Femoral fracture reduction with parallel manipulator robot on traction table

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Background: The purpose of treating the femoral shaft fracture is to stabilize the patient’s fractured femur for fast healing so as to return to his/her mobility and function by means of fracture fixation. Nevertheless, without proper alignment and reduction, the fast healing by improper fixation would result in femoral shaft mal-alignment, creating angular deformity and limb length discrepancy which will hinder the returning of full functions of daily activities of injured patient (1-3). The growing demand for precise and minimally invasive surgical intervention is driving the search for ways to use computers in conjunction with advanced assistant devices to improve surgical planning and execution (4). Robot assisted reduction of the femur is a newly developed technique that could minimize potential complications and pitfalls associated with fracture reduction and fixation (5). The objectives for femoral shaft fracture reduction are to restore its pre-fractured limb length and mechanical axis and eventually, to bring back patient’s normal life. Application of Parallel Manipulator Robot (PMR) opened a brand new opportunities for long bone fracture reduction in both traction and alignment management (6).

Method:

I) Parallel Manipulator Robot (PMR) on traction table: The distal platform of PMR is attached to the central pole on standard traction table by a boot adaptor. A leg model with soft tissue made by Pacific Research Laboratory, Inc. is flexed at the knee with patella on the top. The 2/3 circular ring, with 1/3 open circle down, fixed to the fractured distal femur with one trans-wire and one self-tapping screw, acting as adaptable stirrup fixing scheme. To secure proximal femur, a half ring fixation, a table adapter, is assembled to the traction table and is screwed on to the proximal femur. In this configuration, the distal platform of PMR and the proximal femur of the patient can be considered as one rigid body or quasi-rigid body. The distal femur, fixed to the 2/3 circular ring platform, will perform the 6 DOF movement relative to proximal femur, based on the fracture alignment and reduction algorithm.

II) Femoral fracture reduction planning: The principle of alignment and reduction algorithm is to restore the pre-fractured limb length and mechanical axis. Surgical planning is performed by first acquiring the bi-planar images from the C-Arm X-ray machine. Making simulated fracture on 3-D femoral model, proximal and distal segments of the model will be superimposed with background bi-planar images. Finally the pre-fractured length and mechanical axis of 3-D femoral model will be restored and the alignment and reduction of the model can be achieved. In the process of the restoration, a table of schedule for length changes of each of six struts of PMR is created.

III) Two step reductions, coarse and fine: The table of schedule created from the planning is used next to driving the PMR for fractured femur alignment and reduction. Total of two-step reduction could be performed, coarse by the created table of schedule and fine by adjustment. If for any reason, the reduction by planning is not satisfied by viewing the C-Arm X-ray intra-operatively, the surgeon is able to perform further alignment by fine adjustment until it achieves better result.

IV) Separation from traction table: When reduction completed, a special designed external fixators is assembled. Its distal end is tightened to the 2/3 ring proximal platform of PMR and its proximal end is fixed to the proximal segment of fractured femur with two self tapping screws. Then six motor driven...
struts are removed, together with the screws on table adapter used to fix the proximal segment of fractured femur. The patient then can be free to be removed from the traction table.

**Results:** Eight femoral sawbones model were artificially broken into eight different fracture patterns. All fracture patterns had characteristics of distal segments overlapping with proximal segments. The positions of the distal segments overlapping with proximal segments were as follows: anterior, posterior, medial, lateral, anterior-medial, anterior-lateral, posterior-medial and posterior-lateral. Therefore, the reductions were all following the initial tractions. The reduction errors of eight artificial fracture patterns were recorded. These errors included axial discrepancy, lateral translation and angular deformity by coarse traction and reduction, axial discrepancy and lateral translation by fine adjustment. The statistic showed that the mean errors were 1.31±0.45mm for axial discrepancy, 2.43±0.49mm for lateral translation, 2.26±0.23mm for angulation in coarse step and 0.63±0.19mm for axial discrepancy, 0.75±0.26mm for lateral translation in fine adjustment step. A cadaveric experiment was conducted later on to verify the approach’s clinical feasibility.

**Conclusions:** Femoral Shaft Fracture Reduction with PMR on Traction Table has been built with femoral soft tissue model and on an orthopedic traction table. The experiments had been made on both artificially broke femoral sawbone models and the human cadaver. The experiments had been proven that such approach is fairly accurate for femoral shaft reduction and is feasible for clinical trial. Further experiment is necessary for making it an applicable robotic assisted fracture alignment and reduction clinically.

**References**


