Original article

The use of Poller screws in intramedullary nailing is associated with decreased callus formation

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Summary

The use of the Poller screw technique in tibial nailing has been shown in biomechanical studies to improve stability at the fracture site. However no study to date has investigated the *in vivo* effect of Poller screws on callus formation at the fracture site.
This study had three purposes. First, to investigate the association between Poller screw use and the size of callus formed at the fracture site. Second, to investigate if there is a difference in size between the ipsilateral and contralateral callus in the plane of action of the Poller screw. Third, to investigate if there is a difference between callus size in and out of the plane of action of the Poller screw.
A retrospective cohort was formed of 24 patients treated with tibial intramedullary nailing and use of a Poller screw between December 2007 and December 2014. These were compared to a control group of 11 patients from the same period with comparable injuries treated with intramedullary nailing without use of a Poller screw. Follow-up radiographs were utilised to measure the maximum width of the cortex, the maximum callus width and the maximum width of the cortex and corresponding callus on each side of the fracture (in order to quantify callus formation). This was repeated in anterior-posterior and lateral radiographic planes. The position and plane of action of the screw in reference to all measurements was recorded. One-tailed paired t-tests were computed for hypothesis testing. In order to evaluate the relationship between callus size, age and injury classification, an analysis of variance (ANOVA) was performed.
The Poller screw group formed significantly less callus than the control group. In the plane of action of the Poller screw, the contralateral callus was significantly smaller than the ipsilateral callus relative to the Poller screw location. There was no significant difference in callus size in and out of the plane of action of the Poller screw. This study demonstrates an association between the use of Poller screws in intramedullary nailing of tibial fractures and decreased callus formation *in vivo*. This supports the findings of previous biomechanical studies which show increased stability at the fracture site when Poller screws are placed.

KEY WORDS: Poller screw; bone healing; intramedullary nailing; callus.

Introduction

Since their introduction early in the twentieth century by Ernest William Hey Groves, the use of intramedullary nails to treat fractures in the metaphyseal region of long bones has posed two main challenges: poor stability and high rates of malunion (1-3). Popularised in the 1930's by Gerhard Kuntscher with the introduction of his straight, V-shaped nail, subsequent evolutions in nail design have aimed to address these challenges. From Kuntschers adoption and development of reaming, to Grosse et al. developing the interlocking nail, the evolution in intramedullary nailing has continued to improve union rates whilst reducing the rates of malunion (4-7). However, intramedullary nails continued to have appreciably poor control of proximal and distal fracture fragments around the metaphysis (8-11). Recognising that the reduced nail to cortical contact in proximal and distal tibial fractures was responsible for these malunions, Krettek et al. developed the Poller screw technique (12). Using a screw to block the passage of the nail and therefore reduce the apparent metaphyseal width, they were able to demonstrate improved fracture reduction leading to a profound reduction in malunion rates (13-15). Krettek was also able to show with biomechanical studies that there was an increase in stability at the fracture site (14).
Krettek's original description for the use of Poller screws included the placement of two screws either side of the fracture, on the concavity of the deformity (15, 16). Stedfield et al. have since described recreating three point fixation with the use of a single Poller screw, placed in the shortest fragment, on the concavity of the curve. This technique has been validated with the use of mechanical models and is consistent with the findings of others (17, 18).
Assessment of fracture stability can be performed radiographically. Several studies have confirmed the indirect proportional relationship between the stability of fixation and the size of the fracture callus formed (19, 20). Using the width of the callus as a ratio of the width of the cortex in two planes allows accurate assessment of the size of the callus, accommodating slight changes in magnification and angulation (18). Eastaugh-Waring et al. used this method to quantify the callus formed by a

fracture, and related this radiological assessment to confirmation of union (18). This method of callus measurement has its shortcomings, particularly in reference to fractures with any obliquity, resulting in callus at split levels, and fractures that abut the metaphyseal flare where cortical width changes dramatically depending on the level at which it is measured.

To our knowledge no study to date has investigated the *in vivo* effect Poller screws have on fracture stability. We therefore sought to investigate this relationship. This study had three purposes. First, to investigate the association between Poller screw use and the size of callus formed at the fracture site. Second, to investigate if there is a difference in size between the ipsilateral and contralateral callus in the plane of action of the Poller screw. Third, to investigate if there is a difference between callus size in and out of the plane of action of the Poller screw.

Patients and method

This retrospective cohort study was performed at a level I Major Trauma Centre in the United Kingdom.

Inclusion criteria: trauma patients with closed fractures of the distal tibial metaphysis treated with intramedullary nailing and the use of a Poller screw technique in a single plane (AP or ML). Following a search of the lead consultants log book, between December 2007 and December 2014.

Control group inclusion criteria: we identified trauma patients admitted in the last ten years with closed fractures of the distal tibial metaphysis who were treated with intramedullary nailing of the tibia as their definitive procedure, without the use of Poller or blocking screws. Pre-operative radiographs from these patients were then presented to the lead consultant to determine suitability for the use of a Poller screw.

All patients in the Poller screw group were treated using the same surgical technique under the supervision of a single consultant. The patients were positioned supine with a sand bag to the contralateral buttock as described by Granville-Chapman et al. (21). Screw placement was performed as described by the Cambridge team (22). The screw was positioned to narrow the medullary cavity and deflect or deform the nail to gain reduction and compression of the fracture with three point fixation. All patients were treated with the titanium Synthes Expert Tibial nailing system. Size of nail was decided by diaphyseal medullary width intraoperatively, with reaming 1mm greater than the nail chosen. The screws used to achieve blocking were the same cortical screws used for locking the nail. The screws were therefore either 4 mm or 5 mm screws depending on nail width and were titanium. All patients were followed up until radiographic and clinical union were established.

All radiographs were viewed with General Electric's Centricity Enterprise Web version 3.0 Picture Archiving and Communication System and were viewed at the same magnification factor 1:1 and calibration measurements were made based on the known diameter of the intramedullary nail. Measurements were taken using the inbuilt measurement tool (23). Radiographs were chosen by the Authors for each patient that represented the maximum callus index, thereby representing the fracture at its closest time to union (24). Two sets of measurements were made by two orthopaedic registrars and a department clinical fellow blinded to the purpose of the trial, each-others measurements and their previous measurements.

The observers were asked to measure the width of the nail, the maximum width of the cortex, the maximum callus width and the maximum width of the cortex and corresponding callus on each side of the fracture, in two planes and record the position and plane of action of the screw in reference to all measurements (Figure 1). These measurements were then used to calculate the Callus index as described by Spencer et al., and to calculate modified callus measurements to account for fracture obliquity (20). One patient had a segmental fracture and each segment was measured independently.

Statistical testing

Inter-rater reliability was assessed on all measures, with calculation of the intraclass correlation coefficient (ICC). Additionally, F-test and confidence intervals were computed. For hypothesis testing, one-tailed paired t-tests were computed. In order to evaluate the relationship between callus size, age and injury classification, an analysis of variance (ANOVA) was performed. All testing was performed in R, version 3.0.2.

Results

A total of 75 tibial nails was performed by the lead consultant. Of these, 27 patients met the inclusion criteria for the Poller screw group. Three of these patients were excluded; one revision for non-union having had a tibial nail without Poller screw previously, one lost to follow-up as out of area and one as the indication was deformity correction not trauma. One patient had a segmental fracture and both fractures were measured independently. The final sample included 24 patients with a mean age of 45 (range 19-97); Male: Female 15:8, and mean follow-up of 32 weeks. 22 fractures were of the distal metaphysis, 3 of the proximal metaphysis. For the control group, we identified 11 patients between December 2012 and January 2015 who met the inclusion criteria. The group was populated from six different surgeons. The mean age of the control group was 34 (range 17-64); Male:Female 7:4, and a mean length of follow-up of 28 weeks.

The modified method for measuring callus in oblique fractures detected more callus than the standard callus index. One-tailed paired t-testing of patients with Poller screws and controls re-

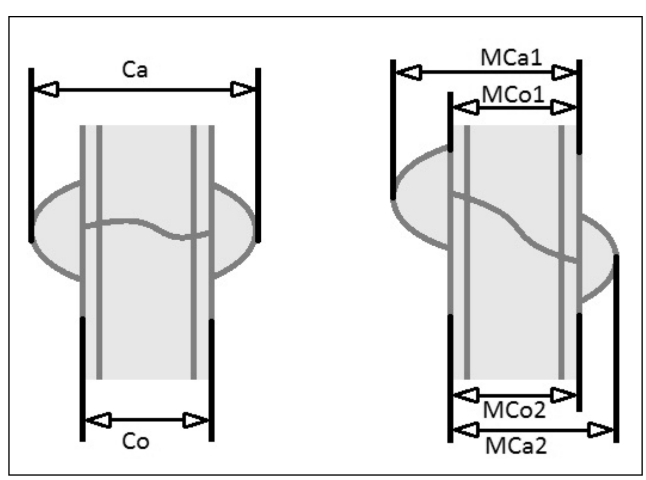

Figure 1 - Diagram comparing Callus Index and Modified Callus Index measurement (Co-Cortex, Ca-Callus, MCo-Modified Cortex, MCa-Modified Callus).

vealed that the modified method calculated a significantly larger callus size than the original method (t = -4.75, df = 34, p = <0.001) with a mean callus size of 7.8 mm in the standard measurement compared to 10.1 mm in the modified measurement. The inter-rater reliability of the modified callus method was robust and comparable. Intraclass correlation coefficients ranged from 0.760 (95% CI 0.593-0.878) to 0.967 (95% CI 0.936-0.984) (Table 1, Figure 2).

Poller screw use was associated with less callus formation. Control group mean total callus size was 25.9 mm (anteroposterior and medial to lateral combined), compared to cohort mean total callus of 17.7 mm (t = -2.38, df = 15.4, p = 0.015) (Figure 3 a-d). The relationship between callus size, age and injury classification was not found to be significant (age f = 0.215, p = 0.649; injury classification f = 0.780, p = 0.578). In the control group, there was no difference between the modified callus size in an anterior to posterior direction compared to a medial to lateral direction (mean ±SD 11.90 ± 6.15 *vs* 13.96 ± 5.52 respectively, p = 0.871).

The contralateral callus was smaller than the ipsilateral callus in the plane of action of the Poller screw. Mean contralateral callus size was 2.8 mm, significantly smaller than the mean ipsilateral callus size of 5.5 mm (t = -4.56, df = 23, p = <0.001). In the control group, there was no difference in callus size between the ipsilateral and contralateral side (mean ± SD 7.3 ± 3.0 *vs* 6.7 ± 4.1 respectively, p = 0.332).

There was no difference in callus size in and out of the plane of action of the Poller screw (t = -1.03, df = 23, p = 0.156).

Discussion

In order to quantify callus formation, we have utilised a modified version of the callus index described by Spencer et al. (20). We showed strong intraobserver reliability proving that this is a reliable method for radiographic callus assessment. Statistical analysis also showed a significant increase in the callus measured, suggesting that the modified callus measurements record a greater amount of callus for the same fracture than the original method, and might be more useful for assessing the quantity of callus formed by a fracture especially in the case of fracture obliquity with callus formed at different levels.

Table 1 - Inter-rater reliability: Intraclass Correlation Coefficient Results.

	Measure	**ICC**	**f(23,48)**	**p-value**	**95% CI**
In plane of action of Poller	*Original Callus*	0.961	74.5	<0.001	0.925-0.981
	Original Cortex	0.863	19.9	<0.001	0.754-0.933
	Original Callus Index	0.784	11.9	<0.001	0.629-0.891
	Original Callus Size	0.845	17.4	<0.001	0.724-0.924
	Ipsilateral Callus	0.951	59.8	<0.001	0.908-0.977
	Ipsilateral Cortex	0.831	15.8	<0.001	0.701-0.916
	Ipsilateral Callus Index	0.853	18.5	<0.001	0.738-0.928
	Ipsilateral Callus Size	0.891	25.6	<0.001	0.801-0.947
	Contralateral Callus	0.937	45.9	<0.001	0.882-0.97
	Contralateral Cortex	0.889	24.9	<0.001	0.796-0.946
	Contralateral Callus Index	0.783	11.8	<0.001	0.626-0.89
	Contralateral Callus Size	0.822	14.8	<0.001	0.686-0.911
	Modified Callus Size	0.875	22.1	<0.001	0.774-0.939
Out of plane of action of Poller	*Original Callus*	0.961	75.2	<0.001	0.926-0.982
	Original Cortex	0.816	14.3	<0.001	0.678-0.908
	Original Callus Index	0.860	19.5	<0.001	0.749-0.931
	Original Callus Size	0.904	29.3	<0.001	0.823-0.954
	Ipsilateral Callus	0.881	23.2	<0.001	0.783-0.942
	Ipsilateral Cortex	0.867	20.6	<0.001	0.76-0.935
	Ipsilateral Callus Index	0.767	10.8	<0.001	0.602-0.881
	Ipsilateral Callus Size	0.760	10.5	<0.001	0.593-0.878
	Contralateral Callus	0.967	88.3	<0.001	0.936-0.984
	Contralateral Cortex	0.846	17.5	<0.001	0.726-0.924
	Contralateral Callus Index	0.854	18.5	<0.001	0.738-0.928
	Contralateral Callus Size	0.915	33.4	<0.001	0.843-0.959
	Modified Callus Size	0.853	18.4	<0.001	0.737-0.928

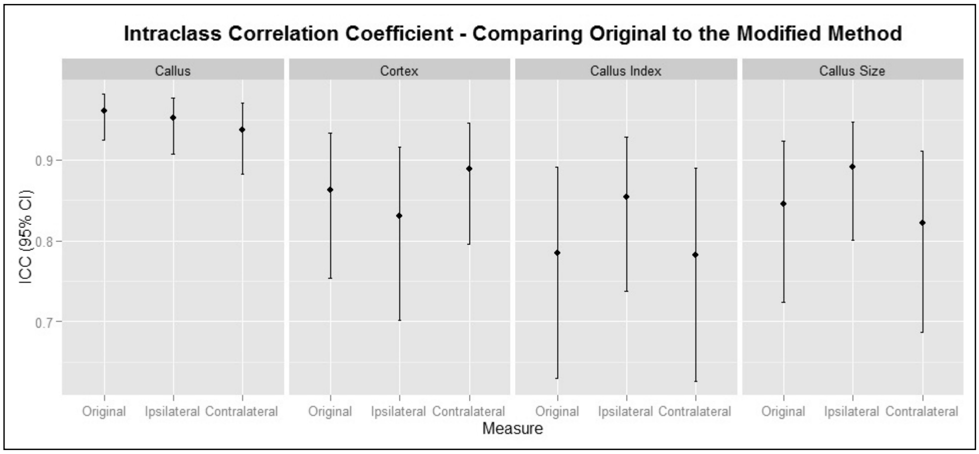

Figure 2 - Intraclass correlation coefficient. Comparing original callus index to the modified callus index.

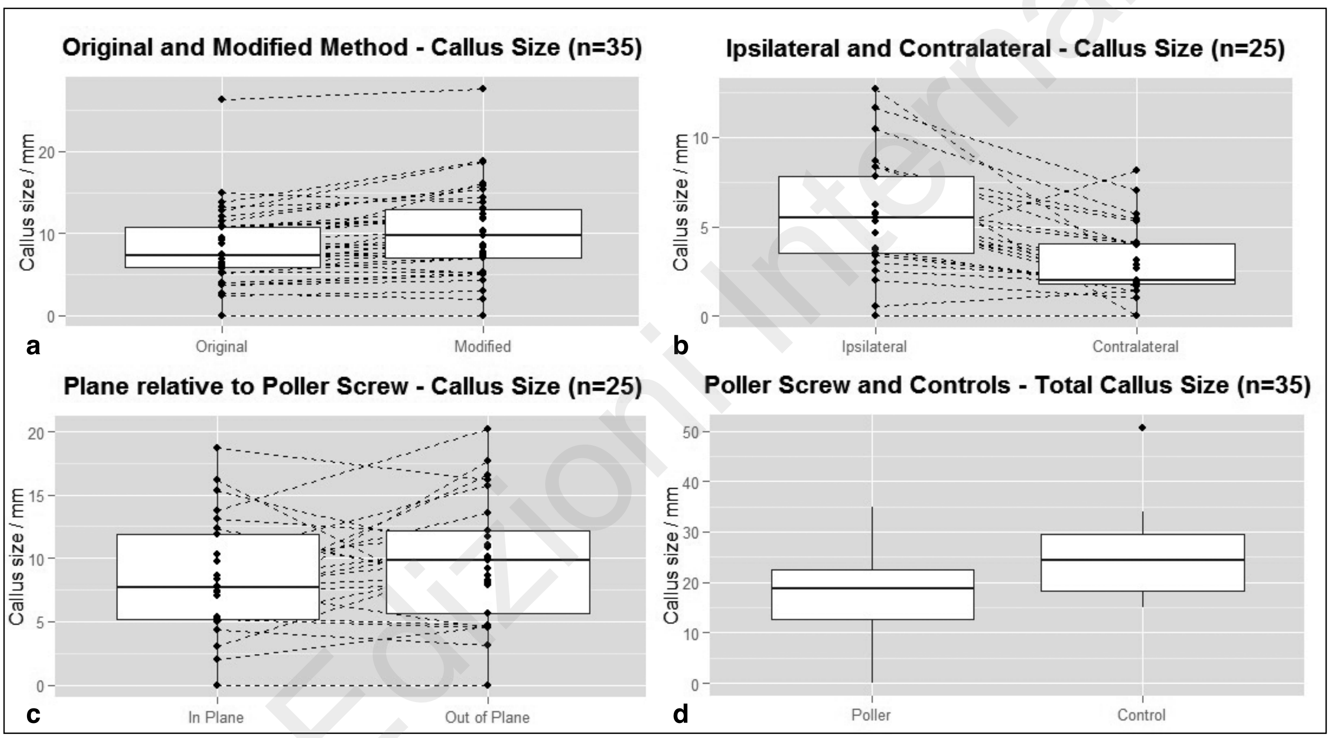

Figure 3 a-d. a. Box plot comparing total callus measured by the original callus index measurement technique and the modified callus measurement technique, including paired data connected by dotted line and P-value for paired t-test. b. Box plot comparing callus size ipsilateral and contralateral to the poller screw, including paired data connected by dotted line and P-value for paired t-test. c. Box plot comparing callus measured relative to the plane of action of the Poller screw, including paired data connected by dotted line and P-value for paired t-test. d. Box plot comparing total callus measured between cohort and control group using the modified method for measurement, including P-value for paired t-test.

The first purpose of this study was to investigate the association between Poller screw use and the size of callus formed at the fracture site. We found significantly less callus formation when a Poller screw was utilised. This is in keeping with the results of previous biomechanical studies that show the use of a Poller screw significantly increases fracture stability (15, 19).
The second purpose was to investigate if there is a difference in size between the ipsilateral and contralateral callus in the plane of action of the Poller screw. We showed a significant difference with the cortex contralateral to the screw forming very little callus. By contrast callus formation in the control group was equal around the cortices. This suggests that the increase in fracture stability associated with Poller screw use is most pronounced at the site contralateral to the Poller screw (18, 19). Whilst this implies compression at this site, we are unable to test this hypothesis directly.
The third purpose was to investigate if there is a difference between callus size in and out of the plane of action of the Poller screw. Our results showed no significant difference. It is possible that given the obliquity and spiral nature of the fractures observed (none of the cohort were transverse AO 42 A3 fractures), a single Poller screw was sufficient to provide an increase in stability in all planes. Other than to aid in fracture reduction and the prevention of malunion this suggests that there is no advantage to the use of a Poller screw in more than one plane. Analysis of variance showed no relationship between

the fracture morphology or patient age with callus formed, which was expected and confirms the findings of other studies (24).

This study had some limitations. As a retrospective study there was no standardised follow-up regime. In principle patients were seen at six weeks and then every 6-8 weeks until clinically and radiologically united. No standardised outcome measures were used and have therefore been excluded from this study. The control group, although comparable for age, gender, injury mechanism, injury, and follow-up , was formed from multiple surgeons. We were able to isolate a reasonably sized control population for comparison, however there are difficulties in achieving greater numbers. Due to the extended indication Poller screws afford treatment with intramedullary nails, those patients not treated by this method were often treated with open reduction and internal fixation. This was due to surgeons either not familiar or not comfortable with the Poller screw technique, who recognised that intramedullary nailing of metaphyseal fractures would result in an unacceptable risk of malunion and instability.

It is important to recognise that bone healing is a complex physiological process regulated by a variety of local and systemic factors (25, 26). Cigarette smoking, malnutrition, inflammatory conditions, osteoporosis and diabetes as well as a variety of medications have been shown to dramatically increase rates of non-union (27). Due to the size of this study we are unable to control for factors such as these, which could have affected our results. Larger, prospective studies with clear exclusion criteria would minimise any confounding factors. Further studies should also include outcome measures such as time to union and return to activity.

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