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Original Article

Morphometry of the superior articular surface of head of radius

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ABSTRACT

The human elbow joint has three different articulations surrounded by a common joint capsule. These joints are the humeroulnar joint, humeroradial joint, and the proximal radioulnar joint. The humeroradial joint is a shallow ball-and-socket, hinge type of synovial joint. This aims to provide morphometric data concerning the superior articular surface of the head of radius. In a sample of 30 dry specimen of the radius, high-precision measurements were recorded to derive a statistical inference concerning: the maximal depth of the superior articular surface, its average diameter, and the articular surface area and its concavity volume. The depth and the diameter were measured using an electronic Vernier. Measuring the surface area and volume at such a small-scale was a challenge. Hence, three methods were deployed: a mathematical method, a cast material technique, and a low-surface tension fluid application.

The 95% confidence intervals were 1.847–2.119 mm (depth), 18.963–20.445 mm (diameter), 2.961–3.451 cm^2 (surface area), and 0.277–0.359 cm^3 (volume). There was a strong positive correlation for: depth vs. volume, depth vs. area, area vs. volume, diameter vs. depth, diameter vs. area, and diameter vs. volume. However, the correlation was absent (not significant) for age vs. diameter (*p*-value 0.361), age vs. depth (*p*-value 0.937), age vs. area (*p*-value 0.342), age vs. volume (*p*-value 0.512), limb orientation vs. area (*p*-value 0.149), limb vs. volume (*p*-value 0.146). This is the first study of its kind, to analyze the morphometry of the superior articular surface of the radial head, both experimentally and statistically. Derived data are of high impact in standardization and practical application in anthropology, biotechnology and biomedical applications, orthopedics, and rheumatology.

1. Introduction

The elbow joint is a synovial hinge joint between the distal end of the humerus and the proximal end of the radius and ulna; this anatomic configuration allows two axes of movement to take place: flexion–extension and pivotal rotation.[1] The humeroradial joint component of the elbow, also known as the radiocapitellar joint is a shallow ball-and-socket synovial joint. The superior articular surface (SAS) on the radial head, is a shallow cup-like disc, which is prone to dislocation of radius in relation to ulna at the proximal radio-ulnar joint. However, the presence the annular ligament secures the head of the radius in relation to the ulna, thus preventing its dislocation during elbow movements.[2,3] The relationship of articular geometry and supporting ligamentous structures provides stability to the elbow joint in flexion–extension, varus and valgus stresses, and pivotal rotation.[4] Surprisingly, radiocapitellar joint stability depends, in part, on concavity-compression mechanics.[5,6]

Numerous pathologies may affect the proximal end of the radius and its head. These pathologies include subluxation–dislocations, fractures, degenerative diseases, and other less frequent conditions that may result in alteration of joint mechanics including osteochondromas and heterotopic ossification.[7–9] These conditions do require corrective procedures including radial head resection, prosthesis implantation, and joint arthroplasty. All these corrective procedures require a high-precision restoration of joint mechanics and joint morphometry, which can be achieved well by simulation of its original in vitro dimensions and geometry,

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including those of the SAS of the radial head, i.e., diameter and depth of the articular surface, its surface area and volume, and its three-dimensional inclination (mediolateral and anteroposterior).

An important biomedical application in parallel with the scope of this research, is the radial head fractures. They comprise 5.4% of all adult fractures and 33% of elbow fractures. The treatment of radial head fractures remains controversial, and general treatment guidelines for elbow fractures are based on their severity. Accordingly, treatment for Mason's type II and III fractures include splinting and early motion, radial head excision, open reduction internal fixation (ORIF), or radial head replacement.[10,11]

In relation to Mason's fractures of the radial head, most investigators suggest ORIF for the treatment of Mason's types II and III.[10,12–18] Furthermore, De Lee and co-workers,[19] recommend excision if there is more than 3 mm of depression, 30° of angulation, or 30% involvement of the radial head. Radin and Riseborough,[20] on the other hand, achieved satisfactory results for type II and type III fractures in 83% of the cases. Mikic and Vukadinovic, had 77% good results.[21] However, Weseley and colleagues,[22] achieved 82% good results with non-operative treatment.

Although good results do not deteriorate over time, unsatisfactory results do occur in up to 50% of patients, including an intermittent elbow pain, post-traumatic elbow arthritis, restricted elbow motion, weakness, and elbow instability.[21,23–25]

We opine with high confidence, that if the prosthesis engineering could be based on the measurements reported in this study, the complications and morbidity should be substantially minimized. The primary objective of this study, is to carry out methodologically-innovative techniques for measuring the SAS morphometry. The researchers of this study, aim to provide statistically analyzed data which could be valuable for application the management of chronic elbow instability, radial head fracture, biotechnology designs and surgeries.

2. Materials and methods

All procedures in this study were conducted in accordance with the ethical standards of various committees on human experimentation in Iraq and the region of the Middle East, and in accordance with the Helsinki declaration of 1964, as revised in 1983. Identities and affiliations were concealed. The study was conducted in accordance with the ethical approval of the faculty of Medicine at the University of Baghdad. Materials used included: 30 dry specimens of human radial bone, an electronic Vernier, and a fast-setting type of an elastic dust-free alginate impression material known commercially as Hydrogum.[26] Other materials included a 100-units calibrated insulin plastic syringe, a five cubic centimeters syringe, and Acetone solution. The bony specimens belong to 30 adults, they were deceased members of the Iraqi population of Middle-Eastern and Arabic ethnicity. Unfortunately, the gender was not documented in the records. Bony specimens belonged to right and left upper limbs, 26 right and 4 left. The mean value for age was 34.3 years.

A standard electronic Vernier (UPC number 814870023454), was used to measure four dimensional parameters in relation to the SAS of the head of the radius. These included: the depth (maximum depth of the SAS in relation to the outer brim of the

Table 1
Data summarization and statistical analyses.

		Depth	Diameter	Surface area	Volume
Sample size		30	30	30	30
Mean		1.983	19.704	3.206	0.318
Median		2.045	19.46	3.12	0.31
Mode		2.04, 2.05	None	2.28, 2.97, 3.49	0.16, 0.2, 0.26, 0.28, 0.31, 0.35, 0.38, 0.39, 0.45
Lowest value		1.23	16.33	2.16	0.14
Highest value		2.58	24.17	4.75	0.53
Range		1.35	7.84	2.59	0.39
Interquartile range		0.58	3.17	1.008	0.16
First quartile		1.695	18.048	2.66	0.23
Third quartile		2.275	21.218	3.668	0.39
Variance		0.1326	3.934	0.429	0.012
Standard deviation		0.3641	1.984	0.655	0.109
Confidence interval (CI)	90%	1.87005–2.09595	19.08853–20.31947	3.00281–3.40919	0.28419–0.35181
	95%	1.84704–2.11896	18.96316–20.44484	2.96142–3.45058	0.27730–0.35870
	99%	1.79977–2.16623	18.70556–20.70244	3.00281–3.40919	0.26315–0.37285

	Correlates	Figure no.	Pearson's r value	Slope	p-Value*	Significance
Pearson's correlation test	Depth vs. volume	3	0.907	0.272	<0.00001	Yes
	Depth vs. area	4	0.764	1.374	<0.00001	Yes
	Area vs. volume	5	0.959	0.160	<0.00001	Yes
	Diameter vs. depth	6	0.754	0.138	<0.00001	Yes
	Diameter vs. area	7	0.999	0.329	<0.00001	Yes
	Diameter vs. volume	8	0.950	0.052	<0.00001	Yes
	Age vs. diameter	9	0.173	0.038	0.361	No
	Age vs. depth	10	0.015	0.00061	0.937	No
	Age vs. area	11	0.180	0.013	0.342	No
	Age vs. volume	12	0.125	0.0015	0.512	No
	Limb vs. area	13	−0.270	−0.512	0.149	No
	Limb vs. volume	14	−0.272	−0.086	0.146	No

	Variables	Age	Limb orient.	Depth	Diameter	Area	Volume
Summarization of present (Yes) and absent (No) correlations	Age	N/A	#	#	#	#	#
	Limb Orient.	No	N/A	No	No	No	No
	Depth	No	#	N/A	Yes	#	#
	Diameter	No	#	#	N/A	#	#
	Area	No	#	Yes	Yes	N/A	#
	Volume	No	#	Yes	Yes	Yes	N/A

* Statistical data were considered significance was considered at p-value less than 0.05.
# Duplicate results of correlation was written only once in the table.

radial head), average diameter of radial head, surface area of the SAS, and the volume of the concavity of the SAS. The units of measurement were in millimeters (mm) for each of the depth and the diameter, in square centimeters (cm^2) for surface area, and in cubic centimeters (cm^3) for volume. All measurements were approximated to the nearest percentile of a unit. Measurements were taken while the bony specimen, i.e., the radius, was aligned vertically and securely on a solid stable platform. The Vernier external jaws were used to calculate the diameter, while the Vernier's beam was used to measure the depth. Each measurement was recorded independently by two professional anatomists to avoid man-made errors and/or biases.

Concerning the calculation of surface area and volume, different confirmatory methods were used to record the most accurate morphometric measurement. In relation to the volume measurement, three methods were used. The 1st method, an aqueous method, in which an acetone solution was slowly poured via a calibrated insulin syringe on the SAS of radial head, until the solution completely fills the concavity impression of that articular surface and up to the level of the superior rim of the radial head. Acetone, as a fluid, was used instead of water due to the fact Acetone's lower surface tension. In other words, the acetone solution gives a more accurate volume measurement, while water gives faulty and exaggerated readings, owing to its high surface tension. Acetone's surface tension value, is approximately one-third that of water.[27,28]

In the 2nd method, Hydrogum alginate impression was used material to create a cast for the SAS.[26] Again, the impression

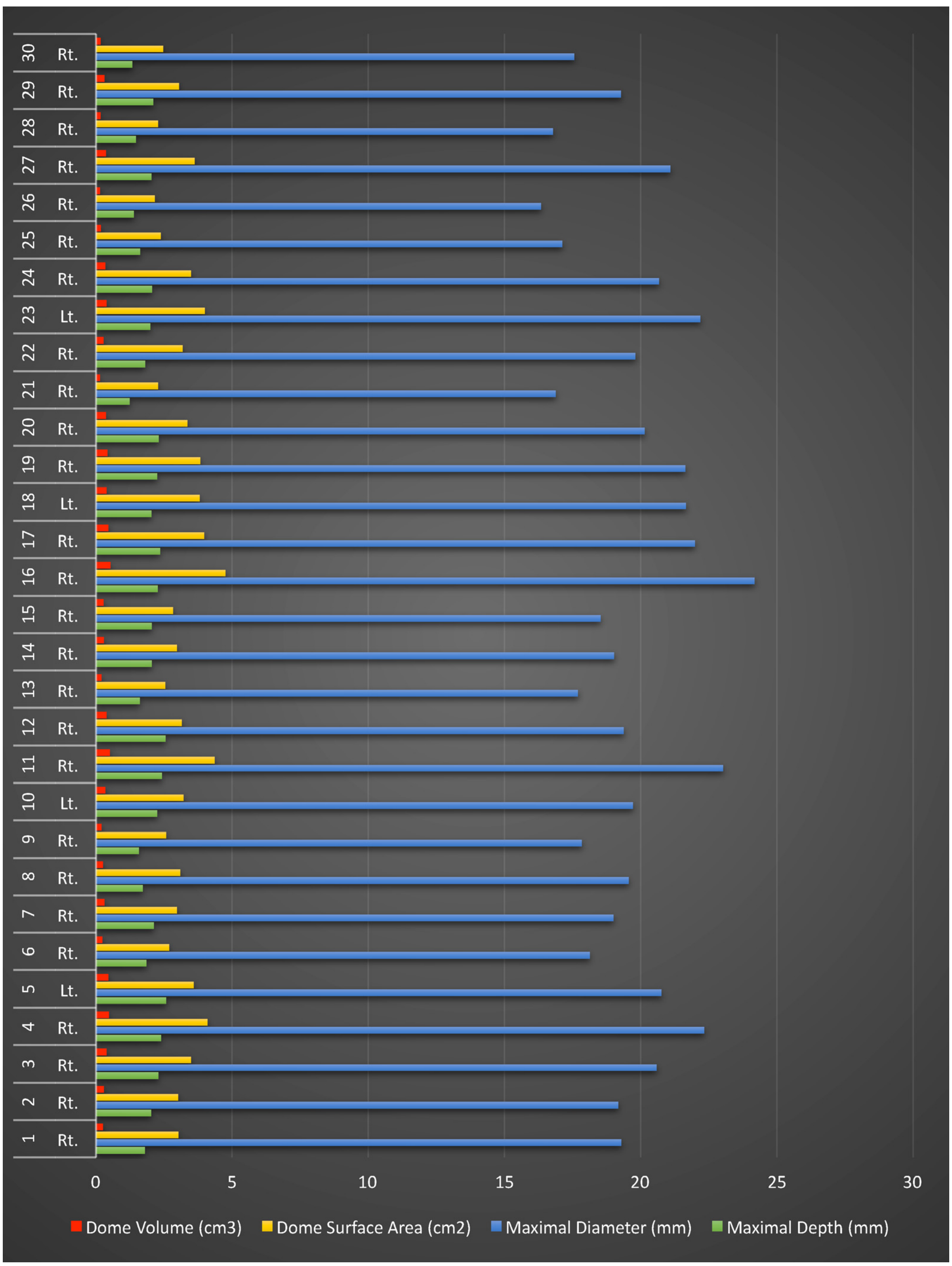

Fig. 1. Bar chart representation of the recorded parameters.

material was casted precisely with a flattened plateau up to the level of the superior rim of the radial head. The cast volume was then estimated by removing it from the radial bone and immersing it inside the barrel of a water-filled 5-cm^3 syringe. The volume was then estimated by exploiting the sue of the famous Archimedes' fluid displacement principle.[29]

The 3rd method, purely mathematical one, in which both the volume and the surface area of the superior articular radial head were calculated by mathematical formulae, by using the previously recorded parameters of diameter and depth. From a geometrical perspective, the superior articular concavity of the radial head, was considered to be a miniature hemispherical dome.[30,31]

For these three different methods, all recorded morphometric data were concurrent and accurate. However, the fluid displacement method was the least accurate for measuring the volume, while the other two methods were more accurate and consistent to the nearest percentile of a unit of measurement (i.e., cm^3). Further, to prevent man-made errors and/or biases while taking measurements, two anatomists recorded each morphometric parameter independently from each other. Moreover, when the independent measurements were of a numerical disparity at the nearest 1/10th of a unit, a third confirmatory measurement was taken to resolve the measurement disparity. The final readings were presented in Table 1, represents the average readings for each measurement, as recorded accurately using the electronic Vernier.

Pearson's correlation test was used as a tool of statistical analysis including The Statistical Package for Social Sciences version 20,

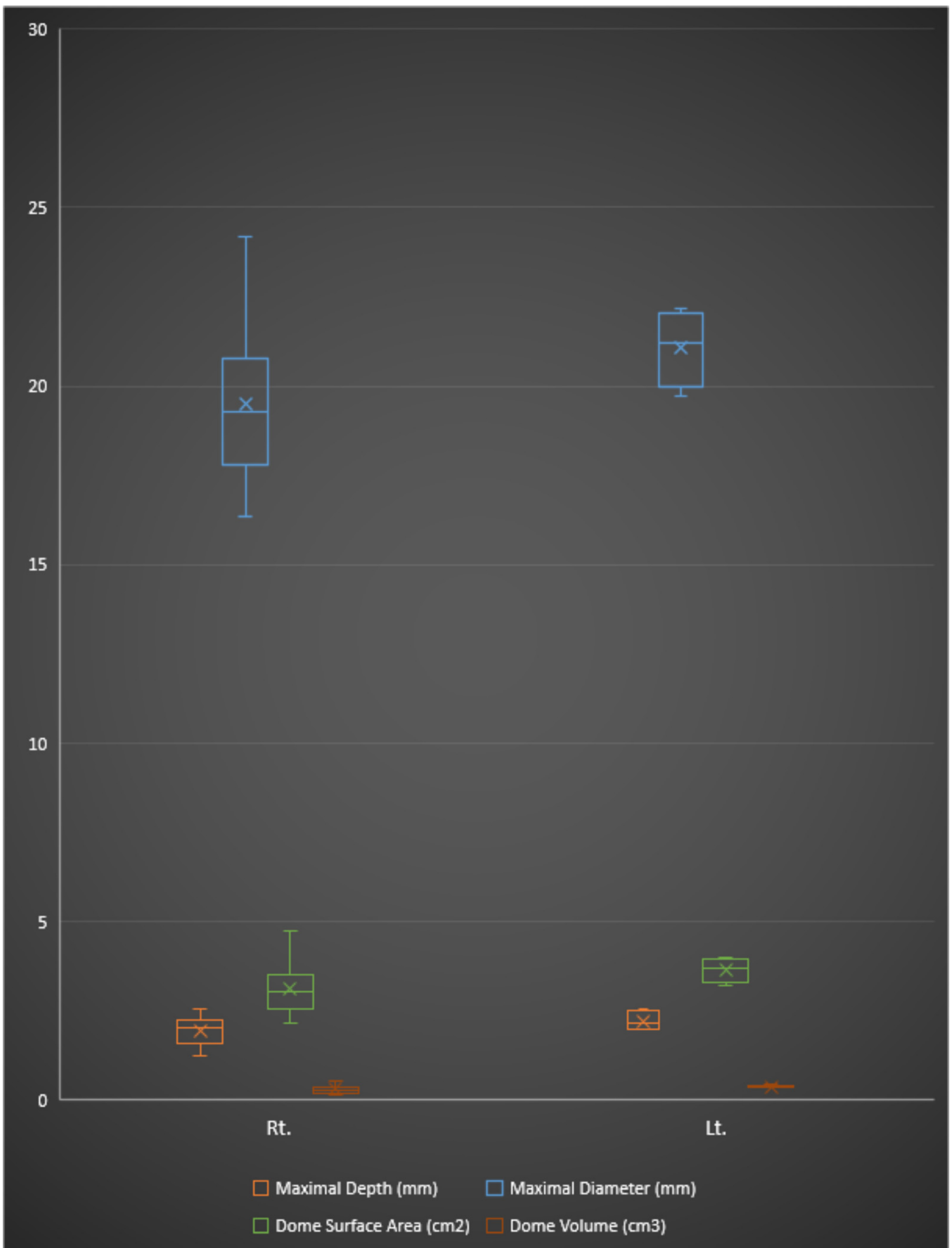

Fig. 2. Comparative Box–Whisker plot, right (26) vs. left (4) radial bones.

Microsoft Excel 2016, and Shodor software.[32] According to the classification system by the Oxford Centre for Evidence-based Medicine (CEBM), the overall evidence in this research is level-5.[33]

3. Results and discussion

Data tabulation (Table 1), some of these data are also graphically presented as a bar chart (Fig. 1) and a Box–Whisker plot chart (Fig. 2). The Box–Whisker plot is comparative, i.e., it visualizes data related to both right and left radial specimens. The mean values ± standard deviation were: 1.983 ± 0.3641 (depth), 19.704 ± 1.984 mm (diameter), 3.206 ± 0.655 cm^2 (articular surface area), and 0.318 ± 0.109 cm^3 (volume). The 95% confidence intervals (95% CI) were 1.847–2.119 mm (depth), 18.963–20.445 mm (diameter), 2.961–3.451 cm^2 (surface area), and 0.277–0.359 cm^3 (volume).

Statistical analyses using Pearson's correlation test (Table 1 and Fig. 15), proved an existing correlation between depth vs. volume (Fig. 3), depth vs. area (Fig. 4), area vs. volume (Fig. 5), diameter vs. depth (Fig. 6), diameter vs. area (Fig. 7), diameter vs. volume (Fig. 8). In all of correlations, the *p*-values were found to be less than 0.00001, which is a very strong positive (+ve) linear correlation for these tested parameters.

However, other correlations were not statistically significant, i.e., for age vs. diameter (*p*-value 0.361), age vs. depth (*p*-value 0.937), age vs. area (*p*-value 0.342), age vs. volume (*p*-value 0.512), limb vs. area (*p*-value 0.149), limb vs. volume (*p*-value 0.146). Scattered plots of these data were used for each pair of correlates (Figs. 3–14), from which any reader can instinctually judge the presence/absence of a significant correlation. From Fig. 7, we can visually perceive the presence of an evident positive (+ve) linear correlation (p-value of <0.00001 and an r-value of 0.999) between the depth and the articular surface area of the SAS. On the contrary and while inspecting Figs. 11 and 12, there was some sort of weak negative (−ve) linear correlation between limb orientation

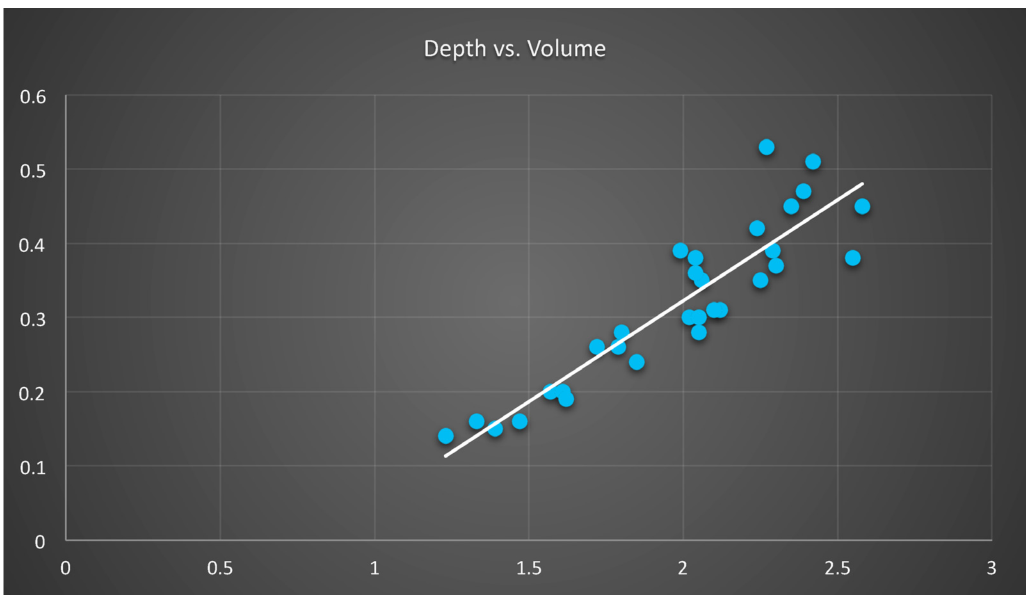

Fig. 3. Scatter plot, depth in mm (*X*-coordinate) vs. volume in cm^3 (*Y*-coordinate).

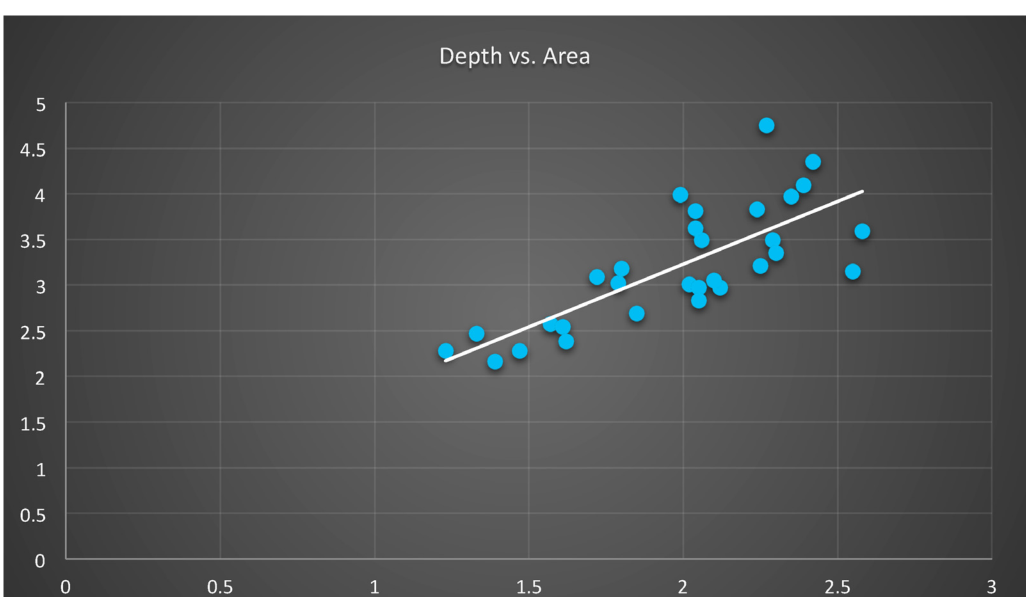

Fig. 4. Scatter plot, depth in mm (*X*-coordinate) vs. Area in cm^2 (*Y*-coordinate).

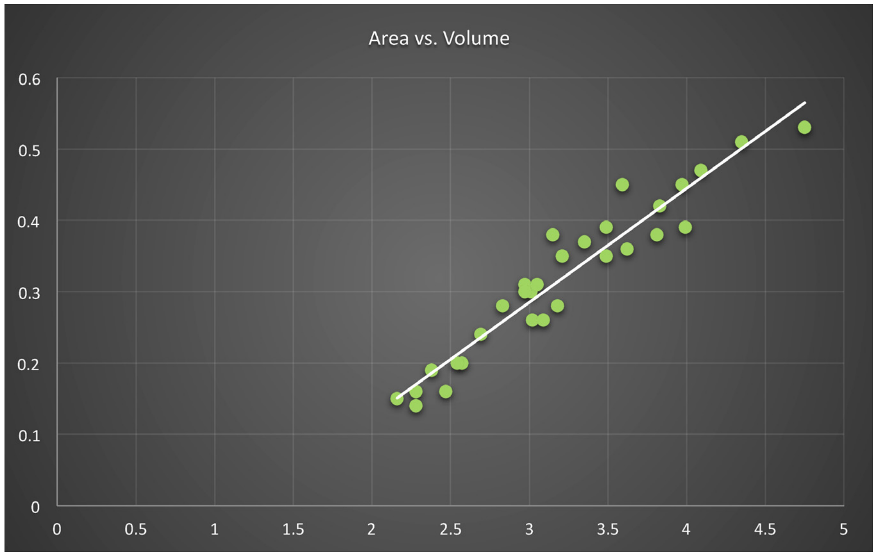

Fig. 5. Scatter plot, area in cm^2 (*X*-coordinate) vs. volume in cm^3 (*Y*-coordinate).

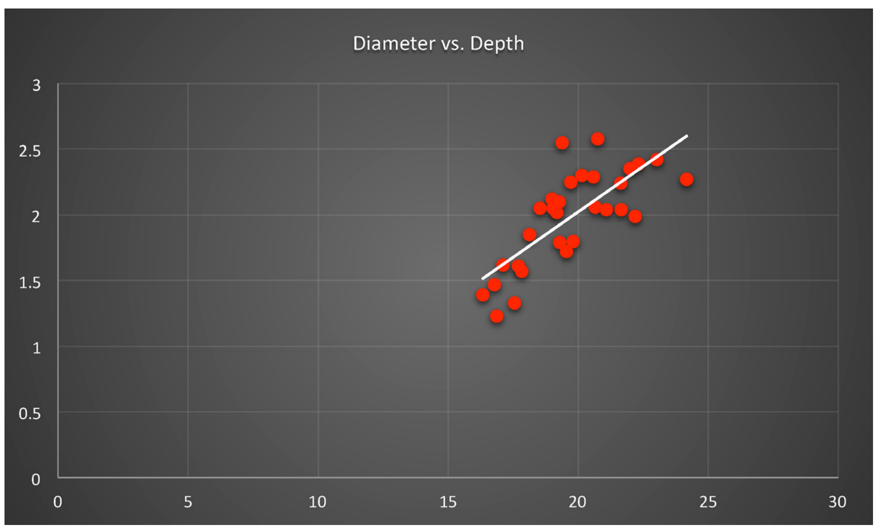

Fig. 6. Scatter plot, diameter in mm (*X*-coordinate) vs. depth in mm (*Y*-coordinate).

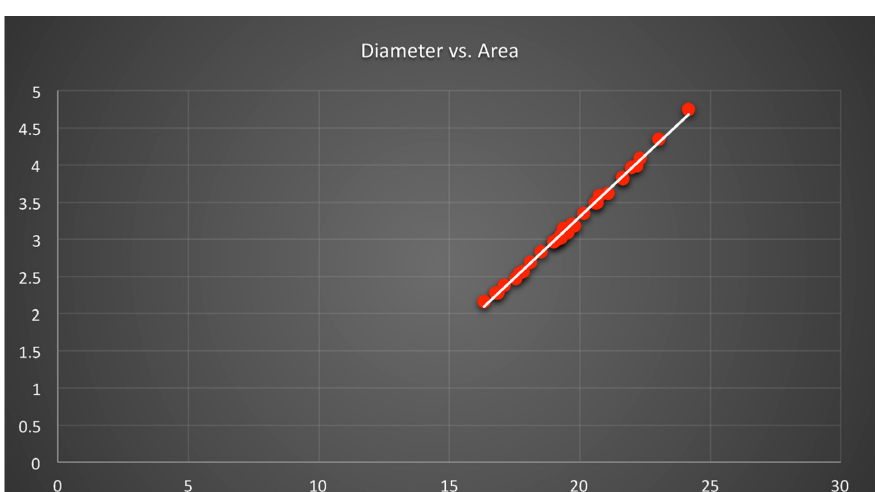

Fig. 7. Scatter plot, diameter in mm (*X*-coordinate) vs. area in cm^2 (*Y*-coordinate).

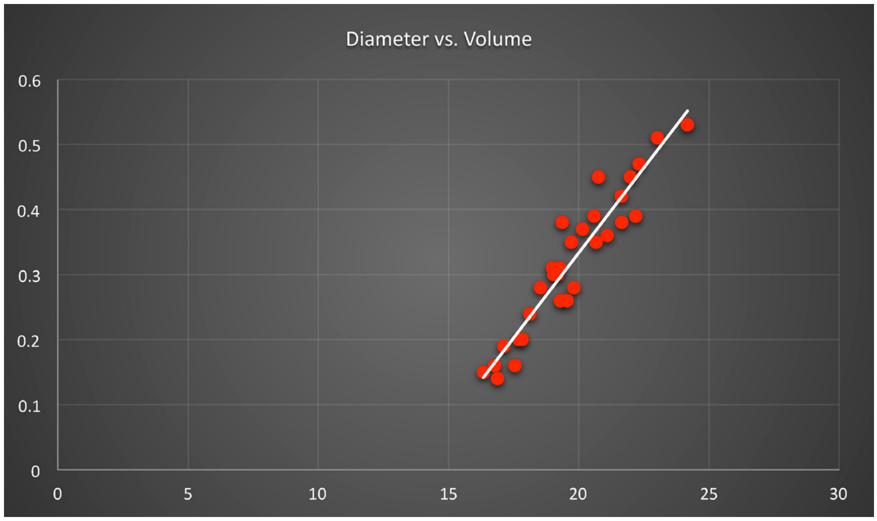

Fig. 8. Scatter plot, diameter in mm (*X*-coordinate) vs. volume in cm^3 (*Y*-coordinate).

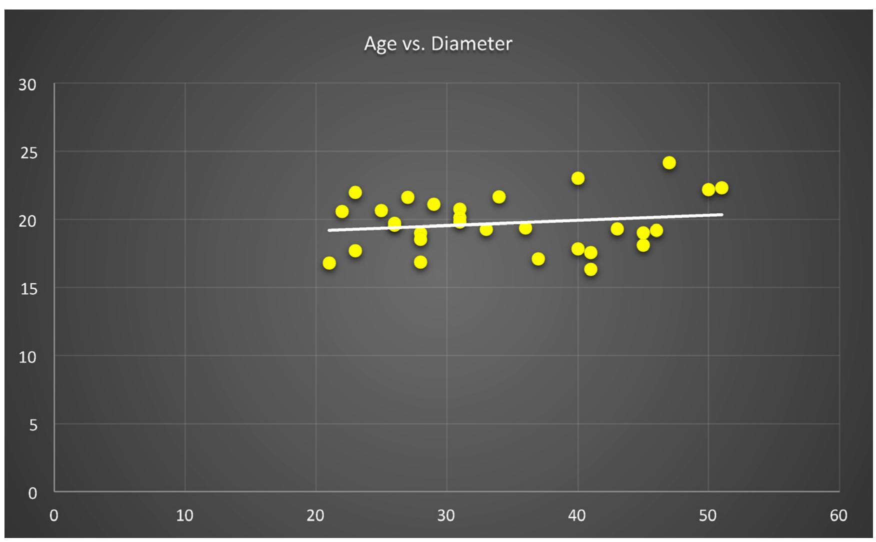

Fig. 9. Scatter plot, age in years (*X*-coordinate) vs. diameter in mm (*Y*-coordinate).

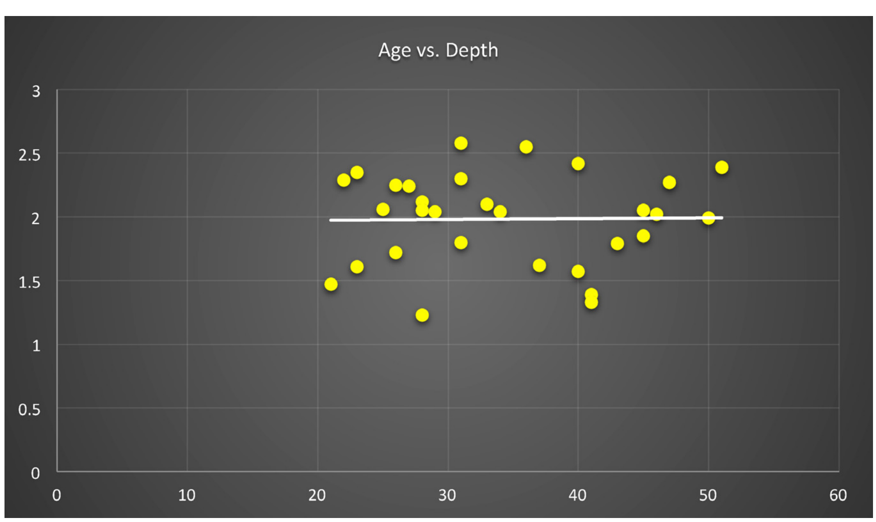

Fig. 10. Scatter plot, age in years (*X*-coordinate) vs. depth in cm^3 (*Y*-coordinate).

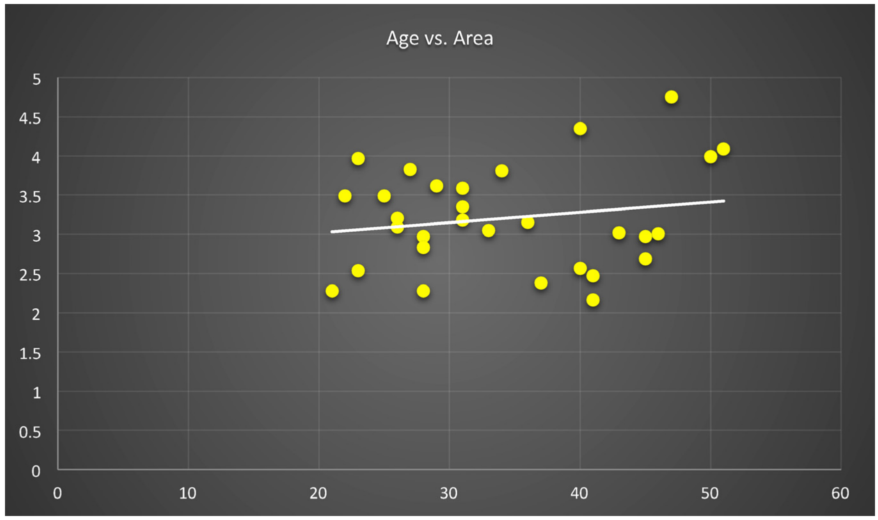

Fig. 11. Scatter plot, age in years (*X*-coordinate) vs. surface area in cm^2 (*Y*-coordinate).

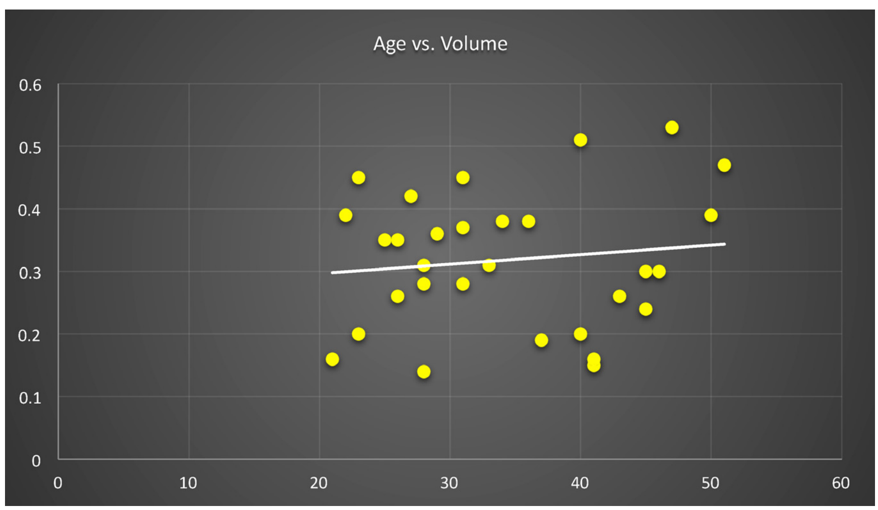

Fig. 12. Scatter plot, age in years (*X*-coordinate) vs. volume in cm^3 (*Y*-coordinate).

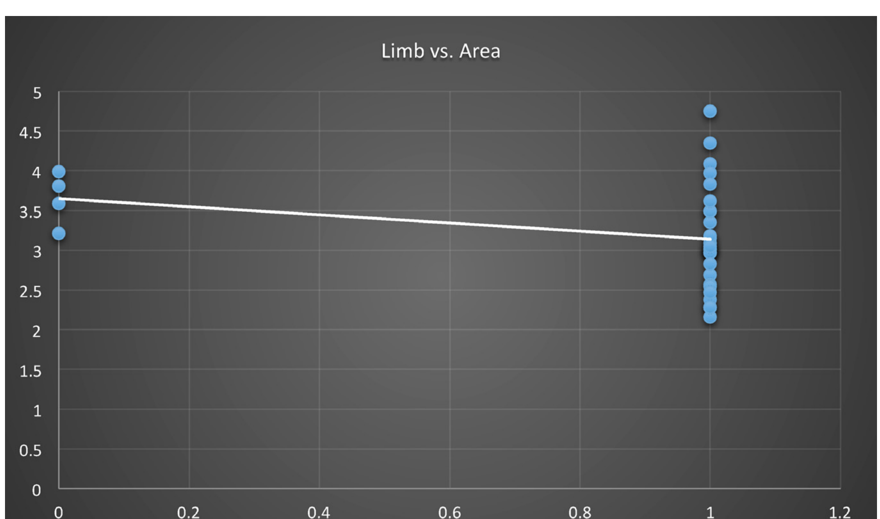

Fig. 13. Scatter plot, limb orientation (*X*-coordinate) vs. area in cm^2 (*Y*-coordinate).

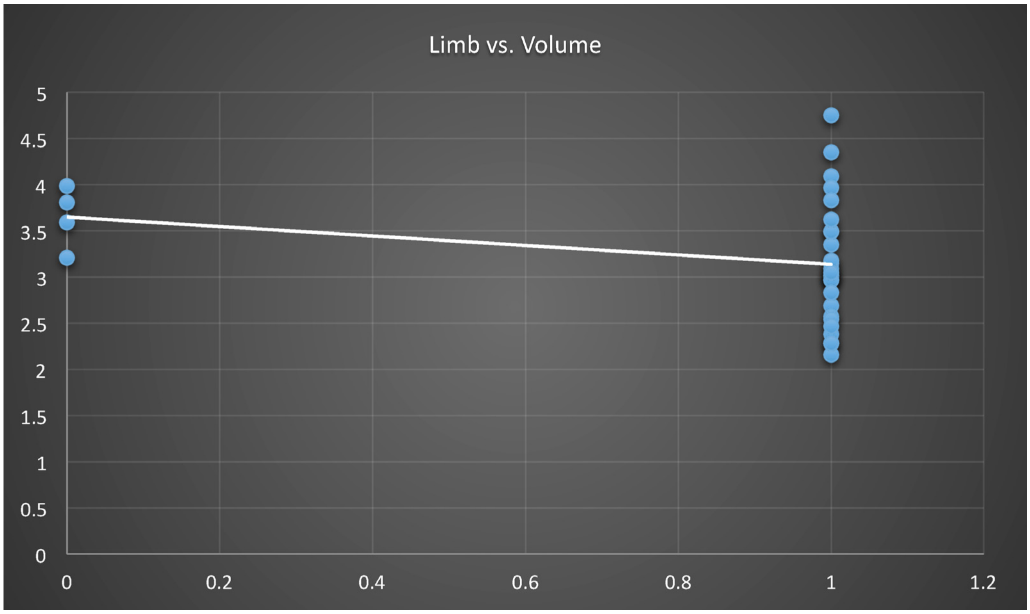

Fig. 14. Scatter plot, limb orientation (*X*-coordinate) vs. volume in cm^3 (*Y*-coordinate).

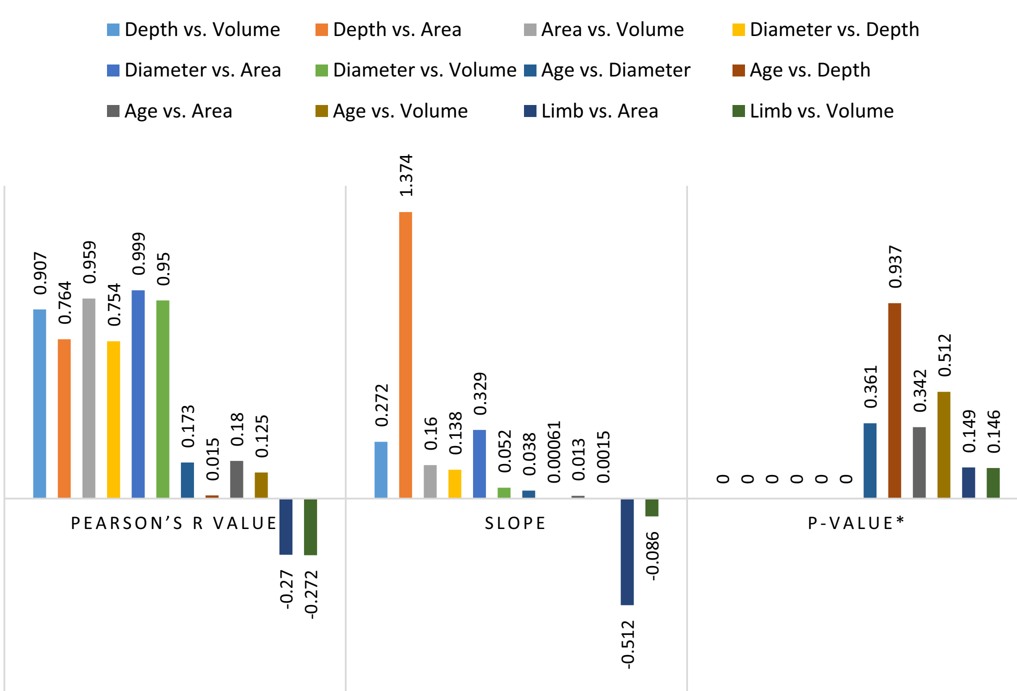

Fig. 15. Pearson's correlation test, '*r*-value', slope, and '*p*-value'.

(right–left radius bone) vs. articular surface area, and between limb orientation and the volume of the SAS. Correlation was also absent for limb orientation vs. depth, and limb orientation vs. diameter.

It is highly evident that some of these strong correlations are of prime clinical value and a relevant practical application(s). In a similar sense and in relation to the SAS of the radial head, Al-Imam[34] presented a case of anomalous medio-lateral inclination of the SAS of the radial head. The same author also reported normal (physiological) medio-lateral inclination of the SAS of the radial head.[35] All these interlinked studies, indicate the significant importance and high demands for an accurate morphometry studies, thereafter pathological cases can be easily contrasted, explored, and managed.

4. Conclusion

To the best of our knowledge this is the first study of its genre, for which divergent innovative experimental techniques were thoroughly used to accurately measure the morphometry of the superior articular surface of the radial head, with a succeeding hypothesis-testing via statistical implementation.

The statistical correlations of this study based on Pearson's correlations test and linear regression, shows strong correlations between four of the measured parameters: depth and diameter, surface area, and volume.

The practical applications of the data, will fit optimally into the hands of a dextrous orthopedic surgeon for reconstructive surgeries. These data will also provide a precision leverage and validity for the biomedical engineering industry, to manufacture explicit radial head prostheses. These prostheses will simulate the in vitro geometrical dimensions of the radial head, exceptionally when some data (including radiological, clinical, and surgical) are lacking owing to a complex trauma or an aggressive pathology that may affect the radial head for instance.

Besides, data from this study can be used widely in anthropology, forensic science, comparative anatomy and evolutionary biology, prosthesis synthesis, biotechnology and biomechanical applications, and as surgical reference values for orthopedic and arthroscopic surgery, rheumatology and degenerative medicine, and anthropometrics.

Conflicts of interest

The authors have none to declare.

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References

1. Kapandji IA. *The Physiology of the Joints: Lower Limb*. Elsevier Health Sciences; 1987.
2. Ricciardi A. Thieme atlas of anatomy: general anatomy and musculoskeletal system. *Yale J Biol Med.* 2015;88(March (1)):100.
3. Hayashi S, Kim JH, Rodriguez-Vazquez JF, et al. Influence of developing ligaments on the muscles in contact with them: a study of the annular ligament of the radius and the sacrospinous ligament in mid-term human fetuses. *Anat Cell Biol.* 2013;46(June (2)):149–156.
4. Shukla DR, Thoreson AR, Fitzsimmons JS, An KN, O'Driscoll SW. The effect of capitellar impaction fractures on radiocapitellar stability. *J Hand Surg.* 2015;40(March (3)):520–525.
5. Chanlalit C, Shukla DR, Fitzsimmons JS, Thoreson AR, An KN, O'Driscoll SW. Radiocapitellar stability: the effect of soft tissue integrity on bipolar versus monopolar radial head prostheses. *J Shoulder Elb Surg.* 2011;20(March (2)):219–225.
6. Chanlalit C, Shukla DR, Fitzsimmons JS, An KN, O'Driscoll SW. The biomechanical effect of prosthetic design on radiocapitellar stability in a terrible triad model. *J Orthop Trauma.* 2012;26(September (9)):539–544.
7. Foruria AM, Augustin S, Morrey BF, Sánchez-Sotelo J. Heterotopic ossification after surgery for fractures and fracture-dislocations involving the proximal aspect of the radius or ulna. *J Bone Jt Surg Am.* 2013;95(May (10)):e66.
8. Niu XF, Yi JH, Hu J, Xiao LB. Chronic radial head dislocation caused by a rare solitary osteochondroma of the proximal radius in a child: a case report and review of the literature. *BMC Res Notes.* 2015;8(April (1)):131.
9. Taylor TK, O'connor BT. The effect upon the inferior radio-ulnar joint of excision of the head of the radius in adults. *J Bone Jt Surg Br Vol.* 1964;46(February (1)):83–88.
10. Koslowsky TC, Mader K, Dargel J, Koebke J, Hellmich M, Pennig D. Reconstruction of a Mason type-III fracture of the radial head using four different fixation techniques. *Bone Jt J.* 2007;89(November (11)):1545–1550.
11. Geel CW, Palmer AK, Ruedi T, Leutenegger AF. Internal fixation of proximal radial head fractures. *J Orthop Trauma.* 1990;4(3):270–274.
12. Mason ML. Some observations on fractures of the head of the radius with a review of one hundred cases. *Br J Surg.* 1954;42(172):123–132.
13. McArthur RA. Herbert screw fixation of fracture of the head of the radius. *Clin Orthop Relat Res.* 1987;224(November):79–87.
14. Sanders RA, French HG. Open reduction and internal fixation of comminuted radial head fractures. *Am J Sports Med.* 1986;14(2):130–135.
15. Shmueli G, Herold HZ. Compression screwing of displaced fractures of the head of the radius. *Bone Jt J.* 1981;63-B(4):535–538.
16. Bunker TD, Newman JH. The Herbert differential pitch bone screw in displaced radial head fractures. *Injury.* 1985;16(November (9)):621–624.
17. Geel CW, Palmer AK, Ruedi T, Leutenegger AF. Internal fixation of proximal radial head fractures. *J Orthop Trauma.* 1990;4(September (3)):270–274.
18. Geel CW, Palmer AK. Radial head fractures and their effect on the distal radioulnar joint: a rationale for treatment. *Clin Orthop Relat Res.* 1992;275(February):79–84.
19. De Lee JC, Green DP, Wilkens KE. Radial head fractures. In: Rockwood Jr CA, Green DP, eds. In: *Fractures in Adults*. Philadelphia: JB Lippincott; 1984:628–639.
20. Radin EL, Riseborough EJ. Fractures of the radial head. A review of eighty eighty-eight cases and analysis of the indications for excision of the radial head and nonoperative treatment. *J Bone Jt Surg.* 1966;48A(6):1055–1061.
21. Mikic ZD, Vukadinovic SM. Late results in fractures of the radial head treated by excision. *Clin Orthop.* 1983;181(December):220–228.
22. Weseley MS, Barenfeld PA, Eisenstein AL. Closed treatment of isolated radial head fractures. *J Trauma Acute Care Surg.* 1983;23(January (1)):36–39.
23. Coleman DA, Blair WF, Shurr D. Resection of the radial head for fracture of the radial head. *J Bone Jt Surg Am.* 1987;69(March (3)):385–392.
24. Morrey BF, Chao EY, Hui FC. Biomechanical study of the elbow following excision of the radial head. *J Bone Jt Surg Am.* 1979;61(January (1)):63–68.
25. Adler JB, Shaftan GW. Radial head fractures, is excision necessary? *J Trauma Acute Care Surg.* 1964;4(January (1)):115–136.
26. Zhermack. Hydrogum. http://en.zhermack.com/Clinical/Clinical/Alginates/Hydrogum/C302025.kl [accessed 5.05.16].
27. Moore WJ. *Physical Chemistry*. 3rd ed. New York: Prentice-Hall Inc.; 1962.
28. Jasper JJ. The surface tension of pure liquid compounds. *J Phys Chem Ref Data.* 1972;1(October (4)):841–1010.
29. Stein S. *Archimedes: What Did He Do Beside Cry Eureka?*MAA; 1999, September.
30. Polyanin AD, Manzhirov AV. *Handbook of Mathematics for Engineers and Scientists*. CRC Press; 2006, November.
31. Monolithic.org. Dome Calculator. http://www.monolithic.org/calculators/dome-calculator [accessed 5.05.16].
32. Interactivate. Box Plot. http://www.shodor.org/interactivate/activities/BoxPlot/ [accessed 30.03.16].
33. Oxford Centre for Evidence-based Medicine. *Levels of Evidence*. 2009, March. http://www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/ [accessed 22.06.16]
34. Al-Imam A. Post-mortem case report, anomalous radial head inclination. *Asian J Bio-Med Res.* 2016. ISSN:2454-6275, http://pmindexing.com/journals/index.php/AJBR/ [in press]
35. Al-Imam A. Medio-lateral inclination of proximal and distal articular surface of the radius. *Asian J Med Sci.* 2016. http://dx.doi.org/10.3126/ajms.v7i5.14973. E-ISSN 2091-0576; P-2467-9100 [in press].