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Is the stability of a tibial fracture influenced by the type of unilateral external fixator?

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Abstract

Objective. To examine whether the type of unilateral external fixator significantly influences the stability of a tibial fracture.

Design. Inter-fragmentary displacements were measured during walking while the fractures were stabilized, first with one type of fixator then with another.

Background. It is commonly claimed that one type of fixator exerts a different influence on mechanical stability at a fracture in comparison with another.

Methods. This study compares inter-fragmentary displacement, fixator displacement and weight bearing during walking, in four patients stabilized with an Orthofix DAF, which was replaced by a Howmedica International Monotube.

Results. The null hypothesis of no difference in fixator performance was unproved ($P<0.05$) through insufficient data. Inter-patient variability in inter-fragmentary displacement implies that anthropometry, gait and fracture type may influence fracture stability more than the type of fixator.

Conclusions. Since weight-bearing and displacements were not substantially different, no basis was found for the claim that one fixator provides a mechanical environment substantially different to another. Sample size was not large enough to prove that a small but statistically significant difference exists.

Relevance

The influence on fracture stability of one type of unilateral fixator in comparison with another appears to be less than the influence of anthropometry, gait and the type of fracture.

Keywords: External fixator; Fracture; Tibia; Displacement; Stability

1. Introduction

Very little is known about the relative influence of external fixators on the stability of long bone fractures. Although traumatists may prefer a particular design of unilateral external fixator, they have been unable to prove whether one fixator influences the mechanical environment at the fracture differently to another. Therefore, although the mechanical environment has been shown to substantially influence the morphology and speed of healing [1], it has been impossible to determine whether the environment imposed by one fixator may be superior to the environment imposed by another.

Methods of evaluating the mechanical performance of external fixators have involved laboratory simulations, which have examined either individual fixators, or groups of fixators under simulated fracture conditions [2–5]. However, the conditions of applied loading and inter-fragmentary support are unlikely to have closely resembled the environment of real fractures. Creating a simulated fracture environment is a difficult problem. To what degree should the model simulate tibial load transfer across the fracture by end bearing fragments and inter-fragmentary gap tissue or external callus [6]. Also, how should loading be applied to the model fracture to simulate weight-bearing and muscle

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response during routine daily activity, and how should the healing and stiffening of the repair tissue be simulated which causes the conditions of load and support at the fracture to change progressively [7]. The present study avoids the difficulty arising from experimental and theoretical simulations by using real fractures to examine the relative performance of two fixators. The influence of unspecified variables such as fracture structure, severity of injury, gait and weight-bearing were neutralized by examining the performance of different fixators on the same patient. To compare their relative influence on fracture stability, inter-fragmentary motion was monitored during routine patient activity, firstly with the DAF (Orthofix, Verona, Italy — bending stiffness 1.8 Nm/degree) supporting the fracture, and secondly the blue Monotube (Howmedica International, UK — bending stiffness 1 Nm/degree).

2. Methods

2.1. Patient selection and treatment

Four subjects (aged 28–36) were selected with non-comminuted diaphyseal tibial fractures (two transverse and two oblique) that were treated with DAF external fixators. As a result of the limited availability of consenting patients with the required type of fracture and fixator, only four subjects could be tested. Three 6 mm diameter bone screws were inserted into the medial cortex at each side of the fracture, and the fragments were reduced to ensure tibial load would be transferred across the fracture during weight-bearing. As part of the treatment regime, the fixator columns were unlocked after 6 weeks to allow free telescoping movement, which was confirmed by applying axial compression at the column ends.

2.2. Monitoring inter-fragmentary motion

Dynamic relative motion was monitored at the fractures during walking activity with patients adopting a normal gait, and weight-bearing was measured by a floor-mounted force plate recording vertical reaction force. Displacement was measured by an instrumented spatial linkage attached to the bone screws immediately above and below a fracture [8]. Linkage displacements arising from motion during weight-bearing were translated trigonometrically to provide inter-fragmentary displacements in three dimension at the fracture centre. Correlation between the linkage and vernier measuring apparatus indicated that linkage measurements were accurate to within +/−0.025 mm and +/−0.025°. Although data arising from loose screws may be identified and discarded from the study [6], none was found.

2.3. Test protocol

Subjects were tested at fortnightly intervals from 2–10 weeks post-fracture, and on each occasion the following procedure was performed. A temporary fixator was clamped close to the ends of the bone screws alongside the subject's normal fixator, to maintain the relative position of the fragments. The normal fixator was then removed and replaced by the first of the test fixators, and the temporary fixator was removed leaving only the test fixator ready for the walking test. The same technique was adopted to exchange the first test fixator with the second. Both test fixators were supplied new for the study. The Monotube clamps had slightly amended bone screw spacings and fixing bolt positions, to allow the fixator to be attached to the same screws as the DAF. After measuring inter-fragmentary displacement at the fracture, the instrumented linkage was attached to the ends of the screws on the opposite side of the fixator to the limb, to measure relative displacement between the two sections of fixator column during free telescopic movement.

2.4. Analysis

Maximum axial relative displacement at the cortical surface was calculated from the amplitudes of axial and angular displacement at the fracture centre. Relative transverse and torsional shear displacements and weight-bearing were provided direct from the instrumented linkage and force plate. The orientation of the axis of maximum angular displacement (about which bending occurred) and the direction of maximum transverse shear were calculated. These axes lay in a plane perpendicular to the long axis of the proximal fragment; their radial angles at the bone centre were measured clockwise (over 360°) from zero in the medial direction. 'Mean' values of each variable were calculated for each of the four subjects to examine intra-patient variability. A two tailed paired t-test assuming a null hypothesis ($P<0.05$) was used to determine whether disparities between the group 'means' were statistically significant, and the mean of the 'difference' that existed at each test session was calculated.

3. Results

Results are shown in Tables 1–8. The null hypothesis was not accepted for all variables, either for individuals or for the group. Large SD values for each patient and

Table 1
Weight-bearing during walking (locked fixator) — each subject

Subject	Orthofix DAF		Howmedica B-Monotube		Paired *t*-test		Difference	
	Mean (N)	SD	Mean (N)	SD	$P(T<t)$	n	Mean (%)	SD
1	450.6	105.3	368.0	81.8	0.107	5	17.0	14.9
2	559.8	100.8	519.8	160.3	0.368	6	8.20	22.5
3	445.3	282.5	406.7	269.5	0.318	3	0.07	0.13
4	337.8	61.5	397.2	47.4	0.220	5	−22.6	38.7
All	454.6	150.0	429.7	146.1	0.285	19	2.23	28.1

Table 2
Axial inter-fragmentary displacement (locked fixator) — each subject

Subject	Orthofix DAF		Howmedica B-Monotube		Paired *t*-test		Difference	
	Mean (mm)	SD	Mean (mm)	SD	$P(T<t)$	n	Mean (%)	SD
1	0.77	0.41	1.09	0.74	0.154	4	−35.6	25.1
2	0.48	0.27	0.72	0.54	0.233	5	−43.6	56.1
3	0.13	0.02	0.16	0.05	0.546	3	−31.9	69.1
4	0.27	0.28	0.10	0.03	0.261	5	38.9	29.9
All	0.43	0.35	0.53	0.59	0.247	17	−15.4	55.2

Table 3
Transverse inter-fragmentary displacement (locked fixator) — each subject

Subject	Orthofix DAF		Howmedica B-Monotube		Paired *t*-test		Difference	
	Mean (mm)	SD	Mean (mm)	SD	$P(T<t)$	n	Mean (%)	SD
1	0.50	0.23	0.82	0.45	0.144	4	−67.6	63.5
2	0.35	0.23	0.37	0.36	0.874	5	−10.9	50.6
3	0.13	0.04	0.13	0.04	1.000	3	−3.67	31.0
4	0.22	0.14	0.16	0.02	0.431	5	−6.93	70.5
All	0.31	0.22	0.37	0.38	0.332	17	−21.8	58.8

Table 4
Torsional inter-fragmentary movement (locked fixator) — each subject

Subject	Orthofix DAF		Howmedica B-Monotube		Paired *t*-test		Difference	
	Mean (°)	SD	Mean (°)	SD	$P(T<t)$	n	Mean (%)	SD
1	0.31	0.06	0.29	0.03	0.713	4	−49.3	105.3
2	0.25	0.19	0.17	0.05	0.493	5	−23.9	96.1
3	0.005	0.007	0.01	0.01	0.500	3	0	100
4	0.16	0.11	0.10	0.01	0.333	5	1.53	54.0
All	0.19	0.14	0.20	0.18	0.856	17	−18.2	82.5

Table 5
Orientation of axis of bending (locked fixator) — each subject

Subject	Orthofix DAF		Howmedica B-Monotube		Paired t-test		Difference	
	Mean (°)	SD	Mean (°)	SD	$P(T<t)$	n	Mean (°)	SD
1	46.4	31.1	48.6	27.2	0.853	6	−3.67	22.6
2	128.8	79.2	148.8	91.8	0.462	6	−20.0	61.5
3	251.7	153.1	258.7	134.9	0.607	3	−7.00	20.1
4	89.4	93.2	85.2	122.3	0.948	5	76.2	62.6
All	122.0	106.0	129.1	114.5	0.664	20	10.9	59.5

each fixator are a result of the high degree of variance in each subject's fracture displacement over the period of measurement (typically from 0.7 to 0.2 mm axially). Temporal changes in displacement are caused by healing and stiffening of the external callus. Therefore mean 'differences' in each table (calculated from percentage differences at each test session) neutralize temporal effects, and more accurately reflect changes in fracture stability than a comparison between the 'mean' displacements of the two groups. The mean 'difference' in weight-bearing for the group (Table 1) was only 2.23%, implying that differences in direction and magnitude of displacement did not arise from changes in weight-bearing. 'Differences' in axial, trans-

Table 6
Orientation of axis of transverse shear (locked fixator) — each subject

Subject	Orthofix DAF		Howmedica B-Monotube		Paired t-test		Difference	
	Mean (°)	SD	Mean (°)	SD	$P(T<t)$	n	Mean (°)	SD
1	166.8	74.0	128.0	29.7	0.402	5	−33.2	69.0
2	159.8	57.0	166.8	74.2	0.669	6	−7.00	37.8
3	164.3	107.1	161	113.7	0.674	3	3.33	11.8
4	136.4	97.6	114.7	117.6	2.78	5	21.7	79.9
All	156.2	75.3	142.0	82.2	0.345	19	−4.71	57.6

Table 7
Axial telescoping movement (unlocked fixator) — for group

Position	Orthofix DAF		Howmedica B-Monotube		Paired t-test		Difference	
	Mean (mm)	SD	Mean (mm)	SD	$P(T<t)$	n	Mean (%)	SD
At fixator	0.23	0.12	0.25	0.10	0.225	3	−12.5	12.5
At fracture	0.21	0.18	0.30	0.31	0.296	4	−20.6	51.9

Table 8
Torsional movement (unlocked fixator) — for group

Position	Orthofix DAF		Howmedica B-Monotube		Paired t-test		Difference	
	Mean (°)	SD	Mean (°)	SD	$P(T<t)$	n	Mean (%)	SD
At fixator	0.20	0.10	0.14	0.02	0.363	3	19.4	30.5
At fracture	0.18	0.14	0.13	0.10	0.178	4	−3.61	65.5

verse and torsional displacement were also small clinically (Tables 2–4 indicate −15.4, −21.8 and −18.2%). However, Monotube displacements were consistently greater than the DAF. 'Differences' for the orientation of maximum bending and maximum transverse shear were also small clinically (Tables 5 and 6 indicate 10.9° and −4.71°), as were group mean differences in displacement at the fracture and at the fixator (Tables 7 and 8).

4. Discussion

The small sample sizes and large standard deviations suggest that there was insufficient data to demonstrate at the 95% confidence level that there was no difference in fracture stability between the two fixators. Although the sample size was not large enough to prove whether or not a small but significant difference exists, the results imply that the type of external fixator does not influence substantially a patient's weight-bearing, inter-fragmentary displacement, or the directions of shear and bending at the fracture. Although the Monotube frame is almost twice as flexible in bending than the DAF [9], it would appear that this degree of difference is not transferred to the fracture site. Therefore, there would seem to be no basis for the argument that one unilateral fixator may offer a substantially different stability to the fracture than another, in comparison with the degree of influence on stability exerted by anthropometry, gait and the type of fracture.

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