A Practical Fracture Healing Endpoint Assessment Criterion For Tibial Fractures Treated With External Fixation.

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Abstract

There is a need for a quick, simple, repeatable, but quantifiable assessment of fracture healing end-point that does not rely on the use of x-rays or on un-measured manipulation. This paper presents an argument to support a "maximum of one degree of bending" criterion. We propose that a mid-shaft tibial facture may be considered healed when it is not possible to bend the fracture by more than 1 degree, by hand, in two orthogonal planes. The criterion was established from an examination of patient fracture stiffness profiles following observations made in clinics. A proprietary monolateral external fixator was used to test the criterion. 400 patients had their fracture healing end point assessed using this criterion and it was deemed to be successful.

An analysis of the criterion's use in frame (Illizarov) fixation was conducted. Again, it was shown to be a useful method of detecting fracture healing end point. For a standard frame 1 degree of bending may be assessed using the thread pitch of the support rods. The thread pitch is 1mm, and 1 degree of bending is equivalent to the D/114, where D is the diameter of the ring measured at the 6 mm hole centres. For a 180mm ring this is about 1.5 thread pitches.

The two most common forms of clinical assessment of healing end-point are inspection of radiographs and manual manipulation of the fractured limb. X-ray radiographs have been shown to be, at best, qualitative, and at worst erroneous by several authors[i,ii]. Fracture manipulation has been demonstrated to be inaccurate[iii]. They are, clearly, unsatisfactory criteria. There is a need for a quantifiable measurement of fracture healing end-point.

We have studied the mechanical properties of healing callus in humans[iv,v]. In a previous study we suggested that to be considered healed when fracture stiffness exceeds 15Nm/deg in two orthogonal planes. The consequence of this is that maximum stiffness is much greater with an average of 25(± 4.2) Nm/deg. But we also observed that when the criterion of 15Nm/deg in two orthogonal planes was achieved the fracture could not be bent more than 1 degree.

We propose that if a fracture cannot be deformed, by hand, by more than 1 degree then it can be considered healed.

The force required to create 1 degree of bending for a stiffness of 15 Nm/deg and 25 Nm/deg is 170N and 284 N respectively. Maximum pressing force at elbow level is 290 N[vi]. Hence it is unsurprising that we observed a maximum of 1 degree of bending. Using 290 N, the degree of bending one would observe when the stiffness is 15 and 25 Nm/deg would be 1.7 and 1.02 degrees respectively. Hence our observation compares with theory. We, therefore, investigated this criterion using proprietary external fixation.

Patients presenting with a diaphyseal tibial fracture were treated with a proprietary monolateral external fixator. Bending angle, under manual manipulation, was assesse once a critical component had been removed. When the fracture was manipulated by hand one could observe when the fixator pins touched the side of a location hole. In the longitudinal axis this occurred at 1.3 degrees, and in the orthogonal plane at 1.5 and 1.2 degrees (long a short bodies respectively). Hence if the pins did not touch the sides of the hole the fracture was observed as healed. 400 patients have been assessed using this methodology. In addition fracture healing was assessed using fracture stiffness using our two-plane criterion described earlier.

Early comparisons of the stiffness criterion versus the angulation criterion showed good correlation. When the fracture stiffness criterion was achieved the fracture could not be manipulated in order to make the fixator pins touch the sides. This correlation became so regular that stiffness measurements became redundant and the clinical team relied on the bending criterion only. Of the 400 patients treated and assessed using the 1 degree criterion have progressed to malunion or refracture.

The criterion was adapted for use with Illizarov frames. By loosening the vertical support bars at one end bending can be assessed in a similar way to that of the monolateral fixator. Movement relative to thread pitch can assess bending (given by $\theta D/114$: θ is the angle of bending and D is the diameter of the hole centres). One degree of bending for a 180 mm ring is 1.6mm, which is about 1½ thread pitches.

We have investigated the use of a maximum of "1 degree of bending in two orthogonal planes" as a criterion for assessing fracture healing. We tested this criterion in over 400 patients and found that the criterion is clinically sound.

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