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A Modified Ponseti Method for the Treatment of Rigid Idiopathic Congenital Clubfoot

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ABSTRACT

This study reviewed the efficacy of a modified Ponseti method (MP) for treating rigid clubfeet insufficiently corrected by the classic Ponseti method. Briefly, the MP consisted of 3 procedures. First, Achilles tenotomy, abductor hallucis tenotomy, and plantar fasciotomy were conducted through 3 small incisions. Second, the talocalcaneal and talonavicular joints were manually reduced. Third, plaster immobilization was introduced to maintain the initial correction. Dimeglio scores, radiographs, and pain evaluations were used to analyze outcomes. All 38 patients with 56 clubfeet enrolled in the present study achieved initial correction after the MP, followed by a mean of 3.68 ± 0.77 (range 3 to 5) cast immobilizations, which were changed each week. The average duration of treatment was 30.63 ± 6.45 days (range 23 to 47), and 6 (10.71%) clubfeet exhibited cast-related pressure injury. After a mean follow-up period of 19.71 ± 4.83 months (range 12.47 to 31.33), no child presented foot pain, and except for 1 patient with relapse, all patients received correction, with Dimeglio scores of 0.55 ± 1.06 points (range 0 to 7). The recurrence rate was 1.79% (1 of 56) at the first year. The anteroposterior talocalcaneal angle was 34.83° ± 10.65°, and the lateral talocalcaneal angle was 31.38° ± 9.86° at the last follow-up period, and both were significantly improved compared with the corresponding preoperative angles ($p < .001$). The anteroposterior talus-first metatarsal angle was 12.33° ± 10.04°, and the lateral calcaneal tibial angle was 74.15° ± 14.12°, which were significantly decreased compared with the preoperative values ($p < .001$). In conclusion, the present short-term evaluation of this minimally invasive soft-tissue release method showed promising results for treating rigid clubfoot that was not responsive to the traditional Ponseti method.

Idiopathic congenital clubfoot (ICCF) is a common congenital deformity with an incidence in newborns that ranges from 0.06% to 0.17%, of which ~80% occur in low- and middle-income countries (1,2). The Ponseti method has become the primary choice for treating clubfoot because of its simple manipulation and ease of grasping. In addition, previous studies have shown satisfactory results with low complications when treating clubfoot with this method. Nevertheless, some studies have also reported that rigid deformity cases might be prone to unresponsiveness to the conventional Ponseti method or vulnerable to relapse, even when initial correction has been achieved (3,4). A previous study reported that patients with rigid deformity (Dimeglio score 16 to 20) at presentation might suffer a higher recurrence risk after initial correction. Sangiorgio et al (5) reported that 3% to 34.6% of children with initial correction after the classic Ponseti method suffered relapse and needed further surgery. The surgical risk of the severe grade (Dimeglio score 16 to 20) was 5.75 times that of the moderate grade (Dimeglio score 11 to 15) and 7.27 times that of the mild grade (Dimeglio score 1 to 10). In our preliminary clubfoot treatment series, we reached a tentative conclusion that difficulty in initial correction, long treatment period, and many cast-related complications were major challenges during the Ponseti management of Dimeglio type IV severely rigid clubfoot.

Patients and Methods

Thirty-eight patients with 56 clubfeet were reviewed in the present study, and these patients underwent MP from December 31, 2015, to May 5, 2017. All clubfeet achieved initial correction and remained corrected during the follow-up period. Thirty-two (84.2%) of the patients were male, and 6 (15.8%) were female; 19 (50%) patients had unilateral clubfoot, and 19 (50%) had bilateral clubfoot. Of the patients with bilateral clubfoot, 1 child underwent a modified Ponseti method (MP) on the left foot, and the right clubfoot was treated with the Ponseti method. The initial Dimeglio score was 18.46 ± 0.93 points (range 17 to 20), the mean age at intervention was 14.17 ± 10.19 months (range 4.58 to 45.92), and the mean follow-up duration was 19.71 ± 4.83 months (range 12.47 to 31.33). Before the first cast, there was no fever, lower-extremity skin rash, skin damage, local skin irritation, multiarticular contracture,

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Table 1
Statistical description of the case series (N = 56 feet in 38 patients)

Sex	
Male	32
Female	6
Clubfoot	
Unilateral	19
Bilateral	19
Age at surgery (months)	14.17 ± 10.19 (4.58 to 45.92)
Follow-up (months)	19.71 ± 4.83 (12.47 to 31.33)
Initial Dimeglio score	18.46 ± 0.93 (17 to 20)

Data are mean ± standard deviation (range).

or constriction bands, except for neurogenic, traumatic, and cerebral clubfoot. All patients received complete correction. General patient information is listed in Table 1. The study was approved by the Ethics Committee of the Children's Hospital of Chongqing Medical University. Consent was obtained from every guardian of the children involved in the study.

Treatment Procedure

Indications

This study included patients with rigid clubfoot (Dimeglio type IV). All patients were initially treated with Ponseti serial casts (1 week for each cast) to obtain deformity correction at presentation. After the first 2 casts, (1) if the Dimeglio scores were >15, an MP would be performed; (2) if the Dimeglio scores happened to be 15, then the third cast could be continued; and (3) the traditional Ponseti serial casts followed if the Dimeglio score was ≤14. However, if the scores still showed a value of 15, then an MP was performed.

Techniques

Straight or curved tourniquets were chosen to reduce intraoperative bleeding, depending on the condition of the patient's limb during surgery. Posterior release: A ~0.5- to 1.0-cm longitudinal incision was made on the medial side of the heel; next, the subcutaneous tissue was separated, and the Achilles tendon was exposed. The Achilles tendon was horizontally cut off, avoiding damage to the peroneal artery, small saphenous vein, and sural nerve near the lateral margin. Medial release: A 0.5- to 1.0-cm incision was made at the base of the first metatarsal in the medial aspect, and the subcutaneous tissue was separated. The tendon was cut off fractionally in the muscle belly of the abductor hallucis close to the tendon. Plantar release: A 0.5- to 1.0-cm incision was made at the tensest point of the plantar fascia, which was the apex of the longitudinal arch of the foot. The tense plantar fascia was transversely cut to correct the high arch. Then, the dislocated talus was pushed continuously and gently to achieve subtalar joint and talonavicular joint reduction. The passive dorsiflexion of the ankle joint was >20° (Fig. 1). Immobilization with a plaster cast: By using the same method as the Ponseti technique, long leg casts were fixed from under the groin to the toes with 90° knee flexion and 5° to 15° forefoot abduction. One or two casts were used to maintain correction after the MP, with 1 week for each cast. Malformation was corrected after the last cast was removed (Fig. 3).

Bracing

The dynamic Knee Ankle Foot Orthosis (6) with foot dorsiflexion and eversion was worn after the last cast, at least 23 hours a day for the first 3 months, and then only at night for 2 to 3 years. Infants <1 year old were required to wear orthopedic shoes at walking age, and children who had started walking wore the dynamic Knee Ankle Foot Orthosis at night and orthopedic shoes during the day.

Manipulations

During the entire treatment process, manipulations lasted at least 0.5 hours according to the French method before surgery and after the last cast (7). Forefoot abduction and derotation of the calcaneopedal complex around the talus were performed.

Follow-Up

The first follow-up occurred the second week after the last cast was removed, with subsequent evaluations at 1 month, 2 months, 3 months, and once every 6 months thereafter. For guardians who displayed negative attitudes and poor compliance during treatment, as well as guardians with unstable living conditions and low income, internet and telephone communications were used to ensure follow-up. For children with severe deformities or difficult corrections, the follow-up interval was shortened appropriately, and the knowledge related to recurrence was strengthened. The appearance of this minimally invasive soft-tissue release method showed promising results (Fig. 4).

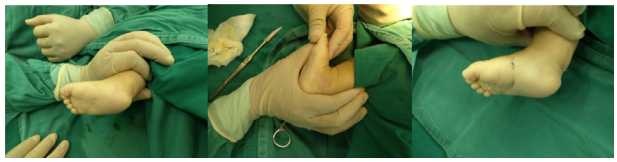

Fig. 1. The mini-incisions of the modified Ponseti method.

Radiographs

Anteroposterior and lateral radiographic films of were taken before treatment, immediately after surgery, at the third month and sixth month after surgery in the follow-up period, and once a year thereafter.

Evaluation method

All children enrolled in this study were evaluated by Dimeglio scores from an experienced specialist at the first visit, before surgery, and at each follow-up. Treatment duration, age at surgery, bleeding during surgery, number of casts, and cast-related stress injuries were evaluated (8). Radiographs were analyzed by experienced radiologists and pediatric orthopedic specialists, and the mean value was used for the evaluation index. The initial deformity and the condition at the subsequent follow-up were compared by physical examination, pain evaluations, and radiographs that included the talocalcaneal angles (anteroposterior, TCA-AP, and lateral, TCA-LT), anteroposterior talus-first metatarsal angle (TMT-AP), and lateral calcaneal tibial angle (CTA-LT) (9).

Statistical analysis

All variables were analyzed by SPSS 22.0. Statistical data are indicated by the mean ± standard deviation. Between-group comparisons were made by analysis of variance, and the level of statistical significance was determined with the p value set at .05.

Results

In 38 patients with 56 clubfeet treated with the MP, the bleeding during surgery was <2 mL with tourniquet support. The operation time per clubfoot was <15 minutes, including the surgery and cast. The entire surgical procedure could be performed independently by a skilled pediatric orthopedic surgeon. The mean number of casts preoperation was 2.41 ± 0.50 times (range 2 to 3), the total number of casts including casts before and after surgery was 3.68 ± 0.77 times (range 3 to 5), and the total treatment duration was 30.63 ± 6.45 days (range 23 to 47) (Table 2).

The Dimeglio score was 18.46 ± 0.93 points (range 17 to 20) at presentation, followed by treatment with the classic Ponseti method. The Dimeglio score was 15.55 ± 0.74 points (range 15 to 17) before minimally invasive release. The Dimeglio score of the clubfeet was 0.55 ± 1.06 points (range 0 to 2) after the 19.71 ± 4.83-month (range 12.47 to 31.33) follow-up period, except for 1 relapsed case, and none of the children complained of foot pain at the latest follow-up visit. The relapsed case occurred in the 9-month follow-up period, with forefoot

Table 2
Variables during the modified Ponseti method

Variable	Mean ± SD	Range
Number of casts before minimally invasive release	2.41 ± 0.50	2 to 3
Dimeglio scores before minimally invasive release	15.55 ± 0.74	15 to 17
Number of casts after minimally invasive release	1.27 ± 0.45	1 to 2
Total number of casts	3.68 ± 0.77	3 to 5
Bleeding during surgery (mL)	1.27 ± 0.45	1 to 2
Treatment duration (days)	30.63 ± 6.45	23 to 47
Dimeglio score at the last follow-up	0.55 ± 1.06	0 to 7

Abbreviation: SD, standard deviation.

Table 3
Prognostic evaluation

Measure	Clubfeet	Ratio (%)
Cast-related stress injuries	6	10.71
Pain	0	0.00
One-year recurrence rate	1	1.79

Table 4
Radiographs of clubfeet

Angle	Before MP	At the last follow-up	*F*	*p* value
TCA-AP	18.61 ± 9.96	34.83 ± 10.65	69.364	<.001
TMT-AP	44.06 ± 21.32	12.33 ± 10.04	101.545	<.001
TCA-LT	17.31 ± 10.76	31.38 ± 9.86	52.041	<.001
CTA-LT	93.70 ± 25.23	74.15 ± 14.12	25.617	<.001

Abbreviations: MP, modified Ponseti method; CTA-LT, lateral calcaneal tibial angle; TCA-AP, anteroposterior talocalcaneal angle; TCA-LT, lateral talocalcaneal angle; TMT-AP, anteroposterior talus-first metatarsal angle.

adduction and equinus; the Dimeglio score was 7 points without soft tissue rigidity. A traditional Ponseti treatment was performed, and the child achieved correction. The recurrence rate in the first year was 1.79% (1 of 56), and the results are presented in Table 3. Among the clubfeet in the study, there were 6 clubfeet (10.71%) with cast-related pressure injuries during the treatment. With respect to the changes in bone alignment in the clubfeet in this study, TCA-AP and TCA-LT were significantly larger than the corresponding values before treatment ($p < .001$). In addition, the CTA-LT and the TMT-AP were decreased compared with the corresponding values before treatment ($p < .001$) (Table 4 and Fig. 2).

Discussion

Before the 1990s, surgery was accepted as the best treatment for ICCF. However, this conception has been reversed owing to the development and promotion of the Ponseti method, which is a conservative treatment for ICCF. Furthermore, increasing evidence has also shown that extensive surgical releases for ICCF result in painful, arthritic feet in adulthood. Previous studies have reported that the number of surgeries on ICCF decreased at a rate of 6.7% per year in the United States from 1996 to 2006 (10). Currently, the Ponseti method has become the standard procedure for ICCF patients at the initial visit.

Although numerous studies have reported a high initial correction rate and satisfactory long-term results by using the Ponseti method for the treatment of ICCF, it should be noted that the effectiveness of the Ponseti method for rigid ICCF is still undefined. Zhang et al (11) reported that the Ponseti method for treating ICCF with a Dimeglio score of ≤11 points could reach a nearly 90% satisfactory rate at a patient age of 2 years; unfortunately, in that study, only a 60% satisfactory rate was achieved for ICCF patients with a Dimeglio score of ≥16 points. Therefore, surgery could not be eliminated completely when confronted with ICCF, especially for rigid cases. A recent prospective study reported that the severity of deformity is associated with outcome; the mean initial severity of deformity in patients with a good outcome is significantly lower than that in patients with a fair outcome.

In the present study, the rigid degree of clubfoot deformity in the included patients was evaluated by the Dimeglio classification. The overall grading of the deformity was relatively severe, with an average score of 18.46 ± 0.93 points (range 17 to 20). According to the previous study, the severe deformity in our case series might result in unsatisfactory results; however, we still tried to correct the deformity by the Ponseti method because some studies also showed that the Ponseti method can treat rigid clubfoot with good results. After 1 or 2 casts, we assessed the deformity again and found that the patients in the present study showed a few improvements in the Dimeglio score, with an average of 15.55 ± 0.74 points (range 15 to 17). Based on the rigid deformity at the initial visit and the poor response to the Ponseti method, we sought some positive action that would avoid the poor results. Studies have reported that conservative treatment is often ineffective for severely rigid clubfoot, and early surgical treatment can achieve good results (12,13). However, soft tissue release is an alternative for rigid ICCF, and some shortages have been reported, including vascular and nerve injury, wound infection, overcorrection, joint stiffness, refractory pain, osteoarthritis, and gait disturbance (14–16).

To overcome these shortcomings, we introduced a minimally invasive release method to treat rigid ICCF in the present study. Briefly, we used the method of selective release of soft tissue through a small

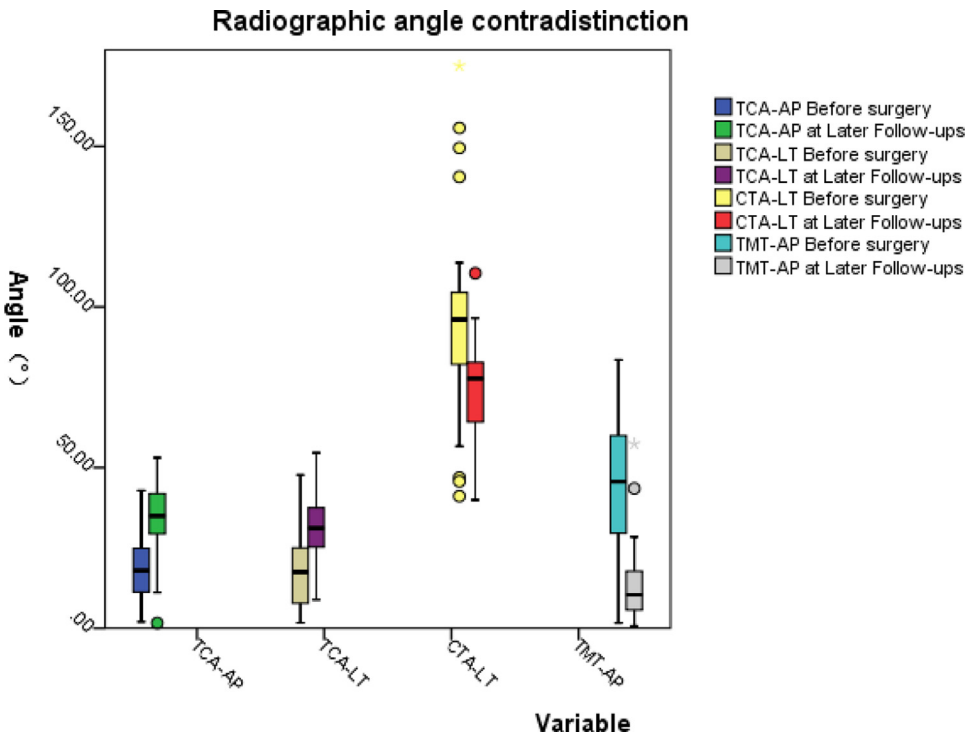

Fig. 2. Radiographs of clubfeet.

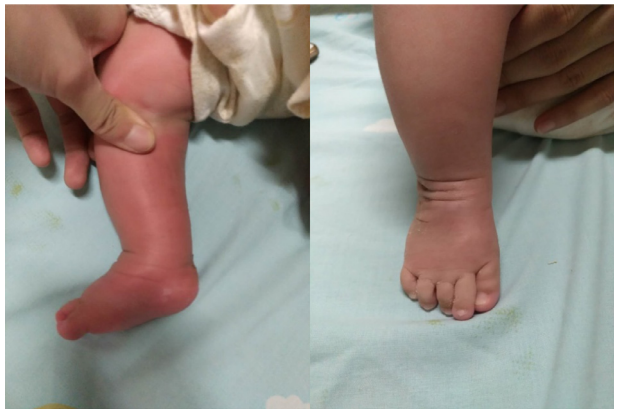

Fig. 3. Appearance after the last cast in a male with right idiopathic congenital clubfoot treated with the modified Ponseti method.

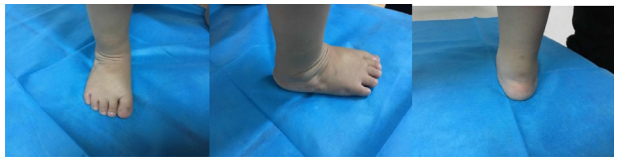

Fig. 4. Appearance of the male with right idiopathic congenital clubfoot (Fig. 3) 29 months after the modified Ponseti method.

incision to improve the therapeutic effect and reduce relapse. Because forefoot adduction is the most common residual deformity of the Ponseti method (17,18), the adductus deformity was treated with percutaneous section of the hallux abductor through a medial incision (19). Because equinus deformity is difficult to correct through casting only, it has been reported that 90% of patients receiving a Ponseti treatment need Achilles tenotomy or Achilles tendon lengthening. We corrected the equinus by percutaneous Achilles tenotomy at the same time; moreover, the cavus deformity was treated with percutaneous planter fasciotomy when needed.

In the present study, all patients underwent the MP, which combined serial casting and a minimal soft tissue release procedure to treat the rigid clubfoot. The Dimeglio scoring system was used to evaluate the deformity correction. Our results showed a significant decrease ($p < .05$) in the Dimeglio score from pretreatment to the last follow-up. However, this was a subjective assessment and might have doubtful validity and reproducibility. Therefore, we also used radiographic parameters as a more objective method to evaluate the efficacy in the present cases (20–22). The CTA-LT indicated stiffness of the ankle, and the higher CTA-LT angle reflected the more severe ankle equinus deformity. Both the TCA-LT and TCA-AP angles represented hindfoot alignment, and decreases in the former indicated equinus or hindfoot varus or both. However, the latter angle was decreased only by varus of the hindfoot. Radler et al (20) reported changes in the lateral tibiocalcaneal angle and TCA-LT in clubfoot patients after undergoing Achilles tenotomy. The lateral tibiocalcaneal angle decreased significantly by an average of 16.92°, namely, from 85.64° ± 12.64° to 68.72° ± 11.58° after the tenotomy. In the present study, we observed similar trends in the mean CTA-LT, which was significantly decreased from 93.70° ± 25.23° to 74.15° ± 14.12°, an average reduction of 19°. In contrast, TCA-LT and TCA-AP increased significantly, from 17.31° ± 10.76° to 31.38° ± 9.86° and 18.61° ± 9.96° to 34.83° ± 10.65°, respectively. All these changes in the 3 radiographic parameters indicated the efficacy of correcting hindfoot deformity, including equinus and varus, which might be attributed to Achilles tenotomy. A previous study reported the normal radiographic criteria of the foot; the TCA-AP has been reported to range from 15° to 55°; the TCA-LT, from 25° to 55°; and the tibiocalcaneal angle in maximum dorsiflexion, from 25° to 60° (23,24). At the last follow-up, the TCA-LT and TCA-AP in our patients were practically in these ranges. Although the mean CTA-LT at the last follow-up in our series was still greater than that in the normal data as reported, we did not perform further intervention, as the physical examination showed that the dorsal flexion of the ankle in all patients was >15°, which might be a more beneficial evidence of foot function. The relationship between the hindfoot and forefoot was evaluated by the TMT-AP on the foot AP film (25). The increase in TMT-AP could indicate the varus and adduction of the forefoot. The mean TMT-AP angle in the present study decreased significantly from 44.06° ± 21.32° preoperatively to 12.33° ± 10.04° at the last follow-up, suggesting effective correction in forefoot adduction (Fig. 5).

It has been reported that the more rigid the deformity is, the more casting times are needed to achieve initial correction (26,27). An increased number of casts may result in more incidences of cast-related

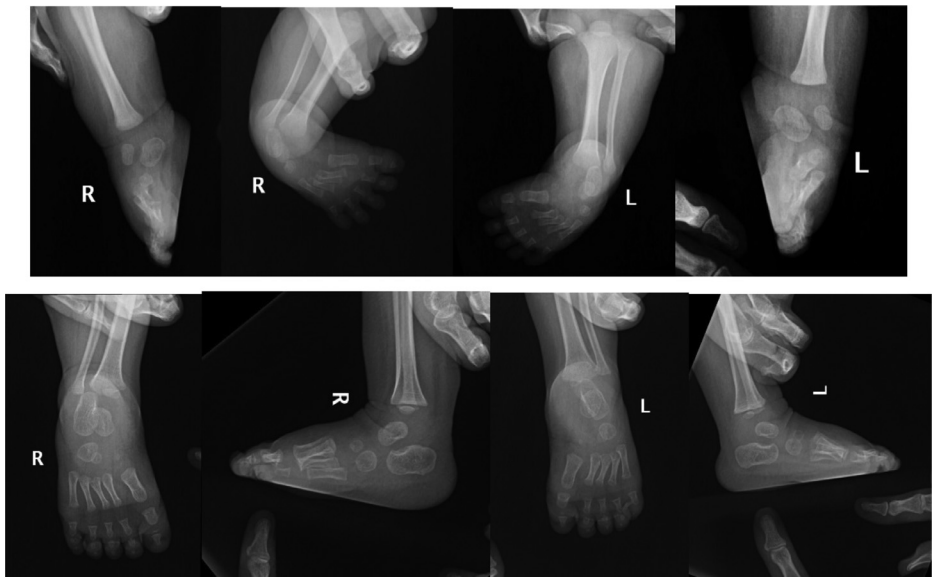

Fig. 5. Radiographs before treatment and at the last follow-up for a patient with bilateral clubfoot (Dimeglio IV).

stress injuries, cast slippage, forced interruptions in treatment, prolonged hospital stays, and increased medical costs (28–30). Importantly, some studies have suggested that excessive casts may impair the confidence of parents, leading to a decreased follow-up period and less brace compliance as well as increased risk of relapse (12,31). In the present study, the included patients had a relatively higher Dimeglio score at admission, which indicated a rigid deformity. However, the mean number of casts required for complete initial correction was only 3.68 ± 0.77 times, with a mean time of 30.63 ± 6.45 days, which is even less than the traditional Ponseti method (ranging from 5 to 8 times casting). Furthermore, our procedure has the advantages of a small incision, with only 2 or 3 minimal 1-cm-long incisions and little bleeding (an average of 2 mL). Altogether, these results indicated that the MP is effective with minimally invasive procedures for the treatment of rigid clubfoot.

In conclusion, the Ponseti method has been reported to yield a relatively high rate of deformity relapse. The recurrence rate ranges from 3% to 62.5% within 5 to 72 years after initial correction, of which 3% to 34.6% of cases require additional procedures, especially for rigid ICCF (3,4). The more severe the clubfoot, the worse the treatment outcome and the greater the tendency to relapse (32). The recurrence rate in patients with MP at the first year was 1.79% in the present study. One patient showed relapse at the 9-month follow-up visit, with forefoot adduction and equinus. This child had begun to wear braces after the last cast removal; however, he did not wear the brace for a sufficient amount of time, and because of the influence of long trips, relapse was found at his first follow-up visit ~9 months after the last casting. No relapse occurred in the other patients who complied with our bracing plan and regular follow-ups. It has been accepted that poor compliance with bracing is the most important risk factor leading to relapse (5,33). However, complete initial correction was conducted before brace compliance, which eventually prevents the occurrence of relapse. We concluded that patients in the present study achieved initial correction without residual deformity, which might have been the reason for good compliance, in turn yielding low recurrence of the deformity.

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