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CORR Insights®: What Are the Biomechanical Properties of the Taylor Spatial Frame™?

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Where Are We Now?

Mechanobiology is the key to success when external circular frames are applied for fracture treatment or gradual correction of bone deformities. The new formation and healing of bone depends on the mechanical stimuli at the fracture or the osteotomy. Too much or too

little strain impairs bone healing. High strains often arise from uncontrolled torsional or bending forces. One of the advantages of circular frames is their capacity to lower the strains from torsional and bending forces while maintaining sufficient axial loading at the site of bone healing. Additionally, the circular frames allow bone correction in all planes. But when performing multiplanar fracture reduction or bone deformity correction, the original Ilizarov frames can be difficult to apply, and frequently must be rebuilt during treatment, which might result in additional trips to the operating room.

Therefore, new hexapod frame designs have been introduced to simplify both the surgical application and the postsurgical multiplanar bone correction. Henderson and colleagues test the mechanical properties of one of these hexapod frame designs, the Taylor Spatial Frame™ (TSF) (Smith

& Nephew Inc, Memphis, TN, USA). The TSF uses six hexapod struts (instead of conventional straight rods and hinges) to facilitate multiplanar bone corrections [5]. The TSF is not new, as it has been used for two decades, but an increasing number of new variations of the hexapod frame are being introduced.

Considering the importance of the biomechanical properties of circular frame constructs, I am surprised that I could find only one study [6] that investigated the mechanical properties of a hexapod frame prior to the current study.

Where Do We Need To Go?

For the first time, Henderson and colleagues provide data on the clinical laxity in the universal joints of the TSF struts that is anecdotally reported by patients. However, it remains unclear how this laxity is influenced by the postsurgical reduction and loading conditions of the frame, and whether this laxity is important for bone healing.

Bone healing depends on a certain mechanical strain at the healing site [1]. As new circular frame configurations

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are introduced to reduce detrimental high strains from bending and torsional forces, researchers should investigate whether bone healing might be impaired by too high axial rigidity of these new constructs. It is believed that the mechanical strain at the site of bone healing will benefit from the correction of a malaligned limb to a properly aligned limb. Clinical studies reporting on time to union after fracture or on bone healing index after corrective osteotomies might explore whether the mechanical stimulation of bone healing also can be improved through functional rehabilitation tailored to each patient.

Further research should determine whether the changes in mechanical properties introduced by hexapod frame constructs can be used to enhance bone-healing conditions. This research into how hexapod frames might influence mechanical strains at different fracture patterns and deformity corrections would provide valuable information on how to tailor patient-specific frame constructs. Researchers should also investigate how the rigidity of hexapod frame constructs depends on the angulations of the applied hexapod struts.

Basic research can provide valuable information on the correction capacities of different circular hexapod frames [2, 4]. The study by Henderson and colleagues shows that there is also

a need for biomechanical testing when new frame constructs are being introduced.

How Do We Get There?

Frame constructs should be tested during highly controlled conditions as well as in clinically relevant models simulating both bone and soft-tissue conditions. Experimental in vivo studies should examine how the biological bone healing is influenced by different frame constructs, and how this biological healing is dependent on the forces on bone and soft tissues during correction.

The use of circular frames is not a static treatment. Instead, the possibility of changing the mechanical environment, and thereby influencing the biology at the bone healing site, must be considered in patient-specific tailored treatment protocols. Future biomechanical studies should explore how hexapod frames can modulate mechanical stiffness during treatment without rebuilding the frame constructs. Feedback systems might be developed to provide information on when and how to change the loading conditions over the fracture or the osteotomy, as well as providing information on when the strength of bone healing is sufficient for frame removal.

Clinical studies using stringent treatment algorithms and well-defined outcome parameters can provide important information on the treatment of different diseases with circular frames. Using a novel treatment algorithm, it seems possible to obtain a high union rate when treating tibial nonunions with circular frames [3]. With this approach, a large majority of the nonunions healed when provided an improved mechanical environment, and nearly all of the remaining ones healed with autogenous bone grafting. Bone healing is dependent on both mechanical and biological factors like age, environmental factors, and underlying disease. Prospective clinical studies might help identifying patients to be treated by mechanically stable circular fixation in combination with local bone grafting or systemic bone anabolic or antiresorptive medications.

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