

Stability of Locally Utilized External Fixators

A Comparative Study

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ABSTRACT : Biomechanical tests on simulated fracture stabilization with a locally manufactured Roger - Anderson device and two improvised external fixator frames using plywood and polyvinylchloride pipes respectively were done using a Swiss made Hoffman - Vidal apparatus as standard in a uniplanar bilateral configuration. All experimental models were subjected to compression, antero - posterior bending, lateral bending and torsion loads. The forces needed to displace the fracture site under each load were subjected to statistical analysis. The Hoffman - Vidal apparatus showed superior stability in compression, lateral bending and torsion loads. The locally manufactured Roger - Anderson device performed favorably compared with standard in all loads and was better in antero - posterior bending. The two improvised external fixators were less stable but the one which uses polyvinylchloride pipes was significantly more stable than the other and appears to be a better alternative. Clinically, great care should be considered in bearing weight on a limb with an unstable fracture treated with our external fixators since the highest recorded value in all load tests was just a fraction of the total body weight.

INTRODUCTION

External fixation of long bone fractures is indispensable in the treatment of complex problems related to traumatology and limb reconstruction. Over the last decade, designs have evolved to meet the complexities of osteosynthesis. Later models, have evolved as lighter but stronger alloys and polymers, continue to be discovered and applied in western technology. Foreign literature is abundant with biomechanical studies which describe the conduct of these devices. Such information also helps to broaden the clinical applications of external fixation, such as its use in correction of deformity, arthrodesis and temporary joint fixation. The use of these state of the art devices in our country is presently not possible because of its unavailability and its prohibitive cost. Nevertheless we have continued to apply the concepts of external fixation using locally fabricated devices and improvised set - ups. To date, there is a lack of published material which

describes the biomechanical performance of devices we use for external fixation. This study aims to provide data that will describe the stability of some devices used in the local setting

MATERIALS AND METHODS

Biomechanical tests on simulated fracture stabilization with a locally manufactured Roger-Anderson (R-A) device and two improvised external fixator frames using plywood and a polyvinylchloride pipe as outrigger respectively, were conducted using a Swiss made Hoffman - Vidal (H-V) apparatus as standard. Each of the external fixation devices including the standard was attached to a system simulating a long bone transverse diaphysial fracture in a uniplanar bilateral configuration. A solid pylon machined into a solid cylinder with a diameter of 4.0 cm. and length of 35.0 cm. and with the grain parallel to the long axis was used as a bone model. It was divided transversely and fixed on an external fixator with a 1.0 centimeter gap to simulate a comminution or bone loss. Each bone model was drilled with 3.0 mm. holes to fit 4.0 millimeter diameter transfixation pins. Three transfixing pins were inserted 4.0 cm. apart with the nearest pin 2.5 cm. away from the simulated fracture edges on both proximal and distal segments. The external fixator was applied 6.0 cm. from the bone model to accommodate for soft tissue thickness of the leg. The apparatus was applied in a quadrangular fashion patterned after the study conducted by Finlay¹

The experimental models were subjected under the following loads : compression, AP bending, lateral bending and torsion using the Tinius-Olsen universal testing machine at the metallurgical laboratory of the U.P. College of Engineering. The machine registers increments of 0.1 pounds per second from zero to 500 pounds. A special steel jig was fabricated to mount the bone models on the material testing machine for compression and bending load testing. Torsion was similarly tested on the jig with the use of a torque wrench which registers increments of 1 pound-foot from zero to 500 pounds-foot. This was operated manually. One sample of each of the experimental models under each of the aforementioned loads totally sixteen specimens were tested five times each. A buckle gauge was applied on each of the simulated fracture

sites. These gauges detected displacement as increasing load was applied on the experimental models. Based on experiments by Goodship and Kenwright², a maximum relative movement of one mm. between opposing points of fracture gap is safe and will not compromise bone healing. Finlay accepted this experiments and arbitrarily chose 3.5 mm. of fracture displacement as stabilization failure. For points of relative comparison on axial and transverse displacement of 1.0 mm. and 3.5 mm. for axial loading and bending tests respectively and a displacement of 5 degrees and 10 degrees on torsion were used to mark the endpoints of stabilization failure.

One - way or unilateral analysis of variance at equals .05 was used to determine any significant differences in the data on the stability among the four models of external fixators. The Uncan's multiple range test was used in determining significantly different stabilities between the four models.

RESULTS

On compressive loading, the R-A was found to be most stable in resisting displacement of 1 mm. The PVC performed almost as equally as the apparatus with both types being significantly more stable than the Plaster of Paris (PPS). The H-V however proved to be superior in withstanding the greatest load before displacement of 3.5 mm. The strength of each model was found to be significantly different from each other in the order seen in.

On A-P bending loads, the R-A and PVC unexpectedly showed superior stability compared to the H-V both in stabilizing fracture fragments at 1 mm. and 3.5 mm. displacements. At 1 mm. displacement, the PVC was significantly better than the H-V. The latter's performance was not significantly different from the PPS. At 3.5 mm. displacement, the H-V and the two improvised fixators did not show any significant difference in their performance.

On lateral bending loads, there was no significant difference between the four fixator models at 1 mm. displacement. All the fixator models performed equally at 3.5 mm. displacement; the H - V apparatus afforded the best stability. In torsion, the H - V apparatus was superior in with standing both 5 degree and 10 degrees of rotational displacement. The R - A was the next better device being significantly stronger than the two improvised fixators, both of which were equal in their performance. Owing to the intricate design of the clamps and universal joints of the H-V, it was expected to show superior stability at 1 mm. and 3.5 mm. displacements. The R - A; however, proved to be comparable when tested in compression and lateral bending. The other improvised devices did not compare but the PVC proved to be significantly better than the PPS. Clamp and joint slippage were not evident even at 3.5 mm. displacement, which we accepted to be the endpoint of stabilization. In both the H-V and R-A, there was marked bending of the pins and outrigger bars. In the improvised

models, slippage of the pins was observed from the outriggers of both the PVC and PPS. Furthermore, in the PPS, breakage of the plywood on two occasions occurred.

DISCUSSION

In vitro studies on external fixation is difficult due to their many limitations. Dynamic forces acting on long bones, the human tibia, for example, can never be simulated by static loads applied on experimental models.^{1,2,3,4} Many investigators have mounted fixator frames on plastic and wooden substitutes in order to overcome the innate variability of bone.^{1,5,6,7} In so doing we can never approximate the "natural" bone to pin interphase which has been shown to be the most important factor among the variables of stable external fixation.^{3,4} Nevertheless, the use of standardized substitute models eliminate the variance of bone to pin interphase which arises when different cadavera are used. Pre-testing bone models to arrive at a more homogenous material is another controversy. Armstrong and Finlay¹ however believed that this was only necessary when experiments were conducted on models with no gap over the simulated fracture sites. All our experiments were conducted with a 1 cm. gap to represent bone loss or comminution. With such a set-up it was not necessary to test the wooden models used because the only clinically relevant variable for ability to stabilize was the displacement of the fracture ends under load since the fixator carries all of the applied load when there was no bone continuity.^{1,7} Furthermore, the basic factors governing the rigidity of the frame of the fixator, namely : the number, diameter, distance from the fracture has been standardized⁸. The importance of altering the configuration of the fixator frame has also been emphasized but, because of the constrained versatility of the improvised fixators being tested, the uniplanar bilateral mode of fixation was used. Such standardization made it possible to isolate the variable of fixator frame material for analysis. As might be expected, the H-V appeared to be the best device to support fractures with bone loss and comminution owing to its rigid quadrilateral frame. In the preceding experiment however, it was shown that the R-A device performed favorably compared with the standard and was even better in A-P bending loads wherein the H-V performed equally with the other two improvised devices. PVC pipes as an outrigger were tested in this experiment. Such had promising clinical applications since it had been shown to be significantly better than the improvised fixator we used which utilizes plywood and PPS. Though the PPS device had empirical results to its credit, this experiment had shown that it had inferior qualities instabilizing fractures. The PVC had other advantages aside from greater stability compared to POP which we usually used in our institution in the absence of other available appliance. It is autoclavable, easier to apply, light, durable and radioluscent. These advantages outweigh the additional expense needed in the PVC, which is still affordable by our standards. Unlike the

H - V and the R - A, however, the PVC, just like the PPS, possesses difficulty of application because it does not have versatile joints.

Clinical Applications

It should be noted that none of the fixators we tested represents the best model since the highest load (390 newtons in compression for H-V apparatus) represents only a fraction of the total body weight in a healthy average Filipino male (60 kg = 588 newtons). This would be of concern when the models are used for weight-bearing limbs with an unstable fracture. Clinically, an external fixator should be used for a stable, reduced fracture in order to ensure soft tissue healing while weight bearing is permitted. We should realize that on actual weightbearing, our fixators are subjected to combination of loads unlike our experiment where different loads are given one at a time. Thus the clinical application of external fixation should be individualized. In treating unstable fractures secondary to comminution or bone loss, non-weight bearing should be emphasized. In stable and reduced fractures, nothing more than partial and guarded weight bearing should be allowed. It is not within the scope of this paper to discuss current trends of dynamization in external fixation. While

adjustable rigidity may be the focus of present biomechanical studies, most authors still agree that effective healing is ensured by preventing excessive relative motion of bone fragments. A more important clinical value of this study is the economics involved in the use of external fixation. Most patients with external fixators stay in the hospital until such a time when the device is removed and a dynamic brace or cast is applied. Similarly, we often lose expensive external fixators on noncompliant patients who were sent home when the utilization of the hospital bed is given priority. From our study, we have the option of shifting an expensive external fixator device to an improvised set-up after a certain period of time so patients can be sent home early to preserve their finances, maximize hospital admissions and prevent losses of devices that can still benefit other patients. This study has provided some objective data that describes the stability of external fixator devices commonly used in the local setting. In addition, a new method of improvised external fixation has been tested. It has shown promising advantages for clinical application. Finally, the methodology used in this experiment while adopted from previous studies will provide a standard model on which future local studies of a similar nature may be patterned.

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