10.5005/jp-journals-10040-1019

ORIGINAL ARTICLE

First and Second Metatarsal Wire and Button Fixation with First and Fifth Bunionectomies for Correction of Splay Foot

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ABSTRACT

Splay foot is a common foot deformity causing pain and disability. Various osteotomy techniques have been recommended for correction of the intermetatarsal angle, with variable success rates. Knowing that wire and button fixation device can provide strong and stiff repair, the aim of the present study was to assess the clinical and radiographic outcomes following 1st and 2nd metatarsal wire and button fixation with 1st and 5th bunionectomies in patients with symptomatic splay foot. The preoperative and postoperative radiological measurements and American Orthopaedic Foot and Ankle Society (AOFAS) scores were statistically assessed in 12 patients (19 feet) with symptomatic splay foot using Wilcoxon signed rank test. The postoperative hallux valgus angle, 1st and 2nd intermetatarsal angle, and maximum distance between 1st and 5th metatarsal heads decreased significantly ($p < 0.05$). The AOFAS score improved significantly from 49.0 ± 6.0 to 82.0 ± 5.0 points ($p < 0.05$). The overall postoperative radiological and clinical outcomes in patients with symptomatic splay foot suggest that the technique of 1st and 2nd metatarsal wire and button fixation with 1st and 5th bunionectomies is safe, feasible and effective for surgical treatment of splay foot deformity.

Keywords: Hallux valgus, Splay foot, Tailor's bunion.

How to cite this article: Xie B, Zhou D-P, Tian J. First and Second Metatarsal Wire and Button Fixation with First and Fifth Bunionectomies for Correction of Splay Foot. J Foot Ankle Surg (Asia-Pacific) 2015;2(1):1-7.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Splay foot is defined as an abnormal broadening of the forefoot in relation to the heel. Clinically, a bunion and a bunionette could both be noticed in this deformity. The term bunion refers to the pathological bump or inflammation on the side of the great toe joint associated with either a bursal sac or a bony deformity involving the 1st metatarsal bone, which is characterized by valgus of the great toe with a relative varus position of the 1st metatarsal, a condition called 'hallux valgus'.[1] The term bunionette or tailor's bunion refers to a protrusion of bone and soft tissue at the lateral edge of the 5th metatarsal head, which is characterized by varus deformity of the 5th toe with a relative valgus position of the 5th metatarsal.[2] Radiologically, splay foot is featured by an intermetatarsal angle (IMA) between the 1st and 2nd rays (IMA_{1-2}) of greater than 12°, an IMA between the 4th and 5th (IMA_{4-5}) of greater than 8°, and a slant of the distal articular surface of the medial cuneiform of more than 105°.[3]

As the concept that splay foot is a structural abnormality that must be corrected by bony realignment has prevailed for decades, many surgical procedures have been described, though such osteotomies can be technically challenging and difficult to perform.[4,5] In addition, the consequences and potential complications from these surgical procedures are a dissatisfactory list that includes delayed union, malunion, nonunion, excessive shortening of the 1st metatarsal, avascular necrosis, hardware failure, prolonged protected ambulation and recurrence.[6-8] The wire and button fixation device can provide a strong and stiff repair. It has been successfully used in reconstruction of anterior cruciate ligament, Achilles tendon and acromioclavicular joint.[9-11] Nevertheless, there have been few studies reporting the application of this device in the treatment of splay foot.

In this study, we assessed the clinical and radiographic outcomes in 12 patients with splay foot (19 feet) who underwent 1st and 2nd metatarsal wire and button fixation in combination with 1st and 5th bunionectomies.

PATIENTS AND METHODS

This prospective study followed all consecutive patients who underwent wire and button fixation for splay foot between July 2011 and June 2012 in our hospital. According to the patient history and preoperative clinical and radiographic evaluation, the patients who were diagnosed with splay foot were considered suitable candidates for 1st and 2nd metatarsal wire and button fixation with 1st and 5th bunionectomies. The inclusion criteria for this study required patients to suffer from pain and soft tissue inflammation at the bunion and bunionette

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and have a splay foot deformity with an $IMA_{1-2} > 12°$, an $IMA_{4-5} > 8°$, and the hallux valgus angle (HVA) >15°. In addition, splay foot deformity should have a short first metatarsal. Exclusion criteria included patients who had received prior osseous procedures for splay foot, or with acute inflammation of the forefoot, hypermobility of the 1st ray, overlength of the 1st metatarsal, lateral tilt of the articular cartilage surface of the 1st metatarsal head, and symptomatic osteoarthritis of the 1st metatarsaophalangeal (MTP) joint. All surgical procedures were performed by 1 of us (TJ). Patients who met the inclusion and exclusion criteria were fully educated before surgery and then signed the institutional review board-approved consent form to allow release of their data for publication. All the patients were followed-up on the outpatient basis monthly during the first 6 months after operation and at a 6-month interval thereafter. The research protocol was approved by the institutional review board.

OPERATIVE PROCEDURE

The patient was placed on the operating table in the supine position. After ankle peripheral nerve anesthesia, the foot and ankle were prepared and draped in the usual sterile fashion. No tourniquet was needed because of the minimal risk of blood loss with this procedure. According to the protocol of the hospital, the patient also had to receive a preoperative antibiotic within 30 minutes before making the incisions.

Four incisions were made on the foot. A 2 cm longitudinal incision was made between the 1st and 2nd metatarsal head for releasing the adductor, transverse metatarsal ligament, lateral capsule, and distal soft tissue binding of the 1st and 2nd metatarsals. The transverse metatarsal ligament was sectioned and adductor tendon was carefully delineated and tenotomized, with caution to avoid injury to the lateral head of the flexor hallux brevis tendon lest hallux varus should result.[12] A scalpel was used to vertically perforate the lateral capsule of the 1st MTP joint. A varus stress was exerted to place a controlled tear of the lateral capsule, so the contracted lateral capsule could be released. Then, the ease of the reducibility of the IMA_{1-2} was assessed with 2-finger medial and lateral compression across the distal metatarsal heads.

A second longitudinal incision was made on the medial side of the 1st ray from the base of the proximal phalanx to the middle level of the 1st metatarsal shaft. A U-shaped flap was then developed from the medial capsule. The flap was shaved thinly and dissected free from its proximal attachment. The joint was exposed and the medial prominence was removed at the sagittal groove. A third 1 cm longitudinal incision was made between the 2nd and 3rd metatarsal heads for insertion of the Endobutton$^{\diamond}$ CL BTB fixation device (Endobutton, Smith and Nephew, Andover, MA, USA). The IMA_{1-2} was reduced manually and maintained in the normal range as confirmed by fluoroscopy. A drill was used to drive a 1.5 mm guide channel through the metaphyseal-diaphyseal junction of the 1st metatarsal toward the distal one-third of the 2nd metatarsal. The distance between the medial side of the 1st metatarsal to the lateral side of the 2nd metatarsal through the channel was measured, and the button with appropriate suture loop was chosen accordingly. A 2-0 Ethibond excel^{TM} polyester suture strand (Ethicon, Somerville, New Jersey, USA) was passed through the suture loop, and then both free ends of pull-through suture strand were attached through the eye of the pull-through needle and manually pulled through from the lateral to the medial of the channel using a hemostat or needle holder. Both free ends of the strand should be pulled tightly from the medial side in order to press the button against the 2nd metatarsal. Two separate 2-0 Ethibond excel^{TM} polyester suture strands should be looped twice through the 1st and 2nd apertures of the second button, leaving the two free ends of suture stand free for tying. The second button was inserted just under the suture loop. An intraoperative image of the reduction was obtained to confirm the lack of soft tissue interposition between the button and the metatarsals, reduction of the IMA, and reduction of the sesamoids beneath the 1st metatarsal head. Once these components of the reduction were confirmed, a total of 5 to 6 knots were tied for the medial button. The U-shaped flap of capsule was then placed on tension to correct the valgus deformity of the great toe and was sutured to the periosteum with 4-0 coated Vicryl plus antibacterial suture strand (Ethicon, Indigo Creek Drive, Rochester, New York, USA).

A fourth incision was made on the lateral side of the 5th ray from the tuberosity of the 5th metatarsal to the proximal phalanx of the 5th toe. Through this lateral incision, the bunionette on the lateral aspect of the 5th metatarsal head was removed after the MTP joint capsule was incised longitudinally.

Two metatarsals were operated due to metatarsalgia and MTP joint subluxation with an additional Weil osteotomy (both the 2nd metatarsals), and two tenotomy operations were performed due to mallet toes (one patient with the 3rd and 4th mallet toes).

Toe alignment was maintained by bandage or orthosis for 6 weeks. The patient was kept on non-weight bearing or partial weight bearing for 2 weeks as long as he or she could tolerate, followed by full weight bearing for 4 weeks in a postoperative hallux shoe or short CAM boot. If all things went well, the patient would be transitioned to a comfortable shoe and allowed on full weight

bearing. Sports with a high impact on the foot were allowed after 12 weeks.

RADIOGRAPHIC EVALUATION

Standardized anteroposterior and lateral radiographs of the foot were taken pre- and postoperatively in the base of gait in the bilateral resting calcaneal stance position. The postoperative radiographs used in the present study were only taken after the patients were able to bear full weight on their foot without pain or altered gait. In this study, HVA, IMA_{1-2}, IMA_{4-5}, distal metatarsal articular angle (DMMA), and maximum distance between the 1st and 5th metatarsal heads were measured preoperatively, 6 weeks postoperatively, and in the final follow-up. All radiographic measurements were performed by a single investigator (XB) with the use of a picture archiving and communication system (PACS, Philips Medical Systems, Netherlands) software.

CLINICAL EVALUATION

Clinical assessment included pre- and postoperative objective and subjective assessment based on the American Orthopaedic Foot and Ankle Society (AOFAS) scoring system.[13,14] The AOFAS scale covers three major items: pain (40 points), function (45 points), and alignment (15 points). The score ranges from 0 to 100, and the higher the score the less the pain and disability. AOFAS score results were graded as: very good (90–100), good (80–89), sufficient (70–79) and poor (less than 70). For early complications, we recorded incision healing problems, prolonged time of full weight bearing, metatarsal bone fracture and abnormal gait secondary to surgery. At the final follow-up, we recorded recurrence of splay foot, pain amelioration according to the pain domain of AOFAS scale, cosmetic satisfaction of the foot, and time of return to work.

STATISTICAL ANALYSIS

All statistical analyses were performed using SPSS software (version 17; SPSS, Chicago, IL) and Microsoft Excel (Microsoft, Redmond, WA). Data were expressed as median ± quartile interval and analyzed by a 2-sided Wilcoxon signed rank test. Only a p-value less than or equal to 0.05 was considered statistically significant.

RESULTS

A total of 12 patients (3 men and 9 women) with 19 operated feet (7 patients with bilateral and 5 patients with unilateral procedures) responded for participation in this series. The mean age at the time of surgery for this group was 51.0 ± 9.0 (41–62) years. The longest follow-up was 24 months and the shortest 12 months, with an average follow-up of 18.5 ± 5.0 months (Table 1).

A superficial wound infection and a suture reaction were noticed in two feet (10.5%) as early complications and were treated with oral antibiotics and dressing change, respectively. Two feet (10.5%) had mild stiffness of the 1st MTP joint after surgery, which was gradually relieved in 3 months. One feet (5.2%) had got some sensory disturbance in the medial aspect of the 1st MTP joint at the last follow-up (12 months). A stress fracture of the second metatarsal occured in one patient (5.3%) at 11 weeks postoperatively. He was treated with a CAM walker and healed uneventfully without obvious dorsal tilt of the metatarsal head. No recurrence of splay foot was observed during the follow-up periods. Of the 19 feet, 15 feet (78.9%) achieved

Table 1: Series of patients treated with 1st and 2nd metatarsal wire and button fixation combined with 1st and 5th bunionectomies for correction of splay foot (N = 19 feet in 12 patients)

Patient	*Sex*	*Age*[a]	*Foot location*	*Coexisting deformity*	*Full weight bearing time (week)*	*Time of return to work (week)*	*Follow-up period (month)*
1	F	41	B	-	3	6	15
2	F	46	R	-	2	5	20
3	M	55	B	-	4	7	18
4	F	46	B	2nd metatarsalgia and MTP joint subluxation[b]	6	10	18
5	F	54	B	-	3	8	24
6	M	62	L	-	3	7	12
7	F	43	L	-	2	6	24
8	F	59	B	3rd and 4th mallet toes[c]	4	7	18
9	F	52	B	-	2	8	12
10	F	47	L	-	2	6	24
11	F	57	B	-	4	7	18
12	M	51	R	2nd metatarsalgia and MTP joint subluxation	6	9	19

F: female; M: male; L: left; R: right; B: bilateral; MTP: metatarsophalangeal
[a]Age at surgery; [b]Right foot; [c]Right foot

complete forefoot pain alleviation, two feet (10.5%) in 2 patients who received unilateral procedures still suffered from mild pain; and two feet (10.5%) in one patient who received bilateral procedures suffered from moderate pain. All the patients expressed cosmetic satisfaction with the surgery. The mean preoperative AOFAS score for the 19 feet of the 12 patients was 49.0 ± 6.0 (38–60) and improved to 82.0 ± 5.0 (67–90) postoperatively ($p < 0.05$). One feet (5.2%) had a very good score, 13 feet (68.4%) had good scores, 4 feet (21.1%) had sufficient scores, and one feet (5.2%) had a poor score. Three patients (25.0%) postponed the time of full weight bearing at the 4th week postoperatively because of foot pain and swelling, and two patients (16.7%) with additional Weil osteotomy postponed the time of full weight bearing at the 6th week. The time of return to work averaged 7.0 ± 2.0 (5–10) weeks after surgery.

Pre- and postoperative radiographic values of HVA, IMA_{1-2}, IMA_{4-5}, DMMA, and maximum distance between 1st and 5th metatarsal heads are shown in Table 2. HVA, IMA_{1-2}, and maximum distance between 1st and 5th metatarsal heads were significantly decreased postoperatively ($p < 0.05$) (Figs 1A to E). The final follow-up X-ray showed a mean of 12.0° ± 3.0° correction of HVA, 6.0° ± 1.0° correction of IMA_{1-2}, and 0.8 ± 0.2 cm correction of the maximum distance between 1st and 5th metatarsal heads. No statistically difference was obtained in DMMA and IMA_{4-5} postoperatively.

DISCUSSION

Splay foot is a relative common foot problem, mostly occurring with or secondary to other foot deformities.[15] It is therefore, primarily important to understand the physiopathogenic mechanism and main factors contributing to the pathogenesis of splay foot before it can be treated effectively. As shown by the imaging changes, valgus of the great toe and the 5th metatarsal is the main cause for the structural deformity of splay foot.

Hallux valgus is a complex condition with a range of deformities, and many potential intrinsic factors (such as genetics, ligamentous laxity, pes planus and 1st ray hypermobility) and extrinsic factors (such as high-heel narrow shoes and excessive weight bearing) are all related to the development of hallux valgus.[16] A normal HVA usually does not exceed 15°, and a normal IMA_{1-2} does not exceed 9°. According to the severity of deformity, hallux valgus could be classified as mild (HVA < 20°, IMA_{1-2} < 11°, less than 50% subluxation of the lateral sesamoid), moderate (20° ≤ HVA < 40°, IMA_{1-2} < 16°, 50% to 75% subluxation of the lateral sesamoid), and severe (HVA > 40°, IMA_{1-2} > 16°, more than 75% subluxation of the lateral sesamoid).[17] In addition, whether or not the 1st MTP joint is congruous should also be considered. Common strategies for hallux valgus deformity include MTP soft tissue reconstruction, distal or proximal or diaphyseal metatarsal osteotomy, proximal phalangeal osteotomy, MTP arthrodesis, metatarsocuneiform arthrodesis, or excisional arthroplasty, depending on the deformity to be corrected and the correction power of the particular technique, knowing that each has its advantages and disadvantages.[18]

The tailor's bunion refers to the protrusion of bone and soft tissue at the lateral edge of the 5th metatarsal head. It is often seen in female adolescents and adults.[19] Although, various etiologies have been suggested, no single definite contributing factor has been confirmed.[20] The main complaint is pain, which occurs as a result of the friction between the prominence of the 5th metatarsal head and the footwear that develops as a painful bursa. The most frequently used measurements for evaluating the tailor's bunion include $IMA_{,4-5}$ lateral deviation angles, and the 5th MTP angle, which indicates the magnitude of medial deviation of the 5th toe in relation to the axis of the 5th metatarsal shaft.[21] Besides, the width of the 5th metatarsal head is also measured. A tailor's bunion is usually treated by conservative therapy. Surgery is indicated when nonsurgical treatment fails. The aim of surgery is to decrease the width of the forefoot and the prominence of the lateral metatarsal. Bunionectomy, metatarsal osteotomy, metatarsal head resection, or even amputation is currently used for surgical correction of the tailor's bunion.[22,23] However, the rate of delayed union or nonunion for metatarsal osteotomy remains high, particularly in diaphyseal osteotomy.[24]

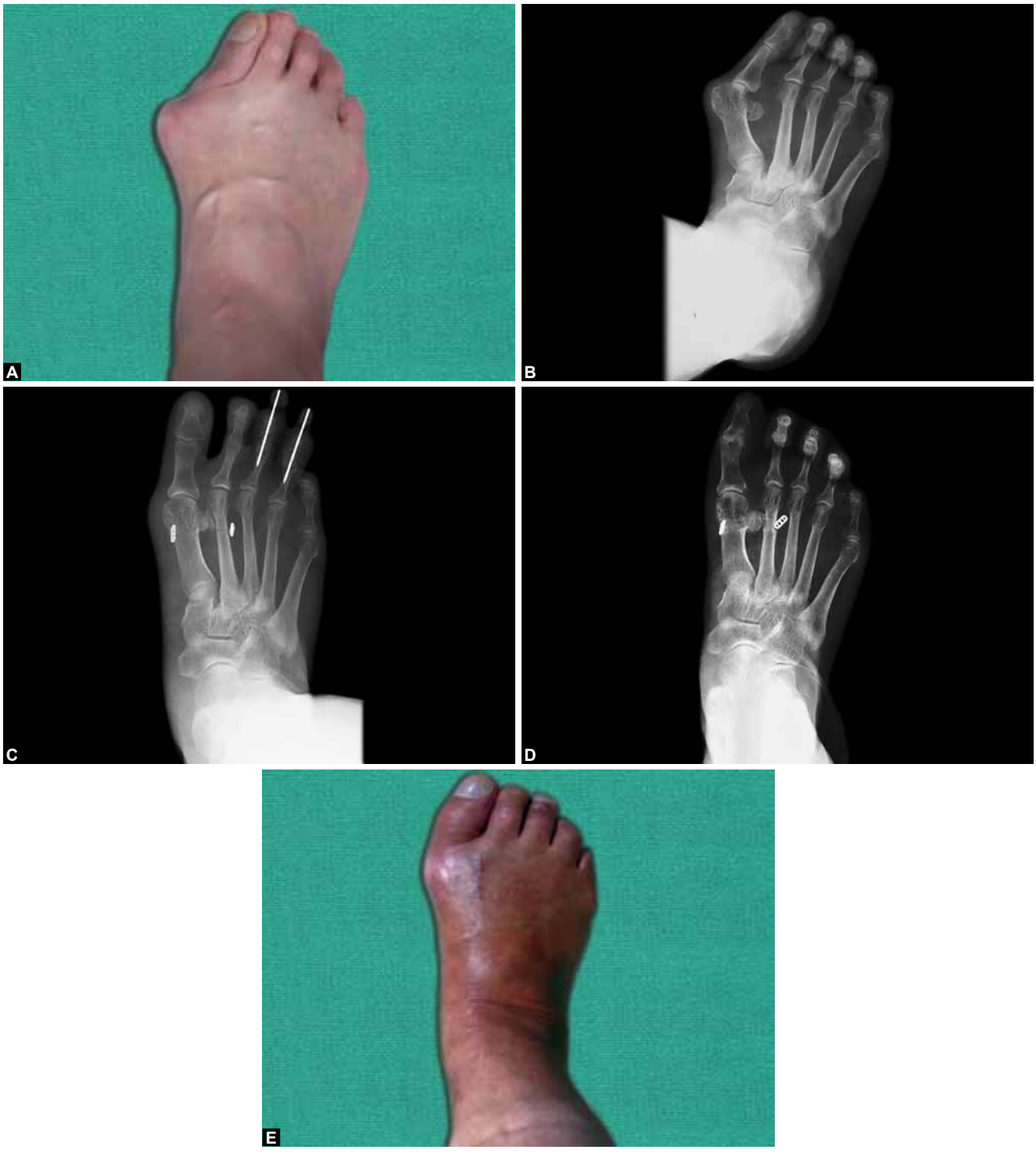
The abnormal condition of the transverse metatarsal arch is closely related to functional disturbance of the

Table 2: Median, quartile interval, and range of the pre- and postoperative radiological measurements of 19 feet in 12 patients evaluated in this study

	Preoperative	*Six weeks postoperative*	*Final follow-up*
Hallux valgus angle (°)	29.0 ± 7.0 (22–45)	15.0 ± 4.0 (12–32)[a]	16.9 ± 5.2 (13–36)[b]
Intermetatarsal angle between 1st and 2nd rays (°)	16.0 ± 3.0 (12–21)	8.0 ± 2.0 (5–11)[a]	9.8 ± 3.1 (7–14)[b]
Intermetatarsal angle between 4th and 5th rays (°)	10.0 ± 3.0 (7–12)	9.0 ± 3.0 (7–12)	9.8 ± 2.3 (8–12)
Distal metatarsal articular angle (°)	10.0 ± 2.0 (8–17)	9.0 ± 3.0 (8–15)	9.7 ± 2.4 (8–16)
Distance between 1st and 5th metatarsal heads (cm)	9.2 ± 1.1 (8.0–11.2)	8.1 ± 0.9 (7.2–9.4)[a]	8.5 ± 0.9 (7.4–9.7)[b]

[a]Significantly different compared with preoperative measurement ($p < 0.05$); [b]Significantly different compared with preoperative measurement ($p < 0.05$)

forefoot, especially with hallux valgus.[25] The transverse metatarsal arch plays an important role during normal gait cycles. During the transition for a standing phase to a push-off phase, the gravity of the foot moves forward, which increases weight bearing of the 2nd and 3rd metatarsals and causes the metatarsals to move downward and contact with the ground, resulting in collapse of the transverse arch.[26] Studies[27,28] have demonstrated that in patients with hallux valgus, the 2nd and 3rd metatarsals bear weight too early, the transverse arch collapses too early, and the metatarsals bear weight for a prolonged time, all of which operate to cause the development of splay foot. Therefore, correcting hallux valgus deformity is the key link in the improvement of splay foot. Osteotomy is the mainstay of previous therapies for splay foot with hallux valgus. However, bony procedures have such



Figs 1A to E: (A) Preoperative appearance of the right splay foot, (B) Preoperative weight bearing, anteroposterior (AP) view of the right splay foot, (C) Postoperative AP view (nonweight bearing) of the foot at 1 week after the wire and button fixation. The patient also had mallet toes of the 3rd and 4th toes and underwent tenotomy simultaneously on the same foot, (D) Postoperative AP view (weight bearing) of the foot at 6 months after the wire and button fixation and (E) Postoperative appearance of the foot in the final follow-up

problems as delayed healing, nonunion and prolonged immobilization.[4,5,29]

The technique described in the present study inserted a strong suture loop through 2 holes drilled at the some position in the 1st and 2nd metatarsals in combination with the use of two button plates that tightly holded around the opposite side of the 1st and 2nd metatarsals. The wire and button fixation device functions as a 'flexible band' or 'tension band' that exhibits flexible characteristics and maintains the 1st metatarsal in the corrected or normal (non-deviated) position. That means, it can apply a tightening force that pushes the 1st and 2nd metatarsals together, thus, providing a slow correction of the deformity by decreasing the metatarsal angle over time without requiring the acute damage to the bones or tendons of the foot, such as that created by osteotomies. Holmes and Hsu[30] reported a series of 14 patients treated for hallux valgus deformity by using small suture button devices, and achieved a notable reductions in HVA and IMA between pre- and postoperative measurements and the curative effect maintained through 6 months of follow-up compared with preoperatively, with HVA and IMA decreases of 6° and 19°, respectively. Only one (7.1%) intraoperative second metatarsal fracture was recorded in their study.

In our study, we only performed bunionectomy for tailor's bunion instead of osteotomy. Just as we have mentioned above, hallux valgus deformity is the main problem in treating splay foot. Although the IMA_{4-5} was not significantly improved postoperatively, the pain in the 5th metatarsal head was obvious relieved, accompanied with the decrease in HVA, IMA_{1-2} and distance between the 1st and 5th metatarsal heads. No severe complication was noticed during operation or the postoperative follow-up periods. The patients who underwent soft tissue reconstruction with the wire and button fixation were required to wear postoperative shoes or boots for about 4 to 6 weeks in comparison to about 8 to 10 weeks for patients who routinely underwent osteotomies. The last follow-up showed that the wire and button fixation device was still able to provide good strength and security.

The main limitation of the present study is that the number of patients is small and the follow-up period is not long enough. Prospective randomized controlled trials are needed to further analyze the long-term efficacy and compare the wire and button fixation versus traditional osteotomies for the sake of judging the overall efficacy of this technique.

In conclusion, our results have indicated that the technique of using 1st and 2nd metatarsal wire and button fixation with 1st and 5th bunionectomies might be safe, feasible and effective for surgical treatment of splay foot deformity in patients with pain symptoms, devoid of potential complications commonly seen in routine osteotomies. However, future clinical trials are needed to better define its indications and contraindications, assess its long-term efficacy, and compare it with other bunion correction surgical procedures.

ACKNOWLEDGMENT

The authors would like to thank Dr Peng-Fei Luo from the Department of Medical Statistics of the Second Military Medical University for assistance with statistical analysis. There is no financial support or relationships that may pose conflict of interest in the present paper.

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