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Dental arch form in a sample of Iraqi adults with sickle cell anemia using 3D scanning technique: A cross-sectional study

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Abstract

OBJECTIVE: Sickle cell anemia (SCA) is a hematological condition that involves the synthesis of sickle-shaped, hemoglobin with a short lifespan. This study employed three-dimensional (3D) scanning to pinpoint the most common arch form in a sample of Iraqi adults with SCA.

MATERIALS AND METHODS: A cross-sectional study included maxillary and mandibular casts of 50 patients (25 male and 25 female) with SCA and 50 participants in a control group (25 male and 25 female). The facio-axial (FA) point was digitized on each tooth's labial or buccal surface using SolidWorks® 2020 software. The dimensions of the arch were calculated using two proportional measures and four linear measurements. The dental arch form was determined using 3M templates, and the arches were categorized as square, ovoid, or tapered to establish the most-common arch form. Chi-square was used to compare arch form distribution, and an independent *t*-test was used to calculate the difference between the control group and the SCA group.

RESULTS: The tapered arch was the predominant form in SCA males and females for the maxilla and the mandible. The molar vertical distance (upper and lower) was significantly higher in males in the SCA group than in males in the control group. There was no significant difference between females in the SCA group and females in the control group.

CONCLUSION: Most patients with SCA had tapered arches. Sagittal jaw dimensions in males with SCA were more affected by marrow hyperplasia. There was little if any to no effect on females with SCA.

Keywords:

Arch form, facio-axial point, Iraqi sample, sickle cell anemia, three-dimensional

Introduction

Sickle cell disease (SCD) refers to a collection of inherited disorders in which the predominant hemoglobin (Hb) variant known as HbS results from a point mutation that changes glutamic acid to valine at position 6 of the beta-globin chain.[1,2] There are subcategories that fall under the SCD umbrella, including sickle cell trait HbAS, sickle-beta-thalassemia, and sickle cell anemia (SCA). There are few symptoms associated with HbAS, which is caused by a heterozygous mutation. SCA is the most prevalent type and causes organ damage, pain, and hemolytic anemia, which is a lifelong condition that requires blood transfusions.[3]

As a result of hyperplasia and bone marrow expansion, some of the craniofacial alterations that can affect SCA patients are excessive midface growth, enlargement of the maxilla, vertical development, mandibular setback, and facial convex profile.[4]

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Because skeletal or occlusal anomalies are possible in SCD, their correction can increase a child's self-confidence; orthodontic procedures are elective for these patients.[5]

Orthodontists are particularly interested in the study of dental arches, and the proper selection of orthodontic wires may improve the effectiveness of tooth movement, resulting in straighter and more stable teeth and lowering the risk of recurring orthodontic issues after treatment.[6,7]

Numerous specialists have used biometric measurements such as angles, linear distances, and ratios to determine dental arch curvature.[8,9] However, this analysis has drawbacks when characterizing a 3D structure like the dental arch. Camporesi *et al*.[10] evaluated the common arch shape using 3D-generated facio-axial (FA) points, which are more suited for clinical application and connected to bracket points. FA points utilized landmarks on two-dimensional (2D) cast photocopies, which might not be accurate because FA point digitization was not present.[11] Because of its high precision, FA points were utilized in our work on 3D models for arch form analysis and classification.[12]

According to our literature review, no study has been done to measure the dimensions and shape of dental arches in SCA patients. Therefore, the aims of the study are as follows:

1. Identify the most typical arch form in male and female SCA patients.
2. Compare arch dimensions between SCA patients and the control group (both males and females).
3. Establish the normative values for dental arch dimensions as represented by dental arch measurements (width and length) in a sample of SCA patients of both genders.

The null hypothesis stated, "There is no significant difference between the SCA group and the control group in arch form and arch dimensions in both arches."

Materials and Method

The ethical committee of the College of Dentistry, University of Baghdad, approved this study (Ref. No. 592, April 2022).

In the Karbala governorate, a cross-sectional study was carried out from April 2022 to August 2022. The participants in this study consisted of 50 patients with SCA (25 male and 25 female). They were from the Karbala Teaching Hospital for Children and Ein-Altamr in Karbala. The control group consisted of 50 normal and healthy subjects (25 male and 25 female) from Karbala University and Karbala specialized center. The sample size was small compared to the total population in Karbala governorate. According to the medical records taken from the hospital, the total number of patients with SCD was 516 (with different ages and different types of SCD). Only 50 patients attained the criteria of the study. The participants were between 17 and 25 years in both groups (SCA and control). The selection criteria for the SCA group were:

- The participants were SCA patients; this was proven by a laboratory and a medical examination in addition to their medical history.
- They were Iraqi Arabic.
- They had completely permanent dentition, excluding the third molar.
- They possessed teeth with Class I (molar, canine, and incisor) relationship (overjet 2–4 mm).
- Normal vertical relationship (overbite 1–3 mm).
- Their teeth were devoid of localized components that jeopardize the integrity of dental arches, such as congenitally absent, retained deciduous, and extra teeth.
- They had normally shaped teeth, no heavy fillings, and no history of facial surgery, orthopedic, or orthodontic treatment.
- They had no history of poor oral habits like thumb sucking or mouth breathing.

The criteria used for the control group were the same as those used for the SCA group except for the following:

- The subjects were healthy and had no disease of genetic origin.

To ascertain the dimensions and form of the arch, Lee *et al.*'s[13] methodology was applied. Upper and lower dental stone (Durguix, Spain) casts for each participant were digitized using a dental scanner (DOF Inc., Edge, South Korea) according to the manufacturer's instructions [Figure 1a] and were stored in the Standard Triangle Language (STL) file format. 3D models were analyzed using a laptop (Intel Core i5, 250 + GBs SSD Drive, Windows 10, 64 bit) via a dedicated 3D planning software (SolidWorks® 2020), which enabled us to assess the dental arch measurements. The program allowed various movements of the digital cast, enabling users to see the precise locations of landmarks [Figure 1b].[14] The X-axis and Y-axis were set to the transverse and anteroposterior directions, respectively. The initial X-axis was changed so that it was parallel to the average inclinations of line A (the line between the first and second premolars' contralateral contact points) and line B (the line between the second premolars and the first molars' contralateral contact points) [Figure 2].

Determination of arch dimensions and form: The FA point was identified at the point where two lines joined: (I) a line midway between the gingival margin and the incisal edge, cusp tip, or line between the cusp tips in molar teeth; and (II) the facial axis of the clinical crown (FACC).[15] The FACC showed the line between the center of the buccocervical and incisal edge for the anterior teeth. For

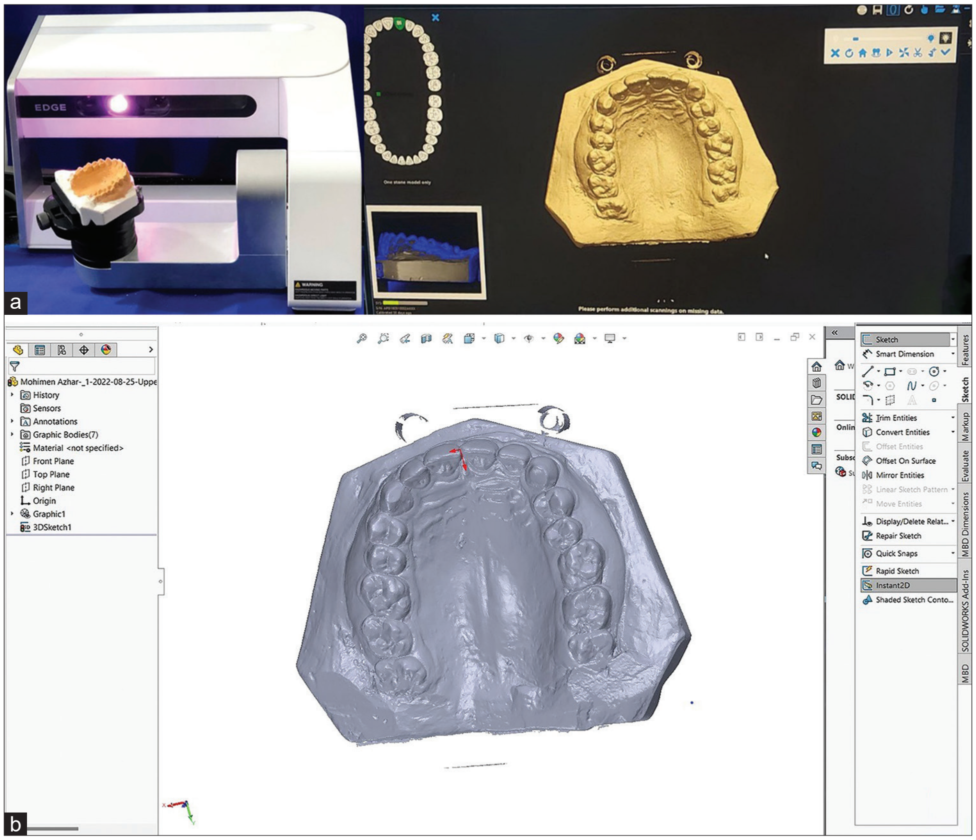

Figure 1: (a) dental cast scanning, (b) display of 3D model on the software

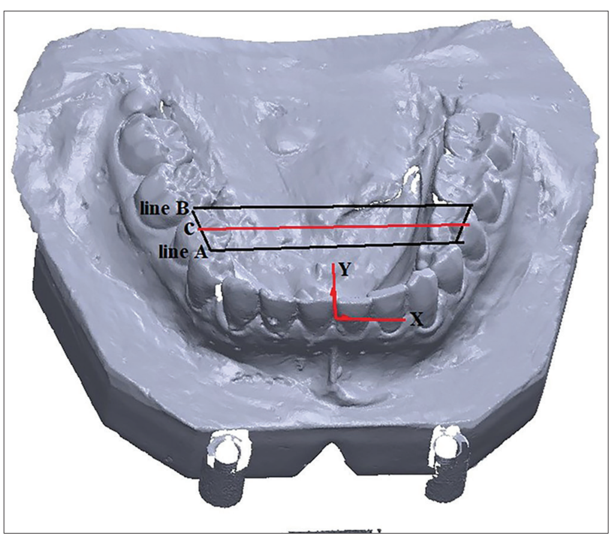

Figure 2: The x-axis was set so that it was parallel to the mean inclination line (C) of line (A) and line (B)

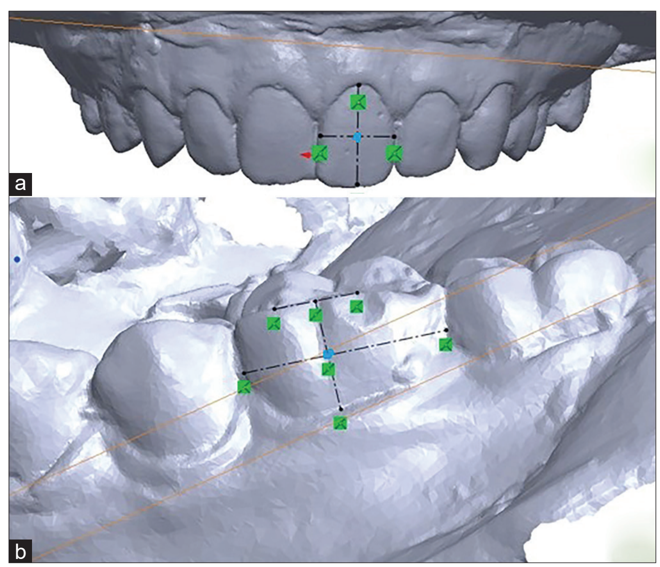

Figure 3: Blue dot facio-axial point, (a) anterior teeth, (b) molar teeth

the premolars, it was the line running from the buccal cusp to the center of the buccocervical region. For the molars, it was defined as the line connecting the center of the buccocervical region and the midpoint between the mesiobuccal and distobuccal cusps [Figure 3a and 3b].[16]

The evaluated linear measurements [Figure 4] and proportions were:

1. **Intercanine distance (ICD):** The distance between the canine FA points.
2. **Intermolar distance (IMD):** The distance between the first molar FA points.
3. **Canine vertical distance (CVD):** The shortest distance between a line connecting the canine FA points and the origin between the central incisors.

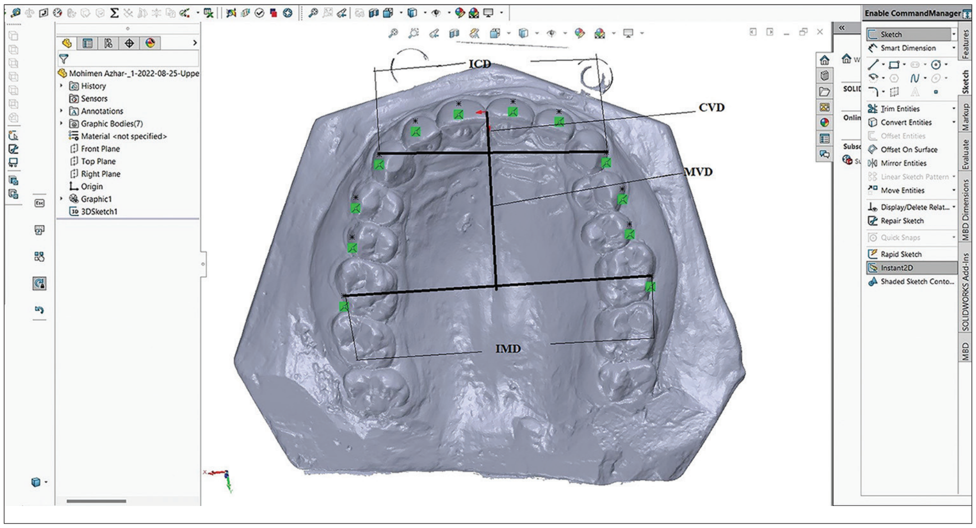

Figure 4: (ICD - Intercanine distance) distance between canine FA points; (IMD - Intermolar distance) distance between first molar FA points; (CVD - Canine vertical distance) distance from the line connecting canine FA points to the origin between central incisors; (MVD - Molar vertical distance) distance from the line connecting first molar FA points to the origin

4. **Molar vertical distance (MVD):** The shortest distance between a line connecting the first molar FA points and the origin between the central incisors.
5. **Canine Width/Depth ratio**: The ratio of the ICD and the canine depth.
6. **Molar Width/Depth ratio:** The ratio of the IMD and the molar depth.

After the software identified the clinical bracket point (FA), these points were connected, forming a curved line. Three alternative arch forms (tapered, ovoid, and square) were found using the 3M Unitek templates (OrthoForm; 3M Unitek, Monrovia, CA, USA),[17,18] after the picture of the digital model was produced at a 1:1 scale. This was done using an arch form that properly fit the eight FA points' first premolars from right to left [Figure 5].

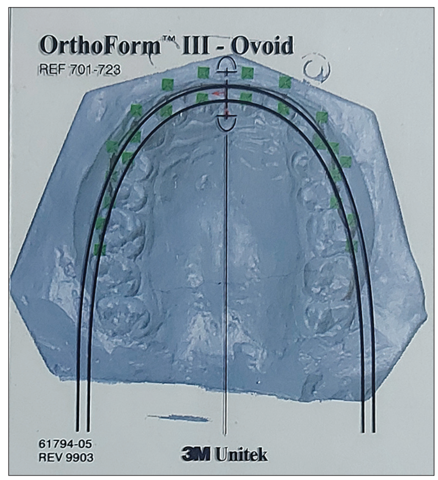

Figure 5: Superimposition of clear orthoform template on a printed digital model

Statistical analysis

The statistical analysis was performed using the Statistical Package for Social Sciences for Windows, version 26.0 (SPSS Inc., Chicago, IL, USA). Mean, standard deviation, maximum, minimum, frequency, and percentages were used to describe the data. Intra-examiner and inter-examiner calibration using intraclass correlation coefficient were used for 12 study models, and the weighted kappa test was used to determine the inter- and intra-examiner reliability of the arch shape selection. The following inferential statistics were used:

1. **Independent: sample t-tests for the comparisons between:**
- SCA group and control group (males and females) for all the dimensions of both dental arches.
- SCA group males and females for all dimensions of both arches.

2. **Chi-square test:**[19]

To compare arch shape distribution between the SCA group (males and females) and the control group.

The level of statistical significance was defined at ($P < 0.05$).

Results

Descriptive statistics and the comparison between males in the control group and males in the SCA group as shown in Table 1 indicated that there was a statistically significant difference, which was highly significant in UMVD and LMVD, where the P value was 0.00. As shown in Table 2, there was no significant difference between females in the control group and females in the SCA group. All the dimensions were higher in males than in females in the SCA group with no significant difference except for LIMD where the P value was

Table 1: Descriptive statistics and linear measurements comparison between SCA and control males (independent *t*-test)

Variables	Male group	Mean	SD	Mini	Maxi	Mean difference	*t*-test	*P*
UMVD	Control	29.81	2.23	25.49	33.33	-3.94	2.98	0.00**
	SCA	33.75	8.31	26.88	64.64			
UIMD	Control	56.53	2.32	51.59	60.43	0.22	-0.26	0.80
	SCA	56.31	3.52	48.53	63.44			
UICD	Control	36.56	1.82	32.89	40.08	-0.66	0.97	0.34
	SCA	37.22	2.86	32.37	43.54			
UCVD	Control	7.99	1.49	5.02	9.92	-2.52	2.03	0.05
	SCA	10.51	6.02	6.47	34.82			
LMVD	Control	24.63	1.88	20.38	27.52	-1.73	2.98	0.00**
	SCA	26.36	2.21	22.42	32.07			
LIMD	Control	52.17	2.26	47.84	55.63	0.46	-0.66	0.51
	SCA	51.71	2.70	44.14	57.31			
LICD	Control	27.96	3.93	10.26	32.25	-1.18	1.36	0.18
	SCA	29.14	1.93	25.77	32.89			
LCVD	Control	4.25	1.19	32.25	2.10	-0.6	1.77	0.08
	SCA	4.85	1.22	1.31	7.45			

Nonsignificant difference *P*>0.05; **highly significant *P*≤0.01; UMVD - upper molar vertical distance; UIMD - upper intermolar distance; UICD - upper intercanine distance; UCVD - upper canine vertical distance; LMVD - lower molar vertical distance; LIMD - lower intermolar distance; LICD - lower intercanine distance; LCVD - lower canine vertical distance; SCA - sickle cell anemia; SD - standard deviation; mini - minimum; maxi - maximum

Table 2: Descriptive statistics and linear measurements comparison between SCA and control female (independent *t*-test)

Variables	Female group	Mean	SD	Mini	Max	Mean difference	*t*-test	*P*
UMVD	Control	30.88	2.27	25.49	33.33	-0.83	0.86	0.39
	SCA	31.71	4.29	25.94	49.47			
UIMD	Control	54.90	2.58	50.37	60.73	0.33	-0.46	0.65
	SCA	54.57	2.40	50.26	59.16			
UICD	Control	36.36	1.90	33.12	39.49	-0.46	0.93	0.36
	SCA	36.82	1.63	34.44	40.39			
UCVD	Control	8.80	1.80	5.02	9.92	0.11	-0.23	0.82
	SCA	8.69	1.55	5.78	11.49			
LMVD	Control	25.57	2.77	21.09	31.18	-0.52	0.76	0.45
	SCA	26.09	2.03	22.42	32.07			
LIMD	Control	50.35	2.48	45.58	56.82	0.46	-0.65	0.52
	SCA	49.89	2.56	45.64	55.87			
LICD	Control	28.24	1.69	24.88	30.96	-0.35	0.79	0.43
	SCA	28.59	1.43	25.54	31.32			
LCVD	Control	5.09	1.82	2.48	8.38	0.7	-1.60	0.12
	SCA	4.39	1.18	1.15	6.73			
	SCA	18.47	2.38	14.96	22.70			

Nonsignificant difference *P*>0.05; UMVD - upper molar vertical distance; UIMD - upper intermolar distance; UICD - upper intercanine distance; UCVD - upper canine vertical distance; LMVD - lower molar vertical distance; LIMD - lower intermolar distance; LICD - lower intercanine distance; LCVD - lower canine vertical distance; SCA - sickle cell anemia; SD - standard deviation; mini - minimum; maxi - maximum

0.02, as shown in Table 3. When comparing the ratio between the control group and the SCA group (males and females), there was a significant difference in upper CW/CD (*P* = 0.02); it was highly significant in upper MW/MD; and lower in MW/MD, where the *P* value was 0.01 and 0.00 for males, respectively, with no significant difference in females, as shown in Table 4.

In the entire sample, the tapered arch was the most prevalent, followed by the ovoid and square arches in the upper and lower arches [Figure 6]. There was a significant difference in the upper arches between males in the SCA group and males in the control group, where the *P* value was 0.03 [Figure 7], with no significant difference in the lower arches [Figure 8]. There was no significant difference between the upper [Figure 7] and lower arches [Figure 8] between the females in the SCA group and the females in the control group.

Discussion

SCA is the most common disease in the world; it is caused by a mutation in the gene that makes hemoglobin A, which results in another mutant gene, hemoglobin

S (or HbS), which causes sickling of the blood cells.[20] Even though SCA can be diagnosed in the 16th week of pregnancy, symptoms typically do not present until the sixth month after delivery. The diagnostic technique consists of hemoglobin electrophoresis through neonatal screening by taking blood drops from the newborn's heel.[21] According to a literature review, there has been no previous study on arch form and dimensions in an SCA group, only studies concerning crowding and spacing in anterior segments of the upper and lower arches in SCA patients[22-24] and anteroposterior relationship.[25,26]

Numerous markers have been utilized in studies on dental arch form. The incisal edges and cusp tips were the most widely used landmarks.[27] Others used clinical bracket points as landmarks in their studies.[28] This method has the advantage of using labial tooth surfaces as points, reflecting the clinical bracket slot rather than incisal edges and buccal cusp tips. The points produced in this way simulate the effects of the arch wire form used in orthodontic therapy and represent the actual clinical orthodontic arch form.[29]

Data from this study showed that MVD and CVD mean values in maxillary and mandibular arches were higher in males in the SCA group than males in the control group [Table 1] and this could be due to the erythroid's compensatory enlargement, which causes some bone overgrowth in the maxillary anterior region.[30] This

Table 3: Descriptive statistics and linear measurements comparison between SCA male and female (independent *t*-test)

Variables	Male		Female		Mean difference	*t*-test	*P*
	Mean	SD	Mean	SD			
UIMD	56.31	3.52	54.57	2.40	1.74	2.04	0.05
UICD	37.22	2.86	36.82	1.63	0.4	0.61	0.54
LICD	29.14	1.93	28.59	1.43	0.55	1.14	0.26
LIMD	51.71	2.70	49.89	2.56	1.82	2.45	0.02*
UMVD	33.75	8.31	31.71	4.29	2.04	1.09	0.28
UCVD	10.51	6.02	8.69	1.55	1.82	1.47	0.15
LMVD	26.36	2.21	26.09	2.03	0.27	0.44	0.66
LCVD	4.85	1.22	4.39	1.18	0.46	1.35	0.18

Nonsignificant difference *P*>0.05,* Significant difference 0.05≥ *P*>0.01; UIMD - upper intermolar distance; UICD - upper intercanine distance; LICD - lower intercanine distance; LIMD - lower intermolar distance; UMVD - upper molar vertical distance; UCVD - upper canine vertical distance; LMVD - lower molar vertical distance; LCVD - lower canine vertical distance; SCA - sickle cell anemia; SD - standard deviation; mini - minimum; maxi - maximum

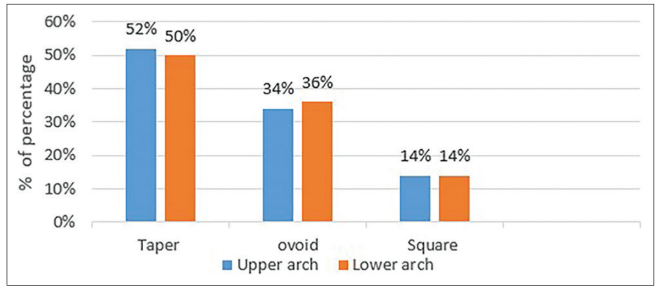

Figure 6: A graph showing arch form distribution in the total sample

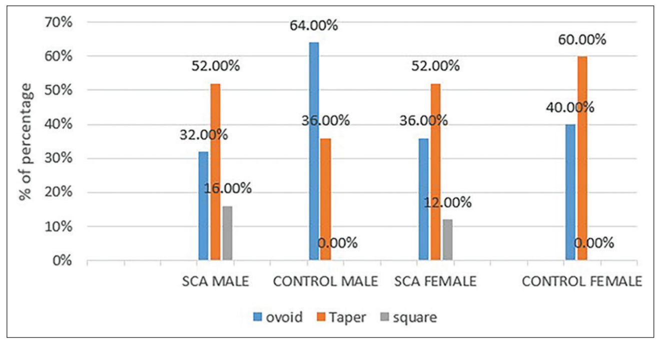

Figure 7: A graph showing upper arch form distribution in SCA and control (male and female); SCA-sickle cell anemia

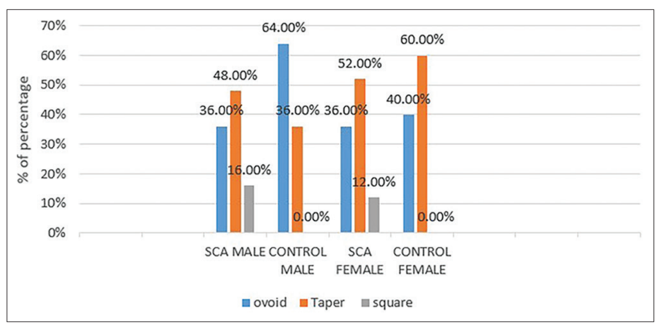

Figure 8: A graph showing lower arch form distribution in SCA and control (male and female); SCA-sickle cell anemia

Table 4: Descriptive statistics and ratio comparison between SCA and control (male and female) (independent *t*-test)

Gender	Ratio	SCA		Control				
		Mean	SD	Mean	SD	Mean difference	*t*-test	*P*
Male	Upper MW/MD	1.73	0.26	1.91	0.19	-0.18	-2.82	0.01**
	Upper CW/CD	4.00	1.16	4.76	1.07	-0.76	-2.39	0.02*
	Lower MW/MD	1.97	0.15	2.39	0.02	4.36	-3.10	0.00**
	Lower CW/CD	6.59	2.91	7.23	2.76	-0.64	-0.80	0.43
Female	Upper MW/MD	1.74	0.20	1.79	0.15	-0.05	1.79	0.15
	Upper CW/CD	4.67	1.19	4.30	0.94	0.37	4.30	0.94
	Lower MW/MD	1.92	0.16	1.99	0.23	-0.07	1.99	0.23
	Lower CW/CD	7.38	3.96	6.29	2.29	1.09	6.29	2.29

Nonsignificant difference *P*>0.05; * Significant difference 0.05≥ *P*>0.01; **highly significant *P*≤0.01; MW/MD - molar width/molar depth; CW/CD - canine width/canine depth, SCA - sickle cell anemia; SD - standard deviation; mini - minimum; maxi - maximum agrees with Licciardello *et al.*,[31] Onyeaso, and da Costa.[32]

According to Brown and Sebes,[33] the increased PAR angle (the angle between the hard palate and the superior alveolar ridge), rather than the lengthened hard palate, is what causes the maxillary protrusion.

The mean difference in measurements that are higher in the maxilla than in the mandible is because the maxilla contains more bone marrow spaces. Therefore, marrow hyperplasia occurs in the maxilla rather than in the mandible. It may be connected to the mandible's thick cortical plates, which appear to impede the expansion.[34] No significant difference in the upper and lower ICD and the IMD between males in the control group and males in the SCA group despite the mean value for ICD in both arches was higher in the SCA patients than in the control group.

In the female group, there was no significant difference in linear arch dimensions [Table 2] between females in the SCA group and females in the control group. The mean value of the upper and lower MVD was higher in females in the SCA group than females in the control group but this difference was not significant statistically.

The results in this study disagree with the finding of Bandeen,[35] who discovered that SCD patients of all ages had smaller craniofacial measurements.

According to some researchers, SCA is a disease whose clinical manifestations are influenced by a variety of genetics and environmental factors, including dietary and socioeconomic factors.[36] Furthermore, with advancements in SCD treatment, patients today differ fundamentally from those in the past.[37]

In a comparison between males and females with SCA, the mean value for arch dimensions (UIMD, UICD, LICD, LIMD, UMVD, UCVD, LMVD, and LCVD) was higher in males than in females. There was a statistically significant difference in UIMD as in Table 3 and this might be explained by females' smaller alveolar processes and bony ridges and by average female muscular weakness had a significant impact on facial breadth measurements, as well as the width and height of the dental arch. Males also have a longer growing period than females.[38]

It is important to note that the impact of thalassemia on bones relies on several variables, such as the degree of anemia, the age of the patient, the period of time they have suffered clinical symptoms, as well as the timing of therapeutic blood transfusions and splenectomy.[34] These factors may affect the result of the linear measurement of the arch size dimensions. This also could be applied to an SCA patient because both of them have hemolytic anemia.

In the male group, the maxillary and mandibular molar W/D ratio was significantly reduced in the SCA group than control as the difference was highly significant and this was due to higher molar depth and smaller width for both arches in SCA males. This means that those patients have narrower and longer arches than control due to the effect of expansion as shown in Table 4. There was a mean difference in upper canine depth of more than 2 mm between the SCA group and the control group and a significant reduction in the upper canine W/D ratio due to the higher upper canine depth. When choosing an arch wire for orthodontic treatment, a difference of this size may be important. Therefore, it is important to be careful when planning treatments to avoid overly generalizing cases.[39] In the mandible, the canine W/D ratio in males in the SCA group was smaller than males in the control group but it was not significant like that of the maxillary arch. This may be because of the effect of bone marrow hyperplasia, which was higher in the maxilla.

The molar W/D ratio in the maxilla and mandible of the females was smaller in females in the SCA group because the MVD was higher in females in the SCA group, while the canine W/D ratio was smaller in females in the control group because the canine depth was higher in females in this group, but it was not significant.

In the whole sample, the tapered arch predominated, followed by the ovoid and square in the maxillary and mandibular arches [Figure 6]. Prevalence of tapered arch form due to increasing in the canine depth and molar depth, which increased as the arch form changed from square to ovoid to taper. There was a significant difference in upper arches between males in the SCA group and males in the control group as tapered arches were prevalent in the SCA group due to increased MVD and CVD while ovoid arches were prevalent in the control group [Figure 7]. We rejected the null hypothesis, as there was a significant difference in males with SCA. In females, there was no significant difference between the control group and the SCA group as the tapered arch was prevalent in both groups and this agrees with Ali and Yassir,[40] who found a higher percentage of tapered arches in normal Iraqi females [Figures 7 and 8].

Strengths and limitations of this study

From our knowledge of previous studies, we believe this work might be the first study in Iraq of SCA patients, as we found no previous study of these patients. In addition, arch form and the determination of dimensions were carried out using 3D methods with special 3D software and a dental scanner while previous Iraqi studies, which researched arch form determination, relied on 2D methods. This study also has limitations, such as a small sample size, because most of the patients do not obtain regular checkups in the hospital, especially when their health improves. It is also difficult to obtain impressions from these patients when they have crises. Another limitation of our study was COVID-19, which interfered with sample collection.

Conclusion

- Tapered arches were the most suitable for patients with SCA, followed by ovoid arches and square arches in both males and females.
- Sagittal jaw dimensions were most severely affected by bone marrow expansion in the male group and this was observed by increased MVD and CVD.
- Bone marrow expansion had little or no effect on the female group.
- In general, males with SCA had larger dental arch dimensions than females.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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