Outcomes-Based Assessment of Distal Third Femur Fractures Using Cluster Analysis: A Pilot Study

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INTRODUCTION:
The type of implant (nail [NL], plate [PL], or nail/plate [NP]) for patients with distal femur fractures is typically determined by fracture type and surgeon experience. This study implements a cluster analysis to determine outcomes of distal femur fractures based on the implant and fracture type.
METHODS:
Using retrospective chart review, we identified patients 18 years of age or older who presented to a single Level-1 trauma center from January 1, 2012 to December 31, 2022 with a non-polytraumatic distal femur fracture. Current Procedural Terminology ® (CPT) codes were used to identify patients fixated for a distal femur fracture (27511, 27513, 27514). Cluster analysis was used as it allowed grouping of patients based on pertinent clinical characteristics to identify which characteristics led to a certain outcome. Using a partitioning-around-medoids (PAM) approach, Gower distances were calculated between patients to partition them into different clusters. Two variables were included in the model: AO femur fracture classification and implant type (NL, PL, or NP). The number of clusters which would yield the highest possible Silhouette Score (a measure of how well patients fit in a cluster based on shared characteristics), while not yielding clusters with redundant implant type and fracture classification combinations, was used for this study. A successful surgical outcome was defined as a surgery which did not result in infection, mortality, nonunion, malunion, implant failure, or a substantial decline in baseline ambulatory status. Success rate was determined for each cluster as the percentage of successful surgeries within a cluster.
RESULTS:
A total of 169 patients (68.64% female, average age 66 years) met the inclusion criteria. A total of 15 clusters were used, allowing for a high Silhouette Score (0.9078). Twelve clusters were 100% homogeneous, while 3 of the 15 clusters had approximately 60% of patients with the majority fracture classification. Extra-articular simple spiral fractures (33A2.1) treated with a PL (n = 4) had a 75.00% success rate (vs. 100% with NL [n = 12]). An oblique simple fracture at the distal metaphysis (33A2.2) stabilized with a NP (n = 3) had a 66.67% success rate (vs. 72.73% with NL [n = 11] and 72.22% with PL [n = 18]). Extra-articular transverse simple fractures (33A2.3) had a 100.00% success rate with a dual construct [n = 6] (vs. 78.57% success rate with PL [n = 14]; and 50.00% success rate with a NL [n = 2]). Extra-articular fragmentary wedge fractures (33A3.2) which were treated with a PL (n = 8) experienced a success rate of 75.00%. Extra-articular multi-fragmentary wedge fractures (33A3.3) treated with a PL (n = 11) had a success rate of 45.45% (vs. 40.00% with NL [n = 5]). A partial articular fracture (33B) treated with a PL (n = 17) had a success rate of 88.35%. Patients with complete intra-articular fractures (33C) treated with a dual construct implant (n = 5) had a success rate of 100.00% (vs. 61.36% with PL [n = 44] and 77.78% with NL [n = 9]). Other fracture classification/implant type combinations of the distal femur were not represented as a majority of any of the clusters.
DISCUSSION AND CONCLUSION:
This study demonstrates the application of cluster analysis to determine the rate of a successful surgical outcome based on fracture class and implant type. Patients with 33A2.1 fractures treated with a NL had a 100% success rate whereas those treated with a PL had a 75% success rate. All patients with 33A2.3 and 33C fractures treated with NP had a successful outcome whereas those treated with NL or PL alone had more variable outcomes. 33A3.3 fractures had a low overall success rate when treated with a NL or PL alone suggesting that these more comminuted extraarticular fractures may need an alternative fixation method such as a dual construct. This is a pilot study that is limited by sample size and number of clinical variables included in the cluster analysis. Future study necessitates a larger sample size to allow for greater granularity and inclusion of specific clinical characteristics in the clustering analysis which can be used to better inform surgeons on optimal fixation methods for a given patient profile.

Table 1: Success rates for each cluster, corresponding to a combination of fracture classification and implant. The number of patients in each cluster is given parenthetically.

	Implant		
AO Fracture Classification	Plate	Nail	Nail and Plate
33A2.1	75.00% (4)	100.00% (12)	-
33A2.2	72.22% (18)	72.73% (11)	66.67% (3)
33A2.3	78.57% (14)	50.00% (2)	100.00%* (6)
33A3.1	-	-	-
33A3.2	75.00%* (8)	-	-
33A3.3	45.45% (11)	40.00%* (5)	-
33B	88.35% (17)	-	-
33C	61.63% (44)	77.78% (9)	100.00% (5)

* Non-homogeneous clusters

KEY
100.00%
> 75.00% & ≤ 99.99%
> 50.00% & ≤ 75.00%
≤ 50.00%
No clusters with this combination.

Figure 1: Silhouette Analysis to determine desired number of clusters.