ORIGINAL ARTICLE

Resorption Beneath Silastic Mandibular Implants

Effects of Placement and Pressure

David C. Pearson, MD; David A. Sherris, MD

Objective: To evaluate the extent to which silicone rubber mandibular implant (Silastic; Dow Corning, Midland, Mich) pressure and placement (supraperiosteal or subperiosteal) affect underlying mandibular resorption.

Design: A randomized, controlled animal trial.

Subjects: Ten mixed-breed adult hounds.

Interventions: Each animal's mandible was implanted with 6 Silastic blocks, 3 inserted supraperiosteally and 3 subperiosteally. Within each grouping of 3 implants, pressure was varied from "minimum" to "moderate" to "maximum" by compressing the implant with titanium miniplates. After 4 months, the animals were killed and their mandibles sectioned for microscopic examination.

Results: Mandibular resorption occurred in varying degrees beneath all implants by the end of the study period. The extent of resorption was consistent with retrospective studies in humans. No statistically significant difference was found between supraperiosteal or subperiosteal placement of the implants. However, higher-pressure implants tended to produce less resorption than lower-pressure implants.

Conclusions: While some bone resorption seems inevitable with Silastic mandibular implants, these results would seem to suggest that the placement of implants above or below the periosteum need not be a concern for the surgeon attempting to minimize this consequence. On the other hand, increased pressure may actually decrease resorption, contrary to current assumptions.

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FACIAL AUGMENTATION with alloplastic implants is a commonly performed procedure in facial plastic surgery. Silicone rubber (Silastic; Dow Corning, Midland, Mich), because of its ability to be easily sculpted and its availability in a variety of preformed shapes and sizes, is a popular implant material. Nevertheless, there is concern regarding resorption of the underlying mandible. Robinson and Shuken,[1] and Robinson[2] first reported bone resorption under Silastic and acrylic implants. They found that 12 of the 14 patients studied showed mandibular resorption beneath their implants. Most patients showed up to 3 mm of resorption at an average of 30 months postoperatively, and several showed up to 5 mm of resorption at an average of 48 months.[1] This corresponds to roughly 0.1 mm per month.

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Subsequent studies have confirmed that resorption occurs to varying degrees in many if not all patients.[3,4] There is concern that resorption of underlying bone may lead to loss of chin projection or even that implants may erode to the mandibular tooth roots. Speculation on this phenomenon has led investigators to implicate both the placement of the implant (subperiosteal or supraperiosteal) and the pressure of the implant. Nearly all the studies have been clinical ones, either longitudinal prospective studies or retrospective analyses. Only 1 prospective animal study has addressed the issue of the implant's relation to the periosteum, suggesting that a supraperiosteal placement is preferred.[5] No study has specifically addressed or controlled for pressure effects.

From the Mayo Medical School, Division of Facial Plastic Surgery, Department of Otorhinolaryngology, Mayo Clinic, Rochester, Minn.

RESULTS

Load cell data from the Silastic blocks confirmed a highly linear relationship between strain and force exerted by the implant within the range used in the experimental setup. The Silastic blocks were found to exert approximately 300 kPa of pressure for each millimeter of axial strain.

All 10 animals enrolled were available at the conclusion of the study period. One animal developed a small seroma postoperatively that resolved without intervention. Of the 60 implants initially placed, 3 were displaced laterally from their initial im-

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MATERIALS AND METHODS

Uniform cylinders of Silastic 4 mm in diameter by 5 mm high were cut from medical grade Silastic used for actual chin implants (20A Durometer silicone blocks; Bentec Medical, Sacramento, Calif). These cylinders would serve as our experimental implants. To determine its stress-strain properties, each cylinder was compressed on a hydraulic press, and the pressure exerted on a load cell was recorded.

Ten mixed-breed adult hounds weighing 25 to 35 kg were used as subjects in full accordance with protocols established by the Institutional Animal Care and Use Committee at Mayo Medical Center, Rochester, Minn, and all phases were overseen by the institution's veterinarians and veterinary technicians. Each animal was anesthetized with general inhalational anesthesia and its neck and jaw sterilely prepared and draped. Incisions were made parallel to the inferior border of each mandible laterally and carried down to the mandibular periosteum. The periosteum on the right side was elevated while the periosteum on the left was kept intact, thus permitting each animal to serve as its own control with respect to supraperiosteal or subperiosteal placement. The sterilized cylindrical implants were then placed at equal intervals along each side of the mandible, 3 per side (**Figure 1** and **Figure 2**). On each side, pressure and fixation of the implants were achieved by spanning each implant with a 3-hole, 1.5-mm titanium miniplate (Synthes Maxillofacial, Paoli, Pa) and screwing down each plate to a fixed height from the mandibular surface of either 5, 4, or 3 mm (**Figures 3**, **4**, and **5**). The exact order was randomized among the animals, but each animal received 6 implants: a minimally, moderately, and maximally compressed implant on both the supraperiosteal and subperiosteal sites. To prevent lateral displacement of the implant, once compressed, each implant was surrounded by a loosely tied 3-0 nylon suture, which also encircled the screws of the miniplates (**Figure 6**). Each wound was copiously irrigated and closed in layers with chromic catgut.

After 4 months, the animals were killed in accordance with Institutional Animal Care and Use Committee guidelines and the recommendations of the Panel of Euthanasia of the American Veterinary Medical Association by intravenous injection of a lethal dose of sodium pentobarbital in 10% isopropyl alcohol. Each of the mandibles was harvested, the implants and hardware removed, and the implant sites sectioned through the midpoints of the implant sites (**Figure 7** and **Figure 8**). These sites were then examined under a dissecting microscope fitted with an ocular micrometer (**Figure 9**).

Observations were made in a blinded fashion, measuring from the maximum depth of resorption to a line continuous with the unaffected surrounding bone. Results were statistically analyzed using the generalized estimation equation.

plant site and thus their data were not recorded (1 supraperiosteal maximum pressure implant, and 2 subperiosteal maximum pressure implants).

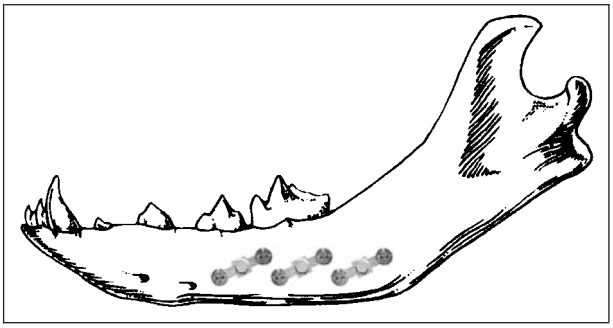

Figure 1. *Schematic side view of implant placement.*

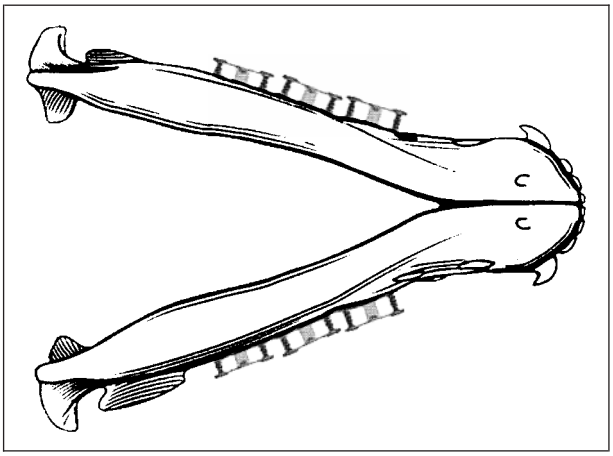

Figure 2. *Schematic bottom view of implant placement.*

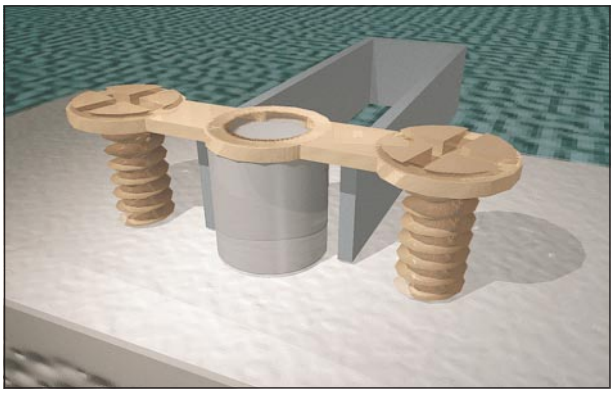

Figure 3. *Schematic of Silastic implant in place on a dog's mandible. A shim was used to set compression height represented by a U-shaped structure in the figure.*

Univariate analysis of the effects of placement (**Figure 10**) indicated no difference in resorption between supraperiosteal and subperiosteal placement ($P = .66$). Also, multivariate analysis considering pressure and placement together (**Figure 11**) indicated no significant interaction effects of placement and pressure ($P = .62$). In contrast, univariate analysis of the effects of pressure alone (**Figure 12**) indicated that higher pressure tended to result in less resorption ($P = .09$).

COMMENT

Alloplastic materials for facial augmentation offer several advantages including, but not limited to, conve-

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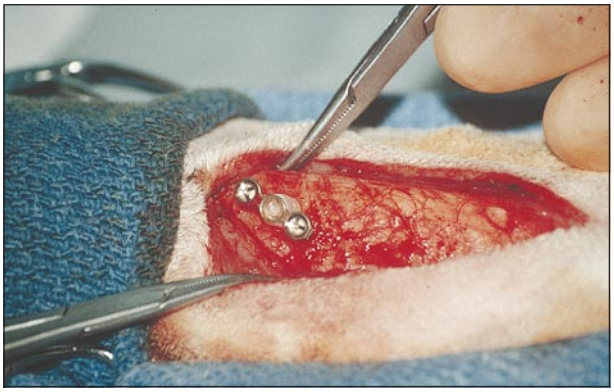

Figure 4. *Intraoperative view of Silastic implant in place with titanium miniplate fixation to provide pressure (supraperiosteal placement in this example).*

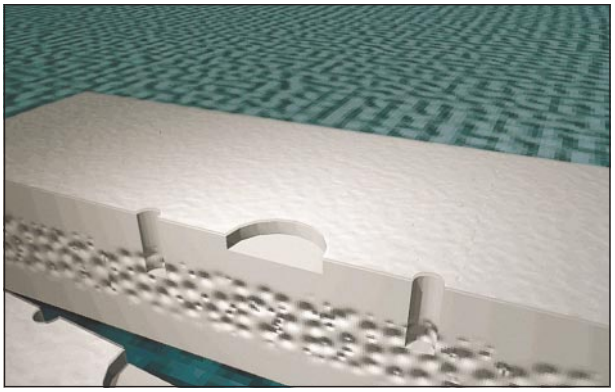

Figure 7. *Schematic view of a single implant resorption pit after hardware removal and sectioning of the mandible. The thin pits laterally represent the drill holes from the titanium screws.*

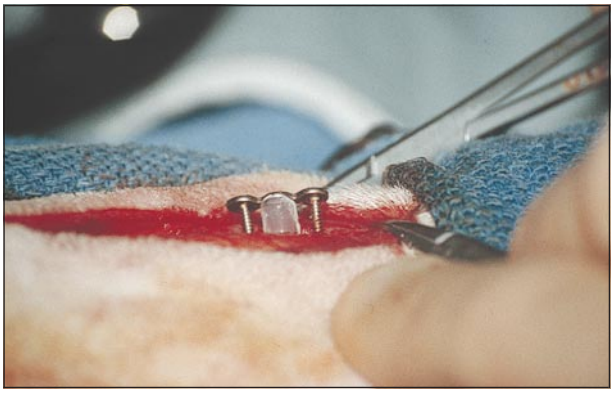

Figure 5. *Side view of implant in place.*

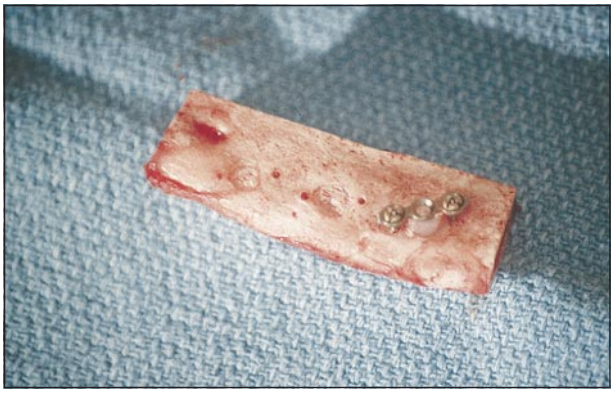

Figure 8. *Gross photograph of harvested mandible with hardware partly removed. Two resorption pits can be seen to the left of the remaining implant.*

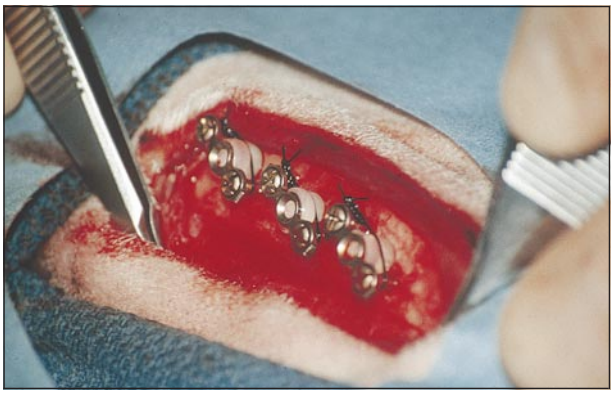

Figure 6. *All implants on one side of dog's mandible in place. Nylon suture tied around the implants provided lateral stabilization.*

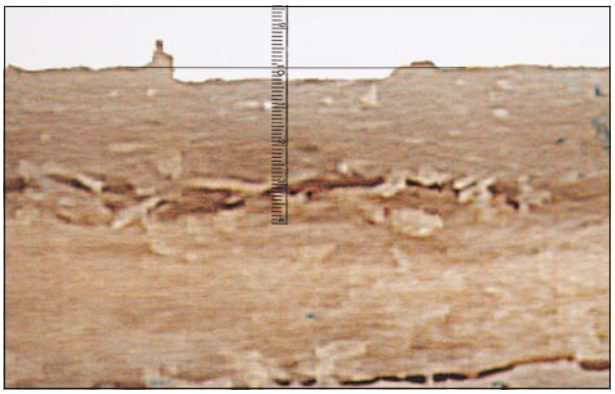

Figure 9. *Photomicrograph of the implant pit in cross-section with superimposed micrometer scale (original magnification ×10).*

nience, permanence, and avoidance of a donor site wound. On the other hand, bone resorption beneath alloplastic implants of all types is a well-recognized phenomenon. The factors influencing this resorption have not been thoroughly elucidated. With respect to chin augmentation, the specific alloplast used as well as the age or sex of the patient has been shown not to affect resorption. Of the factors suspected of causing resorption, pressure and placement with respect to the periosteum have been the most commonly implicated.

In light of this study, it is understandable why no clear consensus exists regarding the effect of placement relative to the periosteum; it seems that there is no difference. We speculate that this may be the result of pressure necrosis of the periosteum underlying an implant placed supraperiosteally, or it may be due to the trauma the periosteum almost inevitably sustains during dissection. Our study suggests that the implant may be placed on or beneath the periosteum at the surgeon's discretion.

Perhaps the least expected result of this experiment was the data comparing the effects of pressure on resorption. It has been suspected since the landmark article by Robinson and Shuken[1] on the subject that pressure correlates directly with resorption. They theorized that greater

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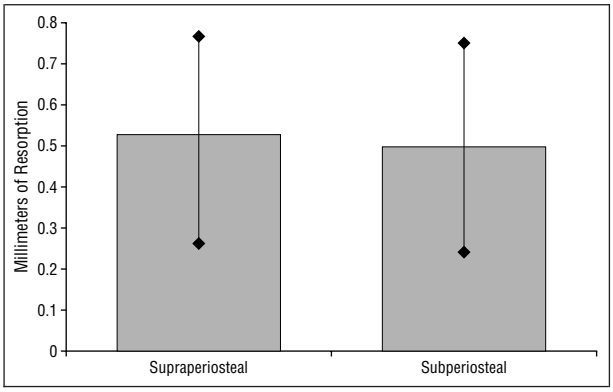

Figure 10. *Comparison of resorption between supraperiosteal and subperiosteal implants.*

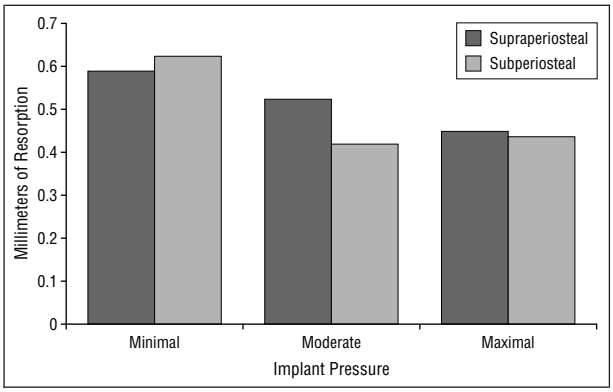

Figure 11. *Comparison of resorption between supraperiosteal and subperiosteal implants within each pressure category.*

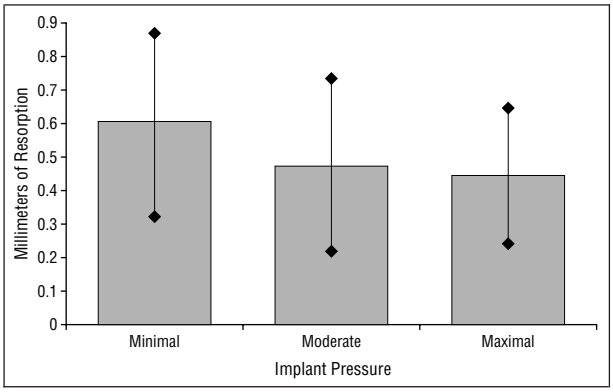

Figure 12. *Comparison of resorption by pressure category only.*

pressure (exerted by a large implant or mentalis muscle strain) resulted in greater resorption. Other authors have come to the same conclusions based on their clinical experience and intuition.

Our data, in contrast, suggest the exact opposite, ie, that greater pressure exerted by the implant resulted in less resorption. And while our statistical analysis of this data, given our limited sample size, did not reach the level of statistical significance (ie, $P = .05$), the P value of .09 strongly suggests this tendency. Certainly there is ample physiologic data to explain this effect.

The phenomenon of bone resorption cannot be likened simply to that of wearing away a surface as though it were some lifeless substance. It is well recognized that living bone reacts to mechanical stress not by eroding away, but rather by depositing actively mineralizing bone at sites of compression and actively resorbing bone at sites of distraction or lack of stress. Several mechanisms by which mechanical strain enhances osteogenesis have been proposed, including "prostaglandin release, piezoelectric and streaming potentials, increased bone blood flow, microdamage and hormonally mediated mechanisms."[6] Consider the remodeling of a broken femur that is set such that the fracture site is angulated: when subjected to loading, bone is deposited at the concave (compressed) surface and resorbed at the convex (distracted) surface.[7] More relevant to this discussion, consider the resorption of the edentulous mandible no longer subject to daily compressive bite forces. This underlying physiology seems to agree with our findings of less resorption with more bone loading by the implant: bone does not yield to compression, rather it pushes back. This can additionally explain the often-observed effect that bone resorption may be self-limited. This may be due to the greater forces exerted by scar contraction over the implant pressing it onto the bone rather than by a settling-in effect suggested by others.

CONCLUSIONS

The results of our study show that bone resorption beneath silicone rubber mandibular implants does not seem to correlate with placement relative to the mandible's periosteum. Furthermore, in distinct contrast to popularly held beliefs that mandibular bone resorption is related directly to implant pressure, we found the opposite tended to be true. This would imply that surgeons need not worry about a larger implant causing excessive resorption, and that the surgeon may choose placement supraperiosteally or subperiosteally based on his or her preference.

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Reprints: David A. Sherris, MD, Mayo Clinic, 200 First St SW, Rochester, MN 55905 (e-mail: sherris.david@mayo.edu).

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