Repositioning of Cranial Bone Flaps Cut with a Diamond-Coated Threadwire Saw: 5-Year Experience with Cosmetic Cranioplasty without Fixation Devices

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ABSTRACT

Artificial fixation systems for cranial bone flaps have problems related to their materials and designs. We developed an alternative technique for supratentorial craniotomy that employs a diamond-coated threadwire saw (diamond T-saw), originally developed for spinal surgery, and reduces the bone gap for fitted bone flap fixation. The study subjects were 77 adults undergoing elective supratentorial craniotomy. After placing a burr hole at each corner of the craniotomy, we performed osteotomy between adjacent burr holes to approximately one-third of the length of the osteotomy with a craniotome; this leaves a bony bridge at each corner. The diamond T-saw was introduced between adjacent burr holes through the epidural space and a bridge was cut with reciprocating strokes. On closure, the bridge firmly supports the flap and only sutures are needed for fixation. Successful bone flap fixation was obtained in all followed-up cases. There were no technique-related complications such as dural laceration, flap displacement, or resorption. Our method is ideal for bone cuts in cosmetic cranioplasty; it is easy, safe, and inexpensive and avoids the need for flap fixation with artificial devices.

KEYWORDS: Craniotomy, cranioplasty, diamond threadwire saw

Artificial, primarily metal fixation systems to secure bone flaps have been used since the 1990s in patients undergoing craniotomy. They are easily manipulated and yield satisfactory cosmetic outcomes by avoiding bone flap depression although problems related to their materials and designs have been reported.^{1–5} Major problems are aesthetically objectionable bulges and scalp erosion over the fixation systems; especially in hairless areas they may be serious. An-

other issue is the cost and availability of different new products.

To address these issues, we developed an alternative technique for supratentorial craniotomy that involves the use of a threadwire saw (T-saw).⁶ The minimum bone gap in the cut line is less than 1 mm; this avoids bone flap depression without requiring support by artificial fixation systems. Here we present our 5-year experience with an improved T-saw

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Skull Base 2011;21:323–328. Copyright © 2011 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662.

Received: March 25, 2011. Accepted: April 26, 2011. Published online: July 21, 2011.

DOI: <http://dx.doi.org/10.1055/s-0031-1284214>.

ISSN 1531-5010.

(diamond T-saw) (Mani Inc., Utsunomiya, Japan), report outcomes, and provide additional tips.

MATERIALS AND METHODS

Patients

Since 2006, we applied our technique in 77 adults who underwent elective supratentorial craniotomy including skull base procedures in the forehead using the basal interhemispheric and orbitozygomatic approach. Patients who required emergent removal of the bone flap for decompression were not subjected to this method.

Surgical Technique

After gently dissecting and reflecting the scalp and pericranium we drilled a burr hole at each corner of

Figure 1 Photograph of a medium-sized diamond T-saw. A 20-cm long section in the midportion of the stainless-steel microcable is coated with diamond particles, 1 mm in width every 1 mm. The diameter of this portion is 0.64 mm.

the intended craniotomy, dissected the dura from the inner table, and used a craniotome for osteotomy between adjacent burr holes. At a point approximately one-third along the length of the osteotomy we left a bony bridge in place. Using a Gigli saw guide, a medium-sized diamond T-saw was introduced between the burr holes through the epidural space (Figs. 1 and 2A). If the burr hole is too small to allow insertion of the saw guide, a

Figure 2 Craniotomy using a diamond T-saw in a patient undergoing left pterional craniotomy with orbital extension. (A) A bony bridge (arrow) is left between two osteotomies performed with a craniotome. The diamond T-saw (arrowhead) is looped to fit the hook of a Gigli saw guide and passed through the epidural space with the aid of the guide. (B) Using reciprocating strokes, a beveled cut is made in the bony bridge. Arrows indicate the diamond T-saw. (C) Completion of the cutting of the bridge. Note that the cut line created by the diamond T-saw in the bridge (arrows) is much thinner than the cut created by the craniotome next to the bridge (arrowheads). (D) In osteotomy of the orbit, the saw (arrow) is introduced by the guide catheter (arrowheads) that has been passed through the supraorbital burr hole and small hole in the orbital roof.

genuine flexible diamond T-saw guide catheter can be used as an alternative introducer. The saw blade was placed along both edges of the bony bridge and both ends were held with Pean forceps. Reciprocating strokes, as with a Gigli saw, a beveled cut was created (Fig. 2B, C). The full length of the midportion of the saw (diamond-coated part) was used gently; cooling it by irrigation with saline solution during the reciprocating motion. In the creation of the bridge, it should be kept in mind that obtaining a curved cut line with the diamond T-saw is difficult; therefore adjacent curved osteotomies made with the craniotome are important to create the desired cut line(s). It is also important to pull the saw as tangent to the calvarium as possible to create a section ideally suitable for flap fixation. Damage to the scalp by the saw motion should be avoided. While two bridges are adequate, three or more are better for assuring flap stability. A minimal amount of bone wax should be applied to the bridges to avoid disturbing the bony fusion process of the flap. In osteotomy of the orbit and zygoma, we introduced the saw with the aid of a guide catheter that was passed through the burr hole (supraorbital burr hole or MacCarty keyhole that exposes both the supraorbital dura and the orbit) (Fig. 2D), the inferior orbital fissure, or the zygomatic arch.

On closure, small drill holes from the surface of the bone to the cut edge at each corner of the craniotomy were used for flap fixation. Nonabsorbable sutures, 2-0 Surgilon (Covidien/US Surgical, Norwalk, CT), were passed through adjacent holes in the window and flap and tied (Fig. 3A, B). Methylmethacrylate was applied to the burr hole, and the scalp was closed in the usual fashion.

RESULTS

With the diamond T-saw we were able to cut bony bridges at any site, including the thick anterior skull base and calvarium. The number of osteotomy sites using the saw was 2 to 6. The osteotomy required less than 30 seconds per bridge. No technique-related complications such as dural laceration or fracture of the saw were encountered during the procedures.

We followed 50 patients for 1 to 50 months; in 40% the frontal sinuses were opened. None experienced depression, displacement, resorption, or infection of the flap (Fig. 4) or the orbit and zygoma piece.

DISCUSSION

Although screw-fixed titanium plates and rivet-like titanium clamps are used to secure bone flaps, they are expensive, require nonuniform surgical techniques and tools, result in low flap resistance to compression forces, can produce aesthetically objectionable bulges and erosion and tenderness of the scalp over the fixation systems, and they can result in screw loosening and

Figure 3 Tie-down fixation of the large frontal bone flap (A) and the zygoma piece (B) cut by the diamond T-saw. Fitted fixation is obtained at osteotomies created with the saw (arrows).

migration into the cranium, growth restriction of the skull in children, and artifacts on neuroimaging studies.¹⁻⁵ Although bulges in the forehead can be avoided by using specially designed pins inserted in the diploe of the skull,⁷ or by embedding ordinary titanium miniplates into the pit of the outer table,⁸ such methods involve special devices and techniques.

While resorbable plates may solve some of these problems, they are more expensive, are slightly thicker than the metal fixation devices before resorption, and raise the risk of granuloma and sterile abscess formation.^{9,10} The insertion of resorbable plates into the diploe, that is, embedding the plate and minimizing the number of screws,¹¹ may address some problems, however, the required technique is complicated.

Modified techniques of bone flap fixation without artificial materials, that is, bridged craniotomy using a thin-bladed chisel¹² and the insertion of bone chips as shims⁴ yielded satisfactory results but required a high level of technical skills. At bridged craniotomy, it may be difficult to see the tip of the chisel at the dural surface,

Figure 4 Postoperative computed tomography scans of a patient who underwent right pterional craniotomy using a diamond T-saw. The axial view just after surgery (A) shows excellent fitting and curvature of the bone flap achieved with the two bony bridges. Note the saw-cut thin beveled cut lines in the bridges (arrows). At follow-up 28 months after surgery (B) the cut lines had disappeared due to primary bony fusion. There is no flap resorption.

especially if the skull is thick, and the secure and balanced fixation of the flaps by appropriately sized shims is difficult.

To solve these problems, we needed a new simple method that avoided the use of artificial materials for fixation, that is, the creation of self-fitting flaps by using a cutting device that required a minimal bone gap. We found that the T-saw, developed by Japanese orthopedic surgeons in 1996,¹³ was appropriate for this purpose.⁶ It was subsequently introduced in spinal surgery, for example, cervical spine laminoplasty to split the spinous process in the midline with minimal bone gaps and its use has continued to increase.^{14,15} The saw features a soft, flexible, disposable stainless-steel microcable measuring 80 cm in length and 0.36 (small), 0.54 (medium), or 0.81 mm (large) in diameter. To sharpen the blade, the saw has a 20-cm section in the midportion of the wire that is coated with diamond particles; this is known as the diamond T-saw. The diameter of the midportion of each diamond T-saw is 0.46, 0.64, or 0.91 mm. We chose medium-sized saws because the cable is strong enough and the width of the bone gap is acceptable. The disadvantage of the T-saw without diamond coating, that is, the lower cutting speed than that of the Gigli saw due to the smooth surface of the threadwire, was solved with the introduction of the diamond T-saw.

The key to success with our technique is to cut beveled bony bridges. This avoids bone flap depression especially at the thin corners of the flap, for example, in

the temporal region. We changed our initial cutting design, that is, the creation of a narrow bridge with a section almost perpendicular to the calvarium, by producing a wide bridge with a section almost tangent to the calvarium. This proved to be a better means of flap fixation.

Our technique offers several advantages over artificial flap fixation systems. First, as the flap is supported by bridges created with the diamond T-saw, no artificial materials are required to fix the bone flap. The wide bony bridges with minimal bone gaps are ideal not only for assuring matched bone fixation and resisting compression forces,⁴ but also for revitalization and remodeling of the flaps. As revascularization of and osteoblast infiltration into the flaps occur from the adjacent bone edge,¹⁶ the bridges may help these processes. Based on our experience we suggest that the flaps created with the diamond T-saw are protected from resorption and infection, resulting in favorable cosmetic results. Another advantage of our method is its low cost. The price of a diamond T-saw including a guide catheter and a minimum set of metal fixation systems (two metal plates and screws for one small craniotomy) is \$197 and \$938, respectively. One diamond T-saw is usually sufficient for one large craniotomy with several bridges. On the other hand, a large craniotomy that uses conventional craniotomes requires many devices to sustain the flap. Consequently, the cost-effectiveness of our method is

obvious. The additional cost of \$181 for methylmethacrylate to fill the burr holes is acceptable.

A disadvantage of our method is that the craniotomy takes more time; consequently, it is not appropriate in patients who require emergent removal of the bone flap for decompression.

In conclusion, the diamond T-saw is useful for supratentorial craniotomies especially in forehead regions. Our method facilitates the safe, secure fitting of the bone flap, is technically easy, and involves minimal additional costs. Further studies are underway to assess long-term cosmetic outcomes and cost-effectiveness.

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