Mechanical Testing Data Favor Modification of Humerus Fracture Treatment Algorithms

John G. Skedros, MD[1], Alex N. Knight, B.S.[1], Chad S. Mears[1], Todd C. Pitts[2], Wayne Z. Burkhead, M.D.[3]
[1]University of Utah, Salt Lake City, UT, USA, [2]U. Texas, San Antonio, San Antonio, TX, USA, [3]Carrell Clinic, Dallas, Texas, TX, USA

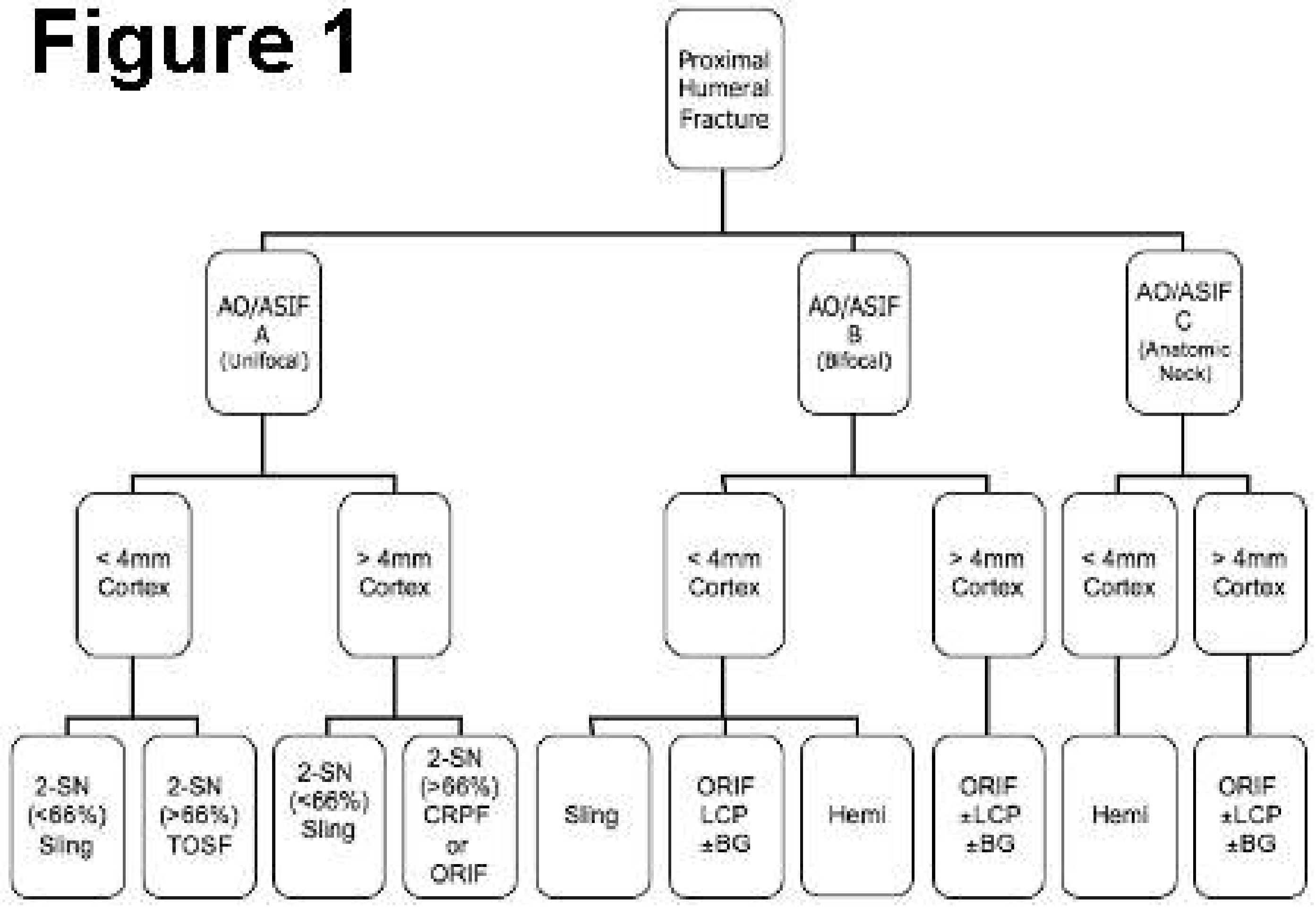
Introduction

Algorithms have been devised that facilitate decision making for the operative and non-operative treatment of proximal humerus fractures. A popular and very useful treatment algorithm is that of Nho and co-workers [1] (Fig. 1). The aspects of their algorithm that is the focus of this investigation are the branch points where cortical thickness measurements are made using an anterior-posterior (AP) radiograph. These branch points are based on the combined cortical thickness measured at the medial and lateral cortices of the proximal metaphysis/diaphysis. If this measurement is <4mm then it is recommended to avoid open reduction and internal fixation (ORIF). A problem with the 4mm cutoff is that it is not based on data derived from mechanical testing. We sought to determine if the 4mm threshold should be modified as the definition of the branch points in the fracture treatment algorithm of Nho et al. (2007). We also sought to determine if the threshold when defined as a value greater than 4mm is better than the "cortical index" (defined below) for determining if ORIF should be used instead of hemi-endoprosthetic replacement for osteoporotic proximal humerus fractures.

Methods

34 fresh-frozen cadaveric humeri (mean 59 yrs; range 39-78; 18 F, 16 M) were used. Anterior-posterior (AP) radiographs were taken next to an aluminum (Al) step wedge (one mm/step; 2-12 mm of Al) (Fig. 2). Using the radiographs, thicknesses of the medial and lateral cortices were measured in proximal locations of each bone, including the surgical neck (D1), and at three locations at these distances below D1: two cm (D2), five cm (D3), and seven cm (D4) (Fig. 2). Cortical index (C.I.) was measured at specific locations of the bone shaft as the difference between the outer (OD) and inner diameters (ID) of the bone divided by the OD [(OD-ID)/OD] (lower C.I. values resent weaker bone). Bone mineral density (BMD) was determined for each proximal humerus using DEXA scans [2]. Each humerus was loaded like a backwards fall (2mm/sec, 30 degrees off axis) (Fig. 3). Test data, recorded included: (1) UFL (N), and (2) area under the load-deformation curve (i.e., energy absorbed to fracture; N-m). Differences between fracture loads and among the other parameters were evaluated using Fisher's PLSD test (ANOVA).

Figure 1



Results

Results, summarized in the table, show that the 6mm combined (medial + lateral) cortical thickness cutoff consistently distinguished the data in terms of donor age, BMD (derived from DEXA scans), UFL (N), and energy absorbed to fracture. The clear distinction between the 6mm cutoff and the other two cutoffs (4mm and 5mm) is shown by the fact that all cells in the 6mm p-value matrix at the right in the table are statistically significant (all cells are grayed for the 6mm value). In contrast to [1] where a 4mm threshold showed a significant difference in proximal humerus BMD (they did not determine UFL), we found no statistically significant difference in UFL and energy absorption when using the 4mm cutoff. The data also showed that the 6mm combined cortical thickness cutoff is also more consistent in distinguishing the age and energy absorption data than C.I. measurements taken at the same locations (Part B of the Table).

Figure 2

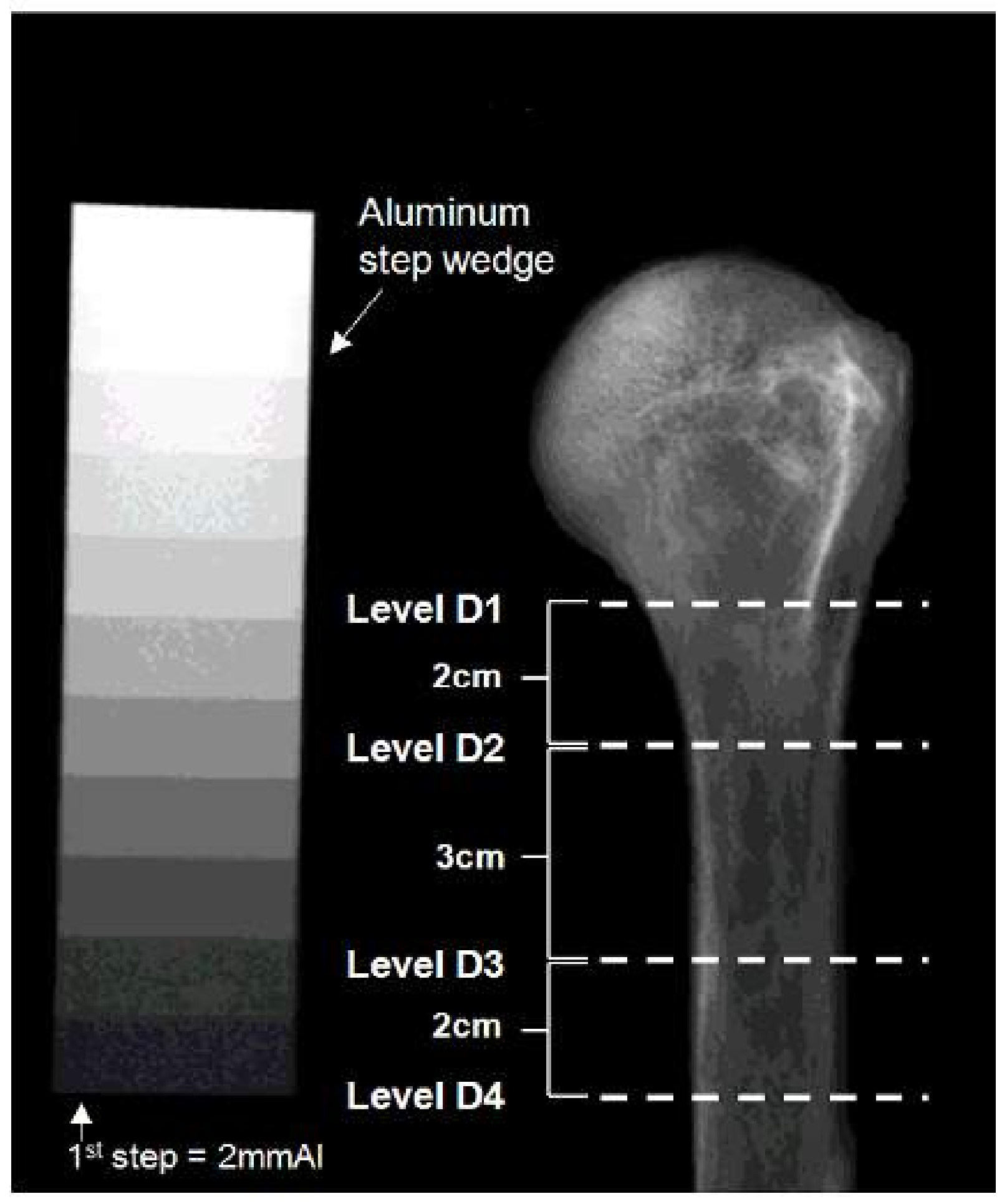
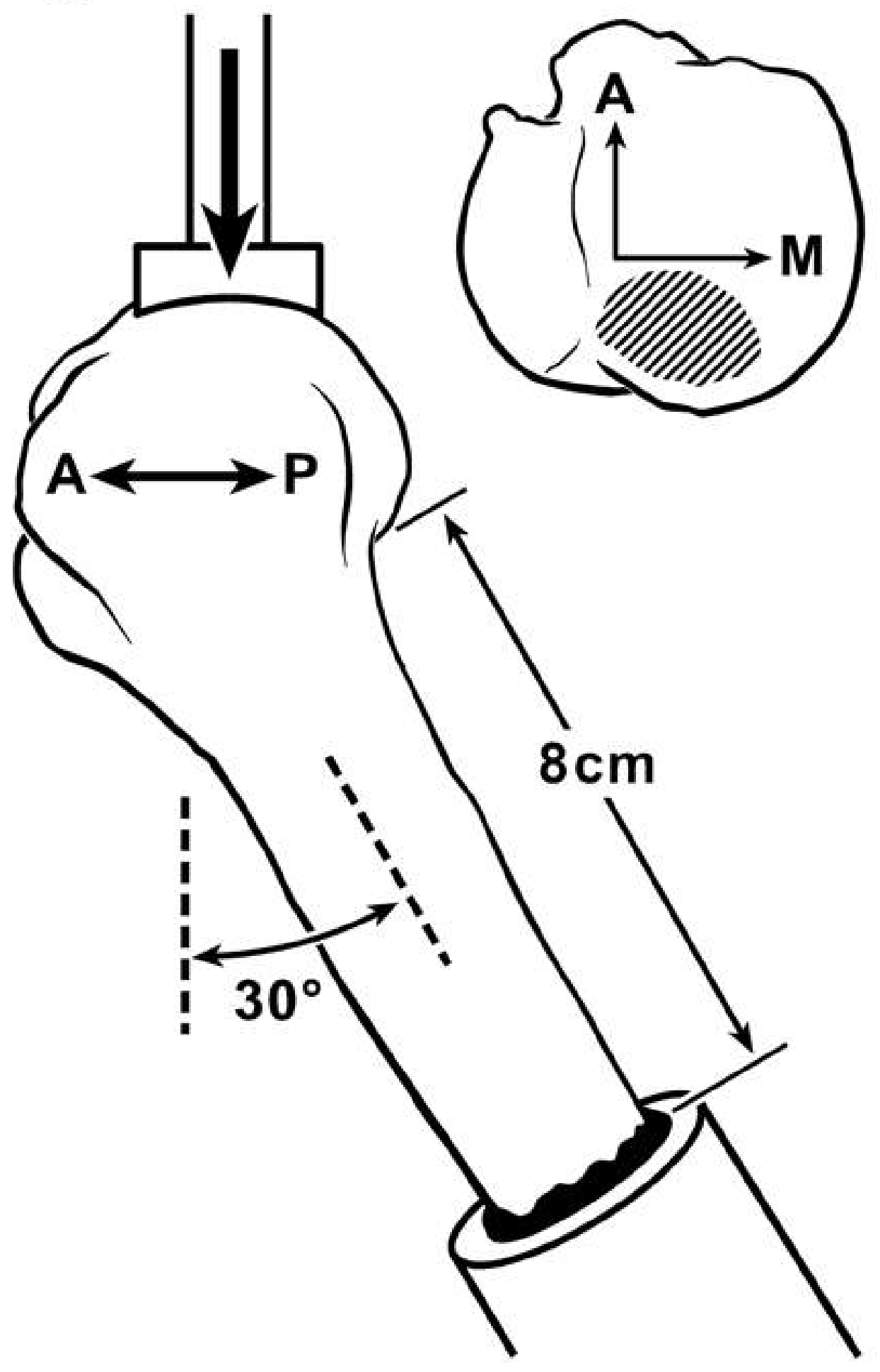


Figure 3



Discussion

Results of this study support modifying the main branch points in the algorithm of Nho et al (2007) [1] (Fig. 1). Consideration should be given for changing the 4mm cutoff that defines the main branch points to 6mm. Data from the present study and our prior study [3] also show that morphological characteristics made using AP radiographs of cadaveric humeri are stronger predictors of UFL and energy absorbed to fracture when compared to chronological age, C.I., and DEXA-derived density values. These findings are consistent with studies showing that DEXA scans do not correlate strongly with fracture risk in a substantial percentage of patients [4,5]. Consequently, we maintain the opinion stated in our prior study [3] that the use of DEXA scans to estimate proximal humerus quality/strength must be questioned, especially in view of the fact that DEXA measurements are becoming more common in biomechanical studies using proximal humeri.

TABLE. COMPARISONS OF AGE, BMD, UFL (N), AND ENERGY ABSORPTION (N-m) FOR MEAN CORTICAL THICKNESS (A) AND CORTICAL INDEX (B) CUTOFFS

A. Cortical Thickness						P values			
		Mean Age		n		Age	BMD	N	N-m
4 mm		<4mm	>4mm	<4mm	>4mm				
	D1	63.1	56.8	12	21	0.1	0.6	0.2	0.9
	D2	68.0	56.7	7	26	0.01	0.006	0.04	0.05
	D3	68.5	57.8	4	29	0.07	0.008	0.08	0.1
	D4	75.0	58.0	2	31	0.03	0.01	0.1	0.3
	D1-3	73.4	56.5	5	28	<0.001	<0.001	0.01	0.04
	D3-4	75.0	58.0	2	31	0.03	0.01	0.1	0.3
	D1-4	73.0	57.7	3	30	0.02	0.001	0.04	0.2
		Mean Age		n		Age	BMD	N	N-m
5 mm		<5mm	>5mm	<5mm	>5mm				
	D1	59.9	46.5	31	2	0.1	0.4	0.5	0.4
	D2	67.5	54.2	12	21	<0.001	0.02	0.1	0.2
	D3	66.4	56.7	8	25	0.03	0.002	0.01	0.06
	D4	72.0	57.3	4	29	0.01	<0.001	0.01	0.07
	D1-3	66.5	55.4	11	22	0.005	0.004	<0.001	0.005
	D3-4	70.2	56.6	6	27	0.005	<0.001	0.007	0.03
	D1-4	71.0	55.8	7	26	<0.001	<0.001	0.002	0.009
		Mean Age		n		Age	BMD	N	N-m
6 mm		<6mm	>6mm	<6mm	>6mm				
	D1	All D1 data <6mm				All D1 data <6mm			
	D2	65.4	49.4	20	13	<0.001	0.006	<0.001	0.006
	D3	67.3	54.3	12	21	<0.001	0.004	0.001	0.009
	D4	71.0	55.8	7	26	<0.001	<0.001	0.002	0.009
	D1-3	64.9	48.9	21	12	<0.001	0.006	<0.001	0.003
	D3-4	69.0	55.8	8	25	0.002	<0.001	0.003	0.008
	D1-4	65.1	53.4	16	17	0.001	0.003	<0.001	0.005
B. Cortical Index (CI)									
		Mean Age		n		Age	BMD	N	N-m
0.4 CI		<0.4 CI	>0.4 CI	<0.4 CI	>0.4 CI				
	D1	All D1 data <0.4 CI				All D1 data <0.4 CI			
	D2	All D2 data <0.4 CI				All D2 data <0.4 CI			
	D3	60.0	50.0	30	3	0.1	0.008	0.04	0.07
	D4	62.4	54.0	20	13	0.03	0.003	0.05	0.6

References

[1] Nho et al. 2007 J Bone Joint Surg 89:44-; [2] Tingart et al. 2003 J Bone Joint Surg Br 85:611-; [3] Skedros et al. 2013 Trans Annual ORS 59, abstract 376; [4] McCreadie and Goldstein 2000 J Bone Miner Res 15:2305-; [5] Dawson-Hughes et al. 2008 Osteoporos Int 19:449-.

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