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Pin Fixation with Nanosurfaces in a Multi-Pin Transfixation Cast System for Fracture Healing

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Background

Fractures of long bones are very often treated with screw and plating systems that are intended to stabilize the fracture and provide some amount of loading resistance to enable physical therapy. When the fracture site is loaded, the screws adjacent to the fracture receive the highest stress load and thus are subject to the most micromotion[1-3]. Excessive micromotion will cause the adjacent bone to break down. This loss of bone around the screw compromises fixation initiating a cascade effect where adjacent screws progressively experience the same deterioration pattern[1-3]. Nanosurfaces have been demonstrated to accelerate and increase the formation of bone around implants[4,5]. Stabilizing the implant earlier can slow the loss of bone keeping the construct more stable for a longer period of time.

In external fixation systems, including this model, micromotion can lead to infections that further cause screw and pin loosening[6-8]. Loose and infected pins also create a lot of pain and discomfort for the patient, further slowing and complicating recovery. This study is based on an external transfixation pin that passes through the skin and bone on both sides of the forelimb and is secured with a cast to treat fractures in racehorses[1]. The large animal weight bearing model provides external exposure to bacteria and strong micromotion. The nanoVIS Ti ™ surface utilized in this study has been shown to lower bacterial attachment in vitro and inhibit biofilm formation in vivo[9,10]. Torque measurements were used to quantify the pin fixation.

Methods

Titanium ex fix pins with or without the nanoVIS Ti™ Surface Technology were implanted into the forelimb of horses. A total of 6 pins per limb were implanted in positions 1 to 6, 1 being proximal and 6 being distal. Pin stress was modeled with finite element analysis and predicted to be highest on the distal and proximal pins with the central pins being stress shielded. Pin constructs were mixed control and nanoVIS Ti™ surface. Pins were placed to ensure an equal number of pins for each surface and at each location 1-6. Pins were transcutaneous and secured in a weightbearing polymer cast directing the weight of the horse through the pins, into the cast and then into the floor, bypassing fractures in the foot. The pins remained in place for 5 weeks with daily weightbearing activity. No supplemental antibiotics or cleaning of the pin-skin interface was done. After the 5 weeks, animals were sacrificed and the cast removed to recover the forelimb with pins. Pins were removed with Snap-On torque wrenches to quantify the extraction torque. Torque was recorded at each pin position.

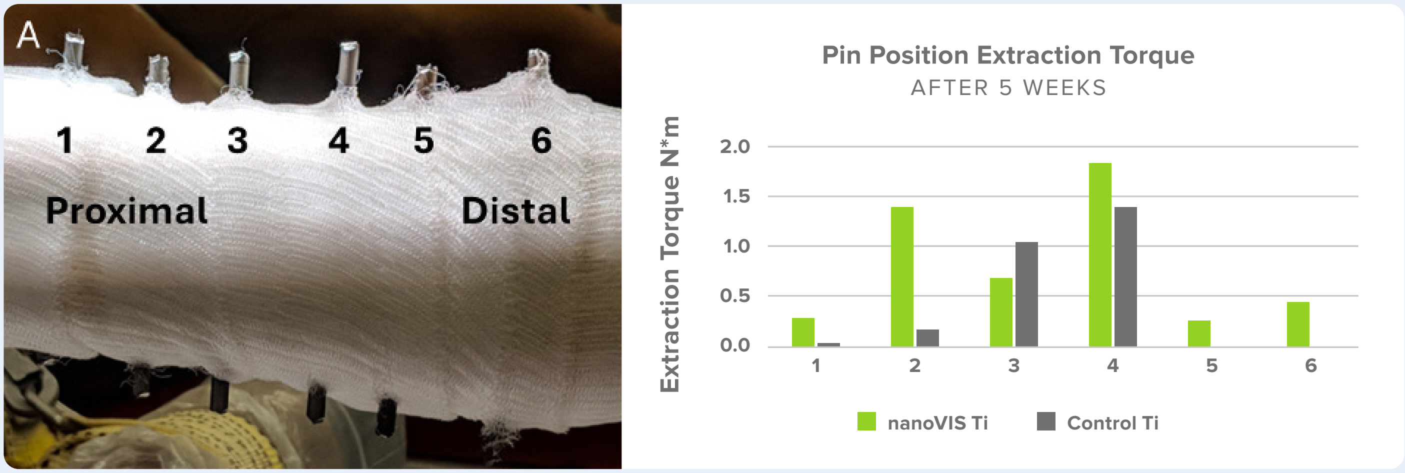

Figure 1 – (A) Pins placed in the cannon bones of the horse. (B) Extraction torque of transcutaneous cast pins after 5 weeks of osteointegration. N = 2 at each pin position.

Results

Control titanium pins, in grey, showed the highest fixation at pins 3 and 4 and very little fixation at pins 1, 2, 5, and 6. Pins with the nanoVIS Ti™ Surface Technology demonstrated higher levels of fixation of all but the most shielded location, pin 3. Significantly higher fixation was seen for pins with higher loading at position 1, 2, 5 and 6 with the nanoVIS Ti™ Surface Technology.

Discussion

Pin position generally correlated with predicted fixation outcomes. Pins 1 and 6 were predicted with finite element analysis to have the lowest fixation based on high pins stress, followed by 2 and 5 with 3 and 4 having the lowest predicted pin stress. The control titanium surface replicated the prediction. The duration of 5 weeks started with fixation loss at pins 1 and 6 at an earlier timepoint and progressed to pins 2 and 5 at the 5-week timepoint. This left pins 3 and 4 with the most fixation potential for the control surface (gray bars, Figure 1B). The nanoVIS Ti™ surface also showed protected central pin locations with higher fixation at pins 2,3, and 4, (green bars, Figure 1B). The nanoVIS Ti™ surface demonstrated higher fixation at pins 1,2,4,5 and 6 vs. control titanium. No single horse had only one surface type. The nanoVIS Ti™ surface outperformed the control surface overall.

Conclusion

The nanoVIS Ti™ surface allowed pins to achieve better fixation in a heavy micromotion and in the presence of infections on pins. If the aim is to allow more time for the fracture to achieve fusion, reduce patient pain and allow for faster recovery, the nanoVIS Ti™ Surface Technology provides a permanent solution to implants for better osteointegration.

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