Acta Orthopaedica et Traumatologica Turcica 51 (2017) 133–137

Contents lists available at ScienceDirect

Acta Orthopaedica et Traumatologica Turcica

journal homepage: https://www.elsevier.com/locate/aott

Treatment preferences in Turkey for open fracture of the tibial diaphysis

Güzelali Özdemir [a, *], Barış Yılmaz [a], Baran Kömür [b], Evrim Şirin [a], Nazım Karahan [a], Erman Ceyhan [a]

[a] Fatih Sultan Mehmet Training and Research Hospital, Istanbul, Turkey
[b] Kanuni Sultan Suleyman Training and Research Hospital, Istanbul, Turkey

ARTICLE INFO

Article history:
Received 10 January 2016
Received in revised form
24 August 2016
Accepted 11 November 2016
Available online 26 January 2017

Keywords:
Antibiotics
Debridement
Fixation
Open fractures
Tibia

ABSTRACT

Objective: The purpose of this study was to investigate different treatment methods employed by orthopedic surgeons for open tibial fracture in adults.
Methods: Survey of 12 questions regarding treatment of open tibial fracture was conducted with 285 orthopedics and traumatology specialists in Turkey in personal interviews and using web-based technique.
Results: Of all survey participants, 99.6% responded that tetanus prophylaxis is necessary emergency procedure in cases of adult open tibial diaphysis fracture. In addition, 96.5% considered antibiotics administration necessary, 85.6% also selected irrigation with saline, 55.4% included debridement, and 45.3% temporary fixation. Only 4 (1.3%) respondents did not use aminoglycoside antibiotics. While 29.8% of those surveyed preferred external fixator as a definitive treatment method, 75.8% use intramedullary nail and 13.7% preferred plate method.
Conclusion: A wide variation was observed among orthopedics and traumatology specialists in Turkey regarding treatment of open tibial diaphysis fracture in adults. Data obtained from this study together with the available literature may be useful to further develop therapeutic approaches.

Among open fractures encountered in orthopedics and traumatology practice, open tibial diaphysis fracture is relatively common. Since the soft tissue around the tibia is thin, fracture of the tibia often breaks through the skin. These fractures are prone to various complications, particularly infection, which can affect treatment outcomes and increase morbidity and treatment costs.[1,2] In addition to preserving life, extremities, and functionality, one goal of treatment is to prevent infection.

There is no current data in the literature regarding preferences and practices of orthopedics and traumatology experts in Turkey with respect to treatment of adult open tibial diaphysis fracture. Results of the current study may prove useful in developing therapeutic approaches.

Patients and methods

Survey respondents were 285 currently active orthopedics and traumatology specialists in Turkey.

Fractures of hand, finger, spine, and pelvis often require special approaches and additional expertise. However, fractures of long bones, particularly the tibia, are common and are most often treated by orthopedic surgeons. Gustilo-Anderson Classification was used in assessment of approach of orthopedic surgeons to all types of open tibial fracture and treatment variations.[3]

The survey, which was called “Treatment approaches to open tibial diaphysis fractures in adults,” comprised 12 questions, and was conducted with orthopedics and traumatology specialists in Turkey by personal interview or via email.

Survey questions used model of open tibia fracture. Questions related to situations requiring advanced reconstruction due to gunshot wound; open fracture with defect; fracture in patient with additional disease; fracture in children or geriatric patient; fracture of special region, such as spine, pelvis, hand, or finger; or fracture with vascular or nerve injury were not included.

* Corresponding author.
E-mail address: drguzelali@yahoo.com (G. Özdemir).
Peer review under responsibility of Turkish Association of Orthopaedics and Traumatology.

http://dx.doi.org/10.1016/j.aott.2016.12.010

Only active professional orthopedics and traumatology specialists were surveyed; trainees, and those who are retired or not in active practice were excluded.

Survey questions inquired about early intervention practices, preferences in antibiotics and duration of use, preferences in type of fixation, performance of soft tissue reconstruction, and means of deciding necessity for amputation. Respondents were also asked about the type of institution at which they worked, years of expertise, type of institution at which they received their specialized education, and number of open tibia fracture cases they typically treated in a year. Response data were statistically analyzed using SPSS Statistics 22 software (IBM Corp., Armonk, NY, USA).

Results

Of total 2893 active orthopedics and traumatology specialists in Turkey, 9.85% were surveyed.[4] Demographic data of survey participants are provided in Table 1.

Emergency interventions

Of all survey respondents, 99.6% agreed tetanus prophylaxis was required emergency procedure for case of adult open tibial diaphysis fracture. Furthermore, 96.5% also selected administration of antibiotics, 85.6% included irrigation with saline, 55.4% added debridement, and 45.3% included temporary fixation (Table 2).

Antibiotic preferences

Preferred antibiotics of participants according to type of open fracture are provided in Tables 3 and 4. For Type I open fracture, 96.5% preferred first-generation cephalosporin (Cef-1), 21.8% selected aminoglycoside (AG), 5.3% penicillin (Pen), and 2.8% replied "other." Response for preferred antibiotic for Type II open fracture was 96.5% Cef-1, 60.7% AG, 8.8% Pen, and 5.6% "other." Type IIIA/B open fracture preferences were 95.4% Cef-1, 96.8% AG, 30.5% Pen, and 23.9% "other." For Type IIIC open fracture, preferences were 94.4% Cef-1, 97.9% AG, 49.5% Pen, and 33.7% "other."

Antibiotic usage period

Average duration of antibiotic treatment favored by respondents for open tibia fracture was 4.21 ± 2.99 days (range: 1–15 days) for Type I, 4.81 ± 3.46 days (range: 1–21 days) for Type II, 5.86 ± 4.10 days (range: 2–21 days) for Type IIIA/B, and 6.16 ± 4.38 days (range: 2–21 days) for Type IIIC (Table 5). Average duration of AG antibiotic use was 3.81 ± 1.96 days (range: 1–15 days). Only 4 (1.3%) of those surveyed stated that they did not use AG antibiotics.

Table 1
Demographic data of the participants.

		n	%
Affiliation	State hospital	84	29.5
	Training and research hospital	102	35.8
	University hospital	61	21.4
	Private hospital	36	12.6
	Other	2	0.7
Experience in orthopedics	1–5 years	116	40.7
	6–10 years	94	33
	11–15 years	41	14.4
	16–20 years	18	6.3
	≥20 years	16	5.6
Training affiliation	Training and research hospital	134	47
	University hospital	146	51.2
	Other	5	1.8
Number of open tibia fractures treated per year	1–10	110	38.6
	10–20	100	35.1
	20–30	48	16.8
	30–40	12	4.2
	>40	15	5.3

Table 2
Emergency applications.

	n	%
1. Tetanus prophylaxis	284	99.6
2. Irrigation	244	85.6
3. Debridement	158	55.4
4. Antibiotic	275	96.5
5. Temporary fixation	129	45.3

Table 3
Antibiotic regimen according to open fracture type.

		n	%
Type I	First generation cephalosporin	275	96.5
	Aminoglycoside	62	21.8
	Penicillin	15	5.3
	Other	8	2,8
Type II	First generation cephalosporin	275	96.5
	Aminoglycoside	173	60.7
	Penicillin	25	8.8
	Other	16	5.6
Type IIIA/B	First generation cephalosporin	272	95.4
	Aminoglycoside	276	96.8
	Penicillin	87	30.5
	Other	68	23.9
Type IIIC	First generation cephalosporin	269	94.4
	Aminoglycoside	279	97.9
	Penicillin	141	49.5
	Other	96	33.7

Fixation preferences

Preferred method of fixation of Type I open fracture was 12.6% external fixator (EF), 93.7% intramedullary nail (IMN), 27.4% plate, and 1.8% "other" (Table 6). For Type II open fracture, responses were 23.9% EF, 87.4% IMN, 21.8% plate, and 0.7% "other." Fixation method favored for Type III A/B open fracture was 84.2% EF, 45.3% IMN, and 10.2% plate. Preferred fixation method for Type IIIC open fracture was 98.6% EF, 10.5% IMN, and 2.5% plate.

While 29.8% of the participants preferred EF as definitive treatment method, 75.8% continue with IMN and 13.7% continue with the plate method (Table 7).

Reamed or unreamed nails

When performing IMN fixation, 25.3% of the participants preferred to use unreamed nails, while 71.2% preferred reamed nails, and 3.5% use either reamed or unreamed nails, according to the case (Table 7).

Soft tissue reconstruction

When soft tissue reconstruction is needed in adult open tibial shaft fracture cases, 26% of participants stated that they routinely did it themselves, while 72.6% stated that they did not. Remaining 1.4% said sometimes they did it themselves and sometimes with assistance (Table 7).

Amputation decision

While 63.2% of the participants made decision regarding limb salvage or amputation based on the Mangled Extremity Severity

Table 4
Antibiotic regimen according to open fracture type.

Type I antibiotic regimen	Type II antibiotic regimen	Type III A/B antibiotic regimen	Type III C antibiotic regimen
Cef-1 73.7%	Cef-1 37.5%	Cef-1 0.4%	Cef-1 0.4%
Pen 2.8%	**Cef-1 + AG 49.8%**	Pen 0.4%	Pen 0.4%
Cef-1 + AG 19.3%	Cef-1 + Pen 0.4%	**Cef-1 + AG 50.5%**	Cef-1 + AG 26%
Cef-1 + Met 1.1%	Cef-1 + Met 0.7%	Cef-1 + Pen 0.4%	Cef-1 + Met 0.7%
Cef-1 + Cip 0.4%	Cef-1 + Cip 0.4%	Cef-1 + Met 1.4%	AG + Pen 1.4%
Pen + Met 0.4%	AG + Pen 2.5%	AG + Pen 1.1%	Pen + Met 0.7%
Cef-1 + AG + Pen 1.4%	Pen + Met 0.4%	Pen + Met 0.7%	**Cef-1 + AG + Pen 38.2%**
Cef-1 + AG + Met 0.4%	Cef-1 + AG + Pen 4.2%	Cef-1 + AG + Pen 23.5%	Cef-1 + AG + Met 22.8%
AG + Pen + Met 0.4%	Cef-1 + AG + Met 2.8%	Cef-1 + AG + Met 16.5%	Cef-1 + AG + Cip 0.4%
Cef-1 + AG + Pen + Met 0.4%	AG + Pen + Met 0.7%	Cef-1 + AG + Cip 0.4%	Cef-1 AG + Sul 0.4%
	Cef-1 + AG + Pen + Met0.7%	Cef-1 + AG + Sul 0.4%	AG + Pen + Met 3.2%
		AG + Pen + Met 2.5%	Cef-1 + AG + Pen + Met5.6%
		Cef-1 + AG + Pen + Met2.1%	

AG: aminoglycoside; Cef-1: first generation cephalosporin; Cip: ciprofloxacin; Met: metronidasole; Pen: penicillin; Sul: sultamicillin (ampicillin + sulbactam).

Table 5
Antibiotic application period according to open fracture type.

	Min–max (days)	Mean ± SD (days)
Type I	1–15	4.21 ± 2.99
Type II	1–21	4.81 ± 3.46
Type IIIA/B	2–21	5.86 ± 4.10
Type IIIC	2–21	6.16 ± 4.38

Table 6
Fixation method according to open fracture type.

		n	%
Type I	External fixator	36	12.6
	Intramedullary nail	267	93.7
	Plate	78	27.4
	Other	5	1.8
Type II	External fixator	68	23.9
	Intramedullary nail	249	87.4
	Plate	62	21.8
	Other	2	0.7
Type IIIA/B	External fixator	240	84.2
	Intramedullary nail	129	45.3
	Plate	29	10.2
Type IIIC	External fixator	281	98.6
	Intramedullary nail	30	10.5
	Plate	7	2.5

Table 7
Definitive external fixator, type of intramedullary nail, soft tissue reconstruction, and amputation decision.

		n	%
Do you prefer EF as definitive treatment?	Yes	85	29.8
	No, I prefer IMN	216	75.8
	No, I prefer plate and screws	39	13.7
If you use IMN, which type of nail do you prefer?	Unreamed	72	25.3
	Reamed	203	71.2
	Use both	10	3.5
If grafting or use of flap is necessary, do you do it yourself?	Yes	74	26.0
	No	207	72.6
	Sometimes	4	1.4
How do you make decision for limb salvage or amputation?	MESS ≥7	180	63.2
	Other	81	28.4
	Both	24	8.4

EF: external fixator; IMN: intramedullary nail; MESS: mangled extremity severity score.

Score (MESS) criteria,[5] 28.4% replied that they use other criteria, and 8.4% said that they use a combination of MESS and other criteria (Table 7).

Discussion

Emergency interventions

Early antibiotic treatment is extremely important in the treatment of open fracture. It has been demonstrated that those who take antibiotics within the first 3 h after the injury have a lower rate of infection.[6] The period between injury and antibiotic administration, and injury and closure of the wound independently determine risk of infection in Type III open tibia fracture.[7]

Tetanus prophylaxis is among the primary applications for open fracture. Penetrating type of injury, burn or freeze injury, high-velocity gunshot injury, presence of clinical sepsis, and cases in which treatment takes place 6 h or more after injury should be considered at high risk for tetanus.[8,9] Tetanus immunoglobulin, along with tetanus vaccination, should be provided in cases of high-risk injuries and unknown vaccination status.[10]

Irrigation is another primary application for open fracture. The irrigation process should be completed with physiological saline solution.[11] It has not been demonstrated that adding antibiotics to the solution has additional benefit.[12]

Early intervention should include cleaning the wound, adequate removal of necrotic tissue, and wound debridement.[13] It has been shown that late debridement of open tibial fracture increases incidence of infection[14] and increases total financial expenditure.[1] In a meta-analysis, it was reported that delayed debridement is not correlated with increase of deep infection rate in long bone open fracture.[2]

The vast majority of respondents preferred application of tetanus prophylaxis (99.6%), antibiotics (96.5%), and irrigation (85.6%) in emergency service; debridement (55.4%) and temporary fixation (45.3%) were of less importance.

Antibiotic preferences

A multidisciplinary working group has recommended cephalosporin as the antibiotic of choice. The group proposed use of clindamycin as an alternative agent for patients with beta-lactam antibiotic anaphylaxis.[15] Cef-1 is recommended in Type I and II open fractures, whereas Cef-1 + AG is recommended in Type III open fractures. Penicillin is additionally recommended for heavily contaminated wounds.[13] However, Surgical Infection Society does not recommend the routine use of AG.[16] In study conducted by Obremskey et al, large variations were reported in approaches of orthopedic surgeons. The authors found that early administration of AG was well supported, whereas penicillin administration was not. Surgeons should be aware of AG toxicity.[17] Despite this, majority of our participants preferred AG, even though choice varied

according to type of open fracture. The most preferred antibiotics of survey participants were Cef-1, AG, and penicillin, respectively. Combination antibiotherapies were preferred in some instances, depending on type of fracture.

Antibiotic usage period

Duration of antibiotic usage proposed in various sources for open fracture is between 24 and 72 h, according to fracture type.[10,13,18] Despite several studies indicating increased risk of resistant pneumonia and other systemic bacterial infections due to prolonged use of antibiotics, the average duration of antibiotic use proposed by survey participants was 72 h or longer.[19–21] Average AG antibiotic use selected by respondents was 3.81 ± 1.96 days (range: 1–15 days).

Fixation preferences

EF was popular as approach for treatment of open tibial diaphysis fracture in the1980s[22,23]; however, IMN technique became more popular in the 1990s.[24,25] Careful treatment of soft tissue and use of unreamed nails in IMN procedure seem to be safe and effective.[26] Etching the canal while reaming does not increase risk of complications in open tibial fracture.[27] Unreamed IMN is more effective than half-pin EF in extremity alignment. However, the severity of soft tissue injury, rather than the selected implant, is seen as more dominant factor influencing surgical site infection rate and bone healing rate.[24] Participants mostly preferred to use IMN for Type I and Type II fractures, and EF in cases of Type IIIA/B and Type IIIC. Majority of those surveyed do not use EF as definitive therapy method.

Plate was preferred fixation method for Type IIIC open fracture for 2.5% of participants. Surgeons explained that their preference was due to lack of C-arm intensifier in the operating room. Details of plate technique and implant choice were not evaluated in the present study.

Reamed or undreamed nail

In a meta-analysis, it was determined that there were no differences between use of reamed or unreamed IMN for open fracture in terms of union, infection rate or additional interventions.[27,28] In another prospective, randomized, and controlled study, it was determined that there was no difference between reamed or unreamed IMN in terms of union, grafting, dynamization, or infection rate.[29] Our study revealed that participants mostly preferred use of reamed IMN.

Soft tissue reconstruction

Early (<5 days) closure is recommended for soft tissue injuries in open fracture.[13] Gastrocnemius flap is suggested for fracture of proximal third of tibia, soleus flap for middle third tibial fractures, and faciocutaneous flap or free tissue transfer for distal third tibial fracture.[13] Majority of respondents stated that they get assistance with soft tissue reconstruction.

Amputation decision

It has been demonstrated that there was no significant difference significant difference in MESS values of patients who underwent limb preservation treatment and amputees. These findings indicated that MESS is neither sensitive nor accurate enough to form basis for decision to amputate.[30] It has also been shown that lack of plantar sensation is not sufficient criterion for amputation and that sensation may return within 2 years.[31] The majority of respondents in this study thought that MESS was adequate to make decision to amputate. Many factors influence decision on this issue and it can be said that evaluation systems currently in use are not sufficient.

Obremskey et al reported that they found great variation in treatment of segmental bone defects among orthopedic surgeons. Use of antibiotic-laden cement was routine, and bone-grafting time was commonly between 4 and 8 weeks after definitive treatment.[32] We did not investigate decision to graft selection or timing in present study.

Limitations of our study are small sample size and lack of investigation of subtypes of open tibial fracture, such as presence of segmental bone defect.

As seen in other studies conducted elsewhere, wide variation was seen among orthopedics and traumatology specialists in Turkey regarding treatment of open tibial diaphysis fracture in adults. Data obtained from this study together with currently available literature may be of use to further develop therapeutic approaches.

References

1. Schenker ML, Ahn J, Donegan D, Mehta S, Baldwin KD. The cost of after-hours operative debridement of open tibia fractures. *J Orthop Trauma*. 2014;28(11):626–631.
2. Schenker ML, Yannascoli S, Baldwin DK, Ahn J, Mehta S. Does timing to operative debridement affect infectious complications in open long-bone fractures? A systematic review. *J Bone Jt Surg Am*. 2012;94(12):1057–1064.
3. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Jt Surg Am*. 1976;58(4):453–458.
4. Kamu hastaneleri istatistik yıllığı. Available at: 2014:46–47. www.tkhk.gov.tr/dosyalar/b4a241a4aab04c26bdf3def6d2f084e2.pdf.
5. Helfet DL, Howey T, Sanders R, Johansen K. Limb salvage versus amputation. Preliminary results of the mangled extremity severity score. *Clin Orthop Relat Res*. 1990;256:80–86.
6. Patzakis MJ, Wilkins J. Factors influencing infection rate in open fracture wounds. *Clin Orthop Relat Res*. 1989;243:36–40.
7. Lack WD, Karunakar MA, Angerame MR, Seymour RB, Sims S, Kellam JF. Type III open tibia fractures: immediate antibiotic prophylaxis minimizes infection. *J Orthop Trauma*. 2015;29(1):1–6.
8. Weber D, Dulai SK, Bergman J, Buckley R, Beaupre LA. Time to initial operative treatment following open fracture does not impact development of deep infection: a prospective cohort study of 736 subjects. *J Orthop Trauma*. 2014;28(11):613–619.
9. Farnworth E, Roberts A, Rangaraj A, Minhas U, Holloway S, Harding K. Tetanus in patients with chronic wounds-are we aware? *Int Wound J*. 2012;9(1):93–99.
10. World Health Organisation. Prevention and management of wound infection. Available at: http://www.who.int/hac/techguidance/tools/guidelines_prevention_and_management_wound_infection.pdf.
11. Bhandari M, Adili A, Schemitsch EH. The efficacy of low-pressure lavage with different irrigating solutions to remove adherent bacteria from bone. *J Bone Jt Surg Am*. 2001;83-A(3):412–419.
12. Flow investigators. Fluidrot Lavage of Open Wounds (FLOW): design and rationale for a large, multicenter collaborativen 2*3 factorial trial of irrigating pressures and solutions in patients with open fractures. *BMC Musculoskelet Disord*. 2010;11:11–85.
13. Miller MD, Thompson SR, Hart JA, eds. *Review of Orthopaedics*. 6th ed. Elsevier Saunders; 2012:701–702 Chapter 11: Trauma; Weiss DB, Milewski MD, Thompson SR, Stannard JP.
14. Kindsfater K, Jonassen EA. Osteomyelitis in grade II and III open tibia fractures with late debridement. *J Orthop Trauma*. 1995;9(2):121–127.
15. Hospenthal DR, Murray CK, Andersen RC, et al. Guidelines for the prevention of infections associated with combat-related injuries: 2011 update: endorsed by the Infectious Diseases Society of America and the Surgical Infection Society. *J Trauma*. 2011;71(2 Suppl 2):S210–S234.
16. Hauser CJ, Adams Jr CA, Eachempati SR. Surgical Infection Society guideline: prophylactic antibiotic use in open fractures: an evidence-based guideline. *Surg Infect (Larchmt)*. 2006;7(4):379–405.
17. Obremskey W, Molina C, Collinge C, et al. Current practice in the management of open fractures among orthopaedic trauma surgeons. Part A: initial management. A survey of orthopaedic trauma surgeons. *J Orthop Trauma*. 2014;28(8):198–202.
18. Luchette FA, Bone LB, Born CT, et al. EAST practice management guidelines work group: practice management guidelines for prophylactic antibiotic use in open fractures. Available at: http://www.east.org/tpg/.openfrac.pdf. Accessed 15 February 2013.

19. Rello J, Ausina V, Ricart M, Castella J, Prats G. Impact of previous antimicrobial therapy on the etiology and outcome of ventilator-associated pneumonia. *Chest*. 1993;104:1230–1235.
20. Koulenti D, Rello J. Hospital-acquired pneumonia in the 21st century: a review of existing treatment options and their impact on patient care. *Expert Opin Pharmacother*. 2006;7:1555–1569.
21. Rello J, Sa-Borges M, Correa H, Leal SR, Baraibar J. Variations in etiology of ventilator-associated pneumonia across four treatment sites: implications for antimicrobial prescribing practices. *Am J Respir Crit Care Med*. 1999;160(2):608–613.
22. Bach AW, Hansen Jr ST. Plates versus external fixation in severe tibial shaft fractures. A randomized trial. *Clin Orthop Relat Res*. 1989;241:89–94.
23. Edwards CC, Simmons SC, Browner BD, Weigel MC. Severe open tibial fractures. Results treating 202 injuries with external fixation. *Clin Orthop Relat Res*. 1988;230:98–115.
24. Henley MB, Chapman JR, Agel J, Harvey EJ, Whorton AM, Swionkowski MF. Treatment of type II, IIIA and IIIB open fractures of the tibial shaft: a prospective comparison of unreamed interlocking intramedullary nails and half-pin external fixators. *J Orthop Trauma*. 1998;12(1):1–7.
25. Schandelmaier P, Krettek C, Rudolf J, Tscherne H. Outcome of tibial shaft fractures with severe soft tissue injury treated by unreamed nailing versus external fixation. *J Trauma*. 1995;39(4):707–711.
26. Kakar S, Tornetta III P. Open fractures of the tibia treated by immediate intramedullary tibial nail insertion without reaming: a prospective study. *J Orthop Trauma*. 2007;21(3):153–157.
27. Finkemeier CG, Schmidt AH, Kyle RF, Templeman DC, Varecka TF. A prospective, randomized study of intramedullary nails inserted with and without reaming for the treatment of open and closed fractures of the tibial shaft. *J Orthop Trauma*. 2000;14(3):187–193.
28. Bhandari M, Guyatt GH, Swiontkowski MF, Schemitsch EH. Treatment of open fractures of the shaft of the tibia. *J Bone Jt Surg Br*. 2001;83(1):62–68.
29. Study of Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures Investigators, Bhandari M, Guyatt G, Tornetta III P, et al. Randomised trial of reamed and unreamed intramedullary nailing of tibial shaft fractures. *J Bone Jt Surg Am*. 2008;90(12):2567–2578.
30. Sheean AJ, Krueger CA, Napierala MA, Stinner DJ, Hsu JR. Skeletal trauma research consortium (STReC). Evaluation of the mangled extremity severity Score in combat-related type III open tibia fracture. *J Orthop Trauma*. 2014;28(9):523–526.
31. Bosse MJ, McCarthy ML, Jones AL, et al. Lower Extremity Assessment Project (LEAP) Study Group.The insensate foot following severe lower extremity trauma: an indication for amputation? *J Bone Jt Surg Am*. 2005;87(12):2601–2608.
32. Obremskey W, Molina C, Collinge C, et al. Current practice in the management of open fractures among orthopaedic trauma surgeons. Part B: management of segmental long bone defects. A survey of orthopaedic trauma association members. *J Orthop Trauma*. 2014;28(8):203–207.