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ACCURACY AND RELIABILITY OF ANATOMICAL LANDMARKS COMPARED BETWEEN 3D FACIAL SCANNING AND CBCT RADIOGRAPHS: A COMPARATIVE STUDY

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Introduction: Facial soft tissue evaluation is an important key for the overall patient diagnosis, treatment planning, and long-term prognoses. 3D patient imaging can be an alternative way to define the face providing the clinician with more accurate details, in comparison to the 2D imaging of soft tissues.

Objectives: The objective of this study was to evaluate the accuracy and reliability of anatomical landmarks comparing the 3D facial scanning with the CBCT radiographs.

Methods: The study was a comparative, crossover and descriptive study. Thirty patients (12 males and 18 females) with 15 to 30 years with a mean age of 22.6 years, who needed orthodontic treatment were recruited from the outpatient clinics, Faculty of Dentistry, Beirut Arab University. All patients had a CBCT radiograph at the beginning with a natural head position and relaxed lips. After that, the patient had 3D facial scanning using the same radiographing machine.

Results: The data collected from the 3D facial images and full skull CBCT radiographs were reliable and consistent for most of the measured parameters with Cronbach's alpha values of 0.870. However, the mouth width parameter exhibited the largest Dahlberg error of 4.08, suggesting substantial variability between the two methods for this parameter. Furthermore, the concordance correlation coefficient (CCC) indicated a positive correlation between the CBCT radiograph and facial scanning for most parameters (average of 0.9). The Bland-Altman revealed a moderate agreement between both sets of scanned measurements with confidence band range (2 and -2), with exceptions, the average mouth width distance (-3.40667).

Conclusions: There was a strong positive linear relationship between the two approaches in the majority of the parameters. However, the mouth width parameter revealed a moderately linear relationship between the two approaches.

Keywords: Facial soft tissue, 3D facial scanning, CBCT radiograph

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Conflicts of interest:
The authors declare no conflicts of interest.

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Orthodontics / *Orthodontie*

PRÉCISION ET FIABILITÉ DES REPÈRES ANATOMIQUES COMPARÉES ENTRE LE SCAN FACIAL 3D ET LES RADIOGRAPHIES CBCT: UNE ÉTUDE COMPARATIVE

Introduction: L'évaluation des tissus mous du visage est essentielle au diagnostic global, à la planification du traitement et au pronostic à long terme. L'imagerie 3D peut constituer une alternative pour définir le visage, offrant au clinicien des détails plus précis que l'imagerie 2D des tissus mous.

Objectifs: Cette étude visait à évaluer la précision et la fiabilité des repères anatomiques en comparant le scanner facial 3D aux radiographies CBCT.

Méthodes: Il s'agissait d'une étude comparative. Trente patients (12 hommes et 18 femmes) âgés de 15 à 30 ans, d'un âge moyen de 22,6 ans, nécessitant un traitement orthodontique, ont été recrutés dans les consultations externes de la Faculté de médecine dentaire de l'Université arabe de Beyrouth. Tous les patients ont bénéficié d'une radiographie CBCT initiale avec une position naturelle de la tête et des lèvres relâchées. Ensuite, le patient a bénéficié d'une radiographie faciale 3D avec le même appareil de radiographie.

Résultats: Les données recueillies à partir des images faciales 3D et des radiographies CBCT du crâne entier étaient fiables et cohérentes pour la plupart des paramètres mesurés, avec un alpha de Cronbach de 0,870. Cependant, le paramètre de largeur de la bouche présentait l'erreur de Dahlberg la plus importante, soit 4,08, suggérant une variabilité importante entre les deux méthodes pour ce paramètre. De plus, le coefficient de corrélation de concordance (CCC) indiquait une corrélation positive entre la radiographie CBCT et le scanner facial pour la plupart des paramètres (moyenne de 0,9). Le test de Bland-Altman a révélé une concordance modérée entre les deux séries de mesures scannées, avec une plage de confiance de 2 et -2, à l'exception de la distance moyenne entre la largeur de la bouche (-3,40667).

Conclusions: Une forte relation linéaire positive a été observée entre les deux approches pour la majorité des paramètres. Cependant, le paramètre de largeur de la bouche a révélé une relation linéaire modérément marquée entre les deux approches.

Mots clés: Tissus mous faciaux, Scanner facial 3D, Radiographie CBCT

Introduction

Facial soft tissue evaluation is an important key for overall patient diagnosis, treatment planning, and long-term prognosis. Accurate diagnosis is the key to treatment planning and a successful treatment outcome. Many clinicians evaluate facial contours, especially the profile, when setting goals for treatment. Considering the perspectives of function, stability, and aesthetics, the orthodontist should plan treatment within the patient's limits of soft-tissue adaptation and contours [1].

Arnett and Bregman (1993) stated that the clinical facial examination is critical in orthodontic and surgical diagnosis and aiming to establish facial balance along with occlusal and dental harmony to obtain reliable results [2]. Moreover, Sarver (2015) has explained in detail the importance of facial soft tissue examination and its relation to the concept of goal-oriented treatment planning [3].

Although cephalometric radiographs, panoramic radiographs and intraoral and extra-oral photographs are still used, greater emphasis has been placed on the 3D virtual image and soft-tissue esthetics [4, 5]. For that, Three-dimensional facial imaging was introduced to orthodontics during the early years of the new decade. Research has demonstrated the value and increased accuracy of three-dimensional photography compared to traditional imaging modalities and has sought with ongoing efforts to develop new analyses for clinical application [6].

CBCT allowed for the 2-dimensional images to be viewed in sagittal, oblique, or coronal planes [7]. The majority of soft tissue components can be imaged using CBCT, which is a great tool for hard tissue structures. However, due to the inability to capture skin's true color texture, 3D imaging techniques like stereophotogrammetry, and laser scanning have been introduced for soft tissue imaging [8].

However, the lack of practical and true 3D analysis of the information collected from 3D photographic images has hindered widespread utilization in the orthodontic profession. Therefore, this study aimed to evaluate the accuracy of 3D facial scanning used for orthodontic diagnosis. The null hypothesis is there is no difference in accuracy between 3D facial scanning and the CBCT.

Materials and Methods

The study design was a comparative and descriptive study. Patients were selected from the Outpatient Clinics at Beirut Arab University with age ranged between 18 to 35 years. Before conducting the study, the proposal was approved by the scientific and ethical review committee and institutional review board at Beirut Arab University (IRP number: 2023-H-0126-D-M-0558). The objectives, risks, and benefits of the study were explained to the parents and/or guardians, and a signed informed consent prepared in Arabic and English versions was obtained before the initiation of the study.

The Sample size estimation was performed using 80% power of the study and sample size using G*power software (ver. 3.1) at alpha = 0.05. The estimated sample size was calculated by taking the mean + SD from a previous similar study conducted by Kim et al. (2018) [9]. The calculated sample size was thirty (30). Therefore, thirty patients who need orthodontic treatment were recruited from the outpatient clinics of the Department of Orthodontics, Faculty of Dentistry, Beirut Arab University, Beirut, Lebanon.

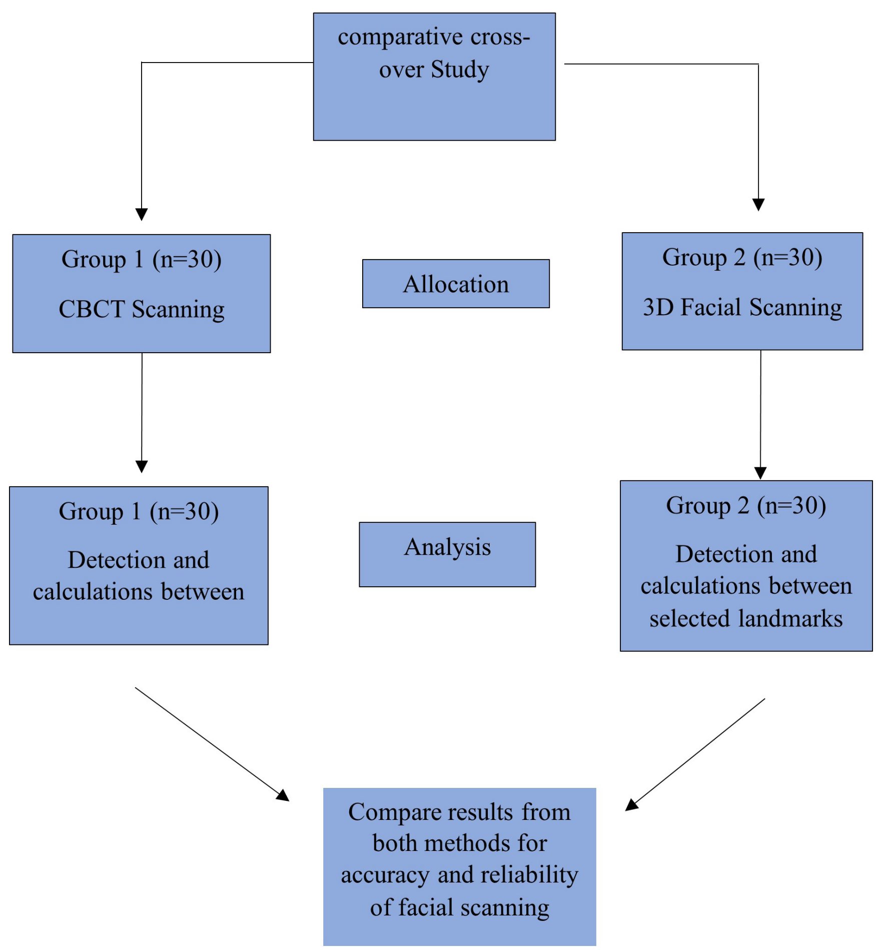

Figure 1. Consort Flow Diagram

The selected patients fulfilled the following inclusion and exclusion criteria according to Kim et al. (2018) [9]. Participants under this study fulfilled the following criteria: Population under study: Caucasian, Age group: 15 to 30 years, all teeth are present with or without the presence of third molars, fully erupted teeth. Whereas for the exclusion criteria, patients with previous orthodontic treatment or orthognatic surgery, systemic diseases, traumatic injuries, subjects who had received facial esthetic treatment including botox and fillers, patients with facial hair that would mask landmarks to be identified.

All patients included in the study went through two different 3D imaging mechanisms separately, which were 3D facial images that were captured using high-definition and high-resolution 3D facial scanner device (Carestream 9600) at the BAU. Full skull CBCT radiographs were also taken of the same patients using the same X-ray unit.

CBCT and facial scanning radiographs were taken with the patient's head in its natural position and his lips were relaxed. The natural or postural head position was the horizontal reference.

According to Kim et al (2018) [9], thirteen (13) landmarks were selected on each participants' images as follows (table 1) and illustrated in figures (2, 3, 4 and 5).

Table 1. Landmarks identification that has been selected for this study.

Landmarks	Identification
N (Nasion)	The sagittal midline point of the nasal root at the nasofrontal suture
Sn (Subnasale)	The midpoint of the point of inflection of the columellar base at the junction of its lower border with the surface of the philtrum
Pg (Pogonion)	The most protrusive anterior sagittal midline point of the chin
Zy (R) (Zygion right)	The most lateral extent of the zygomatic arch on right side
Zy (L) (Zygion left)	The most lateral extent of the zygomatic arch on left side
Ch (R) (Cheilion right)	The most lateral point at the labial commissure on right side
Ch (L) (Cheilion left)	The most lateral point at the labial commissure on left side
Al (R) (alare right)	The most lateral extent of the alar contour on right side
Al (L) (alare left)	The most lateral extent of the alar contour on left side
En (R) (Endocanthion right)	The most medial point on the palpebral fissure, at the inner commissure of the eye on right side
En(L) (Endocanthion left)	The most medial point on the palpebral fissure, at the inner commissure of the eye on left side
Ex (R) (Exocanthion right)	The most lateral point on the palpebral fissure, at the outer commissure of the eye on right side
Ex (L) (Exocanthion left)	The most lateral point on the palpebral fissure, at the outer commissure of the eye on left side

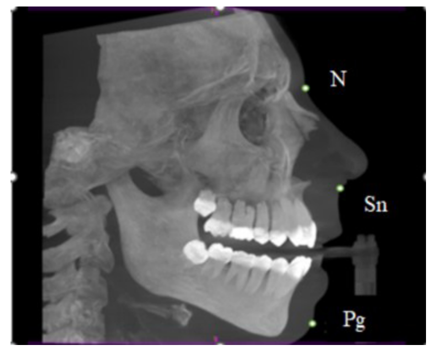

Figure 2. Lateral view of CBCT image for the same patient. In this view, 3 landmarks had been detected, which were: N (Nasion), Sn (Subnasale), Pg (Pogonion)diameter

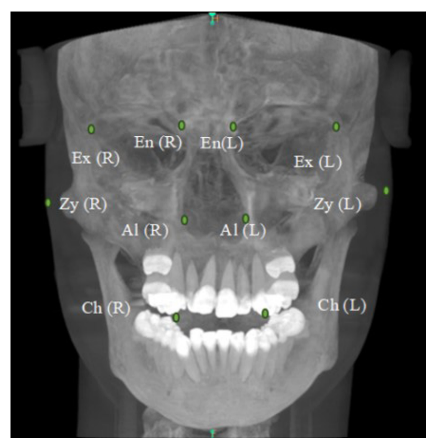

Figure 3. Frontal view of CBCT image .In this view, according to Kim et al (2018), the remaining 10 landmarks had been detected

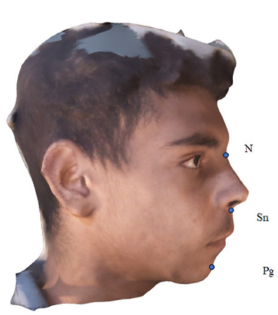

Figure 4. Lateral view of 3D facial scanning. In this view, 3 landmarks had been detected, which were: N (Nasion), Sn (Subnasale), Pg (Pogonion)

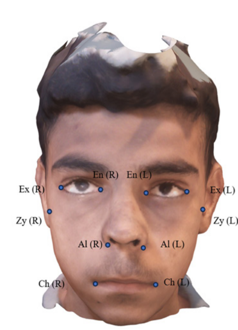

Figure 5. Frontal view of 3D facial scanning. In this view, the remaining 10 landmarks have been detected, which were: Zy (R) (Zygion right), Zy (L) (Zygion left), Ch (R) (Cheilion right), Ch (L) (Cheilion left), Al (R) (Alare right), Al (L) (Alare left), En (R) (Endocanthion right), En(L) (Endocanthion left), Ex (R) (Exocanthion right), Ex (L) (Exocanthion left).

According to Kim et al (2018), the following table 2 illustrates the measured and defined distances illustrated in figures (6,7,8 and 9).

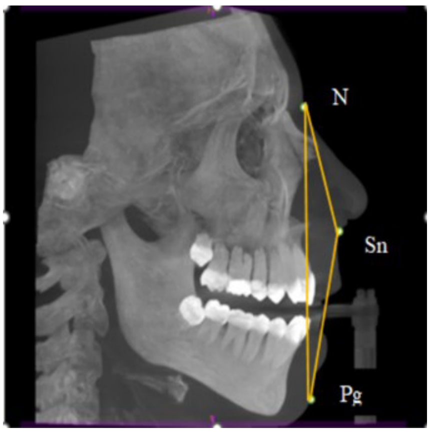

Figure 6: Lateral view of CBCT image for the same patient illustrating measurements. In this view, 3 measurements have been illustrated , which were: N-Pg (Total facial height), N-Sn (Upper facial height), Sn-Pg (Lower facial height)

Table 2. Measured distances used in the study

Measurements	Identification
N-Pg Total facial height	Vertical linear measurement of facial dimension as measured from nasion (N) to pogonion (Pg)
N-Sn Upper facial height	Vertical linear measurement of upper facial dimension as measured from nasion (N) to subnasale (Sn)
Sn-Pg Lower facial height	Vertical linear measurement of lower facial dimension as measured from subnasale (Sn) to pogonion (Pg)
Zy (R)- Zy (L) Width of the face	Transverse linear measurement of the face from Zygion right Zy (R) to Zygion left Zy (L)
Ch(R)- Ch(L) Mouth width	Transverse linear measurement of mouth width from Cheilion right Ch(R) to Cheilion left Ch(L)
En(R)- En (L) Intercanthal width	Transverse linear measurement of intercanthal width from Endocanthion right En(R) to Endocanthion left En (L)
Ex(R)- Ex(L) Biocular width	Transverse linear measurement of biocular width from Exocanthion right Ex(R) to Exocanthion left Ex(L)
Al(R)- Al(L) Width of the nose	Transverse linear measurement of width of the nose from Alare right Al(R) to Alare left Al(L)

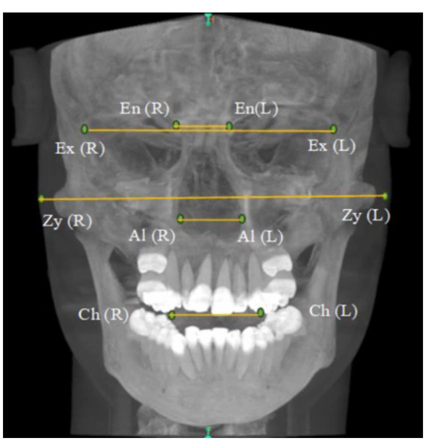

Figure 7. Frontal view of CBCT image illustrating measurements. In this view, according to Kim et al (2018), remaining 5 measurements have been illustrated, which were: Zy (R)- Zy (L) (Width of the face), Ch(R)- Ch(L) (Mouth width), En(R)- En (L) (Intercanthal width), Ex(R)- Ex(L) (Biocular width), Al(R)- Al(L) (Width of the nose).

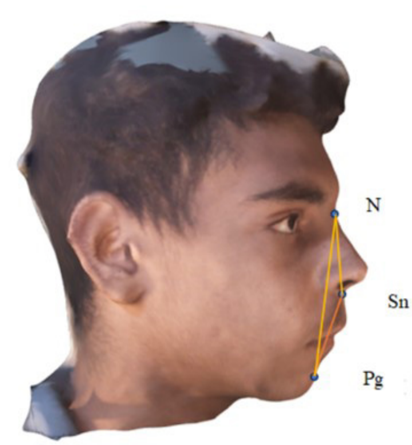

Figure 8. Lateral view of 3D facial scanning illustrating measurements. In this view, 3 measurements have been illustrated, which were: N-Pg (Total facial height), N-Sn (Upper facial height), Sn-Pg (Lower facial height).

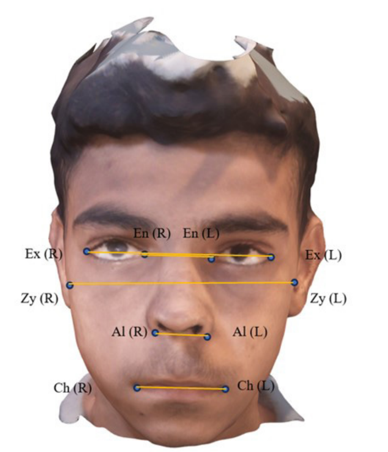

Figure 9. Frontal view of 3D facial scanning illustrating measurements. In this view, the remaining 5 measurements have been illustrated, which were: Zy (R)- Zy (L) (Width of the face), Ch(R)- Ch(L) (Mouth width), En(R)- En (L) (Intercanthal width), Ex(R)- Ex(L) (Biocular width), Al(R)- Al(L) (Width of the nose).

Statistical Analysis

Similar to the studies Kim et al. (2018) [9] and Seliem et al. (2020) [10], the assessment of the agreement between measurements of the 3D facial scan with the CBCT scan method, Dahlberg error, Concordance Correlation Coefficients (CCC) including the 95% confidence limits and Bland, and Altman analysis were used. Intra-observer reliability was assessed using Cronbach's alpha reliability coefficient.

Results

The Intra-observer reliability was done using Cronbach's alpha, which is the coefficient of internal consistency reliability. In this analysis, the calculated Cronbach's Alpha was 0.870, which was relatively high. A Cronbach's Alpha above 0.7 is generally considered to indicate good internal consistency among the measured items.

For most of the facial features, CBCT radiograph tends to yield slightly higher mean values compared to Facial scan. This difference in means was reflected in the Dahlberg error, which ranges from 1.28 to 4.08 units across the features. Notably, Mouth width Ch(R)- Ch(L) exhibited the largest Dahlberg error of 4.08, suggesting a substantial discrepancy between the two methods. (Table 3)

The correlation coefficient (R), as showed in Table 4, indicated a strong positive linear relationship between two approaches in the majority of the parameters, which were as follows: N-Pg, N-Sn, Sn-Pg, Zy(R) - Zy(L), En(R)- En (L), Ex(R)- Ex(L), and Al(R)- Al(L), with respective values of 0.9527, 0.9669, 0.9638, 0.980, 0.980, 0.855, 0.922, and 0.820. However, Ch(R)- Ch(L) revealed a moderate linear relationship of 0.621 between the two approaches.

The Bland-Altman results in Table 5 revealed that the average values of both sets of scanned measurements fell divergently into the confidence band range (2 and -2), with exceptions (the points lying outside the confidence bands that were generally at the extremes of the measurement ranges).

The CBCT measurements had one or more values well above the threshold of the confidence bands especially the average mouth width distance, which was within a range of about (-4 to -2).

Table 3. Dahlberg error assessment of CBCT and 3D facial scan methods

Parameter	Method	Mean	SD	Dahlberg error
(N_pg) total facial height	CBCT radiograph	100.9	7.2	2.97
	Facial scan	98.82	7.71	
(N_Sn) upper facial height	CBCT radiograph	52.8	3.3	2.03
	Facial scan	50.98	3.27	
(Sn_pg) lower facial height	CBCT radiograph	50.9	6.3	1.86
	Facial scan	50.35	6.18	
Zy (R)- Zy (L) width of the face	CBCT radiograph	138.3	7.5	1.88
	Facial scan	137.22	8.08	
Ch(R)- Ch(L) mouth width	CBCT radiograph	37.0	1.9	4.08
	Facial scan	40.37	3.10	
En(R)- En (L) intercanthal width	CBCT radiograph	25.7	1.7	2.69
	Facial scan	28.09	1.89	
Ex(R)- Ex(L) biocular width	CBCT radiograph	91.9	3.5	1.55
	Facial scan	91.12	2.84	
Al(R)- Al(L) width of the nose	CBCT radiograph	22.2	1.6	1.28
	Facial scan	23.07	1.85	

Table 4. Concordance Correlation Coefficient (CCC) results between two methods

Parameter	Method	CCC
(N_pg) total facial height	CBCT radiograph	.9527
	Facial scan	
(N_Sn) upper facial height	CBCT radiograph	.966
	Facial scan	
(Sn_pg) lower facial height	CBCT radiograph	.963
	Facial scan	
Zy (R)- Zy (L) width of the face	CBCT radiograph	.980
	Facial scan	
Ch(R)- Ch(L) mouth width	CBCT radiograph	.621
	Facial scan	
En(R)- En (L) intercanthal width	CBCT radiograph	.855
	Facial scan	
Ex(R)- Ex(L) biocular width	CBCT radiograph	.922
	Facial scan	
Al(R)- Al(L) width of the nose	CBCT radiograph	.820
	Facial scan	

Table 5. Mean difference between both methods and the Bland Altman agreement

Parameter	Method	Mean difference between measurements	Bland-Altman Limit of agreements	
			Lower limit	Upper limit
(N_pg) total facial height	CBCT radiograph / Facial scan	2.06000	1.2386	2.8814
(N_Sn) upper facial height	CBCT radiograph / Facial scan	1.81800	1.5013	2.1347
(Sn_pg) lower facial height	CBCT radiograph / Facial scan	0.57333	-0.0539	1.2006
Zy (R)- Zy (L) width of the face	CBCT radiograph / Facial scan	1.09333	0.4769	1.7098
Ch(R)- Ch(L) mouth width	CBCT radiograph / Facial scan	-3.40667	-4.3127	-2.5007
En(R)- En (L) intercanthal width	CBCT radiograph / Facial scan	-2.42000	-2.7854	-2.0546
Ex(R)- Ex(L) biocular width	CBCT radiograph / Facial scan	0.75833	0.2365	1.2801
Al(R)- Al(L) width of the nose	CBCT radiograph / Facial scan	-0.89667	-1.2924	-0.5009

Discussion

The examination of facial soft tissues is an essential tool for overall patient diagnosis, treatment planning, and long-term assessment. Compared to the traditional imaging devices of soft tissues, such as patient photographs and 2D analog films, 3D patient imaging could be an alternative method to describe face and providing the clinician with additional and more accurate information [11].

In this investigation, CBCT was regarded as the gold standard. This presumption was formed in the light of numerous research publications and articles [12,13,14],which mainly emphasized that CBCT provides accurate measurements for different head diagnostic needs. To our knowledge, since there was inadequate data concerning the true 3D analysis of the information collected from 3D photographic images, therefore, this study aimed to evaluate the accuracy of 3D facial scanning used for orthodontic diagnosis.

Regarding the intra-observer reliability, the Cronbach's alpha with value of 0.870 revealing a strong internal consistency in facial measurements. This suggests that the data collected from the 3D facial images and full skull CBCT radiographs were reliable and consistent.

In agreement with our study, Seliem et al. (2020)[10], who compared a 3D laser facial scanner with CBCT radiographs, demonstrated high internal consistency in facial measurements between the two approaches, with Cronbach's alpha values ranging from 0.884 to 1. Moreover, Wong et al. (2008) [15], in their study about the validity and reliability of craniofacial anthropometric measurements, stated that 17 of 18 facial measurements showed high internal consistency with a mean Cronbach's alpha value of 0.88.

CBCT radiographs tended to yield a slightly higher mean values compared to 3D facial scanning measurements, which, according to [16,17]Metzger et al. (2013) and Fourie et al. (2011), could be attributed to the poorly defined contours of facial structures on the CBCT volume and the difficulty in identifying the landmarks. This difference in means was reflected in the Dahlberg error, which ranges from 1.28 to 4.08 units across the parameters. This suggests that CBCT radiographs may have a slightly higher degree of measurement variability or error compared to 3D facial scanning. However, it is important to note that the difference in means and Dahlberg error may vary depending on the specific facial feature being measured.

Notably, mouth width parameter exhibited the largest Dahlberg error of 4.08, suggesting a substantial variability between the two methods for this parameter. On the other hand, the width of the face and upper facial height parameters showed relatively smaller Dahlberg errors of 1.88 and 2.03, respectively. Controversary, Seliem et al. (2020) [10] showed that the maximum Dahlberg error was 0.34 related to internal eye width measurement and the minimum Dahlberg error was 0.25 related mouth width measurement. This difference is likely due to differing landmark definitions. Seliem et al. (2020)[10] located the Cheilion (Ch) points on CBCT on estimated facial soft tissue, while for this study, the tips of canines were the estimated landmarks for them.

These variations in Dahlberg error indicated that the accuracy of 3D facial scanning may be more reliable for measuring most of the parameters with giving special attention to mouth width. It is crucial to consider these discrepancies when interpreting and comparing the data obtained from different facial features.

There are several potential explanations for the variations in Dahlberg error observed between CBCT radiographs and 3D facial scanning. One possible factor is differences in scanning techniques. For example, CBCT radiographs involve capturing X-ray images of the face, while 3D facial scanning uses optical scanning technology. These different techniques may introduce variations in the measurements obtained. Another factor that could contribute to the variations is equipment calibration. If the instruments used for CBCT radiographs and 3D facial scanning are not calibrated properly, it could result in inconsistent measurements. Additionally, individual anatomical variations, such as facial asymmetry or differences in soft tissue thickness, may also contribute to the observed variations in Dahlberg error [18].

The correlation between the CBCT and soft tissue measurements was indicated by the (CCC). Although most measurements have a range of ±0.9 values, there was typically less correlation between measurements that encompass the corners of the mouth. This small value suggests that the CBCT tends to evaluate distances shorter than the soft tissue distances when considering the left and right corners of the mouth.

The concordance correlation coefficient (CCC) results in Table 4 indicated a positive correlation between the CBCT radiograph and facial scanning for most parameters. However, there was a lower CCC value of .621 for the mouth width parameter, suggesting some disagreement between the two approaches in this specific aspect.

Naudi et al. (2013)[19] found that the lateral regions of the face had the greatest tendency to lose measurement similarity and had a less intimate association between CBCT and facial scans. Similar to the current study, the width of the face and biocular width parameters showed relatively low agreement between the two approaches. The different amounts of subcutaneous tissue present in each patient may be the cause of the tendency to have a lower correlation along the lateral regions of the face; nevertheless, it may also be related to the greater amounts of curved bony surface areas on the lateral profile of the face.

Toma et al. (2009)[20] reported that soft-tissue landmarks on the left and right lateral sides of the face are not very reproducible because it is challenging to place points precisely on a patient's lateral profile.

The CBCT defines the biocular width landmark as the distance between the left and right frontozygomatic sutures, while the facial scanner defines the same landmark as the distance between the left and right most lateral points on the palpebral fissure. These definitions are entirely different. The skeletal sutures extending beyond the palpebral fissure could be the reason for the rather greater CBCT difference.

Moreover, intercanthal width also exhibits a relatively high difference because of differing landmark definitions. The CBCT had shorter distances than the soft tissue, with a mean difference of (-2.42000). Such findings were consistent with the current study, which also discovered that the left and right Zygion (Zy) tend to elicit relatively large differences between soft tissue and CBCT landmark sites, while some landmarks near the center of the face, such as the measurement between the left and right Alare (Al), showed smaller differences (Table 5).

Furthermore, the Zygion (Zy) landmark was similarly determined to be among the least reputable landmarks to identify by Baumrind and Frantz (1971)[21], while the Nasion had a comparatively lower skeletal landmark estimation error.

In an agreement with the current study, Ayoub et al.'s study (2007) [22] examined the superimposition of 3D data obtained from a stereophotogrammetry tool and a CT scanner. It was concluded that errors were mostly within an acceptable range of ±1.5 mm, with the eyelid area showing the largest error. It was observed that surface form variations in the eyelid and eyebrow region cause registration errors when images were captured using these various imaging modalities. Furthermore, some anatomical components, such as the midlateral orbit, do not accurately reflect the anatomical structure of the soft tissues, according to Hwang et al. (2015)[23].

A possible explanation is that the suture between the frontal and zygomatic bones was identified on the CBCT as the biocular width, while the suture between the frontal bone and maxilla, which is positioned close to the nasal bone, was identified as intercanthal width landmark. This mean difference may be due to these sutures being superior on the face than the actual soft tissue outer and inner eye corners. These results suggest that it is challenging to replicate the soft and hard tissue landmarks of the eye.

According to Seliem et al. (2020) [10], every facial parameter revealed high (CCC) values (almost one), indicating a high degree of agreement between the two approaches, which would reinforce our study results. These results were in agreement with Alhammadi et al. (2021)[18], where the concordance correlation coefficients (CCC) showed that most of the soft tissue linear measurements of maxillary and mandibular parameters had high (CCC) values ranging between 0.91 and 0.998 using wrapped photographs and direct CBCT soft tissue measurements.

However, the Bland-Altman results in Table 5 revealed that the average values of both sets of scanned measurements fell divergently into the confidence band range (2 and -2), with exceptions (the points lying outside the confidence bands that were generally at the extremes of the measurement ranges). As shown in the side-by-side plot pairs, the facial scanner generally had a smaller mean difference than the CBCT application.

The CBCT measurements had one or more values well above the threshold of the confidence bands, as illustrated in Table 5, especially the average mouth width distance, which was within a range of about (-4 to -2). Similar results were demonstrated in Pellitteri et al. (2021)[24], who made a comparison of the accuracy of digital face scans obtained by two different scanners. In their investigation, the Bland-Altman plots revealed that the average values of both sets of scanned measurements fell into a relatively narrow range, with few exceptions in left and right Zygion (lateral points of zygomatic arches).

In other words, it was clear that the margin of error of the facial scanning in the sample was lower and more constant than that of the CBCT, which yielded only a few values that deviated from the average range. This, however, may have been ascribable to the small size of the sample or to external environmental factors that were not predictable at the time of the scans. The relatively large amount of time spent capturing the facial scans (almost 1 minute) may cause patients to blink or move their eyes, making it hard to remain steady.

Conclusion

Strong internal consistency was seen among the facial measurements obtained from both the CBCT radiograph and the facial scan. The concordance correlation coefficient (CCC) indicates a strong positive linear relationship between the two approaches in the majority of the parameters. However, the mouth width parameter revealed a moderate linear relationship between the two approaches.

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