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**ORIGINAL ARTICLE**

**Radiographic Outcomes from Minimally Invasive Bunion Surgery in Australia: A Retrospective Cohort Analysis of 169 Procedures Using the Minimally Invasive Chevron Akin (MICA)**

**Procedure**

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**Background:** The emergence of minimally invasive techniques in foot and ankle surgery has aimed to reduce iatrogenic tissue insult by utilising the smallest possible incision area to achieve maximum correction of pathological structures. The objective of this study was to

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assess whether adequate hallux valgus correction can be achieved via the minimally invasive chevron akin (MICA) procedure.

**Methods:** A retrospective analysis was conducted for a single-surgeon case series of 169 MICA procedures between June 2018 and June 2021 in Australia. Radiographic parameters were evaluated independently by two researchers using 1-2 intermetatarsal angle (1-2 IMA) and hallux valgus angle (HVA) as key measures of procedural outcome.

**Results:** 95% of participant-operations resulted in normal 1-2 IMA and HVA being obtained post-operatively in a cohort that largely consisted of moderate hallux valgus deformities; 1-2 IMA Reduction:  $6.38^\circ \pm 3.24$  (95% CI 5.89 to 6.87) and HVA Reduction:  $20.17^\circ \pm 7.69$  (95% CI 19.01 to 21.33).

**Conclusion:** The results of this study help to further strengthen support for the use of minimally invasive bunion surgery as a primary treatment approach in mild to moderate hallux valgus.

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Hallux valgus is a common, progressive condition in which patients are often motivated to seek out surgical management due to pain, cosmesis, or issues with fitting of footwear. (1) Although there are many different surgical approaches available to treat hallux valgus, the demand for minimally invasive surgery (MIS) is increasing globally due to the proposed benefits over traditional open procedures. (2, 3) However MIS is still viewed by many surgeons as controversial, on the basis that there is only limited evidence available that preferences these

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new or 'novel' approaches over traditional open methods that are backed by decades worth of published research. (4, 5, 6)

The minimally invasive chevron akin (MICA) procedure is a MIS approach for hallux valgus which is an adaptation of the traditional open chevron akin osteotomy that is performed percutaneously under fluoroscopic guidance. (7) This study sought to determine whether adequate hallux valgus correction could be achieved via the MICA procedure using the first-second intermetatarsal angle (1-2 IMA) and hallux valgus angle (HVA) as key radiographic measures of procedural outcome. (8, 9)

## **Methods**

Ethics approval was granted by The University of Western Australia Human Research Ethics Organisation prior to conducting the research. Retrospective cohort analysis was undertaken on a series of MICA procedures performed by a single podiatric surgeon in Australia between June 2018 and June 2021. 1-2 IMA and HVA were measured pre-operatively, and post-operatively at various timepoints including 1-2 weeks, 4-6 weeks, 8-12 weeks, until the point of radiographic bone union was observed. Long-term follow-up was also available on some participant-operations spanning up to 2 years in duration. Refer to Figure 1.

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Clinical audit data from the surgeon's hospital was used to identify potential participants who were screened against exclusion criteria to determine eligibility. Exclusion criteria were:

- Less than 18 years of age;
- Aboriginal or Torres Strait Islander origin;
- Observable metatarsus adductus deformity;
- Prior osteotomy at the first metatarsal or proximal phalanx of the hallux;
- Concurrent osteotomy being performed at the second metatarsal;
- The development of iatrogenic hallux varus post-operatively.

### **X-ray Technique and Radiographic Evaluation**

X-rays were all taken by the same operator and with the same Fluoroscanner® InSight™ Mini C-arm. All images were taken in a simulated weightbearing position, with the foot positioned in neutral against the mini c-arm's detector in portrait orientation. As a result, the projection was dorso-plantar with the beam centred on the shaft of the 3<sup>rd</sup> metatarsal and angled approximately 10° posteriorly toward the calcaneus to mimic the arch of the foot. Collimation of the beam was determined by the lateral and medial skin margins of the foot, distal to the distal phalanges and posterior to the mid-tarsal bone skin margin.

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Participant x-rays were de-identified and compiled as DICOM images for assessment with a Cobb angle tool using electronic radiographic evaluation software (OsiriX Lite Version 12.03; Pixmeo Sarl, Bernex, Switzerland). Two researchers performed each measurement independently and recorded values in a customised Excel spreadsheet. The independent measurements were pooled and averaged during data analysis of the cohort.

### **Outcome Measures**

The 1-2 IMA was defined as the angle created by the first metatarsal and the second metatarsal bones, with bisection points being the centre of the head and base of the metatarsals as first described by Miller and later by Srivastava S et al. (10, 11) The HVA was defined as the angle between the longitudinal axis of the first metatarsal and longitudinal axis of the proximal phalanx with bisection points being the centre of the head and base of the bones. This is illustrated in Figure 2.

Subclassification of pre-operative 1-2 IMA was made based on a system described by Coughlin; normal ( $<9^\circ$ ), mild ( $\geq 9^\circ$  to  $<11^\circ$ ), moderate ( $\geq 11^\circ$  to  $\leq 16^\circ$ ), and severe ( $>16^\circ$ ). (12) HVA was categorised into normal ( $\leq 15^\circ$ ) mild ( $> 15^\circ$  to  $\leq 20^\circ$ ), moderate ( $>20^\circ$  to  $<37^\circ$ ) and severe ( $\geq 37^\circ$ ) based on a system proposed by Deenek et al. (13)

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## **Surgical Technique**

One single surgeon performed all operations within a private hospital in Perth, Western Australia under either general anaesthesia or intravenous sedation. The MICA operative technique used in all participants was performed according to the following described method: Extra-articular chevron osteotomy was performed percutaneously under fluoroscopic guidance with a Shannon “44” 2.0 x 12mm burr using a NSK Surgic Pro Console (Nakanishi Inc, Kanuma Tochigi, Japan). The capital fragment was translated laterally through the osteotomy portal using a freer elevator until congruency of the MTP joint was observed, the osteotomy was then temporarily fixated with a 1.4mm k-wire. If inadequate translation of the capital fragment was encountered (i.e. inadequate reduction of 1-2 IMA or lack of joint congruency), a percutaneous release of the lateral sesamoid and adductor tendon was performed through a separate portal made in the 1st interspace. Percutaneous screw placement across the metatarsal osteotomy site was achieved from proximal-dorso-medial to distal-plantar-lateral by using 1 - 2 x 1.1mm guide-wires that were overdrilled and subsequently fixated with 3.0mm headless cannulated compression screws (TriMed Cannulated Screw System, LMT Surgical, Milton, QLD, Australia). Hardware placement was visualised in both dorsoplantar and lateral views using fluoroscopy, and the osteotomy site was tested manually for stability. Following the metatarsal osteotomy, clinical discretion was used intra-operatively by the surgeon to determine whether or not the overall hallux position was satisfactory. Percutaneous akin osteotomy was subsequently

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performed if deemed necessary by the surgeon and fixated with a single cannulated compression screw in an oblique orientation across the phalanx. Percutaneous exostectomy of the metatarsal bone was performed using a wedge burr and the bone paste was evacuated through the same portal. Refer to Figure 3.

### **Post-Operative Management**

The post-operative management was inherently identical for all participants in the study who underwent the MICA procedure. Immediate weightbearing was permitted after surgery in a rigid post-op shoe which was required to be worn at all times for a fortnight. During this time, rest and elevation were encouraged, with short periods of walking only permitted. Wound reviews were undertaken at 1 and 2 weeks post-op and suture removal generally occurred at two weeks. At this point, the surgical site was evaluated and transition into a supportive sneaker was permitted if pain and oedema were otherwise well controlled and there was no evidence of instability at the osteotomy site. Application of local compression to the surgical site and use of a silicone toe spacer was advised in addition to supportive footwear use for two to three months post-surgery. Range of motion exercises and return to low impact exercise was permitted from early on in the post-operative phase, however high impact exercise such as running or jumping was not permitted until bone union was observed radiographically.

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## **Data Analysis**

Data analysis was conducted using statistical software (IBM SPSS Statistics for Mac OS, Version 28.0; IBM Corp, Armonk, New York). A shapiro-wilk test was used to determine normality and paired samples t-tests were used to identify statistically significant differences between pre and post-operative measurements with an alpha level of 0.05. The change in 1-2 IMA and HVA were presented as means, standard deviation and 95% confidence intervals. Inter-rater reliability for x-ray measurements of 1-2 IMA and HVA between the two independent researchers was evaluated by calculating intra-class coefficients using a two-way mixed agreement method with average measures. Further subgroup analysis was performed for participants categorised as having mild, moderate or severe deformities according to either their pre-operative 1-2 IMA or pre-operative HVA.

## **Results**

### **Participant Characteristics**

One hundred twenty seven participants representing 169 bunion operations (42 bilateral and 85 unilateral) met eligibility. The mean participant age was 56 years, with a range of 19 to 81 years. Female participants represented 90% of the cohort (n=114). 48% (n=81) of the cohort

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were classified as having a mild pre-operative 1-2 IMA, 45% (n=76) had moderate 1-2 IMA and 7% (n=12) had severe 1-2 IMA. 17% (n=29) were classified as having mild pre-operative HVA, 72% (n=122) as moderate HVA, and 11% (n=18) as severe HVA.

### **1-2 IMA and HVA Reduction**

Data for pre-operative and post-operative measurements for 1-2 IMA and HVA were normally distributed ( $p > 0.05$  across all measurements) (Refer to Table 1) and the mean duration of participant follow-up was  $16 \pm 13.9$  weeks (CI 95%, 13.9 to 18.1). The intraclass coefficient for both x-ray measures evaluated was deemed to be excellent; 1-2 IMA: 0.982 (CI 95% 0.979 to 0.985), and HVA: 0.995 (95% CI 0.995 to 0.996). Refer to Tables 2 & 3.

Statistically significant ( $p < 0.001$ ) reductions in both 1-2 IMA and HVA were observed following surgery. 1-2 IMA Reduction:  $6.38^\circ \pm 3.24$  (95% CI 5.89 to 6.87) and HVA Reduction:  $20.17^\circ \pm 7.69$  (95% CI 19.01 to 21.33). 95% of participant-operations resulted in normal 1-2 IMA ( $< 9^\circ$ ) and HVA being obtained post-operatively in a cohort that largely consisted of moderate hallux valgus deformities (72%); Pre-Op 1-2 IMA:  $11.46^\circ \pm 2.82$  (95% CI 11.04 to 11.89), Pre-Op HVA:  $27.16^\circ \pm 7.77$  (95% CI 25.98 to 28.33). The largest reduction in 1-2 IMA observed in the cohort was  $15^\circ$ , and the largest reduction of HVA observed was  $44^\circ$ . Table 4 summarises outcomes observed in the total cohort.

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### **Subgroup Analysis**

Subgroup analysis was performed for mild, moderate and severe grouping for 1-2 IMA and HVA measurements. Statistically significant improvements in radiographic measurements ( $p < 0.001$ ) were observed across all subgroups analysed. Refer to Table 5. The proportion of procedures in which normalisation of the 1-2 IMA (*i.e.* 1-2 IMA  $< 9^\circ$ ) were as follows: 1. Mild 1-2 IMA Group 98% ( $n=79/81$ ), Moderate 1-2 IMA Group 92% ( $n=63/69$ ), Severe 1-2 IMA Group 92% ( $n=9/10$ ). The proportion of procedures in which normalisation of the HVA (*i.e.* HVA  $\leq 15^\circ$ ) was as follows: 1. Mild HVA Group 100% ( $n=28/28$ ), Moderate HVA Group 96% ( $n=112/117$ ), Severe HVA Group 83% ( $n=12/15$ ).

### **Discussion**

Minimally invasive surgery for hallux valgus is becoming increasingly popular worldwide however it is yet to gain widespread acceptance over traditional methods of surgery due to a lack of published research. At the time of publication, the authors understand this study represents the second largest published case series on the MICA technique to have evaluated radiographic outcomes. (4, 5, 6, 7, 14, 15, 16)

The radiographic outcomes observed in this study are consistent with findings by Lee et al, Jowett and Bedi, Lai et al. and Lewis et al. which suggested excellent correction can be obtained in mild to moderate hallux valgus deformity using MIS. (5, 15,16) 95% of participant-

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operations observed in this study resulted in normal 1-2 IMA and HVA post-operatively and therefore there was only a small number of participants (n = 9/169 1-2 IMA Group, n = 8/169 HVA Group) who did not obtain normal post-operative radiographic measurements.

It is notable that the largest reduction in 1-2 IMA observed in the cohort was 15°, and the largest reduction of HVA was 44° with the MICA technique. This amount of osseous correction is usually only seen in open proximal procedures, but is consistent with reporting on large capital fragment shifts in open distal chevron procedures. (17) It is understandably desirable to compare results of this study to the analogous open procedure and while this was not the primary focus of this study, the radiographic outcomes suggest non-inferiority to those obtained in an open approach, which consistently report similar post-operative 1-2 IMA and HVA averages. (17, 18, 19)

The strong level of agreement in measurements performed by each researcher should provide a high degree of confidence when interpreting the results obtained in the study. This was attributed to having established uniformity in measurement techniques before the commencement of data collection and the use of electronic radiographic software. Electronic measurement techniques have generally reported good reliability and increased speed of measurement over printed radiographs and manual measurement devices. (20, 21)

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Selection bias is recognised as being present in this study and should be taken into consideration when interpreting the presented results. Patients who demonstrated a significantly large 1-2 IMA, gross 1<sup>st</sup> ray instability, or significant arthritis of the 1<sup>st</sup> MTP joint at pre-operative consultation, were not considered by the surgeon to be suitable candidates for minimally invasive surgery. Therefore the cohort examined in the study mainly consisted of mild and moderate hallux valgus deformities because the surgeon believed that they were more likely to experience a good outcome from the technique being performed.

This study had several other limitations. The authors acknowledge that this study only sought to evaluate outcomes in radiographic measurements from MIS, and therefore conclusions about the other clinical benefits of this procedure cannot be made. In addition, the results of this study are likely to have been influenced by individual surgical skills in minimally invasive surgery. The surgeon performing the operations in this study undertook training through the Academy of Minimally Invasive Foot and Ankle Surgery in the United States, and subsequently performed many surgeries to master the described technique. The results of this study may therefore not be replicable by a surgeon who is inexperienced in MIS, as suggested by Jowett and Bedi who reported on the 'steep learning curve' in their 2017 study. (15)

In conclusion, this study helps to further strengthen support for the use of MIS via the MICA procedure for the treatment of mild to moderate hallux valgus. Future research should consider participant recruitment across multiple centres, with random allocation of participants

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to procedure selection who are matched for severity of deformity. In addition, evaluation of patient reported and other clinical outcomes as well as adverse events in future research will allow further conclusions to be made on whether minimally invasive bunion surgery should be used preferentially over traditional open methods.

**Financial Disclosures:** None reported.

**Conflict of Interest:** None reported.

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<https://www.researchgate.net/publication/318356758> The reliability of measuring acetabular component position on radiographs using everyday diagnostic imaging software

Accessed August 27<sup>th</sup>, 2021.

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**Table 1. Tests of normality**

	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AVPreIMA	.072	169	.033	.990	169	.259
AVPOIMA	.063	169	.099	.990	169	.296
AVPreHVA	.070	169	.045	.993	169	.554
AVPOHVA	.056	169	.200*	.991	169	.330
*. This is a lower bound of the true significance.						
a. Lilliefors Significance Correction						

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**Table 2. Intraclass correlation coefficient for 1-2 IMA measurements**

	Intraclass Correlation <sup>b</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
		Single Measures	.965 <sup>a</sup>	.959	.970	57.082	585
Average Measures	.982 <sup>c</sup>	.979	.985	57.082	585	585	.000
Two-way mixed effects model where people effects are random and measures effects are fixed.							
a. The estimator is the same, whether the interaction effect is present or not.							
b. Type A intraclass correlation coefficients using an absolute agreement definition.							
c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.							

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**Table 3. Intraclass correlation coefficient for HVA measurements**

	Intraclass Correlation <sup>b</sup>	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
		Single Measures	.991 <sup>a</sup>	.989	.992	216.807	585
Average Measures	.995 <sup>c</sup>	.995	.996	216.807	585	585	.000
Two-way mixed effects model where people effects are random and measures effects are fixed.							
a. The estimator is the same, whether the interaction effect is present or not.							
b. Type A intraclass correlation coefficients using an absolute agreement definition.							
c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.							

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**Table 4.** Total cohort statistics.

Variable	Mean	Variable	Mean	p-value from paired samples t-test
Pre-Op 1-2 IMA	11.46 ± 2.82	Post-Op 1-2 IMA	5.08 ±	<0.001
Pre-Op HVA	27.16 ± 7.77	Post-Op HVA	2.67	<0.001
1-2 IMA Reduction	6.38 ± 3.24		6.99 ±	
HVA Reduction	20.17 ± 7.69		4.80	
Follow-Up Duration	16.0 ± 13.9			
Intra-Rater Observer Difference 1-2 IMA	0.43 ± 0.95			
Intra-Rater Observer Difference HVA	0.69 ± 1.33			
Obtained Normal Post-Op 1-2 IMA	160			
Obtained Normal Post-Op HVA	161			

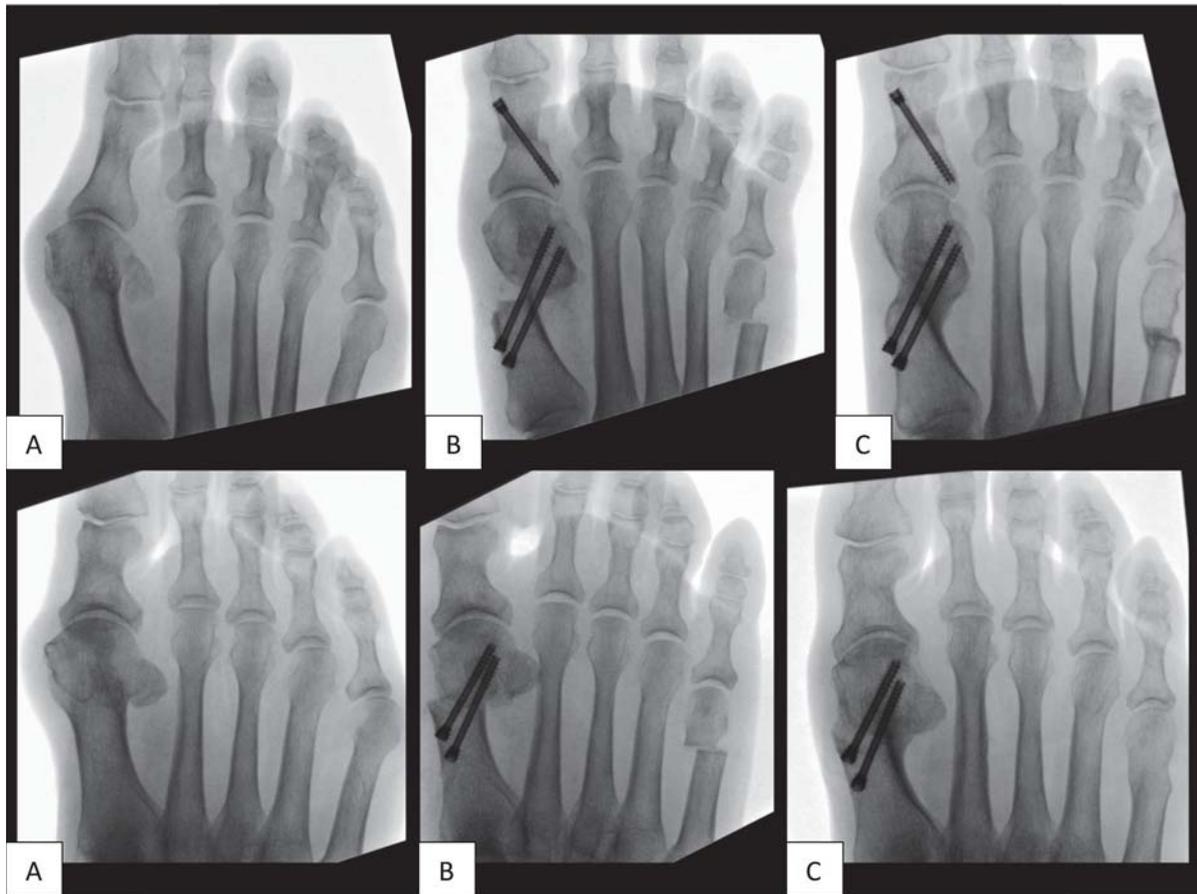
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**Table 5.** Subgroup population statistics.

Variable	Mean	N	Variable	Mean	p-value from paired samples t-test
Mild Pre-Op 1-2 IMA ( $\geq 9$ to $< 11$ )	9.13 $\pm$ 1.45	81	PO 1-2 IMA (Mild Group)	4.34 $\pm$ 2.26	<0.001
Mod Pre-Op 1-2 IMA ( $\geq 11$ to $\leq 16$ )	13.06 $\pm$ 1.33	76	PO 1-2 IMA (Mod Group)	5.78 $\pm$ 2.91	<0.001
Severe Pre-Op 1-2 IMA ( $> 16$ )	17.10 $\pm$ 1.26	12	PO 1-2 IMA (Severe Group)	5.63 $\pm$ 2.49	<0.001
Mild Pre-Op HVA ( $> 15$ to $\leq 20$ )	15.27 $\pm$ 3.70	29	PO HVA (Mild Group)	4.41 $\pm$ 3.61	<0.001
Mod Pre-Op HVA ( $> 20$ to $< 37$ )	27.97 $\pm$ 4.13	122	PO HVA (Moderate Group)	7.11 $\pm$ 4.73	<0.001
Severe Pre-Op HVA ( $\geq 37$ )	40.78 $\pm$ 3.33	18	PO HVA (Severe Group)	10.34 $\pm$ 4.81	<0.001

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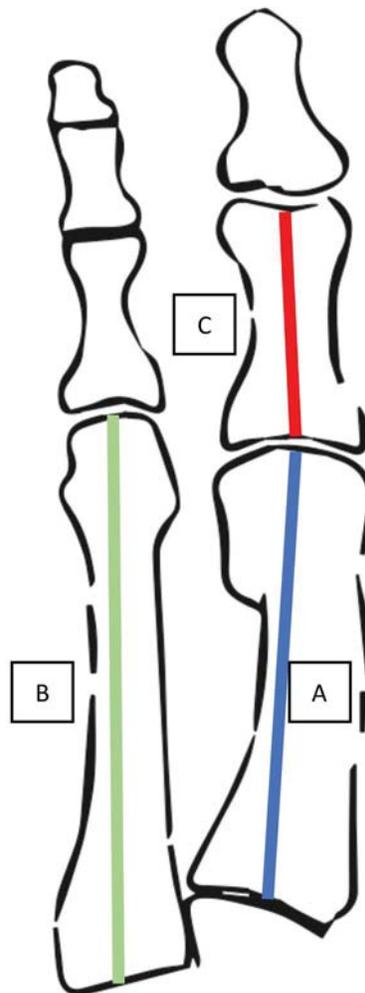
**Figure 1.** MICA Surgical Technique – 2 examples: (A) Pre-Op, (B) 1-2 weeks Post-Op and (C) At Stage of Radiographic Bone Union



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**Figure 2.** Radiographic measurement techniques: 1-2 IMA consisting of lines (A) & (B), HVA consisting of lines (A) & (C).



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**Figure 3.** MICA Surgical Technique Intra-Operative Images: (A) Portal incision, (B) Osteotomy, (C) Lateral translation, (D) Screw fixation, (E) Osteotomy.

