ASSESMENT OF ANTERIOR MAXILLARY LABIAL BONE THICKNESS USING CONE-BEAM COMPUTED TOMOGRAPHY: A RETROSPECTIVE ANALYSIS

Fawaghi Al-Ali
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ABSTRACT

Assessment of Anterior Maxillary Labial Bone Thickness Using Cone-Beam Computed Tomography: A Retrospective Analysis

Fawaghi Al-Ali

Primary supervisor: Maanas Shah

Co-supervisors: Momen A. Atieh, Haifa Hannawi

Background: The morphological variations observed in labial bone thickness (LBT) around maxillary anterior teeth can affect the three-dimensional placement of dental implants and its long-term outcomes; making it imperative for clinicians to thoroughly examine the LBT prior to tooth extraction.

Aim: To measure LBT in relation to the six anterior maxillary teeth at different levels along the long axis and the distance between cemento-enamel junction and bone crest (CEJ-BC) based on Cone-Beam Computed Tomography (CBCT) scans retrieved from patients' records and identify any association with patients' characteristics.

Materials and Methods: A total of 100 CBCT scans were evaluated by one calibrated examiner. The thickness of the labial bone was measured perpendicular to the long axis of the tooth at 1, 3 and 5 mm from the alveolar crest (LBT-1, LBT-3, LBT-5, respectively) and CEJ-BC using medical imaging viewer.

Results: CBCT scans of 58 females and 42 males with a mean age of 39.7 ± 9.5 years were included. A high variation of CEJ-BC was observed (range 0.55 – 3.90 mm). Statistically significant higher CEJ-BC values were associated with males and increased age (> 50 years). The overall means of LBT-1 were 0.76 ± 0.26, 0.79 ± 0.26 and 0.83 ± 0.37 mm; LBT-3: 0.92 ± 0.36, 1.05 ± 0.46 and 1.03 ± 0.48 mm; LBT-5: 1.17 ± 0.52, 0.80 ± 0.45 and 0.81 ± 0.40 mm for central-, lateral incisors and canines, respectively. The LBT was less than 1 mm in 74.2%

of all maxillary anterior teeth with central incisor being the thinnest site (85%). No significant association between LBT and patient characteristics was observed.

Conclusion: The CEJ-BC distance is greater in males and increases with age, particularly in those older than 50 years. The LBT in the six maxillary anterior teeth is predominantly thin (< 1 mm) and has no correlation to age or gender. An increased LBT was observed at 3 mm level when compared with LBT-1 and LBT-5. Such variability should be taken into consideration when planning for immediate implant placement.

DEDICATION

First and foremost, I want to express my gratitude to almighty Allah for his countless blessings and for fulfilling my ambition.

I owe a special debt of appreciation to my devoted parents and grandmother, Abdelaziz, Hawa and Zainab, who have always loved me unconditionally and pushed me to strive hard for the goals I have set for myself. This dissertation is dedicated to the memory of my late grandmother (Fatima) whom always showered us with warmth, love and affection, may she rest in peace. I am grateful for the support of my beloved sisters (Mzoon and Hana) and thankful for the support of my in-laws. Finally, I would like to thank a very special person, my dear husband, Abdullah, who has been a continuous source of support and encouragement throughout graduate school and life's hardships and has pushed me with devotion to fulfill my work with genuine self-confidence. I am lucky and thankful to have you in my life.

DECLARATION

I declare that all the content of this thesis is my own work. There is no conflict of interest with any other entity or organization. The study was non-funded.

Postgraduate students in Hamdan Bin Mohammed College of Dental Medicine receives Master research dissertation fund which might be used to cover any publication fees (if required) and presentation in international conference.

Name: Fawaghi Al-Ali

Signature:

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1. INTRODUCTION

Over the past five decades, replacement of missing teeth with dental implants has become a treatment of choice with long-term survival and predictability (Albrektsson et al., 1986; Buser et al., 2012; Roccuzzo et al., 2014). The presence of adequate hard and soft tissue volume at the time of implant placement, however, is crucial for optimal outcomes in terms of function and aesthetics (Adler et al., 2020). In this context, alveolar ridge resorption after tooth extraction is of great concern, particularly in the aesthetic zone (Mecall & Rosenfeld, 1991). It has been demonstrated that two thirds of alveolar ridge changes occur within the first three months after tooth extraction with 50% loss in ridge width after 12 months (Schropp et al., 2003). An average of 40% to 60% loss of the original alveolar bone height and width after tooth extraction has also been reported, with the greatest loss occurring within the first two years (Mecall & Rosenfeld, 1991). These alterations in soft and hard tissue volume after tooth extraction have been attributed to histological and morphological changes taking place during the socket healing process, resulting in tissue collapse and a ridge deficiency (Araujo et al., 2015). These changes are caused by bone remodeling due to resorption of the bundle bone lining the extraction socket and the disturbance of the periodontal ligament blood supply (Araujo et al., 2015).

It has been suggested that the presence of an inadequate buccal plate prior to tooth extraction could be a significant predictor to hard tissue defects (i.e., fenestrations or dehiscences) or soft tissue recessions (Ghassemian et al., 2012). These deficiencies become highly critical at the time of implant placement, particularly in the highly aesthetic anterior maxillary region (Mecall & Rosenfeld, 1991). The unpredictable dimensional changes and wide range of anatomical variations of the anterior maxilla could be very challenging for clinicians contemplating a prosthetically driven implant placement. For example, majority of the anterior maxillary teeth have thin labial bone thickness (LBT) of < 1 mm with almost half presenting LBT of < 0.5 mm (Januário et al., 2011). Such thin LBT could increase the likelihood of peri-implant tissue recession following an immediate implant placement (Chen & Buser, 2014). In a study by Tomasi and co-workers (2010), a multilevel, multivariate model was utilized to evaluate parameters that may influence bone changes during healing after immediate implant placement. One of the significant factors impacting the distance between the implant surface and the bony crest, according to the analysis, is the thickness of the bone crest prior to extraction. It is essential, therefore, to consider the morphological characteristics of the anterior maxilla prior to tooth extraction or implant placement for optimum diagnosis and treatment planning.

The two most commonly used methods to measure the thickness of buccal bone are calipers and cone-beam computed tomography (CBCT). Of particular interest, is the use of CBCT as a non-invasive diagnostic tool to assess the morphologic features of the alveolar bone in the anterior maxilla (Ghassemian et al., 2012; Januário et al., 2011; Timock et al., 2011). CBCT has shown to have less radiation exposure and time compared with conventional CT while presenting superior image quality, even at the submillimeter levels, making this diagnostic method, an indispensable tool for clinicians planning for implant therapy (Kumar et al., 2015; Timock et al., 2011).

Several studies have used CBCT to measure LBT of the maxillary anterior teeth (Braut et al., 2011; Ghassemian et al., 2012; Januario et al., 2011) and average values in different age groups were reported in a recent systematic review (Tsigarida et al., 2020). However, other well-designed studies evaluating LBT of the anterior maxilla in specific ethnic groups are still lacking (Tsigarida et al., 2020).

2. AIM

The main objective of this retrospective radiographic investigation was to report on the LBT of maxillary anterior teeth and the distance between cemento-enamel junction and coronal alveolar crest (CEJ-BC) in an Emirati population.

3. MATERIALS AND METHODS

3.1 Sample collection

This study was reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations (Vandenbroucke et al., 2007). Ethical approval was obtained from Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU-IRB-2020-010) and Abu Dhabi Health Authority Institutional Review Boards (MF2467-2020-5) to conduct this retrospective study. All participants consented to have CBCT scans taken for the purpose of diagnosing various oral pathological conditions (cysts, tumors, etc.), impacted dentition or implant treatment planning. The scans were obtained between January 2017 and December 2018 via Planmeca ProMax CBCT scanner (Planmeca Oy, Helsinki, Finland). All scans were acquired by the same technician and using the same settings (Field of view (FOV) = 16 × 11 cm; tube peak potential = 85 kvp; tube current= 7 mAs; time= 8.9s; voxel size= 0.15 mm). One hundred CBCT scans were randomly selected and exported in Digital Imaging and Communication in Medicine (DICOM) format. The sample size was determined based on an estimated prevalence and adopting a significance level of 5% with 80% power using Gpower software, version 3.1.9.4 (Faul et al., 2009).

3.2 Inclusion and exclusion criteria

The following inclusion criteria were considered:

- Aged 18 years and above.
- Presence of six pristine maxillary central-, lateral incisors and canines.
- Absence of peri-apical pathology.
- Absence of radiographic horizontal bone loss.
- Good contrast CBCT scans.

Exclusion criteria:

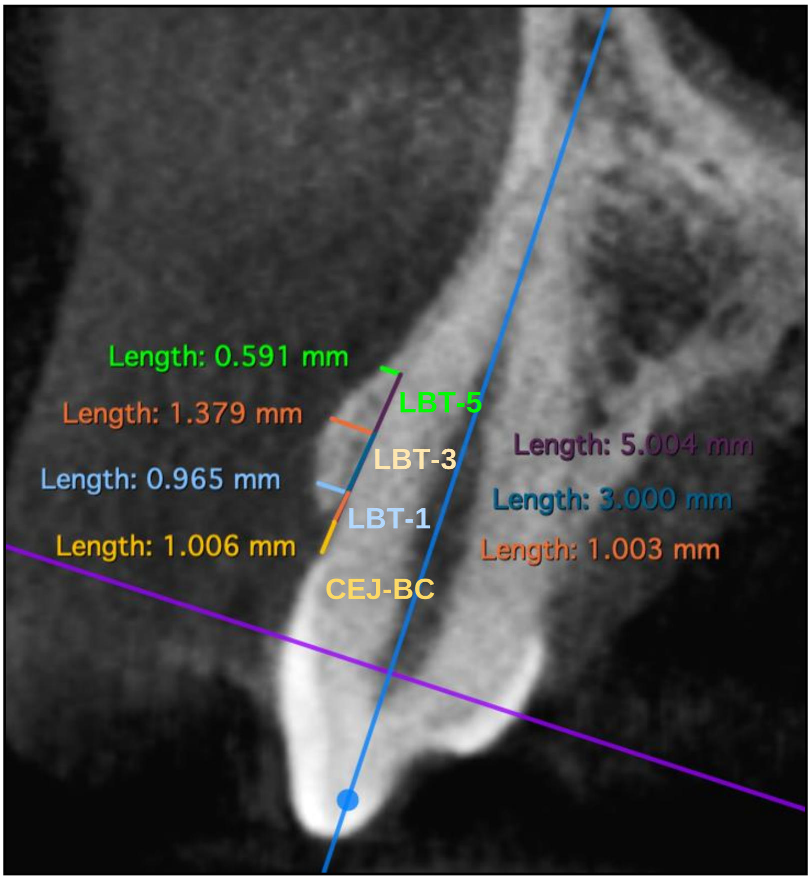
- Crowded teeth, improper teeth alignment or previous history of orthodontic treatment.
- Root canal treated teeth.
- Scattered or unclear CBCT scans.

- Generalized bone loss across all teeth that can be indicative of bone loss due to periodontal reasons.
- Any tooth/teeth associated with localized bony defects.
- Presence of implants in the maxillary anterior area.

3.3 Radiographic evaluation

All CBCT scans were assessed by one calibrated examiner (F.A.). To analyze reliability, intraclass coefficient was measured by examining 10 CBCT scans on two separate occasions, two weeks apart. Scans were assessed on an iMAC computer (27-inch screen size with Retina 5k display; resolution= 5120x2880; supports one billion colors; brightness= 500 nits; Apple, USA) using medical imaging viewer Horos© viewer (v3.3.6#, www.horosproject.org) in a sagittal slice. For each of the six maxillary anterior teeth, LBT measurements were taken perpendicular to the long axis of the tooth at 1-, 3- and 5 mm from the alveolar crest (LBT-1, LBT-3, LBT5 respectively). In addition, the distance of CEJ-BC was also measured, based on a similar protocol previously published in other studies (Januario et al., 2011; Zekry et al., 2014) (Figure 1).

Figure 1: Cone-beam computed tomography (CBCT) image of maxillary right canine region demonstrating the labial bone thickness (LBT) at 1, 3, and 5 mm from the bone crest and the distance from cemento-enamel junction to the bone crest (CEJ-BC)



3.4 Statistical Analysis

Statistical analysis was performed using Statistical Package for Social Sciences SPSS (version 24.0, IBM for Mac). Intraclass coefficient was used to measure the intraexaminer agreement. Descriptive statistics were reported as mean and standard deviation (SD) with a 95% confidence interval (CI). The mean differences in LBT were assessed for demographic characteristics (i.e., age and gender) using Independent *t*-test and ANOVA. Bonferroni *post hoc* test was used to measure the differences between different pairs. Chi-square test ($\chi 2$) was performed to measure the strength of association between the LBT of $\geq$ 1mm and demographic characteristics (i.e., age and gender). The level of significance was set at $P < 0.05$.

4. RESULTS

A total of 100 CBCT scans (58 females and 42 males) were included in the analysis with a mean patient age of 39.7 ± 9.5 years (range: 18-68). An intraclass coefficient of 0.94 across all measurements indicated an "almost perfect" agreement. For further analysis, the subjects were divided into three age groups, < 25 years, 25-50 years and > 50 years. The CEJ-BC distance demonstrated a wide range between 0.55 and 3.90 mm (Table 1).

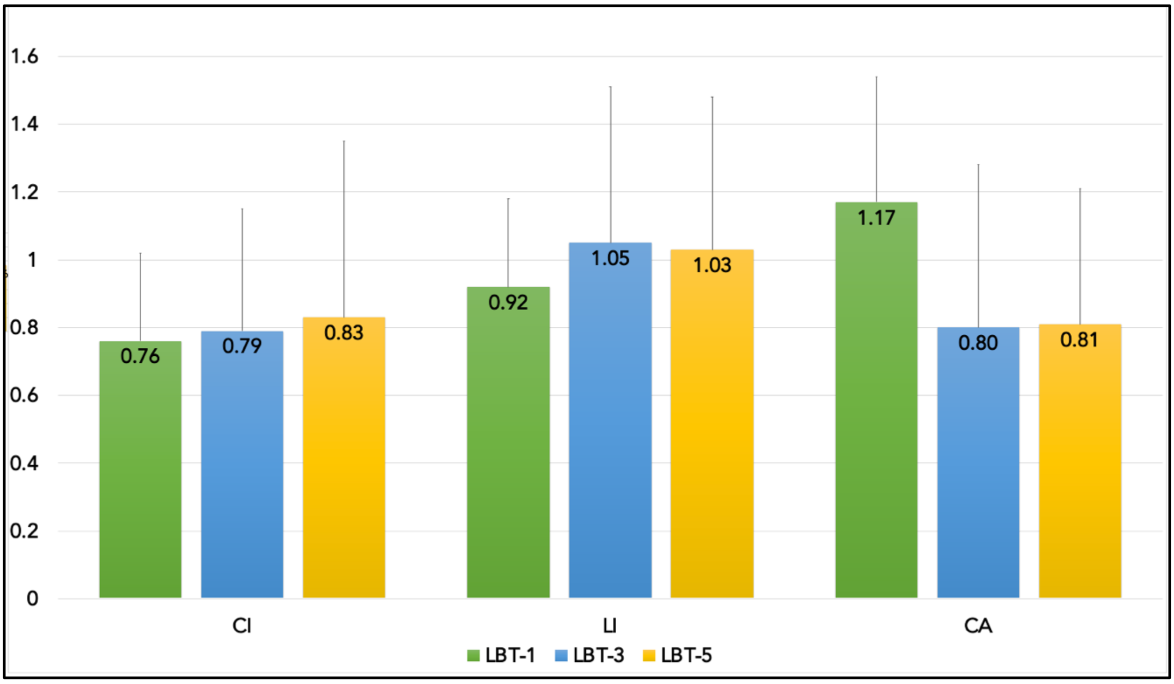
Table 1: Descriptive statistics of bone measurements

	Right side Mean ± SD	Left side Mean ± SD	Overall Mean ± SD (Range)
Maxillary canines			
CEJ-BC	1.95 ± 0.72	1.86 ± 0.74	1.91 ± 0.66 (0.56 – 3.44)
LBT-1	0.82 ± 0.40	0.84 ± 0.40	0.83 ± 0.37 (0.31 – 2.12)
LBT-3	0.99 ± 0.49	1.06 ± 0.53	1.03 ± 0.48 (0.35 – 2.66)
LBT-5	0.75 ± 0.40	0.86 ± 0.50	0.81 ± 0.40 (0.24 – 2.30)
Maxillary lateral incisors			
CEJ-BC	1.79 ± 0.68	1.91 ± 0.68	1.85 ± 0.61 (0.69 – 3.27)
LBT-1	0.77 ± 0.29	0.82 ± 0.29	0.79 ± 0.26 (0.34 – 1.62)
LBT-3	1.03 ± 0.48	1.07 ± 0.51	1.05 ± 0.46 (0.34 – 2.86)
LBT-5	0.80 ± 0.49	0.80 ± 0.49	0.80 ± 0.45 (0.26 – 2.27)
Maxillary central incisors			
CEJ-BC	1.72 ± 0.64	1.88 ± 0.69	1.80 ± 0.62 (0.55 – 3.90)
LBT-1	0.74 ± 0.27	0.77 ± 0.28	0.76 ± 0.26 (0.19 – 1.64)
LBT-3	0.94 ± 0.39	0.90 ± 0.39	0.92 ± 0.36 (0.25 – 2.51)
LBT-5	0.79 ± 0.38	0.77 ± 0.38	1.17 ± 0.52 (0.32 – 3.94)

SD: standard deviation; CEJ: cemento-enamel junction; BC: bone crest; LBT-1: labial bone thickness at 1 mm from coronal alveolar crest; LBT-3: labial bone thickness at 3 mm from coronal alveolar crest; LBT-5: labial bone thickness at 5 mm from coronal alveolar crest

The overall means and SDs (combined right and left sides) for CEJ-BC were 1.80 ± 0.62, 1.85 ± 0.61 and 1.91 ± 0.66 mm for central-, lateral incisors and canines, respectively. The LBT means and SDs (combined right and left sides) measured at LBT-1, were 0.76 ± 0.26, 0.79 ± 0.26 and 0.83 ± 0.37 mm, and at LBT-3 were 0.92 ± 0.36, 1.05 ± 0.46 and 1.03 ± 0.48 mm for central-, lateral incisors and canines, respectively. The corresponding numbers at LBT-5 were 1.17 ± 0.52, 0.80 ± 0.45 and 0.81 ± 0.40 mm for central-, lateral incisors and canines, respectively (Figure 2).

Figure 2: The overall mean standard deviation of LBT according to LBT-1, LBT-3 and LBT-5



CI: Central incisor; LI: Lateral incisor; CA: canine; LBT-1: labial bone thickness at 1 mm from coronal alveolar crest; LBT-3: labial bone thickness at 3 mm from coronal alveolar crest; LBT-5: labial bone thickness at 5 mm from coronal alveolar crest

Males had significantly higher CEJ-BC values at all maxillary anterior teeth than females (Table 2, Figure 3), while there were no statistically significant differences between males and females in LBT-1, LBT-3, and LBT-5 (Table 2, Figure 4).

Table 2: Summary of bone measurements by gender

	Females (n = 58) Mean ± SD	**Males (n = 42) Mean ± SD**	**Mean difference and 95% CI**	***P*-value***
Tooth #13				
CEJ-BC	1.81 ± 0.69	2.15 ± 0.71	0.34 (0.06, 0.62)	**0.02‡**
LBT-1	0.79 ± 0.39	0.86 ± 0.42	0.07 (-0.09, 0.23)	0.40
LBT-3	0.95 ± 0.50	1.06 ± 0.48	0.11 (-0.09, 0.31)	0.29
LBT-5	0.72 ± 0.41	0.80 ± 0.37	0.07 (-0.09, 0.23)	0.37
Tooth #12				
CEJ-BC	1.60 ± 0.61	2.07 ± 0.67	0.47 (0.21, 0.72)	**< 0.0001‡**
LBT-1	0.78 ± 0.30	0.75 ± 0.28	-0.02 (-0.14, 0.09)	0.68
LBT-3	1.02 ± 0.49	1.05 ± 0.46	0.03 (-0.17, 0.22)	0.79
LBT-5	0.79 ± 0.51	0.80 ± 0.47	0.01 (-0.19, 0.21)	0.90
Tooth #11				
CEJ-BC	1.60 ± 0.58	1.88 ± 0.69	0.28 (0.03, 0.53)	**0.03‡**
LBT-1	0.77 ± 0.27	0.70 ± 0.27	-0.07 (-0.18, 0.04)	0.21
LBT-3	0.94 ± 0.41	0.94 ± 0.38	0.004 (-0.16, 0.16)	0.96
LBT-5	0.74 ± 0.38	0.85 ± 0.37	0.11 (-0.04, 0.26)	0.16
Tooth #21				
CEJ-BC	1.73 ± 0.64	2.09 ± 0.72	0.36 (0.09, 0.63)	**0.009‡**
LBT-1	0.82 ± 0.28	0.71 ± 0.28	-0.10 (-0.22, 0.009)	0.07
LBT-3	0.93 ± 0.44	0.87 ± 0.31	-0.05 (-0.21, 0.10)	0.52
LBT-5	0.76 ± 0.41	0.78 ± 0.32	0.02 (-0.13, 0.17)	0.81
Tooth #22				
CEJ-BC	1.78 ± 0.63	2.09 ± 0.72	0.31 (0.05, 0.58)	**0.02‡**
LBT-1	0.82 ± 0.30	0.81 ± 0.27	-0.01 (-0.12, 0.11)	0.87
LBT-3	1.06 ± 0.54	1.08 ± 0.49	0.03 (-0.18, 0.23)	0.81
LBT-5	0.80 ± 0.56	0.78 ± 0.38	-0.02 (-0.21, 0.18)	0.86

Tooth #23				
CEJ-BC	1.72 ± 0.70	2.04 ± 0.76	0.32 (0.03, 0.61)	**0.03‡**
LBT-1	0.85 ± 0.38	0.82 ± 0.44	-0.03 (-0.20, 0.13)	0.69
LBT-3	1.07 ± 0.56	1.05 ± 0.49	-0.02 (-0.23, 0.19)	0.86
LBT-5	0.86 ± 0.55	0.88 ± 0.44	0.02 (-0.18, 0.22)	0.86

SD: standard deviation; CI: confidence interval; CEJ: cemento-enamel junction; BC: bone crest; LBT-1: labial bone thickness at 1 mm from coronal alveolar crest; LBT-3: labial bone thickness at 3 mm from coronal alveolar crest; LBT-5: labial bone thickness at 5 mm from coronal alveolar crest

*Independent *t*-test

‡Statistically significant ($P < 0.05$)

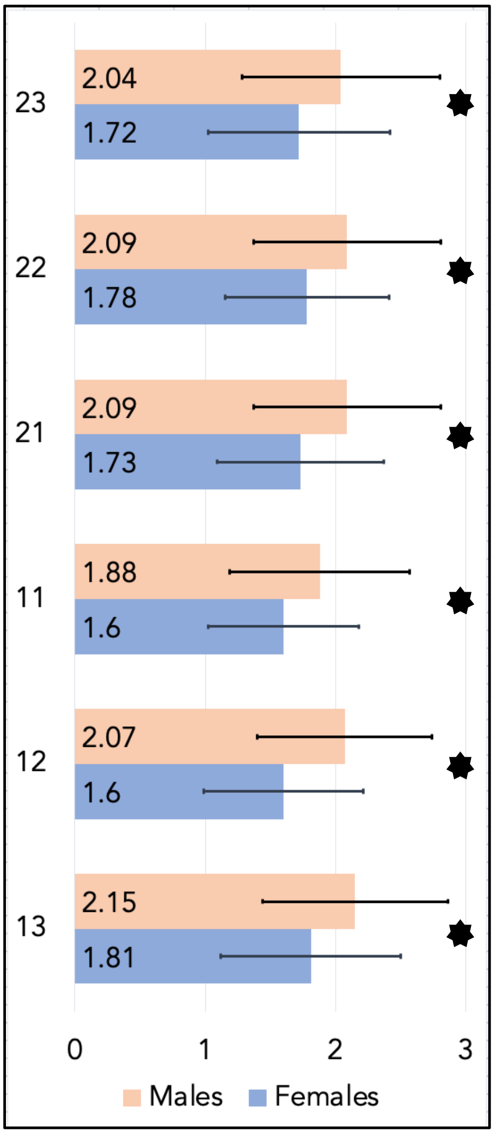
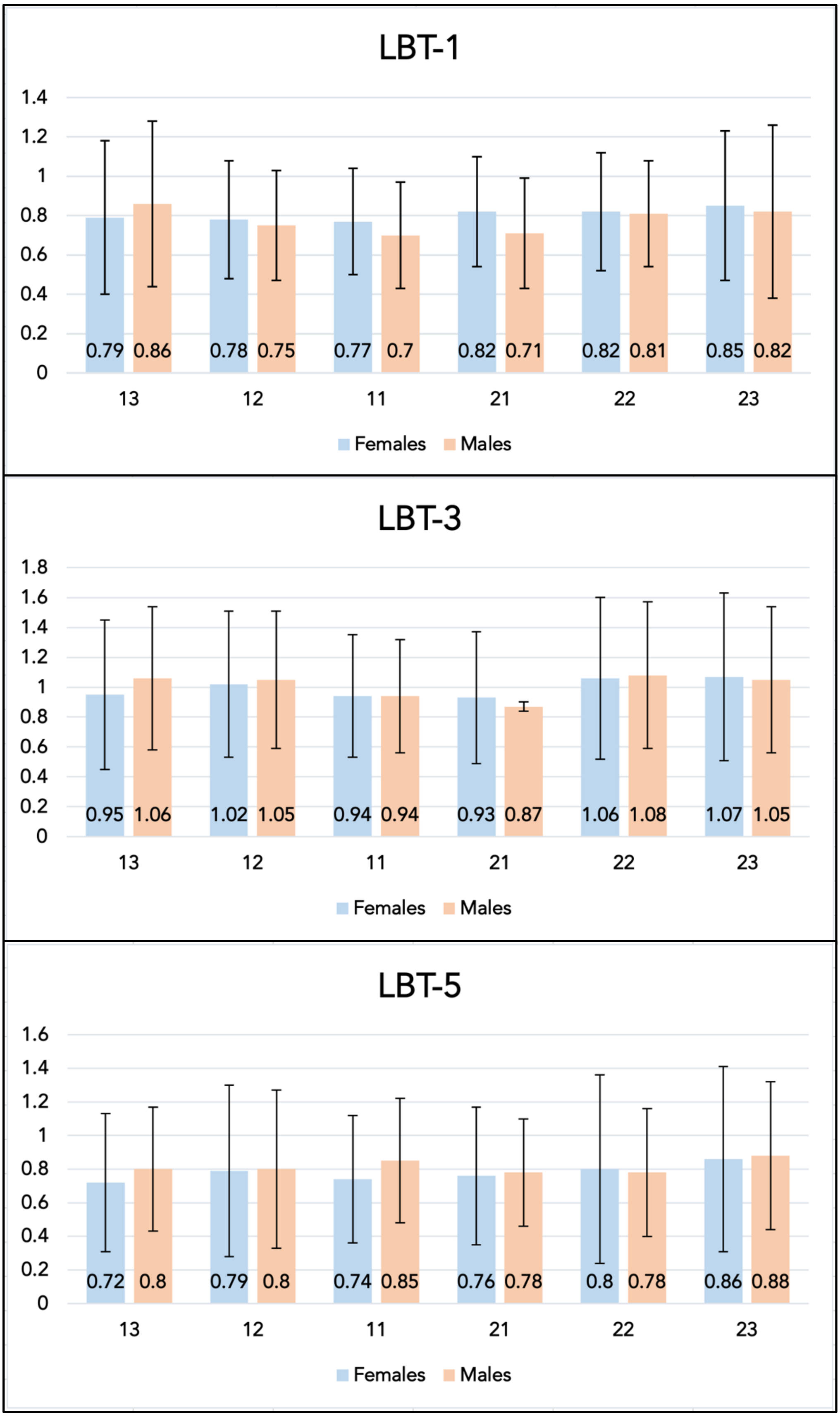


Figure 3: Distance from cemento-enamel junction to the bone crest (CEJ-BC) measurements (mean ± standard deviation) based on gender. The mean difference is statistically significant in all six teeth

Figure 4: LBT measurements based on gender according to LBT-1, LBT-3 and LBT-5 (mean ± standard deviation).



LBT-1: labial bone thickness at 1 mm from coronal alveolar crest; LBT-3: labial bone thickness at 3 mm from coronal alveolar crest; LBT-5: labial bone thickness at 5 mm from coronal alveolar crest

Bonferroni *post hoc* showed that patients older than 50 years of age had significantly larger CEJ-BC measurements for maxillary right and left canines and maxillary left central incisors compared to other age groups (Table 3). The overall means of CEJ-BC measurements in different age groups are displayed in Figure 5.

Table 3: Summary of bone measurements by age

	Age (<25 years); n = 4 Mean ± SD	**Age (25-50 years); n = 83 Mean ± SD**	**Age (>50 years); n = 13 Mean ± SD**	***F* (*df*)**	***P*-value†**
Tooth #13					
CEJ-BC	1.34 ± 0.67	1.92 ± 0.72	2.38 ± 0.51	4.03 (2, 97)	**0.02‡**
LBT-1	0.77 ± 0.24	0.86 ± 0.41	0.58 ± 0.31	2.93 (2, 97)	0.06
LBT-3	0.69 ± 0.27	1.03 ± 0.50	0.84 ± 0.50	1.65 (2, 97)	0.20
LBT-5	0.56 ± 0.26	0.77 ± 0.38	0.71 ± 0.50	0.64 (2, 97)	0.53
Tooth #12					
CEJ-BC	1.14 ± 0.28	1.82 ± 0.69	1.86 ± 0.59	2.02 (2, 97)	0.14
LBT-1	0.88 ± 0.21	0.78 ± 0.29	0.63 ± 0.27	2.09 (2, 97)	0.13
LBT-3	1.08 ± 0.45	1.04 ± 0.49	1.00 ± 0.42	0.06 (2, 97)	0.94
LBT-5	0.89 ± 0.86	0.77 ± 0.48	0.95 ± 0.47	0.85 (2, 97)	0.43
Tooth #11					
CEJ-BC	1.13 ± 0.35	1.70 ± 0.63	1.98 ± 0.68	2.92 (2, 97)	0.06
LBT-1	0.75 ± 0.24	0.75 ± 0.28	0.72 ± 0.25	0.07 (2, 97)	0.93
LBT-3	0.78 ± 0.32	0.95 ± 0.41	0.92 ± 0.34	0.36 (2, 97)	0.70
LBT-5	0.63 ± 0.26	0.80 ± 0.39	0.75 ± 0.35	0.43 (2, 97)	0.65
Tooth #21					
CEJ-BC	1.46 ± 0.39	1.81 ± 0.67	2.44 ± 0.62	6.00 (2, 97)	**0.003‡**
LBT-1	0.80 ± 0.27	0.77 ± 0.30	0.78 ± 0.20	0.02 (2, 97)	0.98
LBT-3	0.70 ± 0.86	0.90 ± 0.40	0.96 ± 0.35	0.73 (2, 97)	0.49
LBT-5	0.60 ± 0.13	0.77 ± 0.39	0.80 ± 0.31	0.47 (2, 97)	0.63
Tooth #22					
CEJ-BC	1.59 ± 0.50	1.87 ± 0.70	2.31 ± 0.47	2.92 (2, 97)	0.06
LBT-1	0.91 ± 0.20	0.83 ± 0.29	0.73 ± 0.24	0.88 (2, 97)	0.42
LBT-3	0.87 ± 0.43	1.09 ± 0.53	1.00 ± 0.45	0.44 (2, 97)	0.65
LBT-5	0.66 ± 0.52	0.80 ± 0.49	0.79 ± 0.48	0.15 (2, 97)	0.86
Tooth #23					
CEJ-BC	1.00 ± 0.41	1.82 ± 0.73	2.36 ± 0.59	6.53 (2, 97)	**0.02‡**

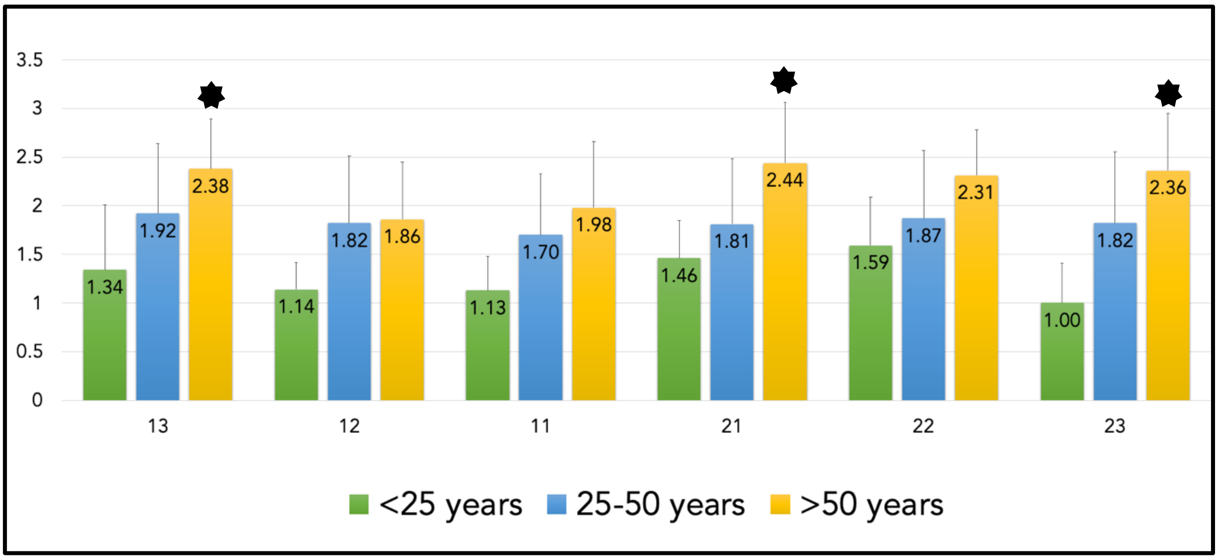
LBT-1	0.93 ± 0.31	0.87 ± 0.42	0.60 ± 0.21	2.73 (2, 97)	0.07
LBT-3	1.06 ± 0.48	1.10 ± 0.56	0.82 ± 0.17	1.60 (2, 97)	0.21
LBT-5	0.85 ± 0.34	0.89 ± 0.54	0.68 ± 0.24	1.03 (2, 97)	0.36

SD: standard deviation; df: degrees of freedom; CEJ: cemento-enamel junction; BC: bone crest; LBT-1: labial bone thickness at 1 mm from coronal alveolar crest; LBT-3: labial bone thickness at 3 mm from coronal alveolar crest; LBT-5: labial bone thickness at 5 mm from coronal alveolar crest

†ANOVA

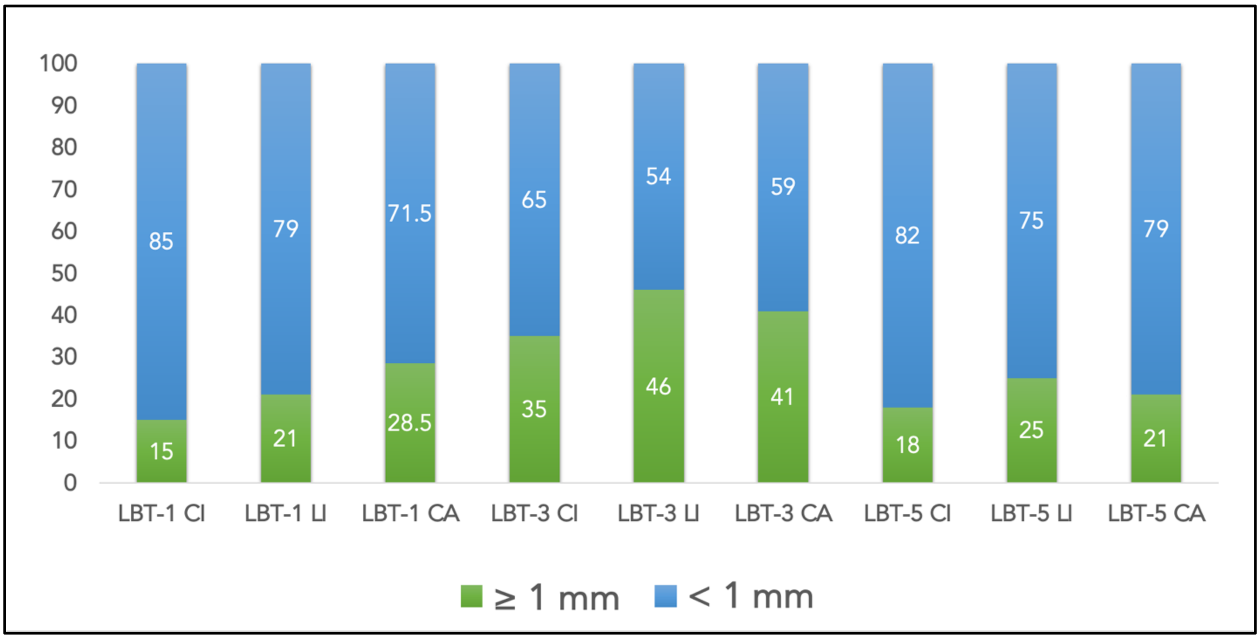
‡Statistically significant ($P < 0.05$)

Figure 5: The distance from cemento-enamel junction to the bone crest (CEJ-BC) according to different age groups in maxillary six anterior teeth (mean ± standard deviation)



Central incisors exhibited a higher prevalence of LBT-1 of < 1 mm (85%) compared to lateral incisors (79%) and canines (71.5%) (Figure 6).

Figure 6: Frequency distribution (%) of examined teeth according to LBT at LBT-1, LBT-3 and LBT-5



CI: Central incisor; LI: Lateral incisor; CA: canine; LBT-1: labial bone thickness at 1 mm from coronal alveolar crest; LBT-3: labial bone thickness at 3 mm from coronal alveolar crest; LBT-5: labial bone thickness at 5 mm from coronal alveolar crest

Likewise, LBT-5 showed similar prevalence with 82% of central incisors, 75% of lateral incisors and 79% of canines having LBT-5 of < 1 mm. On the other hand, LBT-3 of ≥ 1 mm were observed in 35%, 46% and 41% of the measured sites at central, lateral incisors and canines, respectively. The overall frequency distribution of LBT-1 showed predominantly thin LBT (74%) in all six maxillary anterior teeth (Figure 7). No significant association between LBT and gender or age was detected (Table 4, Figure 8).

Figure 7: The overall frequency distribution (%) of labial bone thickness at 1 mm from coronal alveolar crest (LBT-1) in all six maxillary anterior teeth.

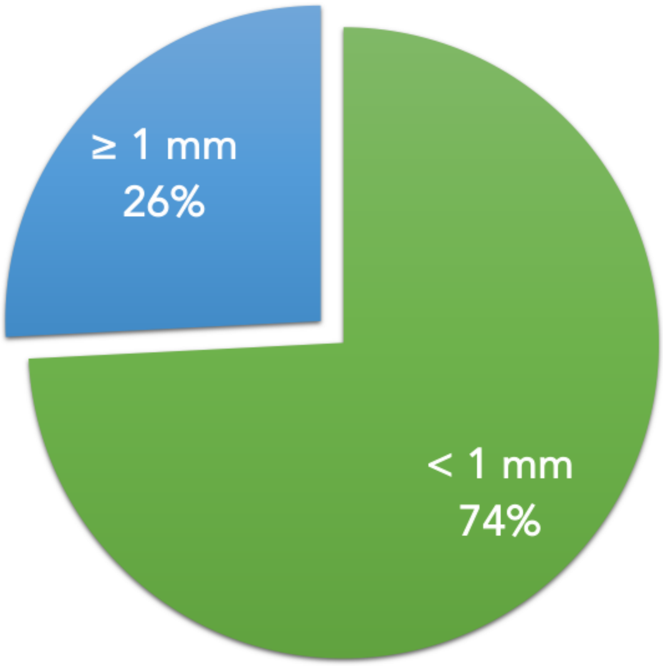


Table 4: Characteristics of patients with LBT-1 ≥ 1 mm

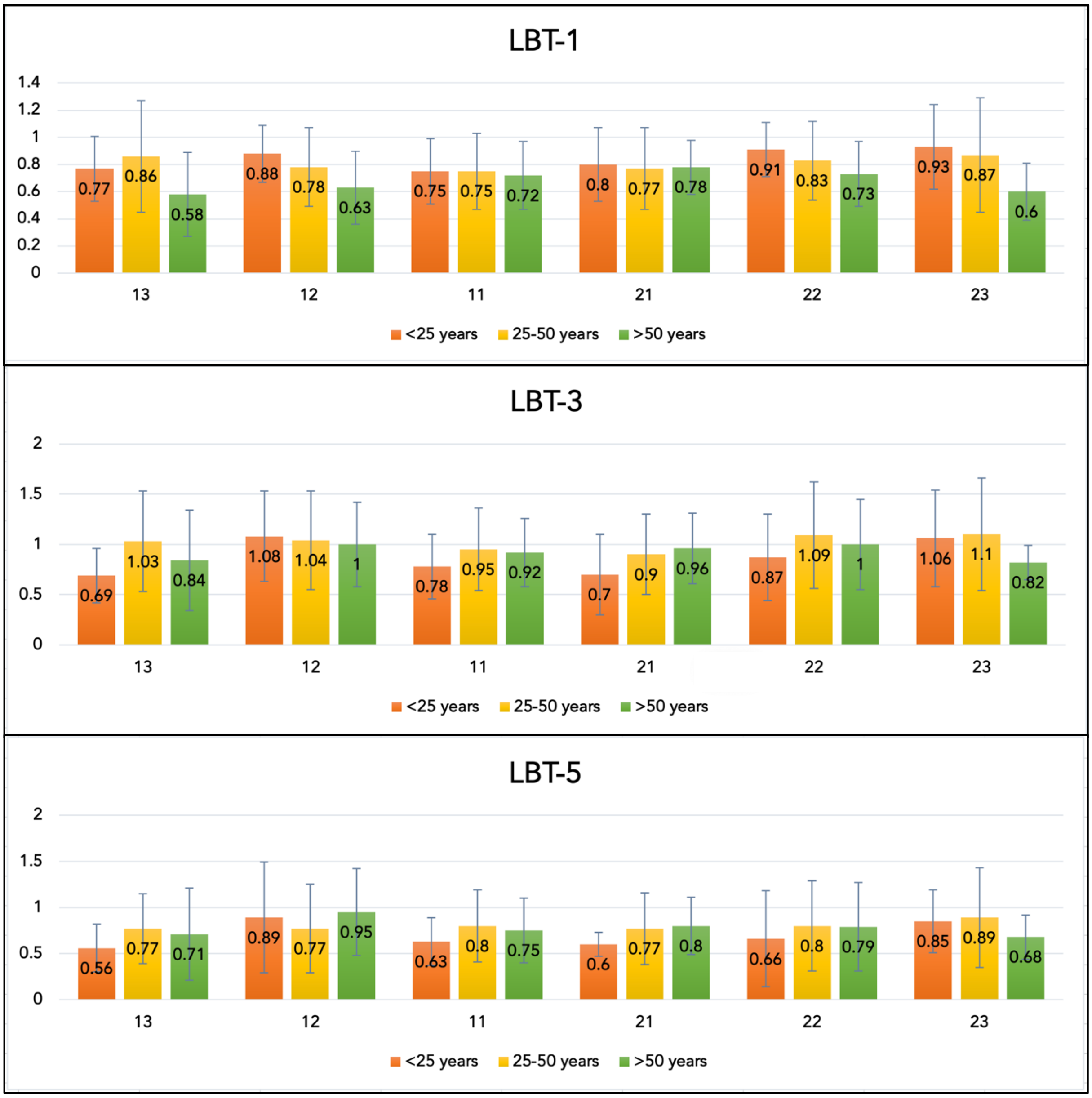
Tooth #13	**N (%) LBT-1 ≥ 1 mm**	**N (%) LBT-1 < 1 mm**	**LBT-1 < 1 mm Relative risk (95% CI)** *	***P*-value**†
Gender				
Female	17 (29.3)	41 (70.7)	1.01 (0.79, 1.30)	0.94
Male	12 (28.6)	30 (71.4)		
Age (years)				
<25	1 (25.0)	3 (75.0)	NA	0.49
25-50	26 (31.3)	57 (68.7)		
>50	2 (15.4)	11 (84.6)		
Tooth #12	**N (%) LBT-1 ≥ 1 mm**	**N (%) LBT-1 < 1 mm**	**LBT-1 < 1 mm Relative risk (95% CI)***	***P*-value**†
Gender				
Female	14 (24.1)	44 (75.9)	1.13 (0.93, 1.37)	0.22
Male	6 (14.3)	36 (85.7)		
Age (years)				
<25	2 (50.0)	2 (50.0)	NA	0.17
25-50	17 (20.5)	66 (79.5)		
>50	1 (7.7)	12 (92.3)		
Tooth #11	**N (%) LBT-1 ≥ 1 mm**	**N (%) LBT-1 < 1 mm**	**LBT-1 < 1 mm Relative risk (95% CI)***	***P*-value**†
Gender				
Female	11 (19.0)	47 (81.0)	1.09 (0.92, 1.29)	0.34
Male	5 (11.9)	37 (88.1)		
Age (years)				
<25	1 (25.0)	3 (75.0)	NA	0.88
25-50	13 (15.7)	70 (84.3)		
>50	2 (15.4)	11 (84.6)		
Tooth #21	**N (%) LBT-1 ≥ 1 mm**	**N (%) LBT-1 < 1 mm**	**LBT-1 < 1 mm Relative risk (95% CI)** *	***P*-value**†
Gender				
Female	7 (12.1)	51 (87.9)	0.95 (0.80, 1.12)	0.51
Male	7 (16.7)	35 (83.3)		
Age (years)				
<25	1 (25.0)	3 (75.0)	NA	0.79

25-50 >50	11 (13.3) 2 (15.4)	72 (86.7) 11 (84.6)		
Tooth #22	**N (%) LBT-1 ≥ 1 mm**	**N (%) LBT-1 < 1 mm**	**LBT-1 < 1 mm Relative risk (95% CI)** *	***P*-value**†
Gender Female Male	 14 (24.1) 8 (19.0)	 44 (75.9) 34 (81.0)	 1.07 (0.87, 1.31)	 0.54
Age (years) <25 25-50 >50	 1 (25.0) 19 (22.9) 2 (15.4)	 3 (75.0) 64 (77.1) 11 (84.6)	 NA	 0.39
Tooth #23	**N (%) LBT-1 ≥ 1 mm**	**N (%) LBT-1 < 1 mm**	**LBT-1 < 1 mm Relative risk (95% CI)** *	***P*-value**†
Gender Female Male	 18 (31.0) 10 (23.8)	 40 (69.0) 32 (76.2)	 1.11 (0.87, 1.41)	 0.43
Age (years) <25 25-50 >50	 2 (50.0) 25 (30.1) 1 (7.7)	 2 (50.0) 58 (69.9) 12 (92.3)	 NA	 0.15

LBT-1: labial bone thickness at 1 mm from coronal alveolar crest; CI: confidence interval; NA: not applicable
*Computed only for 2x2 tables
†Chi-square test

LBT: labial bone thickness; LBT-1: labial bone thickness at 1 mm from coronal alveolar crest; LBT-3: labial bone thickness

Figure 8: LBT measurements at LBT-1, LBT-3 and LBT-5 according to different age groups in maxillary six anterior teeth (mean ± standard deviation)



at 3 mm from coronal alveolar crest; LBT-5: labial bone thickness at 5 mm from coronal alveolar crest

5. DISCUSSION

The present retrospective study assessed the LBT of the maxillary anterior teeth and CEJ-BC distance in an Emirati population. Statistically significant higher CEJ-BC values were associated with males and increased age (> 50 years). These main findings are in accordance with other studies and systematic reviews that evaluated CEJ-BC and LBT of maxillary anterior teeth (Januario et al., 2011; Rojo-Sanchis et al., 2021; Tsigarida et al., 2020; Wang et al., 2014; Zekry et al., 2014) indicating minimal differences between Emirati population and other ethnic groups. The high CEJ-BC values in males were also in agreement with other studies (El Nahass & Naiem, 2015; Tsigarida et al., 2020). Conversely, one study (Demircan & Demircan, 2015) contradicted this gender-related link. The potential impact of an increased CEJ-BC distance on implant placement could result in deep implant placement with subsequent need for long trans-gingival components to connect the implants to the final prostheses. One other significant finding was the increasing CEJ-BC distance with age, particularly, for individuals 50 years of age or older. This observation is consistent with other studies where a correlation between the CEJ-BC distance and age of participants was observed ((Demircan & Demircan, 2015; Dos Santos et al., 2019; Ghassemian et al., 2012; Tsigarida et al., 2020; Wang et al., 2014; Zekry et al., 2014). This increase in CEJ-BC was thought to result from physiological bone remodeling associated with aging (Papapanou et al., 1988, 1989; Persson et al., 1998; Schei et al., 1959; Streckfus et al., 1999). The correlation between CEJ-BC distance and age, however, has not been substantiated in other studies (Januario et al., 2011; Nowzari et al., 2012).

Our findings are consistent with those reported in majority of studies where LBT values of < 1 mm in the maxillary anterior region were observed (Ghassemian et al., 2012; Januario et al., 2011; Vera et al., 2012; Zekry et al., 2014). This phenomenon was further corroborated in a study assessing LBT following tooth extraction (Huynh-Ba et al., 2010). That study has shown that more than 80% of sites had LBT of < 1 mm. Moreover, an increased rate of post extraction bone resorption, has been associated with 71% of sites with thin labial bone (Nevins et al., 2006). Other studies (Braut et al., 2011; Dos Santos et al., 2019; Gakonyo et al., 2018; Kim et al., 2016) showed a similar pattern with 76% to 89% of sites having LBT of < 1 mm at the maxillary central incisor region - similar to the findings of the present study where 85% of the assessed central incisors had LBT of < 1 mm. This observation reinforces our knowledge regarding anterior maxillary sites exhibiting less than 1 mm of LBT.

Implant placement in the anterior maxillary region can be aesthetically challenging, and the timing of implant placement can be highly influenced by the LBT at that region. A majority of studies have a reached a consistent conclusion that immediate implant placement with LBT < 1 mm are associated with progressive loss of buccal plate as well as gingival recession post implant restoration (Ferrus et al., 2010; Qahash et al., 2008; Tomasi et al., 2010). Hence, it would be prudent to alternatively consider early implant placement or alveolar ridge preservation (ARP) followed by delayed implant placement rather than immediate implant placement when LBT is less than 1 mm. Even when ARP is considered, initial LBT of 0.6 mm is associated with at least 10% loss of bone volume (Avila-Ortiz et al., 2020).

A further in-depth analysis of our findings demonstrated a trend towards the presence of an increasing thickness at LBT-3 when compared to LBT -1 and -5. Published data has reported a similar trend of increasing thickness at 3 mm level apical to the alveolar crest (El Nahass & Naiem, 2015; Ghassemian et al., 2012). Few studies have suggested that a possible clinical relevance of this increasing thickness at the 3 mm level by placing implants deep enough to engage the thicker bone apically (El Nahass & Naiem, 2015). Furthermore, more frequent sites with < 1 mm were measured at LBT-5, suggesting a possibility for fenestration type defects at the time of implant placement. The minimum LBT at these levels would actually determine the bucco-palatal position of the implant where a more palatal positioning of the implant placement has been suggested (Chen et al., 2004). Nonetheless, several studies using the same methodology found minimal variation of LBT measurements at multiple levels (AlTarawneh et al., 2018; Januario et al., 2011; Lim et al., 2019; Zekry et al., 2014). The authors suggested that these disparities could be attributed to the different traits of patients included in these studies as well as the variations in the sample sizes.

In our analysis, gender did not appear to have an impact on the LBT. This seems to be consistent with the findings of other published studies (El Nahass & Naiem, 2015; Lim et al., 2019; Zekry et al., 2014). Contradicting findings of gender influence on LBT were also reported where an increased thickness in males was observed in one study (Tsigarida et al., 2020) while others showing higher LBT more apically in lateral incisors of males compared to higher LBT at the alveolar crest of central incisors in females (Demircan & Demircan, 2015).

Age did not seem to influence the LBT in our investigation, which is in agreement with the study of Januario et al. (2011). However, in several other studies, low values of LBT were associated with increasing age (Braut et al., 2011; Dos Santos et al., 2019; Gakonyo et al., 2018; Tsigarida et al., 2020; Wang et al., 2014; Zekry et al., 2014). This could be related to high prevalence of chronic inflammatory periodontal diseases affecting the supporting structures of the dentition of older age patients (Tsigarida et al., 2020). This could be a potential aesthetic risk with implant placement in older age patients (Gakonyo et al., 2018). With the knowledge that only 11 participants in the ≥ 50 age group were included; our findings in this context must be interpreted with caution.

The present study has several limitations that need to be acknowledged. The lack of information on patients' medical and dental history, including systemic conditions or orthodontic treatment that might have influenced the LBT and CEJ-BC distances. Additionally, the study's generalizability is limited due to the small sample size and retrospective design. Furthermore, CBCT scans of labial bone demonstrate a tendency towards overestimation of bone thickness, especially, in sites with LBT <1 mm (Behnia et al., 2015). Finally, image resolution of a CBCT scan can be adversely affected by variations in field of view and voxel size, which in turn, can impact the evaluator's ability to read the scans accurately (Menezes et al., 2016). However, a voxel size of 0.15 mm produced by CBCT scanner at the center, aided in minimizing these measurement errors.

6. CONCLUSIONS

Within the limitations of this study, CEJ-BC distance is greater in males and increases with age, particularly in those aged 50 years and above. The LBT in maxillary anterior teeth is predominantly thin (< 1 mm) and has no correlation to age or gender. There is a trend of increasing thickness at LBT-3 and decreasing at LBT-5. Therefore, immediate implant placement should consider these anatomic variations and be performed judiciously after thorough treatment planning.

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8. APPENDICES

8.1 APPENDIX 1: Mohammed Bin Rashid University of Medicine and Health Sciences ethical approval.

26 July 2020

Fawaghi Ali
Resident - Periodontology
HBMCDM

RE: MBRU-IRB-2020-010

Dear Dr Fawaghi,
Thank you for submitting clarifications to the observations raised by the Board on the study titled "Assessment of Anterior Maxillary Labial Bone Thickness Using Cone Beam Computed Tomography". The Board has reviewed the same and has agreed to approve it. The project can now commence.

The Board suggests that the following points be considered for a better outcome of the research. Please note that these suggestions do not need a response back to the board.

- The application states patient-related outcomes (PRO) as age, gender (probably explore sex differences and not gender), and ethnicity but these are not PRO but sociodemographic factors. Increasing the sample size is recommended to increase power for additional between-group analyses (especially where there is more than one group e.g. age groups, nationalities).
- Ethnicity is very challenging to determine from medical records (even with photographs) unless ethnicity data is specifically collected and self-reported from the patient.

For any questions, please contact the Institutional Review Board irb@mbru.ac.ae.

Thank you for your interest in MBRU-IRB.

Sincerely,

Dr Essa Kazim
Chairman, MBRU-IRB

لجنة أخلاقيات البحوث
INSTITUTIONAL REVIEW BOARD

8.2 APPENDIX 2: Abu Dhabi Health Authority Institutional Review Boards ethical approval.

هيلث بوينت
Healthpoint
A Mubadala Company

Date: 02/07/2020

Healthpoint Research Ethics Committee

Principal Investigator: Dr. Nouf Al Harbi

Telephone: 050 887 7242

Email: N.alharbi@healthpoint.ae

REC Reference: MF2467-2020-5

Title of Project: Assessment of anterior maxillary labial bone thickness using cone beam computed tomography

Dear Dr. Nouf,

The Research Ethics Committee has reviewed the above application at its meeting held on Thursday 02 July 2020 at 11 a.m.
The study will be a collaboration between Healthpoint hospital and Mohammed Bin Rashid University (MBRU), with Dr. Fawaghi Al Ali as their principal investigator.

The Committee has given a favorable ethical opinion for the above project based on the application, protocol and supporting documentation that comply with the conditions and principles established by the International Conference on Harmonization – Good Clinical Practice (ICH GCP).

Yours sincerely,

Dr. Mai Ahmed Sultan Essa Al Jaber, MBBS, MPH
Medical Director
Health Point Hospital L.L.C.

Dr. Mai Al Jaber

Chair, Healthpoint Research Ethics Committee

Abu Dhabi - U.A.E.
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HEALTH POINT HOSPITAL L.L.C.

P.O. Box 112308, Abu Dhabi, United Arab Emirates T +971 2 492 9000 F +971 2 492 9001 E info@healthpoint.ae W healthpoint.ae

8.3 APPENDIX 3: Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page number
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	i
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	i
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	1,2
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4,5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5,6
Bias	9	Describe any efforts to address potential sources of bias	5,6
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6
		(*e*) Describe any sensitivity analyses	6

Results			Page number
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	7-18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-18
		(*b*) Report category boundaries when continuous variables were categorized	7-18
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	18

Discussion			
Key results	18	Summarise key results with reference to study objectives	19-21
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	21,22
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	21,22
Generalisability	21	Discuss the generalisability (external validity) of the study results	21

Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	iv