STANDARDISED POST-OPERATIVE RADIOGRAPHS FOR VOLAR RADIAL PLATE FIXATION: THE “22/11 X-RAY”

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A Research Report submitted to the Faculty of Health Sciences, University of Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Medicine in the branch of Orthopaedic Surgery

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DECLARATION

I, Warren Matthee declare that this research report is my own work. It is being submitted for Master of Medicine (in the branch of Orthopaedic Surgery) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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Warren Matthee

………….. day of …………….…………..…. 20………...

DEDICATION

This research report is dedicated to my family

Faye and Jordan

For their unwavering love and support

PUBLICATIONS AND PRESENTATIONS

There are currently no publications or presentations arising from this research report.

ABSTRACT

The current standard post-operative X-rays for patients who have had volar locking plate fixation for a distal radius fracture may give the impression of intra-articular screw placement due to the normal anatomic inclination of the radiocarpal joint.

Aim: To determine:

1. If anatomically tilted post-operative radiographs increased the observer's confidence with regard to assessment of screw position.
2. The intra- and inter-observer reliability of these X-rays.

Materials and Methods: 30 patients' standard and tilted (11° PA and 22° lateral) post-operative radiographs were assessed by an orthopaedic intern, registrar, consultant, and a radiologist on two occasions. Single and combined views were analysed.

Results: There was no difference in confidence of assessment, but there was a significant change of assessment with fewer intra-articular penetrations reported with the tilted PA view. There was low intra-observer reliability except for the consultant orthopaedic surgeon. Inter-observer reliability was good when the intern's observations were excluded.

Conclusion: The routine acquisition of the tilted PA radiograph can assist senior health professionals with important patient management decisions.

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NOMENCLATURE

CHBH: Chris Hani Baragwanath Hospital

CMJAH: Charlotte Maxeke Johannesburg Academic Hospital

Cons: Consultant

DRUJ: Distal radio-ulnar joint

HJH: Helen Joseph Hospital

Int: Intern

Lat: Lateral

MO: Medical Officer

ORIF: Open reduction and internal fixation

PA: Postero-anterior

Pt: Patient

Rad: Radiologist

Reg: Registrar

PREFACE

Fractures of the distal radius are among the commonest injuries presenting to the orthopaedic surgeon for further management. The treatment itself, the aftercare and the monitoring of these patients relies on the accurate interpretation of their wrist X-rays.

New advances in the internal fixation of these fractures are continually being made, with increased numbers of available implants. Advances in radiographic techniques should ideally mirror advances in surgical fixation. The basic principles of fracture reduction and stabilisation, however, remain unchanged, and it is these principles that the treating medical professional should be competent with.

Unfortunately in many government hospitals in South Africa the orthopaedic clinics face severe time pressures and high patient loads. The level of orthopaedic expertise involved in the aftercare of these patients can range from an intern who has little or no orthopaedic experience, to the consultant orthopaedic surgeon or head of department. Often, the patient is not seen by the same health professional on each follow-up visit, and even worse, may never be seen by the surgeon who performed the procedure.

In such a setting, a successful patient outcome depends on a high level of competency in the radiographic assessment of patients who have had surgery (as well as those who have not). There should also exist consistency in assessment between health professionals, irrespective of their level of orthopaedic or radiologic experience.

CHAPTER 1 - INTRODUCTION

1. INTRODUCTION

The primary purpose of this study is to compare the routine post-operative X-rays of patients who have had a volar locking plate applied to a distal radius fracture, with a new type of X-ray which is taken at a slightly different angle to account for the normal, anatomic tilt of the joint surface and overlying bone shadows. This is to establish if there is a difference in the confidence of the observer in deciding if there are any screws which may be protruding into the joint. A secondary evaluation involves determining the intra-observer reliability for observers with different levels of orthopaedic experience with regard to these X-rays, as well as the determination of the strength of agreement in the assessment of these X-rays between a group of observers (inter-observer reliability).

1.1 Definitions

Abduction: The movement of a limb or other part of the body away from the midline of the body, or from another part.

Adduction: The movement of a limb or other part of the body towards the midline of the body, or towards another part.

Anterior: Nearer the front, especially in the front of the body, or nearer to the head or forepart.

Carpal: Relating to the bones forming the human carpus (wrist).

Caudal: At or near the tail or the posterior part of the body.

Cephalad: Towards the head.

Cortex: The dense bone forming the tubular element of the shaft, or diaphysis (middle part) of a long bone. The term cortex is also applied to the dense, thin shell covering the cancellous bone of the metaphysis. The two terms are generally used interchangeably.

Diaphysis: The cylindrical or tubular part between the ends of a long bone often referred to as the shaft.

Distal: Situated away from the centre of the body or from the point of attachment.

Dorsal: On or relating to the upper side or back of an animal, plant, or organ.

Epiphysis: The end of a long bone that bears the articular component (joint). The epiphysis develops embryologically from the cartilaginous element between the joint surface and the growth plate.

Extension: The action of moving a limb from a bent to a straight position.

Flexion: The action of bending or the condition of being bent, especially the bending of a limb or joint.

Fluoroscope: An instrument with a fluorescent screen used for viewing X-ray images without taking and developing X-ray photographs.

Frontal Plane: This is a vertical plane of the body passing from side to side, so that a bisection of the body in this plane would cut it into a front half and a back half.

Lateral: Situated on one side or other of the body or of an organ, especially in the region furthest from the median plane.

Locking Plate: A metal plate with threaded screw holes that allow mechanical coupling to a locking head screw. The device is typically used in orthopaedic surgery to stabilise a bony fracture to allow healing.

Malunion: Consolidation (final healing) of a fracture in a position of deformity.

Medial: Situated near the median (middle) plane of the body or the midline of an organ.

Metaphysis: The segment of a long bone located between the articular end part (epiphysis) and the shaft (diaphysis). It consists mostly of cancellous bone, within a thin cortical shell.

Posterior: Further back in position; of or nearer the rear or hind end.

Pronation: Turn or hold (a hand, foot, or limb) so that the palm or sole is facing downwards or inwards.

Proximal: Situated nearer to the centre of the body or the point of attachment.

Radio-carpal Joint: A joint between the distal end of the radius and the proximal row of carpal bones.

Radio-ulnar Joint (Distal): A pivot-joint formed between the head of ulna and the ulnar notch on the distal extremity of radius.

Radius: The thicker and shorter of the two bones in the human forearm.

Sagittal Plane: A vertical plane which passes from ventral (front) to dorsal (rear) dividing the body into right and left halves.

Subchondral: Beneath the cartilage.

Supination: Turn or hold (a hand, foot, or limb) so that the palm or sole is facing upwards or outwards.

Ulna: The thinner and longer of the two bones in the human forearm, on the side opposite to the thumb.

Volar: Relating to the palm of the hand or the sole of the foot.

1.2 Background

Fractures of the distal radius are one of the commonest injuries presenting to the orthopaedic surgeon (1), and a variety of methods of treatment are available. In recent years, rigid fixation with an anatomically contoured volar locking plate has gained in popularity, and there are many of these types of plates on the market (2) (3). These plates allow for rigid fixation and thus the advantage of early mobilisation of the wrist in the post-operative period (4).

The distal screw placement in these plates is often a concern for the surgeon, as the stiffness of the construct is increased when the screws are placed in the subchondral bone of the radio-carpal joint (5). Failure to correctly place the screws in subchondral bone may result in collapse of the distal fragments and malunion (2). However, the surgeon must take care not to fix the plate too distally, as this will increase the risk of placing one or more screws into the joint.

The concern with placing the screws into the joint is that the cartilage of the joint surface will be disrupted, and mobilisation of the wrist post-operatively may cause further damage to the smooth cartilaginous surface of the joint. This may produce pain and decreased function of the wrist in the short term, and the development of osteoarthritis in the joint in the long term, especially if the misplaced screws are not identified and removed.

Anatomically contoured plates are designed to fit onto the volar aspect of the distal radius so that the contour of the plate matches the contour of the bone. Thus a well-reduced fracture should present a bony surface which closely matches the contour of the plate that is to be fitted for stabilisation. The distal screw holes in the plate are set at specific angles to obtain maximum purchase in the subchondral bone, and provided the fracture has been correctly reduced, the anatomically contoured plate should theoretically minimise the risk of incorrect screw placement.

If the anatomy of the radius is distorted, or adequate reduction cannot be achieved, or if the plate is positioned incorrectly, this may adversely affect plate and screw placement, and result in a screw being placed into the joint.

Another consideration is that some of the plates available also have the option to place the distal locking screws at variable angles according to the surgeon’s preference. Thus a correctly positioned plate according to the anatomy of the distal radius may still not guarantee that all of the screws are extra-articular, as the surgeon may have erroneously angled one or more screws incorrectly.

The assessment of the fracture reduction and plate placement is usually made with radiographs. Because of the anatomy of the wrist joint, views from a variety of different angles may be needed to make an adequate assessment of the joint.

When considering the distal radius from the front-to-back, or back-to-front (the postero-anterior view), the radial styloid extends distally with respect to the level of the wrist at the radio-ulnar joint. A line drawn from the tip of the styloid process of the radius to the distal radio-ulnar joint will produce an angle with a line drawn perpendicularly to the radial shaft, termed the frontal plane inclination of the distal radius (Figure 1.1). Schuind and Linscheid *et al* (6) performed a radiographic analysis of 120 wrists in normal subjects, and reported this frontal plane inclination of the distal radius to be between 19° and 29°, with a mean of 24°.

Figure 1. 1   Frontal Plane Inclination of the Distal Radius

Similarly, when considering the distal radius from the side (the lateral view), the wrist joint is tilted by a few degrees towards the volar (palmar) aspect. This is the palmar tilt or sagittal plane inclination of the distal radius (Figure 1.2). Another radiographic study of 100 normal wrists using two different methods to calculate the palmar tilt found the angle to be between 2° and 20°, with a mean of 10.8° with the first method and 12.1° (7). Women were found to have greater amount of palmar tilt than men.

Figure 1. 2 Sagittal Plane Inclination of the Distal Radius

A screw or screws placed into the radial styloid may appear to be well-positioned on the PA radiograph, but when a standard lateral radiograph is taken, if the observer does not account for this inclination of the radial styloid, the well-placed screw may give the appearance of extending across the joint line, and appear to be intra-articular. Similarly, a screw or screws placed into distal radius from volar to dorsal may extend distally to engage the rim of subchondral bone of the dorsal cortex of the radius. On a standard PA radiograph, taken perpendicularly to the wrist, the observer may think that the tips of the screws are extending into the joint if they do not account for this volar tilt. These two scenarios are demonstrated in Figure 1.3.

Figure 1. 3   Apparent Intra-Articular Impingement of Screws

Thus in post-operative radiographs, correctly-placed screws may give the appearance of being intra-articular. Standard PA and lateral radiographs of the wrist joint therefore do not allow adequate views of all aspects of the radiocarpal joint. Specific oblique or tangential views have been advocated to evaluate the radiocarpal joint to exclude intra-articular screw placement. Concerning the PA radiograph, by tilting the tube of the X-ray machine by the same number of degrees as the volar tilt of the distal radius, a radiograph may be obtained that gives the observer a view of the wrist joint where the joint surface can be seen without overlying bony shadows. This is demonstrated in Figure 1.4.

Figure 1. 4   The Effect of a Tilted Radiograph on Screw Assessment in a PA Film

Likewise for the lateral radiograph, by tilting the tube of the X-ray machine by the same number of degrees as the radial inclination of the distal radius, a radiograph may be obtained which gives the observer a view of the radiocarpal joint without the overlying bony shadow of the styloid process. This is demonstrated in Figure 1.5.

Figure 1. 5   The Effect of a Tilted Radiograph on Screw Assessment in a Lateral Film

Due to the curve of the radiocarpoal joint, it may still not be possible to have a completely unobstructed view of the radiocarpal joint at one specific angle. The operating surgeon has the advantage of being able position the wrist in a number of different angles while screening the joint with the fluoroscope to check that no screws have been placed into the joint. Thus the use of intra-operative fluoroscopy is imperative in ensuring not only that an acceptable fracture reduction has been achieved, but also in the assessment of correct plate and screw position.

Post-operatively, however, when the formal radiographs are taken of the wrist joint, the picture is taken in the standard way of being perpendicular to the wrist joint. These films are then reported on by radiologists, and in the setting of a government hospital are often reviewed by the attending intern or orthopaedic registrar, who may be the last observer to assess the radiographs before the patient is discharged. Unfortunately when the patient is reviewed at their subsequent follow-up visits in a government hospital, the operating surgeon very seldom sees the patient or the radiographs. Further decisions on mobilisation of the wrist therefore are made by the attending doctor at the clinic who may not have had any involvement with the initial surgery, and this may be the intern, a medical officer, a registrar, or a consultant orthopaedic surgeon.

In many centres, there are no protocols for obtaining standardised anatomically-tilted radiographs for patients who have undergone fixation of the distal radius. A standard post-operative series would include a PA and a lateral radiograph of the wrist, and while this is essential to enable the surgeon to evaluate the adequacy of reduction of the fracture, it does not allow adequate assessment of screw position. This can result in a number radiographs being reported by radiologists showing plate fixation with “several screws in the wrist joint”, when in fact, there may be no intra-articular screws. This, in turn, can cause alarm for the patient and the surgeon, and may lead to further unnecessary surgery or investigations, and may ultimately even have legal ramifications.

1.3 Research Questions

1. Do anatomically tilted radiographs of the wrist improve the ability of the observer to confidently assess screw position with respect to intra-articular placement in post-operative patients who have had a fracture reduced and stabilised with an anatomically-contoured volar locking plate?

2. How reliable are the interpretations of these tilted X-rays?

1.4 Study Objectives

1. To compare two types of X-rays, a standard PA and lateral with a tilted PA and lateral in post-operative patients who have had a fracture reduced and stabilised with an anatomically-contoured volar locking plate. This is in order to analyse confidence of assessment of screw position, as well as assessment of actual screw position with regard to the radio-carpal joint. The comparison would include an assessment of single films as well as the patient's paired films.

2. To compare the intra-observer reliability of the interpretation of tilted radiographs vs. standard radiographs.

3. To compare inter-observer reliability of the interpretation of tilted radiographs vs. standard radiographs between observers who have different levels of orthopaedic knowledge, but who are expected to be involved in the interpretation of such radiographs on a routine basis.

CHAPTER 2 - MATERIALS AND METHODS

2. MATERIALS AND METHODS

2.1 Ethics

This study was approved by the Human Research Ethics Committee of the University of the Witwatersrand. The clearance number obtained was M110208.

2.2 Study Design

This was a comparative study of a cohort of 30 sequential patients undergoing fixation of a distal radius fracture with a volar locking plate.

2.2.1 Study Setting

The study included patients presenting at the Chris Hani Baragwanath, Helen Joseph, and Charlotte Maxeke Johannesburg Academic hospitals between the months of January 2011 to February 2012.

2.2.2 Study Population and Sampling

The population included all patients undergoing primary open reduction and internal fixation of the distal radius with an anatomically contoured volar locking plate. A total of 30 patients were recruited to the study.

2.2.3 Inclusion Criteria

- Age 18 years or above who were able to understand the purpose of the research and consented to being involved in the study
- Patients undergoing a primary open reduction and internal fixation of the distal radius with a locking volar plate, irrespective of fracture type or plate used
- Surgery performed within 10 days of injury

2.2.4 Exclusion Criteria

- Any patients under the age of 18 years
- Patients undergoing a revision procedure
- Any patient in whom pregnancy was suspected or confirmed
- A patient with multiple injuries (polytrauma), who were therefore unable to be easily positioned for the acquisition of the post-operative radiographs

There were no criteria pertaining to the operating surgeon's area of interest or level of experience.

2.2.5 Informed Consent

Each patient was given an information document (Appendix A) and was asked to give consent to be included in the study by signing on the consent form (Appendix B).

2.2.6 Descriptive Data Collection

Each patient's name, age, gender and telephonic contact details were recorded on a "Patient Details" sheet (Appendix C), along with the date of the operation, the side of injury, the name and rank of the surgeon and assistant (if applicable) who performed the operation, the time (in days) it took before the radiographs were performed. The hospital where the surgery took place was noted, along with the hospital number. The type of implant used and any other comments relating to the case were also recorded.

2.2.7 Radiographic Data Collection and Image Processing

All 30 patients had radiographs taken with a Plaster-of-Paris splint applied to the volar aspect of their forearm. The X-ray machines used at all three facilities were from the same manufacturer (Philips). These machines were equipped with a digital monitor which was able to display the angle of tilt of the tube in one-degree increments. A standard postero-anterior (PA) and lateral radiograph of the wrist on which the surgery was performed was acquired in the routine manner. These radiographs formed the control series of images, and there were 30 radiographs (PA plus lateral on one film) in total. In addition, each participating patient had an anatomically tilted PA and lateral radiograph taken by rotating the X-ray tube as described in the following text.

The tilted PA radiograph was acquired with the wrist in full pronation with the arm abducted to 90° and the elbow in 90° of flexion, and the X-ray tube was tilted by 11° from the normal vertical position, pointing towards the elbow (Figure 2.1). The degree of tilt was confirmed by the digital display on the X-ray machine, which indicated in one-degree increments the angle of the X-ray tube.

Figure 2. 1 Method of Acquisition of the Tilted PA Radiograph

The tilted lateral radiograph was acquired with the wrist in a neutral position (midway between full pronation and full supination) with the arm abducted to 90° and the elbow in 90° of flexion, and the X-ray tube was tilted to 22° from the normal vertical position, pointing towards the elbow (Figure 2.2). This resulted in 30 films which contained the images of the tilted PA and lateral views.

Figure 2. 2   Method of Acquisition of the Tilted Lateral Radiograph

Thus for each patient, two sets of radiographs were obtained; one containing the standard PA and lateral views, and another containing the anatomically tilted "22/11" radiographs.

2.2.8 Image Processing

The original intent was to acquire all of the images and save them on a digital medium such as a USB flash drive or a CD for further processing and analysis. However, none of the X-ray machines used in the study at any of the three hospitals had the facility to store the images on such portable digital media, despite all of the machines being digital X-ray machines. Therefore, the radiographs for all 30 patients were printed out in the standard way. Twenty-one of the patient's films were then scanned to a digital format, and photographs of the remaining 9 patients were acquired with a digital camera. All of the radiographs were thus accessible as digital images, stored in JPEG format.

Each patient's radiograph was edited using Paint (Windows Vista) and Microsoft Office 2010. The patient's name, hospital and hospital number were removed from the image. The images were cropped to eliminate empty spaces and to place the wrist joint at approximately the centre of the picture. Using further basic editing features, six separate images were finally obtained for each patient. These included:

- Standard PA and lateral
- Tilted PA and lateral
- Standard PA
- Tilted PA
- Standard lateral
- Tilted lateral

An example of the standard PA + lateral, standard PA and standard lateral images obtained from one of the patients (patient 1) is shown in (Figure 2.3).

Figure 2. 3 Example of Standard PA + Lateral, PA, and Lateral Radiographs for Analysis

Figure 2.4 is an example of the corresponding tilted views for the same patient (patient 1).

Figure 2. 4 Example of Tilted PA + Lateral, PA, and Lateral Radiographs for Analysis

Each image was saved using the patient's name and a description of the radiograph as a reference. The file names were then entered into an Excel spread sheet (Microsoft Office 2010) and arranged in alphabetical order. Thus there were a total of 180 radiographs, labelled and arranged alphabetically as described.

2.2.9 Randomisation

The radiographs were re-ordered alphabetically in such a way that the first 120 radiographs were of single images only, i.e. a single lateral or a single tilted PA view. The remaining 60 pictures were therefore images containing the combined views on one film, i.e. a tilted PA and lateral, or a standard PA and lateral. A random sequence of numbers with the lowest number being 1 and the highest number being 120 was generated using an online random number generator (8). This randomised sequence of numbers was applied to the alphabetically-arranged file names in the Excel spread sheet for the first 120 radiographs containing a single image. The file names were then sorted according to the randomised number, from smallest to largest (i.e. from 1 to 120). In a similar manner, another sequence of randomised numbers from 121 to 180 was obtained, and applied to the remaining 60 images of paired radiographs. These file names were then also sorted according to the randomised number, from smallest to largest (i.e. from 121 to 180).

The final result was a randomised sequence of file names from 1 to 180, with numbers 1 to 120 being of single images (PA or lateral), and numbers 121 to 180 being of paired images (PA plus corresponding lateral).

2.2.10 Presentation of Radiographs

The randomised radiographs were copied to a PowerPoint presentation (Microsoft Office 2010) in numerical order, from 1 to 180. Each slide had a black background to optimise the contrast of the radiographs for ease of viewing. There were 180 slides, each with one image per slide. The first 120 slides presented a single view, and the remaining 60 slides presented the paired views.

2.2.11 Observers

Four observers were asked to participate in the study. No observer had any knowledge of the nature or purpose of the study. No information was given to the observers other than that which was on the PowerPoint presentation.

The first observer was an intern who was currently doing a two-month rotation through the orthopaedic department as part of his internship. He had received his medical degree 18 months previously.

The second observer was an orthopaedic registrar who was in her final year of training as an orthopaedic surgeon. She had received her basic medical degree ten years previously.

The third observer was a consultant orthopaedic surgeon who did not have a special interest in upper limb surgery. He had nine years of specialist post-qualification experience.

The fourth observer was a consultant radiologist who did not have a special interest in musculoskeletal radiology. She had been a qualified radiologist for seven years.

2.2.12 Recording of Observations

Each observer was independently shown the series of 180 images on the Power Point presentation, and asked to answer the question: “Can you tell with certainty where the screws are in relation to the wrist joint? (Y/N)” In addition, if the answer to the question was “Yes” indicating that the observer was certain he or she knew where the screws were, they were then asked if they thought the screws were in the joint “Yes” or not “No”.

The observations for each image were recorded by the author on an data collection sheet (Appendix D). Thus for each image, a “Y” or a “N” was recorded for the first question and when a “Y” was recorded, a further “Y” or “N” was recorded if the observer thought there was a screw in the joint or not. If a “N” was recorded for the first question, then a “U” was automatically recorded for the second question, i.e. if the observer was not confident of their assessment of screw position, it was logical that they were unsure of the actual screw position.

2.2.13 Data Transfer and Sorting

The data obtained from each observer was subsequently entered into an Excel spread sheet (Microsoft Office 2010) containing each image's details in the randomised order. For each image in randomised order, a "Y" or "N" was captured as a response to the first question, and a "Y" or "N" was captured in a second column if there was a "Y" for the first question (a "U" for "Unsure" was recorded in the second column in the instances when "N" was answered for the first question).

Once all the information was entered into the spread sheet, the file names were then re-sorted alphabetically by surname, and then by X-ray type. The end result was an alphabetically ordered list of six X-rays per patient. The first patient alphabetically was designated "patient 1".

2.2.14 Second Observation

The exact same procedure was performed for a second observation by the same observers, at a period of no less than 4 weeks after the first observation. A different sequence of random numbers was obtained and applied to the file names in the same manner as for the first set of observations, and the same procedure for presentation of radiographs, recording of observations and data transfer and sortinig was applied for the second observation.

2.3 Statistical Analysis

The data was further sorted to facilitate the statistical analysis. The responses recorded by the observers were converted to integer values – "Y" was assigned the value "1", "N" was assigned "2", and "U" was assigned "3". The data was separated into two groups: the first pertaining to the level of confidence in assessment of screw position, and the second pertaining to the actual assessment of screw position. Each group therefore contained the integer values of the observer's assessment of each X-ray, on the two occasions. The raw data is presented in this form in Appendix E and Appendix F for each group. (The numbers in parentheses indicate the first and second observations.)

The data was analysed using a statistical analysis software package (Statistica, version 11.0, StatSoft Inc.).

The first assessment that was made was the difference in confidence of assessment of screw position in relation to the wrist joint when comparing the tilted vs. the normal radiographs. This assessment was made for each one of the observers, for each type of radiograph (i.e. lateral, PA, and PA + Lateral) and for both occasions. Using the statistical package, the difference in observations was calculated for each observer using the Fisher Exact 1-Tail test for all of the analyses on the advice of the assisting biostatistician, and the p-values were recorded. A significant difference was regarded as a p-value of less than 0.05.

A second assessment pertaining to the question of whether or not the observer thought that the screw was in the joint was performed. The difference in observations in this assessment was calculated using the Pearson Chi-squared test, again on the advice of the assisting biostatistician, and the p-values were recorded.

The third assessment involved analysis of the intra-observer strength of agreement - confidence of screw position. This was an analysis of the strength of agreement between the first and second observations of each radiograph for each observer. Cohen's Kappa co-efficient with a 95% confidence interval was used to calculate the strength of agreement, with values of 0.6 or greater indicating a "good" or better probability that the agreement was not due to chance alone. (Negative values indicated that the agreement observed was poorer than that of chance alone.)

Likewise, a calculation was performed to determine the intra-observer strength of agreement – screws reported in the wrist joint. The Cohen Kappa co-efficient was again recorded.

The fifth assessment involved inter-observer reliability with regard to the confidence in the assessment of screw position, i.e. the strength of agreement for the particular question between each of the observers for a particular radiograph. This was performed by using the Cohen Kappa co-efficient to determine the strength of agreement between each of the four observers, i.e.:

1. Intern vs. Registrar
2. Intern vs. Consultant
3. Intern vs. Radiologist
4. Registrar vs. Consultant
5. Registrar vs. Radiologist

6. Consultant vs. Radiologist

These results were analysed for the normal and the tilted radiographs, for each occasion, and the mean of the co-efficient was used to determine the final result of the inter-observer reliability for the group as a whole.

The last assessment was similar to the previous analysis, but this time for the question of whether or not the observer thought the screw was in the wrist joint. Again, this assessment was performed between pairs of observers for each type of radiograph, and for each occasion. The mean of the Cohen Kappa co-efficient was used to determine the final strength of agreement of the group for each occasion.

CHAPTER 3 - RESULTS

3. RESULTS

3.1 Demographics and Descriptive Analysis

3.1.1 Gender

There were a total of 30 sequential patients recruited to the study. There were 15 males and 15 female patients.

3.1.2 Side

There were 14 left wrists and 16 right wrists. There were three patients who had bilateral fractures, but in each case, only one side could be used in the study. In the male patient group, two patients had bilateral fractures. In one of these patients, the left side was treated conservatively in a Plaster-of-Paris cast, and in the other patient, the radiographs had not been performed according to the protocol for the left wrist, and were therefore not included. In the female patient with the bilateral fractures, the plate on the right side had been incorrectly sited, and was very obviously too proximal, with the screws obviously far from the wrist joint.

3.1.3 Age

The mean age in the study group was 39.3 years. The range was 20 to 77 years.

3.1.4 Time to Surgery

The mean time between injury and surgery was 2 days (0 – 9 days).

3.1.5 Time to Post-Operative Radiographs

The mean time between surgery and the post-operative radiographs was 2 days (1 – 18 days).

3.1.6 Rank of Operating Surgeon

The surgical procedure was performed by a consultant orthopaedic surgeon in three patients. In one patient, a medical officer with five years of orthopaedic experience performed the procedure. Six cases were performed by first-year registrars, seven cases by second-year registrars, four cases by third-year registrars, and the remaining nine procedures were performed by registrars in their fourth year (or higher) of training.

3.1.7 Hospitals Where Surgery was Performed

Two cases were performed at Chris Hani Baragwanath Hospital. Nine cases were done at Helen Joseph Hospital, and the remaining 19 cases were done at the Charlotte Maxeke Johannesburg Academic Hospital.

3.1.8 Choice of Implant

In 25 patients, the implant of choice was the Aculoc plate from Acumed. In four instances, the DVR (Distal Volar Radius, DePuy) plate was used, and one patient's fracture was fixed with a locking plate from Synthes.

3.1.9 Time Interval between Observations

The mean time between the first and second observations was 11.4 weeks (4.5 – 29).

A summary of the results of the descriptive analysis is presented in Table 3.1.

Table 3. 1   Patient Demographics and Descriptive Analysis

Pt No.	Age	Sex	Days before Surgery	Days before X-rays	Rank of Surgeon	Hospital	Implant	Side
1	38	M	1	3	Reg - 1st Yr	HJH	Aculoc	R
2	52	M	1	2	Reg - 1st Yr	HJH	Aculoc	R
3	20	F	4	2	Reg - 2nd Yr	CMJAH	Aculoc	R
4	53	M	1	3	Reg - 4th Yr	HJH	Aculoc	L
5	49	F	6	1	Reg - 4th Yr	HJH	Aculoc	L
6	44	F	0	2	Reg - 3rd Yr	CMJAH	Aculoc	R
7	55	F	2	1	Reg - 4th Yr	CMJAH	Aculoc	L
8	43	M	1	1	Reg - 4th Yr	CMJAH	Aculoc	L
9	58	F	0	2	Reg - 3rd Yr	CMJAH	Synthes	L
10	32	M	0	1	Reg - 4th Yr	HJH	Aculoc	R
11	77	F	1	1	Reg - 3rd Yr	CMJAH	DVR	L
12	37	M	9	1	MO - 5th Yr	HJH	Aculoc	R
13	31	F	0	1	Reg - 1st Yr	CMJAH	Aculoc	L
14	25	M	9	3	Cons	CMJAH	Aculoc	R
15	29	M	1	18	Reg - 1st Yr	CHBH	Aculoc	R
16	34	F	3	1	Reg - 2nd Yr	HJH	Aculoc	L
17	51	F	1	1	Reg - 3rd Yr	CMJAH	Aculoc	L
18	37	F	3	1	Cons	CMJAH	DVR	L
19	24	M	1	5	Reg - 4th Yr	CMJAH	Aculoc	L
20	33	F	4	2	Reg - 2nd Yr	CMJAH	Aculoc	R
21	22	M	1	2	Reg - 2nd Yr	CMJAH	Aculoc	R
22	34	F	5	1	Cons	CMJAH	Aculoc	R
23	33	F	0	1	Reg - 4th Yr	CMJAH	DVR	R
24	38	F	1	4	Reg - 2nd Yr	HJH	Aculoc	L
25	27	M	1	1	Reg - 2nd Yr	CMJAH	Aculoc	R
26	47	M	1	1	Reg - 1st Yr	CMJAH	Aculoc	L
27	29	M	1	2	Reg - 1st Yr	CHBH	Aculoc	R
28	20	M	4	1	Reg - 2nd Yr	CMJAH	Aculoc	R
29	49	M	0	1	Reg - 4th Yr	CMJAH	DVR	R
30	58	F	1	1	Reg - 4th Yr	HJH	Aculoc	L

3.2 Confidence in Assessment of Screw Position in Relation to the Wrist Joint

The results of "Confidence in Assessment of Screw Position in Relation to Wrist Joint" are shown in Table 3.2.

Table 3. 2 Confidence in Assessment of Screw Position in Relation to Wrist Joint

1st Observation	**Intern**	**Registrar**	**Consultant**	**Radiologist**
Tilted Lateral vs. Normal	0.677	0.101	0.655	0.500
Tilted PA vs. Normal	0.345	0.126	0.563	0.138
Tilted PA + Lateral vs. Normal	0.193	0.538	0.333	0.419
2nd Observation	**Intern**	**Registrar**	**Consultant**	**Radiologist**
Tilted Lateral vs. Normal	0.171	0.462	0.380	0.388
Tilted PA vs. Normal	**0.046**	0.563	0.126	*0.163
Tilted PA + Lateral vs. Normal	*0.080	0.933	0.437	0.100

p-values (Fisher Exact Test, 1-Tail)
*** Students t-Test**

This table summarises the results of testing the tilted radiographs against the normal radiographs for each type of view, for each observer, on each occasion. The values listed are the p-values for the difference in observations as measured by the Fisher Exact 1-Tail test. Significant p-values are highlighted in bold. Some of the values indicated in the table were calculated using the student's T-test as there was not enough integer values to calculate variance, i.e. the intern answered "Y" for every question for the tilted views. The values in Table 3.2 indicate that no statistically significant difference was seen in any comparison of tilted vs. normal views on any occasion by any observer except for the tilted PA vs. normal PA as observed by the intern on the second observation.

3.3 Assessment of Intra-Articular Screw Placement

The results of the assessment of whether or not the observer thought the screws were in the joint are shown in Table 3.3. The values listed are the p-values for the result of the Pearson Chi-Squared test which was used to compare the tilted radiographs against the normal radiographs. Once again, p-values of less than 0.05 are highlighted in bold.

Table 3. 3 Screws Reported to be in the Joint

1st Observation	Intern	Registrar	Consultant	Radiologist
Tilted Lateral vs. Normal	0.469	0.313	0.887	0.543
Tilted PA vs. Normal	0.567	**0.009**	**0.000**	**0.000**
Tilted PA + Lateral vs. Normal	0.164	0.300	0.369	0.221
2nd Observation	**Intern**	**Registrar**	**Consultant**	**Radiologist**
Tilted Lateral vs. Normal	0.337	0.085	0.449	0.390
Tilted PA vs. Normal	**0.000**	**0.000**	**0.000**	0.053
Tilted PA + Lateral vs. Normal	0.133	0.313	**0.000**	**0.003**

p-values (Pearson's Chi-Square Test)

There were several statistically significant differences noted with respect to the tilted PA radiographs compared to the normal radiographs. The p-values were less than 0.05 for all of the observers for this radiograph, except for the intern on the first observation and the radiologist on the second observation (although the difference was nearly significant for the radiologist on the second occasion with p = 0.053). In addition, it was noted that there was a significant difference in the combination of tilted PA + lateral radiographs vs. normal PA + lateral films for both the consultant and the radiologist on the second observation. The values in Table 3.3 suggest that the tilted PA views show a significant difference in the assessment of screw position on both occasions and for most observers. No significant differences were demonstrated for the tilted lateral vs. normal lateral radiographs. Further data is shown in Table 3.4 which relates to the PA films only.

Table 3. 4 Screws Reported to be in the Joint (PA Radiograph Only)

	"Yes"		"No"		"Unsure"	
	Normal (%)	Tilted (%)	Normal (%)	Tilted (%)	Normal (%)	Tilted (%)
1st Observation						
Intern	37	13	33	73	30	13
Registrar	3	0	50	83	47	17
Consultant	7	3	60	90	33	7
Radiologist	10	0	43	90	47	10
Mean	14	4	47	84	39	12
p-value*	0.143		**0.001**		**0.002**	
2nd Observation						
Intern	3	3	17	60	80	37
Registrar	3	0	63	93	33	7
Consultant	3	3	60	93	37	3
Radiologist	27	7	67	93	7	0
Mean	9	3	52	85	39	12
p-value*	0.207		**0.033**		0.089	

*** Student's t-Test, tilted PA vs. normal PA**

Observers consistently reported fewer “Yes” answers for screws being in the joint with the tilted PA films compared to the normal films. This difference was not found to be significant. However, the use of the tilted PA resulted in consistently more “No” answers for screws being in the joint for all observers, and on both occasions this was found to be significant. Also, there was a consistent decrease among all observers in the “Unsure” answers for the tilted PA compared to the normal film, and this was significant on the first observation, but not the second.

Table 3.5 shows further detail as to how observers changed their observations on the tilted PA when compared to the normal PA.

Table 3. 5 Change of Assessment of Screw Position – Tilted PA vs. Normal PA

	1st Observation					2nd Observation				
	Int	**Reg**	**Cons**	**Rad**	**Mean**	**Int**	**Reg**	**Cons**	**Rad**	**Mean**
Y → N	23	0	0	0	**5.8**	0	0	0	20	**5**
Y → U	7	3	3	10	**5.8**	0	3	0	0	**0.8**
N → Y	3	0	0	0	**0.8**	0	0	0	0	**0**
N → U	0	0	0	0	**0**	0	0	0	0	**0**
U → Y	3	0	0	0	**0.8**	0	0	0	0	**0**
U → N	20	33	30	47	**3.25**	43	30	33	7	**28.3**

All figures quoted as a percentage (%)

There were very low proportions of observers who initially reported "No" and then reported "Yes" or "Unsure" with the tilted PA films. By comparison, there were higher proportions of observers who initially reported "Yes" for screws in the joint, who subsequently changed their answer to "No" or "Unsure". The highest proportion of change was in the second observation where an average of 28% of all observers were "Unsure" initially with the normal PA, and subsequently reported "No" screws in the joint with the tilted PA view.

3.4 Intra-Observer Reliability – Level of Confidence in Assessment of Screw Position

The next assessment that was made was a test of the strength of agreement for each observer with regard to their confidence in assessment of screw position. The strength of agreement that was assigned to the Kappa Co-Efficient is based on the work of Landis and Koch (9), and this is summarised in Table 3.6

Table 3. 6 Strength of Agreement According to Kappa Co-Efficient

Kappa Co-Efficient	**Agreement**
< 0.00	Less than chance
0.00 – 0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.81 – 1.00	Very Good

The results of the answer to the question of whether or not each observer individually was confident of the assessment of screw position for a particular radiograph on the first occasion compared to their answer given on the second observation of the exact same radiograph are presented in Table 3.7. The values listed in the table are Cohen's Kappa Co-Efficient.

Table 3. 7 Intra-Observer Strength of Agreement – Confidence of Screw Position

	Normal Lateral		**Tilted Lateral**	
Intern	0.30	Fair	-0.20	< Chance
Registrar	0.18	Poor	0.17	Poor
Consultant	**0.70**	**Good**	**0.76**	**Good**
Radiologist	**0.84**	**Very Good**	0.40	Fair
Mean	0.51	Moderate	0.28	Fair
	Normal PA		**Tilted PA**	
Intern	0.09	Poor	0.42	Moderate
Registrar	0.59	Moderate	0.53	Moderate
Consultant	**0.63**	**Good**	**1.00**	**Very Good**
Radiologist	0.07	Poor	*	*
Mean	0.35	Fair	**0.65**	**Good**
	Normal PA + Lat		**Tilted PA + Lat**	
Intern	-0.07	< Chance	*	*
Registrar	-0.06	< Chance	0.53	Moderate
Consultant	**0.70**	**Good**	**0.65**	**Good**
Radiologist	0.23	Fair	-0.06	< Chance
Mean	0.20	Poor	0.37	Moderate

Cohen's Kappa Co-Efficient
* Too few integer values to calculate Kappa

The strength of agreement was noted to be "good" for the consultant for all films, and on both observations, with Kappa values ranging from 0.634 to 1. The only other result that showed a strong intra-observer agreement concerned the radiologist in the assessment of the normal lateral radiographs between the first and the second occasions, with the Kappa value recorded as 0.839 ("very good"). For all other observers the intra-observer strength of agreement was at best "moderate". At worst, there were a number of results that indicated that the strength of agreement in an individual observer was worse that the value that would have been obtained if the assessment had been left to chance alone. This was seen for the intern (tilted lateral), the intern and registrar (normal PA + lateral) and the radiologist (tilted PA + lateral). The mean statistic for the four observers did not reach 0.6 or higher for any type of radiograph, with the exception of the tilted PA view.

In some cases the Kappa Co-Efficient could not be calculated as there were too few integer values for the calculation, indicated in the table by *. In one instance the value could not be calculated because the radiologist answered "Y" for all of the tilted views. The percentage agreement was therefore calculated to be 0.9. In another similar instance, the percentage agreement for the intern for the tilted PA + Lat view was also calculated to be 0.9.

3.5 Intra-Observer Reliability – Assessment of Intra-Articular Screw Placement

Table 3.8 summarises the results of a similar assessment to the previous analysis. Here, the intra-observer strength of agreement was tested for each observer for their assessment of whether or not the screw was thought to be in the joint.

Similar to the previous analysis, the consultant once again scored "good" intra-observer agreement for all radiographs, with a mean Kappa value of 0.722, range 0.677 – 0.787. Once again, the radiologist had a "good" strength of agreement for the normal lateral views with a Kappa value of 0.714. The registrar had a value of 0.620 for the normal PA films, and 0.686 for the tilted PA + lateral radiographs. The values for the remaining observers ranged from -0.143 to 0.528. The mean value for the group of observers was not greater than 0.6 for any view.

Table 3. 8 Intra-Observer Strength of Agreement – Screws Reported in Joint

	Normal Lateral		Tilted Lateral	
Intern	0.30	Fair	0.23	Fair
Registrar	0.22	Fair	0.35	Fair
Consultant	**0.72**	**Good**	**0.76**	**Good**
Radiologist	**0.71**	**Good**	-0.14	< Chance
Mean	0.49	Moderate	0.30	Fair
	Normal PA		**Tilted PA**	
Intern	0.18	Poor	0.47	Moderate
Registrar	**0.62**	**Good**	0.53	Moderate
Consultant	**0.68**	**Good**	**0.79**	**Good**
Radiologist	0.24	Fair	-0.14	< Chance
Mean	0.43	Moderate	0.41	Moderate
	Normal PA + Lat		**Tilted PA + Lat**	
Intern	0.47	Moderate	0.23	Fair
Registrar	0.30	Fair	**0.69**	**Good**
Consultant	**0.75**	**Good**	**0.64**	**Good**
Radiologist	0.35	Fair	0.13	Poor
Mean	0.47	Moderate	0.42	Moderate

Cohen's Kappa Co-Efficient

3.6 Inter-Observer Reliability – Level of Confidence in Assessment of Screw Position

The Kappa value for the inter-observer analysis for each type of radiograph regarding confidence of screw position was also calculated, and these results are summarised in Table 3.9.

Table 3. 9 Inter-Observer Strength of Agreement – Confidence of Screw Position

	1st Observation				**2nd Observation**			
	Normal Lateral		**Tilted Lateral**		**Normal Lateral**		**Tilted Lateral**	
Int vs Reg	-0.01	< Chance	-0.20	< Chance	-0.17	< Chance	0.36	Fair
Int vs Cons	-0.19	< Chance	-0.15	< Chance	-0.25	< Chance	0.12	Poor
Int vs Rad	-0.07	< Chance	0.13	Poor	0.42	Mod	0.12	Poor
Reg vs Cons	0.44	Mod	0.30	Fair	0.42	Mod	**0.67**	**Good**
Reg vs Rad	0.16	Poor	0.47	Mod	0.05	Poor	0.22	Fair
Cons vs Rad	0.09	Poor	0.27	Fair	0.05	Poor	0.38	Fair
Mean	0.13	Poor	0.14	Poor	0.09	Poor	0.31	Fair
	Normal PA		**Tilted PA**		**Normal PA**		**Tilted PA**	
Int vs Reg	0.38	Fair	**0.61**	**Good**	0.22	Fair	0.05	Poor
Int vs Cons	0.00	Poor	0.27	Fair	0.25	Fair	0.22	Fair
Int vs Rad	-0.16	< Chance	0.19	Poor	0.02	Poor	*	*
Reg vs Cons	0.59	Mod	0.53	Mod	**0.63**	**Good**	0.46	Mod
Reg vs Rad	0.33	Fair	**0.71**	**Good**	0.13	Poor	*	*
Cons vs Rad	0.59	Mod	**0.78**	**Good**	0.11	Poor	*	*
Mean	0.29	Fair	0.52	Mod	0.23	Fair	0.24	Fair
	Normal PA + Lat		**Tilted PA + Lat**		**Normal PA**		**Tilted PA + Lat**	
Int vs Reg	-0.10	< Chance	0.43	Mod	-0.05	< Chance	*	*
Int vs Cons	-0.13	< Chance	0.47	Mod	0.06	Poor	*	*
Int vs Rad	-0.13	< Chance	0.30	Fair	0.35	Fair	*	*
Reg vs Cons	0.12	Poor	0.29	Fair	0.13	Poor	-0.07	< Chance
Reg vs Rad	0.16	Poor	0.59	Mod	-0.05	< Chance	-0.05	< Chance
Cons vs Rad	0.59	Mod	0.20	Fair	0.18	Poor	-0.05	< Chance
Mean	0.09	Poor	0.38	Fair	0.10	Poor	-0.06	< Chance

Cohen's Kappa Co-Efficient
* Kappa value indeterminable as one observer contained less than 2 integer codes

This table details the inter-rater strength of agreement for a particular radiograph. There were six pairs of comparisons for the four observers as shown in the table, and the mean of these Kappa values was calculated to represent the inter-observer agreement for the group as a whole.

There was a "good" strength of agreement between the registrar and the consultant for the tilted lateral radiograph on the second observation, and between the same observers for the normal PA film on the second observation. Regarding the tilted PA radiographs analysed on the first observation, the Kappa values were "good" for the intern vs. registrar (0.609), registrar vs. radiologist (0.714) and consultant vs. radiologist (0.783), with a mean of 0.702 ("good"). However, after measuring the mean Kappa value for all observers, none reached a value of 0.6 or higher for any of the six views, on either observation. The range of means was 0.052 – 0.516. Some of the analyses (marked with *) returned indeterminate Kappa values as there were less than two integer codes for a particular observer. In these instances, the observer recorded "Y" for all 30 observations, with no "N" observations to allow an analysis of variance. In these instances, the **percentage agreement** (not strength of agreement) was as follows:

Tilted PA, second observation:

- Intern vs. Radiologist: 0.63
- Registrar vs. Radiologist: 0.93
- Consultant vs. Radiologist: 0.93

Tilted PA + Lateral, second observation:

- Intern vs. Registrar: 0.93

- Intern vs. Consultant: 0.93
- Intern vs. Radiologist: 0.97

Thus although the strength of the agreement could not be measured, the percentage agreement for these films was high. It is notable that the mean Kappa values for all of the radiographs except for the tilted PA + Lateral film as assessed on the second occasion, returned values for the tilted radiographs that were higher than those for the normal films. Also, on further analysis of the tilted PA radiographs, if the analyses involving the intern are excluded, the mean Kappa value for the first observation is 0.674, or a “good” inter-observer strength of agreement.

3.7 Inter-Observer Reliability – Assessment of Intra-Articular Screw Placement

A similar analysis was also made of the inter-observer strength of agreement of the answer to the question of whether or not the observer thought the screw was actually in the joint. The results are summarised in Table 3.10.

There were a number of comparisons which demonstrated “good” strength of agreement with regard to the normal PA and the tilted PA on both the first as well as the second observations. These Kappa values of 0.6 or more were seen mainly with the comparison between the registrar, consultant and the radiologist. There were no values of greater than 0.6 in any of the comparisons between the intern and another observer. Despite the figures which indicated a high level of agreement between some observers, the mean Kappa values for all observers regarding all radiographs and on both occasions did not score higher than 0.6, and thus the inter-observer agreement for this analysis was not good.

Table 3. 10 Inter-Observer Strength of Agreement – Screws Reported in Joint

	1st Observation				2nd Observation			
	Normal Lateral		**Tilted Lateral**		**Normal Lateral**		**Tilted Lateral**	
Int vs. Reg	0.03	Poor	0.17	Poor	0.01	Poor	0.41	Mod
Int vs. Cons	-0.08	< Chance	0.18	Poor	0.04	Poor	0.25	Fair
Int vs. Rad	0.02	Poor	0.28	Fair	0.22	Fair	0.33	Fair
Reg vs. Cons	0.42	Mod	0.29	Fair	0.43	Mod	**0.69**	**Good**
Reg vs. Rad	0.12	Poor	0.41	Mod	0.4	Poor	0.34	Fair
Cons vs. Rad	0.10	Poor	0.27	Fair	0.09	Poor	0.42	Mod
Mean	0.10	Poor	0.26	Fair	0.14	Poor	0.41	Mod
	Normal PA		**Tilted PA**		**Normal PA**		**Tilted PA**	
Int vs. Reg	0.36	Fair	0.55	Mod	0.26	Fair	0.12	Poor
Int vs. Cons	0.21	Fair	0.39	Fair	0.28	Fair	0.22	Fair
Int vs. Rad	0.12	Poor	0.29	Fair	0.07	Poor	0.16	Poor
Reg vs. Cons	**0.63**	**Good**	0.58	Mod	**0.66**	**Good**	**0.74**	**Good**
Reg vs. Rad	0.41	Mod	**0.71**	**Good**	0.31	Fair	0.48	Mod
Cons vs. Rad	**0.65**	**Good**	**0.82**	**V Good**	0.35	Fair	**0.74**	**Good**
Mean	0.40	Fair	0.56	Mod	0.32	Fair	0.41	Mod
	Normal PA + Lat		**Tilted PA + Lat**		**Normal PA + Lat**		**Tilted PA + Lat**	
Int vs. Reg	0.36	Fair	0.42	Mod	0.42	Mod	0.58	Mod
Int vs. Cons	0.12	Poor	0.46	Mod	0.38	Fair	0.53	Mod
Int vs. Rad	0.01	Poor	0.31	Fair	0.50	Mod	0.15	Poor
Reg vs. Cons	0.39	Fair	0.46	Mod	0.39	Fair	0.38	Fair
Reg vs. Rad	0.29	Fair	**0.64**	**Good**	0.50	Mod	0.39	Fair
Cons vs. Rad	**0.62**	**Good**	0.35	Fair	0.42	Mod	0.29	Fair
Mean	0.30	Fair	0.44	Mod	0.44	Mod	0.39	Fair

Cohen's Kappa Co-Efficient

It may be worth noting, however, that in every instance except for the tilted PA + lateral radiograph as assessed on the second occasion, the mean values for the tilted radiographs were higher than those of the normal radiographs. This is a similar finding to the previous analysis. Therefore although the agreement was not strong in all films, there was an improvement in the agreement of the tilted films.

Also noteworthy is that the agreement between the observers if one excludes the intern for the PA films, yields Kappa values of greater than 0.6 for the tilted PA views on both observations (0.704 and 0.652) compared with the normal PA views (0.564 and 0.442).

CHAPTER 4 - DISCUSSION

4. DISCUSSION

The results of this study indicate that while some anatomically tilted X-rays result in a change in the assessment of screw position by certain observers, others do not appear to do so. Although there are significant differences in the radiographic assessment of the same patient, there are also differences in the intra- and inter-observer assessment of the same X-ray.

Regarding the confidence of assessment of screw position in relation to the wrist joint, no significant difference was found between the tilted post-operative radiographs when compared to the normal films. Thus it could be said that this study did not find an increased level of subjective observer confidence of assessment of screw position with the use of the anatomically tilted radiographs.

However, when asked to indicate whether or not they actually thought the screws were in the joint, there were several significant values with regard to the differences between the tilted films compared to the normal radiographs. This difference was seen almost exclusively with the tilted PA views, for most observers, and on both observations. There were sporadic significances for some of the other views e.g. the combined tilted PA + lateral, but overall these were not as convincing as was the data from the tilted PA view.

Further analysis regarding the PA films only showed that the tilted PA films consistently showed among all observers a decrease in the number of screws reported in the joint, an increase in the number of screws reported not to be in the joint, as well as a decrease in the number of unsure reports. This was significant for the increased number of screws reported not to be in the joint, as well as the decrease in unsure reports. Analysis of the change of opinion regarding the intra-articular screw placement showed higher proportions of observers changing from “Yes” to “No” or “Unsure” and from “Unsure” to “No” with the tilted PA film.

From the results, it appears that although the tilted radiographs do not increase the apparent or subjective confidence of the observer with regard to their assessment of screw position, there is certainly a difference in reporting whether or not the observer actually thinks the screw is in the joint, but only with one view – the tilted PA radiograph. A possible explanation for this would be that although the observer may be confident of their assessment, their assessment may be incorrect, and the observer is “falsely confident”. In other words, they are confident that there are no screws in the joint on the normal PA film, but also confident that there are no screws in the joint on the tilted PA film of the same patient.

This highlights the concept of the diagnostic accuracy of assessment of these radiographs. This study did not attempt to prove that tilted views can accurately exclude intra-articular impingement; instead, these results may serve to focus the direction of further research in this regard, i.e. which tilted view may be appropriate to study for diagnostic usefulness.

The second objective to compare the intra-observer reliability of the interpretation of tilted radiographs vs. standard radiographs in each of the four observers showed that with regard to confidence of assessment of screw position, there was a good level of agreement in the assessment of all views by only one of the four observers – the consultant orthopaedic surgeon. The remaining observers showed poor or fair intra-observer agreement of interpretation of the same radiograph on the two separate occasions, where some observations would have in fact scored higher if they had been obtained by chance alone. The mean Kappa statistic did not indicate a strong level of agreement for the observers as a group, except for the tilted PA films.

With regard to the assessment of whether or not the screw was actually in the wrist joint, the intra-observer reliability was once again “good” for only one of the observers – the consultant orthopaedic surgeon. The results of the remaining observers were not convincing, and again showed only at best a “moderate” strength of agreement for each individual. None of the mean Kappa values for all four observers as a group scored 0.6 or more.

This indicates that there is poor consistency in assessment of orthopaedic radiographs by medical professionals who may be expected to make important decisions based on such an assessment with the exception of the orthopaedic consultant. This was found to be the case not only for the tilted radiographs, but also for the standard post-operative films that are currently ordered routinely for these patients.

At the level of the intern, this poor consistency could be explained by a lack of experience in the interpretation of musculoskeletal X-rays, especially with an associated fixation device. It is hoped that their rotation through the orthopaedic department would give them more exposure to these types of radiographs, and improve their confidence and accuracy in their interpretation.

Of more concern are the results that indicate poor consistency in assessment of these X-rays by the orthopaedic registrar and the consultant radiologist. These are health professionals who are either performing the surgery, or are responsible for the reporting on such X-rays for reasons including medico-legal reports. This lack of consistency may ultimately result in a poor outcome as far as the patient is concerned, and points to a possible lack of understanding or confusion surrounding the anatomy of the wrist joint, and merits further research in this area. Until further information is available, caution should be exercised in the management of these patients based upon the intern's radiographic assessment post-operatively, and it is recommended that they seek a senior opinion before making any treatment decisions.

The results of the third objective, the inter-observer reliability in interpretation of the radiographs for confidence of assessment of screw position, revealed that while there were some individual cases where the strength of agreement between two observers was good, none of the mean Kappa values for each type of radiograph reached a figure of 0.6 or more, indicating that there was not a high level of agreement between the observers as a group. This again points to a potentially serious difference in the level of understanding of the anatomy of the wrist joint and in the interpretation of the radiographs. (It was interesting to note, however, that the mean Kappa values for the tilted views were almost all higher than those for the normal views.)

In our current setting, where health professionals with different levels of experience are expected to manage these patients, it is important that there should exist a high level of inter-rater agreement for all radiographs. If one excludes the observer who supposedly has the least amount of orthopaedic experience or anatomic understanding, i.e. the intern, from the analysis, the data suggests that there is "good" inter-rater agreement for the tilted PA films but not for the normal PA view. This was true for confidence of assessment as well as assessment of actual screw position.

In summary therefore, although the tilted radiographs do not show a significant difference in the observer's subjective confidence of assessment, the tilted PA film does show a significant difference in actual assessment of screw position for all observers, with fewer intra-articular screws reported. Only the consultant orthopaedic surgeon shows good consistency in individual interpretation of all films. There is good inter-observer reliability with this tilted PA view if one excludes the intern from the assessment.

4.1 Comparison of Results with Published Data

4.1.1 The Use of Anatomically Tilted Radiographs of the Distal Radius

The use of anatomically tilted X-rays has been described previously. In 1996, Mekhail and Ebraheim *et al* (10) reported on the use of a 30° cephalad projection of a postero-anterior wrist radiograph which allowed better fracture assessment of the distal radius, especially of the dorsomedial fragment of the lunate fossa in a die-punch fracture.

Similarly, Lundy and Scott *et al* (11) suggested that the use of a 22° lateral view may help the surgeon better understand the intra-articular depression of lunate facet fractures of the distal radius and in turn may in turn aid the surgeon in the subsequent reduction and fixation of the fracture.

Johnson and Szabo (12) recommended tilted lateral views for better assessment of fractures of the distal radius especially when there was significant dorsal angulation. They noted how measurements of volar inclination change with pronation of the radius, but that this change was less with the tilted lateral views compared to normal laterals.

Intra-operatively, the use of fluoroscopy by the operating surgeon is essential to avoid intra-articular screw placement. Several tilted X-rays may be needed to place the screws correctly to compensate not only for the joint inclination, but also for the joint curvature. This was highlighted by Soong and Got *et al* (13), who showed that concerning the tilted lateral X-ray, lower angles of tilt gave a better view of ulnar-side screws, and higher degrees of tilt gave a better view of the radial styloid screws.

Post-operatively, Yi and Kim *et al* (14) studied the use of anatomically tilted lateral radiographs on the determination of the restoration of normal volar tilt of the distal radius, and found moderate to excellent reliability with these radiographs, although no statistically significant difference between volar tilts determined using these tilted views and standard lateral radiographs were found.

4.1.2 Anatomically Tilted Radiographs used in Assessment of Volar Plate Fixation

There are reports in the literature pertaining to the study of tilted X-rays in the evaluation of volar plate fixation and the position of the distal screws with respect to the wrist joint. Kumar and Breakwell *et al* (15) studied a series of ten patients undergoing volar plate fixation. In their study, the screws appeared intra-articular in all ten patients on the standard AP view, and in eight patients on the standard lateral. The tangential views, however, resulted in no screws were seen to be penetrating the joint. In contrast to this study, they did not standardise the degree of tilt in the tangential views, but rather gave ranges of tilt being 10 to 15° in the fully pronated position, and 20 to 25° in the lateral position. They obtained these degrees of tilt by lifting the arm off the table, but do not give any indication as to how this position was maintained. It is difficult, therefore, to make clear recommendations based on their data.

An important aspect of the use of these tilted radiographs is their accuracy in determining whether or not there was actual intra-articular screw impingement. This study made no attempt to assess this aspect. This diagnostic accuracy could only really be confirmed by subjecting the patient to a CT scan or a wrist arthroscopy. Other researchers have also used cadaveric specimens to assess the sensitivity and specificity of these tilted X-rays with regard to intra-articular impingement.

Boyer and Korcek *et al* (16) evaluated anatomically tilted radiographs using dorsally placed plates in cadaveric specimens, comparing the results with arthrotomy and direct visualisation of the articular surface of the cadaveric specimen for joint penetration. The tilted PA radiograph was taken at 11°, and the tilted lateral was taken at 23° using a specially constructed radiolucent table angled appropriately and the angle was confirmed with a goniometer.

They concluded that the tilted lateral view of 23° improved the sensitivity and specificity over the standard lateral view, but there was a false positive rate of 17%. They did not find that the tilted PA view increased the sensitivity or specificity of intra-articular screw placement over the standard PA view. Radiographs were examined on two separate occasions – at first the observers were presented with one view at a time, and two weeks later they were presented with paired views. They did not find any meaningful improvement in the sensitivity and specificity of intra-articular screw detection with the combined tilted views as compared to the combined standard PA and lateral. It was not reported in this study who the observers were.

Soong and Got *et al* (13) reported on anatomically tilted radiographs using one type of volar locking plate in cadaveric specimens. Once again, the accuracy of the X-rays in confirming screw position was determined by arthrotomy and visualisation of the joint. They used a goniometer to tilt the forearm at the required angles (15°, 23°, 30° tilted laterals, and 11° tilted PA). Radiographically they determined that a screw was extra-articular if no part extended beyond the thick shadow of subchondral bone. They reported that the low-angles lateral anatomic tilt views (15 and 23°) were more specific to exclude intra-articular screw placement of screws placed on the ulnar side of the radius, whereas the specificity of the radially-placed screws increased with the high-angle lateral anatmomic tilt views (30°). This is especially true for screws placed in the styloid process. This observation led the authors to speculate that it may be appropriate to place the screws on the ulnar side first, followed by the more radially placed screws on order to obtain unobstructed views.

These previous two studies evaluated cadaveric specimens, only one type of plate was used, and neither of the studies involved an actual fracture fixation. Fracture lines distorting anatomy, as well as Plaster-of-Paris backslabs and soft-tissue shadows may radiographically obscure interpretation of screw location. In addition, the study by Boyer and Korcek *et al* examined plates which were placed on the dorsum of the radius, a method of fixation not commonly used in current practice. There are no other studies in the literature that evaluate the use of anatomically tilted radiographs of the distal radius in living patients similar to this study.

4.1.3 Variability in Assessment of Radiographs Between Health Professionals

There are few reports in the literature concerning variability assessment between observers for radiographs of the distal radius. Yi and Kim *et al* (14) performed a retrospective analysis of 20 patients who had distal radius volar plate fixation, and compared results with 20 controls. They used a 23° tilted lateral radiograph of the wrist, and measured intra- and inter-observer variability in the measurement of volar angulation. The observers were a specialist orthopaedic hand surgeon, a specialist hand fellow, and a senior orthopaedic registrar. Their results indicated that intra-observer reliability was excellent for the tilted lateral X-rays compared to the standard films for both patients and controls, especially for the more senior observers. The inter-observer reliability was excellent for the tilted films, but only moderate for the standard X-ray. Their data agrees with the results in this study in that the intra-rater agreement is good at the level of the orthopaedic consultant.

The study by Boyer and Korcek *et al* (16) also examined inter-observer reliability for screw penetration between the observers who assessed the X-rays. Reliability was significantly improved for the anatomically tilted lateral views compared to the standard lateral view. Improvement in reliability was also noted with the tilted PA views compared to the normal PA views. No change was seen in the comparison of combined tilted PA and lateral views with combined normal PA and lateral. Unfortunately, it is not stated in their study who the observers were. By comparison, in this study, there appears to be a correlation between the level of orthopaedic experience and the degree of inter-observer agreement.

4.2 Alternate Methods of Obtaining Tilted Radiographs

There are a number of ways of obtaining radiographs of the wrist joint in order to account for the anatomical tilt of the distal radius. One method is simply lifting the arm off the radiolucent table to the desired angle (15). A potential disadvantage with this method is the error in consistency of the angles achieved. A radiolucent bolster angled at a specific degree upon which the forearm is rested while radiographs of the wrist are taken in the standard way can also be used to obtain tilted X-rays (11) (17). Disadvantages regarding the use of such bolsters are the expense of extra equipment which can often go missing in a busy hospital, and either the need for two bolsters or alternately a single bolster designed with two different angles of elevation (if both tilted PA and lateral films are required). Another method is to tilt the table on which the forearm rests, and use a goniometer to confirm the angle of tilt (16). Once again, there may be the disadvantage of the need for extra potentially expensive equipment.

The same result can be achieved by using the method described in this study - tilting the X-ray tube to the desired angle in order to obtain tilted views. One advantage of this is that the patient does not need to be re-positioned between the standard PA and the tilted PA radiograph. This is especially important for those patients experiencing pain post-operatively. Another advantage is that there is no need to purchase any extra equipment such as radiolucent bolsters or adjustable radiolucent tables. Tilting the tube does result in a change of the distance between the X-ray tube and the patient's wrist. The resulting change in magnification is small however, and of doubtful significance.

4.3 Considerations for the Routine Acquisition of the Tilted PA Radiograph

The question therefore remains whether or not these tilted radiographs should be requested routinely for all patients undergoing stabilisation of a distal radius fracture with such a fixation device, i.e. should there be a standardised “22/11” post-operative X-ray? Clearly, this study did not find the tilted lateral X-ray to be of additional value, as is the case with the combined PA + lateral radiographs, and their routine acquisition can therefore not be supported. However, the tilted PA view appears to provide additional information to the observer which may have important consequences for the further management of the patient. The use of this radiograph may therefore have importance not in the accurate diagnosis of intra-articular screw placement, but in alerting the treating health professional to the possibility of such an error, and in improved selection of patients who may need further expensive and/or invasive investigations.

The use of only one additional radiograph in the routine series is attractive in that it requires very little extra effort to acquire the film. The post-operative patient would have the standard X-ray in the normal way, and it would be a simple matter to tilt the X-ray tube to the required 11° to obtain the tilted PA, without the patient having to move or be re-positioned. The training required by the attending radiographer would be minimal, as would be the extra time taken to acquire the exposure. The cost of the extra radiograph would be small, especially if it were to be stored in digital format, as opposed to being printed out on expensive X-ray film.

The patient would be subjected to a small amount of extra radiation, but this may be small by comparison to repeated, non-standard radiographs for doubt regarding screw placement. Also, the risk to the patient of one extra exposure would be negligible if it is taken into consideration the amount of radiation the patient would be exposed to if a CT scan was needed to assess the screw placement, or the invasive nature of a wrist arthroscopy to exclude intra-articular penetration.

The anatomically tilted PA radiograph is easy to obtain and may be useful to senior medical professionals who are involved in the treatment of these patients, especially the consultant orthopaedic surgeon. Therefore, the recommendation of its routine acquisition in addition to the standard PA and lateral radiographs in the post-operative patient who has had a volar plate fixation to their distal radius should be supported.

4.4 Study Limitations

4.4.1 Choice of Angle for Tilted Radiographs

Potential limitations of the study are the chosen angles for the tilted PA and lateral radiographs (11 and 22° respectively). These angles were chosen as they represent an estimation of the mean range in a given population, and are easy to remember. Orthopaedic registrars are often taught the "rule of 11" for the radiographic assessment of acceptable fracture reduction of the distal radius because it is easy to remember and apply. Perhaps angles of 10° and 20° may be even easier to remember and to acquire, but these angles are further away from accepted means than 11° and 22°.

This study did not attempt to establish the optimal angle of tilt. This may be challenging as any angle chosen cannot account for the variability of normal tilt of the radio-carpal joint. This could theoretically be done by calculating the exact angle of tilt based on the standard PA and lateral radiographs of the uninjured side first, and then using these angles to obtain the correct degree of tilt for each individual patient. This method would be time-consuming and be labour-intensive for the radiographer, and also expose the patient to additional radiation for very little gain.

4.4.2 The Effect of the Curvature of the Radiocarpal Joint

A point which has not been extensively highlighted is the extent to which the curvature of the joint plays a role in determination of screw position. This study has emphasised the use of tilted X-rays to account for the coronal and sagittal plane inclination of the joint, but the actual curvature of the joint in the coronal as well as the sagittal planes should also be taken into consideration. It can be argued that due to this curvature, it may not be possible to obtain a single radiograph at any one angle that can exclude all possibilities of intra-articular screw placement. This was highlighted in the work of Soong and Got *et al* (13), who used lateral X-rays at several different angles to assess screw position. For uncertain cases, multiple X-rays may be needed or even a CT scan where doubt still exists.

4.4.3 Availability of Digital X-Ray Machines

In this study, modern digital X-ray machines were used that had digital screens enabling the radiographer to accurately set the amount of tilt in one degree increments. However, there are many radiology departments throughout hospitals in South Africa (government and private hospitals) where the X-ray machines may be of the older type with far less accurate, mechanical calibration devices used to set the tilt. These calibrations are usually in two- or five-degree increments. Thus it may not be possible to obtain accurate, reproducible angles of tilt with these machines as was performed in this study. At best, a close approximation to the nearest five-degree increment may be achieved. Bearing this in mind, perhaps it may be better to analyse radiographs tilted to 10° or 20°, as opposed to 11° and 22°, although the drawbacks of this have been discussed previously.

4.4.4 Inadequate Reduction of Fractures

Another potential limit to using these (or any other) particular degrees for the anatomically tilted views is that it is assumed that the operating surgeon has reduced the fracture anatomically. If this is not the case, the normal anatomical inclination of the radius in the coronal and sagittal planes may not have been restored, and therefore the degree of tilt for the tilted radiographs would not be in a range suitable for any meaningful interpretation. The majority of the surgical procedures performed in this study were by surgeons at the registrar level, still receiving training in the fixation of these fractures, and it may be the case that not all fractures were optimally reduced.

4.4.5 Choice of Observers

The four observers in this study were not chosen strictly randomly. They were selected by the researcher based on factors mainly concerning willingness and time to participate in the study and, of course, lack of knowledge as to the particulars of the research (blinding). They were chosen because they each represent a different level of knowledge pertaining to surgical fixation of the distal radius and the interpretation of the post-operative radiographs.

It is conceded that the results of the study may have been different depending on the choice of observer. For example, the intern may have been particularly weak regarding his knowledge of anatomy and orthopaedics, and other interns may have scored significantly differently. This could be the subject of further research on this topic e.g. analysis of the assessments of a group of interns, or a group of consultant radiologists.

One might also argue that such selection of candidates to make the observations may introduce a selection bias to the study, and this may be true. However, an argument can be made that each of the observers was included because they all have the potential to be exposed to the analysis of these radiographs in their differing professional capacities. More importantly, in our current hospital setting, they all have the potential to be involved in making important decisions or treatment-altering observations based on these radiographs.

The medical intern rotating through the orthopaedic department as part of his or her required training was chosen to represent the observer with the least amount of orthopaedic or radiological knowledge and experience, who may very likely be involved in making treatment decisions on a patient based on the analysis of their post-operative radiographs. In a government hospital setting, it is not uncommon for the intern to be the only one to see the post-operative radiographs, whether that be immediately post-operatively, or in the fracture clinic weeks later.

The orthopaedic registrar was chosen to represent the observer who should have a good understanding of the anatomy of the wrist joint, and be competent in applying this information when fixing fractures of the distal radius with a locking plate.

Likewise, the consultant orthopaedic surgeon who does not have a special interest in hand or wrist surgery represents the observer who should be competent in the surgical fixation of these fractures, and who has usually (but not always) amounted the most experience in this regard compared to the other observers.

A consultant radiologist who does not have a special interest in musculoskeletal radiology was chosen as frequently he/she would analyse such a post-operative radiograph and supply a formal written report as to the nature of the fixation and the position of the screws to the treating doctor, especially in private practice. While the radiologist may have a detailed knowledge of the radiological anatomy of the wrist, they may very well not appreciate fully the subtleties of the design of orthopaedic implants as it pertains to the fracture fixation. The radiologist does not have the benefit of having been involved in the surgery, and therefor has not seen all the tilted images that the operating surgeon may have used to ensure that no screws were in the joint. The radiologist can only report what has been given to them, and may have no alternative but to report that “there appear to be several screws penetrating the wrist joint” when, in fact, there may be none.

CHAPTER 5 - CONCLUSION AND RECOMMENDATIONS

5. CONCLUSION AND RECOMMENDATIONS

5.1 Primary Research Question

The use of standardised anatomically tilted radiographs of the wrist does not change the observer's subjective confidence of assessment with respect to intra-articular placement in post-operative patients who have had a fracture reduced and stabilised with an anatomically-contoured volar locking plate. However, there is a difference in the assessment of the actual screw position with regard to the tilted PA view. The tilted PA view results in fewer screws being reported in the joint, as well as less uncertainty of intra-articular screw placement.

5.2 Secondary Research Question

Of the four observers, only the consultant orthopaedic surgeon showed consistency of interpretation of both the normal as well as the tilted radiographs. The inter-observer reliability for the group with regard to confidence as well as actual assessment of screw position was poor with all radiographs, but when the data from the intern was excluded, the reliability for the group was good for the tilted PA radiographs, but not for the normal PA films.

5.3 Recommendations

The tilted PA X-ray appears to provide additional information to the observer, and it's acquisition as a routine post-operative X-ray should be supported especially for interpretation by senior medical professionals involved in treatment of these patients. This recommendation may be strengthened depending on further analysis of these radiographs by groups of observers at the same level of experience.

Further study is recommended to determine the accuracy of tilted views, such as the tilted PA radiograph in this study, with regard to demonstrable intra-articular screw placement.

The intra-observer assessment of musculoskeletal radiographs by orthopaedic trainees and radiologists should be examined further to confirm or disprove the results obtained in this study.

It is recommended that junior members of the surgical team should seek a senior's opinion regarding the patient's further treatment.

APPENDIX A

INFORMATION DOCUMENT

Study title: Standardised post-operative radiographs for volar radial plate fixation: The "22/11 X-ray"

Hello, my name is Dr Warren Matthee. I am a doctor working at the Charlotte Maxeke Johannesburg Academic, Helen Joseph and Chris Hani Baragwanath Hospitals. I am training to be an orthopaedic surgeon – a doctor who operates on fractures and diseases of joints.

I am doing a study on the way in which X-rays are done after somebody has had an operation for a broken wrist. I want to learn if there is any benefit to doing an extra X-ray to make sure that the metal screws are in the right place.

I am inviting you to help me by taking part in this study.

You are being invited because you have just had an operation to fix your broken wrist with a specific type of metal plate. The usual process after the operation is to have an X-ray taken of the wrist to check that the broken bone is in a good position before you are discharged.

For this study, I would like to do one extra X-ray of your wrist, done at a different angle.

This extra X-ray will be done at the same time as the routine X-ray done after an operation while you are still at the hospital. It will take only a few minutes, so there will be no inconvenience to you.

This is all that is needed for you to be in the study. There will be no cost to you whatsoever.

X-rays work by exposing your body to a very small amount of radiation to make a picture of your bones. Radiation is an invisible wave of energy made by certain substances.

Radiation can be harmful in very large amounts. However, you will be absolutely safe to have X-rays as the amount of radiation is very small, and having an extra X-ray will not harm you in any way. But as an extra safety precaution, we will not ask you to be in this study if you are or think you may be pregnant.

You will be one of 30 people involved in the study.

Your X-rays will be shown to four doctors for analysis. Every effort will be made to keep personal information confidential. However, absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Research Ethics Committee and the Medicines Control Council.

If the results of the study are published, may lead to individual identification.

The benefits of being involved in this study are:

- You will be helping to increase medical knowledge
- In the highly unlikely event that a mistake was made in the operation, the extra X-ray may speed up the process to fix the mistake

Once the results of the extra X-rays have been examined, it will be sent for publication in a medical journal for other doctors to learn of any benefits of the extra X-ray. You are fully entitled to any information about your involvement in the study and your results at any time.

You do not have to take part in the study. The treatment of your broken wrist will not be different in any way if you do not take part, and you will still get all the benefits of the operation and further follow-up appointments in the outpatient clinic. You also have the right to leave the study at any time, even if you had agreed to it initially.

If you have any concerns or would like to tell me about any problems, please do not hesitate to ask me. My contact details are:

Dr. Warren Matthee
Cell: 079 510 2235
E-mail: warren.matthee@gmail.com

In order to conduct this study, I have also obtained permission from the ethics committee of the University of the Witwatersrand. If you have any queries in this regard, please feel free to contact them on 011 717 1234.

Consent to be involved in the study:

Standardised post-operative radiographs for volar radial plate fixation:

The "22/11 X-ray"

I ________________________________ (Hospital Number: _______________) hereby consent to be involved in the above study. I confirm that I have read and understood the contents of the information sheet that pertains to this study.

I understand that one extra set of X-rays will be taken of my wrist. I understand that I will be exposed to a small amount of extra radiation which poses no foreseeable risk to my health.

I confirm that I am 18 years or older, and that I am not pregnant.

Signature: ___________________________ Date: __________________________

APPENDIX C

<u>PATIENT DETAILS:</u>

Surname	
Name	
Hospital	
Hospital Number	
Date of Birth	
Age	
Sex	
Telephone 1	
Telephone 2	
Date of Injury	
Date of Operation	
Date of X-rays	
Surgeon	
Implant (e.g. Aculoc)	
Side	
Comments	

<u>Any queries – Dr Warren Matthee (079 510 2235)</u>

Data Collection Sheet **APPENDIX D**

1) Can you tell with confidence where the screws are in relation to the wrist joint? (Y/N) 2) If "Y", do you think that any of the screws are in the wrist joint? (Y/N)	Name: Rank: Highest Qualification and Date:

No.	**1**	**2**	**No.**	**1**	**2**	**No.**	**1**	**2**	**No.**	**1**	**2**	**No.**	**1**	**2**	**No.**	**1**	**2**
	(Y/N)	**(Y/N/U)**		**(Y/N)**	**(Y/N/U)**		**(Y/N)**	**(Y/N/U)**		**(Y/N)**	**(Y/N/U)**		**(Y/N)**	**(Y/N/U)**		**(Y/N)**	**(Y/N/U)**
1			31			61			91			121			151		
2			32			62			92			122			152		
3			33			63			93			123			153		
4			34			64			94			124			154		
5			35			65			95			125			155		
6			36			66			96			126			156		
7			37			67			97			127			157		
8			38			68			98			128			158		
9			39			69			99			129			159		
10			40			70			100			130			160		
11			41			71			101			131			161		
12			42			72			102			132			162		
13			43			73			103			133			163		
14			44			74			104			134			164		
15			45			75			105			135			165		
16			46			76			106			136			166		
17			47			77			107			137			167		
18			48			78			108			138			168		
19			49			79			109			139			169		
20			50			80			110			140			170		
21			51			81			111			141			171		
22			52			82			112			142			172		
23			53			83			113			143			173		
24			54			84			114			144			174		
25			55			85			115			145			175		
26			56			86			116			146			176		
27			57			87			117			147			177		
28			58			88			118			148			178		
29			59			89			119			149			179		
30			60			90			120			150			180		

All Results – Confidence of Assessment of Screw Position

APPENDIX E

Pt No.	View Type	View No.	Int (1)	Int (1) Tilt	Int (2)	Int (2) Tilt	Reg (1)	Reg (1) Tilt	Reg (2)	Reg (2) Tilt	Cons (1)	Cons (1) Tilt	Cons (2)	Cons (2) Tilt	Rad (1)	Rad (1) Tilt	Rad (2)	Rad (2) Tilt
1	Lat	1	1	1	2	2	2	1	1	1	2	1	2	1	2	2	2	1
2	Lat	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1
3	Lat	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	1
4	Lat	1	1	2	2	1	1	1	1	2	1	1	1	2	2	1	2	1
5	Lat	1	1	1	1	1	2	1	2	1	2	1	2	1	2	1	2	1
6	Lat	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
7	Lat	1	2	1	2	2	1	2	1	2	1	2	1	2	2	2	2	2
8	Lat	1	2	1	2	2	2	2	1	2	1	1	1	1	2	2	2	1
9	Lat	1	1	1	1	1	2	2	2	1	2	2	2	2	2	2	2	1
10	Lat	1	1	1	2	1	2	1	1	1	1	1	1	1	2	2	2	1
11	Lat	1	1	1	2	2	1	1	1	2	1	2	2	2	2	2	2	2
12	Lat	1	1	1	1	2	2	1	1	1	2	1	2	1	2	1	1	1
13	Lat	1	2	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1
14	Lat	1	1	1	1	1	1	1	1	2	1	2	1	2	1	2	1	1
15	Lat	1	1	2	1	1	1	1	1	1	2	1	1	1	2	2	2	1
16	Lat	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1
17	Lat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	Lat	1	1	1	2	1	2	2	1	1	1	1	1	1	2	2	2	2
19	Lat	1	1	2	2	1	2	1	1	1	1	1	2	1	2	2	2	2
20	Lat	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1
21	Lat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	Lat	1	2	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1
23	Lat	1	1	1	1	1	2	1	1	1	1	1	2	1	2	1	2	1
24	Lat	1	1	1	1	1	2	2	1	1	2	1	2	1	2	2	2	1
25	Lat	1	1	1	2	2	2	2	1	1	2	1	2	1	2	2	2	1
26	Lat	1	1	1	1	1	1	2	2	1	2	1	2	2	2	2	2	2
27	Lat	1	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2
28	Lat	1	2	1	2	2	2	1	1	1	1	1	1	1	2	2	2	1
29	Lat	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1
30	Lat	1	1	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1
1	PA	2	1	1	2	2	2	1	2	1	2	1	2	1	2	1	1	1
2	PA	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1

3	PA	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	PA	2	1	2	2	2	2	2	2	1	2	1	2	1	2	1	1	1
5	PA	2	1	1	2	1	2	1	2	1	2	1	2	1	2	1	1	1
6	PA	2	1	1	2	1	1	1	1	1	2	1	1	1	2	1	1	1
7	PA	2	2	2	2	2	2	2	2	1	2	2	2	2	1	2	1	1
8	PA	2	2	1	2	2	2	1	2	1	2	1	2	1	2	1	1	1
9	PA	2	1	1	1	1	1	2	1	2	1	1	1	1	1	2	1	1
10	PA	2	2	2	2	2	2	2	1	1	1	1	2	1	2	1	1	1
11	PA	2	2	1	2	2	2	2	2	2	1	2	2	2	1	2	1	1
12	PA	2	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1	1
13	PA	2	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1
14	PA	2	1	2	2	2	2	1	2	1	2	1	2	1	2	1	1	1
15	PA	2	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1	1
16	PA	2	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
17	PA	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
18	PA	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	PA	2	2	1	2	2	2	1	1	1	1	1	2	1	1	1	1	1
20	PA	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	PA	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
22	PA	2	2	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1
23	PA	2	1	1	2	2	1	1	2	1	1	1	1	1	2	1	1	1
24	PA	2	2	1	2	1	2	1	1	1	2	1	2	1	2	1	1	1
25	PA	2	1	1	2	1	2	1	2	1	2	1	1	1	2	1	1	1
26	PA	2	1	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1
27	PA	2	1	1	2	2	1	1	1	1	1	1	1	1	2	1	1	1
28	PA	2	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1
29	PA	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	PA	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	PA + Lat	3	1	1	1	1	2	1	1	1	2	1	2	1	2	2	2	1
2	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	PA + Lat	3	2	1	1	1	1	2	1	2	1	1	2	1	1	2	1	1
5	PA + Lat	3	1	1	1	1	2	1	1	1	2	1	2	1	2	1	1	1
6	PA + Lat	3	1	1	1	1	1	1	1	1	2	1	2	1	2	1	1	1
7	PA + Lat	3	1	1	2	1	1	2	1	2	2	1	2	1	2	2	2	1
8	PA + Lat	3	1	1	1	1	1	1	1	1	2	1	2	1	2	2	1	1
9	PA + Lat	3	1	2	1	1	1	1	1	1	2	1	1	1	2	1	2	2
10	PA + Lat	3	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1
11	PA + Lat	3	1	2	1	1	1	2	1	1	2	2	1	2	1	2	1	1

12	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	PA + Lat	3	2	2	1	1	1	2	1	1	1	1	2	1	1	2	1	1
15	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
16	PA + Lat	3	1	1	2	1	1	1	1	1	1	1	1	1	2	1	1	1
17	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	PA + Lat	3	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	1
20	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	PA + Lat	3	1	1	1	1	1	1	2	1	2	1	2	1	2	1	1	1
24	PA + Lat	3	1	1	1	1	1	1	1	1	2	1	2	1	2	2	1	1
25	PA + Lat	3	1	1	1	1	1	1	1	1	2	1	2	1	2	1	1	1
26	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1
27	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
29	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	PA + Lat	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

All Results – Screws Reported to be Intra-Articular

APPENDIX F

Pt No.	View	View No.	Int (1)	Int (1) Tilt	Int (2)	Int (2) Tilt	Reg (1)	Reg (1) Tilt	Reg (2)	Reg (2) Tilt	Cons (1)	Cons (1) Tilt	Cons (2)	Cons (2) Tilt	Rad (1)	Rad (1) Tilt	Rad (2)	Rad (2) Tilt
1	Lat	1	1	1	3	3	3	2	2	2	3	2	3	2	3	3	3	1
2	Lat	1	1	2	3	2	2	2	2	2	2	2	2	2	3	2	3	2
3	Lat	1	1	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
4	Lat	1	1	3	3	2	2	1	2	3	2	2	2	3	3	2	3	2
5	Lat	1	1	2	1	2	3	2	3	2	3	2	3	2	3	2	3	2
6	Lat	1	3	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2
7	Lat	1	3	1	3	3	2	3	2	3	2	3	2	3	3	3	3	3
8	Lat	1	3	2	3	3	3	3	2	3	2	2	2	2	3	3	3	2
9	Lat	1	1	1	1	1	3	3	3	1	3	3	3	3	3	3	3	1
10	Lat	1	2	2	3	2	3	2	1	2	2	2	2	2	3	3	3	2
11	Lat	1	1	1	3	3	2	1	2	3	2	3	3	3	3	3	3	3
12	Lat	1	1	2	1	3	3	1	1	2	3	2	3	2	3	2	2	2
13	Lat	1	3	2	3	2	2	2	2	2	2	2	2	2	3	2	3	2
14	Lat	1	2	1	2	1	2	1	2	3	2	3	2	3	2	3	2	1
15	Lat	1	1	3	1	2	1	2	2	2	3	2	2	2	3	3	3	2
16	Lat	1	1	2	3	2	1	2	2	2	2	2	2	2	3	2	3	2
17	Lat	1	1	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2
18	Lat	1	1	2	2	2	3	3	2	2	2	2	2	2	3	3	3	3
19	Lat	1	1	3	3	2	3	2	2	2	2	2	3	2	3	3	3	3
20	Lat	1	1	2	1	2	2	2	2	2	2	2	2	2	3	2	3	2
21	Lat	1	3	2	3	2	1	2	2	2	2	2	2	2	2	2	2	2
22	Lat	1	3	2	3	2	2	2	2	2	2	2	2	2	3	2	3	2
23	Lat	1	3	2	3	2	3	2	1	2	1	2	3	2	3	2	3	2
24	Lat	1	1	2	1	1	3	3	2	2	3	2	3	2	3	3	3	2
25	Lat	1	2	2	3	3	3	3	2	2	3	2	3	2	3	3	3	2
26	Lat	1	1	1	3	1	1	3	3	2	3	2	3	3	3	3	3	3
27	Lat	1	1	3	1	2	2	2	2	2	2	2	2	2	3	3	3	3
28	Lat	1	3	2	3	3	3	2	2	2	2	2	2	2	3	3	3	2
29	Lat	1	1	2	3	2	2	2	2	2	2	2	2	2	3	2	3	2
30	Lat	1	1	2	3	2	2	2	2	2	2	2	2	2	3	2	3	2
1	PA	2	1	2	3	3	3	2	3	2	3	2	3	2	3	2	1	2
2	PA	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2

3	PA	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
4	PA	2	1	3	3	3	3	3	3	2	3	2	3	2	3	2	1	2
5	PA	2	1	2	3	2	3	2	3	2	3	2	3	2	3	2	1	2
6	PA	2	1	2	3	2	2	2	2	2	3	2	2	2	3	2	1	2
7	PA	2	3	3	3	3	3	3	3	2	3	3	3	2	1	3	3	2
8	PA	2	3	2	3	3	3	2	3	2	3	2	3	2	3	2	2	2
9	PA	2	1	1	1	1	1	3	1	3	1	1	1	1	1	3	1	1
10	PA	2	3	3	3	3	3	3	2	2	2	2	3	2	3	2	2	2
11	PA	2	3	1	3	3	3	3	3	3	1	3	3	3	1	3	1	1
12	PA	2	2	2	3	2	2	2	2	2	2	2	2	2	3	2	2	2
13	PA	2	2	2	3	2	3	2	2	2	2	2	2	2	2	2	2	2
14	PA	2	1	3	3	3	3	2	3	2	3	2	3	2	3	2	1	2
15	PA	2	1	2	3	2	2	2	2	2	2	2	2	2	3	2	2	2
16	PA	2	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2
17	PA	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2
18	PA	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
19	PA	2	3	2	3	3	3	2	2	2	2	2	3	2	2	2	2	2
20	PA	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
21	PA	2	1	1	3	2	2	2	2	2	2	2	2	2	2	2	2	2
22	PA	2	3	2	3	2	3	2	2	2	2	2	2	2	2	2	2	2
23	PA	2	1	2	3	3	2	2	3	2	2	2	2	2	3	2	2	2
24	PA	2	3	2	3	2	3	2	2	2	3	2	3	2	3	2	2	2
25	PA	2	1	2	3	2	3	2	3	2	3	2	2	2	3	2	2	2
26	PA	2	1	2	3	2	3	2	3	2	3	2	3	2	3	2	3	2
27	PA	2	2	1	3	3	2	2	2	2	2	2	2	2	3	2	2	2
28	PA	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2
29	PA	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
30	PA	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1	PA + Lat	3	2	2	2	2	3	2	2	2	3	2	3	2	3	3	3	2
2	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
4	PA + Lat	3	3	2	2	2	2	3	1	3	2	2	3	2	2	3	2	2
5	PA + Lat	3	1	2	1	2	3	2	1	2	3	2	3	2	3	2	1	2
6	PA + Lat	3	2	2	2	2	1	2	2	2	3	2	3	2	3	2	2	2
7	PA + Lat	3	2	2	3	1	2	3	2	3	3	2	3	1	3	3	3	2
8	PA + Lat	3	1	2	1	2	1	2	2	2	3	2	3	2	3	3	2	2
9	PA + Lat	3	1	3	1	1	1	1	1	1	3	1	1	1	3	1	3	3
10	PA + Lat	3	2	2	2	2	3	3	1	2	2	2	2	2	2	2	2	2
11	PA + Lat	3	2	3	1	2	2	3	1	1	3	3	1	3	1	3	1	1

12	PA + Lat	3	1	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2
13	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	PA + Lat	3	3	3	2	1	2	3	2	1	2	2	3	2	2	3	2	2
15	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
16	PA + Lat	3	2	2	3	2	2	2	2	2	2	2	2	2	3	2	2	2
17	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
18	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
19	PA + Lat	3	1	2	2	2	3	2	2	2	2	2	2	2	3	2	2	2
20	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
21	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
22	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
23	PA + Lat	3	1	2	1	2	1	2	3	2	3	2	3	2	3	2	2	2
24	PA + Lat	3	1	2	1	2	1	2	1	2	3	2	3	2	3	3	1	2
25	PA + Lat	3	2	2	1	2	1	2	2	2	3	2	3	2	3	2	2	2
26	PA + Lat	3	1	1	1	2	1	2	1	2	1	2	1	3	3	2	1	2
27	PA + Lat	3	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
28	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2
29	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
30	PA + Lat	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

REFERENCES

1. Chung KC, Watt AJ, Kotsis SV, Margaliot Z, Haase SC, Kim HM. Treatment of unstable distal radial fractures with the volar locking plating system. J Bone Joint Surg Am. 2006; 88(12):2687-94.

2. Orbay JL, Fernandez DL. Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report. J Hand Surg Am. 2002; 27(2):205-15.

3. Rozental TD, Blazar PE. Functional outcome and complications after volar plating for dorsally displaced, unstable fractures of the distal radius. J Hand Surg Am. 2006; 31(3):359-65.

4. Willis AA, Kutsumi K, Zobitz ME, Cooney WP. Internal fixation of dorsally displaced fractures of the distal part of the radius. A biomechanical analysis of volar plate fracture stability. J Bone Joint Surg Am. 2006; 88(11):2411-7.

5. Drobetz H, Bryant AL, Pokorny T, Spitaler R, Leixnering M, Jupiter JB. Volar fixed-angle plating of distal radius extension fractures: influence of plate position on secondary loss of reduction--a biomechanic study in a cadaveric model. J Hand Surg Am. 2006; 31(4):615-22.

6. Schuind FA, Linscheid RL, An KN, Chao EY. A normal data base of posteroanterior roentgenographic measurements of the wrist. J Bone Joint Surg Am. 1992; 74(9):1418-29.

7. Mann FA, Kang SW, Gilula LA. Normal palmar tilt: is dorsal tilting really normal? J Hand Surg Br. 1992; 17(3):315-7.

8. RANDOM.ORG. [Online]. [cited 2013 03 25]. Available from: http://www.random.org/sequences/.

9. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977; 33(1):159-74.

10. Mekhail AO, Ebraheim NA, McCreath WA, Jackson WT, Yeasting RA. Anatomic and X-ray film studies of the distal articular surface of the radius. J Hand Surg Am. 1996; 21(4):567-73.

11. Lundy DW, Quisling SG, Lourie GM, Feiner CM, Lins RE. Tilted lateral radiographs in the evaluation of intra-articular distal radius fractures. J Hand Surg Am. 1999; 24(2):249-56.

12. Johnson PG, Szabo RM. Angle measurements of the distal radius: a cadaver study. Skeletal Radiol. 1993; 22(4):243-6.

13. Soong M, Got C, Katarincic J, Akelman E. Fluoroscopic evaluation of intra-articular screw placement during locked volar plating of the distal radius: a cadaveric study. J Hand Surg Am.

2008; 33(10):1720-3.

14. Yi JW, Kim RG, Choi JH, Kim JK. Use of standard and anatomic-tilt lateral X-rays to determine distal radius volar angulation. J Hand Surg Am. 2012; 37(4):736-40.

15. Kumar D, Breakwell L, Desmukh SC, Singh BK. Tangential views of the articular surface of the distal radius-aid to open reduction and internal fixation of fractures. Injury. 2001; 32(10):783-6.

16. Boyer MI, Korcek KJ, Gelberman RH, Gilula LA, Ditsios K, Evanoff BA. Anatomic tilt x-rays of the distal radius: an ex vivo analysis of surgical fixation. J Hand Surg Am. 2004; 29(1):116-22.

17. Melton JT, Southgate JJ. Modified lateral radiograph for assessment of the radiocarpal joint following palmar plating of the distal radius. J Hand Surg Eur Vol. 2009; 34(2):274-5.