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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The goal of this project is to improve the treatment of bone defect by leveraging a rat cortical bone allograft model and Er:YAG laser currently used in the dental field. To achieve this goal we tested the hypothesis that: 1) segmental bone defects treated with Er:YAG laser irradiation will form significantly more and stronger cortical bone allograft incorporation; and 2) segmental bone defects treated with cortical bone allograft pre-conditioned by Er:YAG laser will form significantly more and stronger cortical bone allograft incorporation. Results from this project indicate that application of Er:YAG dental laser enhances new bone formation around allografts in a rat segmental defect model without adverse effect or complication.

15. SUBJECT TERMS
erbium:YAG (Er:YAG) laser, bone allograft, bone repair

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INTRODUCTION

It has been reported that more than 30,000 American service members have been wounded in the wars in Iraq and Afghanistan during the last six years. The majority of service members who are wounded in action sustain musculoskeletal injuries such as the orthopedic-related trauma involving the upper and lower extremities present with a significant bone defect. Bone allografts have become an accepted technology to replace bone loss. However, major complications reported for grafting procedures are infection, bone graft fracture, non-union at the graft-host interface, and, rarely, massive allograft resorption. Recent advances in technology have led to a development of novel approaches for use of lasers in hard tissue surgeries in the dental field. The laser that show the most promise for hard tissue surgery is the erbium:YAG (Er:YAG) laser. Recent reports indicates Er:YAG laser provides; (1) advantageous bone surface for bone tissue repair; (2) bactericidal effect; (3) applications for both soft and hard tissue. However, it has not been shown whether Er:YAG laser has a positive effect on orthopedic bone repair. The goal of this project is to improve the treatment of bone defect by leveraging a rat cortical bone allograft model and Er:YAG laser currently used in the dental field. We hypothesis that: 1) allograft bed treated with Er:YAG laser irradiation will lead to more and stronger cortical bone allograft incorporation; and 2) segmental bone defects treated with cortical bone allograft pre-conditioned by Er:YAG laser will lead to more and stronger cortical bone allograft incorporation. Post-operative observations and body weight gain indicated there were no complications such as allergic reactions, abscesses or infections. Body weight gain in the laser-treated animals was similar to that in non-laser treated animals during the healing period. These results showed a successful feasibility of the Er:YAG laser system for the cortical bone allograft model. Moreover, results from this project indicates that application of Er:YAG dental laser enhances new bone formation around allografts in a rat segmental defect model without adverse effect or complication..

BODY

We hypothesized that;

1) segmental bone defects treated with Er:YAG laser irradiation will form significantly more and stronger cortical bone allograft incorporation; and

2) segmental bone defects treated with cortical bone allograft pre-conditioned by Er:YAG laser will form significantly more and stronger cortical bone allograft incorporation.

The proposed work in this project was designed to test these hypotheses by addressing following two aims:

Aim1: Determine the influence of allograft bed preparation by Er:YAG laser on the cortical bone allograft.

Aim2: Determine the influence of cortical bone allograft pre-conditioned by Er:YAG laser on bone repair.

Following groups were used in the study.

Group 1	4 weeks	host bone without Er:YAG	allograft without Er:YAG
Group 2		**host bone with Er:YAG**	allograft without Er:YAG
Group 3		host bone without Er:YAG	**allograft with Er:YAG**
Group 4		**host bone with Er:YAG**	**allograft with Er:YAG**
Group 5		intact bone	
Group 6	8 weeks	host bone without Er:YAG	allograft without Er:YAG
Group 7		**host bone with Er:YAG**	allograft without Er:YAG
Group 8		host bone without Er:YAG	**allograft with Er:YAG**
Group 9		**host bone with Er:YAG**	**allograft with Er:YAG**
Group 10		intact bone	

As reported in the previous annual report, post-operative observations and body weight gain indicated there were no complications such as allergic reactions, abscesses or infections. Body weight (BW) in the laser-treated animals was similar to that in non-laser treated animals during the healing period of 4 week post-op (Figure 1) and 8 week post-op (Figure 2). These results showed a successful feasibility of the Er:YAG laser system for the cortical bone allograft model.

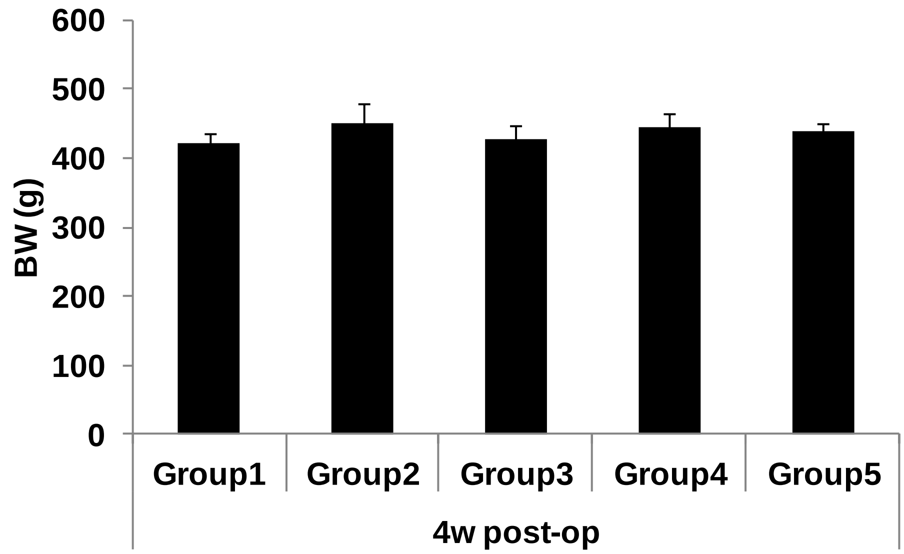


Figure 1: Body weight data for 4 week time point.

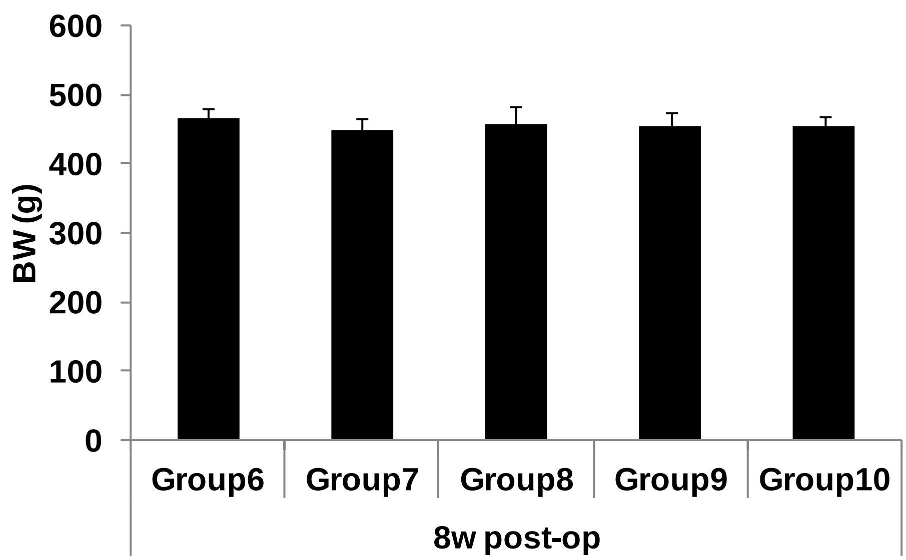


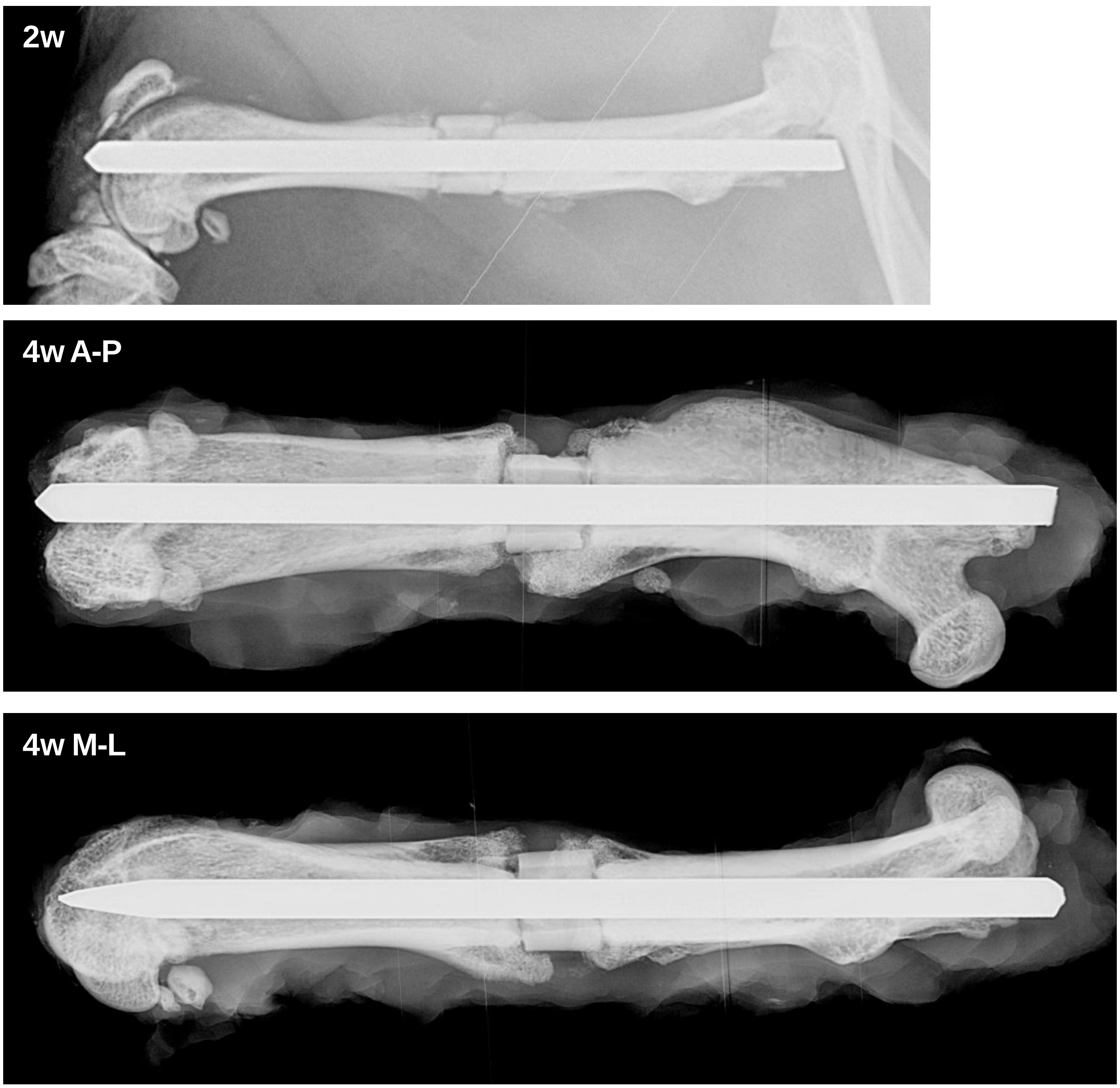
Figure 2: Body weight data for 8 week time point.

Radiographical evaluation

The radiographical analysis at 4 weeks post-op showed that Group 2 which only the host bone was treated with Er:YAG laser resulted in an increased healing/callus size as compared to the non-laser treated/Group 1 ($p<0.05$, Figures 3 & 4).

Figure 3: Representative radiographical images for 4 week time point.

Group 1



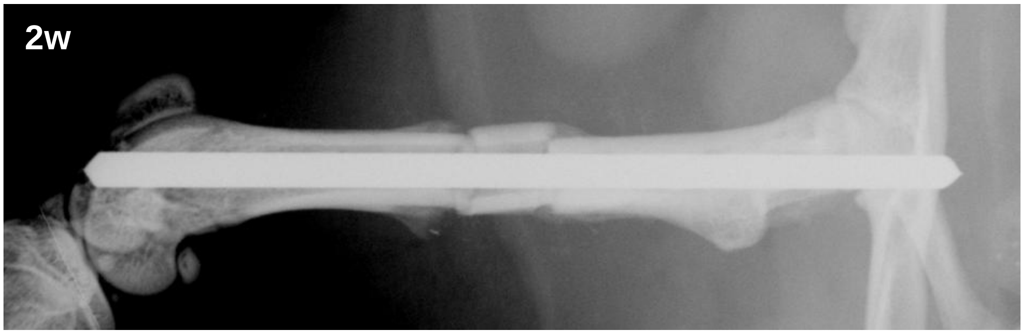
Groups 3 & 4 showed a trend of increase in radiographic healing with the use of Er:YAG laser compared to Group 1 at 4 weeks.

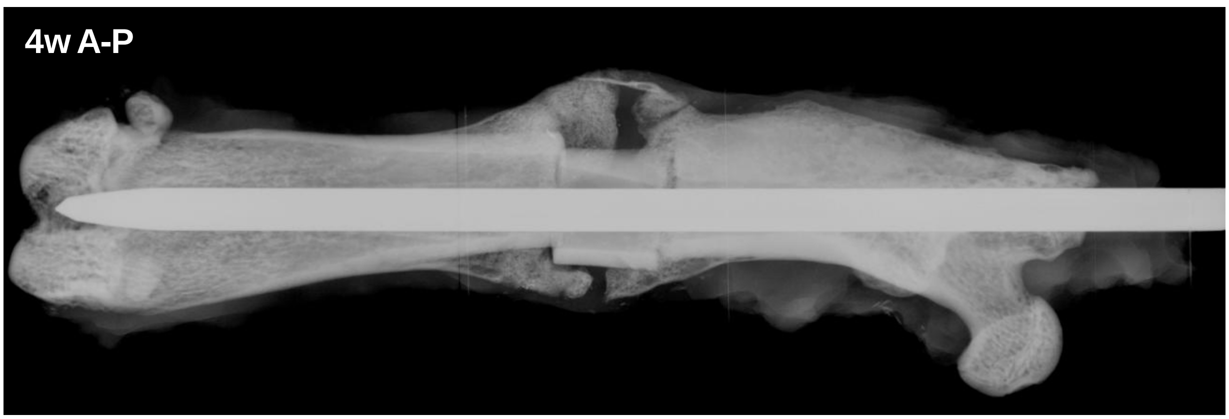
Figure 3: Representative radiographical images for 4 week time point. (cont.)

Group 2

Figure 3: Representative radiographical images for 4 week time point. (cont.)

Group 3





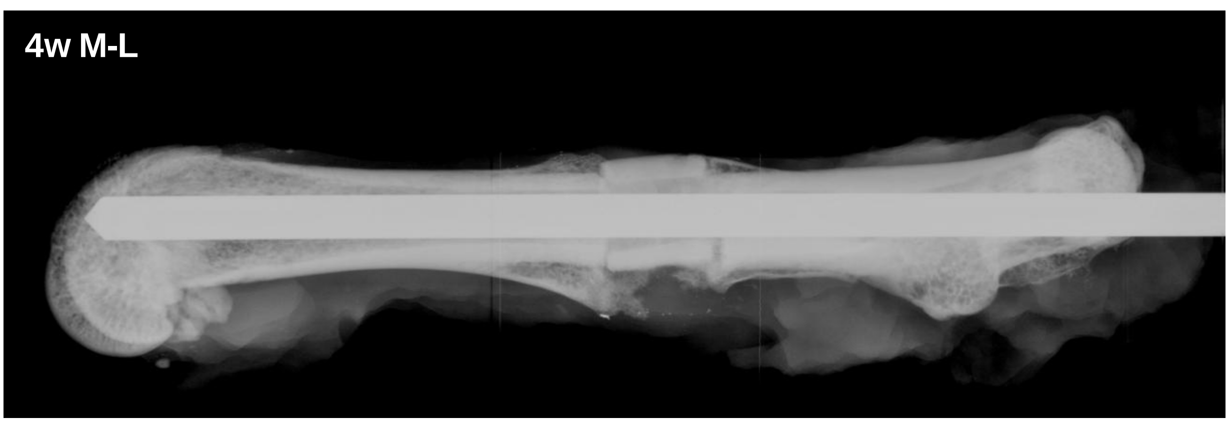
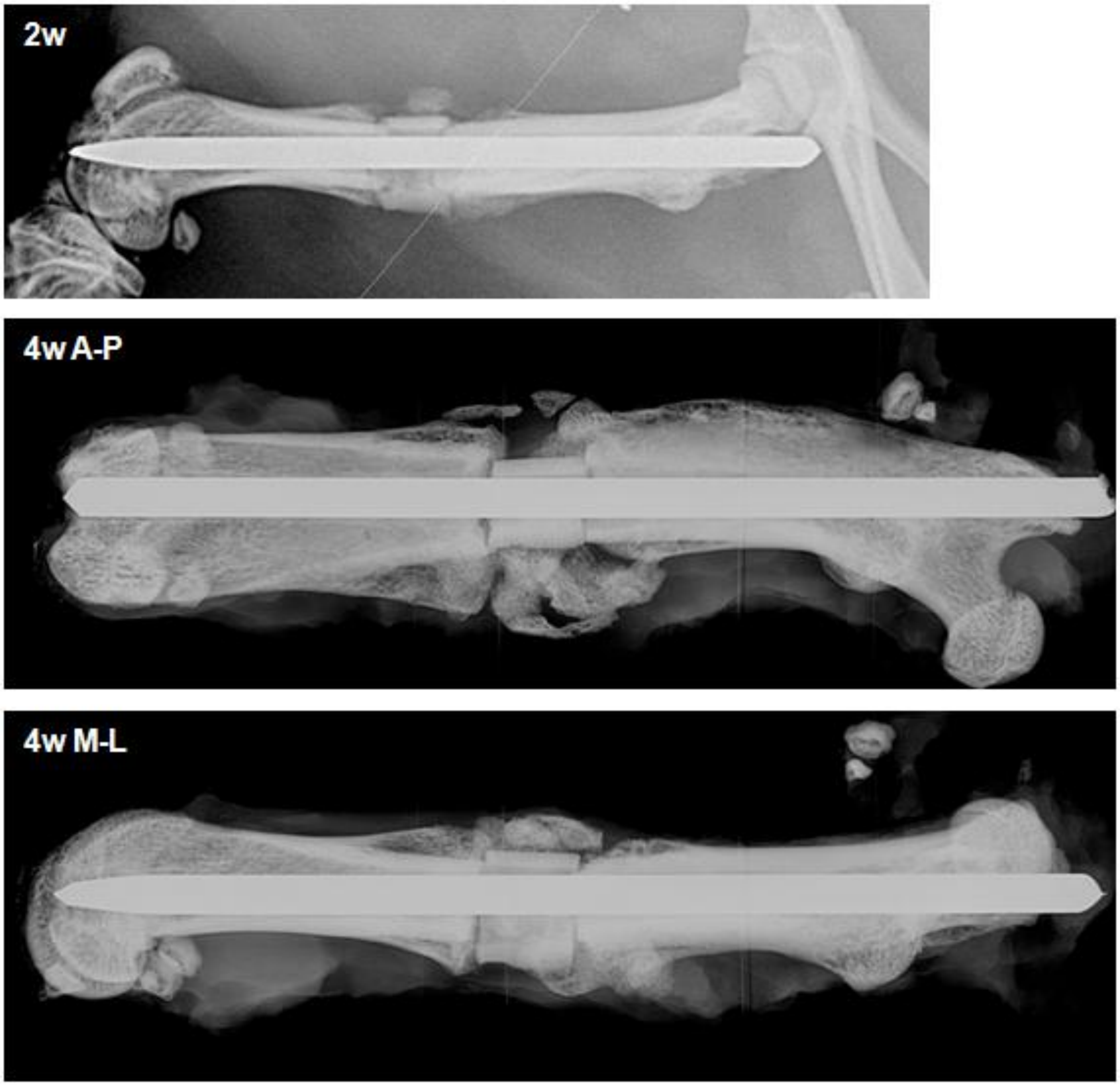


Figure 3: Representative radiographical images for 4 week time point. (cont.)

Group 4



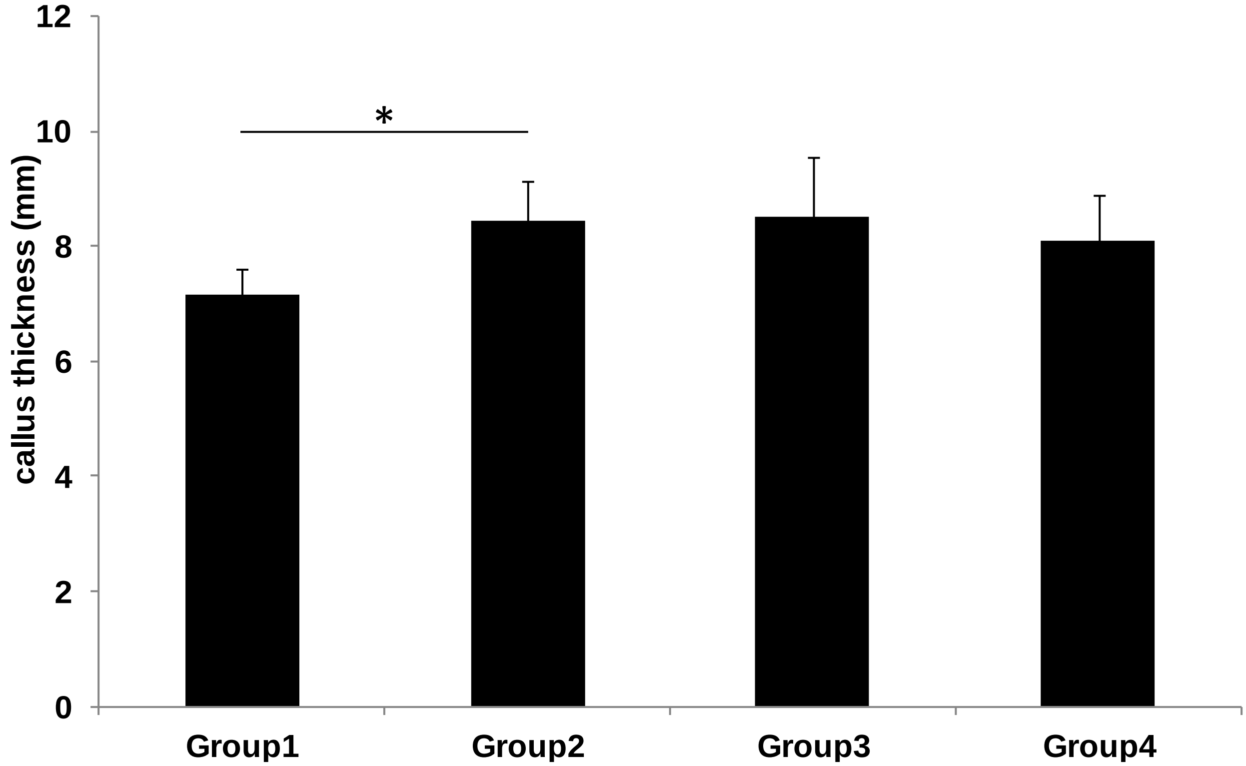


Figure 4: Radiographical data for 4 week time point. *p<0.05.

At 8 weeks post-op, Group 9 resulted in an increased healing/callus size as compared to the non-laser treated/Group 6 (p<0.05) as well as Group 8 (p<0.05) which only the allograft bone was treated with Er:YAG laser (Figures 5 & 6).

Figure 5: Representative radiographical images for 8 week time point.

Group 6

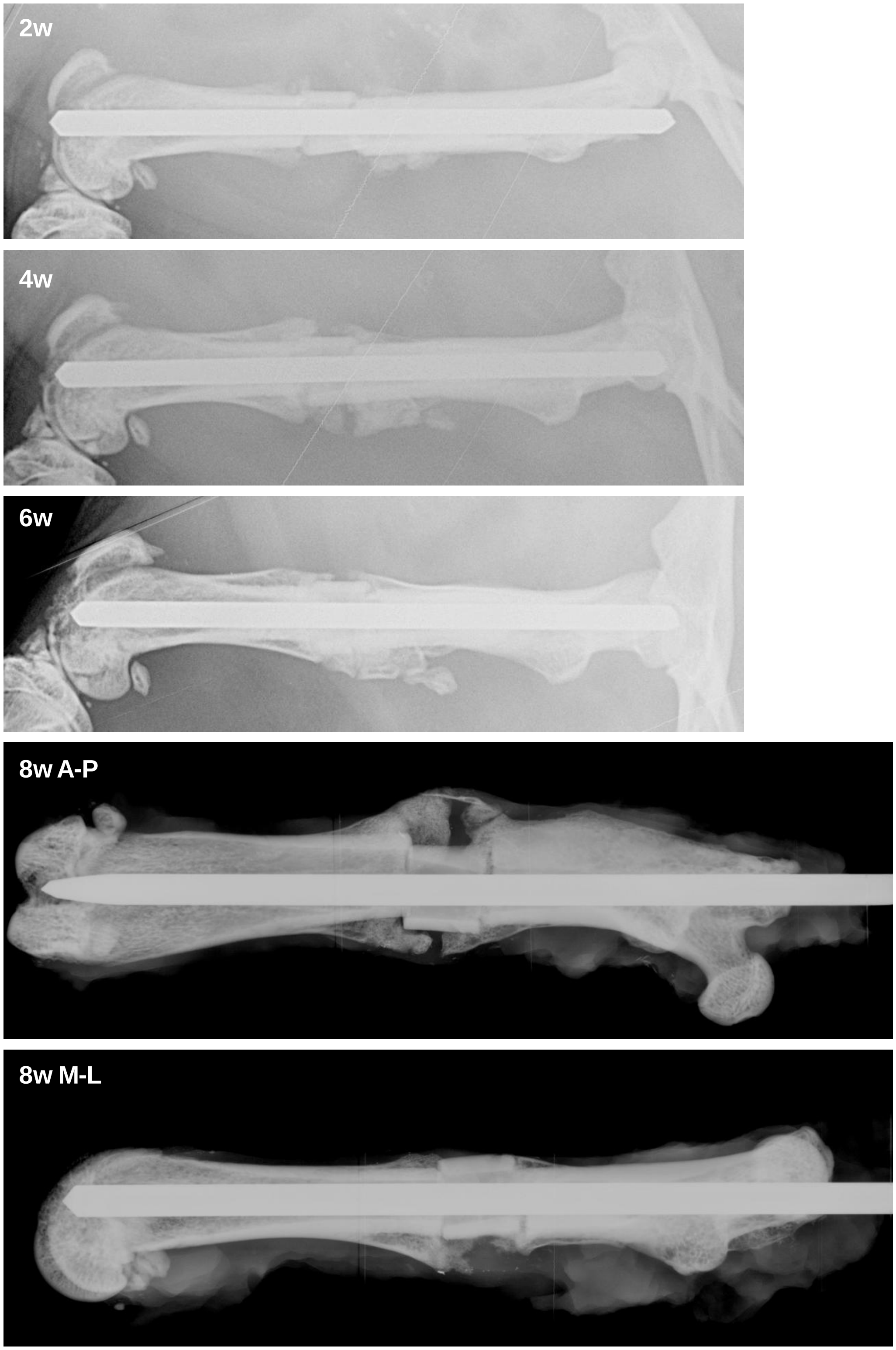


Figure 5: Representative radiographical images for 8 week time point. (cont.)

Group 7

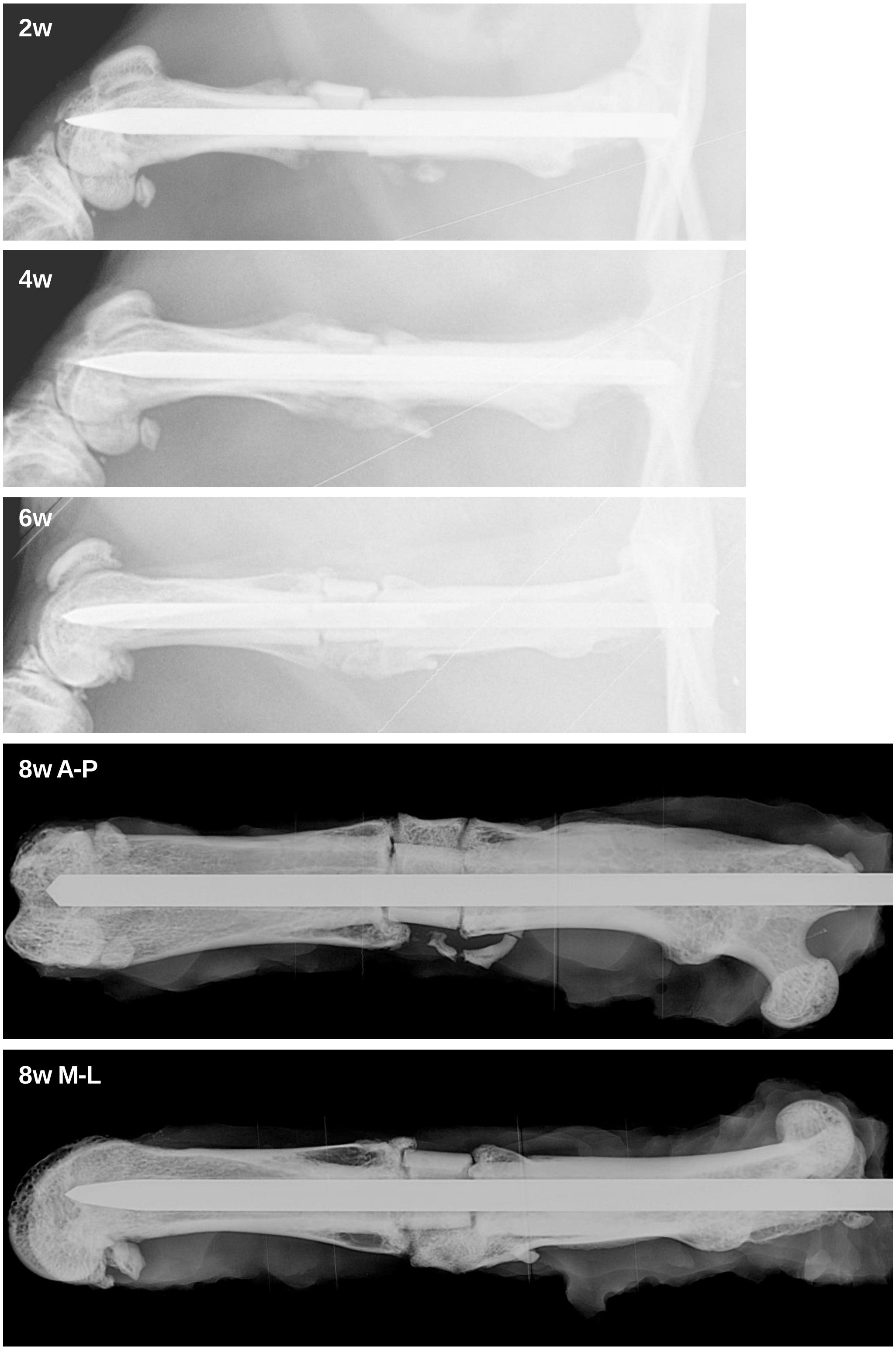
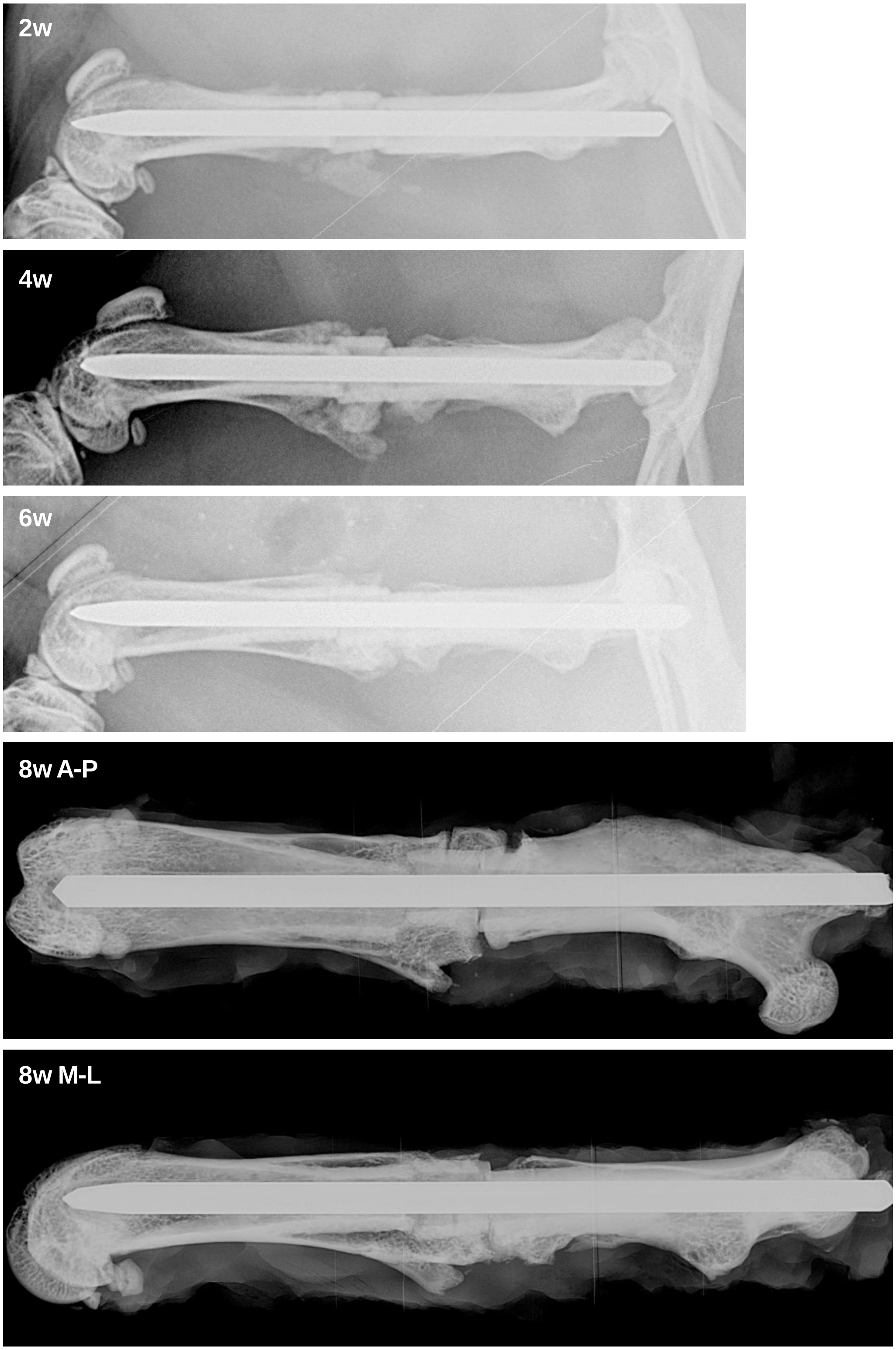


Figure 5: Representative radiographical images for 8 week time point. (cont.)

Group 8

Figure 5: Representative radiographical images for 8 week time point. (cont.)

Group 9



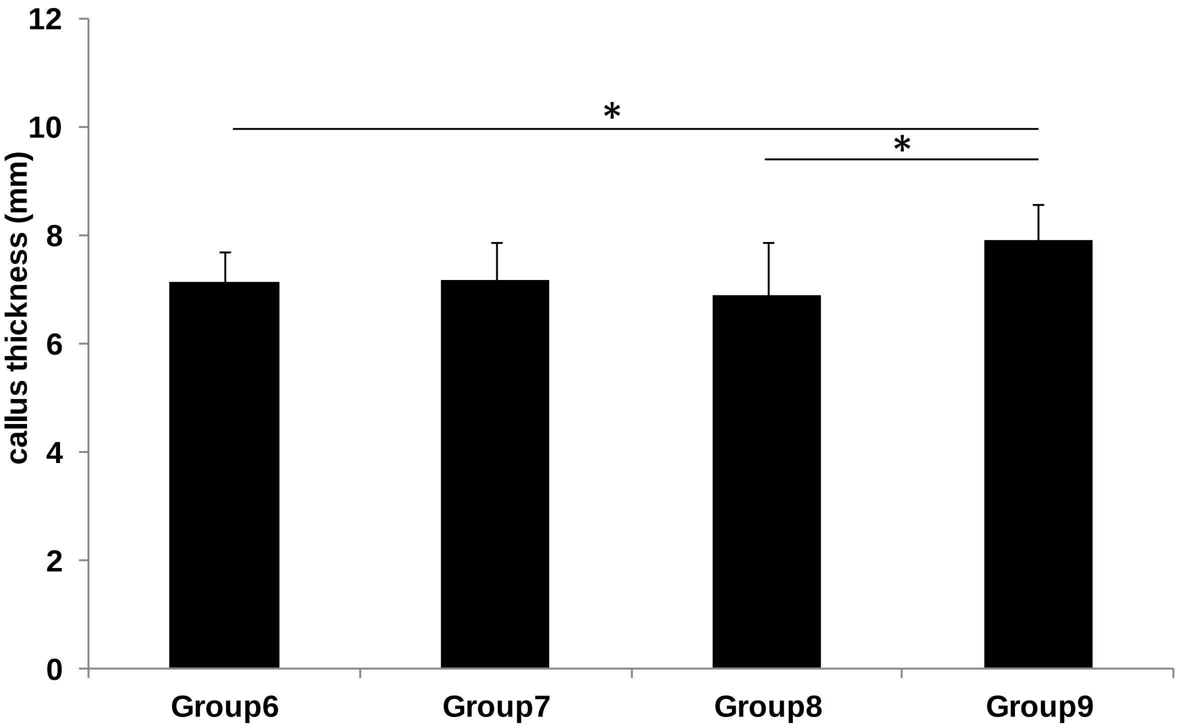


Figure 6: Radiographical data for 8 week time point. *p<0.05

Biomechanical evaluation

The *peak torsion (N-mm)* is a functional estimate of the osseous integration of the newly formed bone with the existing native cortex. The *deformation angle (degrees)* is the total degree of rotation the newly formed bone can withstand before failure. The material property of the regenerated tissue in the defect can be evaluate by the slope of the deformation curve with yields the *stiffness (N-mm/degree)*.

Er:YAG laser treatment only on allograft bone (Group 3) showed significantly increased stiffness compared to the non-laser treated/Group 1 at 4 weeks ($p<0.05$, Figure 7C). The peak torsion for Er:YAG laser treated samples; Groups 2, 3, and 4, showed a trend of increase compared to Group 1 at 4 weeks. At 4 weeks post-op, no statistical changes were observed for peak torsion and deformation angle with the Er:YAG laser treatment (Figure 8).

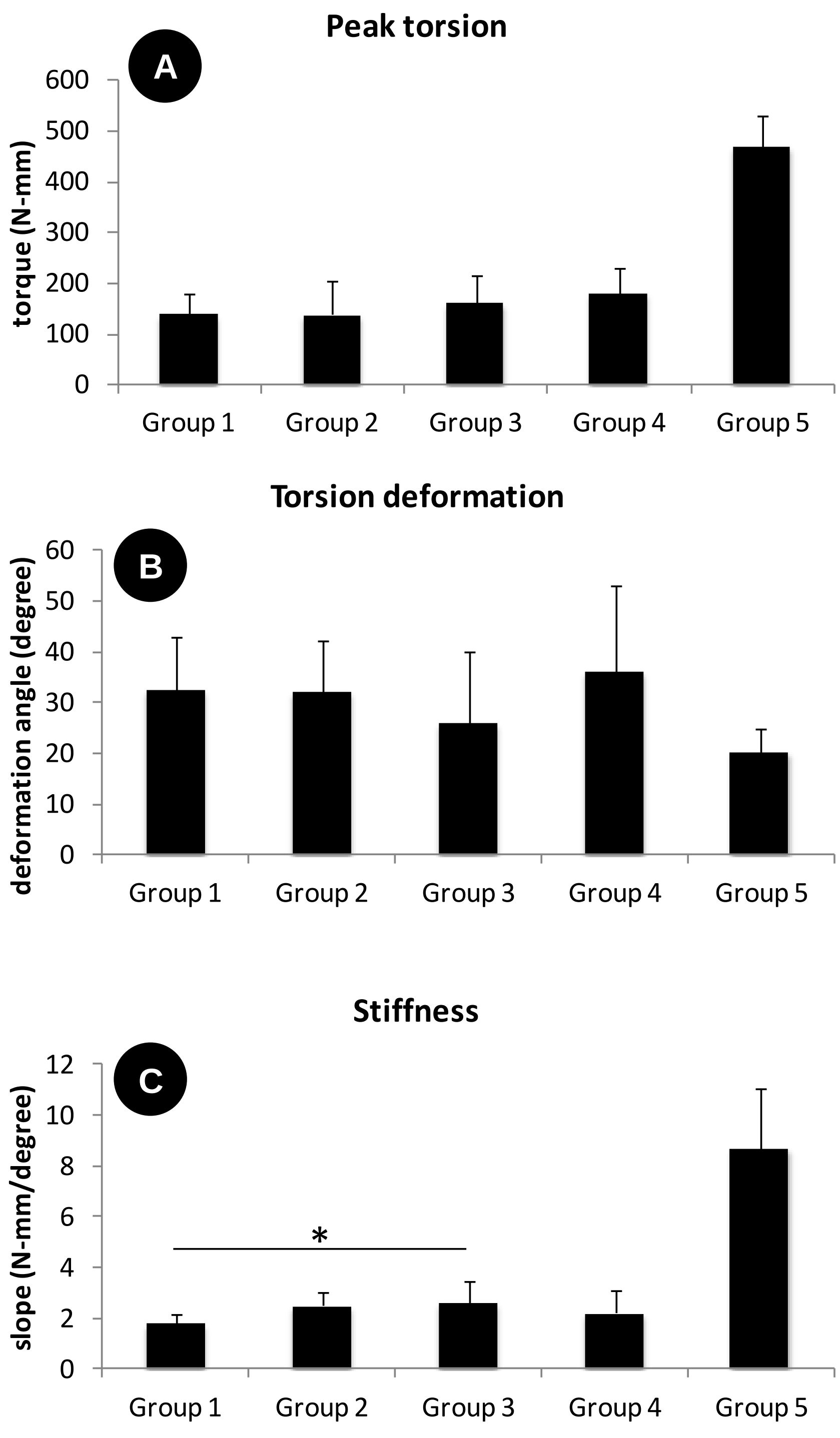


Figure 7: Biomechanical data for 4 week time point. *p<0.05

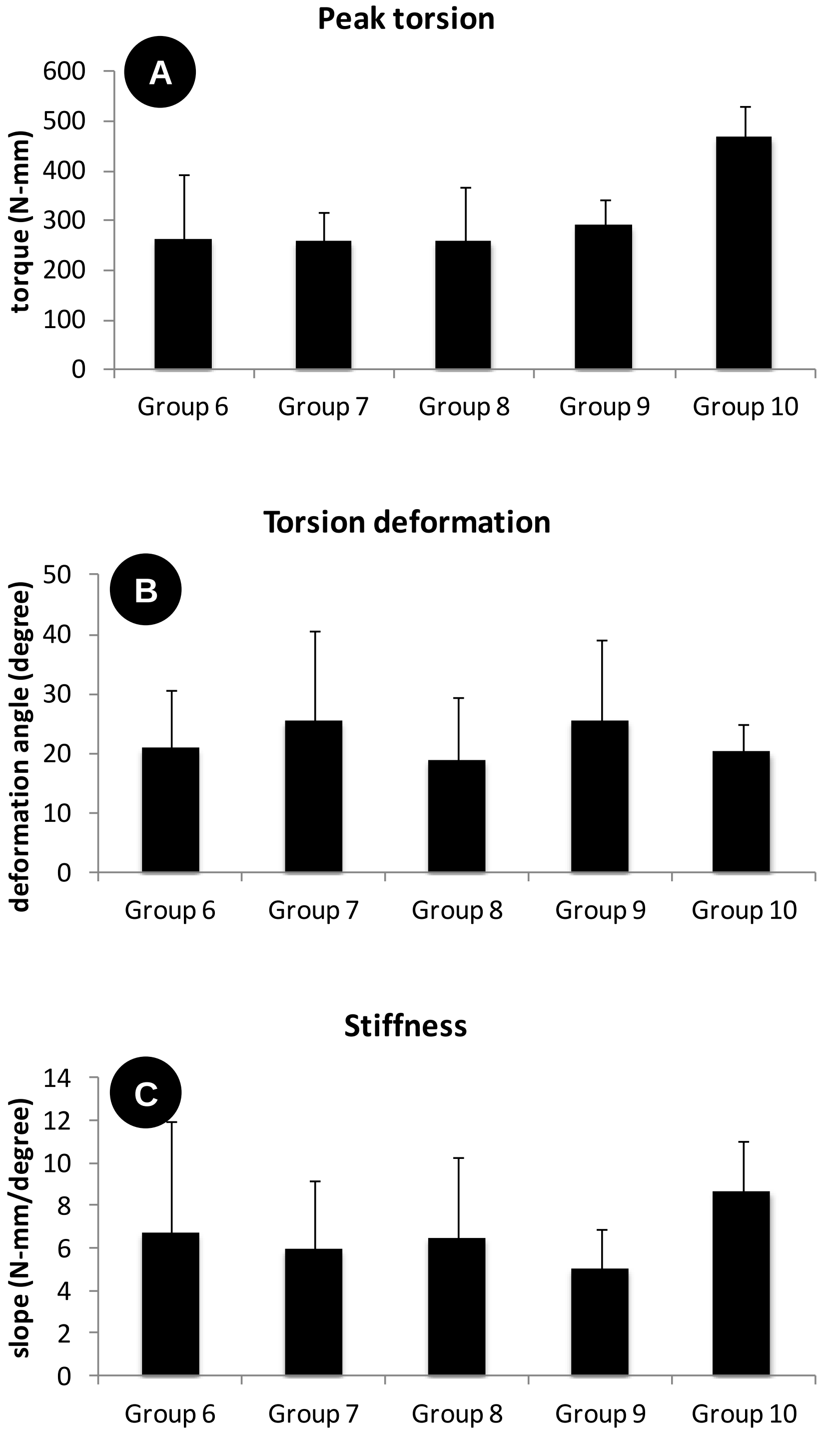


Figure 8: Biomechanical data for 4 week time point.

KEY RESEARCH ACCOMPLISHMENTS

- No adverse effect or complication by use of Er:YAG laser in cortical allograft model.
- Larger callus/more bone was formed by utilizing of Er:YAG laser in cortical allograft model.

REPORTABLE OUTCOMES

Results from this project indicate that application of Er:YAG dental laser may enhance new bone formation around allografts without adverse effect or complication.

Following personnel received research training based on animal procedures in this research project which includes introduction and training for Er:YAG laser.

- Vbenosawemwinghaye Orhue, M.D. – Postdoctoral fellow
- David F. GomezGil, D.D.S., M.S. – Ph.D. candidate
- Siddhesh R. Angle, Ph.D. – Ph.D. candidate
- David G. Karwo, B.S. – Research assistant
- Julie E. Brown, B.S. – Research assistant

CONCLUSION

Results from this project indicate that application of Er:YAG dental laser enhances new bone formation around allografts in a rat segmental defect model without adverse effect or complication.

APPENDICIES

- None