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Original Article

Mangled lower extremity: can we trust the amputation scores?

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Abstract: Background: Limb injuries represent a constant and severe problem. Several lower limb injuries are more frequent than upper limb injuries. Over time, in an attempt to quantify the severity of traumas and to establish guidelines for the decision whether to save or amputate a mangled extremity, several scoring systems have been reported. Most refer to bone fractures, soft tissue damage, vascular, nerves and tendon lesions. Matherials and methods: Articles dealing with mangled lower extremities published in the last 15 years were analyzed. Other inclusion criteria included: articles reporting MESS, PSI, LSI, and Gustillo-Anderson scores, studies based on groups of more than 25 patients, and English language articles. We tried to determine if there was good correlation between amputation recommendations and various scores of injury, with regard to combat wounds and civilian injuries, in adult and pediatric groups. Results: Thirty-two papers fulfilled our criteria; in 17 of these, correlation between mangled extremity scores and the decision to amputate or salvage the limb was well-defined. Good correlation between MESS and amputation was found in 25% of the papers. The highest correlation was found for pediatric injuries and combined adult and pediatric combat injuries. Conclusions: The mangled extremity is a long-lasting, unsolved problem, with much debate and a large number of protocols and scoring systems, but with no unanimously-accepted solution. Many mangled extremities are borderline cases, and the decision to amputate or to salvage a limb must be carefully assessed. With advances in the medical field over the last 15 years, more mangled lower extremities are salvaged, especially in civilian injuries.

Keywords: Mangled lower extremities, MESS, PSI, LSI, amputation

Introduction

Over 100 million people visit annually emergency departments in the USA, with about 36% of the visits to trauma centers [1]. Most severe extremities injuries are encountered during wartime [2-5], but even in quotidian life limb injuries represent a constant and severe problem. The rate of limb injuries has been increasing over the years, particularly accidental injuries; this trend can be attributed to modernization, industrialization, and an increased rate of violence in society. Except for war injuries, the most frequent causes leading to severe limb traumas are road traffic accidents and work related accidents [6].

The three most frequent mechanisms responsible for these types of injuries are: a) Direct force, as a primary mechanism; b) Injuries produced by bone fragment mobilization, as a secondary mechanism; c) Third degree burns, as a tertiary mechanism [7].

Most patients with severe mangled extremities are aged 20-39 years and are predominantly male [8]. Lower extremity injuries are more frequent than upper extremity injuries in civilians. Among lower extremity injuries, tibia and fibula fractures are the most common injury, occurring in about 40% of cases, while vascular injuries are reported to be as high as 48% [9, 10].

Over time, in an attempt to quantify the severity of traumas and to establish guidelines for decision-making, whether to save or to amputate the mangled extremity, several scoring systems have been developed. Most incorporate bone

Table 1. Mangled Extremity Severity Score (MESS) [11]

Skeletal/soft tissue injury	
	Low energy injury (eg. simple bone fracture) – 1 point
	Medium energy injury (eg. multiple bone fractures) – 2 points
	High energy injury (eg. car accidents) – 3 points
	Very high energy injury (eg. high speed trauma with severe contamination) – 4 points
Limb ischemia	
	Normal perfusion with reduces or even absent pulse – 1[x]point
	Absent pulse,paresthesia, diminished capillary refill – 2points
	Cool, paralyzed, insensate limb – 3[x]points
Shock	
	Systolic blood pressure > 90 mm Hg: 0 points
	Hypotensive transiently: 1 point
	Hypotensive persistent: 2 points
Age	
	< 30 years: 0 points
	30-50 years: 1 point
	> 50 years: 2 points

[x]The score is doubled for ischemia > 6 hours

fractures, soft tissue damage, vascular, nerve and tendon lesions.

The Mangled Extremity Severity Score (MESS) is probably the most common scoring system used [11] (**Table 1**), followed by the Predictive Salvage Index (PSI) [12] (**Table 2**), Limb Salvage Index (LSI) [13] (**Table 3**), Mangled Extremity Syndrome Index (MESI), Nerve injury, ischemia, soft tissue, skeletal injury, shock, age of patient score (NISSSA), and the Hannover Fracture Scale [14, 15].

PubMed provides numerous articles dealing with methods of predicting results for mangled extremities. Most extremity injury scoring systems were developed over 15 years ago. Orthopedic, plastic, and vascular surgery techniques and strategies have changed dramatically since then.

Table 2. Predictive Salvage Index (PSI) [12]

Bone Injury		
	Mild trauma	1
	Moderate trauma	2
	Severe trauma	3
Muscle Injury		
	Mild trauma	1
	Moderate trauma	2
	Severe trauma	3
Arterial Injury		
	Suprapopliteal arteries	1
	Popliteal artery	2
	Infrapopliteal arteries	3
Delay to theatre		
	less than 6h	1
	6–12h	2
	More than 12h	3

Materials and methods

The goal of this review was to evaluate the various scoring systems used and published recently. We selected those that used MESS as a first choice, along with PSI, LSI, and Gustillo-Anderson. The studies included in our review met the following criteria: articles dealing with mangled lower extremity; articles reporting MESS, PSI, LSI, or Gustillo-Anderson scores; articles published since 1995; studies based on groups with more than 25 cases; articles published in English in PubMed.

Results

Thirty-two articles met the above-mentioned criteria. In 17, the correlation between the mangled extremity scores and the decision whether to amputate or salvage the limb was well-defined. In all of these articles, the authors used MESS as a scoring system, while LSI was found in four studies, PSI in three, and MESI in three.

Of the 17 studies that fulfilled our inclusion criteria, three were related to war injuries, two were related to severe injuries in children, and the rest were based on civilian injuries, both in

Table 3. Limb Salvage Index (LSI) [13]

Arterial trauma	
	Contusion (with no thrombosis), palpable pulses: 0 points
	Pulseless femoral or popliteal vessels, thrombosis, occlusion of 2 or more shank vessels,: 1 point
	Complete occlusion of femoral, popliteal or all 3 shank vessels: 2 points
Nerve trauma	
	Contusion or elongation of the femoral, tibial or peroneal nerve: 0 points
	Partial transection of the sciatic, femoral, peroneal or tibial nerve or even complete transaction of the femoral, peroneal or tibial nerve: 1 point
	Complete transection of the sciatic nerve or of both peroneal and tibial nerves: 2 points
Bone trauma	
	Closed fracture in no more than two sites or open fracture without comminution, fibula fracture or open joint without foreign body: 0 points
	Closed fracture in at least three sites or open fracture with comminution or open joint with foreign body or bone loss less than 3 cm: 1 point
	Bone loss more than 3 cm; type IIIB, C Gustilo fractures: 2 points
Skin trauma	
	Clean laceration with primary repair or 1st degree burn: 0 points
	Delayed closure due to contamination or wounds requiring skin grafts or flaps or 2nd and 3rd degree burns: 1 point
Muscle trauma	
	One muscle or tendon avulsion or laceration: 0 points
	Two or more muscles or tendons laceration or avulsion : 1 point
	Crush injury: 2 points
Deep vein trauma	
	Contusion, partial laceration or avulsion; complete laceration or avulsion with intact drainage; superficial vein injury: 0 points
	Complete laceration, avulsion, or thrombosis without adequate venous drainage: 1 point
Warm ischemia time	
	< 6 h: 0 points
	6-9 h:1 point
	9-12 h: 2 points
	12-15 h: 3 points
	> 15 h: 4 points

adults and children. Eight of the 17 articles reported good correlation between MESS and the amputation decision. Both articles describing children with mangled extremities showed good correlation, as did two of the three studies on combat injuries. The remaining nine articles did not find MESS helpful in the decision whether to amputate or salvage a limb.

The results were categorised into three main groups: a) Adults and children - civilian injuries - this group was not split into two (adults and children) as the reports did not specify the age of patients included in each category; b) Children – civilian; c) Combat injuries.

Civilian injuries (adults and children)

In a prospective study of 46 upper and lower extremities with MESS injuries scoring higher than 7, Elsharawy [16] was able to save 43 (93%), a specificity of 27.5% for MESS regarding secondary amputations. In agreement with Elsharawy, Menakuru [17] managed to salvage the limb in 20 (69%) of 29 patients with MESS>7 (**Table 4**). Elsharawy [16] excluded patients who underwent primary amputation (28 cases, 31%) from the study. Primary amputation was defined as limbs amputated as the primary treatment modality. The possibility of salvaging the limb was not considered because

Table 4. Literature review on MESS >7

Publishing year	Authors	Limbs	MESS>7 amputation	MESS>7 salvaged
1996	Rodney	51	21	16% (4)
1997	O'Sullivan	54	-	-
2001	Bosse	556	68	34.60% (36)
2002**	Fagelman	52	5	0%
2003	Sansar Sharma	56	28	0%
2005	Menakuru	148#	9	68.90% (20)
2005	Elsharawy	62	3	93.40% (43)
2005	Kumar	61	10	9.09% (1)
2007*	LTC Robert	60#	7	12.50% (1)
2009	Callcut	36	5	-
2009	Korompilias	63#	7	0%
2009*	Brown	86	18	35.71% (10)
2010**	Mommsen	44	8	50% (4)

*Combat injuries; **Children injuries; #upper and lower extremities

the limb was virtually amputated, having only a small bridge of tissue in connection with the proximal stump, or the limb had a long ischemia time.

On the other hand, some reports described good correlation between MESS>7 and amputation [18-23]. In a study on 56 limb injuries, Sharma [22] reported good correlation between MESS>7 and amputation. He did not try a salvage procedure in any case with a MESS higher than 7. Likewise, Korompilias [24] amputated all limbs with MESS>7.

Kumar [21] published a study on 58 cases, including a retrospective study on 25 cases, with 11 injured limbs presenting a MESS score higher than 7. All the limbs in the retrospective group had been amputated (four cases had primary amputation, and one case had secondary amputation), and five of six cases had been amputated with no details about primary or secondary amputation.

The reports for primary amputation for MESS>7 vary from 0% [24] to 41% [25]. Korompilias [24] analyzed 10 cases of massive extremity injuries in which an attempt was made to salvage the limbs. Three patients died and the others were amputated within 15 days of initial salvage. In the interim, all suffered multiple reconstruction techniques and debridements. In a study on 51 limbs published in 1996, Durham [25] found a primary amputation rate of 41.1% and a secondary amputation rate of 11.7%, with a mean MESS score of 8.8 and 21 limbs with MESS >7. The rate of secondary amputation reported ranged from 1.8% [19] to 15.6% [26] (**Table 5**).

Children – civilian

There are some reports on combat mangled extremities in children, but the articles did not make a clear separation between child and adult injuries. This category is discussed in section III.

The English literature is poor in reporting on mangled extremity injuries in children. Most of the studies involving children found good correlation between MESS and amputation. In his study on 44 children, Mommsen [27] reported good correlation between MESS and limb salvage or amputation. In a retrospective study on 36 children, Fagelman [28] evaluated the correlation between MESS score and grade IIIB and C lower extremity fractures and found an accurate prediction in 93% of cases.

Combat injuries

Some studies that treat mangled lower extremities in combat situations found good correlation between MESS>7 and amputation. In a study involving 60 limb injuries in combat settings in Iraq and Afghanistan, Rush [23] validated the utility of the MESS score. Most amputations were performed on young patients with an ischemic limb and with a general health status that precluded lengthy reconstructions [21]. In another study, Brown [29] encountered 77 mili-

Table 5. Primary and secondary amputation rates

Year	Authors	Limbs		No. of amputated limbs	Primary amputation		Secondary amputation	
					No.	%	No.	%
1996	Durham	51		27	21	41,1	6	11,7
1997	O'Sullivan	54		22	15	27.7	7	12.9
2001	Bosse	556		149	63	11.3	86	15.4
2002**	Fagelman	52		12	12***	23	0	0
2003	Sharma	56		39	16	28.5	23	41
2005	Menakuru	148#			-	-	9#	6
2005	Kumar	61		11	7	11,4	4	6.55
2005	Elsharawy	95#			28#	29.4		
2006	Rajasekaran	109		7	5	4.5	2	1.8
2007*	Rush	60#		8#	8	13.3	0	0
2009	Callcut	36		6	2	5.5	4	11.1
2009	Korompilias	63#		7#	0	0	7 (4 LE)	11.1
2009*	Brown	86		22	15	17.4	7	8.1
2009*	Gifford	TVS	64	12	2	3.1	10	15.6
		Control	61	14	7	11.4	7	11.4
2010**	Mommsen	44		8	3	6.8	5	11.3

*Combat trauma; **Children trauma; ***Primary amputation was defined as amputation during the initial hospital stay; - Patients who underwent primary amputation were not included in the study; # upper and lower limbs; LE = lower extremities; TVS = temporary vascular shunt.

tary patients from Iraq and Afghanistan with 85 mangled extremities and also found good correlation between prolonged ischemia time, hypotension, unstable general condition, and amputation. Seventy-four percent of the limbs were salvaged and 26% were amputated, 18% as primary amputation and 8% as secondary amputation. The authors concluded that MESS did not help in the decision as to whether or not to amputate. Ten limbs with MESS >7 were successfully salvaged.

For primary amputation in combat situations, the results range from 3.1% [26] to 17.4% [21], while the range was between 0% [21] and 15.6% [26] for secondary amputation (**Table 5**). In his study, Gifford [26] compared a group of patients who had a temporary vascular shunt (TVS) with a control group with similar characteristics but without temporary vascular shunts. The TVS group had 3% primary amputations and 16% secondary amputations, while the control group had 12% primary amputations and 12% secondary amputations. These results suggested the possible benefit of the TVS, although the results were not found to be statistically significant.

The largest study reporting lower extremity injury severity score was reported by Bosse [30]. He evaluated 556 lower extremities by using five scoring systems and found that 14.5% of patients who did not have an indication for amputation according to their MESS score, underwent amputation in fact. The authors found that LSI had better specificity than PSI, MESS and NISSSA. The MESS had 69.9% specificity and 78% sensitivity. In a study on 54 limbs in 51 patients, O'Sullivan [18] found that MESS and LSI are not predictive for amputation in limbs with Gustillo IIIB and C injuries.

Discussion

Because many mangled extremities are borderline cases with an unpredictable prognosis, the decision to amputate or to salvage a limb must be carefully assessed. Unless the situation is life-threatening, the future of a limb should not be decided on the basis of the initial case evaluation alone. The mangled extremity scoring systems that are currently used were developed more than 15 years ago. Since then, significant advances have been made in surgical techniques and devices, in the intensive care field,

in stabilization methods and in reconstructions, all of which now permit limb salvage in the majority of lower limb trauma cases. Unfortunately, although the operation is usually deemed a success, there are cases that require secondary amputation. Failed attempts at limb salvage result in prolonged hospitalization, along with multiple surgical procedures, pain, and psychological trauma.

Although most recent studies agree that indications for limb amputation have diminished, there are authors who do not agree with performing a salvage operation for patients with an MESS higher than 7. As the results revealed, there are major differences even among publications in the same year. For example, Elsharawy [16] saved 93.4% of limbs with MESS >7 and Kumar [21] had a salvage rate ten times lower (9.09%), although the number of cases in these studies is almost equal (62 and 61, respectively). This can be explained by the inclusion and exclusion criteria, as well as by the different type of studies (prospective versus prospective plus retrospective).

In almost all combat studies with a large number of cases, MESS is the most used scoring system, due to its simplicity. Because most soldiers are under 30 years old, shock and ischemic time are the most important factors when calculating MESS in a combat casualty situation. "Life before limb" should be respected when treating severely mangled extremity injuries. In combat situations, lower limb injuries are frequently associated with other organ injuries, which are sometimes life-threatening. That explains why some authors prefer to apply a tourniquet on a limb with MESS >7 and amputate in critical situations. Most reports agree with amputations for combat limb injuries with MESS >7.

When addressing MESS prediction in children, all the studies reported good correlation between MESS and limb salvage or amputation. This may be explained by the fact that patients younger than 30 years of age receive no points on MESS. The literature has only a small number of studies referring to only a small number of cases of children with mangled extremities. Children have a better outcome compared with adults and have a lower rate of delayed union or osteomyelitis [31-33] after lower limb injuries.

In conclusion, we must note that the last two decades have seen advances in reconstructive techniques, combined with good collaboration between plastic surgeons, orthopedic surgeons, and vascular surgeons, that has made a difference in terms of limb salvage, as well as secondary reconstruction [24, 34].

In his study on 556 limbs, Bosse [30] did not validate the clinical utility of any of the lower-extremity injury-severity scores. We agree that it is better, as a first step, to attempt to salvage the limb; if it proves to be unsalvageable, a secondary amputation should be performed. However, technical viability is not a sufficient criterion for limb salvage [35]. The growing enthusiasm for microvascular surgery may lead to death, sepsis, and preservation of dysfunctional limbs, as well as higher adjusted hospital charges. Those patients who underwent successful limb salvage procedures had more complications, more complex operations, more operative procedures, and longer hospitalizations than patients who underwent early amputation [36]. Unfortunately, a salvaged limb does not guarantee functionality, normal life, a pain-free extremity, or employability. It is important for the patient and his/her family to understand that neither a salvage procedure nor an amputation will guarantee a return to the previous normal extremity. This is why a prediction score alone should not make the decision for amputation or salvage procedure. The final decision should also take into account future functionality, available recovery programs, the patient's demeanor and, as a final criterion, the surgeon's enthusiasm and skill.

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References

[1] Nawar EW, Niska RW, Xu J. National Hospital Ambulatory Medical Care Survey: 2005 emergency department summary. Adv Data 2007; 386: 1-32.

[2] Jovanovic S, Wertheimer B, Zelic Z, Getos Z. Wartime amputations. Mil Med 1999; 164: 44-47.

[3] Soldo S, Puntaric D, Petrovicki Z, Prgomet D. Injuries caused by antipersonnel mines in Croatian Army soldiers on the East Slavonia front during the 1991-1992 war in Croatia. Mil Med 1999; 64: 141-144.

[4] Zelle BA, Brown SR, Panzica M, Lohse R, Sittaro NA, Krettek C, Pape HC. The impact of injuries below the knee joint on the long-term func-

tional outcome following polytrauma. Injury 2005; 36: 169-177.
[5] Nolan PC, McPherson J, McKeown R, Diaz H, Wilson D. The price of peace: the personal and financial cost of paramilitary punishments in Northern Ireland. Injury 2000; 31: 41-45.
[6] Sohn VY, Arthurs ZM, Herbert GS, Beekley AC, Sebesta JA. Demographics, treatment, and early outcomes in penetrating vascular combat trauma. Arch Surg 2008; 143: 783-787.
[7] Lerner A, Fodor L, Soudry M. Is staged external fixation a valuable strategy for war injuries to the limbs? Clin Orthop Relat Res 2006; 448: 217-224.
[8] Ngim NE, Udosen AM, Ikpene IA, Ngim OE. Prospective study of limb injuries in Calabar. J Orthop Surg 2008; 8 [http://www.ispub.com/journal/the-internet-journal-of-orthopedic-surgery/volume-8-number-2/prospective-study-of-limb-injuries-in-calabar.html].
[9] Barros D'Sa AA, Harkin DW, Blair PH, Hood JM, McIlrath E. The Belfast approach to managing complex lower limb vascular injuries. Eur J Vasc Endovasc Surg 2006; 32: 246-56.
[10] Barros D'Sa AA. The value of shunting in complex vascular trauma of the lower limb. In Evidence for Vascular Surgery. Edited by Earnshaw JJ, Murray CK. Shropshire, England, TFM Publications, 1999; pp 189-196.
[11] Johansen K, Daines M, Howey T, Helfet D, Hansen ST Jr. Objective criteria accurately predict amputation following lower extremity trauma. J Trauma 1990; 30: 568-572.
[12] Howe HR Jr, Poole GV Jr, Hansen KJ, Clark T, Plonk GW, Koman LA, Pennell TC. Salvage of lower extremities following combined orthopedic and vascular trauma. A predictive salvage index. Am Surg 1987; 53: 205-208.
[13] Russell WL, Sailors DM, Whittle TB, Fisher DF Jr, Burns RP. Limb salvage versus traumatic amputation. A decision based on a seven-part predictive index. Ann Surg 1991; 213: 473-481.
[14] Krettek C, Seekamp A, Kontopp H, Tscherne H. Hannover Fracture Scale '98-re-evaluation and new perspectives of an established extremity salvage score. Injury 2001; 32: 317-328.
[15] Seekamp A, Kontopp H, Tscherne H. [Hannover Fracture Scale '98-reevaluation and new prospects for an established score system]. Unfallchirurg 2001; 104: 601-610.
[16] Elsharawy MA. Arterial reconstruction after mangled extremity: injury severity scoring systems are not predictive of limb salvage. Vascular 2005; 13: 114-119.
[17] Menakuru SR, Behera A, Jindal R, Kaman L, Doley R, Venkatesan R. Extremity vascular trauma in civilian population: a seven-year review from North India. Injury 2005; 36: 400-406.
[18] O'Sullivan ST, O'Sullivan M, Pasha N, O'Shaughnessy M, O'Connor TP. Is it possible to predict limb viability in complex Gustilo IIIB and IIIC tibial fractures? A comparison of two predictive indices. Injury 1997; 28: 639-642.
[19] Rajasekaran S, NareshBabu J, Dheenadhayalan J, Shetty AP, Sundararajan SR, Kumar M, Rajasabapathy S. A score for predicting salvage and outcome in Gustilo type-IIIA and type-IIIB open tibial fractures. J Bone Joint Surg Br 2006; 88: 1351-1360.
[20] Cannada LK, Cooper C. The mangled extremity: limb salvage versus amputation. Curr Surg 2005; 62: 563-576.
[21] Kumar MK, Badole C, Patond K. Salvage versus amputation: Utility of mangled extremity severity score in severely injured lower limbs. Indian J Orthop 2007; 41: 183-187.
[22] Sharma S, Devgan A, Marya KM, Rathee N. Critical evaluation of mangled extremity severity scoring system in Indian patients. Injury 2003; 34: 493-496.
[23] Rush RM Jr, Kjorstad R, Starnes BW, Arrington E, Devine JD, Andersen CA. Application of the Mangled Extremity Severity Score in a combat setting. Mil Med 2007; 172: 777-781.
[24] Korompilias AV, Beris AE, Lykissas MG, Vekris MD, Kontogeorgakos VA, Soucacos PN. The mangled extremity and attempt for limb salvage. J Orthop Surg Res 2009; 4: 4.
[25] Durham RM, Mistry BM, Mazuski JE, Shapiro M, Jacobs D. Outcome and utility of scoring systems in the management of the mangled extremity. Am J Surg 1996; 172: 569-574.
[26] Gifford SM, Aidinian G, Clouse WD, Fox CJ, Porras CA, Jones WT, Zarzabal LA, Michalek JE, Propper BW, Burkhardt GE, Rasmussen TE. Effect of temporary shunting on extremity vascular injury: an outcome analysis from the Global War on Terror vascular injury initiative. J Vasc Surg 2009; 50: 549-556.
[27] Mommsen P, Zeckey C, Hildebrand F, Frink M, Khaladj N, Lange N, Krettek C, Probst C. Traumatic extremity arterial injury in children: epidemiology, diagnostics, treatment and prognostic value of Mangled Extremity Severity Score. J OrthopSurg Res 2010; 5: 25.
[28] Fagelman MF, Epps HR, Rang M. Mangled extremity severity score in children. J Pediatr Orthop 2002; 22: 182-184.
[29] Brown KV, Ramasamy A, McLeod J, Stapley S, Clasper JC. Predicting the need for early amputation in ballistic mangled extremity injuries. J Trauma 2009; 66: S93-S98.
[30] Bosse MJ, MacKenzie EJ, Kellam JF, Burgess AR, Webb LX, Swiontkowski MF, Sanders RW, Jones AL, McAndrew MP, Patterson BM, McCarthy ML, Cyril JK. A prospective evaluation of the clinical utility of the lower-extremity injury -severity scores. J Bone Joint Surg Am 2001; 83 -A: 3-14.
[31] Bartlett CS, Weiner LS, Yang, EC. Treatment of type II and type III open tibia fractures in children. J Orthop Trauma 1997; 11: 357-362.

[32] Blasier RD, Barnes CL. Age as a prognostic factor in open tibial fractures in children. Clin Orthop Relat Res 1996; 331: 261-264.
[33] Cullen MC, Roy DR, Crawford AH, Assenmacher J, Levy MS, Wen D. Open fracture of the tibia in children. J Bone Joint Surg Am 1996; 78: 1039-1047.
[34] Soucacos PN, Beris AE, Xenakis TA, Malizos KN, Vekris MD. Open type IIIB and IIIC fractures treated by an orthopaedic microsurgical team. Clin Orthop Relat Res 1995; 314: 59-66.
[35] Heitmann C, Levin LC: The orthoplastic approach for management of the severely traumatized foot and ankle. J Trauma 2003; 54: 379-390.
[36] Dirschl DR, Dahners LE. The mangled extremity: when should it be amputated? J Am Acad Orthop Surg 1996; 4: 182-190.