



ROLE OF DIFFERENT CRITERIA IN OUTCOME ANALYSIS OF MANAGEMENT OF GAP NON-UNION

Dr Nirjhar Maji*

Consultant Orthopaedics Surgeon, District Hospital, Asansol. W.b. India-713301. *Corresponding Author

ABSTRACT

Back ground and objectives: Gap or Defect non-union is not uncommon in Orthopaedic practice. Management involves prolonged periods of tedious procedures and decision making. The endpoint of such management does not reveal itself as a well-defined point. Follow ups must include some analysable outcome which should have a standardised criteria-based endpoint. A well-aligned, painless, noninfected, and functional limb is the goal of treatment. The objective of this study is to understand the role of different criterion to understand whether the goal has been reached.

Summary: The study is designed as retrospective, prospective observational study. It is conducted in tertiary care hospital (MIOT Hospitals, Chennai). Initial evaluation of all cases were done by Maurizio Catagni's Classification. Type of surgeries, time spent in hospital, union time were calculated. Patients were followed up for a period of 1 year. Patients with average defect size of 6.29cm on an average underwent 4.47 procedures and for an overall time of 17.8 weeks with around 83.80 % of individuals were able to return to their preinjury activity level. Analysis of the outcome was done by ASAMI bone criteria, ASAMI functional criteria, Cattneo et al criteria and Karstrom-Olerud's functional evaluation criteria for lower limbs at onset of treatment, 6 months and 1 year of treatment.

KEYWORDS : Outcome analysis, Gap or Defect nonunion , Catagni, ASAMI, Karlström-Olerud's, Cattneo

INTRODUCTION

Gap non-union is characterized by loss of segment of long bone. The ends of the fragments may be viable but bone union across the defect is impossible. As time passes the fragments become atrophic. Catagni⁽¹⁾ classified Gap Non-union into different categories by length of gaps and presence of infection.

MAURIZIO CATAGNI'S CLASSIFICATION

- A1- Non infected mobile non-union
- A2- Non infected stiff hypertrophic non-union without deformity
- A3- Non infected Hypertrophic non-union with deformity
- B1- Non infected non-union with bone defect of up to 5 cm.
- B2- Non infected non-union with bone defect exceeding 5 cm.
- B3- Non infected non-union exceeding 10 cm with local scarring
- C1- Infected non-union with atrophy
- C2- Infected non-union with hypertrophy without deformity
- C3- Infected non-union with hypertrophy and deformity
- C4- Infected non-union with bone gap of less than 5 cm.
- C5- Infected non-union with bone gap between 5 and 10 cm.
- C6- Infected non-union with bone gap exceeding 10 cm.

Defect or Gap non-union concerns type B, C3, C4 and C5 and are subject of the study.

Aim of Study

This study aims to understand the role of different criteria in analysis of outcome of Gap non-union treated by different methods at tertiary level trauma centre.

Review of Literature

Different criteria were developed at different times for ascertaining whether an outcome is acceptable and to categorise them, separating actual success from the failures.

Association For The Study And Application Of The Methods Of Ilizarov (ASAMI)⁽²⁾ Table 1

Bone result	Excellent	Union, no infection, deformity < 7°, limb length discrepancy < 2.5 cm
	Good	Union + any two of the following: no infection, deformity < 7°, limb length discrepancy < 2.5 cm

	Fair	Union + only one of the following: no infection, deformity < 7°, limb length discrepancy < 2.5 cm
	Poor	Non-union / refracture / union + infection + deformity > 7° + limb length discrepancy > 2.5 cm
Functional results	Excellent	Active, no limp, minimum stiffness (loss of < 15° knee extension / < 15° dorsiflexion of ankle), no reflex sympathetic dystrophy, insignificant pain
	Good	Active with one or two of the following: Limp, stiffness, RSD, significant pain.
	Fair	Active with three or all the following: Limp, stiffness, RSD, significant pain
	Poor	Inactive (unemployment or inability to return to daily activities because of injury)
	Failure	amputation

As ASAMI protocol does not consider bone union obtained after bone grafting as excellent, patients who had excellent result was considered to have a good result.

Cattneo et al scoring system Table 2

Union:	
U0:	Failure to obtain union
U1:	Solid union
Infection:	
I0:	Unchanged infection
I1:	Persistent minimal drainage
I2:	Complete clinical remission of infection
Function:	
F0:	Invalid function
F1:	Able to perform all daily activity
F2:	Complete recovery

Karlström-Olerud's functional evaluation criteria used for lower limbs⁽³⁾ Table 3

Parameters	Score	
Pain (6 months)	Severe pain	1 point
	Moderate pain	2 points

	None	3 points
Walking difficulties	Significant / limping	1 point
	Moderate	2 points
	None	3 points
Climbing difficulties	Impossible	1 point
	With supports	2 points
	None	3 points
Difficulties during sport activities	Impossible	1 point
	Some sports	2 points
	None	3 points
Working restrictions	Impossible	1 point
	Moderate	2 points
	None	3 points
Skin status	Ulcer / fistula	1 point
	Skin discoloration	2 points
	Normal	3 points
Deformities	Significant over 7 degrees	1 point
	Low up to 7 degrees	2 points
	None	3 points
Muscle atrophy / Tibial circumference	> 2 cm	1 point
	1 - 2 cm	2 points
	< 1 cm	3 points
Lower-limb-length difference	> 2 cm	1 point
	1 - 2 cm	2 points
	< 1 cm	3 points
Knee-joint motion range limitation	> 20	1 point
	10 - 20	2 points
	< 10	3 points
Subtalar -joint motion range limitation	> 20	1 point
	10 - 20	2 points
	< 10	3 points
Capacity of full weightbearing	Yes	1 point
	No	2 points

Points are given and added up based on the above criteria.

Results are evaluated as follows. 36 points: excellent, 35-33 points: good, 32-30 points: acceptable, 29-27 points: moderate, and 26-24 points: poor.

Materials and Methods

Materials

- **Study design: Retrospective-Pro prospective Observational Study**
- Retrospective – cases in different phases of ongoing management i.e. with established gap nonunion or undergoing treatment or in follow-up
- Prospective –enrolled at the onset e.g. following RTA, etc.
- Observational- No interventional measures are taken for the sake of the study.

Sample size- 105

Calculation of sample size

Calculation of the sample size was done with nMASTER software with study done by Miller^[4] et al 2010

Hypothesis Testing for Single Proportion

Population Proportion $P_0 = .60$

Sample Proportion $P_a = .46$

Power (%) = 80

Alpha Error (%) = 5

Sided = 2

Sample size (n) = 97

Alpha Error(%)	Power(%)	Sample Size(n)
1	70	119
	80	145
	90	185
5	70	76
	80	97
	90	130
10	70	58
	80	76
	90	106

Setting-tertiary care hospital (MIOT hospitals, Chennai)

Duration of Study- APRIL, 2014 to OCTOBER, 2015.

Recruitment of cases

Total number recruited in their follow-up period- 86 patients.

Total number recruited on their treatment period- 19 patients.

Inclusion Criteria

All patients

- in the age range 15 to 60 years
- with segmental gap of bone of more than 1cm.

Exclusion Criteria

Patients with

- irregular follow-ups and poor compliance
- distal neuro-vascular deficit
- substance abuse (alcohol, illicit drugs etc.)

Follow-up

The follow-up interval was Monthly and as required and follow-up period was 1 year.

Methodology

Pre-operative protocol

All recruited cases were classified by Maurizio Catagnio's Classification and each surgery recorded and complications documented.

Statistics

Data collection techniques

Data was collected from the OPD and IPD.

Data analysis plan

Data was tabulated and statistically analysed in MS Excel and SPSS 17 (Chicago, Illinois).

Paired sample "t" test was done to compare the group means and the p value was calculated.

Probability value less than 5% was considered as statistically significant.

Observations

Table 4

CATAGNIO TYPE					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	B1	12	11.4	11.4	11.4
	B2	41	39.0	39.0	50.5
	B3	15	14.3	14.3	64.8
	C4	6	5.7	5.7	70.5
	C5	29	27.6	27.6	98.1
	C6	2	1.9	1.9	100.0
Total		105	100.0	100.0	

Catagnio type B2 e.i. non-infected gap-nonunion with gaps of 5 to 10 cm was the major group with 39 percent of cases. All

type C cases were infected.

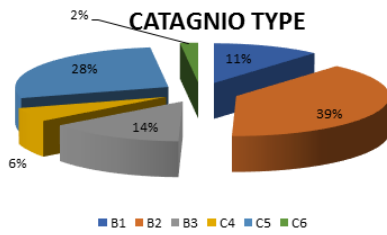


Figure 1

Table 5

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
AGE	105	18	58	30.58	9.231
LENGTH OF GAP-CM	105	1.80	14.00	6.2905	2.31731
DEFORMITY- DEGREES	105	0	30	4.81	8.858
SHORTENING-CM	105	0	9.0	1.070	2.2316
TOTAL NUMBER OF PROCEDURES DONE	105	2	10	4.47	1.582
TOTAL STAY IN HOSPITAL DAYS	105	13	49	27.23	10.054
UNION TIME- MONTHS	89	3	7	4.15	1.173
Karlstrom-Olerud's functional SCORE AT ADMISSION	72	13	16	14.92	1.084
Karlstrom-Olerud's functional SCORE 6 MONTHS	72	24	36	31.69	4.161
Karlstrom-Olerud's functional SCORE 1 YEAR	72	24	36	32.37	3.747
Valid N (listwise)	89				

Results

Table 6

	3 month	3-6 month	6-9 months	No Union
Radius	9	5	1	2
Ulna	3	1	0	2
Humerus	3	3	0	3
Femur	6	11	1	3
Tibia	11	35	0	6

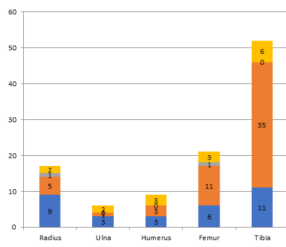


Figure 2

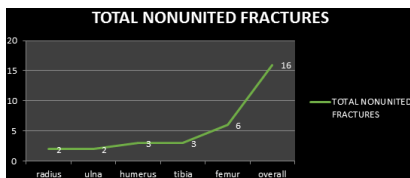


Figure 3

Table 6

Number Of Procedures	Number of patients
2	1
3	37
4	28
5	11
6	8
7	18
>7	1

28 percent of the cases underwent procedures 4 times and only one patient underwent more than 7 procedures.

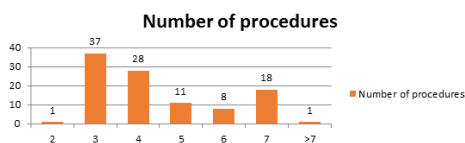


Figure 4

The average hospital stay was 27.23days, maximum stay being 49 days and minimum being 13 days.

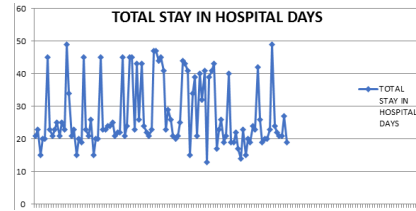


Figure 5

Stiffness was the commonest complication seen in 30 cases with Reflex sympathetic dystrophy seen in only 2 cases.

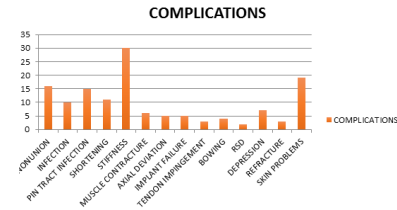


Figure 6

Analysis of results

ASAMI Bone score comparison at Onset , 6 months and 1 year

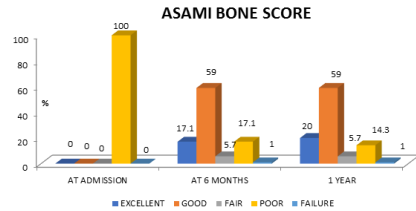


Figure 7

ASAMI BONE SCORE AT ADMISSION * ASAMI BONE SCORE AT 6 MONTHS

Table 7

		ASAMI BONE SCORE AT 6 MONTHS					Total
		EXCELLENT	GOOD	FAIR	POOR	FAILURE	
ASAMI BONE SCORE POOR AT ADMISSION	Count	18	62	6	18	1	105
	% of Total	17.1%	59.0%	5.7%	17.1%	1.0%	100.0%
Total	Count	18	62	6	18	1	105
	% of Total	17.1%	59.0%	5.7%	17.1%	1.0%	100.0%

ASAMI BONE SCORE AT ADMISSION * ASAMI BONE SCORE 1 YEAR

Table 8

		ASAMI BONE SCORE 1 YEAR					Total
		EXCELLENT	GOOD	FAIR	POOR	FAILURE	
ASAMI BONE SCORE POOR AT ADMISSION	Count	21	62	6	15	1	105
	% of Total	20.0%	59.0%	5.7%	14.3%	1.0%	100.0%
Total	Count	21	62	6	15	1	105
	% of Total	20.0%	59.0%	5.7%	14.3%	1.0%	100.0%

Table 9

		ASAMI BONE SCORE 1 YEAR					Total	
		EXCELLENT	GOOD	FAIR	POOR	FAILURE		
ASAMI BONE SCORE AT 6 MONTHS	EXCELLENT	Count	18	0	0	0	0	18
		% of Total	17.1%	0%	0%	0%	0%	17.1%
	GOOD	Count	0	62	0	0	0	62
		% of Total	0%	59.0%	0%	0%	0%	59.0%
	FAIR	Count	0	0	6	0	0	6
	% of Total	0%	0%	5.7%	0%	0%	5.7%	
POOR	Count	3	0	0	15	0	18	
	% of Total	2.9%	0%	0%	14.3%	0%	17.1%	
FAILURE	Count	0	0	0	0	1	1	
	% of Total	0%	0%	0%	0%	1.0%	1.0%	
Total	Count	21	62	6	15	1	105	
	% of Total	20.0%	59.0%	5.7%	14.3%	1.0%	100.0%	

Table 10

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	390.000 ^a	16	.000
Likelihood Ratio	218.734	16	.000
Linear-by-Linear Association	77.451	1	.000
N of Valid Cases	105		

a. 20 cells (80.0%) have expected count less than 5. The minimum expected count is .01.

The ASAMI bone score was Excellent in 17.1 % of cases in 6 months and 20 percent of cases in 1 year. As ASAMI does not consider bone grafting as Excellent so many of the cases had to be categorized into Good. Percentage of Good was 62 at both 6 months and 1 year. Values were statistically significant with P value less than 0.05. One case was a failure as it has undergone amputation following recurrence of tumour.

ASAMI Functional score comparison at Onset, 6 months and 1 year

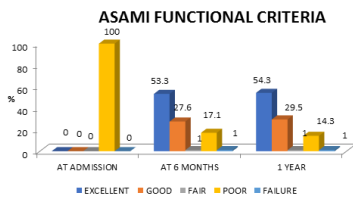


Figure 8

ASAMI FUNCTIONAL CRITERIA AT ADMISSION * ASAMI FUNCTIONAL CRITERIA 6 MONTHS and 1 YEAR

Table 11

		ASAMI FUNCTIONAL CRITERIA 6 MONTHS					Total
		EXCELLENT	GOOD	FAIR	POOR	FAILURE	
ASAMI FUNCTIONAL CRITERIA AT ADMISSION	POOR	Count 56	Count 29	Count 1	Count 18	Count 1	Count 105
	% of Total	53.3%	27.6%	1.0%	17.1%	1.0%	100.0%
Total	Count	56	29	1	18	1	105
	% of Total	53.3%	27.6%	1.0%	17.1%	1.0%	100.0%

ASAMI FUNCTIONAL CRITERIA AT ADMISSION * ASAMI FUNCTIONAL CRITERIA 1 YEAR

Table 12

		ASAMI FUNCTIONAL CRITERIA 1 YEAR					Total
		EXCELLENT	GOOD	FAIR	POOR	FAILURE	
ASAMI FUNCTIONAL CRITERIA AT ADMISSION	POOR	Count 57	Count 31	Count 1	Count 15	Count 1	Count 105
	% of Total	54.3%	29.5%	1.0%	14.3%	1.0%	100.0%
Total	Count	57	31	1	15	1	105
	% of Total	54.3%	29.5%	1.0%	14.3%	1.0%	100.0%

Crosstabs

Table 13

		ASAMI FUNCTIONAL CRITERIA 6 MONTHS * ASAMI FUNCTIONAL CRITERIA 1 YEAR Crosstabulation					Total
		EXCELLENT	GOOD	FAIR	POOR	FAILURE	
ASAMI FUNCTIONAL CRITERIA 6 MONTHS	EXCELLENT	Count 56	Count 0	Count 0	Count 0	Count 0	Count 56
		% of Total 53.3%	0.0%	0.0%	0.0%	0.0%	53.3%
	GOOD	Count 0	Count 29	Count 0	Count 0	Count 0	Count 29
		% of Total 0.0%	27.6%	0.0%	0.0%	0.0%	27.6%
	FAIR	Count 0	Count 0	Count 1	Count 0	Count 0	Count 1
	% of Total 0.0%	0.0%	1.0%	0.0%	0.0%	1.0%	
POOR	Count 1	Count 2	Count 0	Count 15	Count 0	Count 18	
	% of Total 1.0%	1.9%	0.0%	14.3%	0.0%	17.1%	
	FAILURE	Count 0	Count 0	Count 0	Count 0	Count 1	Count 1
	% of Total 0.0%	0.0%	0.0%	0.0%	1.0%	1.0%	
Total	Count	57	31	1	15	1	105
	% of Total	54.3%	29.5%	1.0%	14.3%	1.0%	100.0%

Table 14

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	394.739 ^a	16	.000
Likelihood Ratio	202.236	16	.000
Linear-by-Linear Association	91.330	1	.000
N of Valid Cases	105		

a. 18 cells (72.0%) have expected count less than 5. The minimum expected count is .01.

The ASAMI functional score was Excellent in 53.3 % of cases in 6 months and 54.3 percent of cases in 1 year. Percentage of Good was 27.6 and 29.5 at 6 months and 1 year respectively. Cross tabulation values were statistically significant with P value less than 0.05.

Cattneo comparison at Onset , 6 months and 1 year

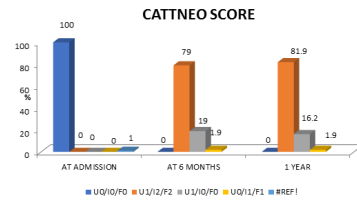


Figure 9

Cattneo SCORE AT ADMISSION * Cattneo SCORE AT 6 MONTHS

Table 15

		Cattneo SCORE AT 6 MONTHS			Total
		U1/12/F2	U0/11/F0	U0/11/F1	
Cattneo SCORE AT ADMISSION	U0/10/F0	Count 83	Count 20	Count 2	Count 105
	% of Total	79.0%	19.0%	1.9%	100.0%
Total	Count	83	20	2	105
	% of Total	79.0%	19.0%	1.9%	100.0%

Cattneo SCORE AT ADMISSION * Cattneo SCORE 1 YEAR

Table 16

		Cattneo SCORE 1 YEAR			Total
		U1/12/F2	U0/11/F0	U0/11/F1	
Cattneo SCORE AT ADMISSION	U0/10/F0	Count 86	Count 17	Count 2	Count 105
	% of Total	81.9%	16.2%	1.9%	100.0%
Total	Count	86	17	2	105
	% of Total	81.9%	16.2%	1.9%	100.0%

Crosstabs

Table 17

Cattneo SCORE AT 6 MONTHS * Cattneo SCORE 1 YEAR Crosstabulation

		Cattneo SCORE 1 YEAR			Total
		U1/12/F2	U0/11/F0	U0/11/F1	
Cattneo SCORE AT 6 MONTHS	U1/12/F2	Count 83	Count 0	Count 0	Count 83
		% of Total 79.0%	0.0%	0.0%	79.0%
	U0/11/F0	Count 3	Count 17	Count 0	Count 20
	% of Total 2.9%	16.2%	0.0%	19.0%	
U0/11/F1	Count 0	Count 0	Count 2	Count 2	
	% of Total 0.0%	0.0%	1.9%	1.9%	
Total	Count	86	17	2	105
	% of Total	81.9%	16.2%	1.9%	100.0%

Table 18

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	191.137 ^a	4	.000
Likelihood Ratio	95.174	4	.000
Linear-by-Linear Association	90.618	1	.000
N of Valid Cases	105		

a. 6 cells (66.7%) have expected count less than 5. The minimum expected count is .04.

The Cattneo score was U1/12/F2 (solid union with no infection and full function) was seen in 79 % of cases in 6 months and 81.9% of cases in 1 year. Cross tabulation values were statistically significant with P value less than 0.05.

Karlström-Olerud's functional evaluation criteria at admission, 6 months and 1 year

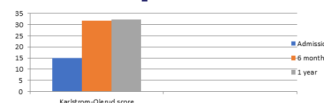


Figure 10

Table 19

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Karlström-Olerud's functional SCORE AT ADMISSION	14.92	72	1.084	.128
	Karlström-Olerud's functional SCORE 6 MONTHS	31.69	72	4.161	.490
Pair 2	Karlström-Olerud's functional SCORE AT ADMISSION	14.92	72	1.084	.128
	Karlström-Olerud's functional SCORE 1 YEAR	32.38	72	3.747	.442
Pair 3	Karlström-Olerud's functional SCORE 6 MONTHS	31.69	72	4.161	.490
	Karlström-Olerud's functional SCORE 1 YEAR	32.38	72	3.747	.442

Table 20

Paired Samples Test									
		Paired Differences			95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Karlström-Olerud's functional SCORE ADMISSION - Karlström-Olerud's functional SCORE MONTHS	-16.778	4.112	.485	-17.744	-15.812	-34.623	71	.000
Pair 2	Karlström-Olerud's functional SCORE ADMISSION - Karlström-Olerud's functional SCORE YEAR	-17.458	3.700	.436	-18.328	-16.589	-40.040	71	.000
Pair 3	Karlström-Olerud's functional SCORE MONTHS - Karlström-Olerud's functional SCORE YEAR	-.681	2.511	.296	-1.271	-.091	-2.300	71	.024

Karlström-Olerud's functional evaluation criteria for lower limbs (femur and tibia gaps) score was 14.92 at admission, 31.69 at 6 months and 32.38 at 1 year. Cross tabulation values were statistically significant with P value less than 0.05.

Overall return to profession percentage was 83.80% of study population.

Table 21

Previous profession	Number	Return to job	Percentage %
BUSINESSMAN	9	9	100
CHEF	2	1	50
CLERK	8	7	87.5
DOCTOR	1	1	100
DRIVER	5	4	80
FARMER	2	2	100
HOUSEWIFE	4	3	75
MANUAL WORKER	9	7	77.7
NURSE	1	0	0
POLICE	4	3	75
SALESMAN	5	5	100
SHOPKEEPER	9	7	77.7
SOFTWARE	4	3	75
SOLDIER	5	5	100
STUDENT	19	17	89.47
SUPERVISOR	7	6	85.71

COMPARISON OF DIFFERENT STUDIES. Table 22

Study	Sample Size	Bone Results (%)				Functional Results (%)				Return to work (%)
		Excellent	good	fair	poor	Excellent	good	fair	poor	
Dendrinis ⁽⁵⁾ et al 1995	27	50	28	4	18	26	41	15	18	82
Sangkaew C 2004	21	81	14.3	0	4.7	85.7	14.3	0	0	90
Sahibzada ⁽⁶⁾ AS et al 2005	20	60	10	15	15	35	40	20	5	85
Md.Shabir ⁽⁷⁾ et al 2010	32	56	22	6	16	63	19	9	9	72
Our study	105	20	59	5.7	14.3	54.3	29.5	1	14.3	83.80

Conclusion

It is essential to use evaluation criteria for outcome analysis of 30 year old presented to the casualty with open injury of leg and ankle.



TEACHER	6	5	83.33
WHITE COLLAR	5	3	60

DISCUSSION

According to the Catagnio's classification, among the non infected cases 12 (11.4%) patients were B-1, 41(39.0%) were B2 (15.2%) and 15 (14.3%) were B3 nonunions. Among the infected cases 6 (5.7) were C4, 29(27.6) were C5, and 2 (1.9%) was C5.

The bone defect was calculated. The average bone defect was 6.29cm, which is comparable to other reports.

The average time of union in our patients was 4.15 months (Range 3 to 7 months) which was also comparable to other studies.

The treatment goal could be achieved in 89 out of 105 patients (84.76 %).

The ASAMI criteria defines unemployment as poor result.

Majority of our patients (83.8%) were able to join their previous work.

Other studies have highlighted that patient satisfaction is more important than the employment status in functional status assessment. This is not true in case of developing countries like India, where no financial support system exists for the unemployed.

According to final ASAMI scoring, the bone results were Excellent in 21 (20%), Good in 62 (59%), Fair in 6 (5.7%), and Poor in 15 (14.3 %) patients.

Some of the excellent results were considered to be Good because ASAMI does not consider bone grafting as excellent result.

According to final ASAMI scoring, the functional results were Excellent in 57 (54.3%), Good in 31 (29.5%), Fair in 1 (1 %), and Poor in 15 (14.3 %) patients.

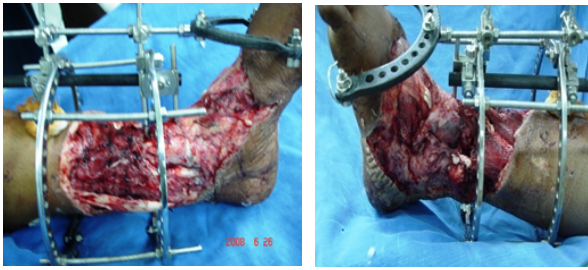
The Cattneo score was U1/I2/F2 (solid union with no infection and full function) was seen in 79 % of cases in 6 months and 81.9% of cases in 1 year.

The lower limb patients were additionally evaluated according to Modified Functional Evaluation System by Karlstrom-Olerud. The score was 14.92 at admission, 31.69 at 6 months and 32.38 at 1 year.

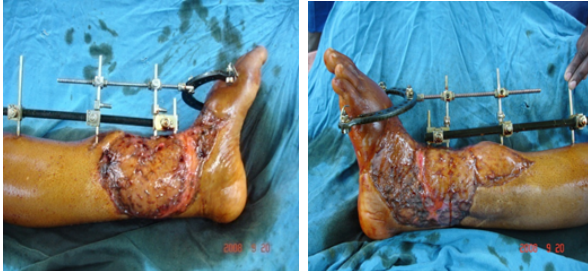
success or failure of gap nonunion management. Proper analysis of outcome is necessary for completion of treatment.

CASE PHOTOGRAPHS

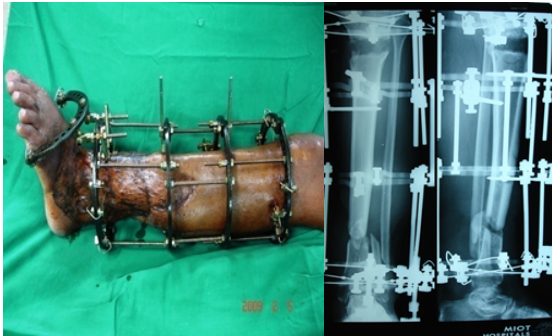
X-ray showed comminution and bone loss



Initial stabilisation was done with ankle spanning Hybrid fixator after debridement



Ring fixator was converted into AO fixator and flap coverage was done.



Segment transport was started with Ring fixator



After 2 months of transport the fixator was removed and regenerate stabilised with Intramedullary nail.



Nail was removed after the union was achieved



Fully functional limb with some stiffness of ankle was achieved in 7 months

REFERENCES

1. Catagni, 1991. Classification of nonunion and treatment. Milan: Medi Surgical; 1991.
2. A.S.A.M.I Group: operative principles of Ilizarov.1991.
3. Karlström-Olerud's functional evaluation criteria BMC Musculoskeletal Disorders 10(1):7 • January 2009.
4. Miller et al. The repair of defects of the radius with fibular bone grafts JBJS 1947.
5. Dendrinis GK, Kontos S, Lyritis E. Use of the Ilizarov technique for treatment of non-union of the tibia associated with infection. J Bone Joint Surg Am 1995.
6. Schibzada AS et al 2005 Management of nonunion of humeral fractures. Archives of Orthopaedics and Trauma Surgery. Jan2011, Vol 131.
7. Md.Shabir Management of infected nonunion of long bones- Int Orthop, 2008 Aug;32.