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Mentorship: a two-way street

Cameron M Anley*

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Throughout our orthopaedic training and subsequent careers, we interact with many teachers and colleagues who help us develop our surgical skills and orthopaedic knowledge. Some may become personal role models, from whom we learn more than the basics of orthopaedics. They help to mould our orthopaedic ‘character’, influencing among other aspects, our bedside manner, compassion towards patients and their families, how we interact with colleagues and how we maintain a healthy work–family balance. Mulcahey et al. clarified these concepts by highlighting that a teacher shares knowledge with a learner while a role model demonstrates behaviour patterns in a passive manner and without conscious effort.1 Although the ability to teach and set a positive example as a role model are considered crucial characteristics of a mentor, these roles should not be confused with mentorship.

The precise definition of mentorship varies widely in the literature. Taking key aspects from various definitions, mentorship can be described as where a senior respected and knowledgeable colleague (mentor) offers their time to coach, teach and guide a younger colleague (mentee) regarding personal aspects, professional attitudes and education. This requires dynamic, active involvement from both the mentor and the mentee and should enhance both of their careers.1-3

The importance of mentorship seems to be underestimated by many orthopaedic surgeons. A recent survey conducted on South African orthopaedic surgeons demonstrated that 72% of those who responded face burnout.4 One of the strategies commonly recognised is the time commitment required to be a mentor.5-7 Although various mentorship models have been developed, the most productive and commonly encouraged method is one-to-one mentorship (dyadic method).2 The success of dyadic mentoring relies on willing mentees and qualified mentors. The first phase of mentorship is initiation.3 During this phase, the mentorship relationship is established. Various methods have been suggested to match a mentee with a mentor. However, many articles have highlighted that the majority of successful outcomes rely on a mentee choosing their mentor.1,2,7-9 The relationship’s success depends upon the commitment of both parties to attend regular meetings during which they establish goals for the mentee and monitor their progress. These goals will vary according to the mentee’s needs and can be personal, work or research related. After discussion with their mentor, a mentee may also consider having more than one mentor.

The programme’s second or cultivation phase is the most fruitful to both parties as the mentorship develops. The third phase is the separation phase, where the mentorship has achieved its goals, and the relationship becomes more collegial than mentorial. The final redefinition stage can be indefinite, where the hierarchical order no longer exists between the mentee and mentor.5 An essential aspect of mentorship is the benefit derived by both the mentee and mentor. Much research has shown a significant benefit to the mentor, including personal fulfilment (‘giving back’), development of leadership and coaching skills, and renewed interest in personal career.10 Senior colleagues should be encouraged to develop the necessary skills to become mentors. Unfortunately, teaching and demonstrating brilliant surgical skills and knowledge does not always translate into being a great mentor. Specific courses have been developed, and there are multiple online resources available that can guide potential mentors through the process.

Although various mentorship models have been developed, the most productive and commonly encouraged method is one-to-one mentorship (dyadic method).2 The success of dyadic mentoring relies on willing mentees and qualified mentors. The first phase of mentorship is initiation.3 During this phase, the mentorship relationship is established. Various methods have been suggested to match a mentee with a mentor. However, many articles have highlighted that the majority of successful outcomes rely on a mentee choosing their mentor.1,2,7-9 The relationship’s success depends upon the commitment of both parties to attend regular meetings during which they establish goals for the mentee and monitor their progress. These goals will vary according to the mentee’s needs and can be personal, work or research related. After discussion with their mentor, a mentee may also consider having more than one mentor.

The importance of the respective roles and responsibilities of the mentee and mentor is highlighted in various articles.1-3 In essence, the mentee must respect the time that the mentor is offering and should thus be prepared for meetings, achieve the agreed goals, and demonstrate a willingness to learn and develop.

Regardless being a mentor, one of the major impediments commonly recognised is the time commitment required to be a mentor.5 Once this has been overcome, several specific traits have been identified as essential to being a good mentor. These include, but are not limited to, being available and reliable with regard to meetings; allowing the mentee to express themselves and listening attentively before offering unbiased advice; not allowing their ego to prevent celebrating the success of the mentee’s achievements; and eventually acknowledging the development of the mentee into a colleague.5-3,9

The programme’s second or cultivation phase is the most fruitful to both parties as the mentorship develops. The third phase is the separation phase, where the mentorship has achieved its goals, and the relationship becomes more collegial than mentorial. The final redefinition stage can be indefinite, where the hierarchical order no longer exists between the mentee and mentor.5 An essential aspect of mentorship is the benefit derived by both the mentee and mentor. Much research has shown a significant benefit to the mentor, including personal fulfilment (‘giving back’), development of leadership and coaching skills, and renewed interest in personal career.10 Senior colleagues should be encouraged to develop the necessary skills to become mentors. Unfortunately, teaching and demonstrating brilliant surgical skills and knowledge does not always translate into being a great mentor. Specific courses have been developed, and there are multiple online resources available that can guide potential mentors through the process.
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We thank the patients and staff of all the hospitals in England, Wales, Northern Ireland and the Isle of Man who have contributed data to the National Joint Registry. We are grateful to the Healthcare Quality Improvement Partnership (HQIP), the NJR Steering Committee and staff at the NJR Centre for facilitating this work. The views expressed represent those of Heraeus Medical GmbH and do not necessarily reflect those of the National Joint Registry Steering Committee or the Health Quality Improvement Partnership (HQIP) who do not vouch for how the information is presented.

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From a personal point of view, I first met my current mentor in his role as a teacher in the mid-2000s. He was a great teacher, passionate and enthusiastic about his field of expertise. Through my interaction with him, due to the humbleness and absolute respect he demonstrated to his patients and colleagues, he became a role model to me. About 18 months ago, he started assisting me as my mentor. I was honoured that he could offer me the time, given his extensive workload. Our first meeting was extremely productive, and together, we formulated a plan for the way forward. Importantly, he made me accountable to him to take certain actions we had agreed upon, and the benefits to me have been immense. Together, we have rekindled my enjoyment of orthopaedics.

Vincent Pellegrini Jr, as the president of the American Orthopaedic Association, eloquently summarised being a mentor and mentorship as follows:11

‘An effective mentor is the guardian and promoter of the young physician’s personal and professional development. So, mentoring is the act of nurturing the emotional and intellectual growth of another person to the point that, and here comes the hard part, he or she is your peer and equal and, ideally, has eclipsed your own accomplishments with the tools and opportunities that you have provided. This requires a special person, with just the right balance of self-confidence and humility, which may be a challenge for any one of us to achieve on any particular day.’

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Impact of correctable mediolateral tibiofemoral subluxation on unicompartmental knee arthroplasty implant survival in patients with anteromedial osteoarthritis

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Abstract

Background

Medial unicompartmental knee arthroplasty (UKA) is advocated for treating symptomatic anteromedial osteoarthritis (AMOA). Correctable mediolateral tibiofemoral (TF) subluxation can be safely ignored according to the UKA enthusiasts. However, no clinical studies compare the results in AMOA patients with and without subluxation. This study reports the early prospective clinical outcomes of medial UKA in AMOA, with and without correctable mediolateral TF subluxation and the comparison to the retrospective larger patient cohort.

Methods

The results of an initial retrospective study (R) consisting of 436 consecutive UKA cases (patients treated from May 2012 to October 2017) were compared to a prospective study (P) consisting of 272 consecutive UKA cases in 248 patients with AMOA (evaluated from November 2017 to May 2020). All patients in both cohorts underwent cementless Oxford UKA and were classified into two groups: group 1 (AMOA without mediolateral subluxation) and group 2 (AMOA with mediolateral subluxation) on anteroposterior (AP) radiological knee stress views. Survival analysis methods (Kaplan–Meier and logrank test) were utilised to compare implant survival between the two groups (1 and 2) and the cohorts (R and P). The multivariable Cox proportional hazards model was used to determine risk factors for time to revision.

Results

The two cohorts, R and P, had patient groups (group 1 vs group 2) matched for age, sex, wear pattern, preoperative Oxford Knee Score and follow-up period. The overall implant survival for the P cohort that had at least 20 months of follow-up was 98%. The overall implant survival for group 1 (AMOA without mediolateral subluxation) and group 2 (AMOA with mediolateral subluxation) on anteroposterior (AP) radiological knee stress views. Survival analysis methods (Kaplan–Meier and logrank test) were utilised to compare implant survival between the two groups (1 and 2) and the cohorts (R and P). The multivariable Cox proportional hazards model was used to determine risk factors for time to revision.

Conclusion

Patients with AMOA and correctable mediolateral TF subluxation have a significantly higher risk of implant failure compared to those without subluxation. This study establishes this association, which has an important implication on patient selection, but does not confirm causality.

Level of evidence: Level 4

Keywords: unicompartmental knee arthroplasty, partial, osteoarthritis, X-ray, implant
Introduction

Medial unicompartmental knee arthroplasty (UKA) is advocated for treating symptomatic anteromedial osteoarthritis (AMOA). By definition, AMOA has bone-on-bone medial compartment osteoarthritis (OA) in the presence of intact ligaments and a functionally intact lateral tibiofemoral (TF) compartment. To confirm the diagnosis of AMOA, use of varus and valgus stress radiographs in addition to weight-bearing anteroposterior (AP) and lateral radiographs is recommended. These radiographs are performed with the patient lying supine and the knee under study flexed at 20°, with either manual or aided stress applied to the knee. The technique is well described elsewhere. A varus stress radiograph is the most reliable radiographic method to demonstrate full thickness loss of articular cartilage (bone-on-bone contact) between the medial femoral and tibial condyles. A valgus stress radiograph helps confirm normal thickness of articular cartilage in the lateral TF compartment and demonstrates that the intra-articular varus deformity is correctable (i.e., the medial collateral ligament is not shortened). In patients with AMOA, the wear pattern on the medial tibial plateau does not extend to the posterior margin of the tibia, and in all the cases there is intact articular cartilage on the posterior margin of the medial tibial plateau.

In a proportion of patients with AMOA, a preoperative AP radiograph demonstrates the presence of mediolateral subluxation of the femur on the tibia. It is typically seen when there is significant loss of bone from the medial compartment (varus > 10°) and this subluxation persists with a varus stress view. The Oxford Group suggests that in such cases, if the valgus and varus stress views show complete reduction of the mediolateral subluxation, the presence of preoperative subluxation can be safely ignored. If the subluxation persists, it is indicative of anterior cruciate ligament (ACL) deficiency and is therefore a contraindication for Oxford UKA (OUKA). Although this has been advocated, no studies exist comparing the long-term results of OUKA in patients with correctable subluxation with those without any subluxation.

Does the subluxation on weight-bearing knee X-rays affect the results and outcome of UKA?

This single centre, single surgeon cohort study of consecutive cases has two aims: first, to present early prospective (P) results of OUKA in patients with AMOA between patients with correctable preoperative mediolateral TF subluxation and those without, from an independent centre; and second, to similarly compare the outcomes of a larger medium-term retrospective (R) AMOA cohort followed up by the same surgeon until 2020.

Methods

The prospective cohort (P) study comprised 272 consecutive AMOA knees (248 patients) treated with medial OUKA (Zimmer Biomet, Warsaw, USA) over a 31-month period from November 2017 to May 2020. The larger retrospective cohort (R), comprising 436 cases from May 2012 to October 2017, was then similarly evaluated according to the selection criteria for OUKA as per the published recommendations. All patients underwent a standardised preoperative work-up including detailed clinical assessments and a series of radiographs as described previously. Preoperative Oxford Knee Score (OKS) and range of movement (ROM) was recorded. The ACL status and integrity of the lateral TF compartment were confirmed intraoperatively. If ACL was found to be friable and fragmented or absent, the patient underwent a total knee arthroplasty (TKA). In addition, the tibial wear pattern was carefully recorded using a method described by White et al. The wear pattern was labelled as either anterior, or central or posterior according to the location of the deepest area of wear in relation to the AP tibial plateau dimension. All plain radiographs were assessed by an independent assessor for the presence or absence of mediolateral TF subluxation and patients were grouped accordingly into group 1 (patients with AMOA without any evidence of mediolateral subluxation) and group 2 (patients with AMOA with presence of mediolateral subluxation). In all cases in group 2, the mediolateral subluxation completely corrected on valgus stress view with parallel reduction of the lateral joint space thereby confirming the suitability for OUKA.

To simplify the assessment of subluxation on the AP views, it was defined as any overhang of the femoral condyle (excluding osteophytes) over the medial border of the tibia.

Figure 1. Group 1 preoperative radiographs. a) 15° AP; b) varus stress view; c) valgus stress view
All patients underwent a cementless medial OUKA using the recommended surgical technique with Microplasty® instrumentation with standardised postoperative management. Patients were followed up at predetermined regular intervals (three months and then annually after surgery) with clinical and radiological assessment. Clinical assessment included OKS, a validated and widely used patient-reported outcome measure (PROM) and active ROM. All complications and/or further interventions on the index knee were recorded on an anonymised secure database. Any surgical intervention needed for removal or exchange of an existing implant or addition of another implant was labelled as revision.

**Statistical analysis**

Description of categorical variables was reported as a number and percentage. Associations between categorical variables were evaluated using chi-square ($\chi^2$) or Fisher’s exact tests as appropriate. Continuous variables were summarised and presented as mean and range, or as median and interquartile range (IQR). A student’s t-test for normally distributed data or Mann-Whitney U test for non-normally distributed data was used to compare group differences in continuous variables. Survival analysis methods such as the Kaplan–Meier survival curves and logrank test were utilised to assess the patterns of implant survival between patients’ characteristics. The multivariable Cox proportional hazards model was used to fit the predictive model for time to revision. A two-sided 5% significance level was used in all the statistical tests.

**Results**

The prospective (P) cohort of 272 knees (248 patients) included 162 (60%) men and 110 (40%) women with an average age of 64 (40–92; SD = 10) years at time of operation. The mean follow-up was 20 months (range 4–34; SD = 10). The mean postoperative OKS in the non-revised knees (at the time of last follow-up) was 43 (range 14–48; SD = 6.3), while for the revised knees it was 44 (range 26–48; SD = 5.6). The mean ROM was 0.3° (range 0–3; SD = 0.86) to 140° (range 120–150; SD = 6.2).

The retrospective (R) cohort of 436 knees (388 patients; 175 [40%] females and 261 [60%] males) had an average age of 64 years (range 42–87, SD = 8.7) at operation. The mean postoperative follow-up was 54 months. The mean postoperative OKS in the non-revised knees (at the time of last follow-up) was 44 (range 12–48, SD = 5.7), while for the revised knee it was 42 (range 22–48, SD = 8.0). The mean ROM for this cohort was 0.68° (range 0–5, SD = 1.3) to 138° (range 110–150, SD = 8.2).

The patient demographics (Table I), implant survival rates (Table II), and clinical outcomes and complications (Table III) for group 1 and group 2 in the respective cohorts P and R are summarised accordingly. The two groups were well matched for all relevant patient demographics as well as preoperative scores, ROM, follow-up period and tibial wear patterns.

The complications were not associated with a specific wear pattern.

**Reasons for revision**

In total, six knees underwent revision at a mean of 25 months (SD = 10.9; range: 8.1–33.2 months) post base year of follow-up in the P cohort. These included two for tibial subsidence, two for bearing dislocation and two for progression of arthritis in the lateral compartment. The R cohort had 23 knees that underwent revision, and these had a slightly longer duration before revisions. The detail of the complications and procedures performed are detailed in Table III.

The life table analysis for patients who had surgery between 2012 and 2017 (R cohort) is presented in Table II with the
respective implant survival for group 1 and group 2. The first three years’ implant survival for patients in both group 1 and 2 was 100%. The implant survival in the subsequent two years was 99% (95% confidence interval [CI]: 96.9–99.6) among those who were diagnosed without mediolateral subluxation (group 1) and 96% (95% CI: 96.2–98.8) among those with mediolateral subluxation (group 2) respectively. The difference between the two groups was statistically significant overall (p = 0.0097) over the follow-up period. The P cohort had only three years of follow-up and in that period, survival for group 1 was 99% (95% CI: 96–99.6) while group 2 was 93% (95% CI: 80.3–97.8). Figure 3 shows the failure patterns in the two groups for both cohorts.

Multivariate Cox regression analysis showed that presence or absence of mediolateral subluxation was a significant independent

| Table I: Patient demographics and relevant preoperative data |
|---------------------------------|----------------|----------------|----------------|----------------|
| Category                        | Prospective (P) cohort | Retrospective (R) cohort | Prospective (P) cohort | Retrospective (R) cohort |
| Group 1      | Group 2 | Group 1 | Group 2 | Group 1 | Group 2 |
| Cases 228     | 44     | 352     | 84       |
| Age in years at operation; mean (SD) 64 (9.5) 64 (11.2) 65 (8.8) 64 (8.5) |
| Males 64 (9.5) 64 (9.9) 65 (8.4) 63 (8.6) |
| Females 64 (9.6) 70 (13.0) 64 (9.3) 64 (8.4) |
| Tibial wear pattern: Anterior 51 (22%) 5 (11%) 87 (25%) 10 (12%) |
| Central 161 (71%) 35 (80%) 247 (70%) 67 (80%) |
| Posterior 16 (7%) 4 (9%) 18 (5%) 7 (8%) |
| Preoperative ROM; mean (from–to) 3–128°* 4–129°* 2–131°* 3–126°* |
| Preoperative OKS; mean (SD) 21 (8.1) 21 (10.1) 22 (8.0) 23 (8.6) |

| Table II: Life table analysis with 95% CI for implant revision for any cause in the 2012–2017 (R) cohort |
|---------------------------------|-----------------|----------------|
| Follow-up (years) | Group 1 | Group 2 |
| No. at start | Survival (95% CI) | No. at start | Survival (95% CI) |
| 0–3 (base) | 352 | 100% (95% CI: 96–99.6) | 84 | 100% |
| 4–5 | 339 | 99% (96.9–99.6) | 83 | 96% (89.2–98.8) |
| 6–8 | 132 | 93% (88.3–96.5) | 52 | 80% (66.7–88.1) |

| SD: standard deviation; ROM: range of movement; OKS: Oxford Knee Score |

| Table III: Clinical outcomes and complications for the two groups in cohort |
|---------------------------------|----------------|----------------|----------------|----------------|
| Category | Prospective (P) cohort | Retrospective (R) cohort | Prospective (P) cohort | Retrospective (R) cohort |
| Group 1 (n = 228) | Group 2 (n = 44) | Group 1 (n = 352) | Group 2 (n = 84) |
| Follow-up period in months; mean (SD) 21 (8.8) 18 (8.4) 57 (15.9) 66 (16.0) |
| Postoperative ROM; mean (from–to) 0.3–140° 0–138° 1–138° 0–138° |
| Most recent postoperative OKS; mean (SD) 43 (6.3) 44 (5.6) 44 (5.7) 43 (8.0) |
| Complications needing revision surgery 3 (1%) 3 (7%) 11 (3%) 12 (14%) |
| Average period to implant failure in months; mean (SD) 24 (13.5) 27 (10.3) 63 (17.1) 65 (16.6) |
| Bearing dislocation – with revision of medial UKA (polyethylene replaced) 0 1 1 2 |
| Bearing dislocation – with revision of medial UKA (implant replaced) 0 1 0 0 |
| Lateral compartment OA – with revision to lateral UKA 2 0 3 3 |
| Tibial subsidence – with revision of medial UKA (implant replaced) 1 1 1 0 |
| Tibial subsidence – with revision of medial UKA (polyethylene replaced) 0 0 2 0 |
| Avascular necrosis in the lateral compartment – with revision to lateral UKA 0 0 1 0 |
| Tibia fracture – with revision to TKA 0 0 0 2 |
| Impingement – with revision of medial UKA (implant replaced) 0 0 0 1 |
| ACL trauma and polyethylene dislocation – with revision of medial UKA (polyethylene replaced) and ACL reconstruction 0 0 0 1 |
| Loose prosthesis – with revision to TKA 0 0 0 1 |
| No bone growth to attach prosthesis – with revision to TKA 0 0 1 0 |
| Complication unknown – patients underwent revision surgery to TKA from other surgeons 0 0 2 2 |

SD: standard deviation; ROM: range of movement; OKS: Oxford Knee Score; UKA: unicompartmental knee arthroplasty; OA: osteoarthritis; TKA: total knee arthroplasty; ACL: anterior cruciate ligament
predictor of implant failure (Table IV). A patient with preoperative mediolateral subluxation had, on average, a three times higher risk of surgical failure (adjusted hazard ratio [aHR] = 3.3; 95% CI: 1.4–8.7; p = 0.0170) compared to a patient without mediolateral subluxation. Age, sex and wear pattern were not significantly associated with the risk of implant failure in this cohort (Table IV).

Discussion
This is the first prospective study to assess the impact of preoperative correctable mediolateral subluxation on the outcomes of UKA in patients with AMOA. Although this is a short prospective study, it confirms the higher failure rate, contrary to the previous recommendations in the literature, when compared to those with AMOA without preoperative mediolateral subluxation.²

AMOA knee is an ideal indication for UKA. Various studies have demonstrated the clinical effectiveness and cost-savings of UKA over TKA in such patients.³⁻⁴ In a significant proportion of patients, preoperative AP radiographs reveal the presence of mediolateral subluxation. Although the exact aetiology for such subluxation is unknown, it is believed to be associated with significant wear and/or bone loss and potentially ACL deficiency – the latter being a contraindication for mobile-bearing UKA.⁴ To ascertain the suitability of such patients for UKA, it is recommended that patients should be assessed using stress views – particularly the valgus stress – and intraoperative assessment of the lateral compartment as well as ACL integrity.⁵ If valgus stress and intraoperative inspection confirms suitability for UKA, patients could be safely offered a UKA. In this series, we prospectively collected data on all the patients undergoing UKA. This included careful recording of preoperative patient demographics including radiological stress views, intraoperative assessment for suitability for UKA, tibial wear patterns and regular clinical follow-up at predetermined intervals. In our cohort we noted correctable mediolateral subluxation in 27% of cases. The implant survival was significantly inferior in patients with correctable mediolateral subluxation compared to those without subluxation. There were no significant differences in demographics between the two patient groups. Although the reasons for implant failure were similar in the two patient cohorts, the frequency of bearing dislocation was significantly higher in patients with mediolateral subluxation.

The assessment of wear patterns was compared to the area of wear (Table V), and no association of complications with a specific wear pattern could be found. If we assess the risk of implant revision based on the pattern of tibial wear, it is interesting to note that the risk increases when the wear pattern changes from anterior to central or posterior. The central/posterior area of wear may contribute to pseudolaxity and higher incidence of bearing dislocation. Although the centre of the deepest portion of the wear pattern was posterior to midline in none of the cases, the wear extended to the posterior margin of the medial tibial plateau. In all cases, the ACL was functionally intact.

Figure 3. Surgical failure in group 1 and group 2 by the presence or absence of mediolateral subluxation on preoperative radiographs in patients followed up a) retrospectively and b) prospectively.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Prospective (P) cohort</th>
<th>Retrospective (R) cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>aHR (95% CI)</td>
<td>p-value</td>
</tr>
<tr>
<td>Mediolateral subluxation</td>
<td>Group 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>11 (1.67–66.1)</td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>0.41 (0.06–2.92)</td>
</tr>
<tr>
<td>Wear pattern</td>
<td>Anterior</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Central/posterior</td>
<td>0.82 (0.08–8.58)</td>
</tr>
<tr>
<td>Age at surgery</td>
<td></td>
<td>1.0 (0.91–1.1)</td>
</tr>
</tbody>
</table>

aHR: adjusted hazard ratio; CI: confidence interval
Table V: Patient characteristics for failed vs not failed implants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Prospective (P) cohort</th>
<th>Retrospective (R) cohort</th>
<th>p-value</th>
<th>Prospective (P) cohort</th>
<th>Retrospective (R) cohort</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surgery failed, n (%)</td>
<td>Surgery not failed, n (%)</td>
<td></td>
<td>Surgery failed, n (%)</td>
<td>Surgery not failed, n (%)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>Female</td>
<td>2 (2)</td>
<td>108 (98)</td>
<td>0.535*</td>
<td>11 (6)</td>
<td>164 (94)</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>4 (3)</td>
<td>158 (97)</td>
<td></td>
<td>12 (5)</td>
<td>249 (95)</td>
</tr>
<tr>
<td>Age in years (range)</td>
<td></td>
<td>64 (57–72)</td>
<td>64 (40–92)</td>
<td>0.865**</td>
<td>64 (48–76)</td>
<td>65 (42–87)</td>
</tr>
<tr>
<td>Mediolateral subluxation</td>
<td>Group 1</td>
<td>3 (1.3)</td>
<td>225 (98.7)</td>
<td>0.056*</td>
<td>11 (3)</td>
<td>341 (97)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>3 (6.8)</td>
<td>41 (93.2)</td>
<td></td>
<td>12 (14)</td>
<td>72 (86)</td>
</tr>
<tr>
<td>Tibial wear pattern</td>
<td>Anterior</td>
<td>1 (2)</td>
<td>55 (98)</td>
<td>0.739*</td>
<td>4 (4)</td>
<td>93 (96)</td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td>5 (3)</td>
<td>191 (97)</td>
<td></td>
<td>18 (6)</td>
<td>296 (94)</td>
</tr>
<tr>
<td></td>
<td>Posterior</td>
<td>0 (0)</td>
<td>20 (100)</td>
<td></td>
<td>1 (4)</td>
<td>24 (96)</td>
</tr>
</tbody>
</table>

*p-chi-squared test
** independent-samples student’s t-test

(on intraoperative assessment), thereby confirming the patient’s suitability for UKA as per established criteria.

This study has certain limitations. It is a single surgeon, single centre study with a short prospective element conforming to the trend seen in the larger retrospective cohort which cannot yet be generalised. The prospective cohort also had very few failures (only six) for both groups, which could increase uncertainty in the risk estimate due to limited power. However, analysis of the prospective (P) cohort is still under continuous evaluation, and will be submitted when the five-year mean has been achieved. The study confirms association (and not causality) between higher implant failures and patients with pre-existing correctable mediolateral subluxation in patients with AMOA.

The indications for surgery, surgical technique and postoperative regimen were standardised. All patients were followed up with detailed records of their clinical outcomes and complications. The follow-up is adequate and overall implant survival is similar to other reported series with the use of cementless OUKA.

Further work is needed to establish if similar findings are observed by other researchers, and attempts should be made to understand the association between smoking status, tibial wear patterns, coronal subluxation and implant failure.

Conclusion

The AMOA with anterior wear and without mediolateral subluxation is the most suitable knee for UKA. In patients with correctable preoperative mediolateral subluxation, caution must be exercised when offering a cementless UKA.

Acknowledgements

The authors would like to thank Margaret Houman (research manager) and Andricha Viljoen (researcher) for their contributions.

Ethics statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

All procedures were in accordance with the ethical approval obtained from the Human Research Ethics Committee at the University of the Witwatersrand (Wits) with clearance certificate numbers M1704111 and M1704112. All patients provided informed consent for inclusion in the study.

Declaration

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

Professor Pandit is a National Institute for Health Research (NIHR) Senior Investigator.

HP: Design, manuscript preparation and revision, critical revision for important intellectual content

SM: Design, manuscript preparation and revision, supervisor, final approval of manuscript version submitted to the journal

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References

Preoperative asymptomatic bacteriuria in patients undergoing total joint arthroplasty in South Africa

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Abstract

Background

Periprosthetic joint infections (PJIs) are a leading cause of revision for total hip arthroplasty (THA) and total knee arthroplasty (TKA), worldwide. Asymptomatic bacteriuria (ASB) is an independent risk factor for PJIs; however, a paucity of data relevant to developing countries exists. The aim of this study was to describe the prevalence of preoperative ASB and the subsequent incidence of PJIs in patients undergoing total joint arthroplasty (TJA) in South Africa.

Methods

We retrospectively reviewed primary THA and TKA patients. All patients were screened for ASB preoperatively. Patients with positive urinalysis for ASB were identified and treated prior to surgery (treated-ASB). The primary outcome was ASB prevalence and the incidence of PJIs and other perioperative complications. Secondary outcomes included risk factors for ASB and subsequent PJIs in treated-ASB patients, respectively, compared to those with no evidence of ASB (non-ASB). Lastly, we aimed to compare the infective microorganisms cultured from preoperative urinalysis and perioperative sampling of PJIs.

Results

We included 179 patients (67 THA; 80% female) with mean follow-up of 2.45 years. ASB prevalence was 22% (n = 39). Patients older than 70 years were 3.5 times more likely to have ASB compared to younger patients (p = 0.005). The prevalence of ASB was 22% (n = 10) for human immunodeficiency virus (HIV) positive and 22% (n = 29) for HIV-negative patients (p = 0.884). PJI incidence was 8% (n = 3) in the treated-ASB and 1% (n = 1) in non-ASB. Treated-ASB patients had an 11.6-fold increased likelihood of PJIs than non-ASB patients (p = 0.046). PJI microorganisms cultured did not correlate to isolates from urine cultures.

Conclusion

The prevalence of ASB in a TJA population in South Africa is 22% which is higher than reported findings worldwide. Although the value of preoperative antibiotic therapy for ASB remains controversial, there is a role for routine urinalysis preoperatively to identify patients predisposed to PJI. This is of specific significance in the management of HIV-positive patients and in developing countries to guide healthcare providers in resource-constrained environments.

Level of evidence: Level 2

Keywords: total hip arthroplasty, total knee arthroplasty, asymptomatic bacteriuria, periprosthetic joint infection, developing country

Introduction

A significant demand for total joint arthroplasty (TJA) exists, with over 1 million procedures performed in the United States of America (USA) annually alone.1 The average rate of total hip arthroplasty (THA) has increased by approximately 30%, while the performance of total knee arthroplasty (TKA) procedures doubled globally between 2000 and 2015.2 Demand for TJA continues to rise and is projected to continue increasing through 2030.3 The increasing demand for TJA translates into a massive economic burden for global healthcare systems further compounded by postoperative readmissions for complications such as periprosthetic joint infections (PJIs).4 PJIs are infective postoperative complications ranging from surgical site infections (SSIs) to deep intra-articular infections. PJIs are the third most common cause of THA revisions and the most common cause of TKA revisions, globally.5 The annual cost for revisions due to PJI is expected to increase to US$1.62 billion by 2020 and has a five-year mortality rate of 21.12% after primary TJA.5 The serious implications of PJI have led to increased efforts to limit infections by the strict adherence to antibiotic prophylaxis, laminar airflow systems in operating theatres, extensive patient perioperative clinical optimisation and stringent sterilisation protocols.6 The incidence of PJI after primary TJA, however, remains at 1.4% rates despite the implementation of preventative measures.7
Asymptomatic bacteriuria (ASB) from the genitourinary tract may be a source of infection for PJI through haematogenous seeding. A multicentre study including institutions from the United Kingdom (UK), Portugal and Spain identified ASB as an independent risk factor for PJI ($p = 0.001$), especially those due to Gram-negative microorganisms. Similarly, a systematic review and meta-analysis of ten TJA studies showed an increased risk for PJI with ASB (odds ratio [OR]: 3.64; 95% confidence interval (CI) 1.40–9.42). However, Sousa et al. (2019) reported that the PJI microorganisms were unrelated to those in the urine of the patients with ASB. Furthermore, there is evidence demonstrating an association between postoperative urinary tract infections (UTI) and PJI. Identifying underlying characteristics, especially modifiable risk factors which predispose TJA patients to infection, is essential to mitigate the risk of adverse outcomes.

There is no international consensus guideline for the screening and management of ASB in patients for TJA. The British Orthopaedic Association recommends routine urinalysis for all TJA patients preoperatively; however, they are not specific on management of positive results. The Spanish Society of Infectious Diseases and Clinical Microbiology recommends treating ASB while the Antibiotic Therapeutic Guidelines for Australia do not support treatment of ASB preoperatively. A meta-analysis by Sousa et al. (2019) concluded that preoperative antibiotic treatment for ASB does not influence PJI risk and should not be implemented routinely. However, no studies have been reported for an African population, particularly concerning demographic risk factors such as human immunodeficiency virus (HIV) and body mass index (BMI). Furthermore, there is a paucity of data relating to the association between ASB and SSI. There are also economic implications of increased costs for routine screening in less-developed countries that must be considered.

The aim of this study was to assess the prevalence of ASB in patients for primary TJA in South Africa. Secondarily, we sought to determine the incidence of PJI in TJA patients with no preoperative ASB (non-ASB) compared to those who received TJA after the treatment of ASB (treated-ASB). Lastly, we evaluated risk factors for both ASB and subsequent PJI in this TJA population. We hypothesise that the high prevalence rates of HIV in South Africa would predispose this sample population to high rates of ASB and subsequent infective complications.

**Materials and methods**

We conducted a retrospective review of prospectively collected data for patients undergoing primary TJA at an academic referral institution in Johannesburg, South Africa. The study was conducted between January 2015 and December 2016. Patients included in the study were adults aged 18 years or older, undergoing primary, elective THA or TKA and who provided consent for voluntary participation in the study. Exclusion criteria included revision THA, revision TKA and patients for primary TJA who did not provide consent. All patients eligible for study inclusion were screened for evidence of symptomatic UTI. Symptoms of UTI that were assessed included a history of urinary frequency or urgency, foul-smelling urine, abnormal colour of urine, dysuria or burning on micturition and a sensation of incomplete bladder emptying. Patients with symptoms of UTI were excluded from the sample population and received appropriate treatment prior to their elective operations.

Demographic data was recorded for all study participants, including age, sex, BMI and tobacco use. Medical comorbidities documented included diabetes mellitus, hypertension and HIV status, and the American Society of Anesthesiologists Classification (ASA class) was noted. All patients provided a mid-stream urine sample that was sent for microscopy, culture and sensitivity (MC&S) by the National Health Laboratory Services (NHLS) of South Africa three days prior to surgery. The urinary specimen was considered positive for bacterial isolation if $> 100$ 000 colony-forming units/ml and antibiotic sensitivity was identified. Patients with evidence of ASB on urinalysis had their operation postponed and were treated for five days with an oral antibiotic according to microorganism sensitivity. Urine MC&S was subsequently performed, and patients received TJA only once their urine sample was sterile.

All patients underwent TJA by the same three fellowship-trained arthroplasty surgeons in a laminar-flow surgical theatre. Both THA and TKA procedures were performed under general anaesthesia (GA). All patients received both tranexamic acid (TXA) and a weight-adjusted prophylactic dose of first-generation cephalosporin intravenously at least 30 minutes before the first surgical incision. Clindamycin was given preferentially in penicillin-allergic patients. Prophylactic antibiotics were continued for 24 hours postoperatively.

All THA procedures were performed using a modified anterolateral surgical approach, and an uncemented Pinnacle acetabular shell and uncemented Corail femoral stem (DePuy Synthes, Midrand, South Africa) in all cases. All TKA were performed by a medial parapatellar surgical approach after a midline skin incision. A cruciate-sacrificing fixed-bearing cemented TKA, using Genesis II (Smith and Nephew, Durban, South Africa) TKA implants was used in all cases. All components inserted in all TKA cases were cemented using Palacos® R + G antibiotic-loaded cement (Hereaus Group, Hanau, Germany). A drain was used and was left in situ for five days with an oral antibiotic according to microorganism sensitivity. Urine MC&S was subsequently performed, and patients received TJA only once their urine sample was sterile.

We hypothesise that the high prevalence rates of HIV in South Africa would predispose this sample population to high rates of ASB and subsequent infective complications.

### Table I: Demographic data for total joint arthroplasty sample population (n = 179)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TJA, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>THA</td>
<td>67 (37)</td>
</tr>
<tr>
<td>TKA</td>
<td>31 (17)</td>
</tr>
<tr>
<td><strong>Age (years), mean (range)</strong></td>
<td>61.5 (33–83)</td>
</tr>
<tr>
<td><strong>Sex, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>144 (80)</td>
</tr>
<tr>
<td>Male</td>
<td>35 (20)</td>
</tr>
<tr>
<td><strong>BMI (kg/m²), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>≤ 30</td>
<td>77 (43)</td>
</tr>
<tr>
<td>31–39</td>
<td>73 (41)</td>
</tr>
<tr>
<td>≥ 40</td>
<td>29 (16)</td>
</tr>
<tr>
<td><strong>Aetiology, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Primary OA</td>
<td>107 (60)</td>
</tr>
<tr>
<td>Inflammatory OA</td>
<td>40 (22)</td>
</tr>
<tr>
<td>AVN</td>
<td>23 (13)</td>
</tr>
<tr>
<td>Post-traumatic OA</td>
<td>5 (3)</td>
</tr>
<tr>
<td>Other</td>
<td>4 (2)</td>
</tr>
<tr>
<td><strong>ASA class, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>48 (27)</td>
</tr>
<tr>
<td>2</td>
<td>103 (58)</td>
</tr>
<tr>
<td>3</td>
<td>28 (16)</td>
</tr>
<tr>
<td><strong>Comorbidities, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>30 (17)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>74 (41)</td>
</tr>
<tr>
<td>HIV</td>
<td>45 (25)</td>
</tr>
<tr>
<td><strong>Tobacco use, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Smoker</td>
<td>45 (25)</td>
</tr>
<tr>
<td>Non-smoker</td>
<td>134 (75)</td>
</tr>
<tr>
<td><strong>Surgical time (minutes), mean ± SD</strong></td>
<td></td>
</tr>
<tr>
<td>THA</td>
<td>94 ± 18</td>
</tr>
<tr>
<td>TKA</td>
<td>108 ± 23</td>
</tr>
</tbody>
</table>
removed within 48 hours of surgery. Physiotherapy was initiated the day after surgery and patients were discharged once they were able to mobilise independently and negotiate steps with two crutches. Postoperatively all patients were routinely followed up for readmission rates and implant failures.

Assessments were at three months, six months and one year after surgery for wound assessment. Subsequent follow-up was 14 days after surgery for wound assessment. The diagnosis of PJI was confirmed on both the traditional MSIS criteria and the current evidence-based criteria defined by Parvizi et al. (2018).

The diagnosis of PJI was definitively confirmed using the evidence-based criteria that has demonstrated a higher sensitivity and specificity compared to confirm the diagnosis of PJI definitively. The diagnosis of PJI was not noted. All infective complications across the spectrum, from wound infection to prosthesis fracture, were assessed. Data was conducted, and all postoperative complications were calculated using the Bonferroni correction. Two-sided statistical significance was p ≤ 0.05 and confidence interval of 95% (95% CI) with respective standard error (SE). All pairwise comparisons were calculated using the Bonferroni correction. For statistical analysis, the patients were divided into two groups: patients who received treatment preoperatively for ASB (treated-ASB) and those without ASB (non-ASB). Bootstrapped statistics with 1000 samples was performed. Two-sided tests were conducted for sex, age, BMI and comorbidities using chi-squared testing with continuity correction. Odds proportions were used to calculate risk ratio (RR) for an outcome of interest, and all pairwise comparisons were calculated using the Bonferroni correction. Two-sided statistical significance was p ≤ 0.05 and confidence interval of 95% (95% CI) with respective standard error (SE) was determined. All statistical analyses were performed using STATA (version 14) statistical package.

**Results**

There were 179 patients, including 67 that underwent THA and 112 TKA respectively. All patients (100%) were evaluated at a mean follow-up of 2.45 years. Demographic details of the sample population are shown in Table I. The prevalence of ASB for our TJA sample was 22% (SE 3.1; 95% CI 15.7–27.9).

The prevalence of ASB according to demographics and comorbidities is depicted in Table II. Females were 3.6 times more likely to have ASB than males (p = 0.060). The prevalence of ASB according to age was 42% (n = 15) for patients 70 years or older, 18% (n = 20) for those 51–69 years of age and 13% (n = 4) for those 50 years or younger, respectively (p = 0.005). Patients 70 years or older are 3.5 times more likely to have ASB compared to patients younger than 70 (odds ASB positive: ≥ 70 years = 0.71; < 70 years = 0.2). Patients with an ASA class of 3 were 4.6 times more likely to have ASB compared to patients with ASA class 1 (odds ASB positive: ASA 1 = 0.12; ASA 3 = 0.54; p = 0.026).

For the statistical analysis, the patients were divided into two groups: patients who received treatment preoperatively for ASB (treated-ASB) and those without ASB (non-ASB). Bootstrapped statistics with 1000 samples was performed. Two-sided tests were conducted for sex, age, BMI and comorbidities using chi-squared testing with continuity correction. Odds proportions were used to calculate risk ratio (RR) for an outcome of interest, and all pairwise comparisons were calculated using the Bonferroni correction. Two-sided statistical significance was p ≤ 0.05 and confidence interval of 95% (95% CI) with respective standard error (SE) was determined. All statistical analyses were performed using STATA (version 14) statistical package.
The prevalence of preoperative ASB in patients undergoing TJA in a single referral institution in South Africa was 22% (n = 39). This is higher than reports for similar populations in other countries. Studies indicate that the prevalence of ASB for TJA patients in Spain varies between 5.1 and 18.2%. Similarly the ASB prevalence rates for the UK range from 3.2% to 12.1%, while Finland and Portugal have reported ASB prevalence of 6.8% and 3.2% respectively for TJA patients.²⁰

Patients with preoperative ASB have been reported to be at increased risk for PJI.²⁰⁻²² In our study we found an overall incidence of 2% (n = 4) for postoperative infections, i.e., SSI and PJI after a mean follow-up of 2.45 years. Despite being treated preoperatively, patients with ASB were 11.6 times more likely to have wound complications than non-ASB patients. A similar study of 4 368 patients reported a preoperative ASB prevalence of 3.2%, and all patients received appropriate antibiotic treatment prior to TJA.²³ Weale et al. found a significantly higher rate of PJI in the ASB group (4.3%) compared to the non-ASB group (1.4%), respectively (p = 0.001).²⁴ Furthermore, patients with ASB who were not treated preoperatively have been associated with a greater risk of PJI than patients who received antibiotic treatment. In a study of 20 226 TJA patients, Honkanen et al. reported a PJI incidence of 0.3% in patients treated for ASB compared to 0.6% for a control group who were not given treatment.²⁵ In a multicentre study, Sousa et al. reported the respective incidence of PJI as 3.9% and 4.7% for ASB patients who received treatment and did not receive treatment preoperatively.²⁶ No international consensus exists to determine whether ASB should be treated preoperatively despite the association with infective complications.

Although patients for TJA with ASB have an established increased risk for PJI, the causative microorganisms are interestingly not consistently associated.²⁶⁻²⁸ The microorganisms cultured in the urine of ASB patients were all different from the PJI cultures in our study. While some studies report similar isolates between the ASB and PJI microorganisms, a systematic review and meta-analysis including 28 588 TJA patients reported that there was no causal association between microorganisms (OR: 0.98; 95% CI 0.39–2.44).²⁹⁻³³

Therefore, the value of preoperative testing for ASB may be controversial, especially in resource-constrained developing countries. However, an additional consideration in our demographic is that the prevalence of ASB was higher for HIV-positive patients than HIV-negative patients (p = 0.084). Although this was not statistically significant, this finding must be highlighted as South Africa accounts for the most people living with HIV and the highest sero-prevalence, worldwide.³⁴ There were 7.7 million people living with HIV in 2020 and 240 000 new adult infections each year. There is an established association between HIV, highly active anti-retroviral treatment (HAART) and osteo-degenerative pathology, which predisposes patients to TJA.²⁵ In a study of 1 007 TJA patients in South Africa, the sero-prevalence of HIV in patients for THA was higher than the general population.³⁶ Furthermore, the 2018 International Consensus on Orthopaedic Infections determined that HIV is an independent risk for PJI.³⁷ This emphasises the importance of ASB in HIV-positive patients that may determine a further predisposing risk factor for PJI. Screening for ASB may allow healthcare providers to identify patients at increased risk for PJIs to guide management of evolving perioperative complications. It may be used as a surrogate marker to identify those individuals likely to have infective complications. Furthermore, the strong correlation with wound complications may provide motivation for more elaborate wound care postoperatively – this, however, needs to be validated in further studies.

There were several significant findings according to demographic characteristics such as sex, age, ASA class and tobacco use in our study population. There is an associated increased prevalence of ASB associated with increasing age and female sex in the general population.³⁸ In our TJA population, females were 3.6 times more likely to have ASB than males (p = 0.060). Sousa et al. similarly reported an increased ASB prevalence for females (16.3%) compared to males (5%) (p < 0.001).³⁹ Our study also found that patients 70 years or older had the highest prevalence (18%) and were 3.5 times more likely to have ASB compared to patients younger than 70 (p = 0.005). Additionally, patients with an ASA class of 3 were 4.6 times more likely to have ASB compared to patients with ASA class 1 (p = 0.026). However, patients with a
higher ASA class were also older in age, which might account for the higher ASB prevalence noted in this group.

To the authors’ knowledge, this is the first study to investigate the prevalence of ASB in a TJA population in sub-Saharan Africa. There were several limitations identified in the study. First, the population size was small and there was no stratified sampling to identify significant risk factor associations, and type 2 error should be considered. The ASB prevalence description for a South African population may be incorporated into future systematic reviews and meta-analyses. The study may guide future research for management recommendations in immunocompromised individuals such as a randomised control trial with treated ASB-positive patients to evaluate any perceived benefit. Despite these weaknesses, there were relevant statistically and clinically significant findings to guide further research and add to current knowledge. The results for microorganism cultures may guide future aetiological studies to better ascertain the pathophysiology of PJs.

Conclusion

The prevalence of ASB in a TJA population in South Africa is 22% higher and higher than reported findings worldwide. There is an established association between preoperative ASB and increased risk of infective complications, which was reflected in our study. Although the value of antibiotic therapy for ASB remains controversial, there is a role for routine urinalysis preoperatively to identify patients predisposed to infective complications that may warrant more elaborate investigation to identify modifiable risk factors not yet known. The high prevalence of HIV represents a large immune-compromised population in South Africa. Furthermore, these findings may guide improved management of patients in other resource-constrained environments such as better wound care in these individuals at risk – a randomised control trial with treated ASB positive patients would need to be done to evaluate any perceived benefit.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. Medical clearance was obtained from the University of the Witwatersrand Human Research Ethics Committee (Medical) registered with the National Health Research Ethics Council (NHREC) of the National Department of Health (M160716). Informed consent was obtained from all patients prior to being included in the study. All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Declaration

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

Author contributions

ZM: First draft preparation, manuscript revision
TP: Data capture, first draft preparation
LM: Study conceptualisation, manuscript revision
JRTIP: Study conceptualisation, study design, manuscript revision

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Patient-reported outcomes following plantar incisions in foot surgery

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Abstract

Background
Plantar incisions may be used in a variety of surgical procedures. Despite numerous studies reporting on procedures which use plantar incisions and thus inadvertently demonstrating good results with plantar incisions, most surgeons still avoid this approach due to the fear of developing a painful plantar scar. There is a shortage of studies demonstrating a clear correlation between plantar scar formation and poor patient-reported outcomes. The aim of this study is to assess the clinical outcome of plantar incisions in various procedures.

Methods
In this retrospective study we identified all patients who underwent surgery using a plantar incision between January 2000 and December 2019. A total of 23 patients were available for assessment. Three common procedures were identified: lesser metatarsal head resection, plantar fibromatosis excision and lateral sesamoidectomy. Demographic data was collected, and clinical outcome was assessed using the Self-Reported Foot and Ankle Score (SEFAS) questionnaire. Twenty-one female (22 feet) and two male patients (two feet) were included. The mean follow-up was 124 (range 6–231) months in the plantar fibromatosis group, 111.5 (range 28–177) months in the lateral sesamoidectomy group and 106.3 (range 42–157) months in the lesser metatarsal head excision group. The study included 12 patients in the sesamoidectomy, nine patients in the plantar fibromatosis and two patients in the lesser metatarsal head excision groups. The mean age of the study population was 45 (range 20–71) years.

Results
The mean postoperative SEFAS score in our series was 44 (range 22–48). Nineteen (82%) patients scored as excellent, two (10%) patients as good, one (4%) patient as fair and one (4%) as poor. All wounds healed well with no symptomatic callouses on clinical examination requiring revision.

Conclusion
This study demonstrates that plantar incisions, irrespective of indication and orientation (21 longitudinal and three transverse), heal well and with good patient-reported outcomes. We believe that it would be erroneous to ‘avoid plantar incisions at all costs’ and that plantar incisions must be considered if deemed technically superior and with less risk than a dorsal approach.

Level of evidence: Level 4
Keywords: plantar incisions, patient-reported outcome
fibrous tissue proliferation and the subsequent formation of nodules. Surgical management has generally been reserved for pain relief, as this condition is of a benign nature. However, more recently, indications for surgery include both pain refractory to conservative treatment as well as local aggressiveness of the lesion. Three main techniques have been employed in the surgical management of plantar fibromatosis: local excision, wide excision and complete fasciectomy. Apart from recurrence, other reported complications that adversely affect patient outcomes include impaired wound healing, painful scarring, nerve entrapment and loss of arch height.

Lateral (fibular) sesamoidectomy can be performed via a dorsal or plantar approach. The dorsal approach has been the preferred approach as it avoids the possibility of causing wound problems or the formation of irritating scars secondary to the plantar approach. However, excision of the lateral sesamoid via a dorsal approach can be difficult with suboptimal exposure and the risk of damage to the adductor mechanism and interdigital nerve.

Metatarsal head resection arthroplasty, as described by Hoffman, is a surgical technique in which a transverse plantar approach is utilised to excise the metatarsal heads. This procedure is described for complex forefoot deformities usually associated with irreducible dislocation of the metatarsophalangeal joints of the lesser toes. The technique has been modified by various surgeons with good outcomes. However, numerous complications, such as painful callosities associated with these procedures, have been reported. The extent to which these complications affect patient satisfaction, however, remains unclear.

Historically, the use of plantar surgical incisions by orthopaedic and foot surgeons alike have been avoided due to fears of complications, particularly scar formation in those patients for whom postoperative non-weight-bearing wound protection would be difficult. The use of this surgical approach was first published in 1940, with Betts et al. reporting its use for the resection of Morton’s neuroma, yielding no complications. Despite numerous studies advocating plantar incisions for certain pathological entities, many surgeons still advise avoiding this approach if possible. We believe that plantar incisions heal well with little risk of a long-term symptomatic hypertrophic scar and do not necessarily correlate with poor subjective outcomes. The aim of this study was to evaluate patient-reported outcomes following plantar incisions and assess clinically for the development of hypertrophic and/or painful scar formation.

Materials and methods

Following ethical approval, we retrospectively reviewed the records of all patients who underwent foot surgery using a plantar incision between January 2000 and December 2019. Inclusion criteria included patients older than 18 years, and a minimum of six-months follow-up. Patients were excluded if their records were incomplete, or they were not available for follow-up. All surgeries were performed at a single centre by two foot-and-ankle surgeons. Subjective outcome was assessed using the validated Self-Reported Foot and Ankle Score (SEFAS) questionnaire.

The SEFAS score ranges from 0 to 48, with 0 representing the most severe disability and 48 as normal function. The grading is assessed as excellent when scoring > 41; good 34–41; fair 27–33; and poor < 27. For statistical analyses, simple descriptive statistical tools were used. All numerical values are presented as a mean with a range. Basic demographic data were also recorded.

Twenty-three patients (24 feet) met the inclusion criteria and were available for clinical evaluation and to complete the questionnaire. The study population included 21 females and two males with a mean age of 45 (range 20–71) years and a mean follow-up of 116 months.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sesamoiditis</td>
<td>8</td>
</tr>
<tr>
<td>Fracture</td>
<td>2</td>
</tr>
<tr>
<td>Avascular necrosis</td>
<td>1</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>1</td>
</tr>
</tbody>
</table>

Table II: Plantar fibroma size

<table>
<thead>
<tr>
<th>Patient</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size in mm</td>
<td>25×15×10</td>
<td>30×20×8</td>
<td>54×13×5</td>
<td>38×18×10</td>
<td>40×20×4</td>
<td>20×10×5</td>
<td>46×10×3</td>
<td>17×13</td>
<td>30×18×5</td>
</tr>
</tbody>
</table>
reconstruction, a plantar-based transverse incision, based over the lesser metatarsal heads, excising an elliptical piece of the overlying skin and superficial subcutaneous tissue was performed. Following careful soft-tissue dissection and protection of important structures, excision of the lesser metatarsal heads was carried out with an oscillating saw while maintaining the normal cascade of the lesser metatarsals. K-wires were then used to align the proximal phalanges to the metatarsals. The plantar incision was closed in a routine manner using 4-0 interrupted Nylon sutures while performing a dermodesis. The postoperative protocol entailed two weeks of strict elevation with weight bearing as tolerated in a forefoot offloading postoperative wedge shoe. Sutures were removed at three weeks and K-wires at six weeks post surgery.

Results
Five patients underwent surgical excision of plantar fibromatosis nodules through a lazy-S incision and four patients through a longitudinal plantar medial approach. No patient received radiotherapy postoperatively. All specimens were confirmed histologically, and no patient developed recurrence of nodules during follow-up. The nodular sizes are reported in Table II.

In the metatarsal head resection group, both patients were being treated with methotrexate and the patient with bilateral disease used additional disease-modifying antirheumatic drugs (DMARDs) and steroids. A biologics-free window was strictly adhered to in this patient prior to having surgery. None of the patients in the cohorts had delayed wound healing or wound infection necessitating additional surgical intervention. On clinical examination at final follow-up, all plantar incisions had healed well with no painful callosities or hypersensitivity requiring scar revision (Figures 2 and 3). The mean postoperative SEFAS score in our series was 44 (range 22–48). Nineteen (82%) patients scored as excellent, two (10%) patients as good, one (4%) patient as fair and one (4%) as poor. The SEFAS score according to procedure is reported in Table III.

The one patient who scored poorly had bilateral rheumatoid forefoot reconstruction, and complained of persistent swelling of the foot and the permanent need for orthotics due to recurrence of the lesser toe deformities. This patient had no complaints related to the plantar scars.

Discussion
There is a paucity in the literature addressing the subjective outcomes of plantar incisions. Most reports on the outcome of plantar incisions are indirectly addressed in studies evaluating

<table>
<thead>
<tr>
<th>Grading</th>
<th>Number of patients</th>
<th>Lateral sesamoidectomy</th>
<th>Plantar fibromatosis</th>
<th>Metatarsal head resection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent (&gt; 41)</td>
<td>19 (82%)</td>
<td>12</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Good (34–41)</td>
<td>2 (10%)</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Fair (27–33)</td>
<td>1 (4%)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor (&lt; 27)</td>
<td>1 (4%)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table III: SEFAS grading
outcomes of various pathologies. There is still a reluctance to utilise this approach due to the fear of complications, particularly a painful scar.

To the best of our knowledge, Richardson et al. conducted the only study in modern literature, reviewing specifically the outcome of plantar incisions for a heterogenous group of conditions. They included 89 patients who underwent plantar incisions for conditions such as adductor release, Morton’s neuroma excision and resection of metatarsal heads. Ninety-six per cent of these patients were satisfied with the outcome. The average follow-up in their study was 25 months, which is considerably less than the current study. In a prospective study assessing the outcome of longitudinal plantar incisions for excision of Morton’s neuroma, Akemark et al. demonstrated that 90% and 98% of their study population reported none to slight scar tenderness and restriction of daily activity respectively.

Ishie et al., Amin et al. and Hamalainen and Raunio all reported satisfactory results utilising a plantar approach for forefoot reconstruction in rheumatoid patients. However, none of these studies included a clear description regarding the effect of plantar scar formation on patient satisfaction. Matsumoto et al., and Hulse and Thomas demonstrated that painful callosity formation of the plantar scar is associated with recurrence of the deformity and is responsible for unsatisfactory outcomes in 40–58% of rheumatoid forefoot reconstruction cases. In comparison, Canedo et al. demonstrated a 100% patient satisfaction rate despite one patient having recurrence of deformities requiring shoe modifications and orthotics, which was the reason for her dissatisfaction.

Plantar fibromatosis is a benign but locally aggressive fibrous tissue tumour. In a recent systematic review, the recurrence rate was reported to be 74.3% in primary cases; hence, most of the literature pertaining to this condition focuses on this complication. Sammarco and Mangone formulated a pre- and intraoperative tumour-staging system based on the nodularity, the presence of skin adherence, involvement of the plantar fascia and tumour extension to the overlying flexor tendon sheath (Table IV). This tumour staging showed good correlation with postoperative wound complications and recurrence. Isolated and solitary nodules can be excised using a transverse approach not crossing the RSTLs. In this study, the majority of patients had extensive lesions (large or multinodular) which required a longitudinal incision crossing the RSTLs, in order to gain adequate exposure. Eight of the nine patients scored good to excellent on the SEFAS score with no wound complications or painful scar formation. Only one patient scored as fair and upon reviewing the patient’s surgical records, it was noted that this patient had multifocal disease with tumour adherence to overlying skin (stage III).

Lateral sesamoidectomy can be performed through either a dorsal or plantar approach. The dorsal is the favoured approach as it avoids the risk of plantar wound complications but is technically more difficult unless there is a relatively large web space due to metatarsus primus varus. Richardson et al. included 105 longitudinal plantar incisions for various conditions and although sesamoid conditions were not included, the plantar incisions used were not dissimilar to the plantar incision used for lateral sesamoidectomy. They found six patients with punctate keratosis which was asymptomatic in two of the patients. The remaining four patients complained of a tender scar, necessitating altering their shoe wear in three of the four patients. Only two of these patients ultimately required excision of the keratosis and went on to heal without any sequelae. Other complications in this group included four patients with mild, intermittent tenderness as well as four wounds that dehisced. All these patients required no further interventions. All the 12 lateral sesamoidectomy patients in our study healed without complications. Saxena and Krisdakumtorn evaluated return to sport following fibular sesamoidectomy and reported that the three patients who underwent plantar incisions returned to impact activity two weeks earlier than the group in which a dorsal approach was used.

The SEFAS is a validated patient-reported outcome measure (PRO), specifically for forefoot and ankle/hindfoot conditions. In the only other study utilising a scoring system to assess the surgical outcomes of plantar fibromatosis, Sammarco and Mangone reported an average postoperative AOFAS score of 77 and Maryland Foot Score of 86. These are functional scoring systems and do not account for the patient’s satisfaction. This is the first study to report on outcomes using a validated patient-reported outcome score. The mean overall SEFAS score in our study was 44, with 92% of patients scoring their outcomes as excellent or good. The only poor outcome was in the rheumatoid patient who had bilateral surgery as discussed above. We found no difference in the SEFAS scoring according to surgery-specific cohorts.

The limitations of this study include the small number of patients, limited procedures and retrospective design. In the literature, the most common indication for plantar incisions is excision of interdigital neuromas but in our unit, we routinely use dorsal incisions for both primary and revision cases.

Table IV: Plantar fibromatosis tumour-staging system

<table>
<thead>
<tr>
<th>Tumour grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Focal disease isolated to a small area on the medial and/or central aspect of the fascia No adherence to skin No deep extension to the flexor sheath</td>
</tr>
<tr>
<td>II</td>
<td>Multifocal disease, with or without proximal or distal extension No adherence to the skin No deep extension to the flexor sheath</td>
</tr>
<tr>
<td>III</td>
<td>Multifocal disease, with or without proximal or distal extension Either adherence to the skin or deep extension to the flexor sheath</td>
</tr>
<tr>
<td>IV</td>
<td>Multifocal disease, with or without proximal or distal extension Adherence to the skin and deep extension to the flexor sheath</td>
</tr>
</tbody>
</table>

Conclusion

Our findings show that plantar incisions heal well with a high patient satisfaction. We believe that good clinical outcome is directly related to sound surgical technique and meticulous soft tissue handling. Plantar incisions must be considered if they are deemed technically superior and with less risk of collateral damage as compared to using a dorsal approach, without the unfounded fear of developing a ‘painful scar’.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.
Prior to the commencement of this study, ethical approval was obtained from the following ethical review board: Human Research Ethics Committee, HREC REF: M191168. Informed consent was obtained from all patients prior to being included in the study.

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

**Author contributions**
ANA: Study conceptualisation, data collection, data analysis, manuscript preparation, manuscript revision
NPS: Study conceptualisation, manuscript revision
PNFF: Study conceptualisation, manuscript revision

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**References**
Do anatomical contoured plates address scapula body, neck and glenoid fractures? A multi-observer consensus study

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Abstract

Background

The surgical management of scapula body, neck and glenoid fractures remains a challenge. This study focuses on templating an available anatomical pre-contoured plating system using three-dimensional (3D)-printed scapulae to assess the ability of these plates to address the aforementioned fractures and to determine consensus on classifying scapula body, neck and glenoid fractures.

Methods

We used a cohort of 22 3D-printed scapulae prototypes and an available anatomical pre-contoured plating system to determine anatomical congruency and fit. Nine investigators templated the scapulae using four pre-contoured plates, and the investigators classified the 22 scapulae using the Ideberg and AO/OTA classification systems.

Results

Eleven out of 22 fractures were found to be fixable using the plates under study. The long lateral plate addressed 83% of fractures involving the lateral border, while the glenoid plate was unable to adequately address any glenoid fractures. We observed good to excellent (p ≤ 0.001) interobserver reliability for three of the four plates. The interobserver reliability was moderate (ICC = 0.74) for the AO/OTA classification and good (ICC = 0.88) for the Ideberg classification.

Conclusion

We believe that the anatomical pre-contoured plating system does not address all the fracture patterns encountered in clinical practice and further development in plate design is required. There is good to moderate interobserver reliability using the Ideberg fracture classification for extra-articular fractures and the AO/OTA classification for extra-articular fractures involving the body.

Level of evidence: Level 3

Keywords: scapula fracture, open reduction and internal fixation (ORIF), South Africa, scapula plate analysis, 3D printing, fracture classification

Introduction

Isolated scapula fractures are rare, accounting for 3–5% of upper limb fractures and 0.7% of all fractures.1,3 They commonly occur in the polytraumatised patient and are generally associated with significant trauma. Low energy scapula fragility fractures sustained after falls may be found in the geriatric population.4

The scapula plays a pivotal role in maintaining the resting position of the shoulder girdle and, together with the clavicle, provides the anchor for the upper limb to the thorax.3 The rotator cuff muscles originate from the scapula and function not only as a dynamic glenohumeral stabiliser, but also in the initiation of glenohumeral motion. Loss of motion at the glenohumeral joint is well tolerated through increased scapulothoracic movement, and displaced fractures may affect this movement. The aim of scapula fracture management should be to restore shoulder function by correcting alterations in anatomy that cannot be compensated for.3 Non-surgical management of minimally to moderately displaced scapula body and neck fractures has rendered clinically acceptable and favourable long-term outcomes. However, the displaced...
and intra-articular fractures types still pose a clinical dilemma due to a lack of comparative literature and well-defined surgical indications. Displaced and malunited intra-articular fractures lead to glenohumeral joint incongruency and increased degeneration, resulting in early onset (accelerated) arthrosis of the glenohumeral joint. Shoulder deformity with chronic pain, and stiffness, are frequently encountered in malunited scapula fractures. Rotator cuff weakness and dysfunction with impingement have also been described.

The surgical management of scapula fractures can be difficult and challenging. Adequate fixation options are limited not only by the osseous anatomy and anatomical variability of the scapula, but also by zones of poor bone stock and the lack of bone thickness. The complexity of fracture patterns, challenging surgical approaches and implant limitations may lead to hesitancy from surgeons to perform open reduction and internal fixation (ORIF). Limited implant options and pre-contoured plating systems have often led surgeons to use alternate fixation systems intended for other bones to fix scapular fractures.

Historically, several classification systems were proposed, attempting to guide the surgeon in decision-making and fracture management. The most used classification system was developed by the OTA Classification Committee in 1996 and revised ten years later. To address the limitations of the existing classification systems, the OTA Classification Committee and the AO Classification Advisory Group (CAG) collaborated to develop a new validated classification system. Although validated and reproducible, the AO/OTA classification system does not determine surgical indications, operative approaches or implant choice.

The primary aim of this study was to quantify anatomical congruence and fit of the only available plating system in the country and to determine its fracture fixation capability. The secondary aim of the study was to determine the interobserver reliability of scapula fracture classifications and consensus among the investigators using 3D-printed scapulae.

Methods

Recruitment and enrolment

Ethical approval was obtained from the host institute’s HREC (Human Research Ethical Committee). The Philips Electronics iSite Electronic Radiology System database was used to search for all shoulder CT scans performed from 1 January 2016 to 31 January 2018. Twenty-six patients with closed scapula body, neck and glenoid fractures were identified. The inclusion criterion was closed scapula body, neck and glenoid fractures. The exclusion criteria were any patient younger than 18 years, penetrating gunshot wounds, isolated acromion and/or coracoid fractures. Twenty-two closed scapula body, neck and glenoid fractures met the inclusion criteria, while four scapula fractures were excluded as they were isolated acromion fractures. The mean age of the cohort was 46.6 years (range 26–71), with a male predominance.

Research procedure

The Digital Imaging and Communication in Medicine (DICOM) files of the 22 fractures were used to create three-dimensional (3D) models (Figure 1) using Materialise Mimics® (Leuven, Belgium), and then printed using the additive manufacturing process. Each fracture fragment was anatomically reduced and glued in place to maintain the reduction. The 3D models were used to template and determine the anatomical congruency of the available pre-contoured anatomical plating system. Templating was performed with the only locally available plating system16 from Acumed® (Hillsboro, OR, USA). The pre-contoured anatomical plating system has four plates designed to address the different anatomical locations of the scapula. The plate options were a long and a short medial plate for the medial scapula border, a long lateral plate and short lateral (glenoid) plate for the lateral border and the glenoid respectively. All four plates were templated on appropriate anatomical locations, determined by the fracture propagation through the scapula anatomy, to attain the best anatomical fixation (Figure 2).

Data collection

Nine investigators (five surgeons and four engineers) templated four plates on 22 scapulae on two separate occasions, one month apart. A scoring system, similar to our previous study,17 was applied to this study where plates were defined in an ordinal scale of fit or no-fit depending on their ability to adhere around the fractured region (Table 1). Templating of the plates around fracture regions was performed in a similar way to Malhas et al.18 The scoring system considered three factors:

1. Plate overhang: defined as plate overhang on either the medial or lateral border of the scapula, preventing the placement of a screw

Table 1: The scoring system

<table>
<thead>
<tr>
<th>Classification</th>
<th>Definition</th>
<th>Ordinal score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fit</td>
<td>The plate fitted around the fracture within surgical limits and there was no plate overhang observed</td>
<td>1</td>
</tr>
<tr>
<td>No-fit</td>
<td>The gap between the plate and the fracture line was above acceptable surgical limits and there was plate overhang</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 1. 3D reconstructed scapula (figure created by the authors)

Figure 2. Templating reconstruction plates (figure created by the authors)
2. Plate offset: defined as the distance (in millimetres) from the inferior border of the plate from the bone

3. Adequate fixation: defined as the ability of the plate to allow for placement of three screws proximal and three screws distal to the fracture line as advocated by the AO society fracture fixation guidelines.

Each plate was scored and subdivided into a fit or no-fit group:

1. Fit: defined as plate offset of less than 3 mm with no plate overhang and adequate fixation (six cortices) proximal and distal to the fracture line

2. No-fit: defined as plate offset of more than or equal to 3 mm with plate overhang (as defined by the aforementioned definition) and/or inadequate fixation (less than six cortices) either proximal or distal to the fracture line

The surgeons (six) classified each scapula fracture pattern using the Ideberg classification for the glenoid fractures and the AO/OTA classification for the body and neck fractures. Five senior shoulder and elbow surgeons and one trainee registrar classified the fracture patterns of the 22 scapulae at a single sitting.

Data analysis

To determine the dependency of plate types and their ability to fit the fracture pattern, the chi-squared test was performed. Intraclass correlation coefficients (ICC) were calculated (model: two-way mixed; type: absolute agreement) to measure the inter-rater variability among the nine observers performing the quantitative-fit analysis of the 22 scapulae. The ICC was also calculated for a fixability rating provided by the surgeons as a binary score (1: fixable; 0: not fixable). The fracture was categorised as fixable when it was rated 1 by at least 80% of the surgeons. The classifications provided by the group of surgeons were also compared using the ICC and chi-squared tests. We reported the ICC values according to the categories specified by Koo and Li. The cut-off for statistical significance was kept at p < 0.05. The statistical analyses were performed in IBM SPSS v.26 (IBM Co., Armonk, NY, USA).

Results

Twenty-seven per cent of fractures were found to propagate through the lateral border, scapula body and the medial border. Of the fractures, 18% involved the lateral border and the scapula body. Other fracture combinations can be seen in Figure 3. Seventy-seven per cent of the fractures involved the scapula body, 54% involved the lateral border, 45% involved the medial body, and only 36% of fractures involved the glenoid.
The involvement of different anatomical regions of the scapula anatomy influenced the fixability potential of the available plates \((p \leq 0.001)\). Good inter-rater reliability \(( ICC = 0.844, \, 95\% \, CI = 0.712–0.927; \, p \leq 0.001)\) was found for the fixability categorisation of the fractures. Overall, 11 out of the 22 fractured scapulae were found to be fixable using the pre-contoured plating system. None of the glenoid fractures were found to be fixable. Potential fixation could be achieved in nine (out of 17) body fractures, ten (out of 12) fractures involving the lateral border, and nine (out of 12) fractures involving the medial border \((Figure \ 4)\). When a fracture was deemed fixable, a combination of a long lateral plate and at least one of the medial plates was used for six (out of 11) fractures. The rest of the fractures could be fixed using only the long lateral plate \((Figure \ 5)\).

Due to the consensus that the glenoid plate was unable to fit the fracture patterns included in this study \((Figure \ 5)\), we excluded the observations for the glenoid plates from the ICC calculations. For the remaining plates we observed good to excellent \((p \leq 0.001)\) interobserver reliability \((Table \ II)\).

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Table II: The intraclass correlation coefficient (ICC) and the corresponding 95% confidence interval (CI) calculated for the two observation sessions presented for each plate

<table>
<thead>
<tr>
<th>Plates</th>
<th>First observations</th>
<th>Second observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC</td>
<td>95% CI</td>
</tr>
<tr>
<td>Long lateral</td>
<td>0.894</td>
<td>0.813–0.949</td>
</tr>
<tr>
<td>Long medial</td>
<td>0.742</td>
<td>0.545–0.876</td>
</tr>
<tr>
<td>Short medial</td>
<td>0.821</td>
<td>0.685–0.914</td>
</tr>
</tbody>
</table>

Table III: The surgeons’ observations of the scapula with isolated body fractures classified using AO/OTA classification

<table>
<thead>
<tr>
<th>AO/OTA</th>
<th>Surgeon 1</th>
<th>Surgeon 2</th>
<th>Surgeon 3</th>
<th>Surgeon 4</th>
<th>Surgeon 5</th>
<th>Surgeon 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scapula 6</td>
<td>14B1P1</td>
<td>14B1P1</td>
<td>14B1</td>
<td>14BP1</td>
<td>14B1</td>
<td>14B1</td>
</tr>
<tr>
<td>Scapula 7</td>
<td>14B2</td>
<td>14B2</td>
<td>14B1</td>
<td>14B1</td>
<td>14B1</td>
<td>14B1</td>
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<tr>
<td>Scapula 16</td>
<td>14B1</td>
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<td>14B1</td>
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<td>14B1</td>
<td>14B1</td>
</tr>
<tr>
<td>Scapula 22</td>
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<td>14B1</td>
<td>14B1</td>
<td>14B1</td>
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</table>

Table IV: Surgeons’ classification of isolated glenoid fractures using Ideberg classification system

<table>
<thead>
<tr>
<th>Ideberg</th>
<th>Surgeon 1</th>
<th>Surgeon 2</th>
<th>Surgeon 3</th>
<th>Surgeon 4</th>
<th>Surgeon 5</th>
<th>Surgeon 6</th>
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<tbody>
<tr>
<td>Scapula 2</td>
<td>ID3</td>
<td>ID3</td>
<td>ID3</td>
<td>Unclassified</td>
<td>ID6</td>
<td>ID2</td>
</tr>
<tr>
<td>Scapula 3</td>
<td>ID2</td>
<td>ID2</td>
<td>ID4</td>
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<td>ID5B</td>
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</tbody>
</table>

Interobserver reliability was moderate \(( ICC = 0.842; \, 95\% \, CI = 0.387–0.921; \, p = 0.001)\) for the AO/OTA classification \((Table \ III)\) and good \(( ICC = 0.883; \, 95\% \, CI = 0.073–0.964; \, p \leq 0.001)\) for the Ideberg classification \((Table \ IV)\). The chi-square test suggested that the surgeon’s ability to classify scapula fractures was dependent on the fracture classification being used \((p \leq 0.001)\).

Discussion

To our knowledge this is the first study done on three-dimensional (3D)-printed scapulae and scapula fracture fixation using an anatomical contoured plating system. Nguyen et al. conducted a similar study but used computerised 3D reconstructions of scapulae and digital templating, using the same plating system. However, the authors used healthy cadaver scapulae, and the templating was done by digitally superimposing the plates onto the scapulae. In another study, the authors physically templated anatomical plates on healthy adult museum scapula specimens. Despite the difference in methodologies, comparable results were observed.
obtained in our study and the previous ones. The results from the studies showed that the long lateral plate achieved a good fit along the fractures of the lateral border of the scapula. This can be attributed to the thicker geometry of the lateral border offering better screw purchase and the linear design pattern of the plate which makes it congruent to the anatomy of the region.

Dugarte et al. conducted a 2D versus 3D scapula fracture mapping study using computerised tomography (CT) reconstructions and found the majority of fracture lines involved the base of the spine and lateral border, just inferior to the glenoid.24 The fracture lines were least likely to involve the inferior lateral border. Armitage et al. reported similar results on 2D images of scapulae.25 We found the long lateral plate successfully addressed all fractures exiting at the subglenoid, middle and distal thirds of the lateral border.

The medial border of the scapula, compared to the lateral border, is much thinner and offers poor to no screw purchase.10 The short medial plate performed marginally better than the long medial plate. Of all four plates, the medial plates measured the greatest plate offset and overhang. This might have been due to the angle between its superior and inferior limbs not being acute enough and causing the plate to extend off the medial border. The medial plate, as with the lateral plate, offers no variable angle screw placement option and no proximal or distal locking options for smaller diameter locking screws.26,27

The glenoid plate had the worst score for anatomical fit compared to the other three plates. It proved challenging to place the short triangular-shaped glenoid plate onto the spinoglenoid notch and posterior glenoid. The glenoid plate was not successful in addressing any glenoid fractures. These observations are in line with our previous findings.17 The Ideberg type 3, 4 and 6 fractures pose the greatest challenge to the treating surgeon and in our study, as we observed that the glenoid plate offered limited screw options to adequately fix these fractures. When the fracture propagated, inferior to the spine, towards the medial border, the glenoid plate was found to be inadequate to address the fracture. When addressing intra-articular glenoid fractures and the associated glenoid rim and/or neck fractures, we prefer cannulated screws as first-line of treatment for these fractures. A variety of fixation techniques, such as cannulated screws, buttressing plates, bone grafting (coracoid/fibiac crest), cerclage wiring, suture anchors or a combination of these, have been described in the literature.28,29

The fixation of scapula fractures is not limited to the anatomical pre-contoured system. The use of alternative fixation is well described in the literature with good to excellent results.11,12,30 Non-anatomical plates, with or without K-wire/screw fixation and even plates designed to address a completely different fracture pattern at different anatomical sites, have been used to fix scapula fractures. Utilising different fixation techniques, as outlined in the literature, corroborates our observation that the current pre-contoured anatomical scapula plates might not be suitable to fit around all types of scapula fractures. Future developments should focus on introducing design changes to the existing designs to make them fit more fracture patterns.

The secondary aim of the study was to determine consensus on two available scapula fracture classifications. We used the AO/OTA and Ideberg classification systems to classify the different types of fractures – scapula body and neck fractures were classified using the AO/OTA classification system, and glenoid fractures were classified using the Ideberg classification system. We found that the consensus remains less than perfect. The AO/OTA and Ideberg classification systems are well described and often referred to in the literature. Although newer classification systems have been proposed, all the investigators unanimously decided on the AO/OTA and Ideberg classification systems.

In a previous study, Armitage et al. stated that many classification systems lack clinical correlation compared to actual fracture patterns.25 In another study, Bartoniček et al. reported that the available classifications are purely descriptive and have neither therapeutic nor prognostic implications.21 Recently, two new scapula fracture classifications systems were proposed which are yet to be adapted in our clinical facility, namely the more comprehensive AO/OTA classification, and the New International Classification for Scapula Fractures (NICSF).13,14

Neuhaus et al. compared the validity of the AO/OTA and the NICSF and concluded the NICSF system is validated and more reliable than the AO/OTA.15 Another study by Harvey et al. confirmed that the inter-rater reliability increased when CT images were used in scapula fracture classifications.16 In both the classification systems, glenoid fractures were observed to have had the best agreement among the observers.

In our study, using 3D-printed fractured scapula models, we observed better consensus among the surgeons when describing glenoid fractures using the Ideberg classification compared to fracture classifications using the AO/OTA classification system.

Implementing 3D prototypes in practice has its limitations. The benefit of 3D printing is not limited to templating only as 3D-printed scapula prototypes have been used as an adjunct to radiographs in detailed preoperative planning and teaching.25-33 The authors caution readers that the cost and time spent on 3D prototyping process may not be feasible in all orthopaedic institutions. With the machinery and expertise needed, institutions embarking on such research need to consider the volume of complicated fracture patterns encountered in an orthopaedic practice, in order to justify the cost-benefit.

The primary limitation of this study was the small sample size of the fractured scapulae used in the study. The secondary limitation of the study was that only one anatomical plating system was used in the study as it is also the only commercially available plating system in South Africa. The ability to address the fracture with non-anatomical plates has been well documented. The study did not use plate bending or other methods to improve plate shape to improve fit and fixation that would be possible in the clinical setting. For future studies, the authors would recommend that other available plating systems, including those not necessarily designed for scapula fractures, and different fracture fixation techniques, be compared on a larger sample size of fractured scapula.

Conclusion

The long lateral plate had the best ability to fit scapula body fractures, followed by a combination of the long lateral plate and one of the medial plates, while the glenoid plate was found to be an unsatisfactory solution for addressing scapula body and glenoid fractures. Further emphasis on improving the scapula plate design is recommended. Classifying scapula fractures using existing scapula fracture classifications remains an underlying challenge among the shoulder surgeons in our part of the world.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. Prior to commencement of the study, ethical approval was obtained from the following ethical review board: University of Cape Town HREC Ref No: 311/2019. All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Declaration

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


The short-term outcomes of hip arthrodesis in children and adolescents with end-stage hip disease

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Abstract

Background

The management of end-stage hip disease in children and adolescents is a challenging clinical problem. While total hip replacement (THR) offers the benefit of improved mobility, this is offset by the risk of multiple revisions. Hip arthrodesis remains a salvage option to relieve pain and restore function at the cost of hip movement. This study aimed to determine the short- to medium-term outcome of hip arthrodesis in paediatric and adolescent patients in a developing world setting.

Methods

All children and adolescents under the age of 18 years who underwent hip arthrodesis between 2010 and 2014 were included in the study. Measurements included diagnosis, preoperative deformity, fusion position, fusion rate and functional outcomes. Our surgery involved transarticular compression screw fixation and subtrochanteric osteotomy. Postoperative skeletal traction maintained optimal limb position for two weeks, after which spica cast immobilisation was used.

Results

Nineteen patients (11 female) had hip fusions at a mean age of 12 years (range 5–18). The mean follow-up period was 5 years (range 1–8). Most cases were due to end-stage TB arthritis (12/19; 63%). Other causes were septic arthritis (3/19; 16%); neglected slipped capital femoral epiphysis (1/19; 5%); post-traumatic avascular necrosis (1/19; 5%); and idiopathic chondrolysis (2/19; 11%). Primary fusion was achieved in 68% (13/19) of cases. Six patients developed complications. Complications included adduction drift (3/19), failed fusion (3/19), screw malpositioning (1/19) and screw breakage (1/19). Eight reoperations were required in six patients. In two of these patients, one additional surgery had to be performed to achieve fusion or correct limb position. The mean fusion position was 31° (range 10 to −10) flexion, 2° (range 10 to −10) abduction, and 1° (range 10 to −10) external rotation. Mean leg length discrepancy was 1.8 cm (range 0 to 4.5) of shortening. All except one patient reported relief of hip pain and satisfaction with the procedure.

Conclusion

While hip arthrodesis is a technically challenging procedure, high fusion rates and reliable pain relief may be expected in these patients. However, complications should be anticipated, and reoperation may be required to achieve fusion and an optimal limb position.

Level of evidence: Level 4

Keywords: end-stage hip arthritis, TB hip, hip arthrodesis, hip fusion, subtrochanteric osteotomy

Introduction

Management of paediatric and adolescent patients with end-stage hip arthritis remains challenging, and the trends in management have changed over time.¹,² When hip preservation is not possible, the treatment options are either total hip replacement (THR) or hip arthrodesis. There is limited evidence to support the choice of one procedure over the other.³ Hip arthrodesis is indicated as a salvage procedure for end-stage hip disease.⁴,⁷ The goals of hip arthrodesis are pain-free, stable hip joint that will improve function.⁷ The procedures’ success was first reported in 1894. Since then, a variety of fusion techniques and modifications have been published, resulting in improved union rates with a decrease in complications.⁸

Total joint replacement in younger patients has been gaining popularity due to the advantage of retained hip mobility and potential for improved functional outcomes. However, the risk of multiple revisions due to the demand placed on the prosthesis is of significant concern.⁹,¹³ Furthermore, appropriate patient selection for THR is crucial. Septic arthritis is a frequent cause of end-stage hip disease in children and adolescents. Prosthetic joint infection due to reactivation of infection is an additional risk in these patients, making hip arthrodesis an attractive alternative.¹⁴,¹⁵
Hip arthrodesis has performed relatively well in the pre-arthroplasty era, demonstrating good to excellent long-term functional outcomes. More recently, similar results have been reported. The occurrence of adjacent joint degenerative disease is a well-known long-term complication of hip arthrodesis. Up to 21% of patients require fusion takedown and conversion to THR.

In the developing world, young patients often present late with advanced disease, severe pain and functional impairment. Furthermore, the prevalence of infective causes like tuberculosis (TB) or septic arthritis is high. In these cases, an abductor-sparing hip arthrodesis may be a good option to relieve pain and improve function. There is limited data on the outcome of hip arthrodesis in children and adolescents, particularly from the Southern African region.

Our study aims to determine the short- to medium-term outcome of hip arthrodesis in paediatric and adolescent patients in a developing world clinical setting. Our objectives were to determine the cause of end-stage hip disease, to measure the fusion position, to document the complication rate and report the subjective functional outcome in a cohort of children who underwent hip arthrodesis.

### Materials and methods

We completed a single-centre retrospective descriptive study of all children and adolescents, under the age of 18 years, who had a hip arthrodesis at our tertiary paediatric orthopaedic unit between 2010 and 2014. All patients 18 years and younger who underwent hip arthrodesis for end-stage hip disease and had follow-up for at least one year were included for analysis. All patients who had a hip arthrodesis after the age of 18 years and patients with active infection of the hip were excluded.

### Patient selection

Patients were considered eligible for arthrodesis following failure of non-operative management for unilateral end-stage hip arthritis. Failed non-operative treatment was defined as inability to achieve or maintain functional position of the hip or inability to control pain sufficiently to allow functional activities of daily living. Prior to the procedure, active infection was excluded through clinical examination, as well as imaging and laboratory investigations.

### Surgical technique

An anterior approach (extended Smith-Peterson) was used to access the hip joint. This was followed by an anterior hip dislocation and acetabular exposure. Mechanical reamers designed for hip resurfacing were used to remove the remaining articular surface of the acetabulum and femoral head. Once bleeding cancellous bone surfaces were obtained, appropriately sized transarticular cannulated compression screws were inserted under fluoroscopic control in the position of maximal bone contact. A combination of autogenic and allogenic bone graft was used in certain cases with insufficient femoral bone stock. An additional subtrochanteric osteotomy was performed without supplemental fixation. The subtrochanteric osteotomy was performed without supplemental fixation. The subtrochanteric osteotomy achieved two goals: first, the strain of the lower limb on the fusion site was removed. Secondly, because optimal bone contact was prioritised at the fusion site, the limb could be placed in the ideal functional position through the osteotomy site (15–40° flexion, 0–10° abduction and 0–10° external rotation).

During the immediate postoperative period, patients were placed in skeletal traction for a period of two weeks. This facilitated soft tissue healing and wound review, while maintaining the optimal alignment, and allowed for some initial soft callus formation. Subsequently a hip spica was applied under general anaesthesia and fluoroscopic

### Table I: Patient demographics

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex (Female/ Male)</th>
<th>Hip affected (Right/ Left)</th>
<th>Age at fusion (years)</th>
<th>Diagnosis</th>
<th>Presentation</th>
<th>Preoperative traction use</th>
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<tr>
<td>1</td>
<td>F</td>
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<td>2</td>
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<td>F</td>
<td>L</td>
<td>10</td>
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<td>Yes</td>
</tr>
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<td>4</td>
<td>F</td>
<td>R</td>
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<td>Progressive pain limp</td>
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</tr>
<tr>
<td>5</td>
<td>M</td>
<td>L</td>
<td>16</td>
<td>TB hip</td>
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<td>6</td>
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<td>L</td>
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<td>TB hip</td>
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<tr>
<td>7</td>
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<td>L</td>
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<td>8</td>
<td>SAH</td>
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<tr>
<td>10</td>
<td>F</td>
<td>L</td>
<td>5</td>
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<td>Progressive hip pain</td>
<td>Yes</td>
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<td>11</td>
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<td>L</td>
<td>12</td>
<td>TB hip</td>
<td>Progressive pain stiff – jog movement</td>
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</tr>
<tr>
<td>12</td>
<td>M</td>
<td>R</td>
<td>6</td>
<td>TB hip</td>
<td>Progressive painful limp</td>
<td>Yes</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>R</td>
<td>14</td>
<td>TB hip</td>
<td>Progressive pain, limp ankylosis</td>
<td>No</td>
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<td>14</td>
<td>F</td>
<td>L</td>
<td>9</td>
<td>TB hip</td>
<td>Progressive pain, non-ambulatory</td>
<td>Yes</td>
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<tr>
<td>15</td>
<td>M</td>
<td>R</td>
<td>18</td>
<td>TB hip</td>
<td>Hip pain, non-ambulatory</td>
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<tr>
<td>16</td>
<td>F</td>
<td>L</td>
<td>14</td>
<td>AVN post-traumatic</td>
<td>Progressive hip pain</td>
<td>No</td>
</tr>
<tr>
<td>17</td>
<td>F</td>
<td>R</td>
<td>12</td>
<td>TB hip</td>
<td>Progressive hip pain</td>
<td>No</td>
</tr>
<tr>
<td>18</td>
<td>M</td>
<td>L</td>
<td>14</td>
<td>TB hip</td>
<td>Progressive hip pain</td>
<td>Yes</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>R</td>
<td>15</td>
<td>SAH</td>
<td>Progressive hip pain</td>
<td>No</td>
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i) slipped capital femoral capital epiphysis, ii) septic arthritis, iii) tuberculosis
guidance to maintain the desired limb position for a further eight to ten weeks. Patients were allowed to mobilise partial weightbearing with crutches, as pain allowed. A standardised follow-up schedule was maintained involving clinical and radiological review at two weeks, six weeks and three months, three months, six months and yearly, thereafter. The spica was removed at ten to 12 weeks postoperatively and union of the subtrochanteric osteotomy was confirmed clinically and radiologically.

Data collection
Demographic and clinical data were collected and analysed. Data points included age, sex, initial diagnosis, side affected, preoperative position of the hip (degree of flexion, abduction, rotation) and leg length discrepancy. The leg length and alignment were assessed in the supine position with the pelvis squared. The amount of hip adduction/abduction can be measured as compared to the nonarthrodesed hip. With addition of the Thomas test, the amount of flexion was obtained. The true leg length discrepancy was measured while placing the limbs in identical positions. Outcome measurements included complications, reoperation, fusion rate, final fusion position and patient satisfaction. All secondary procedures were analysed to determine their indications and subsequent outcome. Clinical fusion was defined as no pain or movement at the hip on clinical examination. Radiological fusion was categorised as either definite fusion (trabecular lines crossing fusion site and clinically fused), probable fusion (no trabecular lines crossing, but no lucency around the screws and no change in position on serial X-rays and clinically fused) or failed fusion (lucent zone across fusion site, with lucency around screws and change in position on serial X-rays; along with movement or pain at the hip on ambulation or examination).

The final functional outcome was conducted in person or by telephonic interview. The components assessed included pain of the fused hip, ipsilateral knee joint, contralateral hip and the lumbar spine. Limitations in sitting and walking were also recorded including the use of assistive devices. An excellent functional outcome was defined as no associated pain and limitations in the activities of daily living (sitting and walking). A good functional outcome was defined as adjacent joint pain with some limitation in activities of daily living. Poor functional outcome was defined as pain of the fused hip with or without adjacent joint pain that was associated with functional limitation (e.g. use of assistive device or inability to sit for a prolonged period).

Statistical analysis was performed using jamovi version 1.2.18.0 open-source software. Continuous variables were reported as means with ranges, and categorical variables as number and percentages. Differences in continuous variables were compared with the use of the unpaired t-test or the Mann-Whitney U test (depending on the distribution of the data). Categorical data was compared using the Fisher’s exact test (if any expected cell count was below 5) or the chi-squared test (if no cell count below 5). All tests were two-sided and the level of significance was set at $p < 0.05$. Binomial logistic regression analysis was used to determine odds ratios (ORs) and 95% confidence intervals (95% CI).

Results
Nineteen patients (11 females) were included in the study from a total of
22 patients who underwent hip arthrodesis (Table I). Two patients were lost to follow-up within the first year following surgery and subsequently excluded. One patient with active bacterial septic arthritis was also excluded. The mean age at surgery was 12 years (range 5–18).

The causes of end-stage hip disease were TB of the hip in 63% (12/19) (Figure 1); septic arthritis in 16% (3/19); 11% (2/19) due to idiopathic chondrolysis; and the remaining two cases were due to post-traumatic avascular necrosis (5%) and complicated slipped capital femoral epiphysis (5%), respectively.

Progressive, chronic and debilitating hip pain was the presenting complaint in 84% (16/19) of patients. This pain was associated with variable degrees of hip stiffness and deformity. With regard to the mean fixed flexion deformity, the data available in 16 patients was 44° (range 20–70). For the mean adduction contracture, the data available in 13 patients was 16° (range 5–30) (Figure 2). For the true leg length discrepancy, the data available in six patients was a mean of 3 cm (range 2–5). Preoperative skeletal traction was used in 47% (9/19) in an effort to improve limb position.

Transarticular fixation comprised two half-threaded compression screws in 18 cases (Figure 3). A single screw was used in the remaining case. The intended limb position was maintained in a hip spica until clinical and radiological healing of the osteotomy site was evident at 10–12 weeks postoperatively. The mean limb positions obtained immediately out of hip spica were: 43.3° flexion, 8.3° abduction, 2.5° external rotation with an apparent LLD of 1.6 cm (Table II).

The mean follow-up time was five years (range 1–8). Definite fusion was obtained in 68% (13/19) of patients (Figure 4), probable fusion in 16% (3/19) and the remaining 16% (3/19) developed a failed fusion after the initial fusion procedure (Figure 5).

The complication rate was 32% (6/19). The complications (Table III) included flexion and adduction drift (3/19), failed fusion (3/19), screw malpositioning (1/19) and screw breakage (1/19). There were no non-unions of the subtrochanteric femoral osteotomies. Eight reoperations were required in six patients. In two of these patients, one additional surgery had to be performed in each patient to achieve fusion or correct limb position. Reoperations included valgus and extension osteotomies (3/8) for flexion and adduction drift; debridement and autologous bone grafting (3/8) for failed fusion; screw reposition (1/8) for screw malposition; and lastly revision surgery with plate osteosynthesis (1/8) for failed fusion with screw breakage.

Subgroup analysis revealed that the quality of fusion was associated with the need for reoperation (p = 0.003). Five out of six patients that developed complications and subsequently underwent reoperation were either classified as probable fusion (2/5) or as a failed fusion (3/5).

At final follow-up, hip fusion was achieved in all patients (19/19). The mean hip position at last follow-up was 31° flexion (range 20–50), 2° abduction (range 10° abduction to 10° adduction) and 1° external rotation (range 10° internal rotation to 10° external rotation. The mean apparent LLD was 1.8 cm (range 0–4.5) (Table II).

Table III: Summary of patients with complications

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Aetiology</th>
<th>Complication</th>
<th>Intervention</th>
<th>Time to reoperation (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>14</td>
<td>SCFE</td>
<td>Adduction deformity</td>
<td>Valgus derotation osteotomy</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>10</td>
<td>SA hip</td>
<td>Failed fusion</td>
<td>Revision surgery, bone graft and refixation</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Male</td>
<td>8</td>
<td>SA hip</td>
<td>Failed fusion with screw breakage</td>
<td>Revision surgery, bone graft and refixation</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>Female</td>
<td>5</td>
<td>TB hip</td>
<td>Screw malposition</td>
<td>Screw revision</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>6</td>
<td>TB hip</td>
<td>Failed fusion</td>
<td>Revision surgery and refixation with dynamic hip screw</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>9</td>
<td>TB hip</td>
<td>Adduction deformity</td>
<td>Valgus derotation osteotomy</td>
<td>29</td>
</tr>
</tbody>
</table>

SCFE: slipped capital femoral capital epiphysis; SA: septic arthritis; TB: tuberculosis

Figure 3. Perioperative images a) demonstrating patient positioning and skin marking for the planned incisions – the extended Smith-Petersen approach to the hip and straight lateral incision for the subtrochanteric osteotomy; b) the superficial dissection of the extended Smith-Petersen approach, with care to be taken in identifying and protecting the lateral femoral cutaneous (LFC) nerve; c) intraoperative AP fluoroscopic image confirming the appropriate screw length and placement, transarticular compression and subsequent subtrochanteric osteotomy; d) postoperative transtibial skeletal traction to allow initial soft tissue healing and to position limb in an optimal alignment.
All but one patient was free of hip pain at final follow-up. This patient experienced pain of the fused hip with long distance walking and when sitting for more than an hour. The same patient also reported ipsilateral knee and lumbar pain. A contributing factor to the symptoms may have been the leg length discrepancy of 3 cm. The clinical outcomes were reported to be excellent in 16 patients and good in three patients. In the three patients with good results, the average apparent leg length discrepancy was 3.5 cm (range 3–4). This was managed with a shoe raise. No lengthening procedures or epiphysiodysis were performed. We found increased odds for complications (odds ratio [OR] 1.5, 95% CI 1.1 to 2.3, p = 0.028) and the need for reoperation (OR 2.07, 95% CI 1.1 to 3.9, p = 0.022) in patients of younger age. We were unable to demonstrate an association between the cause of end-stage hip disease and the development of complications (p = 0.322) or the need for reoperation (p = 0.240).

Discussion

The management of children and adolescents with end-stage hip disease remains a major challenge for orthopaedic surgeons. There is limited data available regarding the outcomes of hip arthrodesis in children and adolescents and for this reason, we aimed to determine the short- to medium-term outcome of hip arthrodesis in children and adolescents in a developing world clinical setting.

Hip arthrodesis remains a treatment option in children and adolescents presenting with unilateral end-stage hip disease with contraindications for joint preservation and replacement surgery. Post-infective and post-traumatic hip arthrosis have been identified as the leading indications for hip arthrodesis. Post-infective causes account for up to 75%, and trauma for up to 47% of cases. In keeping with these findings, 79% of our cases were the result of previous TB or septic arthritis. Two cases were due to idiopathic chondrolysis, and the remaining two cases were due to avascular necrosis following a neck of femur fracture, and chondrolysis following a slipped capital femoral epiphysis.

The indications for hip arthrodesis are debilitating hip pain and deformity due to end-stage hip disease when conservative management fails. The goal of hip arthrodesis is to obtain a pain-free hip in a functional position. In our series, 16 of the patients presented with debilitating pain that was associated with hip deformity (fixed flexion deformity, adduction contracture and leg length discrepancy).

The ideal functional fusion position is still an area of debate with conflicting recommendations. The current recommended position of the limb is 15–40° of flexion, 0–10° of abduction or adduction, and 0–10° external rotation. In our series, the final fusion position achieved was in keeping with these recommendations, with 31° flexion, 2° abduction and 1° of external rotation. Iobst and Stanitski showed a greater degree of hip flexion (average 30°) was important in achieving a rhythmic gait and to facilitate sitting. On the other hand, Karol et al. noted a better gait pattern with a lesser degree of flexion of between 20° and 25°. Benaroch et al. demonstrated that slight abduction was necessary to compensate for the progressive adduction drift. However, Duncan et al. showed that any amount of abduction was associated with later knee varus deformity and instability and recommended neutral abduction-adduction. There appears to be consensus that internal rotation should be avoided to prevent interference with the opposite limb during walking.

The mean leg length discrepancy in our patient group was 1.8 cm. Symptomatic leg length discrepancy above 2 cm was treated with a shoe raise. Leg length discrepancy above 4 cm may require a staged femoral lengthening but was not required in any of our cases.

Multiple surgical techniques are described in the literature. The options include internal fixation with transarticular screws (e.g., cannulated compressing screws or dynamic hip screw system) or extra-articular fixation (e.g., cobra plate, low-contact dynamic compression plate). In the transarticular technique with compression screw, the use of a supplementation external fixation (e.g., AO modular Ex-Fix) is also described. Cobra plates were designed to address high rates of pseudarthrosis seen with transarticular techniques by providing a rigid internal fixation. These plates, however, damage the abductor mechanism, making later conversion to a THR challenging.

The use of external fixators is frequently complicated by pin-track infections and knee stiffness. The procedure we preferred for hip arthrodesis has the following potential advantages: transarticular compression, sparing of the abductor muscles, and preservation of both bone stock and the vascular supply of femoral neck and head. The disadvantages include the prolonged hospital stay and cumbersome spica cast immobilisation. The potential benefits and drawbacks of performing a subtrochanteric osteotomy also need to be considered. Subtrochanteric osteotomy potentially increases the chances of union of the arthrodesis by decreasing the length of the lever arm and the resulting strain at the fusion site. Furthermore, as the hip is positioned in the optimal position to achieve union,
the alignment of the limb can be adjusted at the subtrochanteric osteotomy site. However, THR following a previous proximal femoral osteotomy can be technically challenging with increased complication and revision rates compared to a primary total hip arthroplasty.19,40

While we achieved fusion in all cases, reoperations were required in 32% (6/19). We found that a younger age at surgery was associated with increased odds of reoperation (OR 2.07, 95% CI 1.1–3.9, p = 0.022). Reoperations were required to either obtain fusion, or to maintain a functional position due to adduction and flexion drift. Fusion quality was also associated with reoperation (p = 0.003). All three failed fusions required reoperation to relieve pain and improve poor hip position. Two out of three patients that were categorised as ‘probable fusion’ also required reoperation, both due to adduction drift which was likely the result of incomplete fusion.

Brien et al., in their study of 16 patients fused with an anterior compression plate, demonstrated a 31% reoperation rate for fusion.33 However, Wagner and Wagner had a reoperation rate for fusion of 8% with the use of the cobra plate.37 In a series involving 17 patients fused with cobra plates, Mahar and Omar also demonstrated a high fusion rate with a 6% reoperation rate.22 Hoekman et al. augmented the transarticular compression with an anterior plate and showed a 94% fusion rate.31 While there are no comparative studies to show the superiority of one surgical technique over the other, the use of an anteriorly placed plate to supplement transarticular fixation may improve fusion rates.12,21

Good to excellent short-term subjective functional outcome was achieved in 95% of our patients, with one patient reporting symptoms of adjacent joint pain. This is comparable to other studies on the functional outcome after hip arthrodesis. Scharfroth et al. evaluated the long-term outcome of 30 patients that underwent hip arthrodesis and showed that when the optimal limb alignment is achieved, complaints relating to the adjacent joints is minimal and acceptable quality of life is attainable.27 Hoekman et al. has demonstrated a high satisfaction rate in his 35-patient cohort and reported a good to a very good quality of life.21

After skeletal maturity, the management of end-stage hip disease is controversial, with some authors advocating for THR over hip fusion.3 THR has clear short-term advantages but uncertain long-term outcomes. Takenaga et al., in a ten-year follow-up study looking at patients 50 years and younger, reported a 15% revision rate.11 Furthermore it has been shown that further revisions can be expected in this group of patients (up to 30%) with shorter implant survival times.10 Hip arthrodesis therefore remains a viable option in this high-demand patient group due to the concerns of implant loosening and the risk of multiple revisions.1,6 While hip arthrodesis restores function and relieves pain in end-stage hip disease, it is frequently complicated by adjacent joint degeneration in the long term.27 Later conversion of the fused hip to total hip arthroplasty may be considered to halt these processes and increase function, with improved quality of life.41 However, complications are relatively common in comparison to primary THA, occurring in up to 13% of cases, and the ten-year survival rate of the procedure varies from 74–96%.42

There are several limitations to this study. As the study was retrospective, not all the preoperative measurements were documented in the medical records. The data regarding the disease course and the time from initial diagnosis to arthrodesis was also not available. Despite this limitation, these patients all met the indication for hip arthrodesis: a painful hip in a poor position, with end-stage hip disease that has failed non-operative management. The study was also subject to attrition bias with two patients being lost to follow-up. The small sample size is due to the relative rarity of end-stage hip disease in children and adolescents.

We found no obvious explanation for the finding that there is an association between younger age and increased complications and need for reoperation. This may also, possibly, be a function of the small sample size. Despite the small sample size, the study was sufficiently powered to detect an association between age and the odds of reoperation (post hoc power analysis = 98% power). This is a short-term outcome study on a young group of patients that underwent hip arthrodesis. Long-term complications include flexion and adduction drift and degenerative disease of other joints (ipsilateral knee, opposite hip and lumbar spine). Long-term follow-up is required to accurately determine the outcome of hip fusion in our patient cohort. As this is a single-centre study, further research is required to confirm external validity. Further study is also required to determine the association between underlying cause of hip disease and outcome, as well as the optimal surgical fusion technique.

Conclusion
Hip arthrodesis can provide reliable pain relief in selected children and adolescents with end-stage hip disease. The procedure is technically challenging with a significant complication and reoperation rate. Younger age may be associated with an increased risk of reoperation.

Ethics statement
Institutional Review Board ethical approval was obtained from the University of KwaZulu-Natal Biomedical Research Ethics Committee via an expedited application referenced: BE602/18 prior to commencement of the study.

The author(s) declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. The study was conducted with compliance to the South African National Research Ethics Guidelines (2015). All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed written consent was not obtained for the study.

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

Author contributions
TAM: Data capture, manuscript preparation, manuscript revision
PHM: Manuscript review and revision
LCM: Manuscript review and revision
DMT: Study design, data capture, manuscript review

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References


Incidence of radius shortening following intramedullary nail fixation for gunshot fractures: a retrospective radiological audit

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Introduction
Fractures of the forearm resulting from gunshot wounds (GSW) are often highly comminuted, involving a sizable bone segment, and can be very challenging to treat.¹ The new generation locking intramedullary (IM) nail is an option to manage these highly comminuted fractures.²,³ Minimal disruption to the soft tissue envelope together with its stress-shielding biomechanical properties makes the IM nail an attractive alternative to conventional bridge plate techniques.⁴,⁵ The IM nail is not without its problems, and issues such as nail migration and malunion have been highlighted in the literature.⁶,⁷

At our institution we have been using interlocking IM nails for isolated gunshot fractures of the radius since 2012. At follow-up we have noted some patients presenting with radius shortening following nail fixation to treat GSW fractures. Radius shortening is associated with clinical sequelae such as chronic pain, reduced

Abstract
Background
Intramedullary nail fixation is an option to manage highly comminuted fractures of the radius shaft resulting from gunshot wounds. However, complications including nail migration and malunion are well documented. We have noticed some patients presenting to our clinic with radiological shortening following nail fixation. This may result in chronic pain, reduced pronation and supination, poor grip strength and early onset arthrosis. This study aimed to quantify the incidence of radiological shortening following fixation of isolated gunshot wound (GSW) fractures of the radius with an intramedullary nail. Our secondary objectives were to identify if length of the zone of comminution and anatomical location of the fractures were risk factors for shortening, and to assess whether shortening was a result of surgical error, or whether shortening occurred over time.

Methods
We performed a retrospective review of all (n = 40) isolated radius nails performed between January 2012 and January 2019. Two doctors assessed the latest anterior-posterior forearm X-ray of every patient, using the rule of perpendiculars to calculate ulnar variance (UV). Shortening was defined as a UV > 5.0 mm. If the radius was deemed shortened by consensus, then the immediate postoperative X-ray was also assessed to gauge when shortening occurred. Anatomical location in thirds and length of comminution (mm) were also assessed.

Results
Forty patients with a mean age of 32 years (range 15–59) were included. Twelve patients’ radiuses were assessed as radiologically short. All 12 were deemed to have been fixed short. One case shortened further over time. We found the incidence of shortening being dependent on the fracture location (p = 0.03), with the fractures occurring in the middle third of the arm shortening more. The measured zone of comminution between the shortened and non-shortened groups was not found to be statistically significant (p = 0.55).

Conclusion
The radius nail remains useful to manage comminuted radius shaft fractures following GSW. Meticulous technique is needed to avoid radiological shortening, seen in 30% of our series. This can lead to chronic pain, reduced grip strength and early onset arthrosis. We found no evidence that shortening develops over time. We found that the incidence of shortening is dependent on fracture position but did not find any causative relationship between length of the zone of fracture comminution and shortening.

Level of evidence: Level 4

Keywords: radial nail, shortening, gunshot
pro- and supination, poor grip strength and early onset arthrosis of the distal radioulnar and radiocarpal joints.8-11

Our study aimed to quantify the incidence of radiological radius shortening following radius nails for GSW fractures at our institution. Our secondary objectives were to identify whether the radius was fixated in a shortened position or whether it shortened over time. We also tried to identify any risk factors for radius shortening, specifically looking at whether length of the zone of comminution or anatomical location of the fractures contribute to its incidence.

Patients and methods
We performed a retrospective review of all (n = 40) isolated radius nails for GSW fractures performed at our institution between January 2012 and January 2019. We used the database from the nail provider (Afmed Pty Ltd) to confirm all cases were included in the study. Any radius nail with an ipsilateral fracture of the ulna that required fixation was excluded.

The latest AP forearm X-ray of each patient was assessed by two surgeons experienced in orthopaedic trauma. The rule of perpendiculars was used to calculate ulnar variance (UV)12 (Figure 1). All X-rays were assessed on our Philips Intellispace digital PACS (Philips, Netherlands). Shortening was defined in this study as a positive UV greater than 5.0 mm. If the radius was deemed to be short by consensus using this criterion, then the immediate postoperative X-ray was also assessed to gauge if the fracture was fixed short or if shortening developed over time. This X-ray was taken within 48 hours of surgery. All the cases where index X-rays were deemed not to be shortened were followed up radiologically to confirm that they remained outside the criteria for shortening stipulated in the study. No patients were found to cross over from the normal into the shortened category over the study period. Anatomical location (dividing radius shaft into thirds) and length of the zone of comminution in millimetres were assessed by two independent assessors (and a third in cases of disagreement).

The measurements were segregated into short and not-short groups. The distribution of the data was checked using the Shapiro-Wilk test. Normally distributed data were compared using student’s t-test, and non-normally distributed data were compared using Mann-Whitney U test. Pearson chi-squared test and Fisher’s exact test were appropriately used to find the dependence of shortening with the degree of fracture comminution and fracture location. The condition for statistical significance was set at p < 0.05. All the statistical analyses were performed using IBM SPSS v.26 (IBM Corp, Armonk, NY, USA).

Surgical technique
The procedure is performed with the patient supine on a radiolucent arm table, with the aid of a tourniquet. Prior to commencing the operation, the contralateral forearm is screened to pre-select the appropriate length and diameter of the nail, as well as to assess the patient’s baseline UV in order to try replicate a similar UV on the affected side. There are three different length nails available (Acumed, USA), ranging from 190 to 230 mm. When deciding between two different lengths, we used the shorter of the two to avoid the possibility of a proud nail distally.

The entry point, just ulnar to Listers tubercle and 5 mm proximal to the articular surface, is found with the aid of fluoroscopy. A 1 cm dorsally based longitudinal incision is then made, and blunt dissection performed down to the bone, taking care to avoid injury to the extensor pollicus longus tendon or a small branch of the radial sensory nerve that may cross the surgical field. The near cortex is breached with the entry awl, paying careful attention to the AP and lateral direction of the awl. Inaccuracy of these initial steps, particularly in the AP plane, can result in a malreduction of the radius bow. Directing the awl in a slight radial direction can aid in avoiding

Table 1: The distribution of fracture occurrences and the incidences of shortening across the proximal, middle and distal region of the radius bone

<table>
<thead>
<tr>
<th>Region</th>
<th>Fracture (%)</th>
<th>Shortening (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal</td>
<td>48</td>
<td>17</td>
</tr>
<tr>
<td>Middle</td>
<td>40</td>
<td>58</td>
</tr>
<tr>
<td>Distal</td>
<td>13</td>
<td>25</td>
</tr>
</tbody>
</table>

Figure 1. An example of how to measure ulnar variance: Draw a line tangential to the articular surface of the ulnar. Draw a second line tangential to lunate fossa of radius and perpendicular to shaft. Measure the distance between these two lines. In this example, the UV is measured at 10.7 mm, and would be considered shortened in this study (normal: UV −4.1 to +2.3).

Figure 2. An AP X-ray of a patient, taken three months post surgery. Note the significant ulnar plus (measured at 11.7 mm). She presented with functional loss of supination, requiring revision surgery.
this error. The 3.1 mm reamer is then inserted into the medullary canal, the fracture reduced, and the reamer passed across the fracture, stopping at level of the biceps tuberosity. Depending on the ease of the pass, and the preoperative radiological assessment of the bone’s canal diameter, the surgeon may choose to pass the 3.7 mm reamer to enlarge the medullary cavity to aid in the insertion of a larger calibre nail. The appropriately selected nail is then passed, making sure the fluted nail tip is seated firmly in the subchondral bone proximally to improve purchase. Tapping of the nail using a mallet is often needed to ensure adequate seating of the nail. Restoration of radius length is then achieved radiologically, and rotation confirmed using Evans rule, which states that the biceps tuberosity and radial styloid should be visualised 180° to one another in a normally rotated radius.13 The nail is then locked with the forearm in supination, using a single dorsal 3.5 mm locking screw. Blunt dissection down to the bone is needed to avoid injury to important structures including the extensor tendons or a branch of the superficial radial sensory nerve. Careful intraoperative screening is needed post insertion to ensure the screw is not proud, as this may lead to extensor and flexor tendon irritation. An examination under fluoroscopy is performed to confirm whether the fixation is rotationally stable. If not, an above-elbow slab is used to limit pro- and supination, for a minimum of four weeks, or until soft callus is seen on X-ray.

Results

Forty patients met the criteria for inclusion in the study. No cases were excluded from analysis. Thirty-seven (93%) were male, with a mean age of 32.6 years (range 15–59). Twelve cases (30%) were assessed as radiologically short by both assessors. The mean shortening of the affected group was 7.4 mm (range 5.1–13.0). All 12 were deemed to have been fixed in a shortened position. One case was assessed to further shorten over time by approximately 2 mm.
Most fractures affected the proximal and middle third of the radius. The anatomical distribution of all the fractures was five (13%) distal, 16 (40%) middle and 19 (48%) proximal. The majority (58%) of all shortened fractures were found in the middle third of the radius. Postoperative shortening had a statistically significant ($p = 0.03$) dependency on the position of fracture. Refer to Table I for a summary of results.

We found no statistically significant ($p = 0.55$) difference between the average length of the zone of comminution (41.6 ± 25.9 mm in the shortened group and 35.6 ± 18.9 mm in the not-shortened group) and the incidence of shortening between the two groups.

### Discussion

The surgical goals of any forearm shaft fracture fixation are the restoration of axial and rotational alignment, maintaining stability of the proximal and distal radioulnar joints and early range of motion. 1,3 For most forearm fractures, compression plating remains the gold standard, as anatomical reduction and primary bone healing are considered fundamental in achieving the best functional outcome.3 Complications associated with plate fixation include a 0.8–2.3% risk of infection,14 attributed to the extensive soft tissue dissection required, and up to 30% refracture rate when the plate is removed.15

Fracture comminution however, a constant feature following GSW,1 poses unique treatment challenges and precludes primary bone healing strategies in favour of secondary bone healing. Secondary bone healing can be achieved either by nonoperative means with the use of a plaster cast, or surgically, utilising either bridge plating techniques or IM nailing. Nonoperative management of adult diaphyseal radius fractures is associated with high complication rates, most notably failure to maintain reduction, radius shortening and stiffness.5

The benefits of an intramedullary device over bridge plating include a smaller incision, improved cosmesis and less soft tissue dissection, while also maintaining a more optimal environment for healing due to minimal disruption to the fracture haematoma.6,7 Its stress-sharing biomechanics also promote a predictably stronger fracture callus compared to bridge plating.8

The early radial nails were criticised for their potential to result in iatrogenic injury to the posterior interosseous nerve during proximal locking.9 This led to the development of the currently available radial nail, which has a flanged proximal end, eliminating the need for proximal locking while still providing rotational control through a press-fit mechanism into the unreamed subchondral bone. This requires attention to detail in the reaming step of the surgery (see surgical technique) as reaming beyond the bicapital tuberosity can potentially reduce the proximal purchase into the subchondral bone and therefore reduce the rotational control the nail provides. The modern nail is not without problems either, with nail migration and malunion (failure to restore radial bow) have been highlighted.14

Many authors have investigated the clinical and biomechanical consequences of radius shortening. Crisco et al. reported that radius shortening changes the axis of rotation of the forearm, resulting in reduced joint congruency, reduction in rotation and changes in stress across the triangular fibrocartilage complex (TFCC).16 Adams concluded that the greatest change in kinematics at the distal radius ulnar joint is due to radius shortening, which results in increased strain in the articular disc, and volar and dorsal radioulnar ligaments of the TFCC, leading to reduced grip strength.17 They also reported that radius shortening results in changes in radiocarpal and radioulnar joints and that radius shortening has the most direct correlation with increased symptoms, including an increased risk of arthrofibrosis. Lidstrom concluded their work by claiming that restoring radius length is the most important factor associated with a good clinical outcome.18 Fernandez showed that radius shortening can result in reduced pro- and supination.19 One of the patients in our series presented for her follow-up with significantly reduced supination, affecting her activities of daily living. Her postoperative X-rays show a positive ulnar variance of 11.7 mm (Figure 2), Comparative pictures shown in Figures 3 and 4 demonstrate her limitation in supination compared to the unaffected side. She underwent an ulnar shortening osteotomy (Figure 5) to alleviate some of her symptoms. Figure 6 shows her improved clinical picture, six weeks post revision surgery. Distal radioulnar joint pain, ulnar impaction syndrome, TFCC tears and early onset osteoarthritis are the other commonly associated conditions attributed to radius shortening.9,16

Ulnar variance (UV) is a commonly used radiological method to assess for radius shortening. Plain radiographs are proven to be accurately acceptable to measure UV.10,12 Being a dynamic measurement, it is influenced by several factors including rotation, grip and beam direction,20 and therefore, normal reference ranges differ. While international consensus on UV ranges is lacking, most quoted studies of UV in a neutral, relaxed position is 0.9 mm (range −4.1 mm to +2.3 mm).10 To accommodate for magnification error, potential positional variability when taking the X-ray, and to allow for the potential of a patient having a pre-existing ulnar plus of up to 2.5 mm, we defined radiological shortening as more than or equal to 5 mm positive UV. We used the rule of perpendiculars to measure UV, having been shown to have the best interobserver reliability of the three commonly practiced methods of assessing.10,12,21

There is ample published literature on the clinical impact of a positive UV. Most of the literature suggests that 2.5 mm is the amount of radius shortening beyond which clinical symptoms develop.8,10,22 Early onset osteoarthritis due to increase in the mechanical load through the ulnar,23 ulnar impaction syndrome, distal radius ulnar joint (DRUJ) pain/degeneration, reduced grip strength and carpal instability are also reported in the literature.8,9,17,22

We could only find two articles that specifically looked at IM nails in the setting of GSW. In the first, the author makes mention of a case where DRUJ shortening occurs over the course of the healing process but does not elaborate further on its clinical significance.7 The second paper is an outcome-based study and does not specifically look at radius shortening.1

While formulating this study, we hypothesised that highly comminuted radius shaft fractures would shorten over time. We felt the mechanical properties of the IM nail may not be adequate to maintain length for sufficient time to allow union, as biomechanical studies have proven them inferior to plates.5 The results of our study, however, seem to suggest that, should meticulous care be taken intraoperatively to restore the correct radius length before locking the nail, that shortening does not occur over time.

We therefore advocate the following steps to ensure shortening is avoided. First, take measurements of the contralateral radius for length and diameter in order to plan which available nail will give you the optimal proximal subchondral purchase, without leaving it proud distally. If only a single distal locking screw is available, inadequate purchase of the fluted blade tip into unreamed bone may render the nail length unstable. Pay careful attention to the relationship of the distal radius and ulnar of the unaffected side in order to reproduce it on the operated side. Intraoperatively, the authors feel that tapping in of the nail to get adequate subchondral purchase may inadvertently result in shortening. To mitigate this potential problem, one of our surgeons held the reduced DRUJ out to length before inserting the nail using a K-wire prior to the insertion of the nail (Figure 7). The wire was left in-situ for three weeks, and the patient healed in an acceptable position. Given what we now know about the nail’s seemingly consistent ability to hold fractures out to length if acceptably reduced, we feel that removing the wire at the conclusion of the surgery, thus limiting...
the potential side effects of an in-situ wire, is appropriate. Lastly, we wish to stress the importance of screening for stability at the conclusion of the surgery, and if there is any doubt, liberal use of an above-elbow back slab for four weeks, or until soft callus seen on X-ray, is advocated.

The secondary outcome measures of the study aimed to determine if length of comminution or anatomical location of the fracture had any direct correlation with an increased incidence of shortening. While shortening was found to be dependent on the fracture position, with a predilection for the middle third of the radius, the length of the zone of fracture comminution was found to not be a significant contributing factor.

The study is enhanced by its relatively large sample size, given the sparsity of this surgery, but it is limited by its retrospective design. Being a retrospective review, we could not ensure all the X-rays were standardised, thus potentially affecting the dynamic nature of UV. As detailed in the discussion section, we attempted to overcome this by setting a relatively high positive UV as our cut-off to define shortening. Finally, we are aware of the limitations in our detection methods for identifying and defining radius shortening, due mainly to a lack of formal contralateral control X-rays showing the patients’ baseline UV. Obtaining intraoperative radiographs upon completion of the surgeries would have removed the remote possibility that the fracture was fixed correctly and shortened in the immediate postoperative period. While screening the contralateral side is an important intraoperative step, its accuracy in UV measurements for the purposes of this study is insufficient.

Conclusion

The radius nail remains a useful tool to manage comminuted radius shaft fractures following GSW, yet careful attention to detail is needed intraoperatively to avoid radiological shortening, as seen in 30% of our case series. We found no evidence of subsequent shortening if the radius length is corrected before the nail is locked. We also did not find any causative relationship between length of the zone of fracture comminution and subsequent shortening but found a dependent relationship between fracture location and incidence of shortening.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. Full ethics approval from the University of Cape Research Committee (HREC 580/2019) was obtained for this study. All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Declaration

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

Author contributions

MA: Study conceptualisation, study design, data capture, data analysis, first draft preparation, manuscript revision, manuscript preparation
SM: First draft preparation, manuscript revision
RD: Data capturing, statistical analysis
ML: Manuscript revision, study design, study conceptualisation, manuscript preparation

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References

Abstract

Distal radius fractures (DRFs) are commonly encountered in the elderly population, secondary to low-energy injury mechanisms. In the younger population, DRFs are mainly secondary to high-energy trauma. Stable DRFs can be treated conservatively. However, in the elderly population group, DRFs are often unstable and are likely to benefit from surgical intervention. They are often compounded by comorbid medical conditions requiring optimisation. When treating the elderly group, one should be aware of sarcopenia, as this may have a bearing on return to function. Recent literature reports an increasing trend in the surgical management of these fractures. Current classification systems fail to consistently guide the management of these fractures. Although evidence is still limited in guiding decision-making in the treatment of these fractures, one should consider the economic implications of prolonged immobilisation in young patients in addition to defined indications for surgery. Improvement in implants allows safe dorsal fixation in patients with dorsal comminution, with low complication rates reported. This narrative review summarises current trends and the body of evidence.

Level of evidence: Level 5

Keywords: distal radius, fracture management, osteoporosis

Introduction

Having noted a trend of steady increase in life expectancy globally, the World Health Organization (WHO) declared the years 2020 to 2030 as a decade of healthy ageing. The main aim of this declaration is to develop and maintain the functional ability that enables the wellbeing of the elderly population. Most people over the age of 60 years live in low- to middle-income countries. In South Africa, as of mid-2020, the estimated life expectancy was 68.5 and 62.5 years for females and males respectively, showing a steady annual increase. Distal radius fractures (DRFs) are the second most common fragility fracture. About 1.5% of the patients treated in the emergency unit will present with DRFs, of which 5–17% are due to low-energy injury mechanisms in osteoporotic patients. In an epidemiological review of the Swedish registry, Rundgren et al. noted a higher prevalence of DRFs in females over the age of 50 years compared to males of the same age. The incidence of DRFs in young adults is low, and usually follows high-energy trauma or sports-related injuries, often presenting with complex fracture patterns.

Economic burden

More reconstruction options are available for the treatment of these injuries, each with cost implications. A recent review of a commercial claims database in the United States found conservative management to remain the treatment of choice throughout various demographic groups. More recent literature reported a shift towards surgical intervention in these fractures.
Mauck and Swigler reported an incidence of 634,000 DRFs annually in the American elderly population, with a high financial burden ranging from 385 to 535 million US dollars annually. Comparing treatment options for DRFs in adults from the Medicare dataset, Shauver et al. found the cost of surgery to be almost twice the cost of closed reduction and casting. Among young adults, an additional financial burden applies in the form of ‘loss of productivity’ due to the inability to perform their employment responsibilities.

**Historical background**

Abraham Colles noted the deformities in patients he treated for DRFs in 1814, decades before X-rays were available. He reported good functional outcomes following closed reduction and a splintage with a ‘narrow wooden splint’. With the advancement in radiological investigations, fixation methods and arthroscopic skills, the understanding and management of these injuries is evolving from mostly conservative treatment methods to advanced fracture fixation methods, arthroscopic-assisted surgery and arthroplasty procedures.

**Anatomic considerations**

The distal radius is functionally made up of three columns formed by osteo-ligamentous structures; it rests on a pedestal and transmits 80% of the axial load through the wrist (Figure 1).

**The radial column**

The radial column consists of the radial styloid and the scaphoid fossa, the insertion of the brachioradialis tendon, the long radiolunate ligament and radio-scapho-capitate ligament. This column serves as a radial buttress for the carpal bones during wrist ulnar deviation and weight bearing. This column is often spared in patients with injuries secondary to axial forces. The brachioradialis is responsible for radial deviation, tilt and loss of radial height in these fractures.

**Intermediate column**

The intermediate column is made up of the lunate facet and sigmoid notch and serves as the load transmission column. The ligamentous structures are the short radiolunate and volar distal radioulnar ligaments attached to the volar rim fragment; the dorsal radiocarpal ligament attached on the dorsal wall; and the dorsal distal radioulnar ligament attached to the dorsal ulnar corner. Fractures of the dorsal wall, volar rims, intra-articular fragments and dorsal unlar corner form part of the intermediate column fractures. The dorsal wall provides functional stability against dorsal carpal subluxation. Shear force, axial loads and bending mechanisms can result in fractures of this dorsal wall. Fractures of the ulnar corner and more than 10 mm radial height loss are associated with unstable distal radioulnar joint (DRUJ) and triangular fibrocartilaginous complex (TFCC) injuries.

Reduction of the articular fragment is important for the restoration of the lunate facet. The lunate-lunate facet ratio (LLFR), measured on the lateral view, can help to determine the degree of articular separation. Articular surface congruency is best assessed with Medoff’s teardrop angle (TDA), formed by a line through the central axis of the teardrop and a line in the centre of the distal radius where normal is 68° on the lateral view plain X-rays.

**The pedestal**

The pedestal is the metadiaphyseal segment, immediately proximal to the radial and intermediate columns. Fractures extending into the pedestal are seen in high-energy injuries.

**Evaluation**

**Clinical evaluation**

Clinical examination should include a neurovascular assessment. Careful assessment of the median nerve is important, especially if there is a complaint of paraesthesia or numbness. This may indicate acute carpal tunnel syndrome (CTS). Acute CTS has
been reported in 5.4–8.6% of patients with DRFs. It may develop rapidly, and the diagnosis is made by establishing the presence of severe paraesthesia in the median nerve distribution and sensory testing with two-point discrimination testing and Semmes-Weinstein monofilament testing.\textsuperscript{22,23} Skin puncture is common in elderly patients with thin soft tissues. Care must be taken to avoid shearing of these tissues, especially during closed reductions.\textsuperscript{24} 

Evaluation of elderly patients with DRFs should include assessment of the muscle mass. The Asian Working Group for Sarcopenia recommends the evaluation of hand grip strength and gait speed to diagnose sarcopenia.\textsuperscript{25} The presence of sarcopenia has been reported to be prevalent in elderly patients with DRFs and it is closely associated with osteoporosis. Roh et al. reported 34% of men and 27% of women over the age of 50 years had sarcopenia in a review of 264 patients with DRFs.\textsuperscript{26} The presence of sarcopenia is associated with poor functional recovery after DRF surgery.\textsuperscript{27} 

**Radiographic evaluation**

A minimum of posteroanterior (PA) and lateral view plain X-rays is mandatory for the initial fracture evaluation.\textsuperscript{4} An additional 45° pronated oblique view can be added if deemed necessary. This view is helpful with profiling the dorsal ulnar cortex and lends insight into this biomechanically important region.\textsuperscript{9} 

**Computed tomography scan**

Coronal and axial computed tomography (CT) images with 2 mm slices provide a detailed view for fracture configuration, in occult or complex fractures as well as an assessment of the reduction.\textsuperscript{28} In a study on the utility of radiographs, two-dimensional (2D) CT scans and three-dimensional (3D) CT scans on 30 DRFs, Harness et al. found 3D CT scans to be highly reliable and accurate over other studies and influenced treatment recommendations.\textsuperscript{29} A CT scan should be considered in patients undergoing open reduction and internal fixation (ORIF) or when information about comminution and joint depression is needed.\textsuperscript{30} 

**Classifications**

Most DRF classification systems are descriptive in nature and fail to guide on management. The McMurty and Jupiter as well as the Frykman, Melone and Mayo classification systems focus on the amount of articular involvement, whereas those by Gartland and Werley, and Older and Jenkins emphasise the amount of comminution.\textsuperscript{31} The AO classification lacks interobserver reliability and is mainly used for research and documentation.\textsuperscript{4,32–34} The IDEAL classification\textsuperscript{35} is a five-factor mnemonic used to classify DRFs into three broad groups which could predict stability, guide management and prognosticate. Validation and reproducibility are yet to be confirmed. No classification has been proven to be superior in terms of determining prognosis or guiding management.\textsuperscript{4,31,35} Table I shows a summary of the results of selected studies evaluating inter-rater reliability of the commonly used classification systems. 

**Management of distal radius fractures**

**Decision-making**

The aim of treating DRFs should be to restore wrist anatomical alignment and function. Important factors to consider in decision-making are patient’s age, hand dominance, fracture pattern and radiographic parameters.\textsuperscript{3,4,40,41} Decision on treatment should be tailored based on patient-specific factors.\textsuperscript{42} Being able to predict fracture instability and loss of reduction remains the greatest challenge to treating surgeons. A Cochrane review of 60 DRFs in elderly patients managed with closed reduction found loss of reduction to be at a rate of 88%, of which 75% occurred within one week.\textsuperscript{33} In 1989, Lafontaine et al. proposed that unstable fractures are likely to occur in patients aged 60 years and above and a fracture with greater than 20° dorsal angulation, dorsal comminution, associated ulnar fracture and intra-articular involvement.\textsuperscript{43} These findings have been supported by other authors. Mackenney et al. prospectively reviewed 4000 DRFs over a 5.5-year period with the aim of predicting early and late fracture instability and resultant fracture malunion. They found advanced patient age, fracture 

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants (n)</th>
<th>Image modality (number of wrists)</th>
<th>Inter-rater reliability on radiographs (kappa values)</th>
<th>Interobserver reliability on radiographs and CT images (kappa values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azi, et al. 2019\textsuperscript{36}</td>
<td>Orthopaedic surgeons (n = 5)</td>
<td>Plain radiographs and CT images (n = 43)</td>
<td>AO/OTA Mean ICC: 0.11 (poor)</td>
<td>Mean ICC: 0.28 (fair)</td>
</tr>
<tr>
<td>Van Buijtenen, et al. 2015\textsuperscript{37}</td>
<td>Trauma consultants (2) Radiology consultant (1)</td>
<td>Plain radiographs (n = 54)</td>
<td>AO/OTA Mean ICC: 0.49 First attempt and 0.3 (on second attempt) (fair)</td>
<td>-</td>
</tr>
<tr>
<td>Kleinlugtenbelt, et al. 2017\textsuperscript{38}</td>
<td>Surgeons with over ten years experience (n = 4)</td>
<td>Plain radiographs and CT images (n = 51)</td>
<td>Frykman classification Mean ICC: 0.45 (fair) Fernandez Mean ICC: 0.38 (poor) Universal Mean ICC: 0.32 (poor) AO/OTA Mean ICC: 0.46 (fair)</td>
<td>Mean ICC: 0.28 (poor) Mean ICC: 0.44 (fair) Mean ICC: 0.43 (fair) Mean ICC: 0.40 (fair)</td>
</tr>
<tr>
<td>Mansu and Gripp 2020\textsuperscript{39}</td>
<td>Registrars (n = 4) Consultants (n = 8)</td>
<td>Plain radiographs (n = 14)</td>
<td>Frykman classification Mean ICC: 0.36 (poor) Universal Mean ICC: 0.48 (fair) AO/OTA Mean ICC: 0.25 (poor)</td>
<td>-</td>
</tr>
</tbody>
</table>

ICC: interclass coefficient
comminution and alteration in ulnar variance to be significant predictive factors of loss of reduction.44 Similarly, a more recent systematic review and meta-analysis identified dorsal fracture comminution and female patients aged over 60 years to be significant predictive factors of fracture instability.45

**Treatment methods**

**Non-surgical treatment**

Closed reduction and cast immobilisation remain an acceptable treatment modality for stable fractures with reported good results in elderly patients even in the presence of intra-articular involvement.46 There was no difference in failure rate or final position at five weeks when the fracture was treated with finger trap traction or manipulation.47 Appropriate splintage should be used. Figure 2 shows X-rays of a patient with successful closed reduction and below-elbow cast immobilisation. There is limited evidence on the usage of above-elbow immobilisation compared to below-elbow immobilisation.48

Fracture reduction quality can be assessed with X-rays in a cast. Dailey et al. found no difference between the usage of a mini C-arm and taking radiographs in an orthosis when measuring the quality of reductions.49 There is a lack of reliable evidence for radiographic evaluation of DRFs treated with closed reduction in the literature. The American Academy of Orthopedic Surgeons (AAOS) recommends weekly X-rays for the first three weeks and subsequent X-rays to be taken at six weeks to monitor alignment.48 The results of closed reduction and cast immobilisation were reported to be comparable to those of patients treated surgically for displaced DRFs in a randomised controlled trial of 100 patients aged over 65 years at 12 months follow-up.50 In the young active population, one should remember that a displacement of the fracture in a cast will delay the return to work or sporting activities.

**Closed reduction and percutaneous pinning**

Stable extra-articular fractures can be treated with closed reduction and percutaneous pin fixation. Several pinning techniques have been described in the literature, with the aim of achieving fracture stability and promoting early mobilisation. Most techniques recommend the use of at least three pins with minimum 40° crossing angle to ensure stability.51,52 One should be wary of pin-site infection.

A randomised multicentre trial (DRAFFT) was done on patients (n = 461 adults, mean age 59.1 years) who underwent distal radius acute fracture fixation for dorsally displaced fractures within 3 cm of the radiocarpal joint, from 18 centres in the United Kingdom. No difference was found in functional outcomes, quality of life and number of complications between the group treated with closed reduction and percutaneous K-wire fixation (n = 230) compared to those treated with volar-locking plate fixation (n = 231) at 12 months.52 A five-year follow-up of this population revealed no difference in wrist pain, function and quality of life between the two arms of treatment.53

**Surgical fixation**

**Indications**

The AAOS recommend surgical fixation if post-reduction radial shortening is greater than 3 mm, dorsal tilt is greater than 10°, or intra-articular displacement or step-off is greater than 2 mm.46 Unstable fractures with dorsal comminution or those with secondary loss of reduction should be treated surgically.41,54,55

**Surgical approaches**

**Volar approach**

Henry’s volar approach is the most used approach for the treatment of DRFs. The classic approach makes use of a safe interval between brachioradialis and radial artery, and the modified approach between flexor carpi radialis tendon and radial artery to gain access to the fracture.56,57 Multiple modifications to this approach exist. It can be extended distally to allow the release of transverse carpal ligament for visualisation of complex intra-articular fractures.58

The choice of plate construct and plating technique should be individualised to the patient’s profile, fracture pattern and surgeon’s experience.59,60 Volar plate fixation is the commonly used treatment method among surgeons for displaced DRFs.59 Fixed-angle volar plates are designed to transfer load from the intact subchondral bone through metaphysis to the diaphysis.18 Locking plates have been reported to have improved fracture site stability against axial and bending forces over non-locked plates by biomechanics studies.51-53 However, their superiority over non-locked plates has not been demonstrated in practice. Clinical studies reporting on fixation of displaced articular fractures treated with locked plates have reported good results.64-66 Locked plates allow for polyaxial screw fixation and can address comminuted fragments through...
Plate failure and other complications following volar plating are not uncommon. Wilson et al. reported 17% complication rates in patients (mean age 56.5 years) treated with volar-locking plate, at 17.5 weeks mean follow-up. Loss of fracture reduction and CTS were the two commonly reported complications. Johnson et al. reported similar complications in their cohort of 204 patients with a mean age of 55 years. However, the complication rate following volar plating was lower (9.7%). Flexor tendon rupture is not uncommon following volar plating. Flexor pollicis longus (FPL) is the most commonly ruptured tendon (57% of cases), followed by flexor digitorum profundus (FDP) to the index finger. Extensor tendon irritation and rupture is not uncommon, following volar plate fixation of DRFs, and it has been associated with long dorsal penetrating screws, among other factors.

**Dorsal approach**

The dorsal approach to DRFs provides intra-articular visualisation and direct assessment of articular reduction. It is generally used in patients with severe metaphyseal dorsal comminution and those with dorsally angulated intra-articular fractures. Historically, dorsal plating has been associated with high complications and risk of extensor tendons rupture. Modern plate designs have been shown to reduce the risk of dorsal tendon attrition. Spiteri et al. reported no tendon ruptures in 46 patients treated with modern-design low-profile dorsal plates and 17 treated with combined volar and dorsal plates at the five-year follow-up. However, 8.7% had reported extensor tendons irritation, and the plates were removed in all of them.

**External fixation**

External fixation is a viable option for complex intra-articular DRFs and open fractures. It is commonly indicated for temporary fracture stabilisation. Bajwa et al. reported a significantly worse mean DASH score of 12.2 in patients treated with external fixator for intra-articular DRFs compared to a mean DASH score of 3.5 in those treated with ORIF. Similarly, Roh et al. reported comparable functional outcomes between external fixation and volar plate fixation in a prospective randomised trial of 92 patients with a minimum 12-month follow-up. The external fixator group had higher complication rates of 29% compared to 17% in the ORIF group.

**Intramedullary fixation**

Intramedullary fixation for DRFs has been reported with enthusiasm as an option for treatment of DRFs. Tan et al. reported superior immediate- and intermediate-term functional outcomes in patients treated with intramedullary nails for DRFs compared to those treated in a cast. Similarly, Calbıyık and Ipek reported good results in a cohort of 68 young adults, with a mean age of 46 years treated with an intramedullary fixation for extra-articular and simple intra-articular DRFs.

**Arthroplasty**

Arthroplasty procedure for wrist fracture is a fairly new phenomenon and evidence is limited to small sample size studies. Vergnenège et al. reported good functional outcomes in eight elderly patients treated with Sofia wrist hemiarthroplasty system (Biotech) for unreconstructable intra-articular fractures.

**Arthroscopic-assisted surgery**

Arthroscopic-assisted surgery for DRFs has been used as an adjunct to DRFs since the 1980s. However, it has failed to gain popularity because it is time-consuming and technically demanding, with increased risk of compartment syndrome. Fluoroscopy has been the modality of choice for evaluation of articular step-off. However, multiple studies have shown that arthroscopy is superior to fluoroscopy in evaluation of the articular surface. Adjunct wrist arthroscopy is indicated in patients with radial styloid fractures, die-punch fractures, articular step-off of > 2 mm, flipped osteochondral fragment, central comminution as well as three- to four-part fractures.

**Regional and local anaesthesia**

The wide awake local anaesthesia no tourniquet (WALANT) technique in the management of wrist and hand conditions has been a topic of interest in recent literature. Prior literature could not demonstrate the benefits of WALANT in patients’ wrist fractures. However, recent literature has demonstrated WALANT to be tolerable during fixation of DRFs without a tourniquet, with a faster recovery period and similar functional outcomes to general anaesthesia, and it is more cost-effective.

**Adjuncts to surgery**

**Bone graft**

A Cochrane database analysis of randomised trials concluded that there was insufficient evidence on functional outcomes and safety of the use of grafts in DRFs. That said, in elderly patients with comminuted fractures and metaphyseal bone loss following restoration of length and alignment, bone graft substitutes are sometimes necessary. Although no graft is superior, the iliac crest bone graft can be used in cases of major bone loss, and fracture non-union is recommended. Pedestal bone loss can be managed with bone graft in closed fractures, and staged bone graft reconstruction should be considered in patients with open fractures.

**Calcium phosphate cement**

Calcium phosphate use in DRFs has been reported to provide improved fracture stability in fractures treated with either external fixator or K-wire fixation in biomechanics studies. Zimmermann et al. reported good results and cement incorporation in 26 postmenopausal women managed with injectable calcium phosphate bone cement and K-wires for intra-articular DRFs with a metaphyseal void of at least 5 mm. This was compared to those treated with cast immobilisation or K-wire fixation without the use of bone cement following the reduction. The indications for bone cement use are not clearly defined in the literature. Ozer and Chung concluded that indications and choice of graft substitute should be based on the needs of the individual patient until further comparative research clarifies the indications and most appropriate material for a given fracture and clinical situation.

**Pronator quadratus repair**

Pronator quadratus repair following volar plating has not been shown to have a functional impact. Some studies suggest this repair may be protective against flexor tendons rupture.

**Carpal tunnel release during fracture fixation**

Prophylactic carpal tunnel release (CTR) in patients with DRFs is not recommended. Acute CTR should be done in patients with persistent and progressive features of acute CTS.
Delayed release of more than 36 hours has been associated with irreversible nerve damage, whereas patients released acutely regained full nerve function.\(^{108-110}\)

**Postoperative care and rehabilitation**

Postoperative rehabilitation programmes remain controversial and centre-specific.\(^{111}\) Postoperative care includes immobilisation, analgesia and elevation.\(^{112}\) Postoperative immobilisation of two weeks versus six weeks after volar plate fixation has shown no difference in long-term range of motion or functional outcomes. Although earlier range of motion exercises speeds up recovery in the acute setting, it did not translate into improved ultimate outcomes.\(^{113}\)

Duprat et al. illustrated that the stability of a locking volar plate enabled immediate mobilisation with similar complication rates, but resulted in improved short-term outcomes in all aspects.\(^{114}\) When treatment entails closed reduction and casting, immobilisation for four to six weeks is preferred, provided that evidence of healing can be confirmed.\(^{115}\) In the absence of comorbidities, like diabetes, fracture union will have taken place. If in doubt, radiographs can be used to confirm union.

The majority of function is regained by three months, provided that good alignment was achieved, but continuous improvements up to 12 months can be expected with a slow return of grip strength.\(^{113}\)

Athletes need to be individualised. Contact athletes can return to sport once they have achieved a pain-free range of motion and completed sport-specific drills and practice. Sports where wrist function is not required needs to be discussed with the patient and practised at their own discretion while being well informed and made aware of the risks.\(^{113}\)

**Adjuvant therapy**

**Vitamin C supplementation**

Empiric vitamin C for the prevention of complex regional pain syndrome (CRPS) remains controversial. Its use has been recommended since Zollinger proved some benefit in 1999, but recent randomised controlled trials failed to demonstrate such benefit.\(^{116-118}\)

**Vitamin D supplementation**

Vitamin D deficiency is common in the elderly population with fragility DRFs.\(^{119,120}\) Several studies have demonstrated hypovitaminosis D in young patients, even in the South African setting.\(^{121-123}\) Øyen et al. found that the elderly who sustain DRFs had low vitamin D levels compared to those who did not have fractures.\(^{119}\) However, Rozental et al. reported that, in Israel, there was no association of low vitamin D with DRFs.\(^{124}\) Amid contrasting evidence, we propose selective patient vitamin D testing and sparing medication if indicated.\(^{126}\) Molvik and Khan reported that good alignment was achieved, but continuous improvements in those treated surgically. Osteoporosis treatment should be initiated early in at-risk populations. High-level evidence and treatment guideline protocols are still lacking on this subject.

**Bisphosphonate therapy**

Timing to initiation of bisphosphonates did not alter union times or rates. Patients should be risk-stratified and initiated on bone-sparing medication if indicated.\(^{126}\) Molvik and Khan reported significantly prolonged fracture union time in patients with DRFs treated with bisphosphonates in a systematic literature review.\(^{127}\)

However, the clinical studies reported similar radiographic and functional outcomes between patients with acute DRFs treated with bisphosphonate therapy and those who were not given bisphosphonates.\(^{42,128,129}\)

**Low-intensity ultrasound**

Low-intensity ultrasound showed promise by reducing fracture healing times from 98 days to 61 days in a study by Kristiansen et al., and from 40 days to 32 days in a study by Liu et al. No long-term benefit could be proven in these studies, and the cost over benefit of this modality remain a concern.\(^{130,131}\)

**South African context**

Trauma is a huge burden on an already compromised public healthcare system in South Africa. The private sector treats about 16% of the general population while the government sector treats 84%.\(^{132,133}\) Patients are waiting longer to receive elective surgery because of the limitation of theatres in state hospitals.\(^{134}\) The lack of resources results in delayed referrals of patients, compelling the treating surgeon to manage partially healed fractures that often result in long operating times and a high risk of complications. This ailing system has been further burdened by the Covid-19 pandemic. It is our opinion that surgeons should consider nonoperative treatment of selected DRFs. This could aid in relieving some of the pressure from the overburdened public health sector.

**Conclusion**

Distal radius fractures are common among elderly females, with increasing prevalence among all age groups. Management of these injuries remains controversial with no clear guidelines and contrasting evidence in the literature. Although nonoperative treatment is still a viable option in most cases with good results, the recent trend has seen an increase in surgical treatment. Improvements in fixation plate design have shown promising results in the reduction of complications and restoration of function in those treated surgically. Osteoporosis treatment should be initiated early in at-risk populations. High-level evidence and treatment guideline protocols are still lacking on this subject.

**Learning points**

The incidence of DRFs in young adults is on the rise and they often follow high-energy mechanisms of injury.

Classification systems demonstrate a lack of reliability, and their role in guiding treatment is limited.

The majority of DRFs are amenable to conservative treatment but one should be wary of the risk of fracture collapse in high-risk populations, and time taken off work or sports in young patients.

DRFs are often the first sign of osteoporosis and clinicians should not miss this opportunity to treat these patients accordingly.

Surgical management is associated with higher financial costs.

**Ethics statement**

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on research integrity in Singapore, 2010. Ethical approval for this study was not obtained – review article.

**Declaration**

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

**Author contributions**

PR: Assembled the team of reviewers, co-ordinated the review process, conducted the primary review and compiled the manuscript

SK, MT, FD and GT: Conducted the primary review and assisted with writing and reviewing the written submission

SG: Reviewed the written submission and provided senior guidance
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Minimally invasive subcutaneous anterior fixation of pelvic fractures in the elderly: case report and literature review

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Abstract

Background

As our population ages, the incidence of pelvic fragility fractures will rise accordingly. Despite these fractures having similar mortality rates to proximal femur fractures, there exist discrepancies between the management of these injuries. Although a number of pelvic fragility fractures can be treated successfully with conservative means, early treatment with appropriate surgical means should be considered in those failing conservative treatment or with unstable fracture patterns.

Case report

We present an 84-year-old female who sustained a pelvic fragility fracture after a low-energy fall. Despite adequate conservative treatment, she was unable to mobilise. She was taken for anterior and posterior fixation, using our modified minimally invasive subcutaneous technique (the Bridging Infix) for anterior fixation. At the six-week follow-up she had regained full independent mobility. She had three syncope-related falls during this period, but radiographs revealed no sign of implant displacement. One year after her surgery she had complete union of her fracture, good function and no desire to have the implant removed.

Discussion

With the expected increase in pelvic fragility fractures due to the growing elderly population, our understanding of these injuries has begun to change. Occult posterior ring injuries have been described in up to 80% of cases, while fracture progression to unstable patterns can occur in up to 15% of stable patterns. Despite conservative management being the primary treatment of choice, these patients suffer morbidity and mortality rates comparable to proximal femur fractures. Early appropriate surgical management should be considered in patients failing to mobilise. Various surgical techniques have been described, each with their own advantages and disadvantages. Newer minimally invasive techniques are gaining favour, especially for use in elderly patients. These constructs combine the low profile benefits of internal plate fixation with ex-fix principles.

Conclusion

The Bridging Infix is a modified technique for minimally invasive subcutaneous anterior pelvic fixation. Its use can strongly be considered by even the general orthopaedic surgeon in cases where patients are too frail for extensive or invasive surgeries, such as open reduction and internal fixation with plate and screws.

Level of evidence: Level 5

Keywords: pelvic fracture, anterior pelvic fixation, elderly, minimally invasive

Introduction

As our population ages, the incidence of traumatic and insufficiency pelvic fractures among the elderly is rising.¹ This phenomenon highlights the current common misdiagnosis and management of, particularly, the insufficiency pelvic fractures. Isolated pubic rami fractures respond well to conservative management with minimal pain and a quick return to mobility. A similar management approach applied to complex lateral compression-type pelvic fractures is fraught with pain and prolonged immobility leading to increased morbidity and even death.¹ Increased use of computerised tomography (CT) scans has shown that up to 80% of presumed isolated pubic rami fractures are complex lateral compression-type pelvic fractures.²

Hopf et al. link neck of femur fractures and pelvic insufficiency fractures in the elderly demographic by stating that they share similar mortality rates.³ Despite this, a discrepancy remains between their management. Neck of femur fractures enjoy appropriate and aggressive early treatment leading to a marked reduction in mortality, morbidity and complications, whereas insufficiency pelvic fractures remain misdiagnosed and poorly treated.

As with neck of femur fractures, a percentage of patients with
stable pelvic fracture patterns can be treated conservatively. Early treatment with appropriate surgery for complex or unstable fractures is, however, essential. Transiliac/sacral screw fixation is an effective treatment for most posterior injuries. At the same time, stabilisations with external fixation, open reduction and internal fixation (ORIF) with sub-muscular plating, retrograde pubic rami screw fixation or newer subcutaneous techniques are possible for anterior instability. We propose using a novel internal bridge plate and rod technique that combines the extra-pelvic fixation methods of an external fixator with the low-profile advantages of the pelvic bridge and ORIF.

Case report
We present an 84-year-old female who sustained a pelvic fracture (Figure 1) after a fall while disembarking from a minibus. She was referred to us with a complaint of significant pain and difficulty mobilising despite receiving physiotherapy for the past two days following the injury. Before the injury, the patient was living independently with full mobility and without the use of walking aids. On presentation, the X-rays showed a superior and inferior pubic rami fracture, with the superior rami fracture at the level of the medial edge of the obturator foramen with comminution and extension into the pubis. A CT scan revealed a type 2B fragility fracture of the pelvis comprising anterior pubic rami fractures and a posterior sacral fracture (Figure 2).

She was taken to theatre the following day for fixation (Figure 3) and, under general anaesthesia and a spinal block, a single 6.5 mm cannulated screw was used to stabilise the posterior arch. A modified minimally invasive subcutaneous technique was used for the anterior arch. Our Bridging Infix technique is a variant of the pelvic bridge described by Hiesterman et al., during which we avoid placing pedicle screws in the pubic tubercle. Hence the only fixation points are those at the iliac crest, similar to the INFIX. By avoiding the use of pedicle screws we theoretically reduce the likelihood of patient discomfort caused by prominent screws at the pubis or heterotrophic ossification developing, which was found in around 25–30% of pedicle screw heads which have been removed. An additional advantage this construct has over the original pelvic bridge is that it can be used in cases with bilateral pubic rami fractures, as it is not dependent on screw purchase at the pubic tubercle. The patient spent one night in the high care unit for postoperative observations. Physiotherapy was initiated immediately with protected weight-bearing allowed. The patient was able to mobilise safely and was discharged seven days after surgery to a step-down facility for continued physiotherapy.

At the six-week follow-up, the patient was able to walk unaided and pain-free. She had full active range of motion in her hips and was able to perform active straight leg raises bilaterally (Figure 4). She reported having fallen three times since surgery due to syncope and was subsequently referred to a physician for further work-up. She had recovered complete independent mobility but was advised to continue using a walking frame to assist with balance. Radiographs revealed good early union and no signs of displacement, despite her having fallen several times. She was assessed for a final follow-up one year after her surgery. At this time, she reported no discomfort from the Bridging Infix and did not desire the removal of the implant. Radiological examination revealed a good bony union (Figure 5). Her syncope had also improved with appropriate medical therapy.

Discussion
An estimated 7% of all osteoporotic fragility fractures affect the pelvic ring; and it has also been shown that 73% of all pelvic fractures occur in the elderly. A rapidly growing demographic of older adults is evident as life expectancy increases in developed
The number of pelvic ring fractures among older adults in America increased by 24% between 1993 and 2010. Elderly patients are vulnerable due to their age-related physical condition, pre-existing comorbidities, limited rehabilitation capacity, and impaired coping mechanisms. Pelvic fractures can have a major impact on their quality of life and result in loss of independence. Rehabilitation to independent mobilisation is of critical importance to improve outcomes and prevent common complications such as decubitus ulcers, pneumonia and urinary tract infections, which occur in 58% of patients treated conservatively. With conservative management as the primary choice of treatment, it is evident that an average hospitalisation duration ranges from 9.3 to 45 days. The time to pain improvement and independent mobilisation varies from four weeks to more than three months, and nearly 50% of patients report diminished independence afterwards, while only 85% report complete pain relief after nine months of conservative management. The one-year mortality rate has been reported to reach 27%, while the five-year mortality is as high as 54%, comparable to intertrochanteric and neck of femur fractures among this group.

Even low-energy trauma such as a fall on the side from a standing position can cause a compression fracture of the lateral mass of the sacrum and associated horizontally running fracture of the superior ramus of the pubic bone. Differences like this, between young patients with high energy trauma and elderly patients with fragility fractures caused by low energy trauma, combined with the well-documented change in morphological characteristics of fragility fractures, have led to the proposal of a different classification system for these fractures. The fragility fracture of the pelvis (FFP) classification is based on increasing degrees of instability. Type I consists of an isolated anterior injury; type II has a non-displaced posterior ring fracture; type III, a displaced unilateral posterior element; and type IV, displaced bilateral posterior ring fractures. Types II to IV may or may not have an associated anterior ring fracture. The literature supports conservative treatment of type I fractures, while type II fractures are best treated with percutaneous techniques to allow early mobilisation. Both types III and IV fractures require more aggressive surgical management due to the associated displacement.

Figure 4. Patient able to perform straight-leg raises (left) and stand independently (right) at six-week follow-up

Figure 5. AP radiograph of the pelvis one year after fixation showing good bony union and hardware in situ

Fracture progression has, however, been described to occur over time, with previously stable patterns progressing to more complex patterns with greater instability leading to the eventual collapse of the pelvic ring. Rommens et al. found progression in nearly 15% of pelvic fragility fractures that were treated conservatively. Occult posterior pelvic ring fractures have been described in 54–80% of elderly patients with pubic rami fractures, a statistic highlighting the importance of utilising CT scans to diagnose the fracture pattern correctly.
Biomechanically, the anterior portion provides 40% of the pelvic ring’s stability, while the posterior elements are responsible for the remaining 60%. Traditional methods of fixing the anterior pelvis have included ORIF, external fixation and retrograde pubic rami screws. The most significant benefits of ORIF include allowing for anatomic reduction and there being no need for removal of any implants at a later stage. It remains biomechanically the most rigid construct at the symphysis pubis. Despite the numerous advantages of ORIF, it requires a more extensive surgical approach with a subsequent increase in approach-related complications. Longer surgeries with greater blood loss not only result in greater physiological stress on the patient’s cardiovascular system, but are also associated with a prolonged recovery and increased surgical site infection rate. Both the Pfannenstiel and modified Stoppa approaches are widely used during anterior pelvic ring ORIF. With more lateral extension of the incision, the risk of damage to the inguinal canal and its content increases, which can result in ongoing pain symptoms. It is important to note that there is sparse literature regarding the complications associated with such extensive surgical approaches, specifically in the elderly or frail patient.

External fixation, being a minimally invasive technique, serves to preserve the fracture site’s biology and allows for easy removal. Despite its convenience for the surgeon, it is often unsightly and cumbersome for the patient and has an associated complication rate as high as 62%. Complications include: pin-tract infection in 2.5–50% of cases, osteomyelitis, aseptic loosening in up to 19%, patient discomfort, and poor tolerance due to limitations in activities of daily living or mobility or skin impingement, increased difficulty in nursing care and iatrogenic nerve injury. There is also a risk of loss of reduction, which is dependent on the fracture pattern and additional fixation used. The presence of obesity further increases the risk of loss of reduction and pin-traction complications. Some authors also recommend against external fixation use in fragility fractures.

Another option of anterior fixation is the use of retrograde pubic rami screws. This technique has grown in popularity because it provides a minimally invasive internal fixation option. These screws are not suitable for all fracture types and have a reported loss of reduction in 15% of cases. Rommens et al. pointed out that the type of fracture dictates the type of fixation, and Starr et al. clearly showed an increase in instability with fractures medial to the lateral border of the obturator foramen. They also showed an increase in fixation loss with advanced age and female sex. It is common for all these risk factors to coexist in insufficiency fractures of the pelvis, making retrograde percutaneous screw fixation technically demanding in this subgroup of patients. This technique also requires a high degree of precision.

The recent development of minimally invasive anterior subcutaneous internal fixation techniques is proving to be a popular alternative means of fracture fixation. Their application requires minimal soft tissue dissection, which reduces operating time, intraoperative blood loss and length of stay when compared to ORIF. The subcutaneous location also decreases the risk of surgical site infection, eases the burden of nursing care, and avoids interference with rehabilitation and daily activities. Biomechanically they provide sufficiently rigid fracture fixation to facilitate bone healing. Several studies conclusively demonstrated superior stiffness at the pubic symphysis compared to external fixators, while one study by Vignich et al. demonstrated these constructs could provide some indirect compression of the posterior pelvic elements. This can prove beneficial when acute stabilisation of the posterior elements is contraindicated. Long-term follow-up of these techniques show high patient satisfaction and acceptably low complication rates.

The first of these novel techniques was originally described in German literature in 2009, but it was Vaidya et al. who described the modified method currently being used, and coined the term INFIX for this technique. Their technique involved the placement of pedicle screws in the supra-acetabular area with a connecting curved rod in the epifascial plane. A potential drawback is the rod which transverses the inferior abdominal wall, thus creating a potential for iatrogenic compression or impingement injuries. Screw placement also requires deep dissection in the interval between the sartorius and tensor fascia latae muscles.

A more recent variation of this minimally invasive technique is the pelvic bridge described in 2012. This method involves spanning the anterior pelvis between two ‘pillars’, usually the ipsilateral iliac crest and either the ipsilateral or contralateral pubic symphysis. The bridge is formed with either a low-profile pre-contoured locking plate or a rod-plate construct (originally used for occipito-spinal fusions). The bridge is passed subcutaneously, above the external oblique fascia, along the static anatomic structures namely the iliac crest, inguinal ligament and pubic symphysis. The construct design can allow for either selective percutaneous fixation of the compromised hemipelvis without involving the uninjured side, or two separate fixators can be used with an overlap and rod-to-rod connections at the pubic symphysis for bilateral fractures. These differences in the course of the connecting rod and construct design provide some advantage over the INFIX.

A cadaver study by Reichel et al. compared the INFIX and pelvic bridge techniques. They noted several challenges with the INFIX application. First, its application was variable and highly dependent on the pedicle screws placement and curvature of the rod, which results in an increased risk of impingement due to the patient’s body habitus or when greater flexion is attempted at the waist. Since the connecting rod did not mirror static anatomic structures like the pelvic bridge, there also remained the risk of the rod twisting or being misplaced while securing the locking caps. Lastly, the pedicle screw depth is a subjective measure as it lies several centimetres above the bone; placement at the incorrect depth can lead to either patient discomfort from prominent hardware or impingement of underlying structures. The pelvic bridge utilises four points of fixation, which aids in reducing the chance of misapplying the device in a manner that impinges neurovascular structures. Despite the literature showing that supra-acetabular screws are superior to iliac crest screws, there are no biomechanical studies directly comparing the INFIX and pelvic bridge constructs. Theoretically the four-point fixation of the pelvic bridge may impart greater overall biomechanical strength when compared to the two-point fixation of the INFIX. Another anatomic study demonstrated that despite variations in pelvic anatomy such as pelvic brim width, the pre-contoured rods or plates did not violate any neurovascular structures. The pelvic bridge does, however, have a theoretical risk of bladder injury with erroneous drilling and screw placement into the pubic symphysis, but no such case has been described in the literature to date.

Several studies have looked at the complication rates associated with the INFIX, while literature on the pelvic bridge technique is still sparse. One of the most common complications of the INFIX found in the literature is lateral femoral cutaneous nerve (LFCN) neuropaxia, which most studies found in 25–32% of all cases. Two studies found even higher rates of LFCN neuropaxia, occurring in 55–57% of cases. Patients will present with numbness over the anterolateral thigh; this is, however, well tolerated by most patients and the majority resolve with time after removal of the implant. These findings...
are well explained by Reichel et al., who state that despite the INFIX having a significantly greater distance from most anatomic structures when compared to the pelvic bridge, it lacks a ‘safety margin’ in 90.9% of specimens between the LFCN and pedicle screws. In addition, LFCN injury may be caused by difficulty in locating the nerve during dissection to place the pedicle screws. A review by Vaidya et al. could not find a recommendable solution to prevent this complication with INFIX application. The pelvic bridge was proposed as an alternative to minimise the risk of LFCN neuropaxia, as the implant remains a significantly greater distance from the LFCN when compared to the INFIX. It must, however, be noted that anatomical variations of the LFCN have been described in 2.9 to 4% of the population, which can place the nerve at risk when dissecting near the iliac wing to place the pelvic bridge.

Another common complication noted with the INFIX is heterotrophic ossification around the pedicle screws, which occurs in 21–36% of cases. Despite being asymptomatic, some authors do recommend the use of preventative measures such as prophylactic use of non-steroidal anti-inflammatory drugs or radiotherapy. Other complications occur more rarely and include a surgical site infection rate of 3%, but no documented cases progressed to osteomyelitis. Acute and delayed onset femoral nerve neuropaxia occurred in 1% due to seating the rod too deep in overweight patients. These injuries were more likely to be permanent despite implant removal compared to LFCN injuries, with one study showing total recovery in only one out of eight patients. Vascular occlusion occurred in one case, but was diagnosed early enough to prevent long-term complications. Aseptic loosening with loss of reduction and entrapment of the anterior abdominal wall causing severe discomfort has also been described.

The complications they encountered included superficial wound infection, one asymptomatic pubic ramus non-union and temporary LCFN neuropaxia. In another study they also demonstrated significantly less pain and discomfort at follow-up when compared to an external fixator. A common disadvantage for both minimally invasive techniques is that hardware needs to be removed in theatre at a later stage. This is recommended as there are no long-term studies available, and potentially deleterious consequences from leaving the device in situ are unknown. Pressure over the device can also cause unnecessary discomfort for the patient. Current literature recommends removal of the pelvic bridge between eight and 16 weeks, before excessive soft tissue ingrowth can occur. Campbell et al. described a novel endoscopic technique utilising incisions smaller than those of the original procedure, to successfully remove the implant with excellent preliminary results. They also noted that the more expensive rod-plate construct was easier and less traumatic to remove compared to the locking-plate construct. Since the fracture site is not exposed, there is a risk of soft tissue interposition with resultant non-union, and fracture fragments that may cause neural or organ compression cannot be removed.

Being novel techniques, the ideal indications and contraindications of the INFIX and pelvic bridge are still being defined. Current indications include both high and low energy pelvic ring injuries requiring anterior stabilisation, in either isolated anterior injuries or after posterior stabilisation has been achieved. It is also proving to be advantageous in coagulopathic patients to minimise intraoperative blood loss, in patients expected to have a protracted ICU course to facilitate nursing care and decrease infection risk, and in those requiring the prone position later for procedures such as spinal surgery. Patients with morbidity also tolerate subcutaneous devices better than an external fixator; the pelvic bridge has been suggested to be superior to the INFIX regarding its ease of application as the anatomic landmarks are identified more easily in obese patients. Contraindications include pure ligamentous dislocation at the pubic symphysis or iliac wing dislocations; severe degloving soft tissue injuries or active infection in the suprapubic or iliac crest areas; open pelvic fractures with peritoneal contamination; pregnancy; and haemodynamically unstable pelvic ring injuries requiring rapid stabilisation for life-saving reasons. It has been noted that the pelvic bridge should never be used as the sole fixation method in combined anterior and posterior instability. Stable pelvic fractures in patients who are able to mobilise effectively with partial weight-bearing and acetabular fractures involving the anterior column have also been suggested as potential contraindications. A suggested postoperative rehabilitation programme consists of weight-bearing as tolerated in the first six weeks, followed by full weight-bearing. During this time there is no restriction on hip range of motion.

It is also proving to be an appealing surgical option in the elderly with osteoporotic bone to provide pain relief and allow rapid mobilisation while minimising surgical risk. The use of bone cement can further augment screw purchase in osteoporotic bone. Taking into consideration that prolonged immobilisation is associated with potentially fatal complications in the elderly, early surgical treatment and mobilisation has been suggested to improve mortality rates. This was confirmed by Osterhoff et al. who found that surgically treated patients who survived the initial two years post injury had a better long-term survival compared to conservatively treated patients. Their slightly higher mortality rate in the first two years may be explained by the perioperative risks inherent with anaesthesia and surgery in the elderly. They thus recommend considering early surgical management for patients with a greater than two-year life expectancy. In addition to the improved long-term survival, surgical fixation is gaining favour due to its better pain relief, faster mobilisation and shorter recovery period compared to conservative management.

Conclusion
The incidence of pelvic fragility fractures is on the rise as our population ages. Underestimating the seriousness of these fractures and inappropriate identification and management thereof can lead to significant morbidity and mortality. This is comparable to conservative management of proximal neck of femur fractures. This case demonstrates the effectiveness of appropriate, aggressive surgical intervention in complex fragility pelvic fracture. Here the use of minimally invasive subcutaneous anterior fixation and percutaneous posterior stabilisation provides for rapid pain relief and allows early mobilisation. As the literature demonstrates, our understanding of pelvic fragility fractures is expanding and with that the place and value of early, aggressive and appropriate surgical fixation is becoming more evident.

Ethics statement
Written consent was received to use photos, radiographs and clinical data from the patient and is available on request.
Declaration
The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions
SS: Contributed to the conceptualisation, data collection and writing of the article
CHS: Primary treating surgeon of the case presented, contributed to the conceptualisation, data collection and writing of the article

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References
Impact of correctable mediolateral tibiofemoral subluxation on unicompartmental knee arthroplasty implant survival in patients with anteromedial osteoarthritis (Oosthuizen CR, Maposa I, Magobotha S, Pandit H)

1. Which knee is most suitable for medial unicompartmental knee arthroplasty?
   a. Isolated medial osteoarthritis without mediolateral subluxation A
   b. Isolated medial osteoarthritis with mediolateral subluxation B
   c. Isolated medial osteoarthritis with anterior cruciate ligament rupture C
   d. Isolated medial osteoarthritis with patellofemoral joint osteoarthritis D
   e. Dominant medial osteoarthritis with intact ligaments E

2. How do you confirm the correct diagnosis of medial osteoarthritis on X-ray evaluation?
   a. Anteroposterior and lateral view radiographs A
   b. Anteroposterior, lateral view and skyline view radiographs B
   c. Anteroposterior, lateral view, skyline view and 45° posteroanterior radiographs C
   d. Anteroposterior, lateral view, skyline view and 15° posteroanterior radiographs D
   e. Anteroposterior, lateral view, skyline view, 15° posteroanterior and stress views radiographs E

3. Unicompartmental knee arthroplasty is indicated for patients:
   a. > 40 years A
   b. > 50 years B
   c. > 60 years C
   d. > 70 years D
   e. Any age conforming to the clinical and X-ray indications E

Preoperative asymptomatic bacteriuria in patients undergoing total joint arthroplasty in South Africa (Maharaj Z, Pillay T, Mokete L, Pietrzak JRT)

4. The prevalence of asymptomatic bacteria in patients undergoing total joint arthroplasty is:
   a. 22% in a single institution in Gauteng, South Africa A
   b. 22% in rural South Africa B
   c. 39% in an academic institution in South Africa C
   d. 39% in a multicentre study in Gauteng D
   e. 22% worldwide E

5. What is the five-year mortality rate for PJI following total joint arthroplasty?
   a. 12.5% A
   b. 5.4% B
   c. 27.6% C
   d. 21.12% D
   e. 1.4% E

Patient-reported outcomes following plantar incisions in foot surgery (Alexander AN, Saragas NP, Ferrao PNF)

6. Which comment below is true regarding incisions made parallel to the RSTLs?
   a. The incision runs parallel to collagen bundles A
   b. It lessens the chance of painful hypertrophic scar formation B
   c. The incision runs perpendicular to the axis of muscle contraction C
   d. It results in finer and stronger scars D
   e. All of the above E

7. Which statement regarding plantar fibromatosis is incorrect?
   a. It is a benign condition A
   b. It has a low recurrence rate B
   c. It is a locally aggressive fibrous tissue tumour C
   d. The presence of skin adherence is a poor prognostic sign D
   e. Indications for surgery include pain and local aggressiveness E

8. For which pathology/procedure is a plantar incision not indicated?
   a. Medial sesamoiditis A
   b. Morton’s neuromas B
   c. Metatarsal head resection C
   d. Ledderhose disease D
   e. Turf toe E

Do anatomical contoured plates address scapula body, neck and glenoid fractures? A multi-observer consensus study (De Wet JJ, Dey R, Vrettos B, Du Plessis JP, Anley C, Racuene PA, Haworth LC, Yimam HM, Sivarasu S, Roche SJL)

9. When addressing intra-articular glenoid fractures and associated glenoid rim and/or neck fractures, which of the following do the authors prefer as first-line treatment of these fractures?
   a. Cannulated screws A
   b. Buttressing plates B
   c. Bone grafting (coracoid/iliac crest) C
   d. Cerclage wiring D
   e. Suture anchors E

10. Isolated scapula fractures are rare and account for what percentage of upper limb fractures?
    a. 1–2% A
    b. 3–5% B
    c. 7–8% C
    d. 9–10% D
    e. 10% E
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The short-term outcomes of hip arthrodesis in children and adolescents with end-stage hip disease (Mniki TA, Maré PH, Marais LC, Thompson DM)

11. The commonest cause for symptomatic end-stage hip disease in children and adolescents is:
   a. Trauma
   b. Post-infective sequelae
   c. Metabolic/systemic disease
   d. Neuromuscular disorders
   e. Developmental hip disorders

12. Careful patient selection for hip arthrodesis is important and indicated in children and adolescents presenting with:
   a. Active septic arthritis
   b. Polyarticular inflammatory disease
   c. Monoarticular non-inflammatory end-stage hip disease
   d. Bilateral developmental dysplasia of the hip (DDH)
   e. Ipsilateral knee fixed flexion contracture

13. What is the most accurate way of assessing radial shortening?
   a. Using Evans rule
   b. Ulnar variance on X-ray
   c. Clinical examination of radial styloid
   d. Circle X-ray method
   e. Using the Watson’s shift test

14. What is considered a normal ulnar variance?
   a. 0.9 mm
   b. 1.5 mm
   c. −0.9 mm
   d. −1.5 mm
   e. −2.0 mm

15. Common complications of radial shortening include all of the following except:
   a. Reduced pro-supination
   b. Reduced wrist flexion/extension
   c. Reduced grip strength
   d. Ulnar abutment syndrome
   e. Early-onset arthrosis

Distal radius fractures: current concepts (Rachuene PA, Du Toit FJ, Tsolo GK, Khanyile SM, Tladi MJ, Golele SS)

16. Which of the following is true regarding acute carpal tunnel syndrome in patients with distal radius fractures (DRFs)?
   a. Prophylactic carpal tunnel release should be performed in all patients with DRFs
   b. Delayed carpal tunnel release of more than 6 hours is associated with irreversible nerve damage
   c. Delayed carpal tunnel release of more than 16 hours is associated with irreversible nerve damage
   d. Delayed carpal tunnel release of more than 36 hours is associated with irreversible nerve damage
   e. Delayed carpal tunnel release of more than 26 hours is associated with irreversible nerve damage

17. With regard to stable extra-articular distal radius fractures, which of the following is true?
   a. Closed reduction with minimum two K-wire fixation and 40° crossing angle is considered a stable fixation
   b. Closed reduction with minimum three K-wires fixation and 40° crossing angle is considered a stable fixation
   c. Closed reduction with minimum three K-wires fixation and 20° crossing angle is considered a stable fixation
   d. Closed reduction with minimum two K-wires fixation and 90° crossing angle is considered a stable fixation
   e. ORIF is the only recommended choice in these patients

18. Sarcopaenia is a disorder associated with loss of muscle mass; in patients with distal radius fractures (DRFs) which of the following statements is false?
   a. Sarcopaenia is prevalent in elderly patients
   b. Sarcopaenia is closely related to osteoporosis
   c. Sarcopaenia is associated with poor functional outcomes in patients with distal radius fractures
   d. Sarcopaenia affects females only
   e. Literature reports slightly higher prevalence of sarcopaenia in male patients with DRFs compared to females

Minimally invasive subcutaneous anterior fixation of pelvic fractures in the elderly: case report and literature review (Strydom S, Snyckers CH)

19. What is the most common complication with minimally invasive subcutaneous anterior pelvis fixation?
   a. Patient discomfort
   b. Surgical site infection
   c. Symptomatic heterotropic ossification
   d. Lateral femoral cutaneous nerve impingement
   e. Significant intraoperative blood loss

20. Which statement regarding minimally invasive subcutaneous anterior pelvis fixation techniques is false?
   a. It allows for easier nursing compared to Ex-fix
   b. Patients need to remain non-weight-bearing for six weeks postoperatively
   c. It should not be used in isolation for combined anterior and posterior instability
   d. It can be used in patients with osteoporosis
   e. They combine the low-profile benefits of internal plate fixation with Ex-fix principles

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