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Presentation, treatment and outcome of long-bone non-union: Experience from a Tropical Tertiary Center

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Abstract
Purpose: Non-union is a common complication following management of long bone fractures which requires detailed understanding of its varied presentation and available treatment options to achieve the desired outcome. Possible risk factors can be either patient related or surgeon related. The management is challenging and evolving depending on the type of non-union. The aim of this present study is to detail our experience in the management of long bone fractures highlighting (1) the treatment modalities currently being adopted in our centre (2) the importance of intra-operative compression and autologous bone graft and (3) the union rate following these different modalities.
Methods: Records of all cases of non-union managed in our centre over a 5yr period were retrieved and appropriate data for this present study were collected and entered into an excel spreadsheet while patients with more than three missing data were excluded from the study.
Summary table was generated and appropriate group comparisons were presented in charts and graphs.
Results: Records of 40 patients were found suitable for analysis. The result showed that atrophic non-union was the commonest types. Among the fixation methods currently available for treating non-union in our centre, plate and screws achieves the best outcome. The result further showed that achieving intra-operative compression coupled with autologous bone graft produces a higher union rate.
Conclusion: The management of long bone non-union has evolved but intra-operative compression and autologous bone graft which are commonly adopted in developing countries still report good success rate.

Keywords: Fractures, ununited, management, outcomes

Introduction

Non-union is a common complication following management of long bone fractures which requires detailed understanding of its varied presentation and available treatment options to achieve the desire outcome. Fracture non-union has been defined as persistent fracture line after nine months of injury with no evidence of fracture healing on consecutive radiographs over three months [1, 2].

All the long bones in the body can present with non-union though it is commoner in the lower limbs both in developed and developing countries [3, 4].

Several factors have been identified as possible causes [5]. Among these risk factors are patient-related factors like age of the patient, male gender, lifestyle risk like smoking, presence of co-morbidities such as diabetes and abuse of non-steroidal anti-inflammatory drugs. Other factors which are surgeon related are unstable internal fixation, excessive stripping of the periosteum, fracture pattern and presence of infection [6]. One other factor that is a common cause of non-union in developing countries unlike developed countries is delayed presentation due to initial consultation with traditional bone setters who lack knowledge and training in the management of long bone fractures [7, 8, 9].

Traditionally, non-union can present clinically as septic or aseptic non-union and radiologically as avascular or hypervascular non-union. Avascular non-union which commonly presents as atrophic non-union is usually regarded as a consequent of problem with biology of fracture healing and it is the most common form of non-union encountered in the literature [10, 11] while the hypertrophic type, a common example of hypervascular non-union, is as a result of excessive motion at the fracture site [12]. Another variant of the hypervascular non-union is the oligotrophic type. Septic or infected non-union commonly follows open fractures but it can also be a complication of previous internal fixation [13, 14].

Because of its challenging nature, management of long bone non-union has evolved over the years with introduction of different concepts [16] and treatment modalities [17-20] that is aimed at permanently resolving this orthopaedic surgeon dilemma. The outcome following this revolutionary approaches has however shown that there is still knowledge gap in the treatment of long bone non-union and a realization of this understanding is as a result of several authors sharing their experiences both from developing and developed countries [21, 22, 23, 24, 25, 26].

The aim of this present study is to detail our experience in the management of long bone non-union highlighting [1] the treatment modalities currently being adopted in our centre [2] the importance of intra-operative compression and autologous bone graft and [3] the union rate following these different modalities.

Materials and Methods

Data collection

Records of all cases of non-union managed in our centre between January 1st 2017 and December 31st 2022 were retrieved and the following information were extracted and entered into an excel spreadsheet: age of the patient, gender, duration of non-union, initial fracture treatment, type of non-union, fixation option, use of bone graft or otherwise, if compression during fixation was achieved or not, region of bones affected, duration of follow-up and if healing was attained or not at the time of last follow-up. For this study,

cases are treated as non-union if [1] a fracture had not received any surgical treatment and there is no evidence of bridging callus in at least 3 cortices in two orthogonal radiological views or [2] if a fracture that has been initially treated surgically requires further surgical intervention to achieve healing after 6 months of initial surgical treatment. Fracture union was confirmed mainly through case notes records (documentation of absent pain at fracture site) and examination of the radiographs (bridging callus in at least three cortices on both anteroposterior and lateral views) where it is accessible. We excluded the following group of patients from our record search: [1] patients who had been treated as a case of non-union who did not meet the criteria for definition of non-union [2] patients who were managed as a case of non-union but whose follow up time as at the time of retrieving the data were less than 6 months and [3] patients who had more than three missing data.

Statistical Methods

The data was first cleaned and recoded to make it suitable for data summary. The baseline patient characteristic was displayed in a table. Two-way/three-way cross-tables were generated across different groups of importance and the result of the comparison were represented in appropriate charts and graphs. A one-way between groups analysis of variance was conducted to show association between mean duration of symptoms and type of non-union. All data were analysed using R and Rstudio, 2023.

Results

A total of 75 patients' records were retrieved but after screening of each records only 40 patients' records were found suitable for further analysis. Fig.1 shows number of patients that were excluded from the study and reasons for exclusion.

Table 1 below shows the baseline characteristics of patients included in this study for analysis.

Table 1: Showing the demographic characteristics of the patients

	Overall (N=40)
age	
Mean (SD)	46.7 (13.2)
Median [Min, Max]	47.0 [24.0, 71.0]
gender	
F	21 (52.5%)
M	19 (47.5%)
diagnosis	
atrophic	20 (50.0%)
hypertrophic	10 (25.0%)
oligotrophic	4 (10.0%)
septic	6 (15.0%)
region	
femur	21 (52.5%)
humerus	10 (25.0%)
tibia	9 (22.5%)
InitialCare	
lexfix	1 (2.5%)
NAIL	2 (5.0%)
ORIF	5 (12.5%)
TBS	32 (80.0%)
implantused	
cexfix	10 (25.0%)
lexfix	8 (20.0%)
nail	6 (15.0%)
PS	16 (40.0%)
folloup	
Mean (SD)	15.9 (15.2)
Median [Min, Max]	12.0 [1.00, 84.0]

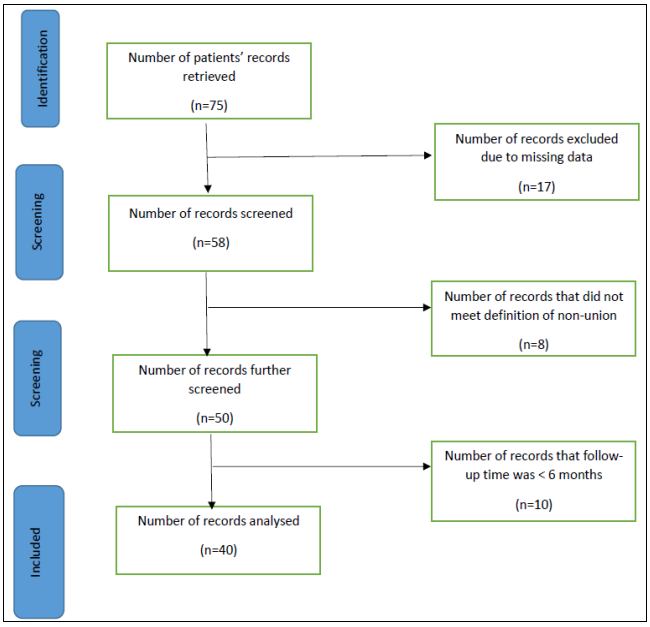
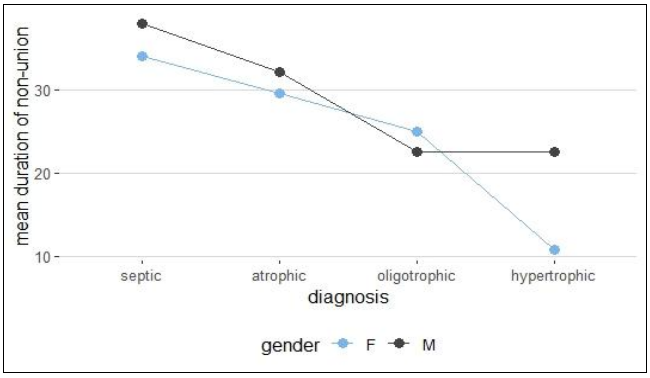


Fig 1: Showing flow chart for the case records retrieved

Relationship Between types of Non-Union, Sex and Mean Duration of Symptoms

Men have a higher mean duration of symptoms for all types of non-union except for oligotrophic type and this difference between the two genders was marked for hypertrophic non-union. This is represented in fig 2a. Re-ordering of the non-union type as shown in fig 2b shows that patients with septic non-union had the longest mean duration of symptoms before presentation.



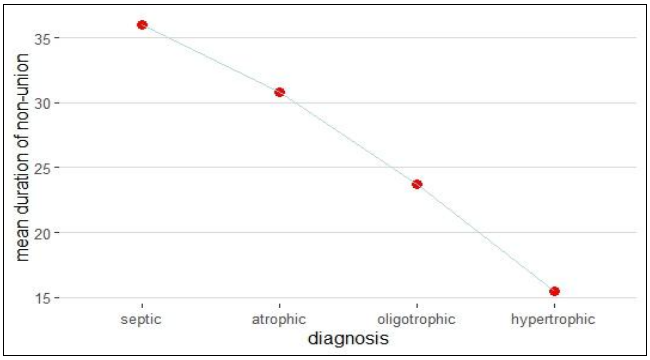


Fig 2a (left) and 2b (right): Showing the relationship between mean duration of symptoms, diagnosis and gender

There was no statistically significant difference noted at P<0.05 in mean duration of symptoms for the four type of non-unions [F (3,36) =2.689, P=0.0608]

Relationship between Types of Non-union and the affected region

The femur is most commonly affected for each type of non-union except for the oligotrophic type of non-union where the humerus is affected more and for each affected region the atrophic non-union is most common as shown in fig 3

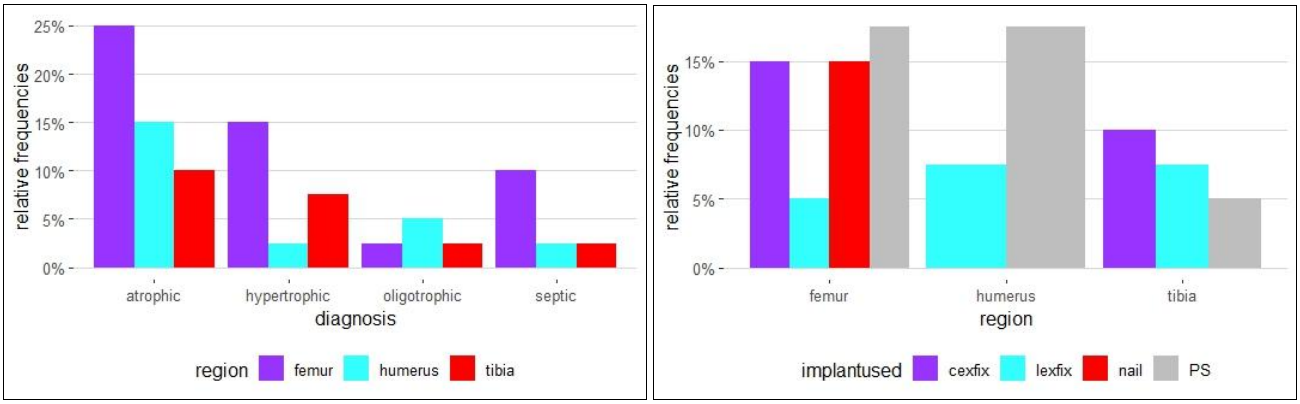


Fig 3 (left): Showing the relationship between diagnosis and region of non-union. Fig 4(right) showing the relationship between implant used and region of the body

Relationship Between the type of implants and the Affected Region

The humerus is most likely to be surgically fixed with plate and screws while the linear external fixator is less likely to be used in treating the femur. The circular external fixator (CEF) is the more common implant of choice for treating tibial non-union. This is depicted in fig 4.

Relationship between Outcome and Type of Implant used

Using plate and screw resulted in higher number of favourable outcome (union) compared to using other implants while the use of CEF resulted in more unfavourable outcome (fig 5).

Relationship between Implant Used, Intra-operative compression, use of Bone graft and Outcome

Using bone graft with plate and screw resulted in a higher proportion union while treating non-union with CEF resulted in higher number of poor outcome (non-union) (fig 6)

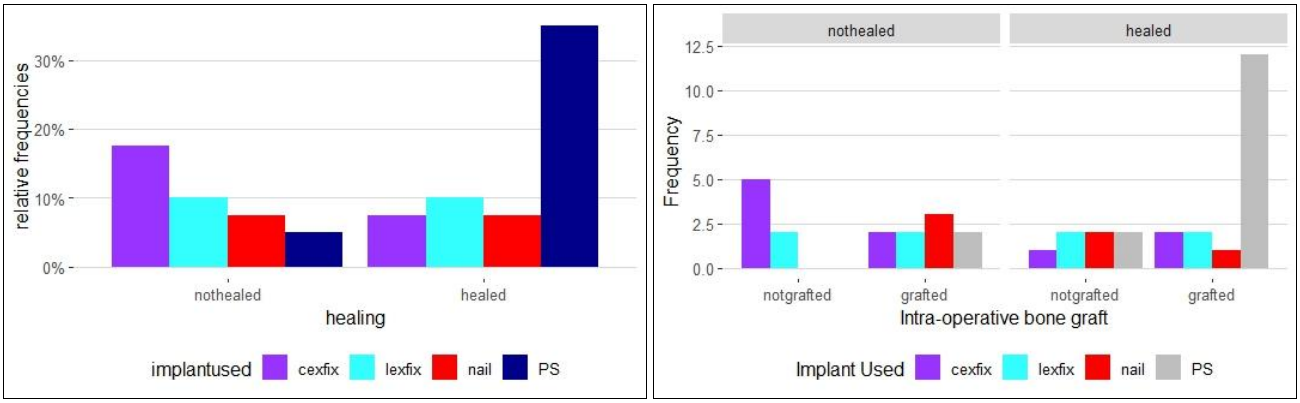


Fig 5 (left): Showing the relationship between outcome and implant used Fig 6(right) showing the relationship between intra-operative bone-graft and implant used

Also, as shown in fig 7, most of the non-union managed with intramedullary nail were not compressed at the fracture site though this did not affect the healing rate but this is different with use of plate and screw which allowed for compression at the non-union site recording

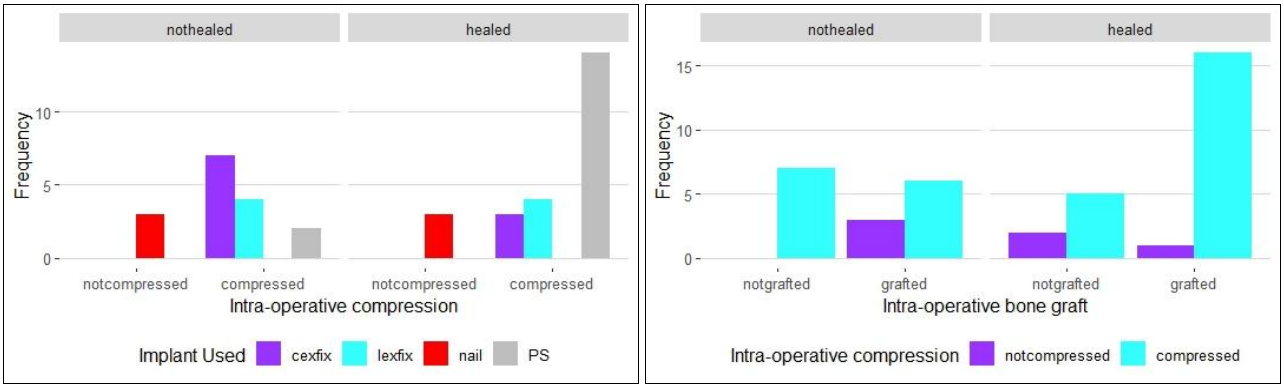


Fig 7 (left): Showing relationship between implant used, intra-operative compression and outcome. Fig 8 (right) showing relationship between implant used, use of bone graft and outcome

a higher proportion of union compared to other implants. Combination of grafting and compression intra-operatively resulted in higher proportion of union (Fig 8).

Discussion

This present study retrospectively focussed on the experience of managing non-union of long bones in a tropical tertiary centre. Managing non-unions can be a challenging endeavour for the orthopaedic surgeon with mixed result despite the current trend and advances documented in the literature [20, 27, 28].

Unlike many studies [29-31] in which there are usually more male patients with non-union, we had a higher number of female patients than male patients that presented with long bone non-union in our series and this is similar to the studies done by Papakonstatinou *et al* [32] and Rollo *et al* [33] though both studies were in patients with proximal humeral fractures. Majority of the cases in this present study were of the atrophic type while hypertrophic non-union was the second most common type and this is the usual presentation as described in the literature [11, 31, 34]. There is no explanation yet in the literature to support this observed pattern. Hashmi and colleague in their study however reported a higher percentage of septic non-union [29]. Also evident from this present study is that majority of patients with long bone fractures in developing countries prefer to initially seek care with traditional bone setters. Some of the reasons given by the patients for high patronage of these traditional bone setters are low cost of services, easy accessibility, promptness of service, culture, diseases having spiritual causes, pressure from families and friends [35], poor service delivery in orthopaedics practise, fear of amputation, greater faith in traditional bone setters and patient brought against wish [36]. This high patronage continue despite negative perception expressed by patients previously treated by these community bone setters [37]. There is an interesting observation that needs to be explored by this finding: treatment by TBS is usually by immobilization with wooden sticks or rulers [35, 38] which will suggest inadequate fracture stabilization leading to excessive motion at the fracture site and hence likelihood of a hypertrophic non-union forming rather than atrophic non-union. This is however not the case in this series. Interestingly, findings from the literature suggest that atrophic non-union is still the commonest type of non-union irrespective of whether initial care was by TBS or by contemporary fracture stabilization [4, 39, 40]. We believe that this finding suggest the traditional method of classifying non-union should be re-evaluated.

This study find that compared to females, males tend to have a higher mean duration of symptoms for all types of non-union except for hypertrophic non-union. While the reason for this is not immediately obvious from this present study, one can only infer that the most likely reason will be the tendency for men, in order to demonstrate strength, to delay presentation for orthodox care even after failure of TBS treatment. This reason however will not explain why females in this present study presented with a higher mean duration for hypertrophic non-union. Also, septic non-union has the longest mean duration of symptoms but because there is no statistical significance compared to other forms of non-union, the interpretation of this finding require caution.

The femur is the most affected long bone irrespective of the type of non-union except for the oligotrophic type of non-union in this present study. This result is similar to the findings of another study previously done in the centre [4] but at variance with two large population-based study. Padilla-Eguiluz and colleagues [3] reported in their study almost equal proportion of non-union for the femur and tibial while Mills and colleague [41] reported the lower leg to have the highest incidence of non-union. While the focus of their study was not on long bone non-union, other researchers had reported that the bone with the highest number of complications managed by TBS was the femur [38, 42, 43]. While the reason for the femur being the most affected long bone is not apparent from this study, we can only infer from the conclusion of Ogunlade and colleagues [4] that the major reason may have been soft tissue interposition with poor immobilization technique from the TBS. This may also explain the high rate of non-union seen in the humerus.

It is evident from our series that plate fixation is the most commonly used implant in treating our non-union though external fixator would have the highest proportion of use if we combine the CEF and the linear external fixator. The decision to separate the external fixator is because the indication for their use in treating non-union is different in our centre. We commonly use CEF for non-union that is associated with shortening and/or septic while LEF is an alternative to other implants i.e nails and plate fixation. The use of different implants in treating non-union in our centre is a reflection of surgeon's choice and preference as our centre does not presently have a consensus treatment for treating non-union and we believe this is not limited to our centre alone. A nationwide survey conducted among 63 surgeon respondents [44] showed that 97% of them use plate fixation in the treatment of non-union which was the highest among other modalities. Another use of plate fixation in treating non-union in the presence of in-situ intramedullary nail with reported excellent result is augmentation plating [45, 46] which is yet to be an adopted practice in our centre as only few of our patients were managed with intramedullary nail. In a review article published recently [18], plate fixation is suggested as the first choice of treatment in long bone non-union. In our series, CEF was the second most commonly used implant and this was mostly used for atrophic and septic non-union of the femur and tibial. It has been reported that CEF is an invaluable tool in the treatment of infected non-union associated with bone loss as it offers bifocal compression-distraction and bone segment transport with excellent result [30, 47-49]. Curiously however, the use of CEF was associated with a higher proportion of poor outcome in this present study compared with other treatment modality. The reason for this observation is not immediately clear from this present study but what is apparent from the literature is that majority of the published articles on CEF for the treatment of infected non-union with excellent results are non-comparative studies that focussed mainly on CEF [50-52] unlike this present study and that compared to CEF, a prospective study showed that LEF achieves comparable result in the treatment of infected non-union [53]. Hence, we propose a future study that compares CEF to other fixation method to ascertain the superiority or otherwise of CEF though we anticipate that this may be a daunting task considering the versatility of CEF in the management of infected non-union with shortening which other fixation methods presently do not have.

Another observation from this study is the importance of intra-operative compression and use of bone graft in treating long bone non-union. These adjuncts with plate and screw as the fixation method achieved the highest number of desirable result which is union. Elliot *et al* [16] had proposed that most non-union are as a result of mechanical factors which if addressed by the appropriate strain environment should lead to healing of the non-union. Intra-operative compression produces a low strain environment that facilitates bone formation and hence not surprising that some authors regard compression plating as the standard treatment for long bone non-union [54]. According to Weil *et al* [55] continuous compression can also be achieved in intramedullary nailing through use of external compression device or compression bolt and this gives accelerated union unlike intermittent compression that is achieved through dynamization of the nail or bony apposition that is achieved through backstriking. This may explain why many of the cases treated with intramedullary nailing in our series did not achieve union because continuous compression was not achieved in these cases and may also emphasizes the need for surgeon to consider achieving continuous compression when using intramedullary nail in the treatment of non-union. Though use of the Ilizarov in the treatment of long bone non-union is consistent with the 'Bone Healing and Non-union' theory proposed by Elliot *et al*, majority of the cases managed with the circular method of fixation in our series did not achieve union but as mentioned earlier, this may be because most of these cases were the infected type. Based on the findings from our study, we agree with other authors [54] that intra-operative compression with autogenous bone graft should be considered in the surgical treatment of long bone non-union as the implementation of the duo addresses both the mechanical and biologic failure that is common to most long bone non-union.

This present study is not without limitations. First is the small number of cases seen in this series. While many of our findings were in keeping with other similar studies, we believe that a larger series may be more representative and will make drawing of conclusions easier. Secondly, some data like type of fracture whether open or close, classification of the fracture type, smoking and co-morbidity status were excluded from the studies because of large number of missing data which if included could have further strengthened the findings from this study. Also, information about bone loss pre-operatively could not be retrieved from the case records. Thirdly, the only outcome that could be assessed in this present study was union either clinically or radiologically which obviously does not assess functional outcomes and quality of life which may be more clinically useful for comparing treatment options.

Conclusion

While the clinical presentation of long bone non-union is generally not different both in developed and developing countries, current practise in developing countries does not reflect adoption of recent treatment concepts and theories being promoted in developed countries. What is important however is the role of intra-operative compression and use of autologous bone graft to achieve union when managing long bone non-union.

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