.06-11.30)	18.1 (15.4-20.8)	10.32 (8.55 - 12.09)
Fridman *et al*[10]	50	71	3.97 (1.27-6.67)	-	-	1.32 (-0.70 - 3.34)
Singh *et al*[12]	18	33	11.9 (9.89-13.91)	15.7 (13.14-18.26)	28.2 (25.9-30.5)	-
Prasad *et al*[13]	30	50	6.92 (2.49-11.35)	18.54 (11.90-25.18)	46.2 (38.7-53.7)	5.8 (2.22 - 9.38)
Herbsthofer *et al*[15]	38	62	10.29 (7.68-12.90)	-	-	9.95 (7.90 - 12.00)
Abulsaad *et al*[16]	54	70	-5.43 (-6.85-4.02)	-	-	-
Docquier *et al*[17]	16	25	-3.5 (-6.52-0.48)	10.9 (6.43-15.37)	15.9 (12.7-19.1)	-3.9 (-7.04 - -0.76)
Difference between treatment			$Q = 2.50$, $P = 0.11$	$Q = 10.74$, $P = 0.001$	$Q = 10.48$, $P = 0.001$	$Q = 16.12$, $P < 0.001$

adherent to low level of evidence studies analyzed and the relatively loose entry criteria.

Extensive soft-tissue release was the preferred method of treatment for many decades because it often provides definitive correction of the deformity. Full correction by addressing all components of the deformity was recommended. Surgical approaches most commonly used can be classified into three main categories: the Turco posteromedial incision[34], the Crawford's circumferential Cincinnati incision[35], and the two-incision Carroll approach[36]. Ponseti *et al*[33] pioneered his manipulative and serial casting technique in the late 1940s and first published his method in 1963. He proposed simultaneous correction of all components of clubfoot by abducting the foot under the talus while a counter pressure is applied to the talar head. Based on long-term follow-up studies of patients who underwent extensive soft-tissue releases for the management of idiopathic clubfoot before 1980, it has been shown that aggressive surgical management results in poor long-term foot function due to pain, stiffness, and degenerative arthrosis[1-4]. Until today, there is a lack in the literature of studies evaluating adults with clubfeet treated with selective posteromedial release techniques, as these were described after 1983. The present meta-analysis, by including data of clubfeet treated with both aggressive and comprehensive release techniques, demonstrated that patients managed with the Ponseti method had a higher rate of excellent or good outcomes than patients treated with open surgery.

Noncompliance of the family to follow the brace protocol is associated with unexpected high recurrence rate ranging from 30% to 45%[7,37-49]. According to a recent study, there is no association between the poor bracing compliance and the families educational level, income or cultural origin[50]. Distance from the treatment centers and accessibility to the health care system are important parameters that may also adversely affect compliance, and secondarily the success rate. In addition, concurrent

Table 4 Between and within-study heterogeneity in outcomes of clubfoot treatment

	Overall		Ponseti method		Soft-Tissue release	
	Q	I^2	*Q*	I^2	*Q*	I^2
Laaveg-Ponseti score	468.8[a]	98.7	2.3	57.2	465.8[a]	99.1
Excellent/Good Laaveg-Ponseti ratings	72.5[a]	86.2	0.35	0	55.6[a]	87.4
TCA-AP	346.8[a]	97.1	4.1	50.9	312.5[a]	97.8
TCA-LT	496.3[a]	98.0	320.8[a]	99.4	158.1[a]	95.6
TCI	274.5[a]	96.4	114.3[a]	98.3	265.5[a]	95.4
TMT-AP	376.3[a]	97.6	0.001	0	365.2[a]	98.1
TMT-LT	67.3[a]	91.1	1.3	20.5	21.0[a]	80.9
MTT-LT	203.8[a]	96.6	2.3	12.0	89.0[a]	95.5
CMT-AP	328.7[a]	97.6	4.0	50.6	121.5[a]	95.9

[a]$P < 0.05$ *vs* patients who underwent open surgery, significant variability. TCA-AP: Anteroposterior talocalcaneal angle; TCA-LT: Lateral talocalcaneal angle; TCI: Talocalcaneal index; TMT-AP: Anteroposterior talus-first metatarsal angle; TMT-LT: Lateral talus-first metatarsal angle; MTT-LT: Lateral first-fifth metatarsal angle; CMT-AP: Anteroposterior calcaneus-fifth metatarsal angle.

Table 5 Correlations between functional and radiographic outcomes after clubfoot treatment

	Length of follow-up *r* (*P* value)	Laaveg-Ponseti excellent/good outcomes *r* (*P* value)
TCA-AP	-0.31 (0.39)	0.80 (0.006)
TCA-LT	0.43 (0.22)	-0.26 (0.46)
TCI	0.13 (0.73)	0.48 (0.16)
TMT-AP	0.27 (0.49)	-0.36 (0.34)
TMT-LT	-0.66 (0.16)	-0.06 (0.91)
CMT-AP	-0.26 (0.53)	-0.64 (0.091)
MTT-LT	0.11 (0.82)	-0.13 (0.79)

TCA-AP: Anteroposterior talocalcaneal angle; TCA-LT: Lateral talocalcaneal angle; TCI: Talocalcaneal index; TMT-AP: Anteroposterior talus-first metatarsal angle; TMT-LT: Lateral talus-first metatarsal angle; MTT-LT: Lateral first-fifth metatarsal angle.

illnesses may affect management of clubfeet with the Ponseti method.

In an effort to objectively evaluate idiopathic clubfoot, assess treatment, and classify residual deformities, a large number of angular measurements have been proposed on the anteroposterior and lateral radiographic projections[51-53]. The TCA-AP and the TCA-LT, as well as the TCI (sum of TCA-AP and TCA-LT angles) are the most widely used parameters and reflect the anatomic relationship between the talus and the calcaneus. Among the other radiographic angles usually used in clinical practice, TMT-LT and MTT-LT angles measure midfoot cavus deformity, whereas TMT-AP and CMT-AP angles are expressions of forefoot adduction that characterize clubfoot. Our study did not reveal statistically significant difference in TCA-AP and TCA-LT angles between clubfeet treated with open surgery or the Ponseti method. The average TCI was measured above 40 in clubfeet managed with Ponseti method as well as in surgically treated clubfeet. A statistically significant difference was recorded in TMT-LT, MTT-LT, and CMT-AP angles.

Although radiographic evaluation has been extensively used as a measure of success of idiopathic clubfoot treatment, several authors have questioned the correlation between functional and radiographic outcomes as well as the prognostic value of radiographs[6,14,54,55]. Evaluation of radiographs is difficult to reproduce due to complexity of the deformity in various planes with multiple bone involvement, the small size or complete absence of ossific nuclei, particularly that of the navicular, the considerable overlap between radiographic values of normal feet and clubfeet, and difficulty in positioning the stiff and deformed foot[56]. Furthermore, the use of different functional systems does not allow direct comparison between studies in order to identify any association between these radiographic parameters and the functional outcome. In the present meta-analysis, the Laaveg-Ponseti score was used to study the correlation between the clinical scoring and angular measurements since it does not rely on any radiographic parameters. A higher TCA-AP angle was associated with a better functional outcome. This is in agreement with several previous studies[57,58], although many authors have found strong correlation between the functional rating and TCA-LT[5,18,34,59,60] or TCI[52,57,61]. Herbsthofer *et al*[15] demonstrated no correlation between angular measurements and functional outcome. It is our opinion, however, that several radiographic parameters representing each of the clubfoot deformities should be used to provide a comprehensive radiological assessment of the three dimensional clubfoot deformities. By measuring TCA-AP, MTT-LT, and TMT-AP angles, the heel varus, midfoot cavus, and forefoot adduction, can be radiologically assessed and correlated with the functional outcome. In contrast, using a severity evaluation system that is based exclusively on radiographic criteria may overestimate the value of radiographs.

Long-term follow-up studies of treated clubfeet evaluating function beyond skeletal maturity are rare[1-3,6,62]. The studies with the longer follow-up were those of Cooper *et al*[6] with an average of follow-up of 34 years, Ippolito *et al*[1] with an average duration of follow-up of 25 years, and Dobbs *et al*[3] with a mean of follow-up of 30 years. Cooper *et al*[6], evaluated 71 clubfeet in 45 patients treated with the Ponseti method. Seventy-eight percent of the patients had an excellent or good outcome. Mild arthrosis in the foot and ankle was found

in 35% of the patients. Twenty-seven percent of the patients had an excellent or good outcome. Ippolito *et al*[1] compared the results of adult patients with idiopathic clubfoot treated during infancy either with the Ponseti method or extensive soft-tissue release. They recorded better long-term functional outcomes when the former technique was used. The mean Laaveg-Ponseti score was 85.4 and 74.7 for the Ponseti method and surgically treated group, respectively. Seventy-eight percent of the patients treated with the Ponseti method had an excellent or good outcome. In contrast, only 43% of the patients treated with extensive soft-tissue release had an excellent or good outcome. Thirty percent of the surgically treated patients and 38% of the patients treated with the Ponseti method were found to have recurrences requiring additional intervention. Among these recurrences, 86% in the surgical group and 27% in the Ponseti group were major. Dobbs *et al*[3] followed 73 clubfeet who had undergone either an extensive combined posterior, medial, and lateral release or a posterior release and plantar fasciotomy. They reported a correlation between the extent of soft-tissue release and the degree of functional impairment. Moderate to severe evidence of arthrosis in the foot and ankle was found in 56% of surgically treated patients. The mean Laaveg-Ponseti score was 65.3. Our study was in agreement with these findings, suggesting that foot function deteriorates over time in patients treated with open surgery. However, it should be noted that surgically treated patients in the last two long-term studies, as well as 20.87% of surgically treated clubfeet included in our study, were operated with extensive soft-tissue releases which does not represent the current surgical practice.

This study analyzed a large cohort of patients with idiopathic clubfoot and presented differences in the functional and radiographic outcomes based on the management employed. Although no statistically significant difference was noted in the overall functional outcomes between patients managed with the Ponseti method or open surgery, patients treated with the Ponseti method had a higher rate of excellent or good outcomes. Serial manipulation and casting has been widely accepted as the initial treatment of idiopathic clubfeet, and soft-tissue release is reserved for clubfeet that cannot be completely corrected. A strict brace compliance remains the major challenge of the Ponseti method.

COMMENTS

Background

During the second half of the twentieth century, the primary treatment of idiopathic clubfoot has ranged from gentle manipulations to aggressive surgical treatment. Although there are a plethora of studies that have assessed the functional and radiographic outcomes following different treatment protocols, there are only a few studies that directly compare open surgery and Ponseti method for the management of idiopathic clubfoot. This can be mainly attributed to variable and simplistic grading systems for scoring the severity of the deformity as well as the differing evaluation systems for assessing outcomes.

Research frontiers

The present study analyzed a large cohort of patients with idiopathic clubfoot and presented differences in the functional and radiographic outcomes based on the management employed. The findings suggest that foot function deteriorates over time in patients treated with open surgery.

Innovations and breakthroughs

In the present long-term study, although no statistically significant difference was noted in the overall functional outcomes between patients managed with the Ponseti method or open surgery, patients treated with the Ponseti method had a higher rate of excellent or good outcomes. Serial manipulation and casting has been widely accepted as the initial treatment of idiopathic clubfeet, and soft-tissue release is reserved for clubfeet that cannot be completely corrected. A strict brace compliance remains the major challenge of the Ponseti method.

Applications

The study results suggest that serial manipulation and casting is the accepted initial treatment of idiopathic clubfeet, and soft-tissue release is reserved for clubfeet that cannot be completely corrected.

Terminology

Ponseti method is the conservative treatment of idiopathic clubfoot consisting of manipulations and serial casting, and frequently minimal invasive surgery.

Peer review

This is an excellent meta-analysis in which authors analyze a large cohort of patients with idiopathic clubfoot and presented differences in the functional and radiographic outcomes based on the management employed. The results are interesting and suggest that Ponseti method has a higher rate of excellent or good outcomes.

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