

Brief Research Report

Angulation and Translation Capabilities of a Minimized Orthopedic Hexapod Ortho-SUV Frame: An Experimental Study

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ABSTRACT

Introduction

Orthopedic hexapods demonstrated effectiveness and accuracy in deformity correction of limbs in both adults and children. Previous studies demonstrated the best reduction capabilities of the orthopedic hexapod Ortho-SUV Frame (OSF) *versus* other models of this group of external fixation devices. Minimized version of this hexapod (minimized Ortho-SUV Frame (OSFm)) was created to reduce common for this group disadvantages: large bulkiness and weight and limitation on working with “short segments”. However, the reduction capabilities of the OSFm have not yet been studied.

Aim

To evaluate translation and angulation capabilities of OSFm with standard struts size and to compare results to OSF with short struts size.

Materials and Methods

The experimental study was performed using plastic models of the tibia with osteotomy at the middle third of the shaft. Proximal and distal bone fragments were fixed with one-ring modules. The reduction capabilities of OSFm in the first series and OSF in the second series of the experiment were studied. According to the method of fixing the struts to the rings, experiments were divided into three groups: directly to the ring, using straight plates, and using Z-shaped plates. Translation and angulation capabilities were evaluated by the maximum displacement of the distal bone fragment relative to the proximal one until any of the struts reached its minimum or maximum possible length.

Results

In translation OSFm outperforms OSF by 2.8-9.5% fixed the struts directly to the rings, by 4.8-9.7% using straight plates, and by 27.3-29.3% using Z-plates. In angulation OSFm with struts fixed directly to the rings outperforms OSF by 33.9-55.4%, by 36.9-47.3% using straight plates, and by 29.6-36% using Z-plates.

Conclusion

OSFm exceeds OSF in translation and angulation capabilities in all series of experiment. Distraction and rotation capabilities and the bone fragments fixation rigidity should be evaluated as further research to prove application of OSFm as a possible better candidate for deformity correction of limbs in children and foot deformity correction.

Keywords

External fixation; Deformity correction; Orthopedic hexapod; Reduction capabilities.

INTRODUCTION

The orthopedic hexapod Ortho-SUV Frame (OSF), like other well-known orthopedic hexapods,¹⁻⁴ has such disadvantages as large bulkiness and weight of the hardware *versus* the Ilizarov apparatus. There is also an objective limitation on working with “short segments” of the limbs, i.e., when the base and mobile rings are located at a close distance less of than 10-12 cm. The use of Z-shaped plates and “dummy” rings do not provide to solve this problem completely.⁵⁻⁸ A “minimized” version of the OSF, minimized Ortho-SUV Frame (OSFm), was developed for this purpose.³ OSFm differs from its “big brother”, OSF, by a significant reduction in size by 70 cm³ and weight by 314 grams (Figure 1). This study aimed to determine the capabilities of OSFm for angulation and translation as the most significant for deformity correction.

METHODS

The bench test was performed using plastic models of the tibia osteotomized at the middle third of the shaft. One-ring 140 mm diameter modules were used to fix each of the bone fragments. The bone fragments were located in the center of the rings. The initial distance between the base and mobile rings was 200 mm.

The reduction capabilities of OSFm with a standard struts size were studied in the first series of experiments. OSF with a short struts size was used in the second comparison series. Three groups were studied depending on the method of fixing the struts to the rings in each series of bench tests: directly to the ring, using six straight plates, and using six Z-shaped plates. Reduction features were evaluated by the maximum displacement of the mobile bone fragment relative to the base one (Figure 2):

1. Plane-parallel in the frontal plane (inward and outward) and in the sagittal plane (anterior and posterior);
2. At an angle in the frontal plane (varization and valgization) and in the sagittal plane (anteurcurvation and recurvation).

The displacement was stopped when any of the struts reached its minimum or maximum possible length, which was a limitation for the subsequent movement of the mobile bone fragment.

Plane-parallel displacements were measured in mm, and angular displacements — in degrees. To obtain statistically significant data, the experiment was repeated five times with each of the six collected models. The obtained quantitative data were statistically processed in the Statistica version 10.1 program. The

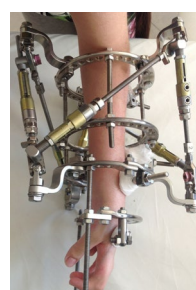
Figure 1. OSF and OSFm



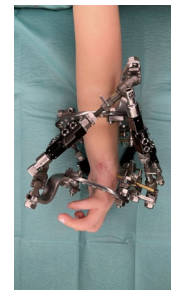
(A) The minimum length of an OSF struts does not provide a possibility to fix them directly between the base and mobile rings. It is necessary to use a dummy ring, which is indicated by a red arrow



(B) More compact OSFm assembly without a dummy ring

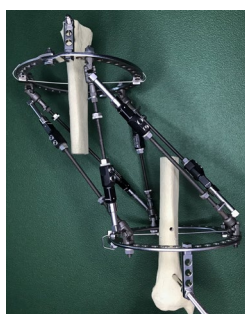


(C) OSF for correcting forearm deformity

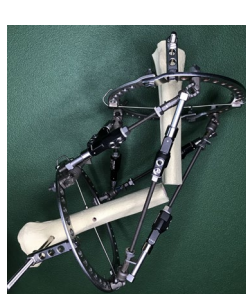


(D) OSFm for correcting forearm deformity

Figure 2. Movements of the Mobile Bone Fragment



(A) Plane-parallel using OSFm



(B) Angle using OSFm



(C) Plane-parallel using OSF



(D) Angle using OSF

Mann-Whitney test, median Chi-square (χ^2) test, and analysis of variance (ANOVA) test were used to compare biases. Differences between groups were considered statistically significant at $p < 0.05$.

RESULTS

OSFm with fixation of the struts directly to the rings exceeds OSF by 6 mm in terms of the capabilities of plane-parallel movement outward and by 3.3 mm inward. OSFm outperforms OSF outward by 6.1 mm and inward by 5.2 mm using straight plates, and outward by 21.6 mm and inward by 15.8 mm using Z-plates. OSFm with fixation of the struts directly to the rings exceeds OSF during plane-parallel movement anteriorly by 9.8 mm and posteriorly by 11.3 mm. OSFm outperforms OSF anteriorly by 7.3 mm and posteriorly by 8.5 mm using straight plates, and anteriorly by 27.5 mm and posteriorly by 29.4 mm using Z-shaped plates (Figure 3).

OSFm with fixation of the struts directly to the rings exceeds OSF by 18.8° in terms of the possibilities of creating (and correcting) varus deformity and with valgization by 19.5°. OSFm outperforms OSF with varization by 19.2° and with valgization by

18.1° using straight plates. OSFm is better at 17.4° with varization and 20.1° with valgization using Z-plates. OSFm with fixation of struts directly to the rings exceeds OSF with antecurvation by 17.3° and with recurvation by 17.4°. OSFm outperforms OSF with antecurvation by 18.4° and with recurvation by 17.9° using straight plates. OSFm provides better result with antecurvation by 18.7°, with recurvation OSF by 16.9° using Z-shaped plates (Figure 4).

DISCUSSION

Two minimized modifications of orthopedic hexapods are known: Small Bone System and OSFm. The first one was created based on the Orthex-frame and differs in the reduced size of the elements from its analogue Orthex-frame, Large Bone System.⁹ Orthex-frame demonstrated clinical efficacy in correcting deformities in children and outperformed the Taylor Spatial Frame (TSF).¹⁰ There have been no targeted comparative studies of the reduction capabilities of the minimized version of this hexapod.

The results of the study of the reduction capabilities of OSF and its minimized version, OSFm, demonstrated significant

Figure 3. Diagrams of the Maximum Possible Values of Plane-Parallel Movement of the Mobile Bone Fragment

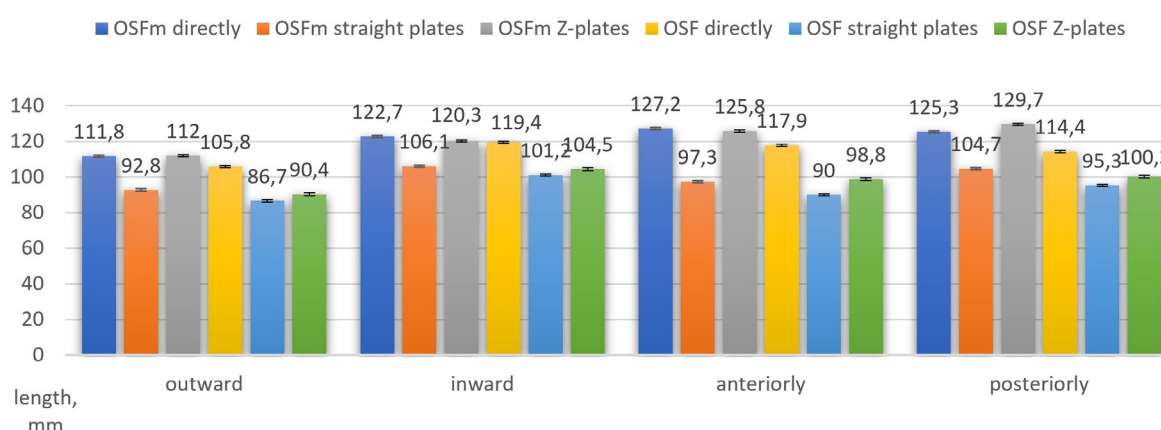
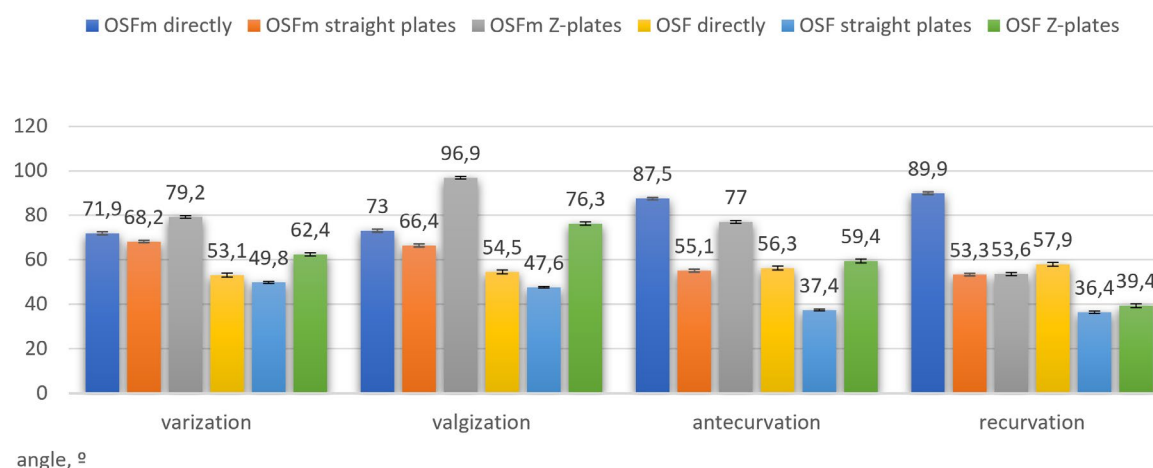


Figure 4. Diagrams of the Maximum Possible Values of the Angular Movement of the Mobile Bone Fragment



differences for all methods of fixing struts to rings. OSFm outperforms OSF in all types of plane-parallel displacements because the maximum possible OSFm struts length is 12 mm longer than the maximum possible OSF struts length. Likewise, OSFm outperforms OSF in all types of angular misalignment because the minimum possible length of the OSFm struts is less than the minimum possible length of the OSF struts by 12 mm.

In translation OSFm exceeds OSF by 2.8-9.5% fixed the struts directly to the rings. OSFm outperforms OSF by 4.8-9.7% using straight plates, and by 27.3-29.3% using Z-plates. In angulation OSFm with struts fixed directly to the rings exceeds OSF by 33.9-55.4%. Accordingly, OSFm outperforms OSF by 36.9-47.3% using straight plates, and by 29.6-36% using Z-plates.

This study was not intended to determine the maximum possible translation and angulation that could be provided by OSFm and OSF. Each indicator from the study can be increased by changing the distance between the base and mobile rings, the angle of their inclination, changing the struts attachment positions, a combination of straight and Z-shaped plates, as well as using additional “dummy” rings.^{4,11,12}

CONCLUSION

The data obtained indicate that OSFm, in comparison with OSF, has better translation and angulation capabilities. Further research will be related to the study provided by OSFm distraction, rotation possibilities, the bone fragments fixation rigidity, as well as the development of optimal OSFm assemblies for long bones, large joints, and foot deformity correction.

AUTHORS CONTRIBUTIONS

(1) Conception and design: L.N. Solomin; (2) Administrative support: L.N. Solomin; (3) Provision of study materials or patients: D.V. Gavrilov, M.A. Baushev, V.A. Vilensky; (4) Collection and assembly of data: D.V. Gavrilov; (5) Data analysis and interpretation: D.V. Gavrilov; L.N. Solomin (6) Manuscript writing: D.V. Gavrilov; L.N. Solomin; (7) Final approval of manuscript: All authors.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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