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A study of fractured cranial flap refixation

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Summary *Objective:* To study the techniques of fractured cranial flap refixation (suture, wire and titanium clamps).
Methods: Twenty-four cadaver craniotomy flaps, sawn as fractured flap models, were divided into three groups, and every eight fractured flaps were reattached with sutures, wires and titanium clamps, respectively. Bone flap refixation was timed and measured for offset. For every fixation technique, load-bearing tests were performed on craniotomied skulls by applying an external force until the refixation system failed. The results were compared.
Results: The titanium clamp required significantly less time (142 ± 16 s) to fix than either suture (631 ± 47 s) or stainless steel wire (1104 ± 48 s). The titanium clamp also showed significantly smaller offset (average offset: 0.35 ± 0.07 mm) than either suture (average offset: 1.93 ± 0.33 mm) or stainless steel wire (average offset: 1.80 ± 0.42 mm). The titanium clamp (maximal force: 384.06 ± 24.89N) was stronger than suture (maximal force 89.43 ± 13.76N) and stainless steel wire (maximal force 285.51 ± 10.46N).
Conclusion: The titanium clamp is a reasonable alternative method of fractured cranial flap refixation with respect to ease of use, time consumption, accuracy and strength.

After craniotomy in patients with intracranial haematoma or depressed skull fractures, a skull flap in several fragments is often found. Traditional management of these cases entails removal of all bone fragments with delayed cranioplasty. Bone fragment removal is intended to reduce the potential for infection. However, bone fragment removal often necessitates a second operation to repair the resultant calvarial defect. Immediate replacement of bone fragments in compound depressed skull fractures does not increase the risk of infectious complications.[1] Elevation and debridement is recommended as the surgical method of choice in patients with compound depressed cranial fractures. Primary bone fragment replacement is a surgical option in the absence of wound infection at the time of surgery.[2] Fixation of cranial bone flaps should be reliable, safe, rapid and aesthetically acceptable, including the artifacts seen on postoperative neuroimaging. Refixation of

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a fractured cranial flap after craniotomy is relatively difficult, with problems such as deformation and dislocation of the fractured flaps often experienced in clinical work.[3] For the purpose of aesthetics and protection, a variety of flap fixation techniques such as suture, stainless steel wire, titanium miniplate, and titanium clamp (CranioFix, Aesculap, Tuttlingen, Germany) are in clinical use. Hydroxyapatite cement is a biocompatible, alloplastic material useful for augmentation of post-traumatic frontal-bone depression.[4] Winston et al. secure the flap with absorbable sutures.[5] Although a variety of methods have been used over the years for cranial flap refixation, few methodical comparisons of this sort have been reported in the medical literature. The purpose of this study was to evaluate the biomechanical characteristics (timing, accuracy and strength) of three different fractured cranial flap refixation techniques (suture, stainless steel wire and titanium clamp).

Materials and methods

Craniotomy technique

Six cadaver skulls were used for the study (provided by the Department of Anatomy, College of Medical Sciences, Zhejiang University, China). Four circular craniotomies were made in each cadaver skull, making a total of 24 overall. The four locations used for the craniotomies were frontal, occipitoparietal, and both temporal. The craniotomy diameter was 6.0 cm, and each bone flap was sawn into four equal fragments by a crucial incision. Three techniques of refixation were used for eight fractured flaps each: suture, stainless steel wire and titanium clamp.

Refixation of fractured cranial flaps (Figure 1)

Suture refixation. Ten pairs of holes were bevel drilled by gas-driven drill in each fractured flap and adjacent skull edge and were positioned at the cross of the saw gaps, 4—5 mm away the edge. Sutures (1/0) were threaded through holes in the skull edges and then through the holes in the flaps. Each suture pair was knotted three times to fix it.

Stainless steel wire refixation. Holes were drilled in the fractured flaps and the adjacent calvarium edges in the same way as that for suture fixation. Stainless steel wires (Φ0.5 mm) were threaded through holes in the skull edges and then through the holes in the flaps. Each wire pair was twisted until taut, the excess was trimmed, and the free end was buried in the hole made in the skull edge. Each fractured flap was secured in five different places.

Titanium clamp refixation. A titanium clamp was positioned at the cross of the saw gaps. Five clamps were used per cranial flap, with a 16-mm clamp placed at the centre of the crux, and the other four 11-mm clamps positioned 90° apart along the circumference of the cranial flaps. The application forceps were then placed over the free end of the pin and sequentially squeezed and released to advance the outer disc over the threaded pin down towards the outer table. The excess pin projecting above the outer disc was snipped off with the pin cutter.

Time consumption for bone flap refixation

The time required for suture refixation was measured starting from drilling holes in the flap and the adjacent skull edge to when the suture pair was knotted. The time required for wire refixation was measured starting from drilling holes in the flaps and the adjacent skull edge to when the wire pair was twisted until taut and the excess was trimmed. The time required for the titanium clamp was measured starting from placing the clamp to squeezing the threaded pin down and snipping off the excess pin projection. Two participants were used in this experiment, and a supervisor neurosurgeon (fellow) was doing the fixation.

Measurement of initial offset

Without external force, positioning of the flap with respect to the height of its surface relative to the surface of the adjacent skull (offset) was assessed by a vernier caliper (grade of accuracy $\pm$ 0.01 mm). Offset of the four fragments of each flap was recorded, and the average value of the four measurements was recorded as initial offset.

Load-bearing test

The mechanical load-bearing tests for three refixation systems were conducted in the Institute of Polymer Composites, Zhejiang University, with the universal test machine Reger 2000-10 (Reger Inc., ShenZhen, China; grade of accuracy $\pm$ 0.1N). Before the test, the cadaver skull was fixed and the target flap was placed at the apogee to make sure that the flap received a vertical force. With the Reger

Figure 1 Fractured cranial flap fixation techniques (left: suture; middle: wire; right: titanium clamp).