Original Article

An Alternative Treatment for Clubfoot in Infants: An Evaluation of the Korat Technique of Serial Casting with and without Early Percutaneous Needle Achilles Tenotomy

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Objectives: To evaluate the efficacy of the Korat technique of serial casting both with and without early percutaneous needle Achilles tenotomy in clubfoot deformity correction, to analyze risk factors related to the recurrence of clubfoot deformity, and to evaluate the midterm clinical and radiographic results in identifying problems following treatment.

Materials and Methods: Clubfoot infants age up to 6 months who were initially treated at the Maharat Nakhon Ratchasima Hospital using the Korat technique between 2002 and 2013 were reviewed. Infants with Dimeglio grade I, postural clubfoot, and those whose clubfoot had previously been treated were excluded. The number of cast changes to achieve normal foot form and the combined duration in cast were evaluated. Potential risk factors for recurrence were analyzed. The mid-term (3 to 13 years) clinical and radiographic outcomes were assessed.

Results: The study included 61 infants with 90 clubfeet, median age at first treatment 12 days (interquartile range 26). Early percutaneous Achilles tenotomy was done in 68 feet (76%). All feet achieved normal foot form with a mean of 4.1$\pm$1.36 cast changes and a mean combined duration in cast of 4.2$\pm$1.30 weeks. Twenty-nine feet (32%) had a recurrence. A grade 0 initial peroneus muscle function was associated with a 4.41-fold increase in clubfoot relapse (95% CI: 1.25, 15.49). At mid-term follow-up, all were pain free, plantigrade, and could walk and run. Twenty-five feet (28%) still had final peroneus muscle function less than grade IV which was related to the residual metatarsus adductus (odds ratio 4.93; 95% CI 1.23 to 19.74).

Conclusion: The Korat technique of manipulation and serial casting, either with or without early percutaneous needle Achilles tenotomy, is an alternative method for clubfoot deformity correction. Close regular follow-up is recommended for infants with grade 0 initial peroneus function and meticulous peroneus muscle strengthening exercises should be performed to decrease the risk of recurrence.

Keywords: Clubfoot treatment, Korat technique, serial casting, Achilles tenotomy, Peroneus muscle grading

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Conservative treatment by manipulation and holding the foot in the correct position by means of serial casting is accepted as the initial treatment of patients presenting with clubfoot early in life[1-6]. Two techniques for manipulation and casting often mentioned in the literature are Kite's method and the Ponseti method. Kite's method manipulates the hind foot by rotating the calcaneus to correct triplane malrotation beneath the subtalar joint and is done without manipulation of the forefoot. The Ponseti method manipulates the forefoot by pulling the first metatarsal base upward to correct cavus along with supination and hyperabduction or by externally rotating the forefoot to move the navicular to the center of the talar head without manipulation of the hindfoot[7,8]. Both techniques can achieve successful clubfoot correction, although there are some differences in the numbers of cast changes and the total period in a cast[9]. Key to

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success with all methods is creating linkage lock between the hind foot and forefoot by supination. If the foot is always kept in supination position during manipulation, the rotated calcaneus will push the forefoot toward to the correct position. Conversely, the pull of the forefoot moves the hind foot under the subtalar joint and into the correct position if the foot is locked in supination.

The present study evaluated the Korat technique of manipulation and casting, which was developed at the Maharat Nakhon Ratchasima Hospital in Nakhon Ratchasima (Korat) Province of Thailand. That technique involves simultaneous pushing and pulling in supination, combining principles of both Kite's method and the Ponseti method of manipulation. It was hypothesized that the Korat technique could achieve clubfoot correction more rapidly and with fewer complications. Although the Korat technique of serial casting to correct clubfoot deformity has been used at Maharat Nakhon Ratchasima Hospital since 2002, the results have never been formally evaluated. The objectives of the present study were as follows:

1) To evaluate the efficacy of clubfoot deformity correction using the Korat technique of serial casting both with and without percutaneous Achilles tenotomy.

2) To evaluate the efficacy of midterm clinical and radiographic results in identifying problems following treatment.

3) To evaluate risk factors for recurrence of clubfoot deformity.

Materials and Methods

Following approval by the ethics committee of Maharat Nakhon Ratchasima Hospital institutional review board, 107 clubfoot patients, age up to 6 months, who had been treated at Maharat Nakhon Ratchasima Hospital between 2002 and 2013 were retrospectively reviewed. Using the Dimeglio system, severity of clubfoot was classified as mild (I), moderate (II), severe (III) or very severe (IV). Twenty-two patients with Dimeglio grade I postural clubfoot and 18 cases who had previously received treatment or had had operations were excluded. Of the remaining 67 cases that were initially treated using the Korat technique of serial casting, either with or without early percutaneous needle Achilles tenotomy, 6 cases had been followed up less than 3 years, so 61 cases (90 clubfeet) were enrolled in the present study.

Data obtained included age at initial treatment, severity and location of clubfoot deformity (left or right side) and initial peroneus muscle function. Risk factors potentially affecting the recurrence of clubfoot deformity which were analyzed included age at first treatment, whether unilateral or bilateral side, initial Dimeglio severity level, and peroneus muscle grade.

The Korat technique for manipulating the hindfoot and forefoot simultaneously is shown in Figure 1 and 2. With the Korat technique, a short leg cast is applied initially, and as soon as the cast has dried the cast is extended to become a long leg cast with a thigh-foot angle of 15 to 25 degrees to create normal tibial torsion. The corrective cast is changed every week until the foot form becomes normal. In cases of a very tight heel cord or inability to achieve passive dorsiflexion of the calcaneus through zero degrees even when holding the knee at 90 degrees of flexion, early percutaneous needle tendo-Achilles tenotomy, performed under local xylocaine anesthesia, allows the calcaneus to be tri-plane manipulated and to rotate freely under the subtalar joint.

After successful clubfoot correction or achievement of normal foot form using the Korat technique of serial casting, casting was discontinued and parents were encouraged to follow an exercise program. The aim of the exercise program is to continue

Figure 1. Korat technique mainpulation and casting for left clubfoot deformity. The right thumb and index finger manipulate the calcaneus to correct triplane malrotation beneath the subtalar joint while the left thumb manipulates the first metatarsal base upward and rotates it laterally to pull the navicular to the center of the talus head which has been stabilized by the left index finger. Care is required to always keep the foot in supination during manipulation and molding of the cast.

stretching the tendo-Achilles and the tibialis posterior as well as to strengthen weak peroneus muscles. Parents were instructed to repeat the program as often as possible, for a minimum total of 200 stretches per day, e.g., 2 sessions of 100 repetitions each or 4 sessions of 50 repetitions each. Most parents reported completing 400 repetitions daily. Improvement of peroneus muscle power was noted and classified into 5 grades: no peroneus muscle contraction observed (0), only the prominence of the tendon seen when stimulated (I), the foot had some eversion motion, but less than perpendicular to the leg axis (II), the everted foot could reach perpendicular to the leg axis (III), and eversion beyond perpendicular to the leg axis (IV) (Figure 3). After removal of the final cast, an ankle-foot orthosis consisting of static splinting (similar to a plastic high-top shoe) in neutral plantigrade foot position was attached. This orthosis prohibits plantar flexion and prevents medial deviation of the forefoot. The orthosis was worn only when the parents slept or were otherwise unavailable to exercise their baby's foot. The ankle-foot orthosis was discontinued either when the child started walking or when the peroneus muscle power reached grade IV. In cases of continued peroneus

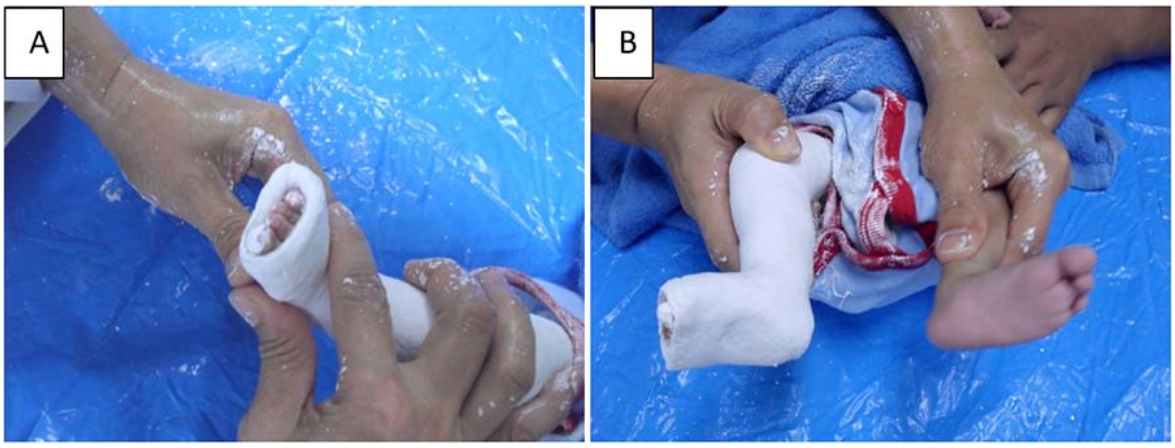

Figure 2. (A) For right clubfoot, the hands are reversed. The left thumb and index finger move the calcaneus while the right hand manipulates the forefoot. The right middle, ring and little fingers gently grasp the leg to prevent simultaneous external rotation of the ankle and also to protect the knee against valgus force during manipulation. (B) Completed casting.

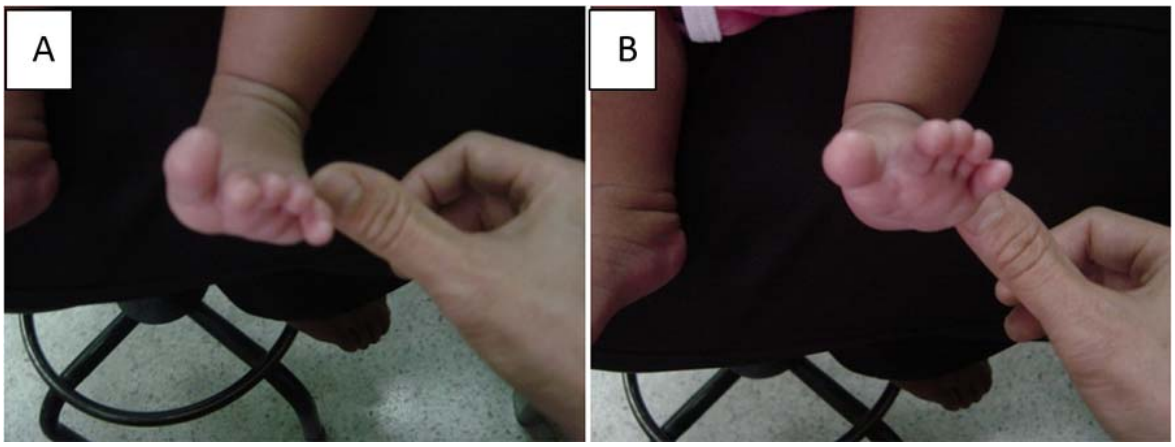

Figure 3. (A) After stimulation of the peroneus muscle by touching the little toe to the lateral malleolus, (B) the foot can be everted beyond the perpendicular line of the leg axis.

Figure 4. (A & B) A Two-day old infant with Dimegelio grade III clubfoot before Korat technique serial casting. (C &D) Korat technique manipulation and casting process. (E & F) After removal of the second cast at 2 week follow-up showing normal foot form achieved.

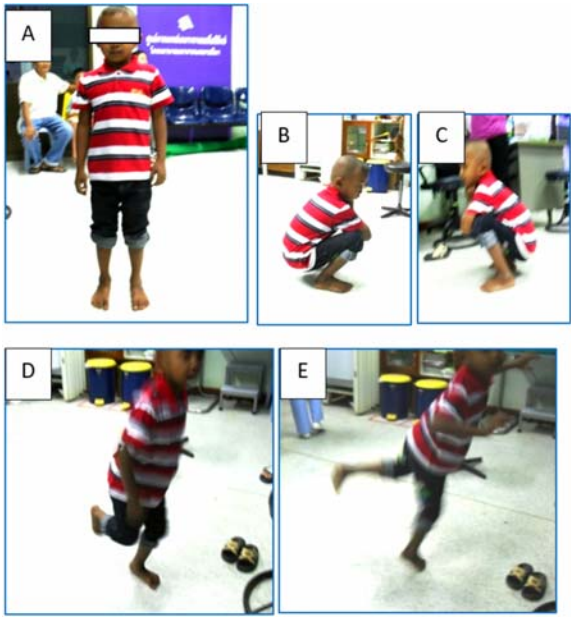

Figure 5. Final clinical follow-up at five years after Korat technique serial casting and percutaneous needle tendo-Achilles tenotomy of both feet. (A) Plantigrade feet. (B & C) Squat with heel touching the ground. (D & E) Hopping on one leg (D = left, E = right).

muscle weakness (less than grade IV) but a flexible heel and a lateral sole wedge were inserted into the shoe until the muscle power reached grade IV. The Korat technique of serial casting both with and without percutaneous needle Achilles tenotomy was done by Dr. Supphmard Lewsirirat, a pediatric orthopedic surgeon who has practiced in this field for more than 25 years. Evaluation of all variables and data collection systematization was also done by her.

The number of cast changes before achieving normal foot form, the combined duration in cast, the recurrence of deformity after correction, causes of recurrence, and details related to further management were also noted.

Midterm clinical results (3 to 13 years after treatment) were assessed including degree of plantigrade stance, heel and forefoot position, ability to wear normal shoes as were physical ability, e.g., walking, running, squatting and jumping. The range of motion of both dorsiflexion and plantar flexion and the level of recovery of peroneus muscle function were also evaluated. Over-correction complications such as planovalgus foot, calcaneovalgus foot, and under-correction problems such as metatarsus adductus, short tendo-Achilles, and cavus foot were assessed. Radiographs of both feet at the latest follow-up were used to measure the AP talocalcaneal angle, the lateral talocalcaneal angle, the talo-first metatarsal angle, and to identify cases of flat-top talus.

Statistical analysis

Descriptive statistics comparing demographic variables, midterm clinical characteristics, overall success, and recurrence status were generated. Categorical data are presented as percentages. Normally distributed continuous data are expressed as mean and interquartile range [IQR]. To estimate the association between potential risk factors and recurrence status, the logistic mixed-effects models of recurrence likelihood was fitted, including side random intercepts with unstructured covariance and fixed effects for potential risk factors. Adjusted odds ratios (95% CI) were calculated for the final models.The sample size needed to achieve the main objective was calculated using the formula: $n = [\{z_{\alpha/2}^2\, p(1-p)\}/e^2]$. If p represents the success rate of clubfoot treatment at age between 0

and 24 weeks[10], and e is 10% of the success rate, the proper sample size would be 59 feet.

Results

Of the 61 cases, 43 were males and 18 were females representing 90 clubfoot deformities (65 male feet and 25 female feet). The median age at initial treatment was 12 days (interquartile range [IQR] 26). Fourteen cases had a left side deformity, 18 had a right side deformity, and 29 were bilateral. Fifty-two cases (77 feet) were idiopathic clubfoot. Of the non-idiopathic clubfoot cases, 4 (7 feet) were associated with arthrogryposis, one (2 feet) had microcephaly, one (1 foot) had epilepsy, one (1 foot) had congenital constriction band syndrome, one (1 foot) had myelomeningocele, and one (1 foot) had Down syndrome. Details of the deformities are shown in Table 1. The duration of follow-up ranged from 36 to 155 months (mean 82, SD28). The overall mean number of cast changes before achieving normal foot form was 4.1 (SD 1.36) and the overall mean duration in cast was 4.2 weeks (SD 1.30) (Table 2).

Of the 90 feet treated, three had developed pressure sores at the edge of the cast: one at the big toe, the other two at the upper border of the posterior thigh. None of the feet had bleeding in the cast following percutaneous needle Achilles tenotomy. No infections or scars were found at the percutaneous needle tenotomy site.

Clubfoot deformity reoccurred in 29 feet (32.2%) (Table 3). Reoccurrence was associated with recurrent tight heel cord in 4 feet, peroneus muscle weakness in 6 feet, and both tight tendo-Achilles and peroneus muscle weakness in 19 feet. Six of the feet in which deformity reoccurred were successfully managed by repeated serial casting. An additional six feet achieved success after repeated percutaneous needle tenotomy and serial casting and 15 recalcitrant feet were successfully managed after undergoing a modified McKay operation combined with flexor hallucis longus tendon transfer to augment the peroneus muscle. The final two feet,which had initially been successfully

Table 1. Details of clubfoot deformities

Details	n (%)
Severity	
Dimeglio II (moderate)	17 (18.9)
Dimeglio III (severe)	61 (67.8)
Dimeglio IV (very severe)	12 (13.3)
Initial peroneus muscle function	
Grade 0	62 (68.9)
Grade ≥1	28 (31.1)
Cause of clubfoot deformity	
Idiopathic (52 cases)	77 (85.6)
Non-idiopathic (9 cases)	13 (14.4)
Early percutaneous needle Achilles tenotomy	
Yes	68 (75.6)
No	22 (24.4)

Table 2. Number of cast changes and total cast duration to achieve normal foot form with the Korat manipulation technique of serial casting with or without percutaneous needle Achilles tenotomy

Factor	Numbers of cast changes mean ± SD (range)	*p*-value	Duration in cast before achievement of normal foot form (weeks) mean ± SD (range)	*p*-value
Severity		0.00		0.00
Dimeglio II (n = 17)	3.4±0.24 (2 to 5)		3.7±0.22 (2 to 5)	
Dimeglio III (n = 61)	3.9±0.13 (2 to 7)		4.0±0.13 (2 to 7)	
Dimeglio IV (n = 12)	5.9±0.50 (4 to 8)		5.9±0.50 (4 to 8)	
Initial peroneal muscle power		0.06		0.090
Grade 0 (n = 62)	4.3±0.16 (2 to 8)		4.4±0.16 (2 to 8)	
Grade ≥1 (n = 28)	3.6±0.27 (2 to 8)		3.9±0.26 (2 to 8)	
Early percutaneous needle Achilles tenotomy		0.36		0.89
Yes (n = 68)	4.2±0.16 (2 to 8)		4.2±0.15 (2 to 8)	
No (n = 22)	3.8±0.31 (2 to 6)		4.2±0.32 (2 to 6)	
Classification of clubfoot deformity		0.23		0.34
Idiopathic (n = 77)	4.0±0.14 (2 to 8)		4.1±0.13 (2 to 8)	
Non-idiopathic (n = 13)	4.8±0.61 (2 to 8)		4.8±0.61 (2 to 8)	

Table 3. Incidence of recurrence of clubfoot deformity after Korat technique manipulation and serial casting with or without percutaneous needle Achilles tenotomy

Details	No recurrence, n (%)	Recurrence, n (%)	*p*-value
Severity			0.031
Dimeglio II (n = 17)	13 (76.5)	4 (23.5)	
Dimeglio III (n = 61)	44 (72.2)	17 (27.8)	
Dimeglio IV (n = 12)	4 (33.3)	8 (66.7)	
Initial peroneal muscle power			0.056
Grade 0 (n = 62)	38 (61.3)	24 (38.7)	
Grade ≥1 (n = 28)	23 (82.1)	5 (17.9)	
Early percutaneous needle Achilles tenotomy			0.793
Yes (n = 68)	47 (69.1)	21 (30.9)	
No (n = 22)	14 (63.6)	8 (36.4)	
Classification of clubfoot deformity			0.749
Idiopathic (n = 77)	53 (68.8)	24 (31.2)	
Non-idiopathic (n = 13)	8 (61.5)	5 (38.5)	

Table 4. Adjusted odds ratio and 95% confidence interval for selected factors potentially affecting recurrence of clubfoot deformity

Covariates	Odds ratio	[95% CI]	*p*-value
Side: bilateral	0.373014	0.1208386 to 1.1514523	0.086
Age at initial treatment	1.002267	0.9872441 to 1.017518	0.769
Dimeglio III (severe)	1.422892	0.3822713 to 5.296296	0.599
Dimeglio IV (very severe)	23.15314	2.45965 to 217.9447	0.006
Non-idiopathic	3.404684	0.5145258 to 22.52924	0.204
Initial peroneus power grade 0	4.408048	1.25457 to 15.48808	0.021

treated by lateral sole wedge shoe inserts alone, later had a tendon transfer at age four years to restore foot balance: one a tibialis anterior and the other a tibialis posterior tendon transfer.

After adjusting for side, age at initial treatment, severity and classification, the risk factor associated with increased recurrence was grade 0 initial peroneus muscle function: odds ratio = 4.41 (95% CI 1.25, 15.49) (Table 4).

At mid-term follow-up, all children were pain free and could place the sole of the foot flat on the ground. Individuals with idiopathic clubfoot had better results: 81% had normal foot form and 90% could wear standard shoes, while only 46% of the non-idiopathic clubfoot children had normal foot form and only 77% could wear standard shoes. Those with other than normal foot form had either under or over correction (Table 5). Although overcorrection resulting in mild residual calcaneovalgus foot occurred in only one foot, it was important to identify the cause, so the case was repeatedly reviewed. The infant was a male with a right side Dimeglio grade II clubfoot, initial age at treatment was 32 days, initial peroneus muscle grade was ≥1. Normal foot form was achieved after only two cast changes and a total duration in cast of only 2 weeks. At final follow-up at 39 months, he could dorsiflex 45 degrees and plantarflex both ankles at 45 degrees, could wear normal shoes, and could do all activities. Physical reexamination of all joints revealed hyperlaxity syndrome. In this case, gastrosoleus muscle strengthening was advised as well as follow-up of improvement in the existing mild calcaneovalgus condition.

Metatarsus adductus was the most common residual deformity. After adjusting for side, age at first treatment, duration in cast, and classification of clubfoot deformity, the risk factor most strongly correlated with metatarsus adductus was peroneus muscle weakness grade 0 to 3 at final follow-up (Table 6).

In terms of ability to be active, all cases could

Table 5. Comparison of midterm clinical outcomes of idiopathic and non-idiopathic clubfoot (number of feet)

Details	Idiopathic (n = 77), n (%)	Non-idiopathic (n = 13), n (%)	Total (n = 90), n (%)
Plantigrade foot	77 (100)	13 (100)	90 (100)
Foot shape/appearance			
Normal	62 (80.5)	6 (46.2)	68 (75.6)
Under correction			
Metatarsus adductus	9 (10.4)	2 (15.4)	11 (11.1)
Metatarsus adductus + mild heel varus	3 (3.9)	1 (7.7)	4 (4.4)
Metatarsus adductus + mild cavus	2 (2.6)	2 (15.4)	4 (4.4)
Overcorrection			
Calcaneovalgus	1 (1.3)	0 (0)	1 (1.1)
Planovalgus	0 (0)	2 (15.4)	2 (2.2)
Passive ankle ROM (degrees) mean $\pm$ SD (range)			
Dorsiflexion	25$\pm$12.4 (0 to 50)	25$\pm$15.6 (0 to 45)	25$\pm$12.8 (0 to 50)
Plantar flexion	45$\pm$8.4 (10 to 60)	43$\pm$14.7 (15 to 60)	44$\pm$9.5 (10 to 60)
Activity ability [n (%)]			
Walking	77 (100)	13 (100)	90 (100.0)
Running	77 (100)	13 (100)	90 (100.0)
Jumping	77 (100)	12 (92.3)	89 (98.9)
Squatting with heel touching the ground	73 (94.8)	9 (69.2)	82 (91.1)
Shoes [n (%)]			
Standard or normal	69 (89.6)	10 (76.9)	79 (87.8)
Modified	8 (10.4)	3 (23.1)	11 (12.2)
Peroneus muscle power at last follow-up [n (%)]			
Grade 0 to 1	0 (0)	4 (30.8)	4 (4.4)
Grade 2 to 3	23 (29.9)	2 (15.4)	25 (27.8)
Grade 4 to 5	54 (70.1)	7 (53.8)	61 (67.8)

Table 6. Adjusted odds ratio and 95% confidence intervals of selected factors potentially affecting the metatarsus adductus

Covariates	Odds Ratio	[95% Conf. Interval]	*p*-value
Side: bilateral	2.0028685	0.5359568 to 7.484711	0.302
Age at initial treatment	0.9981505	0.9817683 to 1.014806	0.826
Cast duration	0.5963811	0.3408073 to 1.043611	0.070
Non-idiopathic	1.415811	0.2244526 to 8.930703	0.711
Final peroneus power grade 0 to 3	4.925537	1.228788 to 19.74378	0.024

walk and run, although one case of arthrogryposis with calf muscle weakness could not jump and 5 cases (8 feet) could not squat with the heel touching the ground due to a short tendo-Achilles. At final follow-up peroneus muscle power improved in most feet after strengthening exercises reaching grade 4 to 5 in 61 feet (67.8%), but power was still poor (grade 2 to 3) in 25 feet, and 4 feet did not improve at all (grade 0).

Radiologic assessment of 88 clubfeet was done. Comparison with the normal side was done in 30 unilateral clubfoot cases (Table 7). Flat-top talus occurred in 5 cases (7 feet).

Discussion

The reported success rate with Kite's method in patients where treatment was started before 1 year of age has been reported to be 90%, with the duration of cast treatment ranging from 26 to 49 weeks[3]. The success rate of the Ponseti method had been reported to be 86 to 98%, depending on the level of parent compliance with Dennis-Browne splint application recommendations, clubfoot classification, severity of

Table 7. Comparison of radiologic evaluation of outcomes after final treatment: idiopathic, non-idiopathic and normal side

Radiologic measurement	Idiopathic (n = 76)	Non-idiopathic (n = 12)	Normal side (n = 30)
AP Kite angle (degrees) mean, SD (range)	27±5.5 (14 to 41)	26±5.2 (18 to 36)	27±4.5 (18 to 39)
Lateral Kite angle (degrees) mean, SD (range)	35±7.8 (16 to 54)	38±6.2 (30 to 51)	38±9.7 (17 to 66)
Talo-first metatarsal angle (degrees) median (IQR)	4.0 (12.8)	-2.0 (22.7)	-2.5 (14.3)
Flat talar dome [n (%)]	5 (6.6)	2 (16.7)	0 (0)

deformity and age at initial treatment, with cast treatment of 3 to 12 weeks[2,9,11]. Alok Sud et al[9] in 2007 described a prospective randomized control trial comparison of the Ponseti and the Kite's methods in the treatment of idiopathic clubfoot in infants aged up to 3 months. That study found a 91.7% success rate with the Ponseti method with a mean number of cast changes of 6.2 (SD = 2.3; range = 3 to 12), while Kite's method had a success rate of 67.7% with an average of 10.7 cast changes (SD = 5.4; range = 3 to 23). A 2009 study by AV Sanghvi et al[10] conducted a randomized comparison of the Ponseti and Kite's methods for treatment of idiopathic clubfoot. In infants age between 0 and 24 weeks, they reported a 92.3% success rate with the Ponseti method with a mean of 7 cast changes (SD = 1), whereas Kite's method had a success rate of 86.7% with a mean of 10 cast changes (SD = 1).

In the present study, all club feet were initially successfully corrected using the Korat technique with serial casting. The relatively low age at initial treatment in the present study (median 12 days; IQR 26) may have enhanced the success rate. The mean number of cast changes was 4.1 (SD = 1.36; range = 2 to 8), less than that with either the Kite's or the Ponseti methods. In addition, careful early percutaneous needle tendo-Achilles tenotomy in the feet was observed to shorten the duration in cast without serious complications such as excessive bleeding, infection or scarring problems. With the Ponseti method, tenotomy is performed after five or six cast changes if the ankle cannot dorsiflex 20 degrees and a final cast is worn for an additional 3 weeks after the tenotomy. Eighty-six to 96%[11,12] of the clubfoot cases treated by the Ponseti method required tendo-Achilles tenotomy, while with the Korat technique only 75.6% required that intervention.

Although the Korat technique was able to correct all clubfoot deformities earlier than the Kite's method, maintaining the correction was problematical. Twenty-two cases (29 feet or 32.2%) relapsed. With the Ponseti method,the percentage of recurrence in idiopathic clubfoot varied between 6 and 23%[9,13-17], while the figure was 10 to 36% with the Kite's method[9,11,16,17]. Non-compliance with the Ponseti method, which requires full-time use of the Dennis-Browne splint for the first three months followed by night splinting for another other four years, had been reported to be the primary cause of relapse with that method[11,12]. However, relapses among individuals with good compliance have been reported[14]. As none of the cases in the present study used the Dennis-Browne splint, noncompliance was not a factor in the relapses. The major causes of relapse in the present study were weakness of the peroneus muscle and recurrent tight heel cord. Gelfer et al[14] reported a significant correlation between poor evertor activity and recurrence, but no statistically significant relationship was found between the rate of recurrence and the severity of the initial deformity, the age at the time of treatment, the number of casts required or rate of compliance with the brace. Results of the present study related to relapse are consistent with the findings of Gelfer: the main risk factor, after adjusting for side, age at initial treatment, severity, and classification that is significantly correlated with recurrence is grade 0 initial peroneus muscle function.

The peroneus muscle strengthening program that the parents were encouraged to follow after cast removal with the Korat technique helped prevent recurrence and should be done in conjunction with stretching of the tibialis posterior tendon to overcome the heel and forefoot varus deforming force. The exercise program was successful in achieving grade 4 to 5 in 61 feet (67.8%). After muscle training, of 62 feet that were initially grade 0, 36 (58.1%) increased to at least grade 4, while 25 of 28 feet (89.3%) that were initially peroneus muscle power grade ≥1 improved to at least grade 4 and the remaining three feet reached grade 3.

Additional exercise programs to stretch the heel cord to increase ankle dorsiflexion and to prevent recurrence of tight tendo-Achilles is also necessary. Stretching exercises are safe and should be emphasized,

even in the tendo-Achilles tenotomy group. In the present study, the mean ankle dorsiflexion at final follow-up of the feet that had undergone tendo-Achilles tenotomy was 23.7degrees (SD = 12.60), slightly less than the serial casting only feet where the mean dorsiflexion was 28.2 degrees (SD = 13.14). The mean ankle dorsiflexion of the normal feet calculated from 32 unilateral clubfoot cases was 28.1 degrees (SD = 13.66).

The goal in management of congenital clubfoot is to obtain a functional pain-free, normal-looking, plantigrade foot that has good mobility and does not require modified shoes[7]. In the present study, all cases were pain free and could plantigrade at final follow-up. Fully normal foot form was achieved in about 80% of the idiopathic clubfoot cases compared to 46% of the non-idiopathic cases. About 18% of the idiopathic and 38% of the non-idiopathic cases had residual metatarsus adductus. After adjusting for side, age at initial treatment, classification and duration in cast, a risk factor which was significantly correlated with residual metatarsus adductus was final peroneus muscle power grade 0 to 3. Fourteen of 29 feet (48.2%) with peroneus muscle grade 0 to 3 had residual metatarsus adductus, while only 5 of 61 (12.2%) with muscle power grade 4 to 5 had metatarsus adductus. Over correction resulting in mild residual calcaneovalgus foot may occur, especially in cases with hyperlaxity syndrome. Gastrosoleus muscle strengthening is advised after the foot form becomes normal.

The mean passive ankle dorsiflexion in the present study (25 degrees) was greater than the 6 degrees reported in a study by Cooper and Dietz[18] which evaluated idiopathic club foot thirty years after treatment with the Ponseti method, although plantar flexion was nearly the same: 44 degrees in the present study versus 31 degrees in the Cooper and Dietz study. Regular tendo-Achilles stretching exercise after removal of the final cast can improve passive ankle dorsiflexion and is probably more effective than exclusively static immobilization with an orthosis, so the shorter duration in a cast with the Korat technique provides the advantage of early exercise and movement.

It is possible that the lack of correlation between outcomes and various radiographic measurements was due to the fact that, as reported by Siapkara and Duncan[19], radiographs are intrinsically not good indicators of outcomes. Other studies have reported satisfactory outcomes, i.e., mobile plantigrade foot without pain and with normal activity, despite apparent radiographic abnormalities[18]. The wide range of normal radiographic values in child foot cases limits its value for predicting poor outcomes.

Although decreased anteroposterior talocalcaneal angle and lateral talocalcaneal angle in clubfoot patients has been reported[18], at final follow-up in the present study the mean anteroposterior talocalcaneal angle and the lateral talocalcaneal angle of patients were not different from those of 30 normal sides of unilateral clubfoot. Poor talo-first metatarsal angle was found to be directly related to residual metatarsus adductus. The mean talo-first metatarsal angle of the residual metatarsus adductus feet was -18.1 degrees, while that of the normal sides was -2.5 degrees.

Flat-top talus has been described as a pathologic change secondary to idiopathic clubfoot condition and/or a direct result of non-operative manipulation involving forced dorsiflexion and molding of the cartilaginous talus. Another issue is that recurrences requiring further treatment results in additional immobilization in a cast. A continuation of cast treatment for more than three months can lead to flat-top talus deformity[20] and so may induce flat-top talus. In the present study, 6 of 29 recurrent feet developed flat-top talus, while only one of 59 non-recurrent feet had flat-top talus. Ankle dorsiflexion was limited in 5 flat-top talus feet that had previously undergone a modified McKay operation. Although none of the flat-top talus cases complained of pain, they will require long term arthritis monitoring.

Limitations of the study

One limitation is that MRI was not used to evaluate the remodeling of the talus, calcaneus or other bones of the foot, although a large number of feet were regularly evaluated using other methods until the midterm followed-up. Another limitation is that the exercise programs carried out by parents for their children were not monitored, so the level of compliance may not have been equal. Regular follow-up encouragement to parents, especially in the peroneus muscle weakness group, could potentially have reduced this limitation. The last limitation is that no direct comparison to results with either the Ponseti or Kite's method was conducted, so further study is needed.

Conclusion

The Korat technique of manipulation and serial casting, either with or without early percutaneous

needle Achilles tenotomy, is an alternative method for clubfoot deformity correction. Advantages include more rapid achievement of normal foot form, reduced number of cast changes and shorter total duration in a cast. Based on this study, eighty-one percent of idiopathic clubfoot cases can achieve normal foot form by midterm follow-up. With the Korat technique, as with other methods, there is a significant risk for relapse in cases with an initial grade 0 peroneus muscle function. Strengthening the peroneus muscles combined with stretching the tendo-Achilles and tibialis posterior tendon after removal of the last cast can help achieve good ankle motion and help prevent relapse. Repeated encouragement of parents to carry out necessary exercises is highly beneficial.

What is already known on this topic?

The proper initial treatment for clubfoot deformity in infants is manipulation and serial casting. Either Kite or Ponseti technique of manipulation and serial casting can effectively be the choice of treatment with difference in success rate and duration in cast. Manipulation and serial casting that combined the principle of Kite and Ponseti has never been done before. Achilles tenotomy was done to improve ankle dorsiflexion after five or six casts in Ponseti method; however, the early percutaneous needle Achilles tenotomy for easily triplane mobilization of the calcaneus during manipulation has not been studied yet. Grading for the peroneus muscle power in infant is difficult so a simpler method to clarify the muscle power score which can be used to follow the muscle improvement is needed. As Gelfer's report, the evertor muscle weakness at the time of application of the foot abduction brace was the significant risk factor of recurrence. Nevertheless, the initial peroneus muscle power before manipulation and serial casting has never been studied as the earlier risk factor of recurrence.

What is this study adds?

An alternative technique called Korat technique, that combined the Kite and Ponseti principle of manipulation and serial casting, with or without early percutaneous needle Achilles tenotomy could achieve normal foot form with less numbers of cast change and less duration in cast. Careful early percutaneous needle Achilles tenotomy was helpful to shorten the duration in cast without serious complications. The midterm clinical and radiographic outcomes had been followed-up. Systematic grading of the peroneus muscle power for infant was clarified and initial peroneus muscle power of grade 0 was determined as the significant risk factor of clubfoot deformity relapse. The strengthening of the peroneus muscle along with stretching the tendo-Achilles and the tibialis posterior tendon to overcome the deforming force was proposed as the dynamic maintenance of normal foot form and the prevention of recurrence.

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Potential conflicts of interest

The authors declare no conflicts of interest.

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