ORIGINAL RESEARCH

Do Patients Achieve "Full Weight-bearing" Immediately Following Application of Circular Frame Fixation of the Lower Limb?

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Abstract

Introduction: The decision to use circular frame fixation for lower limb trauma, or elective deformity correction, often accompanies the assertion that the patient will be able to fully weight-bear through the limb immediately following surgery.

Materials and methods: About 53 patients underwent retrospective review. Included in the study were current attendees of adult specialist physiotherapy, following circular frame application to the lower leg at our Institution between August 2018 and January 2020. Cases with incomplete data, cases given postoperative status of non-weight-bearing, those with physiotherapy follow-up conducted elsewhere, or cases of polytrauma were excluded from the study.

Weight-bearing assessment and rehabilitation supervision were at the discretion of the physiotherapy team. The clinical concept of 'full weight-bearing' is poorly defined, but was documented in the context of displaying a stable gait using elbow crutches and subsequently without walking aids. Comparative data was analysed using an unpaired, two-tailed Welch's *t*-test.

Results: Mean postoperative time to full weight-bearing using crutches was 28.3 days (0–159) ($n = 40$).

Mean postoperative time to independent full weight-bearing with no walking aids was 230.6 days (35–393), or 7.1 months (0–12) ($n = 34$).

No significant differences were seen between:

- Frames for open injuries ($n = 5$) vs closed injuries ($n = 17$; $p > 0.4$).
- Joint-spanning constructs ($n = 18$) vs non-spanning constructs ($n = 21$; $p > 0.6$), or
- Treatment of intra-articular injuries ($n = 14$) vs extra-articular injuries ($n = 17$; $p > 0.2$).

Interpretation of these results should be made with caution due to sample size.

Conclusion: The ability to permit patients to fully weight-bear immediately after surgery is often a distinct advantage of the circular frame over other fixation modalities, for a variety of indications. However, it does not follow that patients are capable of doing so; there is a long dependency on walking aids. This would appear to be the case irrespective of open/closed injuries, intra-/extra-articular injuries, or the use of a spanning construct across the knee or ankle.

Keywords: Early ambulation, External fixators, Recovery of function, Rehabilitation, Tibial Frature, Weight-bearing.

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Introduction

Circular external fixation is a commonly used surgical modality in the treatment of complex injury and the correction of skeletal deformity in the lower limb. Typically, the use of circular frames is confined to larger centres in the UK, a pragmatic response to the requirement for a dedicated multidisciplinary team who specialise in the use of such devices and care for patients who live with them.

The 'weight-bearing status' of a patient may be a familiar concept, however, its meaning and achievability may differ from patient-to-patient, as well as between clinicians and therapists. The concept of 'partial weight-bearing', for instance, is notoriously poorly defined, communicated, and executed;[1–5] it may be unachievable for many patients, in particular the elderly (>65 years).[1,6–8]

In the light of formal guidance on the consent process from the General Medical Council (GMC), last updated in 2020,[9] and the lessons learnt from the Montgomery *v* Lanarkshire case in 2015,[10] it has become imperative for patients to be offered as much information as they need to be involved in (and make their own) informed decisions around their management. This should include the explanation and consideration of all relevant treatment options at the receiving hospital; whether or not that requires liaison with, and transfer to, the nearest major trauma centre (MTC).

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The application of a circular frame to the lower limb, in either an acute or elective capacity, confers an assumption by many clinicians (typically, those who do not perform this type of procedure themselves) that the patient will be able to immediately bear full body weight through the affected limb postoperatively. This assumption can then be (and in the authors' experience, often is) casually communicated to the patient prior to the subsequent formal preoperative counselling process. This may strongly influence the patient's understanding of their management options, and 'muddy the waters' for the operating surgeon who ultimately counsels the patient for surgery, seeking to reach an informed, definitive, management decision in concert with the patient's wishes and expectations (as prescribed in GMC guidance).[11]

We aimed to observe the postoperative rehabilitation of a retrospective series of frame patients from our centre who were concurrently undergoing regular physiotherapy, to establish the postoperative time taken until commencement of full weight-bearing under supervision. We aimed to clarify whether commencement of full weight-bearing on the first postoperative day is the norm; if not, to establish how long a patient may typically take to achieve full weight-bearing on the affected limb following application of circular frame for either trauma or elective limb deformity indications. The purpose of this work was to improve clinician awareness around the practical implications of circular frame use, and to aid all clinicians in the counselling of patients presenting with complex lower limb trauma or limb deformity for which the use of a circular frame may be considered a reasonable management option.

Materials and Methods

A retrospective case series study was designed, to examine a sample of adult patients undergoing out-patient physiotherapy with the specialist circular frame team. All patients in our institution are offered physiotherapy throughout their period of frame treatment, and post-frame in a 'frame-off' class.

Inclusion criteria were all adult patients undergoing physiotherapy at our institution (following the application of a frame) at two time points: 11/06/2018 and 10/02/2020. Exclusion criteria included patients with inadequate data, patients who had not yet reached full weight-bearing status at the point of data collection, those who were not prescribed full weight-bearing status from the first postoperative day, concurrent physiotherapy management elsewhere, or patients with multiple limb injuries.

Electronic patient records and radiographs were assessed to collect data on patient age, frame construct (joint-spanning/non-spanning), indication for application of circular frame (elective/trauma), the need for involvement of plastic surgeons during index procedure, articular involvement, and the prescribed weight-bearing status on the operation note. The timing of specific rehabilitation (weight-bearing) milestones was tabulated for each case.

Under the supervision of the therapy team, a typical postoperative patient journey starts with assisted ambulation using a walking ('Zimmer') frame. Progression to the use of elbow crutches is made only when the supervising therapist is satisfied, not simply with the ability to bear weight safely during locomotion, but primarily when the quality of the observed gait pattern is deemed adequate. In many cases, this may be immediately postoperatively, averting the need for use of a walking frame. Compensatory adaptive, or abnormal gait patterns are identified and addressed prior to progression to the next milestone.

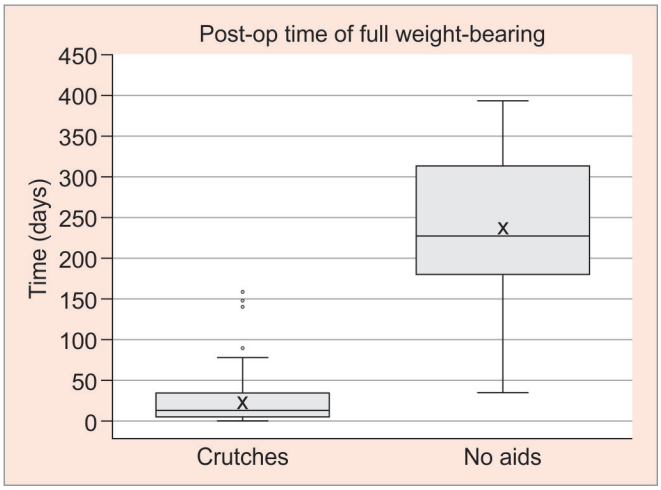

Fig. 1: Box-and-whisker plot comparing time taken (following the application of circular frame) to full weight-bearing with crutches vs time taken to full weight-bearing with no walking aids

Documented assessment of weight-bearing status is made by the supervising physiotherapist, charting the journey from weight-bearing with walker frame, to elbow crutches, walking sticks, a single stick and finally, full weight-bearing free of walking aids. On occasion, some of these milestones are by-passed if ambulation of sufficient *quality* is observed.

Data were tabulated and graphs generated using Microsoft™ Excel for Mac® 2016. Milestones of postoperative time (in days) to both full weight-bearing *using elbow crutches*, and full weight-bearing *without the use of walking aids* were identified as the key outcomes of interest. These data were compared using a box plot. Further subgroup analysis was performed to consider the difference in time taken to mobilise between open vs closed injuries, joint-spanning vs non-spanning constructs, and intra-articular vs extra-articular injuries. In each case, an unpaired two-tailed/Welch's *t*-test was used to demonstrate the presence (or absence) of any relationship between these factors and time to full weight-bearing using elbow crutches.

Results

A total of 53 cases were identified. Of these, 12 patients were excluded due to a prescribed postoperative status of partial, 'toe-touch', or non-weight-bearing. In 7 of the 12 cases, this was at the request of the plastic surgeon, and in 5 cases, this was because of the operating surgeon's choice in the context of Schatzker type VI tibial plateau fractures. The resultant 41 cases had a mean age of 51.5 (14–86) years and a gender ratio (male:female) of 28:13. The majority of cases (25 of 41) involved a frame applied for the treatment of acute trauma. The remaining 16 cases involved the elective application of a circular frame for either deformity correction or as part of the surgical treatment of deep infection.

Data for time to weight-bearing *with crutches* was available for 40 cases (Fig. 1), as one case underwent early removal of circular frame and conversion to cast. Subsequent data for time to weight-bearing *without walking aids* was available for 34 of these 40 patients. The reason for this data attrition was due to

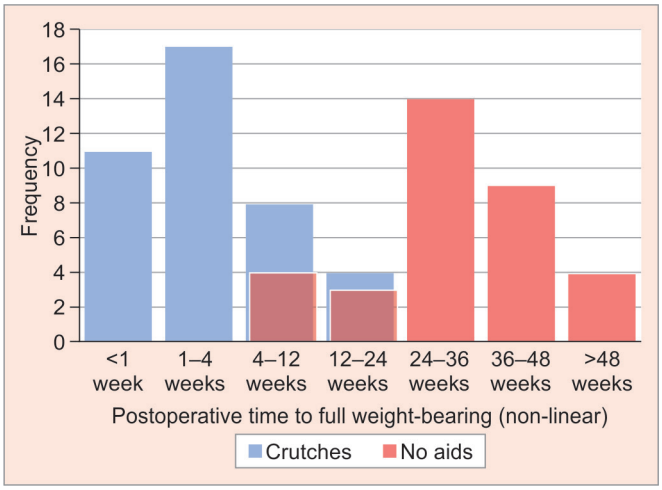

Fig. 2: Histogram showing postoperative time (distribution) to full weight-bearing; elbow crutches vs no walking aids. NB x-axis non-linear

Table 1: Results of unpaired *t*-testing and related descriptive statistics, for time taken to full weight-bearing (in days) with crutches in all subgroup comparisons. No differences were seen

	Mean	*St. dev.*	*95% Confl. int*	*p*
Open injuries ($n = 5$)	50.2	62.65	77.79	
Closed injuries ($n = 17$)	25.9	35.73	18.37	>0.4
Joint-spanning ($n = 18$)	32.2	45.58	22.66	
Non-spanning ($n = 21$)	26.0	36.87	16.78	>0.6
Intra-articular ($n = 14$)	37.9	49.03	28.31	
Extra-articular ($n = 17$)	18.5	27.45	14.11	>0.2

a lack of explicit documentation. It may be that some patients were discharged still using elbow crutches, or it may be that this progression was not documented. Patients who had poor attendance to follow-up, and therefore inadequate data were excluded at the beginning of the study.

The data demonstrated a mean postoperative time to full weight-bearing with crutches of 28.3 (0–159) days, $n = 40$. The mean time to postoperative full weight-bearing without walking aids was 230.6 days (35–393) or 7.1 months, $n = 34$.

A total of six patients achieved full weight-bearing with the use of crutches on day 0 postoperatively. Although half of all cases achieved full weight-bearing with crutches within 2 weeks (median time taken 13.5 days) there were four outliers (Fig. 1). This accounted for 1 in 10 cases that showed a significant delay (in excess of 90 days) to their ability to commence weight-bearing with crutches following application of a circular frame.

It was observed that patients take approximately 7 months to ambulate fully weight-bearing with no aids following the application of a circular frame. Median time taken was 228 days, or 7.6 months (Fig. 1). There was considerable variance in these data, with a range of 35–393 days, or 1–12 months (Figs 1 and 2).

Further subgroup analyses were performed (Table 1) as described above to consider the difference in time taken to mobilise full weight-bearing *with crutches* between: open ($n = 5$) vs closed injuries ($n = 17$), joint-spanning ($n = 18$) vs non-spanning constructs ($n = 21$), and intra-articular ($n = 14$) vs extra-articular injuries ($n = 17$).

Within the constraints of this modestly sized dataset, no significant differences were seen in weight-bearing times following application of a circular frame for any of the subgroup comparisons.

Discussion

This study of elective and trauma patients managed with a circular frame identified the median time to reach full independent weight-bearing without aids to be in excess of 7 months. However, half of all patients achieved full weight-bearing with walking aids within 2 weeks of surgery. This demands some consideration of what is meant by full weight-bearing, and how to manage the expectations of surgeons and patients when this advice is given.

The terminology around weight-bearing is only loosely defined in the literature, if at all.[12,13] Full weight-bearing could imply the ability to ambulate without walking aids, or possibly the ability to stand unsupported on one or both legs. Although full weight-bearing may be clinically and biomechanically permissible immediately following application of a circular frame, the surgeon may not necessarily expect it, and a number of factors may influence a patient's pragmatic ability to do so. These include pain, proprioceptive inhibition or vestibular issues, concomitant soft tissue injury or reconstructive flaps which require protected weight-bearing in the initial postoperative period, contractures, fixed soft tissue deformities, preoperative deconditioning and muscle atrophy, circulatory compromise and/or compartment syndrome.[2,14] These factors are commonly associated with severe lower limb trauma, the typical indication for application of a frame. The size and weight of the frame, stability of the construct, joint-spanning, peripheral oedema and footwear issues may further interfere.

During normal human gait, vertical ground reaction forces peak twice during the stance phase; the values of these peaks vary between approximately 85–115% of total body weight according to some texts.[15,16] GaiTRec is a large online open-access dataset of ground reaction force readings including subjects with both normal gait and impaired gaits, recorded at a rehabilitation centre gait laboratory based in Austria.[17] The mean peak vertical ground reaction force (measured bilaterally) in normal gait from healthy subjects in the dataset was 116% (100–166) of bodyweight, with a standard deviation of 0.1 multiples of net body weight.[18] The authors suggest that clinicians should understand the prescription of 'full' weight-bearing with reference to a singular anatomical zone to imply:

The transmission of the net ground reaction force of a body (+16%), through the relevant lower limb (or joint) during stance phase of a normal gait cycle with the maintenance of a stable and safe gait pattern throughout.

To prevent the eccentric loading through limping or stumbling, the physiotherapist may therefore encourage the use of walking aids. Walking aids will also prevent the development of abnormal gait patterns during rehabilitation.[19–21] Small abnormal compensatory movements can provoke more pronounced aberrations further along the kinematic chain,[22–25] frustrating the progress of rehabilitation and promoting new symptoms and pathology elsewhere. These devices will allow a gradual increased load of the affected limb as postoperative pain, stiffness and confidence improves, until they are only required for proprioceptive control and balance. When walking aids are used, it is difficult to define the point at which ambulation becomes full weight-bearing.

It is of note that much evidence exists to demonstrate that patients who are asked to follow partial weight-bearing regimes often significantly overload the limb, exceeding advice by up to 100% of bodyweight, no matter what technique is used to instruct them.[1–6,8] Further, specific research is needed to clarify whether there is any value in prescribing less than full weight-bearing. The potential protective effects of early weight-bearing on bone health, thrombosis risk, mental state and fracture healing should not be overlooked.[2,14,26]

We found that more than 25% of patients were able to fully weight-bear with the use of crutches within a week of their surgery, irrespective of the complexity of the injury or frame construct applied to the limb. Within 4 weeks of surgery, more than 60% of patients had achieved the same goal. We therefore suggest that this is a significant advantage over a typical 6-week non-weight-bearing regime, commonly observed during either conservative treatment or following internal fixation, of complex lower limb fracture patterns. We are however limited by the absence of a control group against which to compare or to do comparative studies in the literature to further support this assertion.

Within the literature, following internal fixation of tibial plateau fractures, time to full weight-bearing without walking aids has been reported as 13 ± 11 weeks (despite the majority exceeding weight-bearing limits prescribed following surgery, within 2–6 weeks); the measured ground reaction force for the operated limbs had not reached parity with the contralateral limb at 12 weeks, despite weight-bearing limitations being removed at 6 weeks.[27] Furthermore, the same study identified poorer outcomes (such as stiffness and swelling) for patients who were able to bear equal weight through the affected limb (compared with the uninjured limb) within 6 weeks of internal fixation, compared with those with a lower weight-bearing ratio. A further study examining the use of impaction bone grafting in open fixation of tibial plateau fractures reported all patients ($n = 9$) to be 'full weight-bearing' by 6 weeks, although a third of patients were still using walking aids, and a normal gait returned by 3 months.[28] Of these patients, only two were Schatzker grade III or above.

Our data were noted to have considerable variance. Ranges for each group were broad, likely a reflection of the heterogeneity of this patient group. Patients may be submitted for consideration of circular frame fixation for a variety of reasons, and the complexity of the construct employed, the need for surgical approach to reduce a joint surface, or the involvement of a plastic surgeon may be variable. It would appear that these factors made little difference to when weight-bearing commenced.

Regional trauma networks were formed in 2012, with the institution of tertiary MTCs, in a 'hub and spoke' model for complex trauma care.[29–31] Circular frame surgery is typically centralised in these MTCs, in the spirit of the concluding principles from the 2015 'Getting It Right First Time' (GIRFT) report,[32] and in consideration of the frequent need for combined orthoplastic care and specialist rehabilitation. Referring trauma unit surgeons are required to counsel patients regarding their spectrum of management options (which may include the use of circular frame fixation) and their preconceptions can be passed on to the patient. The management of patients' expectations is a frequent challenge for trauma surgeons:[33,34] The MTC surgeon may be faced with a challenging task to manage expectations if their advice deviates from that offered by the previous clinician. We would encourage referral units to understand and explain the reality that the majority of patients continue to use walking aids up to 7 months after surgery, despite the permission to bear full weight through the affected lower limb.

There are a number of limitations to this study. The dataset is small and therefore no firm conclusions can be drawn. All data were recorded prospectively, although not within the design of a formal study, and so retrospective observations should be made with caution, particularly in such a mixed population. However, even tentative conclusions could be argued to be of relevance to a general population. We have also not accounted for patient-related factors (for example, pain or apprehension), which may have delayed full weight-bearing in some cases.

A well-powered prospective, stratified study could identify correlation between injury severity and average time to full weight-bearing, the effect on rehabilitation of delays to acute surgery, as well as differences in the frame construct, elective vs emergency application, and comparison with alternative fixation methods.

Conclusion

This study, despite its limitations, will be useful to inform the preoperative counselling and postoperative management of patients who have undergone circular frame fixation for lower limb trauma. Further research with patient input would be valuable to better identify barriers to early postoperative full weight-bearing.

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