Does the non-union scoring system (NUSS) affect the treatment approach of non-union?

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ABSTRACT

Aim: To investigate the effectiveness of the non-union scoring system (NUSS) in predicting the result and in guiding the treatment by comparing the treatment methods applied to non-union patients we treat in our clinic with the treatment methods suggested by the NUSS.

Methods*:* The study included 116 patients, who were diagnosed with long bone (femur, tibia and humerus) non-union and treated in our clinic. Of the 116 patients with non-union, 48 had femur (41.38 %), 39 had tibia (33.62%) and 29 had humerus (25%) non-union. The patient scores were calculated according to the NUSS criteria. The patients were divided into four groups according to their total scores. There were 34 patients in the first group (0-25 points), 49 patients in the second group (26-50 points), 30 patients in the third group (51-75 points) and three patients in the fourth group (76-100 points).

Results: Union that was achieved in 79 (68.10%) of all patients was detected in 97.05% of the patients in the first group, 83.67% in the second group, and 16.66 % in the third group. Amputation, arthroplasty and arthrodesis were applied to three patients in the fourth group. While union rate was 100 % in the femur and tibia in the first group, it was 90% in the humerus. The union rates were 85.71% in the humerus, 75% in the femur and 100% in the tibia in the second group. They were 20 % in the humerus, 15.38% in the femur and 16.66% in the tibia in the third group. The number of patients treated with the treatment proposed by the NUSS: 100% in the group 1, 83.67% in the group 2, 20% in the group 3 and 100% in the group 4. The risk of non-union in those who were not treated according to the NUSS recommendations was 28 times higher than that of others.

Conclusions: The results of our study suggest that more frequent use of the NUSS procedure in non-union treatment planning may increase treatment success. In addition, NUSS can provide information about the treatment process of non-unions.

Key words: Trauma, fracture, pseudoarthrosis, non-union scoring system (NUSS), bone defect.

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Introduction

Non-union treatment has always been difficult for orthopedic surgeons. There is no consensus among clinicians, and it was found that there were differences of opinion among clinicians up to 55% on non-unions [1]. According to the US Food and Drug Administration (FDA), the diagnosis of non-union may be established "after 9 months from injury and if the fracture does not show any progressive signs of healing for 3 months", but others state that for long bones like the femur, humerus or tibia this process can be defined as 6 months if no radiological evidence of fracture healing

present [2]. On the other hand the treatment of non-union is a challenge and the treatment failure rate of non-union is approximately %20 [3]. Many classification systems were developed to address this issue. Currently, there are classification systems developed by Weber-Cech, Ilizarov, and Paley [4, 5, 6]. The most commonly used one is the radiography-based classification system developed by Weber-Cech. According to this system, non-unions are classified as atrophic, oligotrophic and hypertrophic. While there is a vascular insufficiency in the fracture zone in atrophic and oligotrophic non-unions, vascularity is sufficient in hypertrophic non-union, but reduction is inadequate. It is inevitable that this classification system based on radiography has deficiencies in the treatment-directing.

The new scoring system, Non-Union Scoring System (NUSS), that is described by Calori et al. in 2008, is the most comprehensive classification system ever developed consisting of many parameters [7]. The NUSS is a system in which many factors related to bone, soft tissue and patient are scored, and the treatment options are specified considering the score obtained (Table 1). The NUSS includes the assessment and scoring in terms of the quality of bone, whether the primary injury is open or closed fracture, the number of previous interventions to ensure healing, invasiveness of previous interventions, adequacy of primary surgery, the Weber-Cech classification, bone alignment, bone defect-gap, soft tissues, the ASA grade, diabetes, blood tests (WBC, ESR, CRP), clinical infection status, drugs and smoking status. The score of the patient is calculated by multiplying the sum of the scores by two. In the light of these scores, patients are treated according to the recommended treatment methods in four groups defined. Scores from 0 to 25 is considered

straightforward non-unions that are expected to respond well to the appropriate treatments. The problem in this group is generally mechanical. Scores from 26 to 50 would require more specialized care to be given. The problem is mainly biological and mechanical. For patients with scores from 51 to 75, a specialized care and specialized treatments should be sought. Mechanical and biological failure is more complex and non-union resection and bone defect filling are generally required. Patients with scores over 75 can be candidates for consideration of arthrodesis, arthroplasty or primary amputation [7].

In the present study, the records of patients treated with non-union diagnosis in our clinic were retrospectively reviewed. The results of the treatments were scored according to the NUSS criteria. We investigated the effectiveness of the NUSS in predicting the outcomes and in guiding treatment by comparing the treatment methods applied to non-union patients we treat in our clinic with the treatment methods suggested by the NUSS.

Materials and methods

The study was retrospectively conducted in our clinic. The study protocol was approved by the local Scientific Research Ethics Committee (2019/04) and the study was conducted in accordance with the Declaration of Helsinki. It included 116 patients treated with long bone (femur, tibia, and humerus) non-union. Inclusion criteria were, the presence of the femur, tibia or humerus non-union, over 18 years of age and the patients with adequate follow-up. Exclusion criteria were, pregnancy, pediatric patients, and fractures due to malignancies and autoimmune diseases. The numbers of male and female patients included in the study are 85 (73.3%) and 31 (26.7%), respectively. The average age of the patients

Table 1. Non-union scoring system (NUSS).

The bone		Score	Max. score[a]
Quality of the bone	Good	0	
	Moderate (e.g. mildly osteoporotic)	1	
	Poor (e.g. severe porosis or bone loss)	2	
	Very poor (Necrotic, appears avascular or septic)	3	3
Primary injury –open or closed fracture	Closed	0	
	Open 1º grade	1	
	Open 2–3º A grade	3	
	Open 3º B–C grade	5	5
Number of previous interventions on this bone to procure healing	None	1	
	<2	2	
	<4	3	
	>4	4	4
Invasiveness of previous interventions	Minimally-invasive: Closed surgery (screws, k wires, . . .)	0	
	Internal intra-medullary (nailing)	1	
	Internal extra-medullary	2	
	Any osteosynthesis which includes bone grafting	3	3
Adequacy of primary surgery	Inadequate stability	0	
	Adequate stability	1	1
Weber & Cech group	Hypertrophic	1	
	Oligotrophic	3	
	Atrophic	5	5
Bone alignment	Non-anatomic alignment	0	
	Anatomic alignment	1	1
Bone defect – Gap	0.5–1 cm	2	
	1–3 cm	3	
	>3 cm	5	5
Soft tissues			
Status	Intact	0	
	Previous uneventful surgery, minor scarring	2	
	Previous treatment of soft tissue defect (e.g. skin loss, local flap cover, multiple incisions, compartment syndrome, old sinuses)	3	
	Previous complex treatment of soft tissue defect (e.g. free flap)	4	
	Poor vascularity: absence of distal pulses, poor capillary refill, venous insufficiency	5	
	Presence of actual skin lesion/defect (e.g. ulcer, sinus, exposed bone or plate)	6	6
The patient			
ASA Grade	1 or 2	0	
	3 or 4	1	1
Diabetes	No	0	
	Yes – well controlled (HbA1c < 10)	1	
	Yes – poorly controlled (HbA1c >10)	2	2
Blood tests: FBC, ESR, CRP	FBC: WCC >12	1	
	ESR > 20	1	
	CRP >20	1	3
Clinical infection status	Clean	0	
	Previously infected or suspicion of infection	1	
	Septic	4	4
Drugs	Steroids	1	
	NSAIDs	1	2
Smoking status	No	0	
	Yes	5	5

[a]*Higher score implies more difficult to procure union.*

Table 2. Number of patients treated regarding treatment proposed by non-union scoring system (NUSS).

NUSS Score	The number of patients	Union	The number of patients treated regarding treatment proposed by NUSS/ (%)
Group 1 (0-25)	34	33	34 (%100)
Group 2 (26-50)	49	41	41 (%83,67)
Group 3 (51-75)	30	5	6(%20)
Group 4 (76-100)	3	0	3(%100)
Total	116	79	84

was 40.5 (17-86). The mean follow-up period of the patients was 21.79 (11-63) months. Pediatric patients were not included in the study. The patients who underwent non-union treatment were retrospectively evaluated according to the Non-Union Scoring System (NUSS) developed by Calori et al. [1]. The number of patients who developed non-union (116 patients) in the femur, tibia, and humerus was 48 (41.38%), 39 (33.62%) and 29 (25%), respectively. The score of patients was calculated according to the NUSS criteria. The patients were divided into four groups with respect to their total scores. There were 34 patients in the first group (score: 0-25), 49 patients in the second group (score: 26-50), 30 patients in the third group (score: 51-75) and three patients in the fourth group (score: 76-100) (Table 2). All patients were followed-up at 1, 3, 6, 9, 12 months by x-rays or CT-scans and union was assessed. Radiological presence of callus formation (3/4 of cortical) in AP-Lateral x-rays and clinical absence of pain in the fracture side were accepted as healing of the fracture.

Statistical analysis
The normality of distribution of continuous variables was tested by the Shapiro-Wilk test. The Student's t test was used for the comparison of two independent groups of variables with a normal distribution. The relationship between categorical variables was determined by the chi-square test. Univariate logistic regression analysis was used to estimate odds ratio (OR) and 95% confidence interval. Descriptive statistic parameters were presented as frequency, percentage (%) and mean ± standard derivation (mean ± SD). Statistical analysis was performed with SPSS for Windows version 22.0 and a p value < 0.05 was accepted to be statistically significant.

Results
The patients were divided into four groups according to the NUSS score. There were 34 patients in the first, 49 patients in the second, 30 patients in the third and three patients in the fourth group. Union was achieved in 79 (68.10%) of all patients. The union rate was determined to be 97% in the first group, 83.67% in the second group, and 16.67% in the third group. On the other hand, union was not achieved in the fourth group. The mean fracture healing time was 6.8 ± 1.82 months for the first group, 7.1 ± 1.55 months in the second group and 7.82 ± 1.63 months in the third group. Amputation, arthroplasty and arthrodesis were applied to three patients in the fourth group. While union rates were 100% in the femur and tibia in the first group, it was 90% in humerus. Union rates in the second group were 85.71% in humerus, 75% in the femur and 100% in the

Table 3. Our treatment choices for each bone.

Groups	Treatment choices	The number of patients
Group 1 (NUSS Score 0-25) (n=34)		
Humerus	Fixation system chanced and autogenous bone grafting	10
Femur	Fixation system chanced	3
	Fixation system changed and autogenous bone grafting	6
Tibia	Fixation system chanced	6
	Fixation system changed and autogenous bone grafting	9
Group 2 (NUSS Score 26-50) (n=49)		
Humerus	Fixation system chanced	1
	Fixation system changed and autogenous bone grafting	13
Femur	Autogenous bone grafting	1
	Fixation system chanced	3
	Fixation system changed and autogenous bone grafting	18
	Fixation system changed and vascular bone grafting	2
Tibia	Fixation system chanced	3
	Fixation system changed and autogenous bone grafting	7
	Nonunion resection and segment shifting	1
Group 3 (NUSS Score 51-75) (n=30)		
Humerus	Fixation system changed and autogenous bone grafting	5
Femur	Fixation system changed and autogenous bone grafting	10
	Fixation system changed and vascular bone grafting	2
	Tumor resection arthroplasty	1
Tibia	Fixation system changed and autogenous bone grafting	8
	Fixation system changed and vascular bone grafting	1
	Nonunion resection and segment shifting	3
Group 4 (NUSS Score 76-100) (n=3)		
Humerus	-	
Femur	Arthrodesis	1
	Tumor resection arthroplasty	1
Tibia	Amputation	1

Humerus (n=29); Femur (n=48); Tibia (n=39).

tibia. They were 20% in the humerus, 15.38% in the femur and 16.66% in the tibia in the third group. The fixation system was changed to increase the stability for 34 patients in the first group, and autogenous grafting was performed in addition to the fixation system for 25 patients (Table 3). The fixation system was changed, and autogenous grafting was performed for 38 of the 49 patients in the second group. Seven patients were treated in this group by changing the fixation system used. Two patients underwent vascular bone grafting. The grafting

was applied to only one patient. Non-union was resected, and bone defect was treated by segment shifting method in one patient (Table 3). The fixation system was changed, and autogenous grafting was performed for 23 of the 30 patients in the third group. Vascularized bone grafting was performed by changing the fixation system in three patients. Non-union was treated by non-union resection and segment shifting method in three patients. One patient underwent tumor resection arthroplasty (Table 3). The arthrodesis, tumor resection prosthesis, and amputation were applied for each of the three patients in the fourth group separately (Table 3).

The treatment methods applied to the patients were compared with the treatment recommendations proposed by the NUSS (Table 2). While the treatment methods used in the first and fourth groups were completely compatible with those recommended by the NUSS, it was determined that the treatment methods applied to the second and third group are entirely different from those recommended by the NUSS. The success rate in patients treated with the methods proposed by the NUSS was remarkable.

There was a statistically significant relationship between the treatment proposed by the NUSS and union rate (p=0.001). The risk of non-union in those who were not treated according to the NUSS recommendations was 28 times higher than that of others (Odds Ratio = 28.75% Confidence Interval = 9.66-85.61).

Discussion

In the present study we evaluated the patients who had developed a non-union. And the NUSS was used for scoring the non-unions and to see the process of fracture healing. There are a few studies in the literature investigating the classification systems for non-union [8-9-10].

We used the NUSS for analyzing the non-unions. There are not many studies about this classification system in the literature. Calori et al. have tested the validity of their classification system in the articles published in 2014 [8] and stated that this system might be a valid guideline. In a retrospective study conducted by Abumunaser et al. [11], 40 patients were divided into three groups, asserting that there would be no clear distinction regarding the treatment protocols between the group 2 (Score: 26-50) and the group 3 (Score: 51-75) in this classification. They stated that their treatment protocols were similar to the treatment protocols described in the NUSS, and reported that they achieved similar success rates in the treatment.

All patients in the first group were treated by the methods the NUSS recommended and union rate achieved was 97.05%. In the second group, 83.67% of the treatments were compatible with the methods recommended by the NUSS, and the union rate was 83.67%. On the other hand, only 20% of treatment methods applied to the patients in the third group complied with the treatment recommendations of the NUSS. The treatment success rate in this group was only 16.67%. Those results revealed that the non-union risk was 28 times higher in the patients who were not treated using the methods recommended by the NUSS when compared to patients treated according to the NUSS recommendations. This results were similar the study that published by Calori et al. [8]. In their study they analyzed 300 patients that applied with long bone non-unions.

According to the NUSS, the main problem in the first group is mechanical, and the aim of the treatment is to change the fixation system. In the present study, the fixation system was changed to improve stability in all patients in the first group. Treatment success was achieved

when the mechanical problem was solved. The problem in the second group was generally biological and mechanical. Recovery of fixation and the provision of biological stimulant are suggested for treatment. A more stable fixation was provided by changing the fixation system in 83.67% of the patients we treated in this group and biological support was given with an autogenous iliac bone graft. Union was achieved in these patients. In this group, only the fixation system was changed in seven out of eight patients whose union was not achieved with the treatment, and no biological stimulation was used. Autogenous bone grafting was performed in a patient whose fixation system was not changed. According to the NUSS, the problem is complex in the third group and there is an impairment of both biological and mechanical conditions. Non-union should be resected as the treatment suggestion and the bone defect should be treated. In our series, the treatment protocol suggested by the NUSS was applied only in six patients in this group, and union was achieved in five patients. Thus, the success rate was 83.33% in the treatment. However, union was not achieved in 25 patients in the group. Low success rate in this group may be related to our failure to use more aggressive treatment protocols. The treatment we applied was mostly changing the fixation system and autogenous grafting. Application of more effective methods like segment shifting and vascular grafting after non-union resection could have increased our treatment like our study [12].

The NUSS recommends treatments such as arthrodesis, arthroplasty and amputation for the fourth group. We applied tumor resection arthroplasty, arthrodesis and amputation for our patients in this group.

There are several limitations in the study. The limitations of the study are that the NUSS has yet to be validated [8] and the study was conducted retrospectively. However, it can be thought that as the number of studies on this subject increase, the scoring system will be used more widely.

We think that the more frequent use of the NUSS in non-union treatment planning can increase the success of the treatment and it can be used as a classification guide for the surgeon in the treatment of nonunion.

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical statement:
The study was approved by Local Clinical Research Ethics Committee (Date and Decision Number: 2019/04) and written informed consent was obtained from each subject.

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