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Research Article

Radiographic Evaluation of Patients Undergoing Treatment of Idiopathic Clubfoot by the Ponseti Method

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Abstract

Background: Idiopathic clubfoot is the most common congenital deformity of the foot and the Ponseti method has been widely used as the of choice for treatment. Your treatment should be started early in life, in spite of feet treated late reports that are increasing in the literature. The evaluation method is clinical and based on the clinical appearance and function and requires tests to prove the good found in these assessments.

Objective: Evaluate the radiograph as a method of measuring effectiveness of Ponseti method for the treatment of unilateral congenital clubfeet using plain radiography.

Methods: We conducted a retrospective study from medical record data on patients with congenital idiopathic unilateral clubfoot, with ages ranging from 48 to 177 months. Patients underwent radiographs in anteroposterior and lateral view, in weight bearing and angles were traced to measure the relationship between the tarsal bones of the middle and hind foot of the treaty and normal.

Results: The final average Pirani score was 0.35. Statistical analysis showed that the calcaneal-fifth metatarsal angle on the anteroposterior view, tibial-calcaneal and the horizontal-calcaneus in lateral view, also showed when subjected to the comparison test similarity, with p values > 0.05. Other angles did not show statistical similarity when compared with the foot control ($p < 0.01$). All angles were within the normal range when compared to literature data. There was no significant correlation between radiographic results and parameter based on Pirani's score.

Conclusion: Radiography is not an appropriate method to evaluate the effectiveness of the results of the Ponseti method in cases of unilateral idiopathic congenital clubfeet and may be indicated for after infancy or in treatments of neglected cases. There were no significant correlation between radiographic findings and clinical parameters used to assess correction.

Keywords: Clubfoot; Therapy; Clubfoot; Radiography; Foot Deformities; Congenital

Introduction

Idiopathic congenital clubfeet (ICC) is the most common congenital foot deformity, [1-5]. It is characterized by a complex set of deformities including equinus, calcaneus varus, medial rotation of the calcaneus and forefoot, and adductus. [1,3,4,6-8] Since the 1940´s, Ponseti method has been used as a method for treatment. [1,4,5,7-11] It is a method that corrects primary deformities through series of manipulation, castings, and a tenotomy of the calcaneal tendon, followed by abduction brace. [1-8,10,11] Failures may be attributed to non-adherence to brace, which causes a significant number of relapses. [2,3,5-8,10,11].

Ponseti method does not take radiography into consideration at any moment of the treatment. [1,2,4-7,9-15] Despite this fact, there are several services which uses radiography as a support tool. Only few studies detail the radiographic characteristics of treated feet. [12,14,15] The greatest number of patients start their treatment in the first months of life. [1-7, 9] It should be emphasized that reports about late treatment on feet are increasing in literature, [16-18]. The outcome is measured by clinical parameters, such as arch of movement, reduction in original deformities and observation of foot topological anatomy. In the final analysis, it is relevant to evaluate the joints to bring better notion about the ability for correction. [12-15,20,21] Radiography after first childhood, when feet are

more mature, as well as on late treated feet could be recommended for evaluating results. [16,22,23] The objective of this study is to evaluate radiography as a technique for measuring the efficacy of Ponseti method in ICC treatment.

Methods

A retrospective study was based on data collection from patients of four institutions between January 2008 and May 2015.

We include patients between 2 to 15 years old with unilateral ICC, in walking age, who were treated by the Ponseti method. Patients with bilateral clubfeet, teratologic, secondary to other deformities, trauma, neurological, degenerative or operated patients were excluded.

Patients were in a standing position during radiographies in anteroposterior (AP) and lateral (L) views. For the AP view, the ampoule was positioned in 30º in relation to a perpendicular line on the ground, with the rays pointed towards dorsoplantar on the film [14,22-24] (Figures 1 and 2). The lateral view was with one foot support. The ampoule was 90º towards the ankle (Figures 3 and 4).

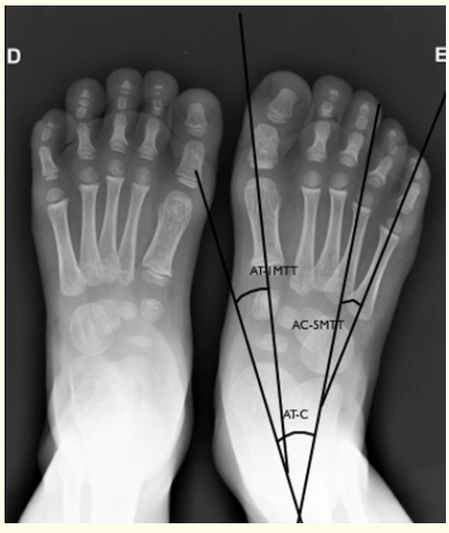

Figure 1: Angles measured in incidence anteroposterial.

The average values of the angles were calculated: talus-calcaneal (TC), talus-first metatarsal (Ta-MT1), calcaneal-fifth metatarsal (Ca-MT5) on AP view and talus-calcaneal (TC), tibiocalcaneal (TiC), tibiotalar (TiTA), talus-horizontal (TH), and calcaneal-horizontal (Ca-H), known as calcaneal pitch, on lateral (L) view, on treated clubfoot and normal foot (control side). Talus calcaneal index was calculated based on the values of Kite angles, in AP and L.

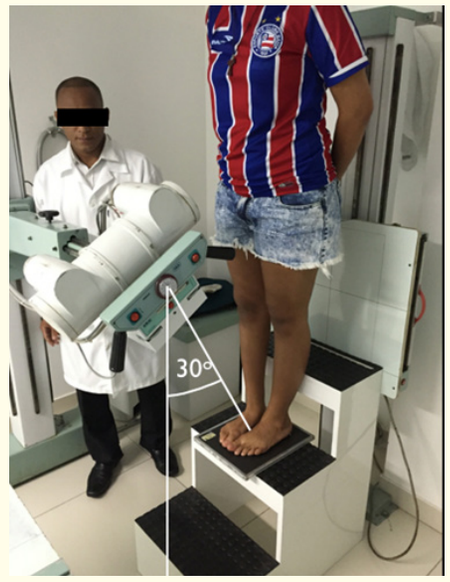

Figure 2: Methodology for conducting foot radiography standing on both, with incidence anteroposterior.

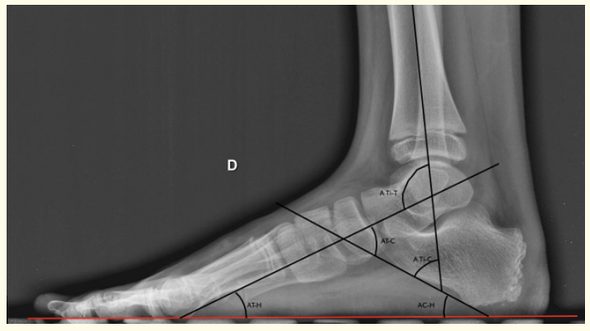

Figure 3: Angles measured with incidence in profile.

Figure 4: Methodology for conducting foot radiography standing on one foot, with incidence in profile.

Kolmogorov-Smirnov test verified normality, while Pearson was achieved for of normal distribution and Spearman in cases of non-normality. The study conducted a comparative analysis between the ICC and the normal foot using paired t test and verification of the significance level.

Pirani´s score was applied during the treatment. Angle measurements were taken by the same professional using the standard methodology.

The sample calculated in 54 patients was based on a standard deviation of 8° on the talocalcaneal angle, based on the literature used in this research [12,23-25].

The research respected bioethics principles and the project was approved by the Ethics Committee.

Results

54 patients participated in the study - 72.2% male (39 patients), the age varied between 2 and 14 years old (24 to 177 months), with an average of 73.30 months. There was no difference relating the side.

There was a prevalence of Afro-descendants, 25.9% (14 patients) Blacks and 25.9% (14 patients) mixed race. Most came either from the state capital or from its metropolitan area, 68.7% (37 patients) (Table 1).

Characteristics (n = 54)	N	%
Sex		
Male	39	72.2
Female	15	27.8
Skin color		
White	26	48.1
Mixed	14	25.9
Black	14	25.9
Laterality		
Right	27	50
Left	27	50
Origin		
Capital/Metropolitan area	37	68.7
Other cities in the state	17	37.4
Age groups		
I - 2 to 4	18	33.3
II - 4 to 6	9	16.7
III - 6 to 8	17	31.5
IV - > 8	10	18.5

Table 1: Demographic distribution of patients submitted to treatment by Ponseti method in reference outpatient centers between 2002 and 2015.

The average age for the first appointment was 5.95 months (0 to 69 months), a median of five plasters (3 to 15) was needed to perform the correction until tenotomy, performed in 97.3%. 63% (34 patients) were submitted to general anesthesia or sedation, 33.3% (18 patients) to local anesthesia, and 3.7% (two patients) did not need tenotomy. 83.3% (45 patients) had any complications, 16.7% (nine patients) evolved with types of complications like skin reactions. 37% (20 patients) had some relapse: equinus (45%) and forefoot varus (40%) (Table 2). Three patients (5.6%) needed anterior tibial transfer (ATT) and 63% stated correct use of the brace.

	%
Complications	
Hyperemia	44.4
Blisters	33.3
Ulcer	22.3
Relapses	
Hindfoot equinus	45
Forefoot varus	40
Combination	15

Table 2: Complications and relapses in ICC treatment by Ponseti method.

The study verified the Pirani's score, at the beginning and at the end of treatment. The mean and median values of the initial score were 5.4 and 5.5 respectively (3.0 to 6.0). The same parameters from the last evaluation were 0.35 and zero (0 to 1.5), which reflects a significant clinical improvement. Besides this objective evaluation based on the Pirani's score, the study also conducted a subjective evaluation and degree of satisfaction of children´s parents - 59.3% (32 patients) considered excellent results, 35.2% (19 patients) good, and 5.6% regular (bad was not mentioned).

The following means and standard deviations were found at the affected side, with AP view: TC, 26.94(± 5.321), Ta-MT1, -0.81(±9.566), and Ca-MT5, -2.30 (±8.181). Values for the normal side were: TC, 31.67 (±6.768), Ta-MT1, 6.54 (±8.091), and Ca-MT5, -1.13 (±6.788) (Table 3).

In the lateral view , the means and standard deviations of the affect side were: TC, 35.30 (±10.430), TiC, 77.65 (±9.254), TiTA, 112.20 (±8.985), TH, 24.00 (±7.586), and Ca-H, 10.11 (±8.293) and the normal side were: TC, 42.00 (±6.780), TiC, 77.11 (±8.732), TiTA, 119.17 (±8.961), TH, 29.43 (±8.032), and Ca-H, 11.89 (±5.933) (Table 4).

Angles	TC		Ta-MT1		Ca-MT5	
	mean	SD	mean	SD	mean	SD
ICC	26.9	5.321	-0.8	9.566	-2.3	8.181
Normal	31.7	6.768	6.5	8.091	-1.1	6.788
	P < 0.01		P < 0.01		P = 0.336	

Table 3: Means and standard deviations of angles AP view.

TC: Talus-Calcaneal Angle; Ta-MT1: Talus-First Metatarsal Angle; Ca-MT5: Calcaneal-Fifth Metatarsal Angle; ICC: Idiopathic Congenital Clubfoot; SD; Standard Deviation

Angles	TC		TiC		TiTA		TH		Ca-H	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ICC	35.3	10.430	77.7	9.254	112.2	8.985	24.0	7.586	10.1	8.293
Normal	42.0	6.780	77.1	8.732	119.2	8.961	29.4	8.032	11.9	5.933
	P < 0,01		P = 0,626		P < 0,01		P < 0,01		P = 0,071	

Table 4: Means and standard deviations of angles in Lateral view.

TC: Talus-Calcaneal Angle; TiC: Tibiocalcaneal Angle; TiTA: Tibiotalar Angle; TH: Talus-Horizontal Angle; Ca-H: Calcaneal-Horizontal Angle; ICC: Idiopathic Congenital Clubfoot; SD: Standard Deviation

Mean and standard deviation were also calculated for talus-calcaneal index as described by Wanderwilde., *et al.* [24]. In the affected side, the mean for the talocalcaneal index was 62.24 (±12.229) and in the normal side it was 73.67 (±10.009).

The statistical analysis conducted by paired t test, demonstrated that angles Ca-MT5, TiC and Ca-H did not present any differences when comparing the group that was treated with the normal group (p > 0,05). From a radiological point of view, this meant that treated feet were successful if these angles were taken as the basis. Ca-MT5, TiC, and Ca-H angles play a role on the capacity for correcting deformities in forefoot varus and equinus, with strong relevance when related to treated ICC. The other angles presented significant difference, CI = 95% (p < 0,05), which suggests a relevant radiological asymmetry between the treated and the normal foot.

A stratified analysis, based on age groups, was conducted according to Vanderwilde., *et al.* [24] In age group I (24 to 48 months old), there was equal measurement in only three angles: Ca-MT5, TiC, and Ca-H (p > 0,05), following standard analysis of patients. In group II (49 to 72 months old), angles TC (in AP), Ca-MT5, TiC, TiTA, TH, Ca-H, and talus-calcaneal index obtained p > 0,05. In group III (73 to 108 months old), angles Ca-MT5, TC, TiA, and TH were similar. Finally, in group IV (above 103 months old, all measured angles had p > 0,05 (Tables 5 and 6).

Age groups		I-2 to 4 (n = 18)	II-4 to 6 (n = 9)	III-6 to 8 (n = 17)	IV- 8 and + (n = 10)
TC	ICC	27.9 (4,96)	30 (6.70) *	25.7 (4.21)	24.6(5.32) *
	Normal	35.9 (7.42)	31.78 (6.98) *	29.3 (4.74)	27.90 (4.41) *
Ta-MT1	ICC	0.2 (9.29)	1.67 (11.97)	-1.9 (8.94)	-3.10 (9.50) *
	Normal	9.9 (10.41)	7.67 (8.37)	5.8 (5.10)	0.70 (3.05) *
Ca-MT5	ICC	1.3 (8.89) *	-3.22 (7.03) *	-4.3 (5.51) *	-4.6 (10.39) *
	Normal	-0.6 (8.27) *	1.00 (4.44) *	-1.9 (5.08) *	-2.80 (8.34) *

Table 5: Means and standard deviations of ICC and normal foot within age groups, with AP view.

(*) Values refer to results with p > 0,05.

TC: Talus-Calcaneal Angle; Ta-MT1: Talus-First Metatarsal Angle; Ca-MT5: Calcaneal-Fifth Metatarsal Angle

Age groups		I-2 to 4	II-4 to 6	III-6 to 8	IV- 8 and +
		(n = 18)	(n = 9)	(n = 17)	(n = 10)
TC	ICC	33.5 (8.67)	39.8 (6.69)	34.8 (13.77)	35.4 (9.73) *
	Normal	42.6 (8.85)	46.0 (7.12)	41.0 (4.11)	39.1 (4.46) *
TiC	ICC	79.6 (9.94) *	79.6 (8.41) *	75.7 (9.05) *	75.8 (9.34) *
	Normal	81.2 (8.62) *	76.4 (9.75) *	74.5 (8.14) *	74.8 (7.39) *
TiTA	ICC	111.3 (9.97)	115.4 (5.68) *	112.3 (8.56) *	110.7 (11.15) *
	Normal	124.4 (9.04)	120.9 (8,33) *	116.0 (5.66) *	113.6 (9.44) *
TH	ICC	25.6 (8.93)	23.2 (5.81) *	24.2 (7.60) *	21.5 (6.57) *
	Normal	35.1 (8.38)	29.6 (10.96) *	25.7 (2.62) *	25.5 (4.67) *
Ca-H	ICC	7.2 (9.59) *	12.4 (5.27) *	10.1 (8.43)	13.2 (6.91) *
	Normal	8.9 (5.90) *	11.8 (6.81) *	13.9 (5.29)	13.9 (4.48) *

Table 6: Means and standard deviations of treated ICC and normal foot within age groups, in Lateral view.

(*) Values refer to results with p > 0,05.

TC= talus calcaneal angle, TiC: Tibiocalcaneal Angle; TiTA: Tibiotalar Angle; TH: Talus-Horizontal Angle; Ca-H: Calcaneal-Horizontal Angle

The study verified correlation between radiological and clinical parameters, as well as those age related. After normality verification, results demonstrated that variables related to Pirani's scores were not normal. Thus, Spearman correlation test was used with a numerical variation related to the difference between the angles before and after the correlation and variables related to the difference in Pirani's scores (initial and final). There is correlation only in the analysis of the difference between Ca-MT5 (0.35) and that there was no significant difference among the other angles. When the correlation was between the difference obtained and the final value in Pirani score, only the difference of Ta-MT1 was significant (0.29) (Table 7).

	TC-AP	TA-MT1	CA-MT5	TC-L	TTC	TTA	TH	CA-H	IND T-C
Difference in Pirani	-0.15	0.22	0.35*	0.20	-0.20	0.13	0.11	0.16	0.12
	P = 0.284	p = 0.112	p = 0.010*	p = 0.165	p = 0.150	p = 0.337	p = 0.431	p = 0.236	p = 0.389
Final Pirani	-0.08	-0.29*	-0.20	-0.25	0.21	-0.15	-0.19	-0.153	-0.24
	p = 0.565	p = 0.035*	p = 0.147	p = 0.068	p = 0.138	p = 0.286	p = 0.178	p = 0.268	p = 0.075

Table 7: Correlation between the angles and Pirani's score.

(*) Values refer to the correlation of positive Spearman and significance value < 0.05.

TC-AP: Talus Calcaneal Angle in AP View; Ta-MT1: Talus-First Metatarsal Angle; Ca-MT5: Calcaneal-Fifth Metatarsal Angle; TC-L: Talus-Calcaneal in Lateral View; TiC: Tibiocalcaneal Angle, TiTA: Tibiotalar Angle, TH: Talus-Horizontal Angle; Ca-H: Calcaneal-Horizontal Angle

Discussion

Comparison among means conducted by paired t test revealed that angles Ca-MT5, TiC, and Ca-H were similar (p > 0,05), which inferred that these angles reached a desired correlation success. The other angles reached statistical significance, proving their non-similarity.

The disagreement between clinical and radiographic results can be attributed to the wide range considered normal for measured angles. There would have been a greater probability to detect similarity between measurement of the two feet, had comparison between clubfoot and contralateral feet been done in relation to them being normal or not. Radiographic angles as a continuous quantitative variable, makes statistical tests applied more robust, which in turn increase the chance for significant differences in measures from each side. When analyzing means and their standard deviations and the average age of patients (73.3 months old) based on the accepted reference values for the angles according to literature, we observe that all measures are in the normal range, which could in turn, justify this clinical-radiographic divergence. Another relevant issue that is the great variability in angular measures in these ages, which make it difficult to establish what normal angle values for feet joints should be. Angle variations are related to children´s anatomy as they get older. Issues such as laxity ligament and tarsal

bones that are not entirely ossified change and create a variability in bones that prevent a reliable conclusion about what is normal, which impedes the possibility of making generalization about a normal standard. However, in individuals below 36 months old, the oval shape of ossification nucleus can lead to erroneous interpretations.

The study demonstrated prevalence in males, thus corroborating with literature (3:1 ratio). There was no difference in laterality and the sample represented people who lived in great urban centers, which in turn could have led to a larger number of good and excellent results since the need of weekly appointments in general makes it more difficult for those who live far from centers. There was a predominance in the number of Blacks and afro-descendants, three times more than in Caucasians [26]. The predominant group was people between two to four years old (33%), which means that they were still wearing braces.

The present study followed literature. There was not any discrepancy in the amount of plasters needed for correction, the need for tenotomy, complications, and relapses. [27,28]. However, most of the tenotomies were conducted with general anesthesia or sedation (63%). According to methodology guidelines, the absence of anesthesia and hospitalization aim to speed treatment and reduce costs related to the chirurgical proceeding. [29] Thus there was no alteration or change in the tenotomy proceeding per se. [30]

Initial Pirani's score mean [5,4] demonstrated severity of most cases. Final evaluation, both clinical and subjective, was satisfactory and the numbers that revealed these results. Final Pirani's score mean demonstrated a very good correction and the foot became functional. Final impression followed the same pattern as Ponseti clinical evaluation with a predominance of excellent and good (94,5%). According to Ponseti method, ICC evaluation is restricted up to this point. Other methods can be used to evaluate treatment, however, in this study radiographies were used to identify possible alterations or asymmetries in feet joints.

Some angles tend to decrease in value as patient gets older (like the TC in AP and Ca-MT5). Others decrease less acutely (lateral TC and Ta-MT1) while others decrease very little but inconsistently (TiTA and TH). [24] Radler., *et al*. [25] demonstrated in their trust study of radiographic measures, that the mean of TC in AP fell from 35.74 (±8.56) between 3 to 12 month-olds to 23.27 (±4.47) in those between 3 to 12 month-olds, and Ta-MT1 varied in both of these age groups from 7.25 (±13.33) to 0.37 (±9.33). In their article, Vanderwilde., *et al*. [24] presented even a greater compliance in accepting results considered normal. Once again, TC in AP was the angle that showed greater variability - it had its normal range defined between 15 and 60º. Herbsthofer., *et al*. [31] correlated treated ICC radiographic findings and normal values of tested angles associating Laaveg and Ponseti´s final score as well. Greater variability was also found when analyzing TC in AP and lateral, therefore it was not possible to attribute definite measures to normal angles through this wide standard deviation.

The current study also presented means and standard deviations in eight angles measured AP and lateral view. In spite of having general good clinical results, there was no relation with the statistical result based on significant test values used in five measured angles (with $p < 0,01$). Perhaps variability encountered in the physiological and morphological trends of this initial age group influenced the result, which reveals that despite the fact that ICC was clinically and functionally corrected, it cannot equal angular values with contralateral (normal) foot. In groups I and II (from our study), the control feet are in an opposite diametrical condition from the recently treated foot due to age anatomy. [23,24,31,32] These feet are flat, pronated and valgus thanks to the appropriate morphology. However, when analyzing children and pre-teens from age groups III and IV of our study, we observe greater correspondence and statistical significance between the age groups.

The correlation between radiographic results and clinical parameters show low level of significance. The reasons for this low correlation include, 1) little cooperation by children, 2) the different positions during radiography, 3) differences in tarsal bones, and 4) the fact that the bones depend on age and on tracing lines for defining angles [33,34]. Even though ultrasound is a less accessible tool, due to the fact that it depends on the level of professional experience and it is only useful in younger children, this exam was superior for determining correlation when comparing radiographic analysis [35].

Radiological evaluations were proven to be a rigorous evaluation method to the extent that there is a comparison established between patients treated and non-treated feet. Despite this consideration, all analyzed mean results of angles in the treated ICC fall within the normal average values in the literature [27,28,36].

The radiographic study presented limitations in the age groups I and II due several factors including immaturity and morphology, its efficacy should be greater in individuals at age seven or above, as suggested by the current research study.

A stratified analysis, limiting the age groups to be analyzed, would offer perspectives for future studies. This would bring more homogeneity to the study and make the results even more reliable. The sample size calculated in this study limited inferences about

strata. Additionally, the use of other evaluation score could provide additional data for correlating results.

However, the possibility to evaluate means and deviations of angular measures made it possible to see that treated feet, which may initially appear asymmetrical from a radiological point of view, are included in values considered normal by the literature. Once improved and matured, treated foot may present similar or the same values as the non-treated foot.

Conclusion

Radiography is not an appropriate method to evaluate effectiveness in Ponseti method when it comes to treating unilateral idiopathic congenital clubfeet. It can be indicated after early childhood or when treating inveterate cases.

The study did not find any significant correlation between radiographic results and clinical parameter used to assess correlation.

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