Arthrodesis for Hallux Rigidus

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KEYWORDS

• Hallux rigidus • First • MTP fusion • Arthrodesis

KEY POINTS

- First metatarsophalangeal (MTP) joint arthrodesis has been a cornerstone in treating hallux rigidus since the 1950s and remains an excellent option.
- Arthrodesis is recommended for patients with advanced joint degeneration.
- Several constructs have been reported in the literature with high union rates. It is our preference to use either dual plating or combination dorsal plate with lag screw.
- Optimal positioning is crucial for success, and malunion is likely underreported in the literature.

Video content accompanies this article at http://www.foot.theclinics.com

INTRODUCTION

Hallux rigidus is a degenerative arthritic condition affecting the first metatarsophalangeal (MTP) joint. This condition results in reduced joint mobility, pain, and the development of osteophytes. It ranks as the second most common ailment targeting the first MTP joint after hallux valgus and stands as the predominant form of arthritis in the foot.[1,2] Women are more prone to this condition than men, and it often manifests bilaterally.[1,2] Many patients, before seeking professional medical intervention, attempt to alleviate symptoms using nonsteroidal anti-inflammatory drugs, but as the disease advances, these methods generally prove ineffective.[3] Initial treatments usually lean toward conservative approaches, resorting to surgical methods when conservative measures fail.[3] There is a wide array of surgical options available, ranging from joint arthrodesis to joint-sparing techniques such as osteotomies or replacements.[4,5] Each option has utility based on the desired outcomes and patient-specific characteristics.

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First MTP joint arthrodesis is a surgical procedure in which the head of the first metatarsal and the base of the proximal phalanx are surgically placed in contact with each other to promote bony bridging and eliminate motion through the first MTP joint. Originally described in 1894 as a procedure for severe hallux valgus, Clutton recommended using an ivory peg to help eliminate motion.[6] Various constructs have since been described, but one of the earliest detailed techniques was published by McKeever. The series was composed of 56 feet in which a stainless steel screw with a washer was inserted from the proximal phalanx, across the MTP joint, and seated in the metatarsal shaft.[7]

During the following decades, the first MTP arthrodesis was regarded as the gold standard to treat end-stage hallux rigidus.[8–10] Multiple techniques have since been developed to improve fusion rates and outcomes ranging from Kirschner wires, lag screws, lag screws with dorsal plating, compression staples, or various combinations of different techniques.[11]

This article highlights our preferred methods of first MTP arthrodesis as well as tips and special considerations based on underlying foot pathology.

PATIENT SELECTION

The ideal candidate for the first MTP joint arthrodesis is one with low functional demand and a grade 4 or a grade 3 arthritic joint with less than 50% remaining cartilage.[12] A patient with high functional demand and more than 50% of cartilage and no pain at mid-range motion does well with conservative management or joint-sparing procedures that are out of the scope of this discussion. It is hard to characterize patients and determine which treatment algorithm they fall into; as such, there is no consensus on the optimal treatment of these patients. Shariff and Myerson emphasize the importance of assessing the motion of the first MTP joint under simulated weight-bearing conditions to identify "functional hallux rigidus." They recommend arthrodesis or treating patients with this condition with arthroplasty.[4]

APPROACH

Three approaches are described in the literature for first MTP arthrodesis: dorsal, medial, and arthroscopic.[13] With the dorsal approach, the extensor hallucis longus tendon is retracted laterally to expose to articular capsule. The medial approach offers direct visualization of the joint, ensuring precise alignment, but care should be made to identify and protect the dorsomedial cutaneous nerve to prevent irritation. A longitudinal capsular incision is made, and the capsule is reflected dorsally. Some investigators expressed concern about the blood supply to the capsule and metatarsal head citing this as a downfall to this approach.[14]

Hodel and colleagues reviewed arthroscopic and percutaneous technique and reported satisfactory results but could not drew a clear superiority of this technique over open approaches.[13] There is heterogeneity in the functional outcome measures reported after arthroscopic arthrodesis; however, some studies have reported improved outcome scores compared to open first MTP arthrodesis.[15]

PREPARATION

Widely accepted today, Rose first suggested to prepare the first MTP joint surfaces with conical reamers in 1950 in an unpublished series reported by Wilson.[16] This was done with a convex and concave reamer on the distal metatarsal head and the proximal phalanx, respectively (**Fig. 2**). Wilson reported that significant soft tissue preparation is

necessary to use the reamers and "*the direction of the cylindrical reaming determines, for the most part, the final position of the arthrodesis*."[16] We believe that conical reamers allow for high degrees of adjustability in a 3 dimensional plane. It is our experience that care should be taken in patients with poor bone quality to avoid unnecessary removal of excess bone and fragmentation of the bone. This can be done by removing large osteophytes that may catch the reamer prior to reaming, keeping the reamer on full speed, and progressing slowly and circumferentially at the preparation sites.

Planar cuts require less extensive dissection; however, it is our experience that the correction and final positioning of the first MTP is more challenging with this technique. With this technique, a first cut is made on the proximal phalanx perpendicular to its anatomic axis (**Fig. 1**), and then a second cut is made on the metatarsal head based on the desired final position. In case of severe deformity or short first metatarsal, this procedure is technically more challenging and can result in shorting of the first ray which can lead to overloading of the lesser metatarsals.[17,18]

It is our preference to perform joint preparation with the cup and cone reamer technique (**Fig. 2**). We believe that flat cut preparation is technically demanding and any malposition requires additional cuts. With the cup and cone reamer technique, there is a large amount of bony contact given the large surface area. Additionally, pronation/supination as well as varus/valgus positioning is easily adjusted to put the toe in optimal position without requiring additional bony resection (see **Fig. 2**).

The arthroscopic and minimally invasive approach requires the use of a burr to prepare the articular surfaces and is not our preferred choice of technique.[13]

There is no superiority of one open approach over the other; however, the dorsal approach allows easier exposure for the use of cups and reams. The medial approach allows better visualization of the orientation of cuts in relation to dorsiflexion. The minimally invasive approach involves the exclusive use of screws.

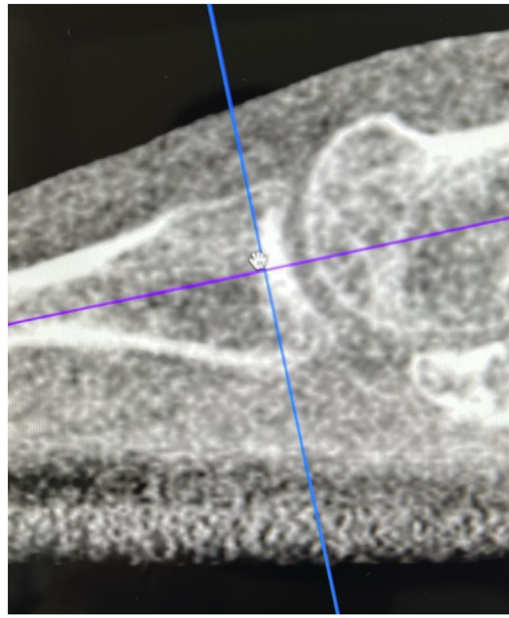

Fig. 1. Demonstration of proximal phalanx cut perpendicular to the anatomic axis (*blue line*).

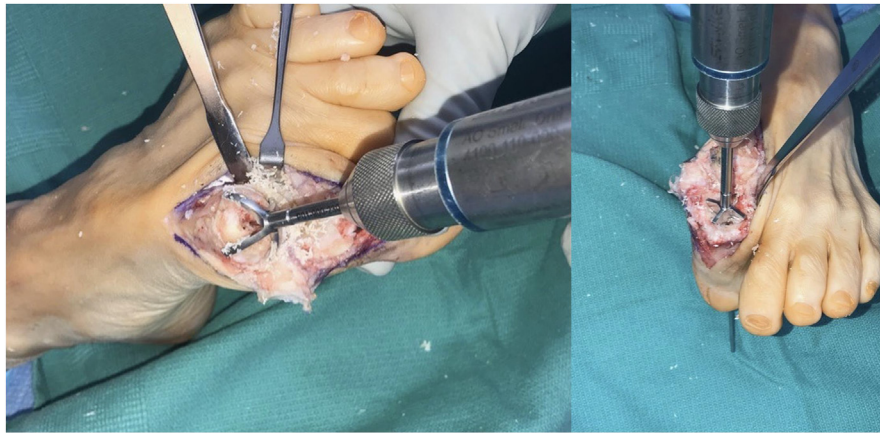

Fig. 2. Cup and cone reamer technique for joint preparation.

Positioning of the First Metatarsophalangeal Arthrodesis

Regarding positioning of the first MTP for arthrodesis, little has changed since the first publication describing this technique. McKeever wrote: "*to determine the angle of arthrodesis between the first metatarsal and the proximal phalanx (...), this is determined by pressing the first metatarsal as close as possible to the second metatarsal and then putting the first and the second toe side by side (…) the angle varies according to the anticipated function. In men it will be approximately 15 to 20 degrees of extension. In women who habitually wear shoes with medium heel it will be from 15 to 25 degrees.*"[7]

One exception since the original publication is the advocation of increased extension of the first MTP in the sagittal plane for women compared to men.

Metatarsus primus elevatus is a common finding among patients with hallux rigidus.[10,19,20] Coughlin and Shurnas reported a normalization of the first metatarsal declination angle.[12] Previously reported optimal dorsiflexion allows the tip of the great toe to touch a flat plate used to simulate weight-bearing and elevation above the simulated weight-bearing plate of a finger width (5 mm).[17]

Lewis and colleagues reported that a proximal shift of an arthrodesis plate was correlated with an increase of dorsiflexion.[21] The effect was greater with a 10° precontoured arthrodesis plate than with a straight plate. Leaseburg and colleagues found a correlation between the bend in the plate and the first MTP angle, but the toe-to-floor distance did not rely exclusively on plate angle. Therefore, the surgeon must consider the anatomy of each patient to optimize the sagittal position of the arthrodesis.

Correct positioning of the toe prior to implanting hardware is critical for successful outcomes in first MTP arthrodesis. We have found that excessive retraction of the medial skin can lead to pronation deformity of the toe. To help prevent deformity during retraction, we advocate for increased provisional fixation prior to hardware implantation (**Fig. 3**).

In terms of rotation, we believe that the toe should be in a neutral position. This allows for uniform contact of the toe tuft on a weight-bearing surface. This is best assessed by viewing the rotation of the toe looking down the axis of the toe from the tip (**Fig. 4**). The toe should also be in a neutral position rather than a slight valgus position.

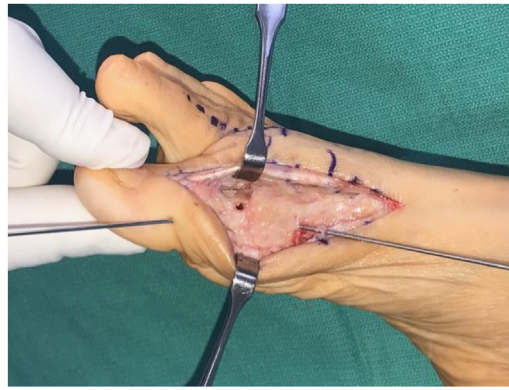

Fig. 3. Increasing provisional fixation can prevent deformity during retraction and hardware implantation.

In the sagittal plane, it is our preferred technique to use a simulated weight-bearing plate for assessment of toe position. We believe that the sesamoids should contact the plate and the tuft should just contact the plate in a way that a freer can pass easily between the plate and the tuft of the distal phalanx (**Fig. 5**). Underlying foot deformity can affect the sagittal positioning of the toe. In a patient with a cavus deformity, proper positioning of the toe may seem elevated when not in a stimulated weight-bearing position. However, under stimulated weight-bearing conditions, the tuft of the toe should just touch the plate as previously described.

An example of this technique can be seen from Supplemental Video 1.

Unlike with hallux valgus, the surgeon has no influence on the rotation of the metatarsal, but the ideal positioning of the hallux is not discussed in the literature. A common clinical finding among patient with hallux rigidus is hyperkeratosis on the medial aspect of the hallux at the level of the interphalangeal (IP) joint suggesting mechanical overload.

Fixation method

Many techniques of fixation are available including the use of oblique lag alone, lag screw combined with dorsal plate fixation, dorsal plate fixation alone, crossed Kirschner wires, or combinations of various techniques.[10,19]

Fig. 4. Rotation assessment of the toe looking down the axis of the toe with ideal neutral rotation.

Fig. 5. Simulated weight-bearing technique in which the tip of the great toe just touches the plate.

Dorsal plating with lag screws offers the most biomechanically stable construct but also is associated with the highest cost.[19] An example of this can be seen from **Fig. 6**.

A review from Haimes and colleagues showed that dorsal plating has a mean cost of $603.57 compared to $374.05 for screw fixation alone. A survey from 2013 to 2018 reported an average additional cost of $1500 with the use of locking plates compared to nonlocking plates without any additional changes in the overall nonunion rate (10.1%).[22]

A retrospective study by Claassen and colleagues examined the effect of locking versus nonlocking plates on fusion rate. They retrospectively reviewed data from 60 patients who underwent first MTP arthrodesis with a lag screw and either a titanium dorsal locking plate or a titanium dorsal nonlocking plate. They reported higher nonunion rate with titanium locked plates (17.2%) compared to nonlocking stainless steel plates (11.7%).[23] Interestingly, this nonunion rate is higher than other studies which reported nonunion rates ranging from 2% to 10%.[24,25] The investigators suggest that placing the lag screw after the locking screw could explain this higher nonunion rate. A recent systematic review confirmed the superiority of dorsal plating with lag screw compared to other techniques.[26]

A cadaveric biomechanical study by Schafer and colleagues examined the use of compression staples in first MTP arthrodesis with unsatisfactory results with 15 out of 16 specimens failing cyclic loading in this study.[27]

Despite its lower fusion rate, satisfactory clinical outcomes are reported with screw fixation. Nevertheless, it is not predictable which patient will need a revision due to a painful nonunion and which patient will not. Therefore, we strongly advocate to choose the construct with the highest fusion rate when performing the first MTP arthrodesis. In

Fig. 6. Dorsal plating with lag screw.

conclusion, dorsal plate with concomitant lag screw is superior to crossed screws. The use of a locking plates compared to a nonlocking plate is associated with higher cost to the public without statistical improvement in union rates. However, patients with inflammatory arthropathy have shown higher fusion rates and shorter time to fusion with the use of precontoured locking plates.[28]

Postoperative Protocol

Mckeever allowed patients' heel weight-bearing in a cut out shoes after 4 days for 6 weeks.[7] Most investigators recommend similar protocols with use of a boot or postoperative rigid shoes when fixed with plate.[12,29,30] With screws fixation only, Brodsky and colleagues recommended 4 weeks of nonweight-bearing.[10] The investigators advocate for immediate heel weight-bearing followed by advancement to full weight-bearing in 4 weeks.

OUTCOMES

Brodsky and colleagues reported excellent pain relief following first MTP arthrodesis with an average pain score of 11 out of 100 at follow-up. Additionally, 36% of the patient population was completely pain free. Over 90% of patients could use stairs and walk more than 6 blocks without limitation, 98% returned to work. The return to sport ranged from 75% (jogging and tennis) to 92% (hiking). Forty-five percent could wear the shoes of their choice, while 47% preferred comfort shoes. Eight percent needed extra-depth shoes with custom orthoses. Only 64% could stand on tiptoes, while kneeling and picking up an object from the floor was reported at 94% and 98%, respectively.[10]

Satisfactory rates were also reported in other similar studies. In a study by DeSandis and colleagues, patient outcome data were reviewed. Short form health status survey (SF-36/12) improved from 65.7 to 81.2, and mean Foot and Ankle Outcomes Survey (FAOS) from 54.4 to 82.6. Eighty five percent of patients were satisfied or highly satisfied and 81% would undergo the same procedure again. The most common complaint among patient was the limitation in the height of heels. When evaluating the effect on age, 23% of younger patients reported limitation in daily and athletic activities which was similar to the older patients. The mean Visual Analogue Score score decreased from 6.1 on both group to 2.2 in the younger group and 2.9 in the older group. About 5% of patients reported a worsening in their functional outcomes.[29]

There is limited literature on long-term outcomes following first MTP arthrodesis.[12,30] Chraim and colleagues reported an average follow-up of 47.3 months (range 39–56 months) in 60 patients with 6.7% nonunion rate. Interestingly, there were no documented revisions for this, but 3.3% of patients underwent removal of hardware. Coughlin and Shurnas reported 34 cases of first MTP arthrodesis with a mean follow-up of 6.7 years. There were 2 cases of reoperation for hardware removals and 2 cases of painless fibrous nonunion. These results demonstrated satisfactory outcomes at nearly 7 year follow-up with low rate of reoperation.

Arthrodesis After Failed Joint-sparing or as Salvage Procedures

First MTP arthrodesis is widely accepted as the main salvage procedure after failed joint-sparing procedures.

Prior cheilectomy does not increase serious complication or fusion rate after conversion to first MTP arthrodesis.[31] Comparing primary first MTP arthrodesis to conversion first MTP arthrodesis after cheilectomy, Rajan and colleagues reported similar improvement in function between the 2 groups. On rare occasion, bone grafting is required after aggressive cheilectomy.[32] After Moberg osteotomy, optimal positioning of the toe could become challenging given the amount and location of prior bone excision.[33] There is limited literature about arthrodesis after interposition arthroplasty.

Myerson and colleagues reported outcomes in 24 patients who underwent first MTP arthrodesis after failed arthroplasty or Keller resection.[34] The defects were of at least 10 mm necessitating structural grafts to avoid medial column shortening in nearly all cases. The grafts were harvested from iliac crest, calcaneus, or resected metatarsal heads. The patients were all nonweight-bearing for 6 weeks following conversion. Reoperation rate was significant, with over half of the patients (7 out of 12) needing further surgery, including hardware removal due to irritation or prominence. The time to fusion averaged 6.9 months but with a wide variation of 3 to 18 months. Delayed union rate was high and occurred in 41.7% of cases. Patients requiring conversion from silicone implants, however, tended to achieve fusion more rapidly with an average time to union of 4.6 months. No patient was completely pain free, yet the majority still reported satisfactory results, with 25% achieving excellent outcomes and another 41.7% reporting good outcomes. Brodsky and colleagues reported similar outcome with no patient completely pain free and an average time to fusion of 3 to 4 months following conversion to first MTP arthrodesis.[35] After synthetic cartilage implant, Grimm and Irwin reported significant bone stock defects which required structural bone grafts.[36]

Both Myerson and colleagues and Brodsky and colleagues reported zero nonunion in patients treated with structural allografts, suggesting a potential benefit of allograft use in these conversion procedures.[34,35] Bei and colleagues reported a 90.9% fusion rate in a retrospective study in which dual plating (dorsal and medial) and allograft

were used[37] (Fig. 7). In this study, 11 patients with bone defects for various etiology such as failed previous surgery or severe rheumatoid arthritis had an average of 11 ± 4.5 mm length restauration and average time to fusion of 10.7 ± 1 weeks. An extensive description of the double-plating procedure has been published by DeCarbo and colleagues.[38]

BIOMECHANICS AFTER FIRST METATARSOPHALANGEAL ARTHRODESIS

In a cadaveric study, Tan and colleagues measured the loss of flexor digitorum longus (FDL) excursion and lesser toe range of motion after first MTP arthrodesis. The release of the FDL at the knot of Henry improved function.[39] The investigators suggest further studies to investigate the benefits of this procedure on metatarsalgia after first MTP joint arthrodesis. A pedobarographic analysis showed an increased in maximal force value under both the first and second metatarsal head after fusion compared to the contralateral foot and a higher peak pressure under the first metatarsal head than under the second.[30] The contact surface was more balanced on the operative side between the first and second metatarsal head. The contralateral nonoperative foot showed increased contact surface value under the second metatarsal head.

Fig. 7. Dual plating for the first MTP arthrodesis.

COMPLICATION AFTER FIRST METATARSOPHALANGEAL ARTHRODESIS

In recent literature, the first MTP arthrodesis fusion rates vary from 77% to 100%.[30] The largest series of 409 patients reported a nonunion rate of 8.6%, with 29.4% of the nonunion being symptomatic and requiring revision surgery.[40] Multiple variables were analyzed, and only preoperative hallux valgus was associated with higher nonunion rate. Weigelt and colleagues underlined the role of residual hallux valgus as a risk factor for nonunion. This large series was one of the only that didn't show a superiority of a dorsal plate construct over crossed screws.[41] A retrospective multicenter analysis of 794 patients who underwent first MTP arthrodesis with either crossed screws, dorsal plating with lag screw, or plate only reported an overall nonunion rate of 15.2% with 72.7% of these patients having a symptomatic nonunion.[42] Nonunion rate was 16.4% for crossed screws, 11.0% for a plate with an interfragmentary screw, and 21.2% for plate fixation only. Of note, flat cuts had a nonunion rate of 8.5% compared to 16.2% after preparation with convex and concave reamers.

Fitzgerald reported outcomes over a decade for 100 cases of first MTP arthrodesis.[43] The study reported that only 16 cases of malunions, which included 9 cases of pronation and 6 of insufficient valgus correction. In a more recent systematic review by Roukis , 2818 arthrodesis cases had a malunion rate of 6.1%. The majority (87.1%) of these malunions were characterized by sagittal malalignment with dorsal positioning of the hallux.[44] A review of 120 consecutive first MTP arthrodesis cases by Drittenbass and colleagues recorded a malunion rate of 9%. A majority of these malunions were related to insufficient extension and excessive valgus.[45] Despite the extensive literature on the first MTP arthrodesis, there is a scarcity of research specifically addressing malunion. When a malunion causes symptoms, corrective options such as opening or closing wedge osteotomies can be employed as salvage procedures to alleviate the discomfort.

Additional complications following the first MTP arthrodesis is the development of adjacent joint arthritis in the IP joint. In a series by Brodsky and colleagues, the degree of IP arthrosis as measured with the grading scale described by Fitzgerald demonstrated 68% of patients had stage I arthritis, 2% had stage II arthritis, and 17% had stage III arthritis.[10] No patient was noted to have stage IV disease in the IP joint. All patients denied having clinical symptoms of discomfort at the IP joint at the time of last follow-up.

Fitzgerald and colleagues reported 25% of patients had radiological IP joint arthritis 10 years after first MTP arthrodesis. Of these patients, 10% were symptomatic. IP joint arthrodesis following a prior first MTP joint arthrodesis has a recorded nonunion rate approaching 40%.[46] DeCarbo and colleagues report that fixation in excessive dorsiflexion of the first MTP leads to IP joint contracture and may lead to acceleration of arthrosis.[38]

Sesamoiditis is often associated with hallux rigidus.[47] Doty and colleagues found 74% of tibial sesamoids and 38% of fibular sesamoids with signs of articular erosions in 39 cadavers with concurrent hallux rigidus. Treatment of this problem is rarely discussed when performing the first MTP joint arthrodesis. Alshouli and colleagues reported satisfactory results after simultaneous first MTP arthrodesis and total sesamoidectomy.[48] In our experience, the routine sesamoidectomy is not necessary, and isolated cases with sesamoiditis treated with secondary sesamoidectomy present satisfactory outcome. These observations have also been reported by Tan and Lau.[49]

SUMMARY

In conclusion, the evolution of first MTP arthrodesis since its inception has been marked by a commitment to refining surgical techniques and expanding the understanding

of hallux rigidus. From McKeever's pioneering work in the 1950s to contemporary practices, the procedure has remained a cornerstone for managing end-stage hallux rigidus, despite a burgeoning array of alternative treatments. The evidence underscores that while the first MTP arthrodesis can deliver substantial relief and restore function, particularly in patients with specific clinical profiles, it is not a one-size-fits-all remedy. The surgical community continues to grapple with the challenges of optimizing outcomes, such as the delicate balance between fusion and function, the nuances of joint preparation and fixation methods, and the management of complications and revisions. Nevertheless, the literature attests to the procedure's efficacy, offering a reliable option for those who have exhausted other treatments. Future endeavors in this field are anticipated to refine patient selection criteria further, improve surgical techniques, and enhance postoperative care, all aiming to provide tailored solutions that align with the etymologic roots of innovation—to make the first MTP joint "new again."

CLINICS CARE POINTS

- Immediate heel weight-bearing for 6 weeks, followed by full weight-bearing within 4 weeks is the most common postoperative protocol.
- Correct positioning of the arthrodesis is critical for the success of the surgery.
- Long-term outcomes are good, with a low number of revisions once fusion is achieved.
- Interphalangeal arthritis is a potential long-term complication.

DISCLOSURE

M.E. Easley is a consultant for Paragon 28 and Treace Medical. A.S. Acker and J. Liles have no commercial or financial conflicts of interest related to this work.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.fcl.2024.02.008

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