The Rule of Fours—Clinical and Radiographic Parameters for Trans-articular Distal Interphalangeal Joint Kirschner Wire Insertion

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Background: Distal phalangeal and interphalangeal joint injuries are common, and confer a significant burden to the individual, healthcare system and society. Operative intervention (when required) may involve retrograde trans-articular Kirschner wire (K-wire) fixation. Safe wire passage through the center of the distal interphalangeal joint (DIPJ) and associated phalanges is key in maintaining alignment and reducing complications. There is little evidence to guide optimal wire entry point and passage.

Purpose: The aim of this study was to determine soft tissue and radiographic landmarks to guide optimal trans-articular k-wire placement at the DIPJ.

Methods: A retrospective cohort study was conducted at a single institute, with 100 uninjured lateral phalangeal radiographs with a clear sagittal projection assessed by 3 independent assessors. Each assessor drew a line of ideal insertion, traversing the isthmus of the middle and distal phalanges, and the midline of the DIPJ, with soft tissue and bony parameters identified.

Results: The mean distance from the dorsal aspect of the nail plate to the line of ideal insertion was 3.86 mm, with a disparity between sexes noted. The distance from the dorsum of the soft tissue to the line of ideal insertion was expressed as a proportion of the total soft tissue diameter—the line of ideal insertion traversed approximately 40% of total width at the DIPJ and DIPJ soft tissue crease.

Discussion: The results suggest that a simple 'rule of fours' can be utilized to allow expedient and optimal passage. The entry point should be midline in the coronal plane, approximately 4 mm volar to the dorsal surface of the nail plate and aimed at a point 40% volar to the dorsal aspect of the soft tissue envelope at the level of the DIPJ crease. These guidelines are easily replicable and conveyable; additionally, they can guide insertion in the absence of fluoroscopy.

Key Words: phalanx, fracture, hand surgery

(*Ann Plast Surg* 2024;00: 00–00)

BACKGROUND

Hand injuries are common, accounting for up to 20% of emergency department presentations, and confer a significant burden to the individual, healthcare system and society.[1,2] The distal phalanx is the most common phalanx involved, with injuries to this region often encountered in the setting of bony or soft tissue mallet injuries.[3,4] The goal of management in these injuries is to restore and maintain the tendinous or bony disruption in a reduced position for an appropriate duration to allow healing to occur and restore active distal interphalangeal joint (DIPJ) extension.[4] Surgical indications with some consensus include open injuries and bony disruptions with DIPJ subluxation despite splinting.[4]

Operative intervention for bony or soft tissue mallet injuries routinely involves retrograde trans-articular Kirschner wire (K-wire) fixation for either primary fixation or as supplementation. K-wire fixation is cheap, versatile, and reliable. However, k-wire fixation imparts the risk of various complications. Wire loosening is thought to be the most common and is associated with poor initial placement, which has been shown to correlate to operator inexperience, with trainees demonstrating higher rates of mispositioning and subsequent complications.[5] Repeated attempts at wire passage may also compromise limited bone stock in the distal phalanx and contribute to loss of position. Wire insertion can also result in iatrogenic damage to tendinous insertions and neurovascular structures. Thus, safe and timely wire passage through the center of the DIPJ and associated phalanges is key in ensuring rigid fixation and reducing the incidence of complications.

There is little evidence in the literature to guide optimal wire entry point and passage. The aim of this study was to determine soft tissue and radiographic landmarks to guide optimal trans-articular k-wire placement at the DIPJ. The identification of reproducible soft tissue landmarks, if possible, will permit satisfactory k-wire insertion regardless of anatomical variation and availability of fluoroscopy.

METHODS

This study was performed in a retrospective cohort fashion. Following institutional ethics approval, 100 radiographs showing clear sagittal projections of all lesser digits in an extended position were procured from the imaging database of a single hospital in Sydney, New South Wales, Australia. Radiographs were obtained from the 20-month period spanning January 2022 to September 2023. Radiographs were eligible for inclusion if they demonstrated true lateral projections of all lesser digits in a patient aged 16 years or greater. Films were excluded if there was evidence of fracture or obvious soft tissue injury on the radiograph or preceding clinical history, or if there was obvious application of synthetic nails. Patient demographics were recorded for the included radiographs.

Each radiograph was then independently assessed by 3 orthopedic trainees (CH, VG, HF), who performed standardized measurements of the index (IF), middle (MF), ring (RF), and little (LF) fingers using the imaging system Sectra IDS7 (Sectra Medical, Linkoping, Sweden). A line of ideal insertion was drawn traversing the isthmus of the middle and distal phalanges, and the midline of the DIPJ. The distances between this line and the dorsal surfaces of the nail plate, soft tissue envelope at the level of the DIPJ, and soft tissue envelope at the level of the DIPJ crease were recorded, as were the dorsal-to-volar soft tissue diameters at the DIPJ and volar DIPJ crease (refer to Figs. 1, 2). The distance from the dorsum of the soft tissue to the line of ideal insertion was expressed as a proportion of the total soft tissue diameter, and referred to as DIPJ ratio and DIPJ crease ratio, respectively.

Statistical analysis was performed using SPSS software Version 27 (IBM, Armonk, NY). Interrater reliability was assessed using 2-way

Received August 11, 2024, and accepted for publication, after revision October 16, 2024.
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Conflicts of interest and sources of funding: none declared.
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ISSN: 1536-3708/24/0000–0000
DOI: 10.1097/SAP.0000000000004157

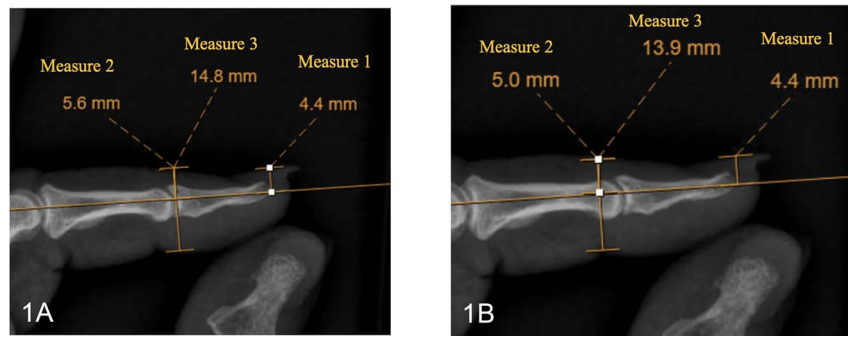

FIGURE 1. Radiographic measurements performed. Measure 1: distance from nail plate to ideal line; measure 2: distance from dorsal surface soft tissue to ideal line (1A = DIPJ; 1B = DIPJ volar crease); measure 3: total soft tissue sagittal diameter (1A = DIPJ; 1B = DIPJ volar crease).

intraclass correlation coefficient, and ranged from 0.73 to 0.97, indicative of good reliability. Simple summary statistics were utilized for all measurements.[6]

RESULTS

The mean age of the 100 patients whose radiographs were assessed was 38 years (range 16–84), with a majority (60%) being female. Fifty-one percent of the radiographs assessed were of the left hand (refer Table 1).

The mean distance from the dorsal aspect of the nail plate to the line of ideal fit was 3.86 mm, with a disparity between sexes noted (4.16 mm in males and 3.66 mm in females). The little finger demonstrated a shorter distance when compared to the other digits (refer Fig. 2).

The mean DIPJ Ratio was 0.40 (0.40 in males and 0.40 in females; refer Table 2). Likewise, the mean DIPJ crease ratio was 0.40 (0.40 in males and 0.41 in females; refer Table 3).

DISCUSSION

Percutaneous retrograde trans-articular k-wire insertion is routinely performed for stabilization of appropriate soft tissue and bony mallet injuries. It may also be utilized in the fixation of extra-articular middle and distal phalangeal fractures (indeed, there has been a move away from closed reduction and toward internal fixation of hand fractures over the last 2 decades), as well as for DIPJ arthrodesis.[7] Despite the frequency of utilization, however, poor positioning of k-wires is a regular occurrence and may lead to numerous complications.[7]

This study aimed to determine safe soft tissue and radiographic landmarks for percutaneous retrograde trans-articular K-wire passage through the DIPJ. Its results suggest that a simple 'rule of fours' can be utilized to allow expedient and optimal passage. The entry point should be approximately 4 mm volar to the dorsal surface of the nail plate, and aimed at a point 40% volar to the dorsal aspect of the soft tissue envelope at the level of the DIPJ crease—this trajectory is slightly dorsal of the midline. The entry point should be midline in the coronal plane, and the position and direction of the wire can be checked using fluoroscopy as necessary (aiming for a point 40% from the dorsal soft tissue envelope at the level of the DIPJ). These principles can be utilized in both genders; however, the ideal entry may be slightly more dorsal in females, particularly in the little finger.

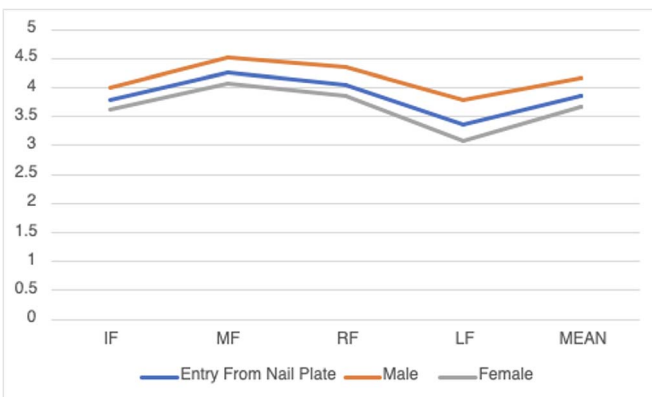

FIGURE 2. Distance from nail plate to ideal line (mm).

This study builds on the limited previous literature guiding percutaneous retrograde k-wire insertion. Rex simply stated that the tip of distal phalanx is a safe entry point.[8] Scott expanded by describing a coronal landmark for wire placement at the middle of a line connecting both distal valles unguii,*, and a sagittal landmark of aiming the wire parallel to the back of the finger at the level of the distal vallum unguis.*[9] Both Gelidan and Wilson recommended premarking the skin using either anatomical landmarks or fluoroscopy to allow accurate and rapid wire passage.[10,11]

The 'rule of fours' is a simple technique, which can provide structure to minimize time and intraoperative imaging requirements and may be useful in settings where fluoroscopy is unavailable. Reducing attempts at k-wire passage in this anatomical region has numerous benefits. The distal phalanx has limited bone stock, which may be reduced further in the presence of fracture—multiple attempts at insertion can reduce viable bone for hold and increase the risk of wire failure.[12] Accurate K-wire passage may reduce the risk of injury to surrounding neurovascular, ligamentocapsular, and tendinous structures. This is particularly relevant in preserving tendon function and range of motion, with wires known to scar and tether when passed through tendons.[13]

Insertion in a timely fashion may also reduce the volume of fluoroscopy utilized and subsequent radiation exposure to theater staff. Orthopedic surgeons have demonstrated a higher risk of malignancy, which is likely related to radiation exposure.[14,15] Any technique to minimize the volume of fluoroscopic imaging required, when combined with adequate protective shielding, will be beneficial in reducing this workplace exposure.

This study has some limitations. The measurements were performed on patients without any pathology, which lends itself to selection bias—the presence of bony pathology, soft tissue injury, or soft tissue swelling may affect the above measurements. Some distal phalangeal fractures are associated with nail plate injuries, which may interfere with the ability to accurately reproduce the entry point. The radiographs were drawn from the database of a small secondary hospital draining a limited area, which may limit the generalizability of the findings.

However, this study (which was inspired by the senior surgeons' boredom and frustration whilst watching their trainees attempt to pass a

*Vallum Unguis: Collective term of nail folds including from eponychium to hyponychium; Valles Unguii: distal nail folds at hyponychium.

TABLE 1. Demographics

Variable	Number
Gender (%)	
Male	40
Female	60
Age (years)	
Mean	38
Range	16–84
Radiograph side (%)	
Left hand	51
Right hand	49

TABLE 2. DIPJ Ratio as Percentage

	IF	MF	RF	LF	MEAN
DIPJ male	0.40	0.40	0.40	0.39	0.40
DIPJ female	0.40	0.40	0.40	0.40	0.40
DIPJ total	0.40	0.40	0.40	0.39	0.40

*Diameter of soft tissue envelope at the level of the distal interphalangeal joint divided by distance between soft tissue envelope and midline of medullary canal at the level of the distal interphalangeal joint.

TABLE 3. DIPJ Crease Ratio as Percentage

	IF	MF	RF	LF	MEAN
DIPJ crease male	0.40	0.41	0.40	0.40	0.40
DIPJ crease female	0.42	0.42	0.41	0.40	0.41
DIPJ crease total	0.41	0.41	0.41	0.40	0.41

*Diameter of soft tissue envelope at the level of the distal interphalangeal joint crease divided by distance between soft tissue envelope and midline of medullary canal at the level of the distal interphalangeal joint crease.

k-wire, again and again) provides a simple guide, using either anatomic or radiographic landmarks, to assist in safe and timely passage of retrograde trans-articular k-wires through the DIPJ. Further cadaveric and clinical assessment would be of benefit to confirm the validity and reliability of the 'rule of fours.'

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