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Anterior mandibular alveolar bone measurements between diabetic and non-diabetic individuals using cone-beam computed tomography

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Abstract. – OBJECTIVE: An adequate alveolar facial bone thickness (FBT) and facial bone height (FBH) in the mandibular anterior region is essential for implant placement. However, the diabetic condition may affect FBT and FBH. The aim of the study is to compare the alveolar FBT and FBH in the anterior mandibular region of diabetic and non-diabetic individuals utilizing Cone Beam Computed Tomography (CBCT) images.

MATERIALS AND METHODS: This cross-sectional study was conducted in dental clinics of Riyadh Elm University, Riyadh, Saudi Arabia. A total of 46 CBCT images belonging to the diabetic (n=23) and non-diabetic (n=23) individuals were obtained from the radiographic image database of the hospital. The alveolar FBT and FBH in the anterior mandibular region were measured directly on CBCT images using Galileos 3D Digital Imaging System in Sagittal and cross-sectional view.

RESULTS: The comparison of mean FBT between non-diabetic and diabetic individuals in central incisors (0.96±0.25 *vs.* 0.79±0.24, *p*=0.025) and lateral incisors (1.00±0.23 *vs.* 0.78±0.17, *p*=0.001) showed a statistically significant difference. Similarly, the mean FBH between non-diabetic and diabetic individuals differed significantly in central (31.37.96±2.98 *vs.* 26.07±6.58, *p*=0.001) and lateral incisor (31.20±3.05 *vs.* 26.79±6.83, *p*=0.008) regions.

CONCLUSIONS: Based on our study, non-diabetic individuals showed higher alveolar FBT and FBH levels than diabetic individuals. Hence, diabetic condition affects the alveolar FBT and FBH around the central and lateral incisor regions.

Key Words:

Alveolar bone, CBCT, Anterior mandible, Diabetic, Non-diabetic, Facial bone height (FBH), Facial bone thickness (FBT).

Introduction

The study of bone thickness around maxillary and mandibular dentition has been gaining attention in implantology[1]. Although alveolar bone is a specialized part of the maxillary and mandibular bone that forms the primary support structure for teeth[2], the height of the alveolar bone is determined according to the distance between the cemento-enamel junction (CEJ) and the alveolar bone crest[3]. Alveolar bone thickness plays a vital role in the treatment planning of a successful implant because such measurement should be taken as the height, width, morphology, and density of alveolar bone surrounding the proposed implant site and determination of implant size and angle of placement[4].

A significant variation in alveolar bone is reported among healthy individuals, and reports indicate that diabetes potentiates the severity of periodontitis and accelerates bone resorption. For example, the percentage of sites with bone loss in poorly controlled type I diabetes mellitus (T1DM) individuals is 44% compared to 28% and 24% in well-controlled and non-diabetic subjects, respectively[5]. The relationship between diabetes and periodontitis is due to changes in the alveolar bone structure[6].

Conventional radiographic techniques, like periapical, bitewing, and panoramic radiographs, are most used to diagnose alveolar bone loss. However, these methods present limitations, such as image magnification, subjectivity in interpretation, 2-dimensional images of 3-dimensional structures, and reduced sensitivity in detecting changes at the levels of the facial and lingual bone crests and in detecting fenestration and alveolar bone dehiscence on the buccal and lingual side of alveolar bone[7]. The recent advent of CBCT in dentistry opens a new horizon for detailed preoperative implant site evaluation and sophisticated dental implant surgical guide[4]. The CBCT imaging technique enables the anatomic study of dental and maxillofacial

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bone structures in high-resolution cross-sectional images *in vivo*[1].

Alveolar bone process measurements are critical for planning implant placement in the anterior mandibular area. However, scant studies reported on the alveolar bone profile of diabetic and non-diabetic individuals utilizing the CBCT imaging technique. Hence, this study was undertaken to compare the FBT and FBH of alveolar bone in the mandibular anterior region between diabetic and non-diabetic individuals utilizing CBCT images. The null hypothesis would be no difference in the FBT and FBH of the alveolar bone in the anterior mandibular region of diabetic and non-diabetic individuals.

Materials and Methods

Study Design and Sample

The present study was a cross-sectional study based on the CBCT images of reported diabetic and non-diabetic individuals who received dental care at the Riyadh Elm University's hospital, Riyadh, Saudi Arabia.

Informed Consent

The CBCT images of adult patients who gave informed consent for dental treatments were obtained from the university radiographic database to measure the alveolar bone thickness and crestal bone height in the aesthetic zone of the mandibular anterior teeth.

Ethical Approval

This study was registered in the research and innovation center of Riyadh Elm University. The ethical clearance for the study was obtained from the Institutional Review Board of the Research Center (FUGRP/2020/195/288/308).

Sample Size Calculation

A sample of 46 CBCT images [(n=23, Diabetic) (n=23, non-diabetic)] of individuals was considered based on the effect size of (0.5), alfa error probability of (0.05), power (0.95) and allocation ratio N2/N1 (1). Sample size calculations were performed by using G*Power sample size calculator version 3.1.9.7.

Inclusion and Exclusion Criteria

The CBCT images of bilateral permanent mandibular anterior teeth of diabetic and non-diabetic individuals aged 18-60 years who previously received dental care in the college of dentistry were included. However, CBCT images with implants in the anterior teeth area and distorted or poor quality were excluded from the study.

CBCT Image Measurements

Two trained investigators analyzed CBCT images. Repeated measures' reliability between investigators was assessed to measure their degree of agreement. Intraclass correlation coefficients (ICCs) were calculated to evaluate outcome reproducibility and consistency between all repeated measures for alveolar bone thickness. Intra and inter-examiner reliability were good, ranging from 0.87 to 0.89.

Radiographic Assessments

The facial plate thickness of the alveolar bone at each mandibular anterior tooth was measured from a sagittal view of the tooth root using Galileos CBCT 3D Digital Imaging System. The sagittal section was made at the middle of each tooth by applying the cursor bisecting the tooth into equal halves. Reference points were used to measure alveolar bone thicknesses at three locations using a digital caliper: point A is determined from the facial plate at the level of the bone crest to the coronal root third, point B to the mid root surface, and point C to the apical third (Figure 1). All measurements were taken in millimeters (mm). Facial bone height was measured as the distance between the alveolar bone crest and the lowest point on the border of the mandible along the long axis of the root. It was carried out in the same sagittal view as the thickness measurements and with the same digital caliper. The integrated digital caliper is used to measure bone on CBCT images directly. All images were viewed on the same monitor and with identical lighting.

Statistical Analysis

Frequency distribution and percentages were determined for the categorical variables. In addition, descriptive statistics of mean, standard deviation, and minimum and maximum values for the FBT and FBH were computed. Normality assessment indicated the near-normal distribution of the data.

The mean FBT and FBH were compared between diabetic and non-diabetic individuals using an independent *t*-test. The statistical analysis was performed using IBM-SPSS version 25 (Armonk, NY, USA). A value of $p<0.05$ was considered significant for all statistical tests.

Figure 1. Measurements of the facial plate of bone thickness in an axial view from the facial aspect of the tooth root in the CBCT. Point **A,** Thickness measurement from the facial plate at the level of the bone crest to the coronal root third. Point **B**, Thickness measurement from the facial plate to the mid root surface. Point **C**, Thickness measurement from the facial plate to the apical root third. (FBH) Facial bone height was measured as the distance between the alveolar bone crest and the lowest point on the mandible's border along the root's long axis (Green line).

Results

Sample Characteristics

Forty-six CBCT images (diabetic=23 and non-diabetic=23) individuals were selected based on the inclusion and exclusion criteria. CBCT images belonging to 24 males and 22 females having a mean age of 44.04±13.22 years were evaluated in this study. A total of 276 mandibular teeth (#13=46, #12=46, #11=46, #21=46, #22=46, #23=46) of non-diabetic (n=138) and diabetic (n=138) teeth were examined for the alveolar bone thickness and height. The characteristics of the study sample are shown in Table I.

FBT

Table II shows teeth with various FBT percentages in studied mandibular anterior teeth. Concerning central incisors, nearly 96.7% exhibited FBT of < 1.5 mm, 3.3% demonstrated FBT between 1.5 mm and 2 mm, and none exhibited thicknesses of >2 mm. Concerning lateral incisors, 97.8% exhibited facial bone thicknesses of <1.5 mm, while 2.2% showed thicknesses of 1.5-2 mm. Finally, among the canines, 91.3% showed FBT of <1.5 mm, 6.5% exhibited thicknesses between 1.5 and 2 mm, and 2.2% showed a thickness of >2 mm.

The mean and standard deviation values of FBT surrounding mandibular anterior teeth

Table I. Characteristics of the study sample.

Status	Gender			Age			
	Male	Female	Total	Mean	SD	Minimum	Maximum
	n	n	n				
Non-diabetic	12	11	23	38.35	14.71	18.00	72.00
Diabetic	12	11	23	49.74	8.25	40.00	67.00
Total	24	22	46	44.04	13.12	18.00	72.00

at points A, B, and C are shown in Table III. At point A, the lowest and highest facial bone thickness of 0.79±0.35 mm and 0.87±0.3 mm was observed with right and left mandibular canine teeth. Similarly, mandibular canines showed the highest 0.62±0.41 mm at point B, and the right central incisor showed the lowest 0.51±0.27 mm FBT. While at point C, the right mandibular canine was 1.49±0.84 mm, and right central incisors at 1.15±0.53 mm had the highest and lowest FBT.

The comparison of mean facial bone thickness around central incisors of non-diabetic and diabetic individuals using an independent *t*-test showed a statistically significant difference (0.96±0.25 *vs.* 0.79±0.24, p=0.025). Similarly, the mean FBT around lateral incisors of non-diabetic individuals compared to the diabetic individuals demonstrated a statistically significant difference (1.00±0.23 *vs.* 0.78±0.17, p=0.001). However, no difference was observed with canines between non-diabetic and diabetic individuals (1.03±0.32 *vs.* 0.91±0.27, p=0.187), as shown in Table IV.

The comparison of FBT at point A between non-diabetic and diabetic individuals showed a statistically significant difference (0.93±0.22 *vs.* 0.74±0.23, p=0.007). Similarly, non-diabetic individuals demonstrated significantly higher FBT at point C than diabetic individuals (1.47±0.45 *vs.* 1.17±0.52, p=0.042). However, no such difference was observed at point B, as shown in Figure 2.

The comparison of FBT on the right and left sides of the jaws between non-diabetic and diabetic individuals is shown in Figure 3. Non-diabetic individuals, compared to the diabetic individuals, showed a significantly higher FBT on the right side of the teeth (1.00±0.28 *vs.* 0.79±0.18, p=0.006). On the contrary, FBT did not differ significantly between non-diabetic and diabetic individuals on the left side (0.99±0.22 *vs.* 0.86±0.24, p=0.057).

FBH

The mean, standard deviation, minimum and maximum values of the facial bone height surrounding the mandibular anterior teeth are shown in Table V. The highest mean facial bone height of 29.09±5.63 mm was observed with the mandibular right lateral incisor (Tooth #42), and lowest of 27.81±5.32 mm was found with left mandibular canine (Tooth #33).

hhthe diabetic individuals, showed a significantly higher facial bone height on the left (30.58±2.59 *vs.* 26.48±6.42, p=0.008) and right (30.67±3.01 *vs.* 26.36±6.56, p=0.007) sides.

Discussion

Dental implant placement is a common dental procedure performed following extraction. Sufficient thickness and height of the facial bone are required for acceptable results and long-term stability with implant treatment. However, the mandibular anterior region presents significant challenges since its changes are frequently noticeable to patients. Moreover, various local risk

Table II. Frequency and percentages of the facial plate thickness of alveolar bone.

Categories of facial bone thickness (mm)*	Central Incisor		Lateral Incisors		Canines	
	n	%	n	%	n	%
<1.5	89	96.7%	90	97.8%	84	91.3%
1.5-2	3	3.3%	2	2.2%	6	6.5%
>2	0	0.0%	0	0.0%	2	2.2%

<1.5: less than required thickness, 1.5-2: minimally required thickness and >2: preferable required thickness.

Table III. Mean and standard deviation values of facial bone thickness.

Tooth #		Point A Mean±SD (mm)	Point B Mean±SD (mm)	Point C Mean±SD
Central incisors	# 31	0.83±0.34	0.59±0.29	1.31±0.6
	# 41	0.85±0.32	0.51±0.27	1.15±0.53
Lateral incisors	# 32	0.82±0.39	0.54±0.26	1.33±0.61
	# 42	0.86±0.3	0.55±0.29	1.23±0.5
Canine	# 33	0.87±0.3	0.62±0.38	1.41±0.84
	# 43	0.79±0.35	0.62±0.41	1.49±0.84

factors and underlying medical conditions, such as diabetes, may impair the quality of implant outcomes[4].

Examining the FBT and FBH at each location where a tooth will be removed and replaced with an implant is essential for establishing the optimal treatment choice for the anterior mandibular region[4]. Hence, this study aimed at determining the thickness and height of the alveolar facial bone between non-diabetic and diabetic individuals concerning the mandibular anterior teeth using CBCT images.

In order to avoid immediate facial bone resorption following dental implant placement and to ensure proper soft tissue support, the facial bone wall should ideally be at least 1.5-2 mm thick. If this criterion is not met, an excessively thin facial bone may result in fenestration, dehiscence, and recession, further contributing to the unattractive appearance[8]. Additionally, buccal bone thickness and crestal labial soft tissue have a bidirectional relationship since bone thickness strongly influences the soft tissue profile preventing crestal bone loss. As a result, thick tissue biotypes are associated with higher crestal bone levels, less gingival recession, and more favorable aesthetic outcomes than thinner biotypes[9].

Previous research[10] found that 73.5% of incisors and 49% of canines had <1 mm FBT measured at point B in the mandibular alveolus. In contrast, this study reported a higher percentage of incisors and canines with bone thickness <1 mm. In this investigation, the apical third of the mandibular alveolar bone seemed to have the optimal thickness, as shown by the greater thickness at point C. A similar finding[11] was reported in the maxillary anterior region, wherein alveolar bone thickness was most significant in the apical region. This result is important because it allows slight deeper placement of implants, thereby providing additional stability[11].

The present study results indicate that the canines have the highest bone thickness (2.2%) while lateral incisors have the least bone thickness. This finding aligns with López-Jarana et al's[10] study in which mandibular canines demonstrated higher facial bone thickness among the anterior teeth. Similar results have been reported in the previous studies[12,13]. Contrarily, Sheerah et al[11] and Ghassemian[14] noted the least bone thickness in the maxillary canine region. These inconsistencies in findings across studies can be attributed to various factors, including sampling variability and population distributions. Therefore, it must be acknowledged that using different samples or datasets may result in both over-and underestimation of bone measurements[11].

Januario et al[15] determined the thickness of the buccal alveolar bone at 1, 3, and 5 mm apically from the alveolar crest and found that the thickness was always < 1 mm, and in 50% of the cases, it was less than 0.5 mm. This study

Table IV. Comparison of FBT between non-diabetic and diabetic individuals.

Bone/Area		Status	N	Mean	SD	SEM	p¶
Facial Bone Thickness	Central Incisors	Non-diabetic	23	0.96	0.25	0.052	**0.025***
		Diabetic	23	0.79	0.24	0.049	
	Lateral Incisors	Non-diabetic	23	1.00	0.23	0.048	**0.001***
		Diabetic	23	0.78	0.17	0.036	
	Canine	Non-diabetic	23	1.03	0.32	0.067	0.187
		Diabetic	23	0.91	0.27	0.056	

¶ independent *t*-test, SD=Standard Deviation, SEM=Standard Error of Mean.

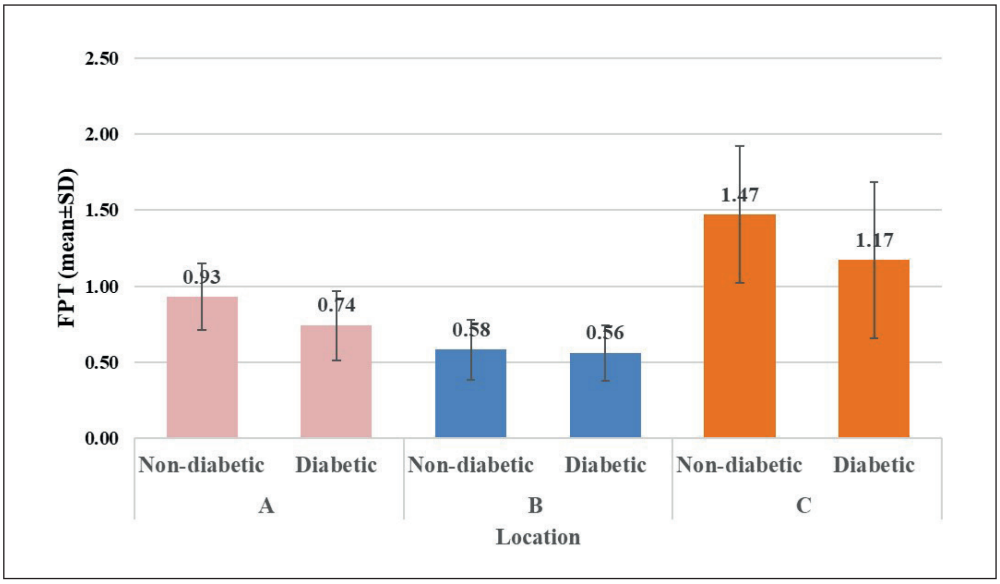

Figure 2. Comparison of Facial bone thickness at Points **A**, **B**, and **C**.

demonstrated that more than 90% of the examined central incisors, lateral incisors, and canines in the mandibular anterior region exhibited a bone thickness of <1 mm. However, this finding is somewhat higher than Sheerah et al[11] reported in anterior maxillary teeth. It could be attributed to the inclusion of the CBCTs of the diabetic patients who were likely to have more bone loss than non-diabetic patients. When mean FBT was compared across different studied teeth and measured points, the highest bone thickness was observed at point C, while point B demonstrated the lowest bone thickness.

When FBT was compared between non-diabetic and diabetic individuals across central incisors, lateral incisors, and canines, a lower bone thickness was found in diabetic individuals than in non-diabetics. Moreover, the difference between non-diabetics and diabetics was significant in central and lateral incisors.

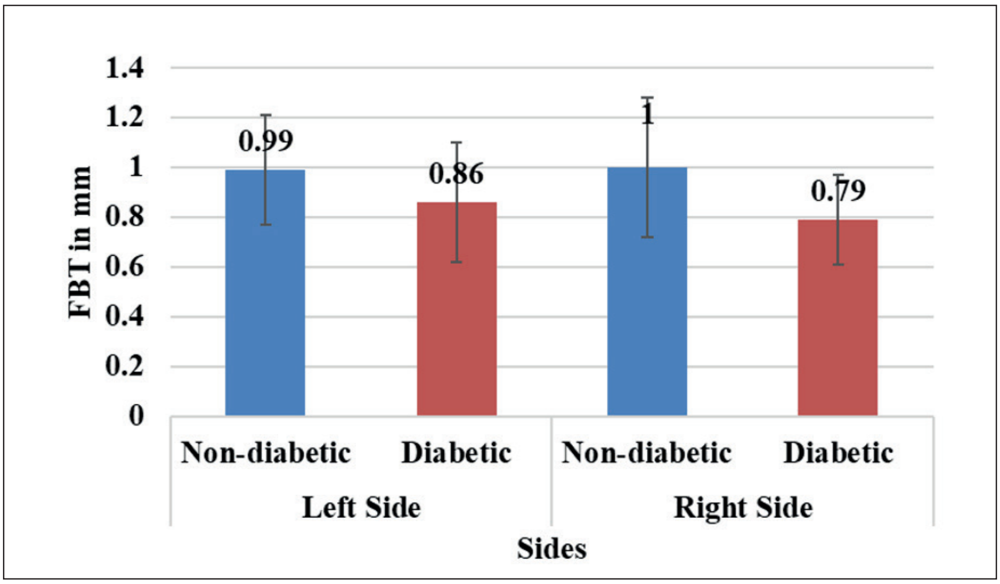

Figure 3. Facial Bone thickness between the non-diabetic and diabetic individuals based on side.

Table V. Descriptive statistics for facial bone height (in mm).

Tooth #	Mean	SD	Minimum	Maximum
Tooth # 31	28.88	5.40	14.04	37.29
Tooth # 41	28.56	6.54	14.35	39.05
Tooth # 32	28.90	5.84	13.16	37.94
Tooth # 42	29.09	5.63	14.20	39.48
Tooth # 33	27.81	5.32	12.96	35.21
Tooth # 43	27.90	5.42	12.14	36.77

Previous studies[16] have pointed out the remarkable decrease in the buccolingual and apico-coronal dimensions in the alveolar ridge after the tooth extraction. Study conducted by Sheerah et al[11] reported that the distance between the facial alveolar bone crest and the CEJ of the anterior teeth varies between 1.74 and 3.37 mm. However, in this study, the facial bone height of anterior mandibular teeth ranged between 27.81±5.32 mm and 29.09±5.63 mm. This considerable variation observed between the studies could be attributed to the reference points considered in our study. FBH was measured along the long root axis from the lower mandibular border to the alveolar crest in this study. Further comparison of FBH between the diabetic and non-diabetic individuals indicated a significantly lower FBH in central and lateral incisors of diabetic individuals on both sides.

The lowered FBT and FBH of the anterior mandibular area in diabetic patients could be attributed to the uncoupled process of bone remodeling that begins with bone resorption by osteoclasts and then the formation of new bone by osteoblasts in the resorption lacunae[17,18]. Diabetes affects osteoclasts and osteoblasts in the periodontium in various ways, including increased expression of inflammatory mediators and RANKL/osteoprotegerin ratios and increased levels of advanced glycation end products reactive oxygen species. Diabetes-enhanced TNF has been shown to prevent the downregulation of genes associated with host defense, apoptosis, cell signaling and activity, and coagulation/homeostasis/complement[19]. In addition, patients with periodontal disease and diabetes demonstrate significantly increased local inflammatory mediators like IL1b, TNF-a, and prostaglandin E2, resulting in more prolonged osteoclastic activity[20]. The increased amount of IL-17 and IL23 in type I diabetes mellitus periodontitis and overexpression of IL-1b and IL-6 in type II diabetes mellitus patients have been reported, resulting in osteoclastogenesis and a prolonged duration of inflammatory responses[21,22]. It has been reported that diabetes potentiates the severity of periodontitis and accelerates bone resorption. In poorly controlled type I diabetes mellitus individuals, the percentage of bone loss sites is 44% compared to 28% and 24% in well-controlled and non-diabetic subjects, respectively.

Comparison of FBT in this study at points A, B, and C between non-diabetic and diabetic individuals showed a statistically significant difference at points A and C. However, there was no such difference observed at point B. In addition, it also varied on the right side of the teeth suggesting heterogeneous bone thickness. Similarly, the mean FBH in diabetic individuals was lower than in non-diabetics. When the bone heights

Table VI. Comparison of FBH between non-diabetic and diabetic individuals.

Bone/Area		Status	N	Mean	SD	SEM	p¶
Facial Bone Height (in mm)	Central Incisors	Non-diabetic	23	31.37	2.98	0.619	**0.001***
		Diabetic	23	26.07	6.58	1.372	
	Lateral incisors	Non-diabetic	23	31.20	3.05	0.635	**0.008***
		Diabetic	23	26.79	6.83	1.425	
	Canine	Non-diabetic	23	29.32	2.80	0.583	0 .051
		Diabetic	23	26.40	6.30	1.314	

¶ independent *t*-test, SD=Standard Deviation, SEM=Standard Error of Mean.

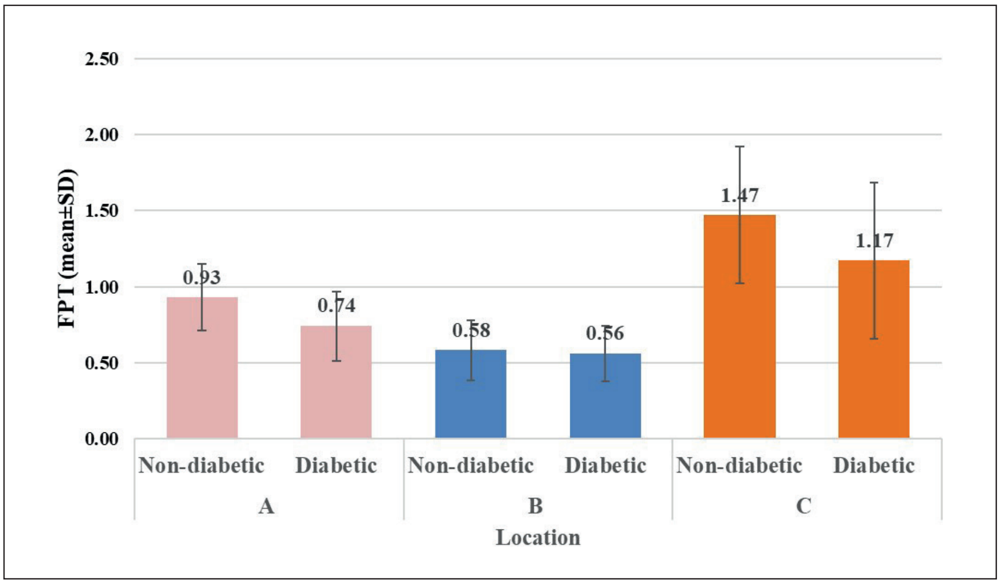

Figure 4. Facial Bone Height between the non-diabetic and diabetic individuals based on side.

were compared between non-diabetic and diabetic individuals, a statistically significant difference was observed concerning the central and lateral incisors, but no significant difference was found in the canine area.

Moreover, the FBH differed significantly on the right and left sides. Therefore, it can be argued that diabetes plays an essential role in mandibular alveolar bone thickness and height levels. Hence the present study's null hypothesis is rejected because the alveolar bone thickness and facial bone height differed significantly in non-diabetic and diabetic individuals. The current study findings may have important implications for future implant placement in the mandibular anterior region of diabetic patients.

Limitations

Limitations of the study include a retrospective analysis of available CBCT and medical records of patients from a single university hospital, where patients of diverse ethnic origins sought treatment and could have influenced the results. In addition, due to the variations in measurement reference points, it was challenging to compare the FBH of this study with other studies. Moreover, this study does not assess the relationship between age, gender, nutritional status, and other health conditions affecting bone metabolism. Finally, the small sample size considered in this study could be another limitation.

Conclusions

Within the limits of the study, there were substantial differences between diabetic and non-diabetic individuals with regards to anterior mandibular alveolar bone thickness and facial bone height. A remarkable reduction in mandibular alveolar bone thickness is linked to the diabetic status of the individuals. The mandibular alveolar bone thickness and facial bone height must be assessed using CBCT radiography before planning for implant placement in this area. In addition, careful consideration should be given to the bone augmentation procedure in this area, especially in diabetic patients. Further clinical studies are recommended to assess facial alveolar bone thickness and height after extraction and immediately following implant placement.

Conflict of Interest

The Authors of this study declare no conflict of interests.

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Authors' Contribution

Osamah Mohammed AlMugeiren: conception and design of the study, analysis, and interpretation of data drafting of the article, supervision, and final approval.

Rana Mohammed AlGhamdi: Acquisition of data, analysis, interpretation of data, drafting of the article.
Nada Hamad Bin Sebayel and Heba Abdullah AlJaruf: Acquisition of data, drafting the article.
Dhuha Ahmed AlKhamis and Latifah Sulaiman AlSuwayyid: Interpretation of data, revising of the article.
All authors approved the final version of the article.

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Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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