



Bilateral Zygomatic Fracture Model in Sheep for Evaluation of Resorbable Fixation Implants

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Introduction

- Craniomaxillofacial fractures account for 26% of battlefield injuries [1].
- Titanium implants are the standard of care for complex zygomatic fractures via 3-point internal fixation.
- Titanium plates and screws are associated with multiple complications, e.g., 10-22% chance of secondary surgery [2, 3].
- Current resorbable implant systems have a lower risk of long-term complications but still require sufficient bone quality for tapping/drilling pin holes.
- BoneTape (Cohesys Inc., Toronto, ON, Canada) is a novel polymeric implant undergoing clinical testing in Canada and pre-clinical development in the US for fixation of non-load bearing midface fractures.
- It is the first resorbable, internal fixation orthopedic device that **does not require drilling**. The flexible, tape-like design allows fixation of thin, poor-quality bone where use of screws is limited.

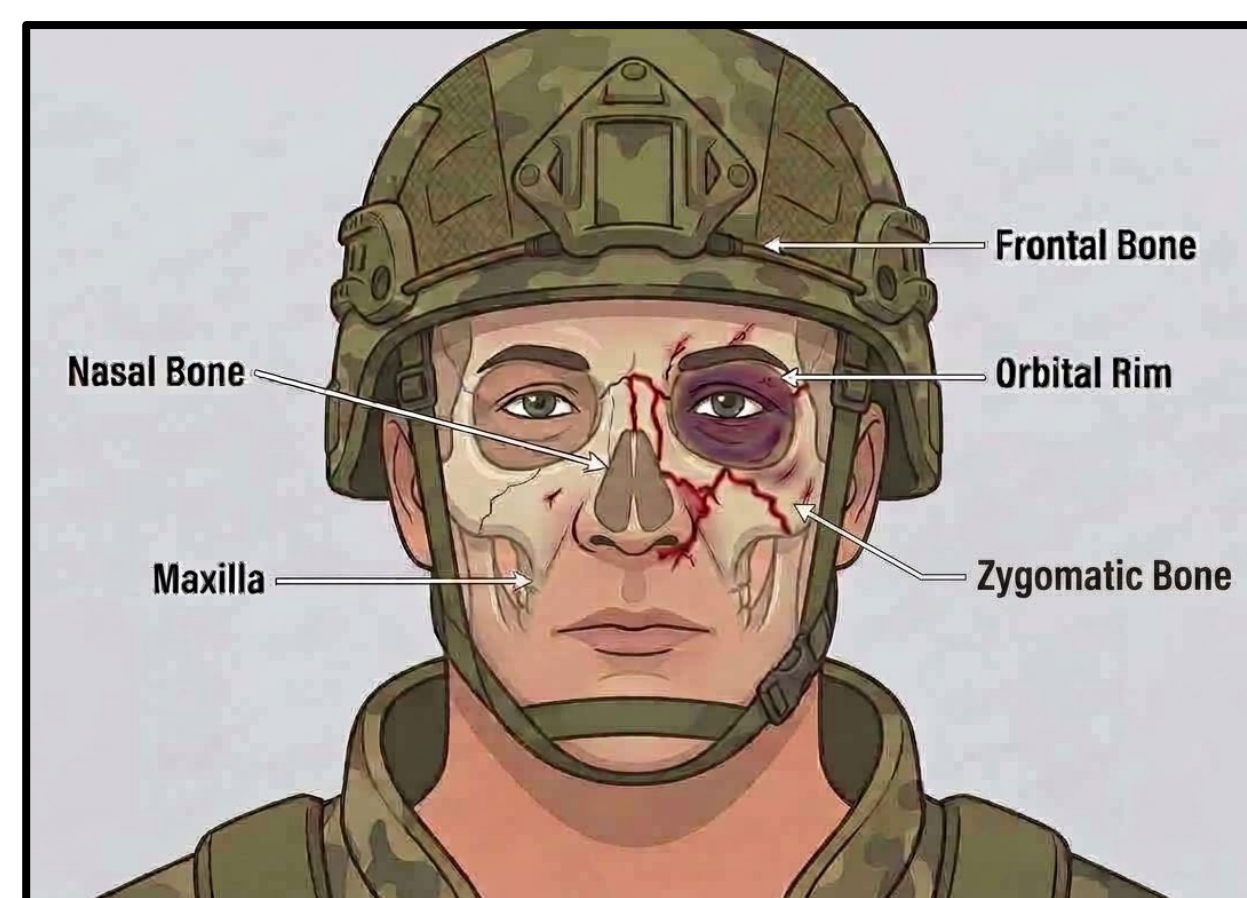


Figure 1. Common midface fracture sites in Warfighters.

- Objective:** Develop a zygomatic tripod fracture model in sheep and evaluate BoneTape compared to an FDA-approved predicate device.

Methods

Resorbable Implant Systems

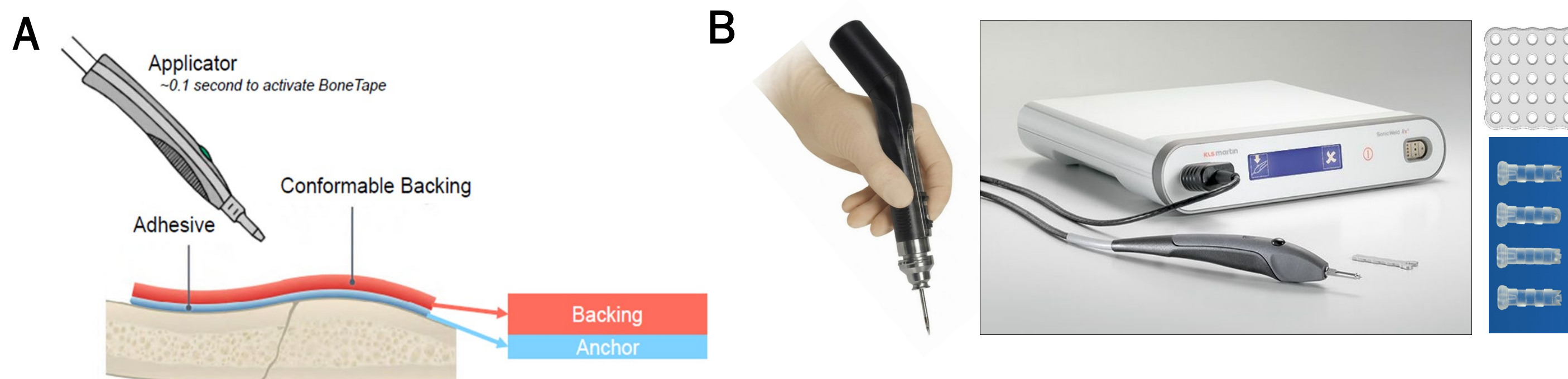


Figure 2. (A) Cohesys BoneTape implant and ultrasonic applicator. (B) Drill, SonicWeld Rx ultrasound unit with handpiece applicator, SonicPins Rx, and Resorb x mesh miniplate made of resorbable poly-D,L-lactic acid polymers (KLS Martin, Jacksonville, FL). (Images: (A) provided by Cohesys; (B) <https://www.klsmartin.com/en-na/products/implants-cmf/resorbable-osteosynthesis>)

- Subjects:** Skeletally mature (~3-4 years of age) female Rambouillet cross sheep
- Zygoma osteotomy sites:** Selected to avoid sinuses, provide adequate spacing for fixation plates, and minimize surgical area and impact on recovery. Marked at ~1 cm from landmark (Figure 3) using calipers.
- Bilateral tripod osteotomies were created with a sagittal bone saw to model a human zygomaticomaxillary complex fracture (Figure 3).
- Implants:** Cut bone was dislocated, reduced, and internally fixed with:
 - Left zygoma – Cohesys BoneTape
 - Right zygoma – KLS Martin SonicWeld Rx resorbable system with Resorb x plates and SonicPins Rx
- Outcomes:** Healing within the defect and callus formation were evaluated at 6- (early healing) and 16-weeks (late healing) (n=8/group) post-surgery by computed tomography (CT), x-ray microtomography (μ CT), and histopathology.

- Data analysis:** Bone density (bone volume/total volume (BV/TV)) data from μ CT was analyzed using a two-way mixed model ANOVA with post hoc Bonferroni test for multiple comparisons. Wilcoxon signed-rank test was used to analyze callus formation data. Histological scoring was conducted by a board-certified veterinary pathologist based on ISO 10993-6 [4] and Oryan et al. [5].

Surgical Procedure

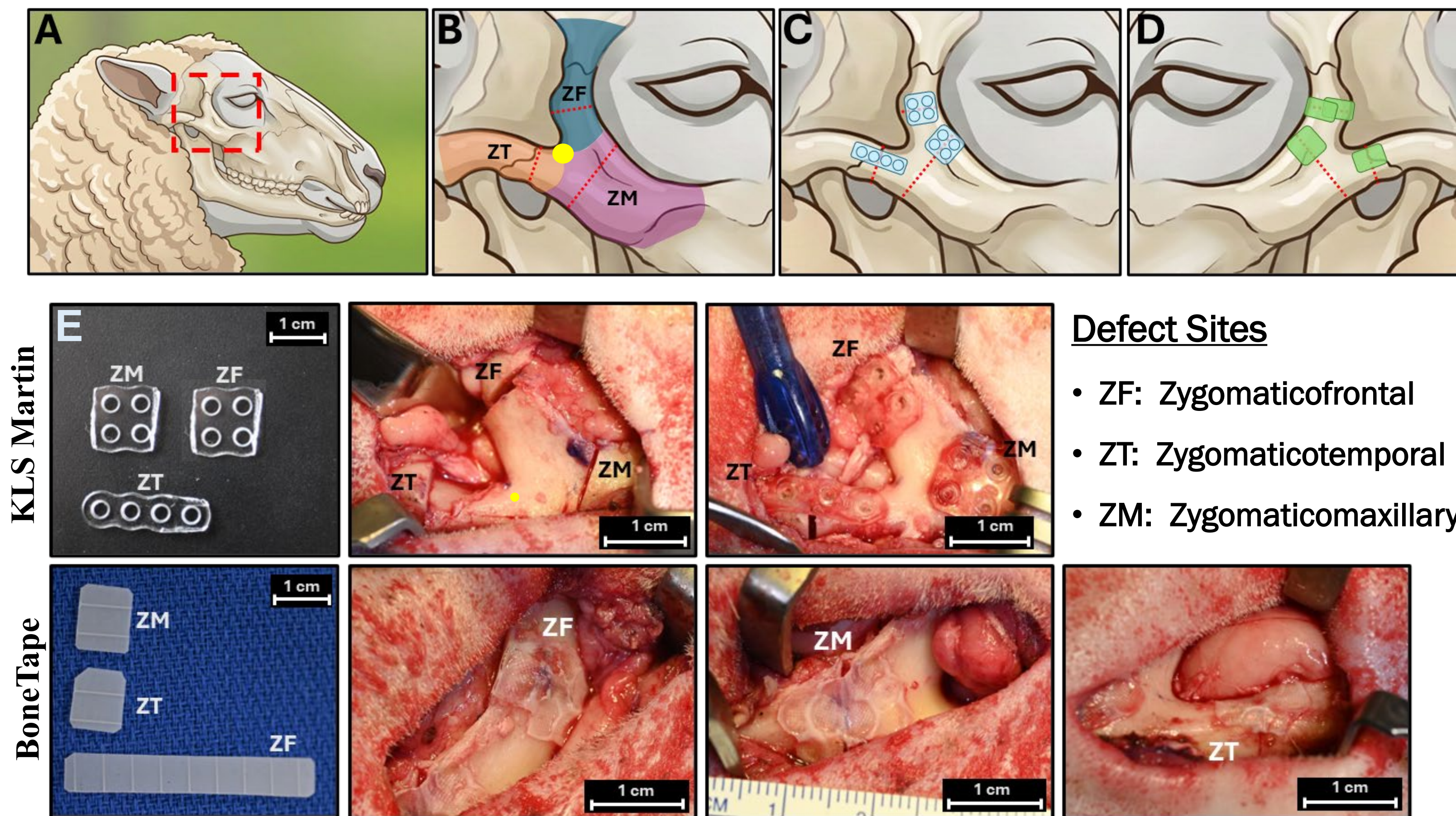


Figure 3. Defect sites and fixation. (A) Anatomical structure of sheep midface bones. (B) Red dotted lines show defect. Yellow dot marks junction of ZF and ZT that was used as a landmark to measure defect locations. Placement of (C) Resorb x with SonicPins Rx and (D) BoneTape. (E) Photographs of implants and zygoma before and after fixation.

CT Radiography

- CT scans allowed non-invasive and qualitative monitoring of fixation stability and bone and callus formation.
- Movement of fixated zygoma was generally seen in the first 2 weeks for both types of implants.
- External calluses were observed by week 4, usually on the inferior side of the defects and along the vertical ridge where the muscle attaches to the zygoma.

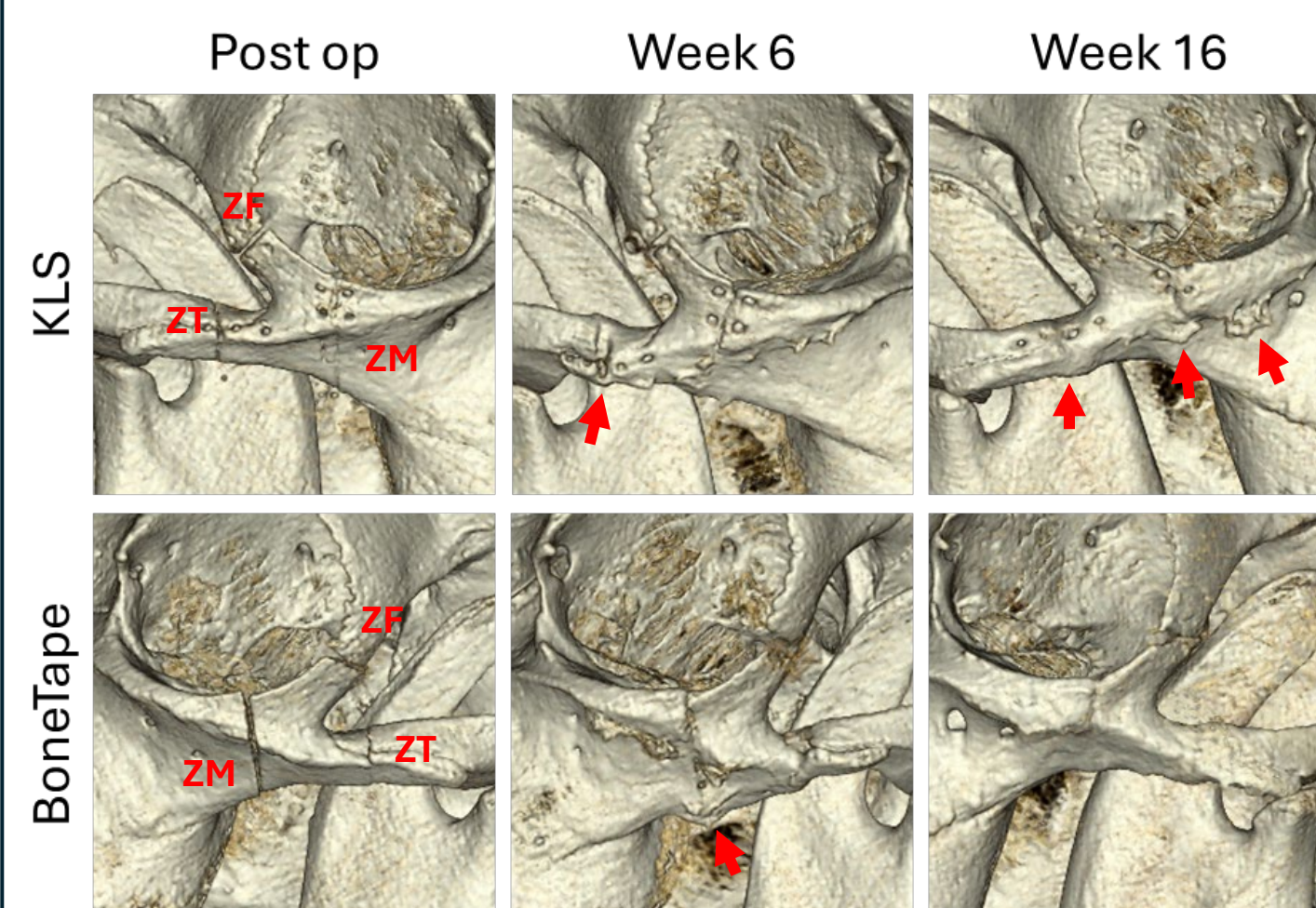


Figure 4. Representative CT scans showing non-invasive monitoring of defects. Red arrows indicate callus formation.

Results

Histology

- At 6 weeks post-surgery, fibrotic tissue in the defect and early osteogenesis were commonly observed.
- At 16 weeks, defects were almost completely filled with new woven bone. A few defects had minor amounts of fibrocartilage.
- Bone response, in terms of bridging and filling of the defects, was consistent between BoneTape and KLS Martin implants at both endpoints as determined by the veterinary pathologist.

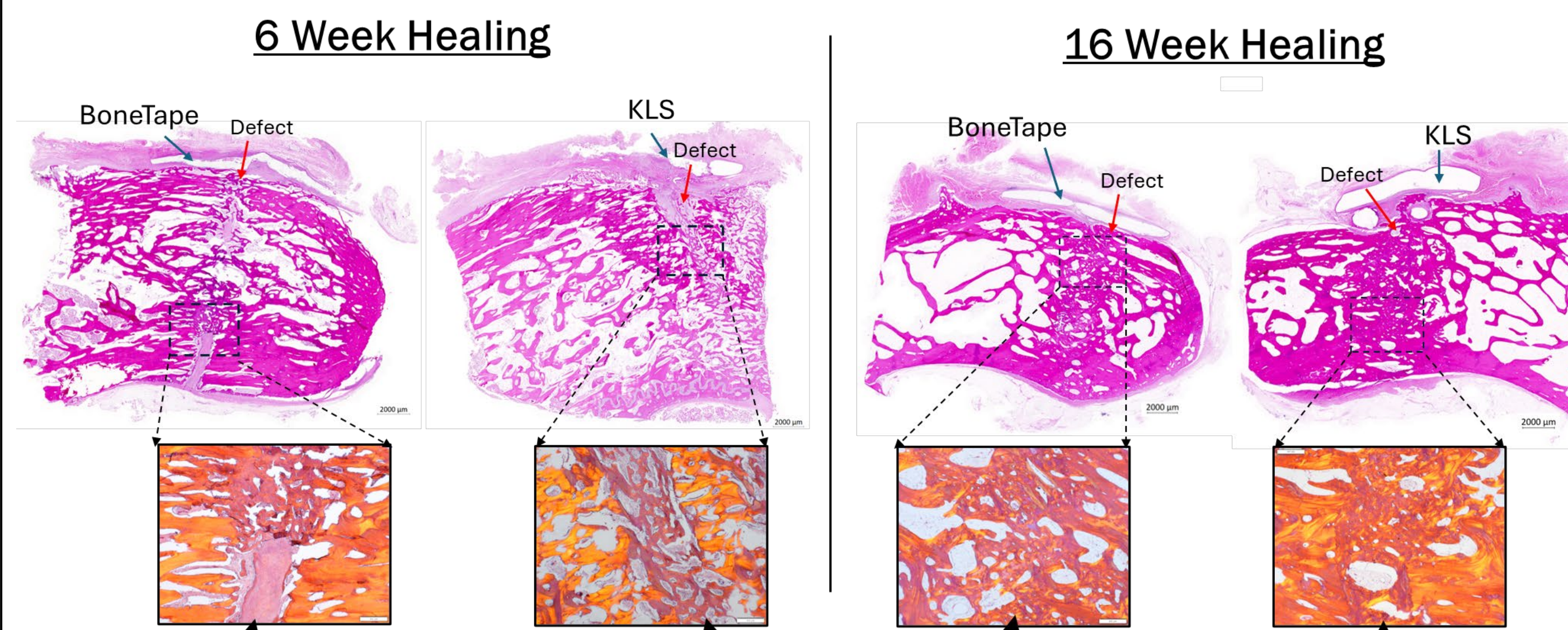


Figure 6. H&E staining of defect healing at 6- and 16-week endpoints with polarized images below.

Table 1. Scoring System and Evaluation of Healing at Each Defect [5].

6-Weeks		BoneTape								KLS							
Animal Number		U20	U26	U28	U29	U30	U31	U33	U34	U20	U26	U28	U29	U30	U31	U33	U34
ZF		3	3	2	2	2	2	2	2	2	2	2	2	3	2	2	7
ZT		3	3	2	7	7	3	7	7	2	7	7	2	7	3	7	7
ZM		7	7	7	8	7	7	7	7	8	8	8	8	8	7	7	7
16-Weeks		BoneTape								KLS							
Animal Number		U10	U11	U12	U18	U21	U22	U24	U27	U10	U11	U12	U18	U21	U22	U24	U27
ZF		2	8	2	2	2	8	2	8	2	2	8	2	2	2	7	7
ZT		7	8	7	7	7	7	7	7	7	8	7	7	7	7	7	7
ZM		3	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

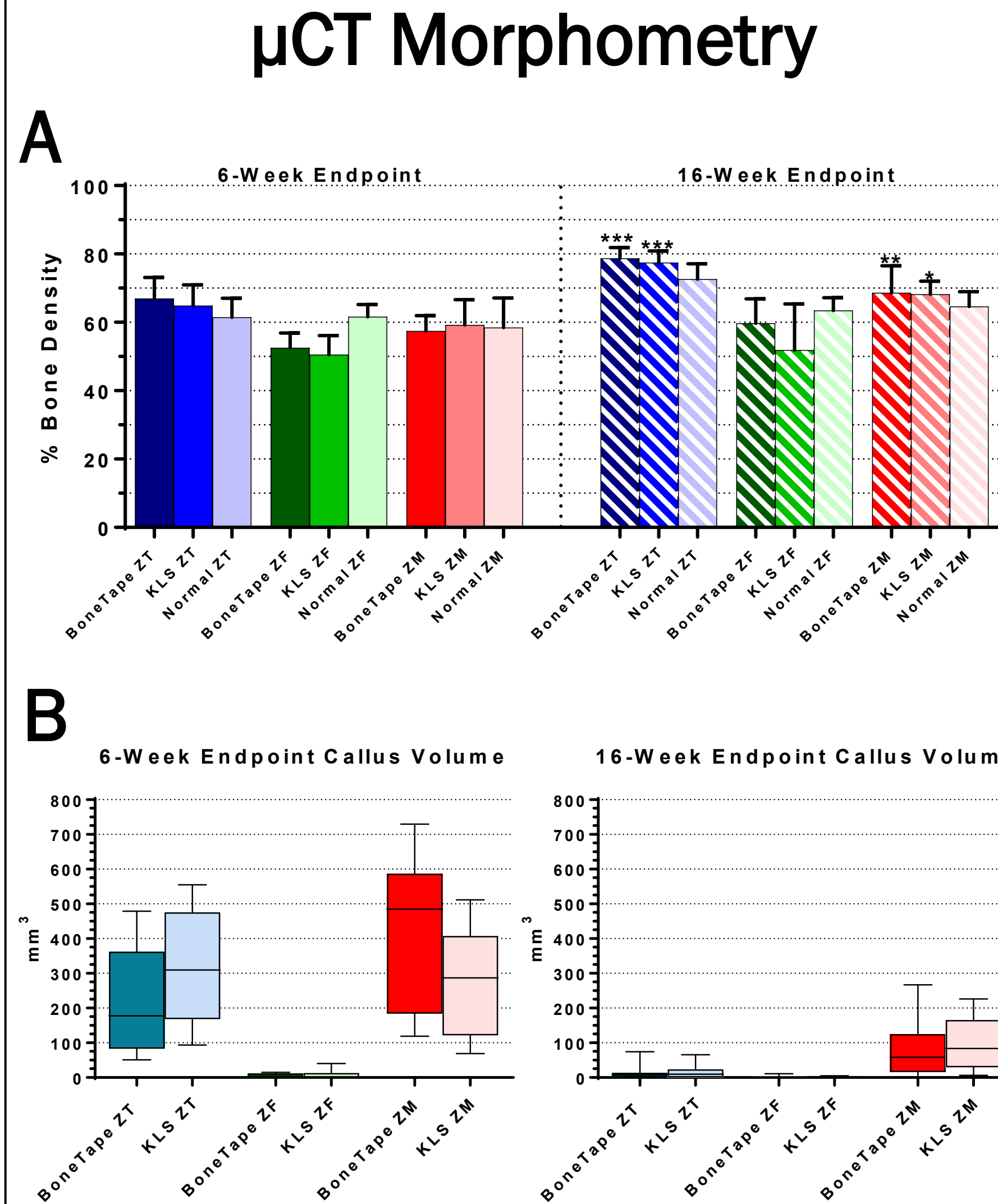


Figure 5. Bone density (BV/TV) and callus volume (external to defect) at 6 and 16 weeks determined by μ CT analysis. (A) Bone density shown as mean $\pm$ SD (n=8/endpoint). "Normal" indicates bone density in non-injured bone. (B) Callus volume shown in box plots with median line, minimum, maximum, first/lower quartile and third/upper quartile. *p<0.05; **p<0.01; ***p<0.001 for bone density in 16-week defect compared to the corresponding defect in the 6-week group.

Conclusions

- The sheep zygoma tripod fracture model was successfully developed and utilized to compare the performance of BoneTape and KLS Martin Resorb x/SonicPin Rx implants at 6- and 16-weeks post-surgery.
- No differences in bone density (BV/TV) were detected by μ CT for BoneTape compared to the KLS Martin Resorb x/SonicPin Rx system at any of the defect sites.
- As expected, bone density was higher in the ZT and ZM defects at 16 weeks compared to 6 weeks. Healing appeared slower at the ZF defect, possibly due to zygoma movement.
- Based on ISO 10993-6 scoring, BoneTape elicited 'minimal/no reaction' or only a 'slight reaction' compared to the KLS Martin implant (data not shown). No differences in quality of bone healing (Table 1) were detected between BoneTape and KLS Martin implants at any defect site or either endpoint.

References

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