French Osteotomy for Cubitus Varus in Children:

A long-term study over 27 years

by

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Declaration

I, David Martin North, hereby declare that the work on which this dissertation is based is my original work and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

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Date: 10 August 2015

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Contents

PART A:

RESEARCH PROPOSAL

Research Proposal

French Osteotomy for Cubitus Varus in Children:

A long-term study over 27 years

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Purpose

The purpose of this study will be to retrospectively review the outcomes of the French Osteotomy for the management of cubitus varus in children, following supracondylar distal humerus fractures. We plan to review the clinical and radiological outcomes. These outcomes will be measured against the international literature.

Background

Supracondylar fractures of the distal humerus are one of the most common fractures in children aged from 2 to 8 years, accounting for up to 30% of fractures in this age group.[1] They are the most common fracture around the elbow in children, accounting for up to 75% of these injuries.[2] Cubitus varus is the commonest long term complication of supracondylar distal humerus fractures with an average incidence of 30% with different forms of management.[3]

Cubitus varus rarely causes any limitation in elbow function, however it results in an unsightly cosmetic deformity with the children's parents often requesting intervention.[4] However late complications have been described in long standing

cases of cubitus varus, these include secondary lateral condylar fractures of the distal humerus,[4] postero-lateral rotatory instability of the elbow,[5] and tardy ulnar nerve palsy.[6]

Several surgical techniques have been described for the correction of the varus deformity in cubitus varus, including:

- Medial opening wedge osteotomy
- Lateral closing wedge osteotomy, with or without rotatory corrections
- Complex osteotomies including the dome, pantalateral, oblique, and step cut osteotomies.[3]

Various methods of fixation have been described for these osteotomies including plaster of Paris casting, Kirchner wires, screws with tension band wiring, plate and screw fixation, staples, and fixation with an external fixator. Corrective osteotomies were initially looked upon with scepticism due to the relatively high complication rate for a largely cosmetic deformity. Most of the complications reported were persistence of the varus deformity and nerve injury, these complications were primarily reported when plaster of Paris casting and the use of Kirchner wires were used for fixation.[3] Far fewer complications have been reported with the use of screw and tension band wire fixation, as in the French technique.[3]

For the correction of cubitus varus our unit makes use of the French osteotomy, a lateral closing wedge osteotomy without rotatory corrections. This technique was initially described by French in the Lancet in 1959. The operation is performed with the patient under general anaesthesia and with the use of an inflated pneumatic tourniquet. Fixation is attained with 2 screws and tension band wiring. The osteotomy is protected in an above elbow backslab for 3 weeks, with the elbow in 90 degrees of flexion. Following this the backslab is removed and the patient is allowed to mobilise.

Definition of terms

Cubitus varus: deviation of the extended forearm towards the midline of the body
Cubitus valgus: deviation of the extended forearm away from the midline of the body
Osteotomy: surgical cutting of the bone or removal of a piece of bone
Wedge osteotomy: surgically removing a wedge of bone
Carrying angle: the angle made by the axes of the arm and forearm with the elbow in full extension

Materials and Methods

Study design

This study is a retrospective cohort study. We will retrospectively review all children, less than 12 years of age, who received a French osteotomy for the management of cubitus varus following a supracondylar distal humerus fracture.

Study population

Inclusion criteria

All patients that had a French osteotomy performed for the management of cubitus varus following a supracondylar distal humerus fracture. All the surgeries were performed at Maitland Cottage Home between 1986 and 2012. Based on the review of the data bases we expect approximately 100 patients to meet the inclusion criteria. This is more than double most similar series that have been published in the literature.

Exclusion criteria

All patients with incomplete clinical records and followup will be excluded from the study.

Recruitment

The data base at Maitland Cottage Home will be reviewed to identify all patients in whom a French osteotomy was performed for cubitus varus following a supracondylar distal humerus fracture.

Data Collection

This study will include a retrospective review of the clinical notes and associated radiographs, pre-operatively and post-operatively, of the included patients. The notes will come from the Maitland Cottage Home records and Red Cross Children's Hospital patient notes when the followup was conducted at Red Cross Children's Hospital. Data collection will include:

- Basic demographic information including patient's name, hospital number, date of birth, and gender.

- Initial injury details including date of injury, side of injury, mechanism of injury, initial treatment and where that treatment was provided.

- Pre-operative evaluation including clinical and radiological carrying angle of the affected and unaffected sides. Radiological assessment of carrying angle will be assessed as the humeral-elbow-wrist angle on an anterior-posterior radiograph of the upper limb. On the anterior-posterior radiograph of the elbow the Bauman's angle will be recorded for the affected and unaffected sides. Range of motion will be assessed as maximum active flexion and extension of the affected and unaffected elbows.

- Surgical information will include the delay from injury to surgery, any immediate intra-operative complications.

- Post operatively carrying angle, both clinical and radiological will be assessed. Bauman's angle will be recorded from the anterior-posterior elbow radiographs. Range of motion will be recorded as maximum active

flexion and extension. For the above parameters the degree of correction from the pre-operative assessment will be recorded and how the post operative values compare to the opposite side will be assessed. In addition any recorded complications will be reported.

Data analysis

All data will be recorded on an excel/numbers spreadsheet. Final decisions on what statistics are necessary will be made once the final data has been collected. However pre-operative and post-operative carrying angle, Bauman's angle and range of motion will be compared and compared with the opposite side. In addition the post operative carrying angle will be compared to the normal side, with results being graded as good if correction is within 5 degrees of the normal carrying angle, satisfactory if correction is more than 5 degrees from the normal side but cubitus valgus is restored and finally outcomes are poor if there is persistent cubitus varus. Any reported complications will be recorded.

Risks and benefits

There will be no risks to the participants as this is a retrospective review of procedures already performed. No additional investigations or procedures will be performed.

Benefits will include measuring the outcomes of a procedure performed in our unit and comparing this to the international literature. We would be able to review our practice and better inform future patients of the expectant outcomes of the operation. We will also be able to contribute to the current body of literature on the subject.

Informed consent

No consent will be obtained, as this is a retrospective review of cases already performed.

Privacy and confidentiality

Privacy and confidentiality of all data will be ensured. All data will be collected by the principal investigator and stored on a password protected computer, to

ensure confidentiality. To further ensure confidentiality no names will be used once the data has been collected and patients will be identified by a random number, held separately from the demographic data.

Outcome of the study

Our aim would be to publish our results in a paediatric orthopaedic journal for peer review and to publish our results at the annual South African Orthopaedic congress.

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PART B:

LITERATURE REVIEW

Literature Review

Introduction

Cubitus varus is the commonest long-term complication of supracondylar distal humerus fractures.[5]Although initially thought to result in a purely cosmetic deformity, late functional impairments have been described with long-term follow-up.[8-10]

There have been numerous surgical techniques described to correct the deformity in cubitus varus, utilising different approaches, osteotomies and fixation methods. French described a lateral closing wedge technique in The Lancet in 1959,[12] this technique has been subsequently modified by Bellemore et al[13] and MCoy and Piggot.[15] This technique has consistently achieved good results in the literature.[13-17]

Objectives:

The objectives of this literature review are:

- To clarify the incidence and potential complications of cubitus varus following supracondylar distal humerus fractures in children
- To research the treatment options used for cubitus varus and critically analyse the outcomes of these described methods
- To review the surgical technique of the French osteotomy, the reported outcomes and documented complications
- To identify potential areas for future research

Methods:

Google Scholar and Pubmed internet search engines were used to search online databases for articles on cubitus varus, its management and outcomes of these techniques. Searches for 'cubitus varus', and 'French osteotomy for cubitus

varus' yielded 3500 and 274 articles on Google Scholar, and 613 and 12 articles on Pubmed respectively. Review articles on the subject were analysed and their references researched. All available evidence was screened and the relevant articles were obtained from the University of Cape Town library. Articles published in peer reviewed journals were included that addressed the aetiology, management and outcomes of the management for cubitus varus following supracondylar distal humerus fractures in children. Only articles published in English were included.

The evidence on the topic included one meta-analysis, one level II randomized control trial but was otherwise limited to retrospective cohort or case series, classified as level IV evidence.

Summary of the Literature:

Background:

Supracondylar fractures of the distal humerus are one of the most common fractures in children aged from 2 to 8 years, accounting for up to 30% of fractures in this age group.[1] They are the most common fracture around the elbow in children, accounting for up to 75% of these injuries.[2] Although the incidence of cubitus varus has decreased since the landmark article of Pirone et al in 1988,[3] which expounded the advantages of closed reduction and percutaneous pinning of supracondylar distal humerus fractures.[4] Cubitus varus still remains the commonest long term complication with an average incidence of 30% with different forms of treatment.[5]

Cubitus varus is thought to occur as a result of a malunion of the distal humerus, not a growth disturbance as initially thought.[6] This results in a triplanar deformity consisting of varus in the coronal plane, internal rotation in the axial plane, and extension in the sagittal plane.[7] The resultant deformity is not progressive and does not appear to improve with remodelling. Although cubitus varus has typically been described as a cosmetic deformity with little functional impairment, late complications such as tardy ulnar nerve palsy,[8] postero-lateral

rotatory instability,[9] and secondary lateral humeral condylar fractures have been described in long standing cases. [10]

Several surgical techniques have been described to correct the deformity in cubitus varus including: Medial opening wedge osteotomies, lateral closing wedge osteotomies with or without rotatory corrections and more complex osteotomies including the dome, step cut and pantalateral osteotomies.[5] In addition various methods of fixation have been described to stabilise these osteotomies including plaster of Paris casting, Kirchner wires, screws with tension band wiring, plate and screw fixation, staples, and fixation with an external fixator.

The lateral closing wedge osteotomy was initially described by Siris in 1939[11] and modified by French in 1959.[12] Although the French technique has consistently achieved good results in the literature,[13-17] more complex osteotomies were developed for three reasons.

Firstly, because the axis of correction of angulation (ACA) of the French osteotomy is proximal to the centre of rotation of angulation (CORA) of the varus deformity (which is situated in the supracondylar fossae), a lateral translation of the deformity results.[18] This has been described as the lateral condylar prominence,[19] and can result in an unsightly lazy-S deformity. To prevent the formation of this deformity the dome and step cut osteotomies were developed. The dome osteotomy achieves this by placing the ACA at the CORA. [20-23] The step cut translation osteotomy prevents the formation of the lazy-S deformity by medialising the distal fragment. [24-28] More complex three-dimensional osteotomies using Ilizarov external fixation and distraction osteogenesis also allowed for medialisation of the distal fragment. [29,30]

Secondly, the lateral closing wedge osteotomies rely on the medial cortex and periosteum for medial stability, if these fail they become inherently unstable.[7] The dome and step cut osteotomies create a large bony contact area and are thought to be more stable than the lateral closing wedge osteotomy. [21,26]

Thirdly, the lateral closing wedge osteotomy primarily corrects the coronal plane varus deformity. Therefore three-dimensional (multiplanar) osteotomies were designed to correct the internal rotation and hyperextension deformities as well. [31,32]

French osteotomy:

The French osteotomy was described by French in the Lancet in 1959,[12] and consisted of a lateral closing wedge osteotomy performed through a posterior triceps splitting approach, the medial cortex was left intact and fixation was provided by two screws and a tension band wire.[12] The screws were placed in different positions in the coronal plane to correct the rotational deformity in addition to the varus deformity.[12]

Timing of surgery

Initially the varus deformity was thought to result from a growth disturbance and therefore surgery was delayed until late puberty, toward the end of skeletal growth to reduce the recurrence rate of the deformity.[33] However the deformity is now thought to occur as a result of a malunion of the distal humerus with the distal humeral physis not being affected, there is minimal resultant progression or remodelling of the deformity.[21] The ideal age for surgery has been suggested between 6 and 11 years of age,[5] as there is enough bone at the distal humerus to allow for stable fixation by the age of 6, [5] and there is the potential for remodelling of the lateral condylar prominence in children less than 12 years of age.[5,34] In addition in children close to skeletal maturity there is an increased risk of complete fracture of the medial cortex with resultant residual instability. Cho et al showed improved long-term outcomes in their prepubertal patients compared to their postpubertal group. [34]

Preoperative assessment

The humero-elbow-wrist (HEW) angle was found by Oppenheim et al[35] to be more consistent and accurate than the humero-ulnar and Baumann's angles. It has been shown to most accurately correlate with the clinical carrying angle.[35] It

is measured with the arm in full supination and the elbow in zero degrees of extension. The HEW for the affected and normal sides is measured to calculate the angle required for correction.

Incision

In the original description by French the incision is from posterior, splitting the triceps in half and detaching the lateral half of the triceps off its insertion in order to visualise the ulnar nerve.[12] Mc Coy and Piggot modified the approach by utilising a lateral incision directly over the supracondylar ridge, which was exposed subperiosteally without visualising the ulna nerve.[15] In a long term comparative study over 50 years Raney et al showed an incidence of nerve injuries, both radial and ulnar, with the posterolateral approach of 14%, whereas there were no reported nerve injuries with the lateral approach.[29] It has been suggested that the lateral incision is more likely to leave an unsightly scar than the posterior and posterolateral approaches, however the incidence of unsightly scars has been shown to be low and equal for both incisions.[7,29]

Deformity correction

Although the original description of the French osteotomy placed the screws in different positions in the coronal plane in an attempt to correct internal rotation in addition to the varus deformity, [12] this was subsequently modified by Bellemore et al to correct only the varus deformity.[13] More complex multiplanar osteotomies have been developed to correct the internal rotation and hyperextension deformities. Kim et al described a step cut osteotomy to correct all three deformities.[31] Takeyasu et al performed a three dimensional correction with the use of a custom made template based on computer simulation.[32]

In a landmark article in 1966, Lyman Smith showed that the varus deformity was due to the varus tilt, and internal rotation did not contribute to the varus deformity.[37] Bellemore et al[13,14] and Oppenheim[35] showed that the cosmetic outcome was paramount, this was achieved by correcting the varus deformity, and attempts to correct internal rotation gave worse results. Tagaki et al[38] compared the outcomes of 34 patients who had a three dimensional osteotomy

with 40 patients who had a simple lateral closing wedge osteotomy. The group who had the three dimensional osteotomy had more significant loss of correction because derotation reduced the bony contact area.[38] Furthermore excessive derotation can cause an anterior bulge that restricts flexion.[16] The internal rotation deformity is well tolerated as it is easily compensated by rotation of the shoulder.[13,38] The hyperextension deformity was shown to remodel in children less than ten years of age, and correction of this deformity is not necessary in patients less than ten.[38]

Fixation

The French technique utilises fixation with two screws and a wire laterally acting as a tension band.[12] Medial stability is provided by the greenstick fracture of the medial cortex and the intact periosteum.[12] Patients close to skeletal maturity may have residual instability if there is a complete instead of a greenstick fracture of the medial cortex. When K-wire fixation was utilised there is an incidence of nerve injury ranging from 7%[39] to 17%.[40] In addition there is a higher rate of return to surgery for loss of reduction with K-wire fixation.[36] Plate fixation has a 10% incidence of nerve injury.[36] In the meta-analysis by Solfelt et al there was no significant difference between the various fixation methods with respect to the overall complication rate, loss of fixation or residual varus.[7]

Outcomes

Solfet et al [7] performed a meta-analysis of 40 studies (894 patients). Techniques compared were lateral closing wedge, dome, complex (including step and mutliplanar) osteotomies and distraction osteogenesis. The overall rate of excellent to good results was 87.8%.[7] No technique was found to significantly affect the outcome.[7] The complication rate was 14.5%, with an incidence of nerve injuries of 2.5%.[7] No technique was found to be statistically safer.[7] In the only randomized control study the French osteotomy was technically less demanding, had better results and fewer complications than the dome osteotomy.[16]

Lateral condylar prominence

Wong et al were the first to describe an unsightly prominence over the lateral condylar region after a lateral closing wedge osteotomy for cubitus varus.[19] They described a radiological measurement, the lateral condylar prominence index (LCPI), which increased after the lateral closing wedge osteotomy.[19] This results in an unsightly lazy-S deformity.[19] They also found that children less than 12 years of age remodelled, but in those patients nearer to skeletal maturity the deformity did not remodel.[19]

With the French osteotomy the osteotomy (ACA) is proximal to the CORA, which is at the supracondylar fossa, therefore the axes of the proximal and distal segments are not collinear, this is analogous to the golf club and dog leg deformities described in osteotomies around the knee.[18,41] By medialising the distal humeral fragment, the axes become collinear and the lateral condylar prominence is avoided. This resulted in the development of techniques, such as the step cut translation osteotomy and distraction osteogenesis, which medialised the distal fragment.[24-28] The dome osteotomy places the ACA at the CORA avoiding the lateral condylar prominence.[20-23]

Raney et al found that although the LCPI was abnormal in 62% cases following a lateral closing wedge osteotomy, only 3% complained of the prominence.[36] They concluded that there was no correlation between the radiographic findings of the LCPI and the patient's complaints of a lateral prominence.[36] Bellemore et al similarly found that only 12% of patients with an increased LCPI were disturbed by the appearance of a "bump".[14] They ascribed this, like Wong et al, to the remodelling in the skeletal immature patients, less than 12 years of age.[14,19] Cho et al evaluated the long-term results of remodelling after the French osteotomy, showing remodelling of the LCPI in prepubertal patients.[34]

Conclusion

The French osteotomy produces results that are comparable to the technically more demanding dome, step cut and multiplanar osteotomies, with a lower

complication rate. There has been shown to be adequate remodelling of the hyperextension deformity in patients less than 10 years of age and of the LCPI in patients less than 12 years of age. The internal rotation deformity is well tolerated by the patient.

Areas for further research:

The literature on cubitus varus in children as a complication of a distal humerus supracondylar fractures consists largely of retrospective cohorts or case series. There are numerous surgical techniques described utilising different surgical approaches, osteotomies and methods of fixation. Even when the same osteotomy technique is used, surgeons often utilise a different surgical approach or method of osteotomy fixation. This makes it difficult to accurately compare the various surgical techniques.

Further research should consist of randomised controlled studies comparing different surgical techniques. There should also be long-term follow up of these patients to assess the outcomes of the correction of the deformity following skeletal maturity. The relative rarity of this condition makes this difficult as most referral centres may only operate on four cases per year.

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PART C:

MANUSCRIPT

This manuscript has been submitted and accepted for publication by the Journal of Pediatric Orthopaedics. The referencing style is according to the instructions for the authors of the journal. (See attached instructions in Part D)

Article

French Osteotomy for Cubitus Varus in children:

A long-term study over 27 years

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The research has been approved by the Research Ethics Committee, Health Sciences Faculty, University of Cape Town (ref: 209/2013)

Abstract

Background

Cubitus varus is a cosmetically unacceptable complication of supracondylar fractures of the elbow in children. We have performed the lateral closing wedge (French) osteotomy to correct the varus for 27 years. More complex osteotomies have been described to correct the associated hyperextension and internal rotation deformities and to prevent a prominent lateral condyle.

Methods

We retrospectively reviewed 90 consecutive patients (1986-2012). The mean age of the patients at surgery was 8.2 years (3 to14 years). The varus angle (mean 21.4°, range 8°-40°) was assessed pre-operatively with the humero-elbow-wrist (HEW) angle. The postoperative carrying angle (mean 10.4) and the pre- and postoperative range of movement were assessed clinically. The lateral condylar prominence index (LCPI) was retrospectively measured at union.

Results

Eighty-four (93.3%) of the patients had a good or excellent result. Six (6.7%) had a poor result (residual varus, loss of >20°of pre-operative range of flexion or extension or a complication necessitating resurgery). There were no neurovascular complications. The mean LCPI was +0.14.

Conclusions

The results of the French osteotomy are comparable to the more technically demanding dome, step-cut translation and multiplanar osteotomies, with a lower complication rate. The literature reports adequate remodeling of the hyperextension deformity (≤10 years) and the LCPI (≤12 years), and that the internal rotation deformity is well tolerated by the patient.

Level of evidence:

Level IV: Case series

Key words: Cubitus varus, lateral closing wedge, French osteotomy.

Introduction

The lateral closing wedge osteotomy described by French[1] to correct cubitus varus deformity following supracondylar fractures of the elbow in children was described in 1959. The procedure is indicated mainly for cosmesis, but late complications such as tardy ulnar nerve palsy,[2] posterolateral rotatory instability[3] and secondary lateral humeral condylar fracture[4] have been described in long-standing cases.

Although good results have consistently been reported with the French technique,[5-8] subsequent more complex procedures have been described. These techniques were developed for three reasons.

Firstly, because the axis of correction of angulation (ACA) of the French osteotomy is proximal to the centre of rotation of angulation (CORA) of the varus deformity (which is situated in the supracondylar fossae), a lateral translation deformity results.[9] This was described as the lateral condylar prominence,[10] and can result in an unsightly lazy-S deformity. It is measured objectively on the AP radiograph with the lateral condylar prominence index (LCPI). To prevent a prominent lateral condyle the dome and step-cut translation osteotomies were developed. The dome osteotomy places the ACA at the CORA.[11-13] The step-cut translation osteotomy,[14-16] medialises the distal fragment. Ilizarov external fixation with distraction osteogenesis,[17,18] also allows medialisation of the distal fragment.

Secondly, the dome and step-cut translation osteotomies create a larger bony contact area and are therefore more stable than the French osteotomy.[12,15]

Thirdly, these osteotomies corrected mainly the coronal plane varus deformity. Three-dimensional (multiplanar) osteotomies were therefore designed to correct the internal rotation and hyperextension deformities as well.[19,20]

Since 1986 we have used the French technique exclusively, because of its simplicity and low complication rate. The purpose of this long-term retrospective study was to compare our results with the more complex and technically demanding procedures subsequently described in the literature.

Patients and methods

We retrospectively reviewed the medical records and radiographs of 90 consecutive patients treated over a 27-year period (1986 – 2012). The mean age of the patients at surgery was 8.2 years (range 3 – 14 yrs). The delay from injury to surgery was a mean of 22 months (range 1 – 6 yrs). Only 20% of the patients were primarily treated at our unit, and only 10% were treated with our current routine method of closed reduction and percutaneous K-wire fixation.

Pre-operatively the carrying angle and elbow flexion and extension were assessed clinically with a goniometer. Radiological assessment was with an AP and lateral of both elbows, and the carrying angles of both elbows were assessed using the humeral-elbow-wrist (HEW) method described by Oppenheim et al (Fig.1).[21] The radiographs are taken with the arm in full supination and 0° extension. The size of the lateral wedge to be removed at surgery was calculated by adding the varus angle to the valgus angle of the normal arm. The mean pre-operative HEW varus angle was 21.4° (range 8° - 40°). The mean HEW valgus angle of the normal arm was 8.8° (range 0° - 20°).

Surgical technique

The technique is as described by French except that we utilise a direct lateral (not posterolateral) approach via the supracondylar ridge and we do not place the inferior screw anteriorly in an attempt to correct internal rotation.

The distal cut is transverse and the proximal cut is oblique (Fig. 2-A). The distal cut is at the proximal end of the supracondylar fossae. The AO 2,5mm small

fragment screws are inserted at least 5mm (to prevent the screws breaking into the osteotomy site) above and below and parallel to the proposed osteotomy cuts. No attempt is made to correct the extension deformity, but it is important to avoid the tendency to saw into extension. With the forearm in supination and the elbow in extension, a greenstick fracture of the medial cortex is created as the osteotomy site is closed and the wire tightened (Fig. 2-B).

Two patients, both 13 years old, had residual instability because the medial cortex fractured completely and required a percutaneous K-wire via the lateral epicondyle.

The carrying angle is assessed clinically and with image. An above elbow posterior plaster splint is applied with the forearm in pronation and the elbow at 90° of flexion.

Post-operative AP and lateral radiographs are done in the above elbow posterior plaster splint to confirm apposition at the osteotomy site. At 3 weeks (4 weeks if the patient is >10 years), the splint is removed, AP and lateral elbow radiographs are done to confirm union and active movement is started.

Follow-up

All patients were assessed at 3 months postoperatively (mean follow-up of 4.8 months). The patients were asked whether they were happy with the cosmetic correction. The carrying angle and range of movement (ROM) were assessed clinically with a goniometer. Radiographs were not routinely done. The LCPI was measured retrospectively on the AP radiograph of all patients at union (3-4 weeks postoperatively) (Fig. 3).

Results were assessed according to the criteria described by Bellemore et al.[5] An excellent result had correction of the carrying angle to ≤ 5° of the normal side and loss of flexion and extension to ≤ 10° of the pre-operative range. A good result had a correction of the carrying angle to within 6 – 10° of the normal side

or loss of flexion and extension 11-20° of the pre-operative range. A poor result had either: residual varus, loss of flexion or extension >20° of the pre-operative range, or a complication necessitating repeat surgery.

Statistical analysis was performed using MS Excel and Stata. The Two-sample t-test was used to compare the pre- and post-operative carrying angles and range of movement (ROM). A p-value of < 0.05 was considered significant. The 95% confidence interval (CI) was used to describe the LCPI.

Results

Table 1 shows the results of the pre-operative and the postoperative carrying angle and ROM and the postoperative LCPI. The correction of the mean pre-operative varus carrying angle of 21.4° to a mean postoperative valgus angle of 10.4° was statistically significant. The mean angle of correction was 31.7° (range 19°-50°).

Of the 90 patients, 75 (83.3%) had an excellent, 9 (10%) a good and 6 (6.7%) a poor result. All the patients were satisfied with the cosmetic result. There were no neurovascular complications.

Of the 6 patients with a poor result, three required a re-operation due to complications. In two patients the screws had pulled out on the postoperative view and one had lost position into flexion. At follow-up all three had an excellent result.

The other three poor results had > 20° (30°) loss of pre-operative range of movement at 3 months postoperatively. Two of these patients had hyperextension with flexion to only 110°. This was due to an initial tendency to cut into extension.

The overall mean LCPI was +0.14. The mean LCPI of the eleven patients >12 years was +0.07 (range -0.07 to +0.22).

Discussion

We performed 90 consecutive French procedures over a 27-year period. Our current management of Gartland type IIB and type III fractures is closed reduction and percutaneous pinning. [22] Eighty percent of the patients in this study, however, were initially treated at peripheral non-teaching hospitals with closed reduction without K-wire fixation.

The humero-elbow-wrist (HEW) angle was found by Oppenheim et al [21] to be more consistent and more accurate than the humero-ulnar and Baumann's angle. We have used it exclusively and found it correlated well with the clinical carrying angle. It is important that the radiograph is taken with the arm in full supination and the elbow at 0° extension (Fig. 1).

Solfelt et al[23] performed a meta-analysis of 40 studies (894 patients). Techniques compared were lateral closing wedge, dome, complex (including step-cut translation and multiplanar) osteotomies and distraction osteogenesis. The overall rate of excellent to good results was 87.8%. No technique was found to significantly affect the outcome or to be statistically safer. The complication rate was 14.5% (nerve injuries 2.5%). In the only randomised control study[8] the French osteotomy was technically less demanding, had better results and fewer complications than the dome osteotomy. In our study the rate of excellent to good results was 93.3%, the complication rate was 3.3% and we had no nerve injuries.

In the original description by French[1] the incision is from posterior, splitting the triceps in half and detaching the lateral half of the triceps off its insertion in order to visualise the ulnar nerve. We used the modification described by McCoy and Piggot,[7] which is a lateral approach directly via the supracondylar ridge. The approach remains subperiosteal and the ulnar nerve is not visualised.

In a long-term comparative study of 50 years by Raney et al [24], the incidence of nerve injuries (ulnar and radial) with the posterolateral approach was 14%,

whereas with the lateral approach there were no nerve injuries. The incidence of unsightly scars was low, but equal for both incisions. None of our patients complained of an unsightly scar and there were no nerve injuries. The lateral incision in our series extended from the epicondyle proximally for not more than the patient's handbreadth to avoid injury to the radial nerve.

With the French[1] technique medial stability is provided by the greenstick fracture of the medial cortex and the intact periosteum. The screws and wire act as a tension band. K-wire fixation has an incidence of nerve injury ranging from 7%[25] to 17%.[26] Plate fixation has a 10% incidence of nerve injury.[24] Patients close to skeletal maturity may have residual instability if there is a complete, instead of a greenstick, fracture of the medial cortex. Of the 11 patients >12 years in our study, two had residual instability and required a percutaneous K-wire via the lateral epicondyle.

The French osteotomy corrects mainly the varus deformity, although in the original description French placed the distal screw anteriorly to correct internal rotation.[1] More complex multiplanar osteotomies were therefore developed to correct the internal rotation and hyperextension deformities.[19,20]

In a landmark article in 1966, Lyman Smith showed that the varus deformity was due to varus tilt, and internal rotation did not contribute to the varus.[27]

Bellemore et al[5,6] and Oppenheim[21] showed that the cosmetic outcome was paramount. This is achieved by correcting the varus. Attempts to correct internal rotation at the same time gave worse results.

Tagaki et al[28] compared the outcome of 34 patients who had a three-dimensional osteotomy with 40 patients who had a simple lateral closing osteotomy. The group who had the three-dimensional osteotomy had more significant loss of correction because derotation reduced the bony contact area. The internal rotation deformity was well tolerated as it is easily compensated by rotation of

the shoulder. They also showed that the hyperextension deformity remodelled in children ≤10 years.

We did not attempt to correct internal rotation or hyperextension. Although we did not assess rotation, no patient voluntarily complained. The improvement in the mean postoperative range of extension (-4.1 to 2.2; p = 0.02) suggests that surgery inadvertently benefited extension. Flexion was not significantly altered.

Raney et al[24] found only 2 of 68 patients (3%) complained of a lateral prominence, but the LCPI was abnormal in 62% of cases. They concluded that there was no correlation between the radiographic findings and the patient's complaint of a "bump". Bellemore et al[6] similarly found only 2 of 17 patients (12%) disturbed by the appearance of a "bump". They ascribe this, like Wong et al,[10] to remodelling in the skeletally immature (≤12 years). Cho et al[29] evaluated the long-term results of remodelling after the French osteotomy. At a mean follow-up of 10 years (range 4.7 yrs to 14.2 yrs) the mean LCPI had remodelled from +0.36 postoperatively to +0.11. The patients who were prepubertal at osteotomy remodelled from +0.42 to +0.05, while the postpubertal patients only remodelled from +0.27 to +0.21.

We did not clinically assess for a prominent lateral condyle, but no patient volunteered cosmetic dissatisfaction. The overall mean LCPI at union of +0.14 (>12 yrs: +0.07) had a 95% confidence interval of +0.08 to +0.19, indicating a narrow range of postoperative results falling close to normal. This was probably due to the proximity of the distal cut at the superior margin of the fossae, and the obliquity of the proximal cut in an endeavour to obtain equal widths of the fragments (Fig. 2-B). No medialisation was attempted, as it would destabilise the medial cortex.

The study is subject to the bias of a retrospective study. The pre- and postoperative range of movement and postoperative carrying angle were obtained from the clinical notes, but the pre-operative HEW angles and the postoperative LCPI were measured by the authors. A longer follow-up would

confirm the remodelling potential of the hyperextension and the lateral condylar prominence as suggested in the literature.

Conclusions

The results of the French osteotomy are comparable to the more technically demanding dome, step-cut translation and multiplanar osteotomies, with a lower complication rate. The literature reports adequate remodelling of the hyperextension deformity (≤10 years) and the LCPI (≤12 years), and that the internal rotation deformity is well tolerated by the patient.

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Figures

FIGURE 1.

The humero-elbow-wrist (HEW) angles of a varus left elbow and the normal valgus of the right elbow. The HEW angle is the angle subtended by the intersection of the forearm and humeral axes. The forearm and humeral axes are drawn by connecting the midpoints of two transverse lines drawn across the proximal and distal forearm and humerus.

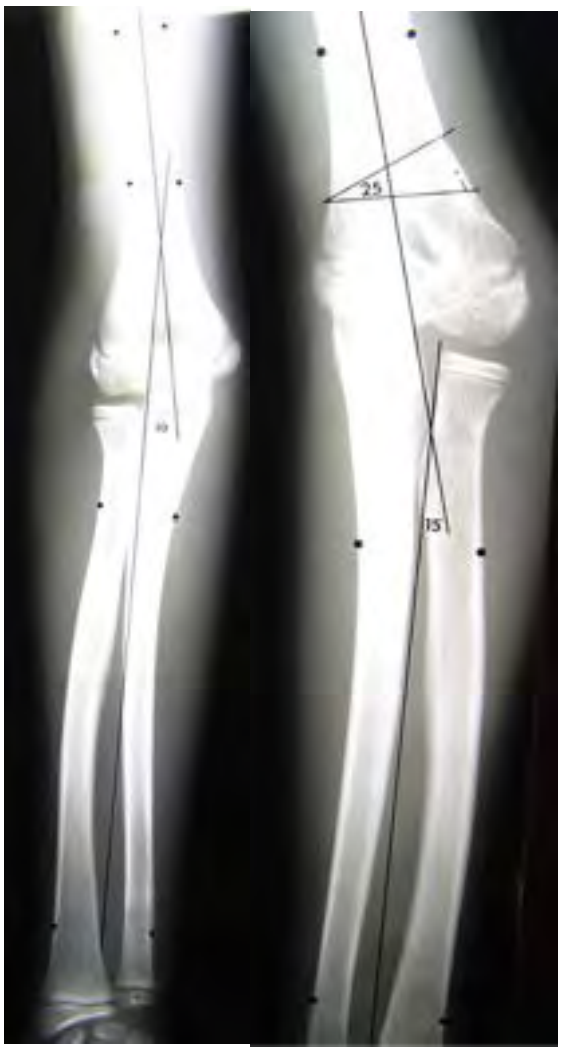

FIGURE 2-A.

AP radiograph of a 13-year-old boy with cubitus varus of the left elbow requiring a 46° lateral closing wedge osteotomy.

FIGURE 2-B.

AP and lateral radiograph 3 months postoperatively. The clinical carrying angle was 5°valgus (normal 6°).

FIGURE 3.

A-P radiograph of the L elbow of a 9-year-old boy after 40° correction. The lateral condylar prominence index (LCPI) is +0.33. The index is the difference between lateral and medial widths measured from the midhumeral axis expressed as a ratio of the total width: LCPI = (AB-BC)/AC. The normal is slightly negative.

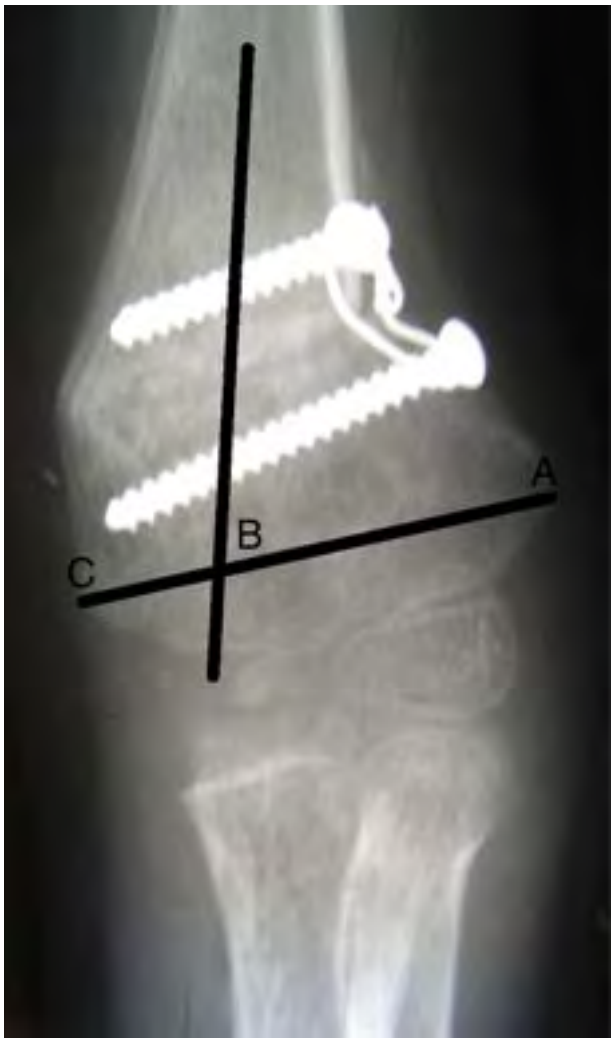

TABLE 1

Pre- and postoperative carrying angle and ROM, and postoperative LCPI.

*CI = 95% confidence interval.

	Pre-operative mean (range)	Postoperative mean (range)	*CI (postoperative)	p-value
Carrying angle	-21° (-8° to -40°)	10.4° (0° to 20°)	9.5° to 11.3°	< 0.01
Flexion	118.2° (90° to 140°)	121° (90° to 140°)	116.9° to 125°	0.34
Extension	-4.1° (-20° to 20°)	2.2° (-30° to 20°)	-2.3° to 6.8	0.02
Lateral condylar prominence angle		+0.14(-0.3 to +0.55)	+0.08 to +0.19	

PART D:

SUPPORTING DOCUMENTS

Ethics Approval Letter

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12 April 2013

HREC REF: 209/2013

Dr D North
Department of Orthopaedics
H-Floor
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Dear Dr North

PROJECT TITLE: MODIFIED FRENCH OSTEOTOMY FOR CUBITUS VARUS DEFORMITY IN CHILDREN

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

It is a pleasure to inform you that the HREC has **formally approved** the above mentioned study.

Approval is granted for one year till the 15 April 2014.

Please submit a progress form, using the standardised Annual Report Form, if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
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sAriefdien

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A structured abstract of no more than 325 words, consisting of five paragraphs, with the headings Background (which states the primary research question), Methods, Results, Conclusions, and Level of Evidence (for clinical articles) or Clinical Relevance (for basic-science articles).Limit the use of abbreviations and acronyms. For the Level of Evidence section, describe the study type and assign a level-of-evidence rating to the primary research question, according to the criteria in the table in the Instructions to Authors.

Levels of Evidence for Primary Research Question[1]				
	Types of Studies			
	Therapeutic Studies—Investigating the Results of Treatment	Prognostic Studies—Investigating the Effect of a Patient Characteristic on the Outcome of Disease	Diagnostic Studies—Investigating a Diagnostic Test	Economic and Decision Analyses—Developing an Economic or Decision Model
Level I	• High-quality randomized controlled trial with statistically significant difference or no statistically significant difference but narrow confidence intervals • Systematic review[2] of Level-I randomized controlled trials (and study results were homogeneous[3])	• High-quality prospective study[4] (all patients were enrolled at the same point in their disease with ≥80% follow-up of enrolled patients) • Systematic review[2] of Level-I studies	• Testing of previously developed diagnostic criteria in series of consecutive patients (with universally applied reference "gold" standard) • Systematic review[2] of Level-I studies	• Sensible costs and alternatives; values obtained from many studies; multiway sensitivity analyses • Systematic review[2] of Level-I studies
Level II	• Lesser-quality randomized controlled trial (e.g., <80% follow-up, no blinding, or improper randomization) • Prospective[4] comparative study[5] • Systematic review[2] of Level-II studies or Level-I studies with inconsistent results	• Retrospective[6] study • Untreated controls from a randomized controlled trial • Lesser-quality prospective study (e.g., patients enrolled at different points in their disease or <80% follow-up) • Systematic review[2] of Level-II studies	• Development of diagnostic criteria on basis of consecutive patients (with universally applied reference "gold" standard) • Systematic review[2] of Level-II studies	• Sensible costs and alternatives; values obtained from limited studies; multiway sensitivity analyses • Systematic review[2] of Level-II studies
Level III	• Case-control study[7] • Retrospective[6] comparative study[5] • Systematic review[2] of Level-III studies	• Case-control study[7]	• Study of nonconsecutive patients (without consistently applied reference "gold" standard) • Systematic review[2] of Level-III studies	• Analyses based on limited alternatives and costs; poor estimates • Systematic review[2] of Level-III studies

Level IV	Case series[8]	Case series	• Case-control study • Poor reference standard	• No sensitivity analyses
Level V	Expert opinion	Expert opinion	Expert opinion	Expert opinion

1. A complete assessment of the quality of individual studies requires critical appraisal of all aspects of the study design.

2. A combination of results from two or more prior studies.

3. Studies provided consistent results.

4. Study was started before the first patient enrolled.

5. Patients treated one way (e.g., with cemented hip arthroplasty) compared with patients treated another way (e.g., with cementless hip arthroplasty) at the same institution.

6. Study was started after the first patient enrolled.

7. Patients identified for the study on the basis of their outcome (e.g., failed total hip arthroplasty), called "cases," are compared with those who did not have the outcome (e.g., had a successful total hip arthroplasty), called "controls."

8. Patients treated one way with no comparison group of patients treated another way.

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Journal article

1. Rand NS, Dawson JM, Juliao SF, et al. In vivo macrophage recruitment by

murine intervertebral disc cells. *J Spinal Disord.* 2001;14:339-342.

Book chapter
2. Todd VR. Visual information analysis: frame of reference for visual perception. In: Kramer P, Hinojosa J, eds. *Frames of Reference for Pediatric Occupational Therapy.* Philadelphia, PA: Lippincott Williams & Wilkins; 1999:205-256.

Entire book
3. Kellman RM, Marentette LJ. *Atlas of Craniomaxillofacial Fixation.*Philadelphia, PA: Lippincott Williams & Wilkins; 1999.

Software
4. *Epi Info* [computer program]. Version 6. Atlanta, GA: Centers for Disease Control and Prevention; 1994.

Online journals
5. Friedman SA. Preeclampsia: a review of the role of prostaglandins. Obstet Gynecol [serial online]. January 1988;71:22-37. Available from: BRS Information Technologies, McLean, VA. Accessed December 15, 1990.

Database
6. CANCERNET-PDQ [database online]. Bethesda, MD: National Cancer Institute; 1996. Updated March 29, 1996.

World Wide Web
7. Gostin LO. Drug use and HIV/AIDS [*JAMA* HIV/AIDS Web site]. June 1, 1996. Available at: http://www.ama-assn.org/special/hiv/ethics. Accessed June 26, 1997.

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