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Title

Refinement of surgery for postaxial polysyndactyly of the toes: esthetic outcome in Japanese feet

Abstract

Purpose: Treatment for polysyndactyly of the toes aims at cosmetic improvement but the lateropantar rotation of the new fifth toe remains challenging. This study evaluated our novel surgical procedure for postaxial polysyndactyly of the toes.

Materials and Methods: Patients with postaxial polysyndactyly involving the fourth, fifth, and sixth toes treated in 2007-2017 with a minimum follow-up duration of 1 year were retrospectively investigated. Our aims of surgery for this condition were to avoid excessive lateropantar rotation of the new fifth toe by using a proximally elongated plantar “shark-fin flap” and to make the tip of this toe appear to be naturally pointing inward by using the dog-ear component of the flap on the tip of the toe. The excess skin of the shark-fin flap was grafted onto the lateral surface of the fourth toe. Lateropantar rotation of the fifth toe in these patients was compared with that in photographs of the feet of 96 normal 4-year-old children.

Results: A total of 11 feet in 10 patients (6 male, 4 female; mean age 1.3 years) were analyzed. Syndactyly between the fourth and fifth toes was complete in 3 feet, incomplete at the level of the distal interphalangeal joint of the fifth toe in 5, and incomplete at the level of the proximal interphalangeal joint of the fifth toe in 3. Lateropantar rotation of the fifth toe, evaluated by the mean angle between two intersecting lines extending from the proximal nail fold of the third and fifth toes, was $25 \pm 10^\circ$ in normal feet and $0 \pm 12^\circ$ in operated feet with polysyndactyly. The absolute left-right difference in this angle was $7 \pm 5^\circ$ in normal children and $22 \pm 12^\circ$ in patients with polysyndactyly. Valgus deformity of the new fifth toe improved in all patients during a mean postoperative follow-up of 3.8 years.

Conclusions: Using our procedure, no excessive lateroplantar rotation has been observed when the tip of the fifth toe is inclined inward using a dog-ear flap component. This procedure could be useful in patients in whom the cosmetic outcome is a priority.

Key words

forefoot, metatarsal valgus, surgical flaps, syndactyly, toes

Introduction

Polydactyly is a common congenital deformity of the foot that can be classified as preaxial, central, or postaxial according to the site of duplication. Postaxial polydactyly involves the lateral rays of the foot and accounts for about 80% of duplications.¹⁻³

In Asian countries, where people do not wear shoes in the home, the appearance of the toes is considered important.⁴ The toenails sometimes have a role in fashion, for example, when nail polish is applied. The main goal of desyndactylization of the toes should be cosmetic rather than functional.^{2, 4} Most reports on surgical procedures used to correct postaxial polydactyly of the toes have come from Asian countries,^{2, 4-12} but the results are not always satisfactory in terms of the morphology of the toes and toenails. Historically, a conventional procedure of excising the fifth toe in the manner described by Kojima et al.⁵ has been used at our institution. This surgical procedure uses a dorsal rectangular flap to cover the interdigital space and a plantar triangular flap and skin graft to cover the divided toes (Fig. 1).⁵ We have developed a novel variation of this procedure for patients with excessive lateroplantar rotation and bulkiness of the new fifth toe (Fig. 2). The aim of this study was to evaluate this novel surgical procedure for postaxial polysyndactyly of the toes. The objectives of this procedure were to (1) avoid excessive lateroplantar rotation of the new fifth toe using the proximally elongated plantar flap and (2) make the tip of the new fifth toe appear to be naturally pointing inward using a dog-ear flap component on the tip of the toe.

MATERIALS AND METHODS

Ethical approval

The study was approved by the institutional review board of Hokkaido University Hospital (number 017-0056) and conducted in accordance with the Declaration of Helsinki. The requirement for informed consent was waived in view of the retrospective nature of the study.

Patients

A retrospective review of medical charts was carried out for all patients with postaxial polysyndactyly treated at Hokkaido University Hospital between 2007 and 2017. Patients with postaxial polysyndactyly involving the fourth, fifth, and sixth toes and a minimum postoperative follow-up duration of 1 year were analyzed. Data were collected for sex, age at time of surgery, and morphology of the toes from clinical photographs and radiographs.

Surgical procedure

Our surgical procedure was performed under general anesthesia with application of a tourniquet. We designed a rectangular flap on the dorsal surface of the fifth toe such that its medial side coincides with the lateral border of the dorsal aspect of the fourth toe (Figs. 3A, 4A). The skin pedicle of the rectangular flap was pointed along the natural curve of the interdigital space located more proximally than the digitopantar fold. The rectangular flap needed to be of sufficient length to cover the height of the fourth interdigital space (10-12 mm) and the width of the flap was designed to be as narrow as possible (3-4 mm). Next, we fashioned a “shark-fin flap” (shaped like a shark's dorsal fin) on the plantar surface of the fifth and fourth toes (Figs. 3B, 4B). The starting point of the plantar shark-fin flap was the digitopantar fold opposite to the lateral side of the rectangular flap. The tip of the shark-fin flap was pointed along the axis of the fourth toe between the digitopantar fold and

metatarsophalangeal joint to avoid incision on the weight-bearing area. The length of the short arm of the shark-fin flap on the plantar surface was designed to coincide with the length of the long side of the rectangular flap.

The first skin incision was made around the fifth toenail to elevate the rectangular flap. After raising the shark-fin flap, the loose soft tissue between the two flaps was dissected, and both incisions were extended toward the notch between the fourth and fifth toe tips. After resection of the toenail and phalangeal bones of the fifth toe, the periosteum of the sixth toe, which became the new fifth toe, was sutured. The rectangular flap was set into the bottom of the interdigital space, and the tip of the rectangular flap was sutured to the donor site of the short arm of the shark-fin flap on the digitoplantar fold. The remainder of the donor site on the plantar surface was closed primarily by suture thread, which was beneficial for reconstructing the narrow interdigital space and prevented valgus deformity of the new fifth toe. The excess fatty tissue of the shark-fin flap was trimmed off, especially near the pivot point of the flap on the new fifth toe. The shark-fin flap covered the medial surface of the new fifth toe with its short arm sutured to the lateral side of the rectangular flap. Next, the long arm of the shark-fin flap was sutured to the new fifth toe from the proximal point toward the tip of the toe. The excess skin on the shark-fin flap (Figs. 4C, 4D) was harvested and grafted onto the lateral surface of the fourth toe (Figs. 3D, 4F, 4H). The dog-ear component of the shark-fin flap was adequately preserved on the tip of the new fifth toe, giving the appearance of a toe that was naturally pointing inward (Figs. 3C, 4E).

Postoperative evaluation

Data were collected on acute postoperative complications (flap necrosis, wound dehiscence, and skin graft loss), late postoperative complications (pain and valgus deformity), and need for secondary surgical procedures during follow-up. Valgus deformity was evaluated by comparing the fifth toe on the affected foot with that on the normal foot.¹³

The primary outcome was the degree of lateroplatar rotation of the new fifth toe, which was evaluated by measuring the angle between two intersecting lines extending from the proximal nail fold at the third toe and the new fifth toe, on postoperative photographs of both feet in the frontal view (Fig. 5B). The feet of normal children without polysyndactyly were used to validate our measurement method.

Validation of our measurement method in normal children

Photographs of the feet of 96 normal 4-year-old children (48 male, 48 female) were obtained with the consent of their parents during annual physical measurements at a kindergarten. The angle between two intersecting lines extending from the proximal nail fold at the third and the fifth toes, was measured in the photographs of both feet in the frontal view. The absolute left-right difference was calculated.

Statistical analysis

Angles are reported as the mean $\pm$ standard deviation, and the differences between normal children and the patients were evaluated using the Student's *t*-test. Statistical analysis was performed using JMP software (version 16.2.0; SAS Institute Inc., Cary, NC). A P-value < 0.05 was considered statistically significant.

RESULTS

In total, 11 feet with postaxial polysyndactyly (5 right, 4 left, 1 bilateral) in 10 patients (6 male, 4 female) were treated during the study period. The mean age at the time of surgery was 1.3 years (range, 10 months to 4 years). All feet showed complete syndactyly between the fifth and sixth toes. The syndactyly between the fourth and fifth toes were complete in 3 cases, incomplete at the level of the distal interphalangeal joint of the fifth toe in 5, and incomplete at the level of the proximal interphalangeal joint of the fifth toe in 3. Shortening

of the fifth and sixth toes was observed for 3 feet in 2 patients. Radiographs showed duplication between the fifth and sixth toes at the phalangeal level in all feet, including the distal phalanx ($n = 1$), middle phalanx ($n = 8$), and proximal phalanx ($n = 2$). There was no flap necrosis, wound dehiscence, or skin graft loss.

The mean duration of follow-up after surgery was 3.8 years (range, 1.2 to 9.4 years). All the reconstructed toes showed a deep fourth interdigital space without unsightly scars on the dorsal side. On the plantar side as well, the scars were not conspicuous and there was no painful callus formation. There were no complaints of foot pain during follow-up. Valgus deformity of the new fifth toe became inconspicuous in all treated feet during follow-up. No secondary surgical procedures were needed.

The mean angle between two intersecting lines extending from the proximal nail fold at the third and the fifth toes, was significantly greater in the feet of normal children ($n = 192$) than in those on the operated side in the patients ($n = 11$) at late follow-up ($25^\circ \pm 10^\circ$ [range, 1° to 54°] vs $0^\circ \pm 12^\circ$ (range, -20° to 26° ; $P < 0.0001$). The mean absolute left-right difference in this angle was significantly smaller in the feet of normal children ($n = 96$) than in the patients ($n = 10$) at late follow-up ($7^\circ \pm 5^\circ$ [range, 0° to 20°] vs $22^\circ \pm 12^\circ$ [range, 1° to 45°]; $P < 0.0001$).

DISCUSSION

When treating postaxial polysyndactyly, selection of the toe to be excised is important because the fourth interdigital space must be reconstructed simultaneously.¹³ Excision of the fifth toe was preferred because of the inferior alignment of the phalangeal bone and hypoplastic tendon seen in most cases of polysyndactyly of the phalangeal type¹ and to prevent an abnormal foot contour and callus formation at the site of the scar on the lateral aspect of the foot as a consequence of excision of the sixth toe.² Excision of the sixth toe was considered when it was hypoplastic or showed severe valgus deformity,^{2, 13} but pain as a

156 result of a medially protuberant middle phalanx on the remaining fifth toe was a common
157 postoperative complication.¹³

158 Surgeons should understand the natural contour of the fifth toe and the interdigital
159 space. The second and third toes are parallel to the first toe, but the fifth toe is inclined
160 inward.¹⁴ The interdigital space is not cubic, and its dorsal boundary locates more proximally
161 than the plantar boundary. In previous reports, the proximal edge of the plantar flap was
162 designed on the digitopantar fold.^{4, 5, 8} When the skin pedicle of the rectangular flap is
163 designed on the dorsal side more proximally than the digitopantar fold, the direction of
164 pulling the plantar triangular flap toward the dorsal defect tends to rotate the new fifth toe in
165 the lateropantar direction (Fig. 6A) if the plantar triangular flap is inadequate. On the other
166 hand, using our design, the tip of the shark-fin flap was more proximal than the digitopantar
167 fold such that the direction of pulling the plantar shark-fin flap toward the dorsal defect did
168 not rotate the new fifth toe in the lateropantar direction (Fig. 6B). Moreover, the fifth toe is
169 more triangular than the other toes, with an acute angle between the medial and plantar
170 sides.⁸ Therefore, lateropantar rotation of the new fifth toe made it appear bulky with the
171 toenail hidden on the dorsal view (Fig. 2B).

172 The method for correction of postaxial polysyndactyly reported by Kojima et al.
173 entailed excision of the fifth toe to create the interdigital space with a rectangular flap on the
174 dorsal surface of the fifth toe, and a triangular flap was designed on the plantar surface of the
175 fifth toe to cover the medial surface of the new fifth toe.⁵ We have modified this surgical
176 procedure by including two novel components. First, the shark-fin flap on the plantar surface
177 of the fifth toe, including the plantar skin, was elongated to avoid excessive rotation of the
178 new fifth toe in the lateropantar direction. Direct closure of the plantar skin defect was also
179 beneficial for the narrow interdigital space and prevention of valgus deformity of the new
180 fifth toe. Second, the dog-ear component of the shark-fin flap was used to give the tip of the

new fifth toe the appearance of pointing inward (Figs. 3C, 5A), given that the fifth toe is naturally inclined inward.¹⁴

There was less rotation of the new fifth toe in the lateropplantar direction in patients than in normal children ($0^\circ \pm 12^\circ$ vs $25^\circ \pm 10^\circ$). The absolute value compared with the contralateral side was 15° greater in patients than in normal children but within the normal range. Lateropplantar rotation of the new fifth toe was corrected efficiently using our surgical procedure. There were no cases of excessive rotation of the new fifth toe in the lateropplantar direction after our surgical procedure.

Some of the surgical procedures used for correction of postaxial polysyndactyly have focused on how to cover the skin defect by a local flap without skin grafting to avoid a color mismatch.^{4, 7, 15} We believe that a deep interdigital space is more natural-looking than a shallow one, so we do not hesitate to use a skin graft to cover the skin defect.⁸ In the surgical procedure reported by Kojima et al.,⁵ full-thickness skin from the groin was used for the lateral surface of the fourth toe. However, skin grafts harvested from excess skin of the toe were unpigmented and matched with the surrounding skin. Valgus deformity is often seen after excision of the fifth toe but this improved with time during follow-up in our cases.

In conclusion, we have evaluated a novel surgical procedure for postaxial polysyndactyly of the toes. Using this procedure, we have not encountered excessive rotation of the new fifth toe in the lateropplantar direction and found that the tip of toe can be inclined inward by including a dog-ear component in the flap. This procedure could be an alternative when an excellent cosmetic outcome is a priority.

Conflicts of interest and sources of funding

None declared.

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240

Figure legends

Figure 1. Schematic drawing of the conventional surgical procedure used to correct postaxial polydactyly of the toes reported by Kojima et al.⁵ **A**, A dorsal rectangular flap used to cover the interdigital space and the incision line around the fifth toenail to the flap. **B**, A plantar triangular flap on the digitopantar fold of the fifth and fourth toes to the tip of the interdigital space between. **C**, **D**, The rectangular flap on the interdigital space. The triangular flap covering the medial surface of the new fifth toe. Full-thickness skin from the groin was grafted onto the lateral surface of the fourth toe. Note that the distal lateral surface of the fourth toe was not sutured in the figure published by Kojima et al.⁵

Figure 2. A case that underwent the surgical procedure reported by Kojima et al.⁵ **A**, Preoperative dorsal view with design of the skin incision obtained at the age of 1 year and 1 month. **B**, **C**, Dorsal and frontal views obtained 2 years after surgery. Use of a plantar triangular flap that was of inadequate size resulted in excessive lateropantar rotation and a bulky new fifth toe.

Figure 3. Schematic drawing of our surgical procedure for postaxial polydactyly of the toes. **A**, The dorsal rectangular flap used to cover the interdigital space and the incision line around the fifth toenail to the flap. **B**, A plantar shark-fin flap extending from the digitopantar fold to the axis of the fourth toe between the digitopantar fold and the metatarsophalangeal joint, then to the tip of the interdigital space between the fourth and fifth toes. **C**, **D**, The rectangular flap on the interdigital space. The shark-fin flap covered the medial surface of the new fifth toe. The excess skin on the shark-fin flap was grafted onto the lateral surface of the fourth toe. The dog-ear component of the shark-fin flap was preserved on the tip of the new fifth toe (arrowhead).

266

267 **Figure 4.** Representative case in which our surgical procedure was performed for right-sided
268 postaxial polydactyly of the toes. **A, B,** Preoperative dorsal and plantar views with the skin
269 incision design at the age of 11 months. **C, D,** The excess skin on the shark-fin flap for full-
270 thickness skin grafting onto the lateral surface of the fourth toe. **E–H,** Intraoperative views
271 before final dressing with valgus deformity of the new fifth toe.

272

273 **Figure 5.** Images obtained at 1 year and 7 months after surgery for a representative case (the
274 same patient as in Figure 4). **A,** Dorsal view of the right new fifth toe compared with that of
275 the normal toes without valgus deformity on the left side. **B,** Frontal view showing the angles
276 between two intersecting lines extending from the proximal nail fold at the third and the fifth
277 toes to be -12° (**a**) on the operated side (right foot) and 18° (**b**) on the normal side (left foot).
278 The absolute left-right difference in this angle was 30° .

279

280 **Figure 6.** Schematic drawings comparing our surgical procedure for correction of postaxial
281 polydactyly of the toes with the conventional procedure. **A,** The surgical procedure reported
282 by Kojima et al.⁵ The direction of pulling the triangular plantar flap toward the dorsal
283 proximal defect (dashed arrow) tended to rotate the new fifth toe in the lateroplantar direction
284 if the triangular plantar flap was inadequate. **B,** Our surgical procedure. The tip of the plantar
285 shark-fin flap was designed more proximally than the digitopantar fold. The direction of
286 pulling the plantar shark-fin flap toward the dorsal defect (dashed arrow) tended not to rotate
287 the new fifth toe in the lateroplantar direction.











