



ORIGINAL ARTICLE

# 3D CBCT human adult odontometrics: Comparative assessment in Saudi, Jordan and Egypt population

Mohammad Khursheed Alam<sup>a,\*</sup>, Bader K Alzarea<sup>b</sup>, Kiran Kumar Ganji<sup>c</sup>,  
Ibadullah Kundi<sup>a</sup>, Santosh Patil<sup>d</sup>

<sup>a</sup> Orthodontic Department, College of Dentistry, Jouf University, Sakaka, Saudi Arabia

<sup>b</sup> Prosthodontic Department, College of Dentistry, Jouf University, Sakaka, Saudi Arabia

<sup>c</sup> Periodontology Department, College of Dentistry, Jouf University, Sakaka, Saudi Arabia

<sup>d</sup> Department of Oral Medicine and Radiology, College of Dentistry, Jouf University, Sakaka, Saudi Arabia

Received 5 December 2018; revised 5 March 2019; accepted 10 March 2019

Available online 15 March 2019

## KEYWORDS

3D CBCT;  
Odontometry;  
Sexual dimorphism;  
Asymmetry

**Abstract Objectives:** To inspect the human adult odontometrics by the assistance of 3D cone beam computerized tomography (CBCT) imaging in Saudi, Jordan and Egypt population.

**Materials and Methods:** Data of this cross sectional study from 252 subject were analysed by 3D CBCT volumetric data in college of dentistry, Aljouf University, from December 2016 to May 2017. All measurements were done by 3D on demand software. The tooth size from 2nd molar to 2nd molar of maxillary and mandibular arch was measured. Independent *t* test and ANOVA were used to examine the differences between gender and among Arabic population (Saudi, Jordan and Egypt) on the all tooth size.

**Results:** Comparison between the right and left side odontometrics were significantly dissimilar in 9 out of 14 pairs ( $p < 0.05$ ). The odontometrics of the 2nd molar to 2nd molar tooth of maxillary and mandibular arch between gender and among Saudi, Jordan and Egypt population were insignificant ( $p > 0.05$ ).

**Conclusion:** 3D CBCT imaging permits us to measure the tooth size effectively and accurately. Based on results, significant asymmetry was revealed in 9 out of 14 pairs in relation to side

\* Corresponding author.

E-mail addresses: [dralam@gmail.com](mailto:dralam@gmail.com) (M.K. Alam), [bkzarea@ju.edu.sa](mailto:bkzarea@ju.edu.sa) (B.K. Alzarea), [kiranperio@gmail.com](mailto:kiranperio@gmail.com) (K.K. Ganji), [dr.ibadullah.kundi@jodent.org](mailto:dr.ibadullah.kundi@jodent.org) (I. Kundi), [dr.santosh.patil@jodent.org](mailto:dr.santosh.patil@jodent.org) (S. Patil).

Peer review under responsibility of King Saud University.



Production and hosting by Elsevier

<https://doi.org/10.1016/j.sdentj.2019.03.007>

1013-9052 © 2019 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University.

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

disparities. No significant differences in tooth size between gender and among races were found. CBCT can elevate the record keeping problem, human adult odontometrics for the analysis can be obtained directly from the digital image.

© 2019 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Introduction

Odontometric morphometry and symmetry/asymmetry is an indispensable in the field of dentistry, specially, Orthodontics, Prosthodontics, Conservative dentistry, Oral surgery, Forensic dentistry and anthropology. Odontometric analysis (Haque and Alam, 2017; Purmal et al., 2013) using direct measurement methods including hand-held digital calipers (Alam et al., 2015a; Rahman et al., 2014; Hasan et al., 2015; Sajib and Alam, 2017; Alam et al., 2015b), graphical representation to record dimensions on dental casts (Khursheed et al., 2014), 2D digital model (Shahid et al., 2016; Shahid et al., 2017), Digital impression model (Noor et al., 2014; Jamayet et al., 2014; Sitthiphan et al., 2015), 3D CBCT model (Alam et al., 2014b; Alam et al., 2015c; Tarazona et al., 2011), laser scanned model (Massoud et al., 2016) have been used. Recent development in technology such as 3D CBCT has made it possible that the odontometric measurements in three-dimension (Alam et al., 2015c). These 3D model findings deliver more precise and consistent tools for obtaining measurements in odontometric study (Alam et al., 2014b; Alam et al., 2015c; Tarazona et al., 2011). Furthermore, 3D CBCT data provides surplus benefits, such as availability of the images produced, lessening in storage expenses and the facility to evaluate the images by sophisticated software (Alam et al., 2014b; Alam et al., 2015c; Tarazona et al., 2011). CBCT technique of 3D digital acquirement can be used in innumerable dental divisions such as endodontic, orthodontics, prosthodontics and implantology.

CBCT permits to determine odontometric morphometry as hastily, consistently and accurately matched with dimensions (measurement) obtained on digitalized plaster models using the Digital Method. No clinical dissimilarities between measurements using the CBCT method and those by means of the Digital Method exists. (2D) (Alam et al., 2014b; Alam et al., 2015c; Tarazona et al., 2011). CBCT helps orthodontist, prosthodontist and other specialist in the dentistry field to utilize the digital diagnostic simulation models (DDS) by the scanning the dental cast or direct in vivo. CBCT delivers excellent and high resolution images in short time and with a minimum amount of radiation than conventional CT. CBCT also offers more specific and precise 3D data of the dentofacial structures than 2D radiographs (Alam et al., 2015c; Tarazona et al., 2011).

Analysis of odontometric morphometry and symmetry/asymmetry is fundamental in clinical orthodontics, prosthodontics and operative dentistry for esthetics and durable occlusal stability through the preservation of the original mesiodistal tooth size (Alam et al., 2014a). There are some basic differences in odontometric morphometry between the different sub-populations. Findings of other populations have supplementary confirmed these verdicts. From the orthodontics, prosthodontics and operative dentistry treatment plan-

ning and diagnosis the odontometric morphometry has a prodigious significance for the position of teeth, smile, esthetics, stability of teeth and dental arches. Current literature reveal relatively few 3D studies of odontometric morphometry and symmetry/asymmetry (Alam et al., 2014b; Tarazona et al., 2011). Based on literature search till to date no such studies has been done in Arabian population. 3D images acquisition, using the CBCT method has great authenticity and reliability for the odontometric morphometry (Alam et al., 2014b; Alam et al., 2015c; Tarazona et al., 2011). Hence, the current study was designed to evaluate the odontometric morphometry between gender and among races (Saudi + Jordan + Egypt = Arabian) and symmetry/asymmetry via side disparities by in vivo 3D CBCT.

## 2. Materials and methods

Informed consent was obtained from all participants regarding willingness prior to CBCT, and this study was approved by the Ethical Committee of the college of Dentistry, Jouf University, which conforms with the Declaration of Helsinki. This study followed the guidelines of Strengthening the Reporting of Observational studies in Epidemiology (STROBE), and the STROBE checklist was utilized in the preparation of this manuscript (Vandenbroucke et al., 2007).

**Subject Characteristics & Study design:** This Cross sectional study was performed on secondary data procured from College of dentistry, Jouf University during period from December 2016 to May 2017. The data source was CBCT volumetric data from the archives of the college of Dentistry Jouf University and samples were selected using simple random technique. Odontometric morphometry and asymmetry was analysed and recorded in 252 3D CBCT volumetric data of maxilla and mandibular arches. Details of the demographic information and selection criteria are shown in Table 1.

**Odontometric analysis on CBCT digital image:** The linear dimensions were made for odontometric morphometry and asymmetry. Tooth size of 2nd molar to 2nd molar of maxilla and mandible were measured. Tooth size, is the mesio-distal width which resembles to the maximum distance across the anatomic contact point of teeth for the maxillary and mandibular teeth. Malposed tooth is measured through imaginary contact point of the proximal area. The carefully chosen 252 CBCT images were analyzed using software OnDemand 3D for odontometric morphometry and symmetry/asymmetry.

**Measurement of error:** Measurements were repeated two weeks delayed to evaluate the systemic and random errors for 50 CBCT images that were randomly selected. Systemic errors were calculated using a two-sample *t*-test for each pair of analyses. Houston (1983) stated that there systemic bias doesn't exist if the *p*-value is larger than 0.1. Arbitrary errors were assessed by measuring the correlation between repeated

**Table 1** Demographic Information, Selection Criteria and Armamentarium.

Selection criteria	Inclusive	Exclusive
	Age between 20 and 45 years; Full dentition in both maxilla and mandibular arches excluding the third molars; High quality CBCT that have proper density and contrast with sharp outlines were selected as a volumetric data; Ethnicity verified from the folder	Severe crowding; Excessive spacing; Radiographic evidence of pathology within the maxilla or mandible (presence of cysts and tumors); Periodontal disease; Retained deciduous teeth; Inter proximal caries or restoration; Missing or supernumerary teeth; Abnormal size or morphology of teeth; Tooth wear to the extent of impairment the contact point; Damage or extorted CBCT 3D acquisitions
<b>Study design</b>	Cross sectional study of secondary data	
<b>Sample size calculation</b>	G*Power software version 3.0.10 with power 90%, $\alpha$ (0.05) and effect size (d) 0.20 was used	
<b>In relation to age</b>	34.806 $\pm$ 7.581	
<b>3D CBCT measurements</b>	Same investigator	Same investigator
<b>3D CBCT measurements</b>	Repeat measurement after 2-week interval, randomly selected 50 CBCT images	
<b>In relation to gender</b>	159 males and 93 females = 252 in total	
<b>In relation to race</b>	198 Saudi + 30 Jordanian + 24 Egyptian = 252 in total	
<b>Armamentarium</b>	1. 3D CBCT images 2. 3D OnDemand software	

**Table 2** Gender comparison of odontometric morphometry in maxilla and mandible.

Gender	Mandible				Maxilla			
	Variables	Mean	SD	p value	Variables	Mean	SD	p value
M	31	5.147	0.663	0.657	11	8.028	0.969	0.906
F		5.108	0.649	0.656		8.013	0.926	0.905
M	32	5.580	0.709	0.999	12	6.345	0.862	0.623
F		5.580	0.718	0.999		6.292	0.778	0.614
M	33	6.314	0.908	0.768	13	7.212	0.855	0.389
F		6.281	0.815	0.761		7.116	0.840	0.387
M	34	6.426	0.880	0.541	14	6.442	0.834	0.884
F		6.358	0.803	0.531		6.426	0.774	0.882
M	35	6.394	0.906	0.613	15	6.060	0.884	0.561
F		6.336	0.844	0.606		5.993	0.845	0.556
M	36	9.900	1.600	0.199	16	9.062	1.303	0.436
F		9.642	1.407	0.184		8.931	1.241	0.430
M	37	9.044	1.524	0.542	17	7.991	1.523	0.295
F		8.932	1.161	0.512		7.792	1.316	0.277
M	41	5.093	0.668	0.923	21	8.021	0.961	0.712
F		5.101	0.630	0.921		8.067	0.929	0.710
M	42	5.567	0.685	0.981	22	6.323	0.859	0.935
F		5.569	0.685	0.981		6.314	0.839	0.935
M	43	6.258	0.986	0.562	23	7.251	0.888	0.752
F		6.330	0.875	0.550		7.215	0.876	0.751
M	44	6.492	0.882	0.578	24	6.547	0.797	0.791
F		6.429	0.820	0.571		6.520	0.745	0.787
M	45	6.447	0.922	0.494	25	6.157	0.867	0.598
F		6.367	0.859	0.486		6.099	0.787	0.589
M	46	10.013	1.545	0.417	26	9.155	1.231	0.885
F		9.855	1.350	0.401		9.131	1.235	0.886
M	47	9.090	1.382	0.351	27	8.056	1.507	0.317
F		8.929	1.188	0.332		7.869	1.276	0.296

measurements (index of reliability). Stirrup (1993) stated that a correlation value larger than 0.95 is satisfactory (Stirrups, 1993). All test and retest measurements presented an intra-class correlation of value greater than 0.91. Outcomes from these variables showed that there were no random errors. All

pairs of measurements showed a *p*-value greater than 0.1, suggesting that there was no systemic bias in these analyses.

Statistical Analysis; Obtained data were introduced to the Excel spread sheet and the data was statistically analysed using SPSS version 24 (Chicago, IL, USA). Independent *t* test and

**Table 3** Racial comparison of odontometric morphometry in maxilla and mandible.

Race	Maxilla				Mandible				
	Variables	Mean	SD	p value	Variables	Mean	SD	p value	
Saudi	11	8.008	0.966	0.936	31	5.107	0.651	0.491	
Jordan		8.032	1.015				5.145		0.673
Egypt		8.080	0.786				5.276		0.722
Saudi	12	6.327	0.843	0.976	32	5.558	0.704	0.481	
Jordan		6.319	0.839				5.577		0.662
Egypt		6.287	0.760				5.744		0.828
Saudi	13	7.171	0.870	0.941	33	6.274	0.875	0.725	
Jordan		7.210	0.862				6.392		0.896
Egypt		7.128	0.722				6.367		0.882
Saudi	14	6.417	0.833	0.750	34	6.377	0.858	0.715	
Jordan		6.538	0.807				6.427		0.792
Egypt		6.422	0.648				6.523		0.896
Saudi	15	5.989	0.861	0.311	35	6.345	0.906	0.682	
Jordan		6.224	0.924				6.409		0.793
Egypt		6.143	0.867				6.504		0.831
Saudi	16	8.956	1.295	0.518	36	9.683	1.521	0.068	
Jordan		9.175	1.359				10.161		1.618
Egypt		9.193	1.122				10.300		1.440
Saudi	17	7.879	1.493	0.807	37	8.927	1.451	0.363	
Jordan		7.965	1.427				9.182		1.269
Egypt		8.073	1.206				9.290		1.188
Saudi	21	8.014	0.955	0.840	41	5.083	0.646	0.55	
Jordan		8.111	1.070				5.042		0.668
Egypt		8.084	0.763				5.225		0.728
Saudi	22	6.306	0.876	0.859	42	5.554	0.692	0.643	
Jordan		6.297	0.865				5.537		0.657
Egypt		6.406	0.649				5.689		0.661
Saudi	23	7.244	0.904	0.848	43	6.257	0.968	0.756	
Jordan		7.237	0.905				6.371		0.882
Egypt		7.134	0.697				6.359		0.863
Saudi	24	6.518	0.793	0.824	44	6.449	0.867	0.661	
Jordan		6.601	0.806				6.438		0.831
Egypt		6.579	0.628				6.616		0.865
Saudi	25	6.100	0.839	0.476	45	6.393	0.902	0.674	
Jordan		6.287	0.870				6.429		0.889
Egypt		6.204	0.788				6.565		0.909
Saudi	26	9.107	1.242	0.740	46	9.862	1.471	0.213	
Jordan		9.283	1.324				10.186		1.587
Egypt		9.204	1.107				10.336		1.386
Saudi	27	7.932	1.471	0.624	47	8.971	1.323	0.494	
Jordan		8.096	1.264				9.149		1.315
Egypt		8.194	1.352				9.271		1.326

paired *t* test was used to examine the disparities in gender and side asymmetry respectively. For the racial disparities, ANOVA was used.  $p < 0.05$  were considered to be statistically significant.

### 3. Results

#### 3.1. Gender comparison

A total of 28 variables were measured. The odontometric morphometry (mesio distal tooth width of the 2nd molar to 2nd molar of the maxilla and mandible) between gender show no significant differences ( $p > 0.05$ ) (Table 2). Out of 28, male had larger value in 23 variables than female.

#### 3.2. Race comparisons

Among 3 races (Saudi, Jordan and Egypt) odontometric morphometry of all 28 variables of maxilla and mandible show no significant differences ( $p > 0.05$ ) (Table 3).

#### 3.3. Side comparison

For the odontometric symmetry/asymmetry, among 14 pairs of comparison, 9 pairs revealed significant differences (Table 4). Pair no. 4–6 and no. 13 revealed highly significant differences ( $p < 0.001$ ), pair no. 4 and no. 11 showed moderately significant differences ( $p < 0.01$ ) and pair no. 7, 8 and no. 12 showed less significant differences ( $p < 0.05$ ).

**Table 4** Side comparison for odontometric symmetry/asymmetry (Maxillary right vs left and Mandibular right vs left, 2nd molar to 2nd molar teeth).

Pair	Variables	Mean	95% CI		p value
			Lower	Upper	
Pair 1	11 vs 21	-0.015	-0.045	0.016	0.335
Pair 2	12 vs 22	0.007	-0.035	0.049	0.727
Pair 3	13 vs 23	-0.062	-0.098	-0.025	0.001**
Pair 4	14 vs 24	-0.102	-0.141	-0.063	0.000***
Pair 5	15 vs 25	-0.101	-0.140	-0.062	0.000***
Pair 6	16 vs 26	-0.132	-0.189	-0.076	0.000***
Pair 7	17 vs 27	-0.069	-0.129	-0.008	0.026*
Pair 8	31 vs 41	0.036	0.011	0.062	0.006**
Pair 9	32 vs 42	0.013	-0.022	0.047	0.481
Pair 10	33 vs 43	0.017	-0.052	0.086	0.632
Pair 11	34 vs 44	-0.067	-0.107	-0.027	0.001**
Pair 12	35 vs 45	-0.046	-0.087	-0.004	0.033*
Pair 13	36 vs 46	-0.147	-0.205	-0.090	0.000***
Pair 14	37 vs 47	-0.029	-0.127	0.070	0.566

#### 4. Discussion

The uniqueness of the current study stands upon the following points: (1) 252 CBCT data; (2) Three different Arabian sub-population data; (3) assessment of odontometric morphometry and symmetry/asymmetry using new approach. This study assessed the overall odontometric morphometry which is imperative for different field in dentistry. The records existing for the population are advantageous in the forensic odontology, orthodontic, prosthodontic and operative treatment designs. Before managing different orthodontic analysis for the odontometric morphometry and symmetry/asymmetry there should be records for the odontometric morphometry for gender, relevant ethnic and several variations in malocclusion. The 3D CBCT are as accurate and duplicate as the digital models accomplished from the plaster study casts for analyzing the odontometric morphometry. The inconsistencies present among both methodologies were clinically acceptable (Alam et al., 2014b; Alam et al., 2015c; Tarazona et al., 2011). CBCT digital models are as precise as OrthoCAD digital models in production of linear measurements for overjet, overbite, and crowding assessments (Kau et al., 2010). This study was carried out on CBCT data of 252 patients using the In-Vivo Dental program and the digital models obtained out of 3D onDemand software. The sample size was significantly higher than the previous studies (Alam et al., 2014b; Alam et al., 2015c; Tarazona et al., 2011; Kau et al., 2010).

Bishara et al. investigated the mesio-distal and buccolingual crown dimensions of the permanent teeth in three populations from Egypt, Mexico and the United States. The findings from this report demonstrated significant disparities in the mesio-distal dimension among the evaluated populations. Besides racial disparities, the other aspects correlated with tooth size inconsistency are gender, environment, hereditary factors (Bishara et al., 1989). Current study also revealed racial differences among Saudi, Jordan and Egypt population. 18/24 variables, Egypt population had larger measurements than Saudi and Jordan. However, the differences were not statistically significant. Between gender disparities, male showed larger measurements than female without any significant

differences. In a study by Asiry and Hashim, (Al-Khateeb and Abu Alhaija, 2006) and Al-Khateeb and Abu Alhaija, (Asiry and Hashim, 2012), Saudi and Jordan population respectively showed gender disparities without any significant disparities. These results coincide with the current study. However, these measurements were done by digital caliper on plaster model. In relation to odontometric symmetry/asymmetry, our results coincide with the findings of Al-Khateeb and Abu Alhaija, (Asiry and Hashim, 2012; Al-Khateeb and Abu Alhaija, 2006). Significant differences between right and left side tooth size measurement were reported.

Our results verdict with the results presented by Alam et al. (Alam et al., 2014a; Alam et al., 2013) and Shahid et al. (Shahid et al., 2015) in relation to the gender differences. Tooth size in upper and lower canine presented the greatest variation of sexual dimorphism (Shahid et al., 2015). Shahid et al. (Shahid et al., 2015) reported that the greatest difference in the tooth size was associated with the upper lateral, second premolars and lower lateral incisors in males whereas in females it was associated with upper canine and lower incisors. However, Shahid et al. (Shahid et al., 2015) found the tooth dimensions of right and left side were alike with only exception in second premolar which was significantly higher than its counterpart. This outcome was significant but the disparity was very small, hence findings verdict with the results of the current study. In a study by Alam and Iida, (Alam and Iida, 2013) found overjet, overbite, dental midline shifting as a contributing factor in tooth size discrepancy. Al-Khateeb and Abu Alhaija, (Asiry and Hashim, 2012) found tooth size varies in relation to different type of malocclusion. We intend to discover such disparities using 3D CBCT methods in future studies.

We measured odontometric morphometry and symmetry/asymmetry through the 3D CBCT analysis of several measurements for 252 maxilla and 252 mandible. Findings from the current study provide an insight knowledge to orthodontist for appropriate diagnosis and treatment planning within the Arabian sub-population. We did multi-population comparison using 3D CBCT with the limitation of less number subjects of Jordan and Egypt and other nationals are not included within



the range of Arabian peninsula. Comparable outcomes might be obtained in another population thereby providing a scope for further research in this field.

## 5. Conclusion

Within the limitations of the study following summary can be drawn -

- 3D CBCT imaging allows us to measure the odontometric morphometry and symmetry/asymmetry.
- The odontometric morphometry didn't showed any variation in gender and racial dimorphism.
- The odontometric symmetry/asymmetry revealed the significant differences in 9/14 pairs of measurements.
- CBCT provides a valuable tool in record and data management for odontometric morphometry and symmetry/asymmetry assessment obtained directly from the digital image.

## 6. Authorship/Researcher contribution

1. Conception and design of the work: MKA, BKA, IK, KKG, SP.
2. Acquisition of data, or analysis and interpretation of data: MKA, IK, SP.
3. Drafting the article or revising it critically for important intellectual content: MKA, BKA, IK, KKG, SP.
4. Final approval of the version to be published: MKA, BKA, IK, KKG, SP.

## Conflict of interest

None declared.

## References

- Al-Khateeb, S.N., Abu Alhajja, E.S., 2006. Tooth size discrepancies and arch parameters among different malocclusions in a Jordanian sample. *Angle Orthodontist* 76, 459–465.
- Alam, M., Shahid, F., Purmal, K., Sikder, M., Saifuddin, M., 2015a. Human Mesiodistal Tooth Width Measurements and Comparison with Dental Cast in a Bangladeshi Population. *J. Contemp. Dent. Pract.* 16, 299–303.
- Alam, M.K., Hassan, R., Mahmood, Z., Haq, M.E., 2013. Determination and comparison of tooth size and tooth size ration in normal occlusion and different malocclusion groups. *Int. Med. J* 20, 462–465.
- Alam, M.K., Iida, J., 2013. Overjet, overbite and dental midline shift as predictors of tooth size discrepancy in a Bangladeshi population and a graphical overview of global tooth size ratios. *Acta Odontologica Scandinavica* 71, 1520–1531.
- Alam, M.K., Khamis, M.F., Malik, S.N., 2015b. Sex Determination based on mesiodistal tooth width in bangladeshi population. *Int. Med. J.* 22, 181–183.
- Alam, M.K., Shahid, F., Purmal, K., Ahmad, B., Khamis, M.F., 2014a. Bolton tooth size ratio and its relation with arch widths, arch length and arch perimeter: a cone beam computed tomography (CBCT) study. *Acta Odontologica Scandinavica* 72, 1047–1053.
- Alam, M.K., Shahid, F., Purmal, K., Ahmad, B., Khamis, M.F., 2014b. Tooth size and dental arch dimension measurement through cone beam computed tomography: effect of age and gender. *Res. J. Recent Sci.* ISSN 2277, 2502.
- Alam, M.K., Shahid, F., Purmal, K., Khamis, M.F., 2015c. Cone-beam computed tomography evaluation of Pont's index predictability for Malay population in orthodontics. *J. Nat. Sci., Biol., Med.* 6, S113.
- Asiry, M., Hashim, H., 2012. Tooth size ratios in Saudi subjects with Class II, Division 1 malocclusion. *J. Int. Oral Health* 4, 29.
- Bishara, S.E., Jakobsen, J.R., Abdallah, E.M., Garcia, A.F., 1989. Comparisons of mesiodistal and buccolingual crown dimensions of the permanent teeth in three populations from Egypt, Mexico, and the United States. *Am. J. Orthod. Dentofacial Orthopedics* 96, 416–422.
- Haque, F., Alam, M.K., 2017. Tooth size dimension norms and sexual disparities for various populations: an overview. *Int. Med. J.* 24, 272–274.
- Hasan, M.N., Hassan, G.S., Rafique, T., Alam, M.K., 2015. Anterior tooth discrepancy in different bangladeshi malocclusion group at BSMMU. *J. Bangladesh College of Physicians Surg.* 33, 191.
- Jamayet, N.B., Viwattanatipa, N., Amornvit, P., Pornprasertsuk, S., Chindasombatjaroen, J., Alam, M.K., 2014. Comparison of crown width/length ratio of six maxillary anterior teeth between different facial groups in Bangladeshi population. *Int. Med. J.* 21, 49–54.
- Kau, C.H., Littlefield, J., Rainy, N., Nguyen, J.T., Creed, B., 2010. Evaluation of CBCT digital models and traditional models using the Little's Index. *Angle Orthod.* 80, 435–439.
- Khurshed, M.A., Shahid, F., Nowrin, S.A., 2014. Digital Impression Model (DIM) a new, quick, simple, reliable and cost effective procedure. *Bangladesh J. Med. Sci.* 13, 231–232.
- Massoud, M.M.H., Alam, M.K., Ab Rahman, N., Kida, A., Mizushima, H., Osuga, N., 2016. Validity and reliability of arch size measurements using laser scanned 3D model. *J. Hard Tissue Biol.* 25, 335–340.
- Noor, M.I.M., Tajuddin, M.F., Alam, M.K., Basri, R., Purmal, K., Rahman, S.A., 2014. Variation in tooth size and arch dimension in Malaysian Malay subject with torus palatinus. *Int. Med. J.* 21, 193–195.
- Purmal, K., Alam, M.K., Cheong, N.W., 2013. Pont's index is not exact science: a reappraisal. *Int Med J* 20, 204–207.
- Rahman, M.A., Begum, N., Farzana, F., Alam, M.K., 2014. Analysis of Tooth Size Discrepancy (Bolton Ratio) among Orthodontic Patients at Combined Military Hospital (CMH), Dhaka. *Int. Med. J.* 21, 38–40.
- Sajib, N.H., Alam, M.K., 2017. Validity of Pont's analysis in a sample of Bangladeshi orthodontics patients. *J. Oral Res.* 6, 36–38.
- Shahid, F., Alam, M.K., Khamis, M.F., 2016. New prediction equations for the estimation of maxillary mandibular canine and premolar widths from mandibular incisors and mandibular first permanent molar widths: A digital model study. *Korean J. Orthod.* 46, 171–179.
- Shahid, F., Alam, M.K., Khamis, M.F., 2017. A new formula to predict mesiodistal width of maxillary canines: a digital model study. *Orthodontic Waves* 76, 18–25.
- Shahid, F., Alam, M.K., Khamis, M.F., Honda, Y., Sugita, Y., Maeda, H., 2015. Geomorphometrics of tooth size and arch dimension analysis by conventional digital caliper and digital stereomicroscope to establish standard norms for the Pakistani population. *J. Hard Tissue Biol.* 24, 155–168.
- Sithiphan, P., Viwattanatipa, N., Amornvit, P., Shrestha, B., Srithavaj, M.T., Alam, M.K., 2015. Comparison of maxillary anterior teeth crown ratio (width/length) between gender in laotian population. *Int. Med. J.* 22, 199–205.
- Stirrup, D., 1993. Guidance on presentation of cephalometry-based research studies. A personal perspective. *Br. J. Orthod.* 20, 359–365.

- Tarazona, B., Llamas, J., Cibrian, R., Gandía, J., Paredes, V., 2011. A comparison between dental measurements taken from CBCT models and those taken from a digital method. *European J. Orthod.* 35, 1–6.
- Vandenbroucke, J.P., Von Elm, E., Altman, D.G., Gøtzsche, P.C., Mulrow, C.D., Pocock, S.J., Poole, C., Schlesselman, J.J., Egger, M., Initiative, S., 2007. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS Med.* 4, e297.