# Temporal Fascial Periosteal and Musculoperiosteal Flaps in the Pig: Design and Blood Flow Assessment

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**The availability of a vascularized periosteal flap with bone-forming potential could greatly enhance the reconstructive capabilities of the craniofacial surgeon. Previous observations seem to indicate that the bone-forming potential of periosteal flaps depends on the vascularity of the flap. The purpose of the present experiment was to design temporal fascial periosteal and musculoperiosteal flaps in the pig and to compare the periosteal blood flow with unoperated periosteum in the same location. The radioactive microsphere (15-μm diameter) technique was used to measure periosteal capillary blood flow in periosteal flaps and unoperated control, randomized to each side of the head in nine pigs (Yorkshire; weight, 12–14 kg). The periosteum was (1) raised based on the temporalis muscle with vascular supply from the deep temporal vessels (n = 6), (2) raised based on temporoparietal fascia–deep temporal fascia with blood supply from the superficial temporal vessels (n = 6), or (3) left intact (n = 6). The mean periosteal capillary blood flow rates in the intact periosteum (0.107 ± 0.001 ml/min/g), the temporal musculoperiosteal flaps (0.081 ± 0.01 ml/min/g), and temporal fascial periosteal flaps (0.087 ± 0.012 ml/min/g) were not significantly different. These observations indicate that the blood flows for both musculoperiosteal and fascial periosteal flaps were comparable to control intact temporal periosteum.**

*Key Words:* Capillary blood flow, fascial periosteal flaps, musculoperiosteal flaps

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The reconstruction of the growing craniofacial skeleton remains a challenge to the craniofacial surgeon. Present-day techniques of vascularized bone transfer are limited by the anatomical constraints of available donor sites and the structural configurations of the associated bone segments. Optimal reconstruction involves the use of an autogenous tissue with a consistent capability to produce new bone to fill a defect of a specified size and shape. We hypothesized that a vascularized periosteal flap raised in the temporal region may have the potential to fulfill this role.

The temporal region has become an increasingly popular donor site for local reconstruction of the facial skeleton. Several investigators examined the vascular perfusion of the fascial layers of the scalp and calvarium [1-4]. However, the blood supply to the periosteum in the temporal region has not been studied directly.

Previous experimental studies have demonstrated that vascularized periosteal flaps are a potential source of new bone formation [5-12]. These investigators used vascularized periosteum from the limbs [5-7] or ribs [8-12] of several different animal models. In all these studies, an intact vascular supply seemed to be the most important factor for consistent bone formation.

The aims of this study were, therefore, to design different temporal periosteal flaps in the pig and to study vascular perfusion of the temporal periosteum using different flap models. This information is potentially useful in identifying an optimal design for a bone-forming vascularized periosteal flap in the temporal region.

## Materials and Methods

### Animal Management

Yorkshire pigs about 8 weeks old (weight, 12–14 kg) were used. With the exception of other than primate species, the anatomy of the temporoparietal region in the pig most closely resembles that of the human [13]. The pigs were housed in a temperature-controlled (24°C) and

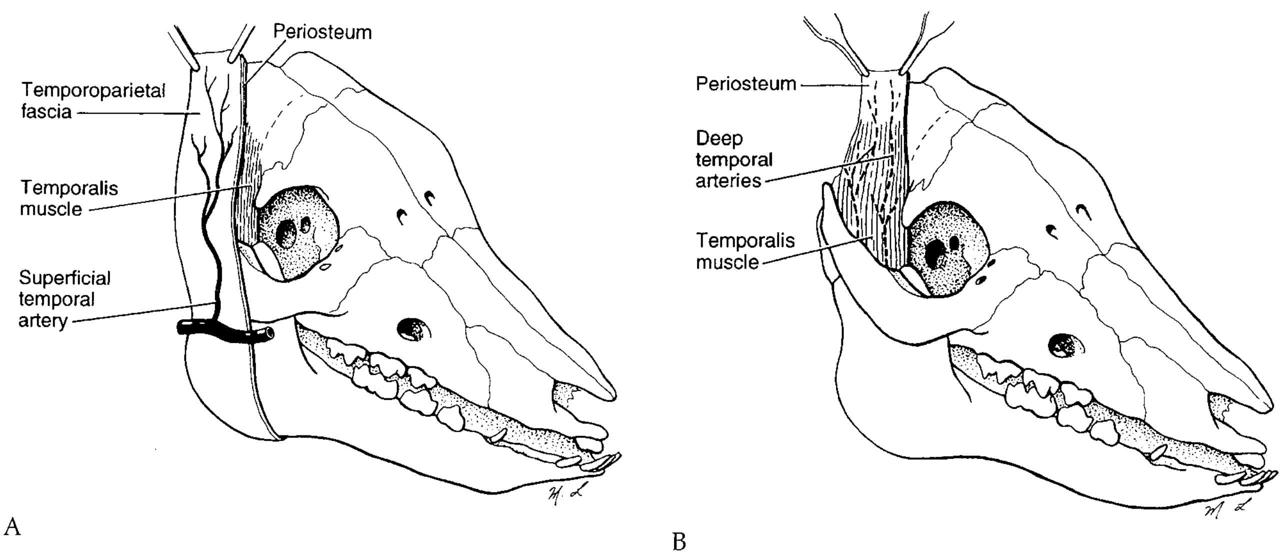


**Fig 1** (A) Fascial periosteal flap. The temporal periosteum is elevated in continuity with the temporoparietal and deep temporal fascia. The temporalis muscle is excluded from the flap. The periosteum obtains its blood supply from the superficial temporal vessels in this design. (B) Musculoperiosteal flap. The temporal periosteum is elevated in continuity with the temporalis muscle. The overlying temporoparietal and deep temporal fasciae are excluded. The periosteum obtains its blood supply from the deep temporal vessels, running on the deep surface of the temporalis muscle, in this flap.

light-controlled (0700–1900 hr) holding room in the Animal Facility at the Hospital for Sick Children in Toronto. The protocol for the present experiment was approved by the animal care committee of the Hospital for Sick Children.

## Flap Design

Two types of temporal periosteal flaps were designed: a fascial periosteal flap and a musculoperiosteal flap.

### *Fascial Periosteal Flap*

A 3 × 3-cm fascial periosteal flap was elevated as a pericranial extension in continuity with the temporoparietal and deep temporal fascia with blood supply from the superficial temporal vessels (Fig 1A).

### *Musculoperiosteal Flap*

A 3 × 3-cm periosteal flap was elevated as a pericranial extension in continuity with the temporalis muscle, vascularized by the deep temporal vessels. The overlying fascia and superficial temporal vessels were excluded (Fig 1B).

## Experimental Design

Nine pigs were used in this study. In each pig, a musculoperiosteal flap (n = 6), fascial periosteal flap (n = 6), or unoperated periosteum (n = 6) was randomized to each side of the head. The animals were anesthetized with ketamine (25 mg/kg intramuscularly) and pentobarbital (30 mg/kg intravenously), intubated with an endotracheal tube (internal diameter = 5 mm), and mechanically ventilated with a mixture of nitrous oxide and oxygen (50-50) by a respirator (Harvard ventilator model 607). A heating blanket was used to maintain constant body temperature. An intravenous catheter was started through an ear vein to infuse isotonic saline (2 ml/min) and pentobarbital (10 mg/kg/hr) to maintain blood volume and satisfactory anesthesia throughout the experiment.

A bicoronal incision was used to gain exposure to the periosteum. The scalp was elevated in the subfollicular plane above the galea. A midline incision was made to create two periosteal flaps (each 3 × 3 cm). In elevating the musculoperiosteal flap, the temporoparietal fascia and temporalis fascia were dissected off the periosteum and muscle. The deep temporal arteries and nerves were preserved on the deep surface of the temporalis muscle. In elevating the fascial periosteal flap, the overlying fascia and superficial temporal vessels were left intact and dissected off the temporalis muscle.

In both flaps the periosteum was sharply dissected off the cranium to include the cambium layer in the flap. A six-hour waiting period was allowed to recover from any vasoconstriction caused by manipulation before blood flows were measured.

## Blood Flow Studies

A quantitative determination of capillary blood flow to the periosteum in each type of flap was made using the

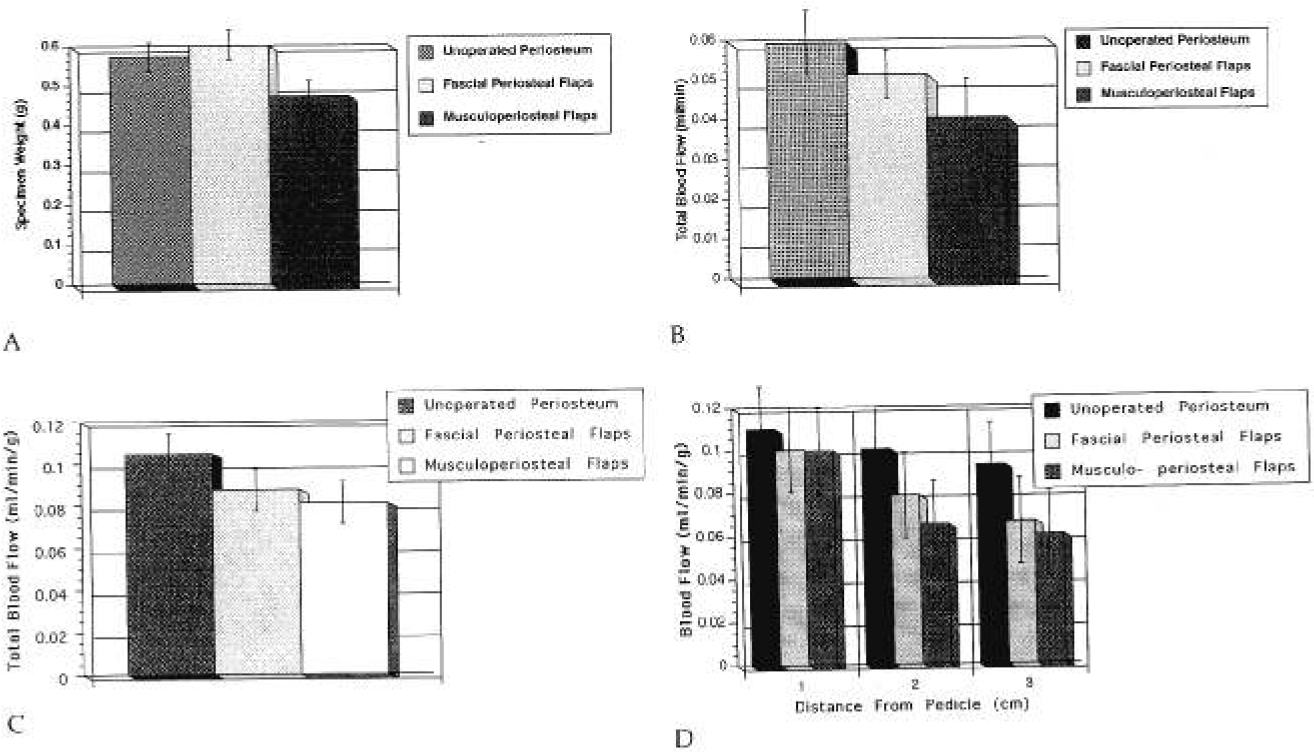


**Fig 2** (A) Periosteal flap weight (3 × 3 cm) (n = 6). Values are the mean ± standard error of the mean. (B) Total periosteal blood flow in each flap design (n = 6). Values are mean ± standard error of the mean. The values are not significantly different. (C) Total periosteal blood flow-flap weight for each flap (n = 6). Values are the mean ± standard error of the mean. The mean values are not significantly different. (D) Segmental periosteal blood flow along each flap (n = 6). Each flap was cut into 1-cm segments, and blood flow was measured in each segment. Values are the mean ± the standard error of the mean.

radioactive microsphere technique. This method is described in detail by us in a previous publication [14]. The left ventricle was catheterized for injection of the microspheres. The left and right femoral arteries were catheterized for monitoring mean arterial blood pressure (Hewlett Packard model 7700) and for collecting reference samples (Harvard syringe withdrawal pump model 940), respectively.

The microspheres of diameter 15.7 ± 0.5-μm (New England Nuclear, Boston, MA) were suspended in 10 ml of 0.9% saline containing 5% sucrose and 0.05% Tween 80. They were then subjected to 5 minutes sonication and were swirled vigorously for 1 minute before injection. The withdrawal pump (set at 4.1 ml/min) was turned on 10 seconds before and 60 seconds after injection of microspheres. The reference blood sample collected in the syringe of the withdrawal pump was transferred to counting vials. The animal was then killed using an overdose of pentobarbital (100 mg/kg). The periosteal flaps were removed from both sides. Each flap was cut transversely into 1-cm segments, and the radioactivity of the periosteum and the blood samples was determined using a gamma counter (Beckman model 8000). The segmental and total blood flow for each periosteal flap was then calculated.

One-way analysis of variance was used to detect treatment effect on periosteal blood flow, and Duncan's multiple-range test was used for multiple comparison of means. A probability of less than 0.05 was considered significant.

## Results

The mean arterial blood pressure at the time of blood flow studies for the nine pigs was 110 ± 5 mm Hg. The flap weights of periosteum in the unoperated sites (control), fascial periosteal, and musculoperiosteal flaps were not significantly different (Fig 2A). Mean total blood flows for each flap design and control are shown in Figure 2B. Once again, these values were not significantly different. Similarly, the periosteal blood flows normalized to wet tissue weight were also similar among these three groups (Fig 2C). Mean segmental blood flow at each centimeter along the flap is plotted in Figure 2D. Although the observed trend was for a greater segmental and total blood flow to the fascial periosteal flap, this difference was not significant. Both segmental and mean total blood flow for the various flap designs were not significantly different than intact periosteum. This suggests that the temporal periosteum may be vascularized using either flap design.

## Discussion

Our study has demonstrated that in this pig model a vascularized periosteal flap can be raised based on the temporalis muscle and deep temporal vessels or based on the overlying fascia pedicled on the superficial temporal vessels. In addition, we have demonstrated that the blood flow to the periosteum in both of these flap designs was not significantly compromised compared with control intact temporal periosteum. Blood supply is considered the most important factor in periosteal flap osteogenesis. These findings are, therefore, important in determining the prospect of consistent bone-forming capability in these flaps.

The anatomy of the human temporoparietal region is very close to that of the pig. It is often misunderstood, however, because of a plethora of confusing nomenclature. Immediately deep to the hair follicles of the skin is the superficial temporal or temporoparietal fascia. This thin, highly vascular connective tissue is continuous with the subcutaneous musculoaponeurotic system in the face and with the galea in the scalp [1]. Beneath the temporoparietal fascia lies a dense collagenous layer surrounded by vascularized areolar tissue. This loose connective tissue layer is continuous throughout the scalp and has been termed "the subgaleal fascia" [15]. As the subgaleal fascia is reflected, a thin layer of fat is found in its inferior extent. This has been called the superficial temporal fat pad and is variable in size [16]. The next layer is a dense, tough uniform structure that invests the temporalis muscle. This deep temporal fascia (temporal fascia, temporalis fascia) extends from the upper end of the zygomatic arch to fuse with the skull periosteum at the superior temporal line [1]. Between the temporal fascia and the muscle is the deep temporal fat pad [15]. The periosteum of the skull or pericranium is the innermost layer of the scalp. Anteriorly, it is continuous with the periorbita, and laterally it fuses with the deep temporal fascia at the superior temporal lines.

The blood supply of the various layers of the human scalp has been studied in cadavers. In the temporoparietal region, the blood supply is derived from the superficial and deep temporal vessels. The superficial temporal artery (STA) runs superiorly usually within the temporoparietal fascia. It supplies this layer and the subgaleal fascia [15]. It also gives off a middle temporal branch around the level of the zygomatic arch that supplies the deep temporal fascia [1]. The STA was also noted to give off perforators down to the calvarium beyond the superior temporal line [2–4]. The deep temporal arteries branch off the internal maxillary artery in the infratemporal fossa. They supply the temporalis muscle running on its deep surface. The vascular perfusion of the human skull periosteum has not been studied directly.

However, McCarthy and Zide [17] and later Psillakas and colleagues [18] examined the vascular perfusion (in cadavers) and clinical uses of vascularized calvarial bone flaps. In these studies, the outer calvarium was based on its periosteal blood supply. In their work, at least two types of calvarial flaps were designed. One was based on the temporalis muscle deriving its blood supply from the deep temporal vessels. The other was based on the temporoparietal with or without deep temporal fascia, pedicled on the superficial temporal vessels. The fascial flap is advantageous for a number of reasons: (1) It has a wider arc of rotation; (2) it avoids the transfer of the temporalis muscle; (3) it has the capability for free tissue transfer. Abdul-Hassan and associates' [1] work showed the consistent presence of the superficial temporal vessels. The length of the vascular pedicle was 2.1 to 6.0 cm. Clinically, temporal fascial free flaps based on these vessels have been used in difficult lower limb and hand reconstruction [19–21].

A fascial periosteal flap with bone-forming capability and the potential for free tissue transfer would be very advantageous. In our pig model, the temporal periosteum could be perfused equally well by either the deep temporal vessels or the superficial temporal vessels. These findings will have direct implications in future studies evaluating osteoneogenic potential of temporal periosteal flaps. It is also hoped that it will stimulate future investigation into the vascular perfusion of human pericranium.

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This article was presented at the Fifth International Congress of the Society of Craniofacial Surgery, Oaxaca, Mexico, October 1993. This work was supported by grants from the Hospital for Sick Children Foundation and the Combined American Academy of Otolaryngology Head and Neck Surgery-Plastic Surgery Education Foundation Award.

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