Authors have nothing to disclose with regard to commercial support.

nonabsorbable hemostatic agents whose residual matters would impair bone healing were excluded. Bridging the radiolucent gap by osteoinductive materials might be a potent adjuvant treatment in addition to the rigid fixation.

The second-generation fixation device used in the report of Allen and colleagues¹ achieved excellent long-term outcomes without any late complications requiring plate removal as late as 6 months after the fixation.¹ Implant failures from metal fatigue, less flexibility, and chronic pain are likely to occur after chest wall osteosynthesis, however, especially in osteoporotic or obese patients with anteriorly placed implants,⁴⁻⁶ which suggests that long-term observation longer than 6 months may be necessary to validate the rigid fixation. One of these causes is associated with repeated and concentrated load at one point on a plate, and to minimize potential harmful effects, biomaterials with good biocompatibility and optimal mechanical properties that can correspond to the flexible respiratory movements are therefore desirable, and they will also facilitate repeated sternotomies because of the minimal reactions to the normal tissues.

Finally, we have one question concerning reoperation. The method reported by Allen and colleagues¹ requires at least 10 screws on one side of the sternum. In reopening cases, rigid fixation has to be achieved again with the potholed sternum caused by the first screwing. Because reopening after rigid fixation was not described in detail,⁶ we request the technical details regarding reopening and refixation.

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References

1. Allen KB, Thourani VH, Naka Y, Grubb KJ, Grehan J, Patel N, et al. Randomized, multicenter trial comparing sternotomy closure with rigid plate fixation to wire cerclage. *J Thorac Cardiovasc Surg*. 2017;153:888-96.e1.
2. Sakai A, Oshige T, Zenke Y, Menuki K, Murai T, Nakamura T. Mechanical comparison of novel bioabsorbable plates with titanium plates and small-series clinical comparisons for metacarpal fractures. *J Bone Joint Surg Am*. 2012;94:1597-604.
3. Hamaji M, Sakaguchi Y, Matsuda M, Kono S. Reinforced closure of the sternum with absorbable pins for high-risk patients. *Interact Cardiovasc Thorac Surg*. 2009;9:559-61.
4. Berthet JP, Gomez Caro A, Solovei L, Gilbert M, Bommart S, Gaudard P, et al. Titanium implant failure after chest wall osteosynthesis. *Ann Thorac Surg*. 2015;99:1945-52.
5. Grabert S, Erlebach M, Will A, Lange R, Voss B. Unexpected results after sternal reconstruction with plates, cables and cannulated screws. *Interact Cardiovasc Thorac Surg*. 2016;22:663-7.
6. Roughton M, Agarwal S, Song DH, Gottlieb LJ. Rigid sternal fixation in the management of pediatric postmedian sternotomy mediastinitis: a 20-year study. *J Plast Reconstr Aesthet Surg*. 2015;68:1656-61.

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STEEL AND BONES: A PERFECT UNION?

Reply to the Editor:

The principles of fracture and osteotomy management include reapproximation and stabilization through rigid fixation of the bone.

The study by Allen and colleagues¹ suggests that strict adherence to these principles through application of rigid plate fixation (RPF) can lead to both improvement in radiographic sternal healing (primary end point) and lower rates of sternal complications (secondary outcome) compared with traditional wire cerclage (WC). This suggests that RPF leads to enhanced mechanical stabilization and immobilization of the bone compared with WC.

Yutaka and colleagues highlight an important aspect in bone wound healing: biocompatibility and osteoconduction. The most common materials with osteoconductive properties include calcium sulfate and calcium phosphate, allowing for the process of passive bone tissue regeneration.² However, the search for the perfect biomaterial to promote bone healing and to restore function while remaining biologically stable dates back to the 18th century in the field of restorative dentistry.³ The use of ceramics to restore the physical appearance and function of teeth continues to evolve from using cadaveric teeth to injectable biocompatible bone substitutes that promote osteoconduction.^{4,5} Similar to dentistry, situations arise in trauma and orthopedics when there is a need for osteoconductive material to treat fractures associated with tissue loss or contaminated wounds (ie, compound fractures or osteomyelitis).⁶

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Although a full review of osteoconductive material is beyond the scope of this letter, the role of biocompatibility in sternal healing remain limited to early clinical phase 1 and 2 evaluation studies in healthy individuals. Yutaka and colleagues suggest that the use of biomaterials may optimize sternal healing through being more physiologically adaptable to chest-wall movement. A single arm study of 51 patients examined bioresorbable pins placed into the sternal marrow as an adjunct to conventional WC and showed a lower than expected sternal infection rate of 2% compared with the predicted 4%.⁷ In a retrospective cohort study of 75 patients who underwent aortic surgery, bioresorbable osteoconductive pins were compared with nonosteoconductive pins. Although there was significant increase in cortical bone density area on radiographic examination, there was no difference in sternal complication rates or rate of sternal healing at 12 months between the 2 groups.⁸ A small randomized clinical trial (RCT) examined bone cement applied to 2 sternal edges demonstrated benefits in surrogate outcomes of improved respiratory mechanics, reduced narcotic use, and improved sternal healing on radiography.⁹ Similar to the study by Allen and colleagues,¹ these studies highlight the need for larger RCTs to evaluate these interventions with clinically relevant primary end points.

An extension of the role of biocompatible material includes using the bone scaffold to locally deliver antibiotics at the site of the sternotomy. However, local application of antibiotics has not been successful to date, given the challenges in maintaining an effective concentration of antibiotics over time.¹⁰ With the advent of nanoparticles, delayed release of antibiotics over months to maintain the minimum inhibitory concentration to prevent bacterial growth until the sternum heals may be achieved in an effort to prevent deep sternal wound infections.¹¹ Given that Medicare has deemed deep sternal wound infections as a “never event,” osteoconductive compounds may be a valuable adjunct to both WC and RPF. Furthermore, the impregnation of antimicrobial agents within biodegradable carriers with osteoconductive properties could provide the means for 1-stage surgical treatment of osteomyelitis by filling the tissue defect and treating the infection simultaneously.

We thank Yutaka and colleagues for reiterating the importance of biocompatibility and emphasizing that the process to achieving perfect union may require more than just steel and bones. However, further evaluation of these agents in the form of an RCT is required to demonstrate both benefit in reduced sternal complications and improvement in quality of life, and rigorous cost analyses are necessary to assess the cost-effectiveness of these adjuncts.

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References

1. Allen KB, Thourani VH, Naka Y, Grubb KJ, Grehan J, Patel N, et al. Randomized, multicenter trial comparing sternotomy closure with rigid plate fixation to wire cerclage. *J Thorac Cardiovasc Surg*. 2017;153:888-96.e1.
2. Roberts TT, Rosenbaum AJ. Bone grafts, bone substitutes and orthobiologics: the bridge between basic science and clinical advancements in fracture healing. *Organogenesis*. 2012;8:114-24.
3. Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: historical roots and current perspectives. *J Prosthet Dent*. 1996;75:18-32.
4. Weiss P, Layrolle P, Clergeau LP, Enckel B, Pilet P, Amouriq Y, et al. The safety and efficacy of an injectable bone substitute in dental sockets demonstrated in a human clinical trial. *Biomaterials*. 2007;28:3295-305.
5. Baino F, Novajra G, Vitale-Brovarone C. Bioceramics and scaffolds: a winning combination for tissue engineering. *Front Bioeng Biotechnol*. 2015;3:202.
6. Masrouha KZ, El-Bitar Y, Najjar M, Saghi S. Epithelialization over a scaffold of antibiotic-impregnated PMMA beads: a salvage technique for open tibial fractures with bone and soft tissue loss when all else fails. *Arch Bone Jt Surg*. 2016;4:259-63.
7. Hamaji M, Sakaguchi Y, Matsuda M, Kono S. Reinforced closure of the sternum with absorbable pins for high-risk patients. *Interact Cardiovasc Thorac Surg*. 2009;9:559-61.
8. Fu X-M, Oshima H, Araki Y, Narita Y, Mutsuga M, Okada N, et al. A comparative study of two types of sternal pins used for sternal closure: poly-L-lactide sternal pins versus uncalcined hydroxyapatite poly-L-lactide sternal pins. *J Artif Organs*. 2013;16:458-63.
9. Fedak PWM, Kieser TM, Maitland AM, Holland M, Kasatkin A, Leblanc P, et al. Adhesive-enhanced sternal closure to improve postoperative functional recovery: a pilot, randomized controlled trial. *Ann Thorac Surg*. 2011;92:1444-50.
10. Lazar HL, Barlam T, Cabral H. The effect of topical vancomycin applied to sternotomy incisions on postoperative serum vancomycin levels. *J Card Surg*. 2011;26:461-5.
11. Gu J, Wang T, Fan G, Ma J, Hu W, Cai X. Biocompatibility of artificial bone based on vancomycin loaded mesoporous silica nanoparticles and calcium sulfate composites. *J Mater Sci Mater Med*. 2016;27:64.

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