Bone Wax in Neurosurgery: A Review

Joe M. Das

Key words
- Bone
- Bone wax
- Hemostasis
- Neurosurgery
- Review literature
- Waxes

Abbreviations and Acronyms
BW: Bone wax
PEG-PPG-PEG: Polyethylene glycol—polypropylene glycol—polyethylene glycol

Department of Neurosurgery, College of Medical Sciences—Teaching Hospital, Chitwan, Nepal

To whom correspondence should be addressed: Joe M. Das, M.Ch. (Neurosurgery) [E-mail: drjoemdas@gmail.com]

Citation: World Neurosurg. (2018) 116:72-76. https://doi.org/10.1016/j.wneu.2018.04.222

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

It has been 125 years since the so-called initial use of bone wax (BW) by Sir Victor Horsley, and a review of this age-old hemostatic agent seems appropriate. The first use of BW for hemostasis occurred in the eighteenth century, when modeling or candle wax was used for hemostasis. Although the pioneers in the use of BW in craniofacial surgeries were Jean Louis Belloq, Khristian Khristianovich Salomon, and François Magendie, the first successful use in neurosurgery was demonstrated by Henri Ferdinand Dolbeau in 1864 after extirpation of a frontal osteoma. This technique was further popularized by Sir Victor Alexander Haden Horsley, the father of British neurosurgery, who is often incorrectly mentioned as the inventor of BW. Originally derived from beeswax, the currently available commercial preparation also contains paraffin wax and isopropyl palmitate. The main action being mechanical tamponade, BW has found several other uses in neurosurgery, other than being a hemostatic agent. Although it is cost-effective, the use of BW is associated with several complications also, including ineffective bone healing and infection. Several alternatives are being developed, but none are yet a full replacement for "Horsley's wax."

INTRODUCTION

Bone wax (BW) is a widely used hemostatic agent in both cranial and spinal surgeries. It is mesmerizing to watch the heavy gush of blood from a diploic vein during a craniotomy being controlled by the prompt application of BW. Frequently, however, BW is used unnecessarily to control minute bone bleeding. Thus, a question has been raised in several specialties and surgeries, especially spine surgeries: Is the use of BW really indicated? This question is important because the use of BW has been associated with numerous complications, especially defective bone healing. Hence, many other alternatives are being developed and tried. We aim to review all the characteristics, uses, and complications associated with the use of BW, especially in relation to neurosurgery.

HISTORY

Henri-Ferdinand Dolbeau (1830—1877), the Professor of External Pathology and Surgeon of Paris Hospitals, was the first person to use BW for neurosurgery. He was the first surgeon to extirpate a frontal osteoma and use BW for the same in 1864.[1] For experimental purposes in closing the venous sinuses, even Magendie (1783—1855) had used BW previously.[2] It has been documented that unadulterated beeswax was used for amputation stump hemostasis during the American Civil War (1861—1865).[3] Sir Victor Alexander Haden Horsley (1857—1916) popularized the use of BW as a hemostatic agent after experimenting on cranial bones of dogs in 1885.[4] He modified his preparation of BW with the help of an Oxford Street pharmacist named P.W. Squire, as the original one was not meeting the standard of modeling wax.[5] The first documented use of this modified BW was by Rushton Parker, who reported its use in craniocervical surgery in 1892 for chronic suppurative otitis media with sigmoid sinus and jugular vein thrombosis.[6] Since this period, the term *Horsley's wax* remained synonymous with BW, although several modifications in its composition occurred over 125 years. Many Russian neurosurgeons argue that the formulation was developed and introduced into neurosurgery as early as the 1850s by surgeons in Moscow. In addition, some hospitals in Russia continue to prepare beeswax according to the original nineteenth-century formula.[7] In the 1924 edition of *Carson's Modern Operative Surgery*, the use of BW is recommended not for bone hemostasis—the currently prevalent application—but for preventing bone healing and for the creation of a pseudoarthrosis.[8] There has not been a significant change in the formulation of BW since 1924. The material is still composed of insoluble and nonresorbable beeswax softened with paraffin or isopropyl palmitate, or both.

COMPOSITION AND INGREDIENTS

Beeswax (cera alba; melting point ≈ 60°C), the main ingredient of BW, is secreted by wax glands of worker bees of the genus *Apis* and is used in the construction of hive. Chemically, BW comprises waxlike polyester oligomers of lower hydroxycarboxylic acids that range from viscous fluids to solids at room temperature.[9]

BW is a sterile mixture of 85%—90% white beeswax and 10%—15% isopropyl palmitate, a palm oil-based emollient, moisturizer, and thickening and antistatic agent used as a wax solvent.[10] In addition,

Table 1. Alternative Products and Improvisations to Bone Wax

Product	Composition	Advantages over Bone Wax
Ostene or AOC bone wax[35]	Water-soluble alkylene oxide copolymers derived from ethylene and propylene oxide	• Inert • Not metabolized; eliminated from the body over time • Decreased rates of infection and tissue reaction
Hemasorb[36]	Mixture of calcium stearate, vitamin E acetate, and liquid surfactant	• Absorbable (within 30 days) • Spreads easily with minimal adhesion to gloves • Biocompatible • Allows strong bone adhesion • Water resistant • Requires no kneading
Surgifoam[36]	Absorbable porcine gelatin sponge composed of a sodium chloride solution from oxidized regenerated cellulose	• Rapid hemostasis • Large absorbing ability • Water soluble • Malleable for ease of handling
	Bioactive glass/chitosan/carboxymethyl cellulose composite scaffold[37]	• Excellent biocompatibility • No cytotoxicity • Dominant role in bone regeneration and hemostasis
	PEG-PPG-PEG copolymer mixtures and pregelatinized starch at 0% and 25% by weight[38]	• Resorbed within 2 days • As effective as the commercial bone wax in hemostasis • Better adherence to the bone surface • The incorporation of pre-gelatinized starch further helps in improved molding texture and decreased glove adherence • Does not inhibit the osteogenesis
Absele[39]	Stabilized fibrin and soluble collagen	• Absorbed totally within 3 weeks • Minimal tissue reaction
Calcium phosphate cement[40]	Hydrophilic polyethylene glycol and hydroxyapatite	• Self-setting • Mechanical performance is comparable to that of cancellous bone
Auto suture bone wax[41]	Mixture of glycolide, caprolactone, mannitol and G-tricalcium phosphate	
Gelatin based bone wax[42]	Gelatin powder added to rifamycin	• Better sternal wound healing after cardiac surgery
	Microporous polysaccharide hemospheres[43]	• Not detected in postoperative imaging as early as day 1 • No tumor-mimicking contrast enhancement. • Do not inhibit bone healing
	Polyethylene glycol/microfibrillar collagen[44]	• Excellent bony hemostasis • Does not inhibit bone growth
Pluronic implants[45]	90% Pluronic P85/10% Pluronic F88	• Handling properties similar to those of bone wax • Readily achieves hemostasis • Does not inhibit bone regrowth
OsteoStat[46]	Hydroxyapatite and biodegradable poly-lactic acid	• Higher amount of bone growth • Easily sterilized • Biocompatible • Immunogenic and allergen free, as it does not contain biological components

Continues

Table 1. Continued

Product	Composition	Advantages over Bone Wax
Vancomycin cream[47]	Vancomycin	• Prevents infection
	Hydroxyapatite, chitosan and starch[48]	• Excellent biocompatibility • Mechanical stability • Antibacterial property
Monopolar electrocautery		• Useful for small bone bleeders

AOC, alkylene oxide copolymer.

commercially available BW may contain up to 30% soft paraffin wax as a softening agent.

MECHANISM OF ACTION AND CHEMICAL PROPERTIES

BW coats the bleeding bone surfaces and forms mechanical tamponade for the blood to ooze out. The hemostatic effect of BW is based on its physical properties; it acts as a tamponade by stopping the blood flow from damaged vessels in the trabecular bone and thereby facilitates clot formation.

Optimum working temperature is 70°–74°F (21°–23°C).[11] BW should be used immediately after removal from the package. Using aseptic technique, BW should be warmed to the desired consistency by manipulation with the fingers or by immersion of the unopened foil packet in a warm, sterile solution. It can be applied with fingers or the tip of the dissector; if left in situ after use, it is better to remove the excess. BW is neither absorbed nor metabolized.

Alberius et al.[12] used a rat calvarial bone model to identify the 3 stages of inflammatory reaction to BW: 1) a nonspecific inflammatory response, 2) a foreign body reaction, and 3) a marked fibrous reaction. The observations are consistent with histologic findings associated with the implantation of BW in a rat tibia model, which typically include foreign-body reactions characterized by giant cells, plasma cells, fibrous tissue, and a lack of bone formation.[13]

HISTORICAL VARIANTS

The original Horsley's wax (antiseptic wax) as used by Rushton Parker was composed of 7 parts beeswax, 1 part almond oil, and 1% salicylic acid.[4]

Moorhof's BW (iodoform BW) was invented by Mosetig-Moorhof in 1903 and was used in the treatment of chronic osteomyelitis with bone abscess. Equal parts of spermaceti and sesame oil were sterilized in a water bath, and later 60 parts of this was mixed with 40 parts of iodoform. This mixture resulted in a yellowish, brittle Moorhof's BW, melting at approximately 50°C. Before using, it was heated to just above the melting point and kept constantly stirred to prevent iodoform from settling to the bottom of the flask.[14] Moore modified Moorhof's BW with 1% iodine, 2 parts olive oil, and 8 parts spermaceti as ingredients. At first, spermaceti and olive oil were mixed in a water bath and heated. Iodine was added later, and heating was stopped. The mass became solid at body temperature.[15] Another historical alternative was Beck's bismuth emulsion, which consisted of bismuth subnitrate (30 g), white wax (5 g), and petroleum jelly (60 g).[15]

Geary and Frantz' carbowax was invented in 1950, and it consisted of oxidized cellulose as the active component and a mixture of high-molecular-weight resorbable polyethylene glycols as vehicles to deliver it. Instead of beeswax, they used 60% carbowax, 15% polyethylene glycol, and 25% oxidized cellulose. They compared their material to original BW in a rib fracture model. Polyethylene glycol was resorbed and caused only a minor inflammatory reaction.[16]

USES OF BW IN NEUROSURGERY

Although BW is used mainly in neurosurgery for attaining hemostasis of oozing bone surfaces and to control bleeding from emissary and diploic veins, it has several other uses. One use is to prevent cerebrospinal fluid leakage following skull base repair, such as anterior cranial fossa repair, by applying across the bony defect. Sometimes during craniotomy and temporal bone nibbling, the middle meningeal artery can become torn and the stump can retract into the foramen spinosum, producing heavy bleeding. In such cases, BW can be applied across the foramen to plug it, producing rapid hemostasis, which can be life-saving. During drilling of skull, BW can be applied over the surrounding tissues and act as a protective covering against the blades of the drill.

During spine surgeries, it is common to see the screws falling down from screwdrivers because of the lack of a proper grip. If such a technical problem occurs, BW can be applied to the tip of the screwdriver to adhere the screw to it.[17] Other well-known uses for BW in spine surgery are to attain hemostasis after removal of distraction pins during anterior cervical spine surgery,[18] following vertebral artery injury after placement of cervical spine screws,[19] and as a marker for spatial orientation in intraoperative magnetic resonance imaging.[20]

BW can also be used as a template for intraoperative evaluation of craniofacial defects and shaping of polyethylene implants for covering the same.[21] If a cavernous carotid aneurysm exhibits repeated or massive epistaxis, sphenoid sinus packing with BW can be done as a temporary measure to control the epistaxis.[22]

COMPLICATIONS

Although BW is widely used in neurosurgery, its use is not free from complications. Some of the complications reported in the literature include allergy

and granuloma[23]; inflammation and infection[24]; interference with bone healing[25]; cord compression leading to neurological deficits, including quadriplegia[26]; osteohypertrophy[27]; venous sinus thrombosis[28]; soft tissue sarcomas following retained BW[29]; migration into the sigmoid sinus, into the parenchyma, and outside through the wounds[30-32]; and ptosis and diplopia.[33]

ADVANTAGES AND DISADVANTAGES

Bone wax is cost effective (with one plate costing around $10) and acts immediately, but its use can result in infection because it diminishes the ability of bone to clear bacteria. As it interferes with bone healing, its use should be restricted in sites where fusion is desired, especially in spine surgeries. It should not be used within the spinal canal, as it can lead to neurologic deficits.

AVAILABILITY AND PACKAGING

Bone wax has a white to off-white color with a specific gravity of 0.95. It is sterilized by gamma radiation and should not be stored in areas warmer than 77°F (25°C). It has a shelf life of approximately 5 five years if stored properly, and it is usually available commercially as plates or sticks weighing 2.5 g per pack.[34]

ALTERNATIVES AND IMPROVISATIONS

There is a wide range of hemostats for use in neurosurgery. BW has undergone several modifications, and alternatives have been devised over the ages, although none have been found to beat this age-old hemostat.

At least 16 agents have been described in the literature (**Table 1**) that are being used as alternatives to BW. Some of these agents are in the experimental phase, and others are being used in specialties such as orthopedics and cardiac surgery. Many of these agents are claimed to be superior to BW, although none of them have been able to replace it. Ostene (Ceremed, Inc., Los Angeles, California, USA), Hemasorb (Abyrx, Inc., Irvington, New York, USA), and Surgifoam (Ethicon, Inc., Somerville, New Jersey, USA) are the most commonly used alternatives. Pluronics are tri-block copolymers, consisting of a hydrophobic polypropylene oxide unit in between 2 basic hydrophilic units of polyethylene oxide, with the basic sequence of an A—B—A structure. Absorbable agents include Hemasorb, polyethylene glycol—polypropylene glycol—polyethylene glycol (PEG-PPG-PEG) copolymer mixtures, and Absele (Ethnor, Division of Ethicon, Inc., Edinburgh, UK). Agents that do not impair bone healing include bioactive glass/chitosan/carboxymethyl cellulose composite scaffold, PEG-PPG-PEG copolymer mixtures, microporous polysaccharide hemospheres, polyethylene glycol/microfibrillar collagen, pluronic implants, and OsteoStat. Hemasorb, Surgifoam, PEG-PPG-PEG copolymer mixtures, and similar pluronic implants have the advantage of ease of handling and decreased adhesion to surgical gloves during usage. Hemasorb, bioactive glass/chitosan/carboxymethyl cellulose composite scaffold, OsteoStat, and hydroxyapatite/chitosan/starch are absolutely biocompatible with almost no allergic reaction. There is a reduced chance of infection because of some antibacterial properties following the use of Ostene, gelatin-based bone wax, vancomycin cream, and hydroxyapatite/chitosan/starch complex.

Some newer local hemostatic agents include FloSeal (Baxter International, Inc., Deerfield, Illinois, USA) and Surgiflo (Ethicon, Inc., Somerville, New Jersey, USA) hemostatic matrix. They are composed of a granular gelatin matrix derived from collagen cross-linked with glutaraldehyde. FloSeal is made of a matrix of bovine gelatin and human thrombin with a preparation time of approximately 168 seconds, and it is reabsorbed by the body in 6—8 weeks.[49] Surgiflo hemostatic matrix is composed of porcine gelatin and human thrombin. Its preparation time is approximately 81 seconds, and reabsorption time is 4—6 weeks.[50] Both of them can be used at their best to control diffuse capillary oozing from the epidural space or from the resected tumor cavity. It is natural to have doubts as to whether these agents can act as alternatives to the antique BW; however, the safety and effectiveness of these agents, for use in neurosurgical procedures, have not been established through randomized clinical studies. A study comparing both agents in spine surgeries did not show any differences in terms of efficacy and ease of use or their effectiveness in bleeding control. Neither of these agents is to be used as a substitute for conventional procedures for hemostasis, including BW. Moreover, both agents are associated with thrombotic complications, especially when used in the presence of bleeding from bone spongiosa.[51,52]

CONCLUSION

Despite BW being useful in controlling massive bone bleeding and being the only hemostat of choice in certain situations, its use is limited by several complications. The following recommendations can be proposed regarding the use of BW in neurosurgery. It can be used in massive bleeding from diploic veins during cranial surgery, just at the site of bleeding. The use of BW in a large quantity is, however, not recommended. Its use is desirable if the patient is having coagulopathy. It is better to restrict its use in spine surgery, where fusion is desired. BW alternatives can be used instead. For minor bleeding from the bone surface or edges during craniotomy, monopolar cautery at a high ampere setting is a good, cost-effective alternative. Some agents have been recently marketed, claiming to overcome one of the disadvantages of bone wax—impaired bone healing. Additional trials are needed to validate the efficacy of these agents versus BW.

REFERENCES

1. Gupta G, Prestigiacomo C. From sealing wax to bone wax: predecessors to Horsley's development. *Neurosurg Focus*. 2007;23:1-4.
2. Steimle R. A note on the use of wax for bone hemostasis Henri-Ferdinand Dolbeau (1840—77). *J Hist Neurosci*. 1993;2:243-244.
3. Wellisz T, An Y, Wen X, Kang Q, Hill C, Armstrong J. Infection rates and healing using bone wax and a soluble polymer material. *Clin Orthop Relat Res*. 2008;466:481-486.
4. Horsley V. Antiseptic wax. *BMJ*. 1892;1, 1165-1165.
5. Dormandy T. *The Worst of Evils*. New Haven, CT: Yale University Press; 2006:427.
6. Parker R. Aural pyaemia successfully treated by removing putrid thrombus of jugular vein and lateral sinus. *BMJ*. 1892;1:1076-1077.
7. Chivukula S, Weiner G, Engh J. The early days of hemostasis in neurosurgery. *Neurosurg Focus*. 2014; 36:E5.

8. Verrall PJ. Operation on joints. In: Carson HW, ed. *Modern Operative Surgery*. Vol 1. London: Cassell & Co; 1924:69.

9. Fues J, Ritter W. *Resorbable bone wax. U.S. Patent No. 5,308,623*. Washington, DC: U.S. Patent and Trademark Office; 1994.

10. Katre C, Triantafyllou A, Shaw R, Brown J. Inferior alveolar nerve damage caused by bone wax in third molar surgery. *Int J Oral Maxillofac Surg*. 2010;39:511-513.

11. Surgical Specialties Bone Wax. Hospeqcom. 2018. Available at: https://www.hospeq.com/v/vspfiles/photos/pdfs/surgical-specialties-bone-wax.pdf. Accessed March 21, 2018.

12. Alberius P, Klinge B, Sjögren S. Effects of bone wax on rabbit cranial bone lesions. *J Craniomaxillofac Surg*. 1987;15:63-67.

13. Howard T, Kelley R. The effect of bone wax on the healing of experimental rat tibial lesions. *Clin Orthop Relat Res*. 1969;1:226-232.

14. Simmons C. Bone abscess treated with Moorhof's bone wax. A report of five cases. *Ann Surg*. 1911;53:67-76.

15. Wharton HR. *Minor Surgical Procedures in Minor and Operative Surgery Including Bandaging*. 7th ed. Philadelphia and New York: Lea and Febiger; 1909:176.

16. Geary J, Fhantz V. New absorbable hemostatic bone wax. *Ann Surg*. 1950;132:1128-1137.

17. Uppal N, Baliga M. Bone wax to improvise a screw-holder: a makeshift emergency tool. *Trop Doct*. 2015;46:67-68.

18. Evans A, Stokes O, Tsegaye M. Syringe-pressurised bone wax to stop bleeding from vertebral body pin sites during anterior cervical discectomy and fusion (ACDF). *Ann R Coll Surg Engl*. 2016;98:228-229.

19. Peng C, Chou B, Bendo J, Spivak J. Vertebral artery injury in cervical spine surgery: anatomical considerations, management, and preventive measures. *Spine J*. 2009;9:70-76.

20. Celtikci P, Celtikci E, Emmez H, Ucar M, Börcek A. Utilization of bone wax as a marker for spatial orientation in intraoperative magnetic resonance imaging. *Clin Neuroradiol*. 2017;28:117-121.

21. Mavili E, Akyürek M. Use of bone wax as a template for intraoperative evaluation of facial defects and shaping of polyethylene implants. *Plast Reconstr Surg*. 1997;100:1247-1253.

22. Sadigh P, Clifton A, Toma A. Giant bilateral cavernous-carotid aneurysms complicated by epistaxis. *Eur Ann Otorhinolaryngol Head Neck Dis*. 2016;133:129-131.

23. Schonauer C, Tessitore E, Barbagallo G, Albanese V, Moraci A. The use of local agents: bone wax, gelatin, collagen, oxidized cellulose. *Eur Spine J*. 2004;13:S89-S96.

24. Gibbs L, Kakis A, Weinstein P, Conte JE. Bone wax as a risk factor for surgical-site infection following neurospinal surgery. *Infect Control Hosp Epidemiol*. 2004;25:346-348.

25. Rockwood C, Perkins JC, Roberts L, Dixon D. Reaction of bone wax on bone and muscle. *J Bone Joint Surg*. 1968;50:837-838.

26. Cirak B, Unal O. Iatrogenic quadriplegia and bone wax. Case illustration. *J Neurosurg*. 2000;92(suppl 2):248.

27. Kamide T, Nakada M, Hirota Y, Hayashi Y, Hayashi Y, Uchiyama N, et al. Skull osteohypertrophy as a complication of bone wax. *J Clin Neurosci*. 2009;16:1658-1660.

28. Crocker M, Nesbitt A, Rich P, Bell B. Symptomatic venous sinus thrombosis following bone wax application to emissary veins. *Br J Neurosurg*. 2008;22:798-800.

29. Verborgt O, Verellen K, Van Thielen F, Deroover M, Verbist L, Borms T. A retroperitoneal tumor as a late complication of the use of bone wax. *Acta Orthop Belg*. 2000;66:389-391.

30. Byrns K, Khasgiwala A, Patel S. Migration of bone wax into the sigmoid sinus after posterior fossa surgery. *Am J Neuroradiol*. 2016;37:2129-2133.

31. Fahradyan A, Ohanisian L, Tsuha M, Park MJ, Hammoudeh JA. An unusual complication of bone wax utilization. *J Craniofac Surg*. 2018. https://doi.org/10.1097/SCS.0000000000004321. [Epub ahead of print].

32. Baird SM, Teh BM, Lim KKM, Campbell MC. Bone wax extrusion through postauricular wounds: a case series. *Laryngoscope*. 2018;128:369-372.

33. Maki Y, Ishibashi R, Yamada D, Morita T, Chin M, Yamagata S. Postoperative ptosis and diplopia induced by the intraoperative application of bone wax. *World Neurosurg*. 2017;103:951.e1-951.e3.

34. Phillips N. Wound healing and hemostasis. In: Phillips N, ed. *Berry & Kohn's Operating Room Technique*. 13th ed. St Louis: Elsevier; 2017.

35. Wellisz T, Armstrong JK, Cambridge J, Fisher TC. Ostene, a new water-soluble bone hemostasis agent. *J Craniofac Surg*. 2006;17:420-425.

36. Hill J, Little J, Ford T. Bone wax: a foreign body/giant cell reaction in the foot. *Foot Ankle Spec*. 2013;6:236-238.

37. Chen C, Li H, Pan J, Yan Z, Yao Z, Fan W, et al. Biodegradable composite scaffolds of bioactive glass/chitosan/carboxymethyl cellulose for hemostatic and bone regeneration. *Biotechnol Lett*. 2015;37:457-465.

38. Suwanprateeb J, Suvannapruk W, Thammarakcharoen F, Chokevivat W, Rukskul P. Preparation and characterization of PEG-PPG-PEG copolymer/pregelatinized starch blends for use as resorbable bone hemostatic wax. *J Mater Sci Mater Med*. 2013;24:2881-2888.

39. Harris P, Capperauld I. Clinical experience in neurosurgery with Absele: a new absorbable haemostatic bone sealant. *Surg Neurol*. 1980;13:231-235.

40. Brückner T, Schamel M, Kübler AC, Groll J, Gbureck U. Novel bone wax based on poly(ethylene glycol)-calcium phosphate cement mixtures. *Acta Biomater*. 2016;33:252-263.

41. Wellisz TUS. *AOC Bone Wax Submission, Patent No. K041363*. Washington, DC: U.S. Patent and Trademark Office; 2004.

42. Van Loock K, Plazier M, De Ridder D, Menovsky T. Gelatine based "bone wax.". *Neurosurgery*. 2010;67:E521.

43. Tschan CA, Nie M, Schwandt E, Oertel J. Safety and efficacy of microporous polysaccharide hemospheres in neurosurgery. *Neurosurgery*. 2011;69(suppl 1). ONS49-63.

44. Orgill DP, Ehret FW, Regan JF, Glowacki J, Mulliken JB. Polyethylene glycol/microfibrillar collagen composite as a new resorbable hemostatic bone wax. *J Biomed Mater Res*. 1998;39:358-363.

45. Wang MY, Armstrong JK, Fisher TC, Meiselman HJ, McComb GJ, Levy ML. A new, pluronic-based, bone hemostatic agent that does not impair osteogenesis. *Neurosurgery*. 2001;49:962-968.

46. Tham T, Costantino P, Roberts K, Burban J, Shanahan J. Analysis of bone healing with a novel bone wax substitute compared to bone wax in a porcine bone defect model. *bioRxiv*. 2017. Available at: https://www.biorxiv.org/content/early/2017/12/20/236430. Accessed March 21, 2018.

47. Arruda MVF De, Braile DM, Joaquim MR, Suzuki FA, Alves RH. The use of the vancomycin paste for sternal hemostasis and mediastinitis prophylaxis. *Rev Bras Cir Cardiovasc*. 2008;23:35-39.

48. Hoffmann B, Volkmer E, Kokott A, Weber M, Hamisch S, Schieker M, et al. A new biodegradable bone wax substitute with the potential to be used as a bone filling material. *J Mater Chem*. 2007;17:4028-4033.

49. Available at: http://www.floseal.com/us/pdf/FLOSEAL_Needle-Free_5mL_IFU.pdf. Accessed March 21, 2018.

50. Available at: https://www.ethicon.com/na/system/files/2017-10/040237-150911_SURGIFLO%20Sales%20Aid_05.26_CA.pdf. Accessed March 21, 2018.

51. Landi A, Gregori F, Marotta N, Delfini R. Efficacy, security, and manageability of gelified hemostatic matrix in bleeding control during thoracic and lumbar spine surgery: FloSeal versus Surgiflo. *J Neurol Surg A Cent Eur Neurosurg*. 2016;77:139-143.

52. Gazzeri R. Commentary on: Efficacy, security, and manageability of gelified hemostatic matrix in bleeding control during thoracic and lumbar spine surgery: FloSeal vs Surgiflo. *J Neurol Surg A Cent Eur Neurosurg*. 2016;77:143-145.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 22 March 2018; accepted 30 April 2018

Citation: World Neurosurg. (2018) 116:72-76.
https://doi.org/10.1016/j.wneu.2018.04.222

*Journal homepage: **www.WORLDNEUROSURGERY.org***

*Available online: **www.sciencedirect.com***

1878-8750/$ - see front matter