Comparison of visual estimations of distal radius fracture radiographic parameters between different levels of orthopaedic doctors

Vishad Naidoo,* Brenda Milner, Jason du Plessis

Department of Orthopaedic Surgery, University of the Witwatersrand, Johannesburg, South Africa

**Corresponding author: vishadnaidoo@gmail.com*

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Abstract

Background

Distal radius fractures are common injuries in South Africa. Accurate and decisive radiographic parameter interpretation is key in appropriate management. Digital radiographic facilities are rare in the public setting and goniometer usage is low; thus, visual estimates are the primary form of radiographic assessment. Previous research has associated orthopaedic experience with accuracy of distal radius fracture parameter estimation, but often, doctors treating orthopaedic patients are not experienced in orthopaedics. Differences in radiographic visual estimation accuracy between different experience levels of orthopaedic doctors has yet to be explored in this setting.

Methods

A cross-sectional questionnaire including four distal radius fracture radiographs was administered to 149 orthopaedic doctors at three teaching hospitals. Participants were grouped into ranks of consultants (n = 36), registrars (n = 41), medical officers (n = 20) and interns (n = 52). Participants estimated values of distal radius fracture parameters visually, stated whether they would accept the position of the fractures, and stated their percentage of routine usage of goniometers in real practice.

Results

The registrar group was most accurate in visually estimating radial height ($p = 0.024$), while the consultant, registrar and medical officer groups were equally accurate in estimating radial inclination. The consultant and registrar groups were equally accurate at estimating volar tilt, while the medical officer and intern groups were least accurate ($p < 0.001$). The intern group was also the least accurate in estimating radial height and radial inclination ($p < 0.001$). The Gwet's AC1 agreement was 0.161 ($p = 0.047$) for acceptance of the position of the first radiograph, 0.877 ($p < 0.001$) for the second, 0.888 ($p < 0.001$) for the third, and 0.806 ($p < 0.001$) for the fourth. All groups showed no difference in goniometer usage, using them largely in 0–25% of practice ($p = 0.194$).

Conclusion

Accuracy of visual estimations of distal radius fracture parameters was associated with orthopaedic experience but not with inter-rater agreement on acceptability of fracture position, nor with routine goniometer usage level. Visual estimates do not match the accuracy of gold-standard goniometer or digital measurements, regardless of orthopaedic experience level.

Level of evidence: 3

Keywords: distal radius, X-ray comparison, orthopaedic experience

Introduction

Distal radius fractures are common injuries, constituting a significant portion of orthopaedic trauma presentations.[1,2] Radiographic assessment is key to effective and appropriate management, and mismanagement can cause substantial patient morbidity via loss of hand and wrist function, and chronic pain.[3-5]

Radiographic assessment of distal radius fractures includes evaluation of radial height, radial inclination and volar tilt.[3] Acceptable ranges of these parameters, as per the *Arbeitsgemeinschaft für Osteosynthesefragen* (AO) Foundation, are radial height of 7–14 mm, radial inclination of 17–22° and volar tilt of 11° volar to neutral 0°, notwithstanding inter-institutional and individual-based influences on radiographic acceptability.[6-13]

The South African setting often precludes the case that a doctor specially trained in orthopaedics makes the radiographic assessment and final management decision for orthopaedic patients that present to emergency departments. This circumstance is especially prevalent at peripheral facilities within non-urbanised regions, making up a large proportion of facilities in the country. Some doctors in this situation may be immediately post-internship,

highlighting the deficits of higher orthopaedic training and insight in decision-making.

The interpretation of radiographic parameters can either be made with gold-standard methods such as goniometers or digital radiographic measurements, being equally accurate, or with the naked eye.[14] Visual estimates have been found to be less accurate in the evaluation of distal radius radiographic parameters compared to digital measurements and goniometers, especially as it pertained to management decision-making as reported in a United Kingdom study.[14-20] There was also a positive association found between the accuracy of visual estimates and the number of years of orthopaedic experience.[15,16] However, a 2015 study in the United States found that, although the number of years of experience was associated with more accurate visual estimates, consultants who did not regularly treat distal radius fractures performed inferiorly to those who did.[17] A Netherlands-based study found that visual estimates of distal radius radiographic parameters where bony landmark-template lines were provided proved more accurate than estimates without them, even among orthopaedic-trained individuals. They were also as accurate as digital measurements, affirming the importance of goniometer training and regular practice of goniometer usage.[18-20] Nevertheless, it is valuable to acknowledge that fluoroscopic evaluation in theatre largely precludes the usage of typical measurement tools, obviating reliance on sole visual estimates for assessment of radiographic fracture parameters.

Many South African public sector hospitals do not have access to digital radiographic facilities and many doctors do not habitually use goniometers in practice, underscoring the dependence on visual estimations for assessment.[19] There is a paucity of literature evaluating the accuracy of purely visual estimations of distal radius radiographic parameters, and none in the South African setting.

The aims of the study were to compare the accuracy of purely visual estimations of distal radius fracture radiographic parameters between different levels of orthopaedic doctors; to explore the agreement on acceptability of fracture position; to ascertain proportions of routine goniometer usage in real practice time; and to suggest recommendations around the routine use of measurement tools and training around it.

Methods

A questionnaire-based cross-sectional study was conducted at three Johannesburg university teaching hospitals, with the study population including interns, medical officers, registrars and consultants within the respective orthopaedic surgery departments. A total of 149 volunteers participated in the study, in the following groups: 36 consultants, 41 registrars, 20 medical officers and 52 interns.

Four radiographs of distal radius fractures were procured and prepared from the Picture Archiving and Communication System (PACS), available at one of the abovementioned teaching hospitals. The radiographs were selected for ease of interpretation, with the positions of all four radiographs being outside of acceptable AO-defined parameters, ranging from visually mildly displaced to severely displaced extra-articular fracture configurations. Anatomical landmarks for parameters were discerned and agreed upon by all investigators, and baseline measurements of those parameters were performed on a digital PACS system and corroborated by all investigators. The radiographs had superimposed lines drawn in, marking out the parameters of radial height, radial inclination and volar tilt (*Figure 1*). All images were printed at equal size and magnification with standardised radiographic scale bars included on the side for assistance with length estimation, noting that radial inclination and volar tilt did not specifically require it, as they are angular measurements that are unaffected by magnification.

The questionnaires were administered to the volunteers of the respective orthopaedic surgery departments of the hospitals after consent was obtained, and an explanation was provided as to the nature and purpose of the study, followed by elaboration of the relevant parameters with AO-defined acceptable values explained. Instructions defined that estimations had to be via purely visual means, without assistance of equipment, and that images could be addressed in any order. The questionnaire also asked whether the participant considered the fracture position of each radiograph to be acceptable or not, with a final enquiry of the participant's goniometer usage in real-life practice with options of either 0–25%, 25–50%, 50–75% or 75–100% of the time. All data were kept anonymous except for documentation of rank in the department, with questionnaire sheets and electronic copies of the data stored securely.

Data analysis

De-identified data were captured and organised on a Microsoft Excel spreadsheet (Microsoft, Seattle, Washington) and analysed using Stata 15 (StataCorp. 2017. Stata Statistical Software: release 15. College Station, TX: StataCorp LP), as well as GraphPad Prism 9.0 (GraphPad Software, Inc., San Diego, CA).

P-values < 0.05 with a 95% confidence level were considered statistically significant. Statistical assumptions such as normal distribution of the data were tested to ensure these assumptions were not violated during data analysis. The sample size required for the study was calculated using the OpenEpi toolkit (https://openepi.com/SampleSize/SSPropor.htm).

The disparities between visual estimate readings and baseline PACS values and differences between groups were analysed using the Kruskal-Wallis test for non-parametric data with Dunn's post-tests, and a chi-square test was used to compare goniometer usage percentages between groups.

Gwet's AC1 agreement coefficient was used to measure the agreement between the groups as it incorporates both the number of rating categories and the frequency with which they are used by the raters. Agreement coefficients apply to the case of

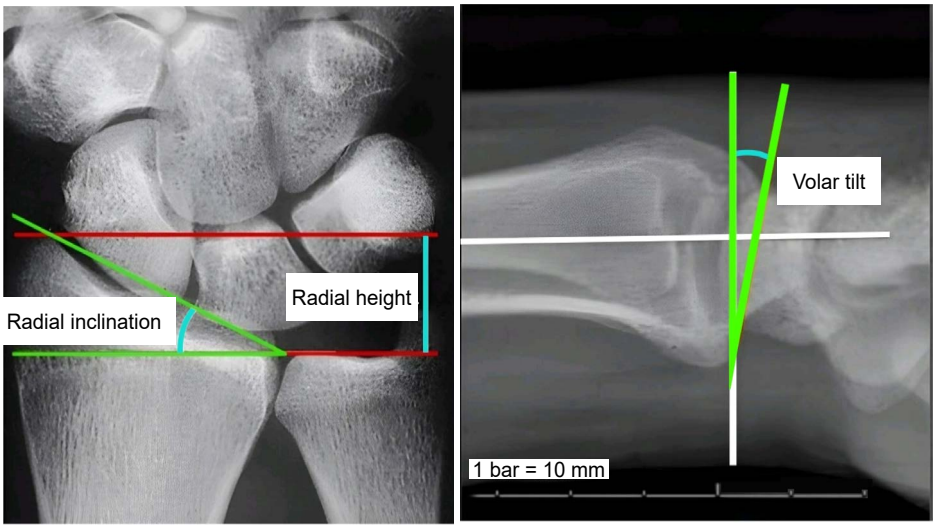

Figure 1. Distal radius radiographic parameters

Table I: Gwet's AC1 coefficient ranges and associated strength of agreement

Gwet's AC1 coefficient	Strength of agreement
< 0.20	Poor
0.21–0.40	Fair
0.41–0.60	Moderate
0.61–0.80	Good
0.81–1.00	Very good

multiple raters or groups, multiple rating categories, any level of measurement, and in the presence of missing values. Gwet's AC1 coefficient is superior to alternative agreement measures as it most closely resembles percentage agreement (*Table I*). Standard errors are estimated based on concepts for finite population inference, and the uncertainty associated with the estimated coefficients is accounted for by a probabilistic benchmarking method for strength of agreement.

Results

Radial height

The registrar group demonstrated the highest accuracy for radial height, with a mean disparity from the PACS baseline of 2.5 mm (SD 2.1 mm, 43% [SD 41%]). This was significantly more accurate than the consultants, who showed a mean disparity of 3.7 mm (SD 2.9 mm, 68% [SD 73%], p = 0.005). Medical officers had a mean disparity of 3.5 mm (SD 2.5 mm, 66% [SD 63%]), while interns had the largest disparity of 5.3 mm (SD 4.5 mm, 98% [SD 104%]). Both medical officers and interns were significantly less accurate than the registrars (p = 0.024 and p = 0.001, respectively). There were no statistically significant differences between consultants, medical officers, and interns (*Figure 2a*).

Radial inclination

For radial inclination, consultants demonstrated a mean disparity of 3.9° (SD 4.2°, 25% [SD 27%]), which was comparable to the registrars (4.6°, SD 3.7°, 28% [SD 24%]) and the medical officers (6.1°, SD 6.5°, 27% [SD 24%]). Interns showed the largest mean disparity of 9.0° (SD 9.4°, 56% [SD 60%]), which was significantly less accurate than all other groups (p < 0.001) (*Figure 2b*).

Volar tilt

The consultant group demonstrated a mean disparity of 7.0° (SD 6.3°, 46% [SD 41%]) for volar tilt, which was similar to the registrar group's mean disparity of 6.1° (SD 5.3°, 39% [SD 26%]). Both groups were significantly more accurate than the medical officers (12.8°, SD 9.5°, 86% [SD 67%], p = 0.024) and the interns, who had the largest disparity of 16.0° (SD 12.6°, 103% [SD 81%], p = 0.001). No significant differences were found between the medical officers and interns (*Figure 2c*).

Agreement on fracture acceptability

The level of agreement for fracture position acceptability varied across the four radiographs. Agreement was categorised as very

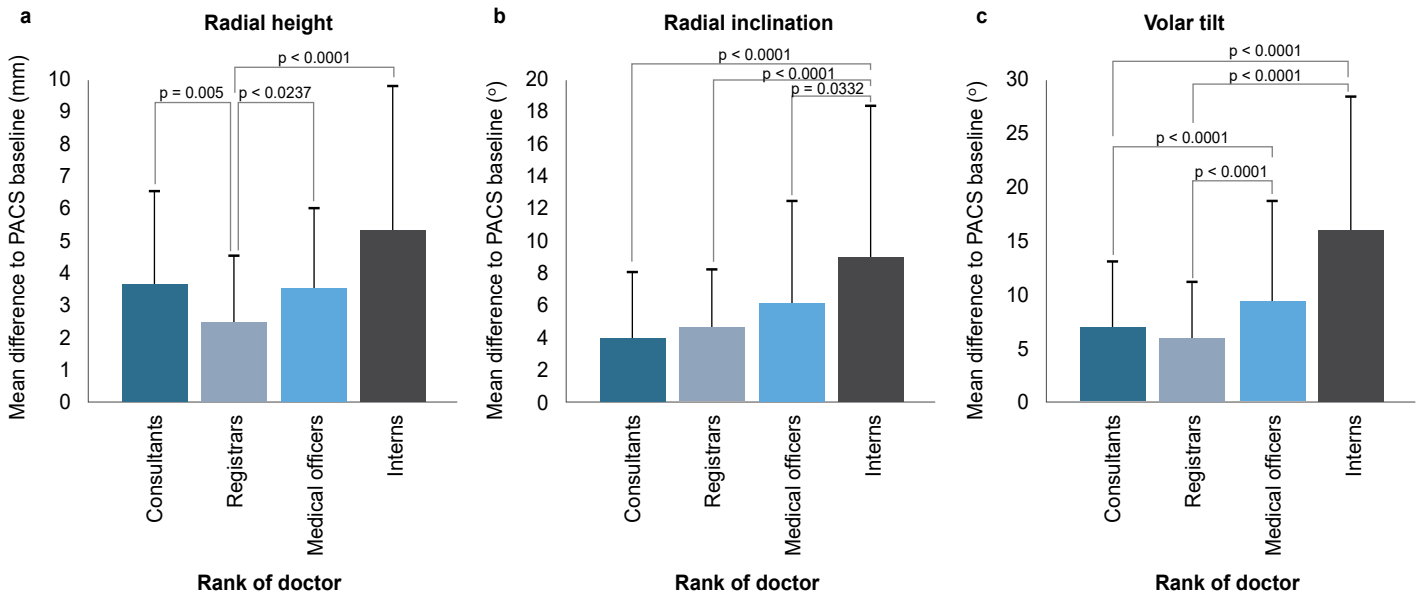

Figure 2. Mean difference to PACS baselines for each radiographic parameter

Table II: Agreement on whether to accept radiograph positions

Rank of orthopaedic doctor	Radiograph 1		Radiograph 2		Radiograph 3		Radiograph 4	
	Accept	Do not accept	Accept	Do not accept	Accept	Do not accept	Accept	Do not accept
Consultants (n = 36)	4	32	1	35	0	36	4	32
Registrars (n = 41)	9	32	9	32	7	34	8	33
Medical officers (n = 20)	13	7	2	13	2	18	9	11
Interns (n = 52)	36	16	4	48	5	47	15	37
Gwet's AC1 coefficient	0.161 (p = 0.047)		0.877 (p < 0.0001)		0.889 (p < 0.0001)		0.806 (p < 0.0001)	
Level of agreement	**Poor**		**Very good**		**Very good**		**Good**	

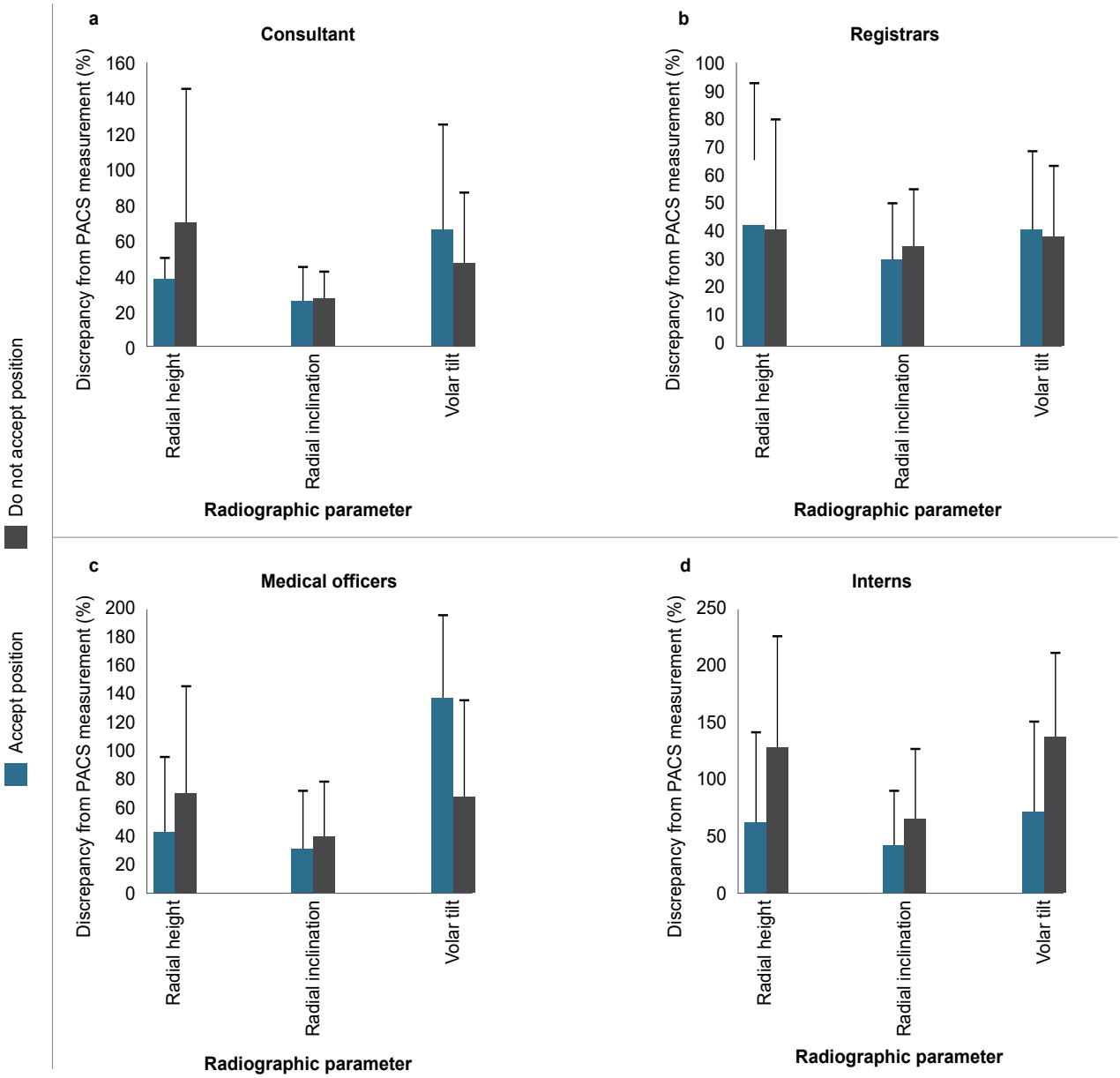

Figure 3. Discrepancies from PACS baselines for radiographic parameters between groups for decision to accept or not accept radiograph position

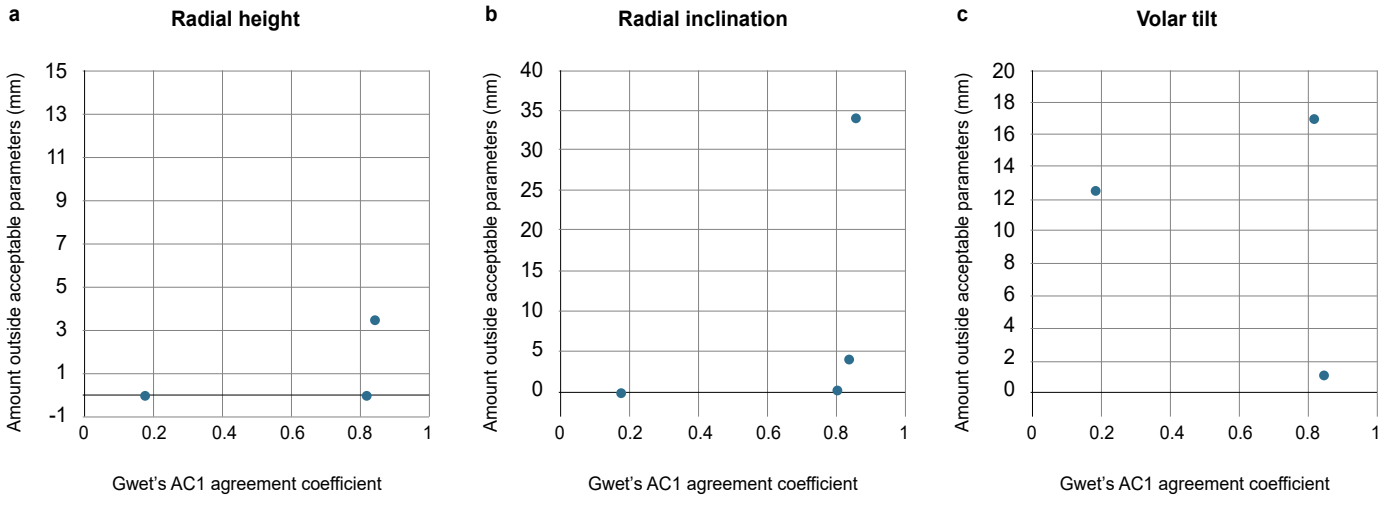

Figure 4. Gwet's AC1 agreement coefficients for amount outside of acceptable range for radiographic parameters

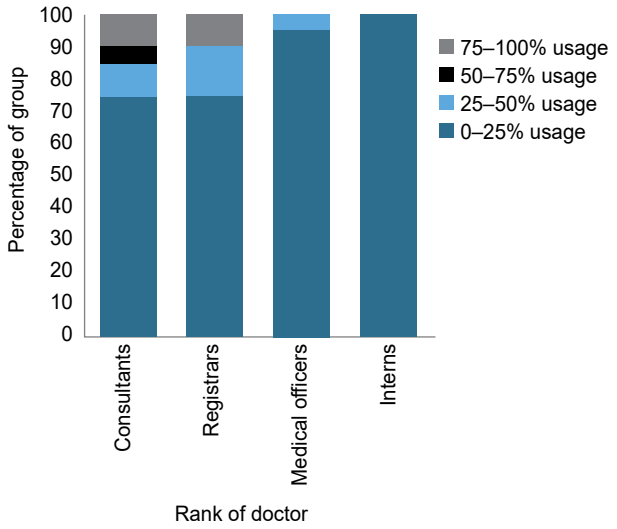

Figure 5. Percentage of goniometer usage for groups

good for radiographs 2 and 3, good for radiograph 4, and poor for radiograph 1 (*Table II*). There was no statistically significant association between the visual estimation accuracy of any radiographic parameter and the decision to accept or not accept the fracture position within any of the study groups (*Figure 3*). Additionally, no statistically significant relationship was found between the level of agreement and the severity of deviation of parameters from acceptable ranges (*Figure 4*).

Goniometer usage

There was no statistically significant difference in goniometer usage across the four study groups. All groups predominantly reported using goniometers 0–25% of the time in orthopaedic practice (p = 0.194) (*Figure 5*).

Discussion

The study primarily set out to compare the accuracy of visual estimations of distal radius fracture parameters between different levels of orthopaedic doctors in the South African public healthcare setting, where digital measurement facilities are scarce and where routine goniometer usage may be minimal.

The intern group showed the lowest accuracy, with the highest mean collective disparity to baseline PACS values, in visually estimating all three distal radius fracture radiographic parameters. The registrars and consultants performed most accurately, with the medical officer group generally falling in between. These findings could infer some association between orthopaedic experience, implied by rank, and accuracy in visual estimations of distal radius fracture parameters. Previous research has found that the number of years of orthopaedic experience correlates positively with accuracy of visual estimates of distal radius fracture parameters, which is essentially paralleled in our results.[14] The exception was that the registrar group was statistically more accurate than the consultants at radial height estimation. This aligns somewhat with previous research whereby consultants who did not regularly treat distal radius fractures performed poorer than those who did, despite having more overall years in orthopaedic practice.[17]

The overwhelming predilection to minimal goniometer usage in real practice of 0–25% with no statistical differences across all four groups implies that accuracy is unlikely to be associated with routine goniometer usage, considering the difference in accuracy in visually estimating parameters between the groups. However, it is important to appreciate differences in goniometer-usage experience levels between different study groups as well as between individuals who fell within each usage percentage groups.

Several factors may influence an individual's choice of whether or not to accept the position of a distal radius fracture radiograph, and the results suggest that accuracy of visual estimations of parameters was, statistically, not a factor. Other doctor-related factors may encompass nature of experience, personal preference, level of training, inter-institutional protocols and resource constraints, or a cross-interaction of any of them.[6] Radiograph 1 could be considered the most visually contentious or borderline image, deviating the least from the AO-defined acceptable parameters, which may explain the low agreement coefficient on whether to accept the position or not. Notably, radiograph 1 is still outside of the AO-defined acceptable parameters and is ultimately an unacceptable position. Radiographs 2, 3 and 4 could be considered visually more severely outside of the AO-defined acceptable parameters than radiograph 1, thus possibly explaining their higher comparative agreement coefficients. This finding infers that, although more overtly displaced distal radius fractures may be easier to define via visual estimations for all experience levels, more subtly unacceptably positioned distal radius fractures could be overlooked and potentially mismanaged, even by more experienced orthopaedic doctors. It also emphasises the importance of the usage of goniometers or digital measurement instead of sole reliance of visual estimations, across all experience levels.

The three teaching hospitals included in the study belong to a single training institution, which may drive certain common management strategies or philosophies that may not necessarily represent other institutions within the country, presenting a limitation. The study excluded previous findings on the influences of factors such as absolute number of years of orthopaedic experience, frequency of treating distal radius fractures in practice, as well as comparison of visual estimation accuracy on radiographs with provided parameter measurement lines, as was done in this study, to those without provision of measurement lines.[14,17] Inclusion of these factors and comparisons may have added depth and nuance to the results. The questionnaire included four radiographs that allowed participants to complete them in any order, though it may have inadvertently encouraged participants to begin at the top of the page and move down sequentially, by general habit or by unintentionally implied order for completion, thus, introducing an element of order–effects bias.

Although no association was found between agreement of fracture position acceptability and severity of fracture deviation from acceptable parameters, the number of radiographs used in the study was insufficient to properly power an exploration of that particular association. The study's voluntary opt-in nature of participation was prone to voluntary response and non-response bias, whereby the participants may have elected to participate, or not participate, based on their own known abilities to visually estimate lengths and angles. The medical officer group was the smallest, due to inherent staff number limitations within the relevant orthopaedic departments, with highest variability with levels of experience.

Further future research could address these limitations and explore their influence by widening the study region and population, including different institutions and an ample number of radiographs of diverse displacement severities. Inclusion of a comparison between visual estimations of radiographs, not only with but also without, provided marked parameters measurement lines, administered in random sequences instead of a set order, could enhance the practical relevance of the results while somewhat mitigating order–effects bias. Moreover, repeated measures could be incorporated to examine intra-observer reliability.

Our findings suggest that junior doctors managing orthopaedic patients receive more focused teaching on goniometer usage and radiographic assessment, including and especially on distal radius radiographs. Further, encouragement of routine goniometer usage in practice could improve radiographic parameter assessment accuracy and consistency, even in more experienced orthopaedic doctors, especially in settings where digital resources are constrained.

Conclusion

Accuracy of visual estimations was positively associated with more experienced orthopaedic doctor ranks but not associated with inter-rater agreement on acceptability of fracture position, nor with routine goniometer usage levels. Purely visual estimations do not match the accuracy of, nor suitably replace, gold-standard goniometer or digital measurements, regardless of orthopaedic experience level.

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Ethics statement

The author/s declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. Ethics clearance to conduct the study was obtained from the Human Research Ethics Committee (HREC), of the University of the Witwatersrand (M220430) as well as the National Health Research Database (NHRD) (GP202111055). Permission to conduct the study was also obtained from the departmental heads of departments (HODs) and chief executive officers (CEOs) of the three aforementioned hospitals. All the radiographs had any identifying information removed to protect patient confidentiality and ensure anonymity. All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed written consent to participate in the study was obtained. All questionnaires were anonymous with no personal information except for rank in the relevant department.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

VN: study conceptualisation, study design, data capture, data analysis, manuscript preparation, manuscript revision
BM: manuscript preparation, manuscript revision
JdP: study conceptualisation, study design, manuscript preparation, manuscript revision

ORCID

Naidoo V https://orcid.org/0009-0007-4189-5655
Milner B https://orcid.org/0009-0008-3188-5899
du Plessis J https://orcid.org/0000-0002-4617-9742

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