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Buccolingual Inclination of Posterior Teeth in Untreated Adults with Unilateral Tooth Loss: A CBCT Investigation

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Abstract

Background: To evaluate the buccolingual inclinations of posterior teeth in untreated adults with and without unilateral, partial edentulism by using CBCT images.
Methods: One hundred and one untreated adults (47 males, 54 females), who had CBCT images (average age: 49.79 years) participated in the study. Two sub-groups of patients were considered: fully dentate patients and patients with loss only of the first molar. The images were oriented according to the long axis of the tooth and visualized in coronal slices. Dental landmarks were used to evaluate the buccolingual inclination of the second permanent maxillary and mandibular molars.
Results: The buccolingual inclination of the second mandibular molar on the edentulous side is greater than the buccolingual inclination of the second maxillary molar on the edentulous side. The inclination of the second right mandibular molar shows a significant difference between the group of fully dentate patients and the group of patients with a first molar absent (p=0.001); the angle Ay(MMd2)r/MdP being more closed in partially toothed subjects (86.7°). In other words, only the second right mandibular molar has a more pronounced bucco-lingual inclination
Right mandibular second molars of the subjects with the first mandibular molar absent appeared to be approximately 14° more inclined in lingual direction than those of the other subjects. There was no significant difference related to gender.
Conclusion: There exists a significant increase of the lingual tilting of mandibular molars adjacent to the sites of the partial edentulism. Correction of this inclination will therefore be necessary to maintain a certain degree of Wilson's curve at the end of orthodontic treatment to meet physiological needs and stability.

Keywords: Buccolingual inclination, Molars, Partial Edentulous, Cone Beam, Untreated Adult.

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Introduction

Although the number of totally edentulous patients are clearly decreasing due to diagnostic and therapeutic progress in dentistry, the number of partially edentulous patients keeps increasing in relation with life expectancy[1-4].

Profiles of edentulous subjects were assessed in various populations of different countries and the frequency of the partial edentulism seems to vary significantly across countries.[5-6] Partial edentulism refers to the presence of residual spaces after the loss of one or more teeth. This edentulism, either old or recent is often not compensated. However, the loss of one or several teeth generally leads to a disturbance of the operational stability of the remaining teeth. Uncompensated edentulism frequently results in egressions, versions or rotations of adjacent remaining teeth, thus leading to a disturbance of the dental occlusion with unilateral chewing habits[7-12].

These movements have been widely observed on conventional X-rays and dental casts. Cephalometric analyses achieved on cephalograms, and on panoramic X-rays always form the basis of the orthodontic reasoning.

Yet, the orthodontist's action area that relates to dentitioncranio-facial skeleton and soft tissues, could be considered through the three dimensions of space[13].

Buccolingual inclination of incisors has been widely studied by the use of lateral cephalograms, which allows a practical view of the longitudinal axis of the incisor and its relation with the skeletal patterns. Meanwhile, CT scan remains useful to visualize the longitudinal axis of posterior teeth[14].The use of CT scans has proved to be useful for the measurement of transverse dimensions and to evaluate the relation

between the inclination of the first mandibular molar, and the facial type[14-16]. The first molar was "the key of occlusion" by Angle since he thought it was by far, the most permanent tooth in its normal position. On a clinical basis, this tooth is frequently missing[17-19]. Buccolingual inclination of posterior teeth remains as one of the six keys of Andrew's normal occlusion. In his description of the six keys of normal occlusion, Andrew pointed out that the third key applied to the inclination of the crown that he measured from the oral crown surfaces[20] shown that the buccolingual inclination of posterior teeth was important not only for occlusal, intercuspation but also for the aesthetics of frontal smile[21].

However, most of the previous studies on buccolingual inclinations of teeth, didn't take into account partial edentulisms which could be the source of important dental-alveolar compensations[12].

Given that buccolingual inclination of teeth stands as important transversal feature of occlusion, it's crucial to identify the nature of such occlusion in partially edentulous subjects.

By using the CBCT, we can measure the coronal-radicular inclination on the basis of the tooth's major axis.

The purpose of this study was to evaluate the buccolingual inclination of posterior teeth in untreated adults, with and without partial unilateral edentulism by using CBCT images.

Material and Methods

This was a retrospective study based on data retrieval. Nevertheless, this study was developed according to established precepts by the National Research Ethics Committee, approved under IRB000111917. The images were previously taken in a private practice. Images included pretreatment radiograph is taken on the same equipment: CS 8100 3D CBCT (Carestream Dental LLC, Atlanta, GA).All images have been anonymized before they were downloaded and analyzed by a unique operator (SOK).

Patients and Radiographic Equipment

Relevant and anonymized CBCT images taken between January 2011 and January 2018 were analyzed; these images concerned black African patients admitted in a private dental practice specializing in Orthodontics and Oral surgery. The gathered sample consisted of three-dimensional (3D) cranial CT images of 47 males and 54 females subjects with a average age of 48.89 (±12.77) years, all of whom had undergone cranial CT examinations for various dental diagnostic reasons, over approximately a 5-year period. All the CBCT examinations were performed due to clinical indications and not for the purpose of this study.

The patients selected were waiting for an implant therapeutic project with or without orthodontic corrections. Finally, a sample of 101 untreated black African patients was selected using convenience sampling method. A CBCT image was taken as a pretreatment record on each subject. The subjects were divided into two sub-groups: group1 fully dentate patients consisted of 21 subjects (10 males, 11 females) with a mean age of 35.95±12.24 years, group 2 patients with loss only of the first molar consisted of 80 subjects (37 males, 43 females) with a mean age of 52.16 ±10.60 years.

CBCT- Scans

The CBCT Scans used in this study were all taken with the same equipment: CS 8100 3D CBCT (Carestream Dental LLC, Atlanta, GA) having the same exposure setting (8mA, 90 kV, voxels size: 150μm x 150μm: scanning time 15s). All CBCT images provide a slice thickness of 0.25mm.

Patients were positioned according to the manufacturer's instructions.

Patients Selection and Inclusion Criteria

Only scan acquisitions with a field of view (FOV) including the full dentition of both archs without artifacts and only patients from sub-saharan Africa were included. Other inclusion criteria were listed as follows:

- No prior orthodontic treatment
- Less than 5mm crowding per dental arch.
- No prior craniofacial trauma, surgery, or symptoms of TMJ joints disorders.
- A permanent dentition.
- A nearly normal occlusion.
- Partial dentition with loss of the first molar more than 2 years

Non-inclusion criteria were stated as follows:

- Prosthetic crowns, or major restorations on first and second molars, or severe tooth wear.
- Retained primary teeth
- Complete edentulousness
- A systemic and disfiguring disease.
- A very aggressive periodontal disease.
- A craniofacial malformation.

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Measures on the CBCT data
Software

Data provided by the 3D radiography Scanner, were recorded in DICOM format (Digital Imaging and Communication in Medicine) and treated by the means of the CS 3D Imaging software (Carestream Dental LLC, Atlanta, GA). The software features 3 split windows for coronal, digital and axial view. After screening of the respective 3D-data sets, orthoradial adjustments to the x-, y- and z- plane level were made to enable reproducible three-dimensional measurements.

Dental Measurements

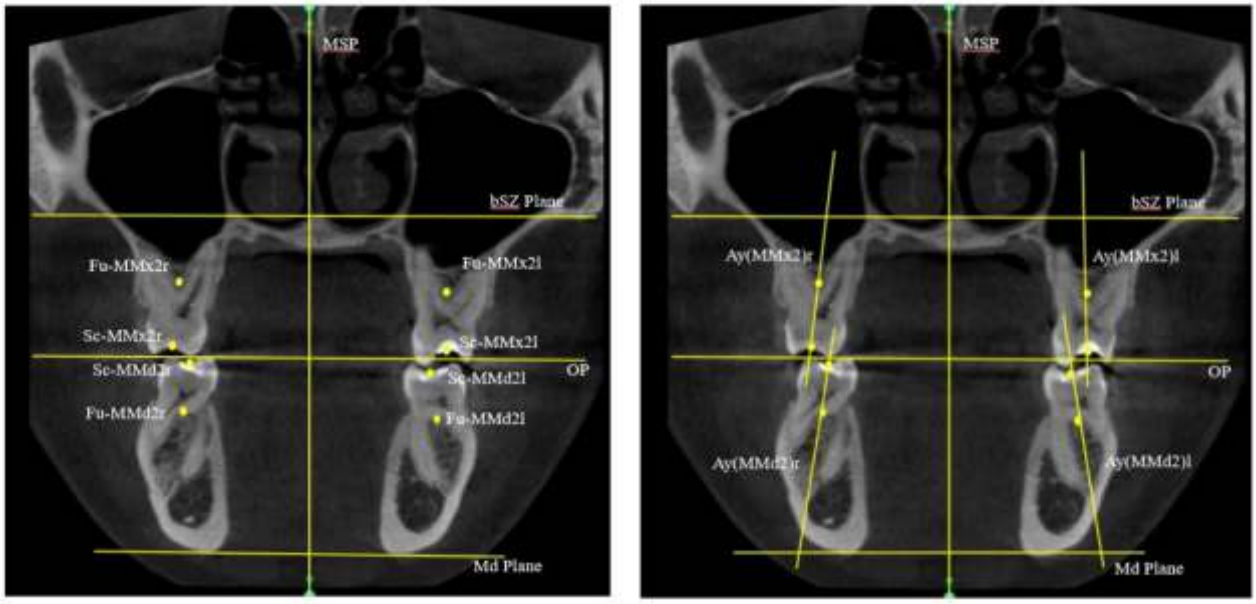
CBCT images were oriented in accordance with the Frankfort horizontal plane (FHP).

Images were oriented according to the tooth's long axis *(Figures 1 and 2)* and visualized in coronal slices. Dental measurements were then related to both crown and root of the tooth. These measurements were achieved using a median reference plane and a set of points and radiographic reference lines *(Figures 1 and 2, Table 1)*.

A section through each tooth measured it at its widest occlusal buccolingual distance and was

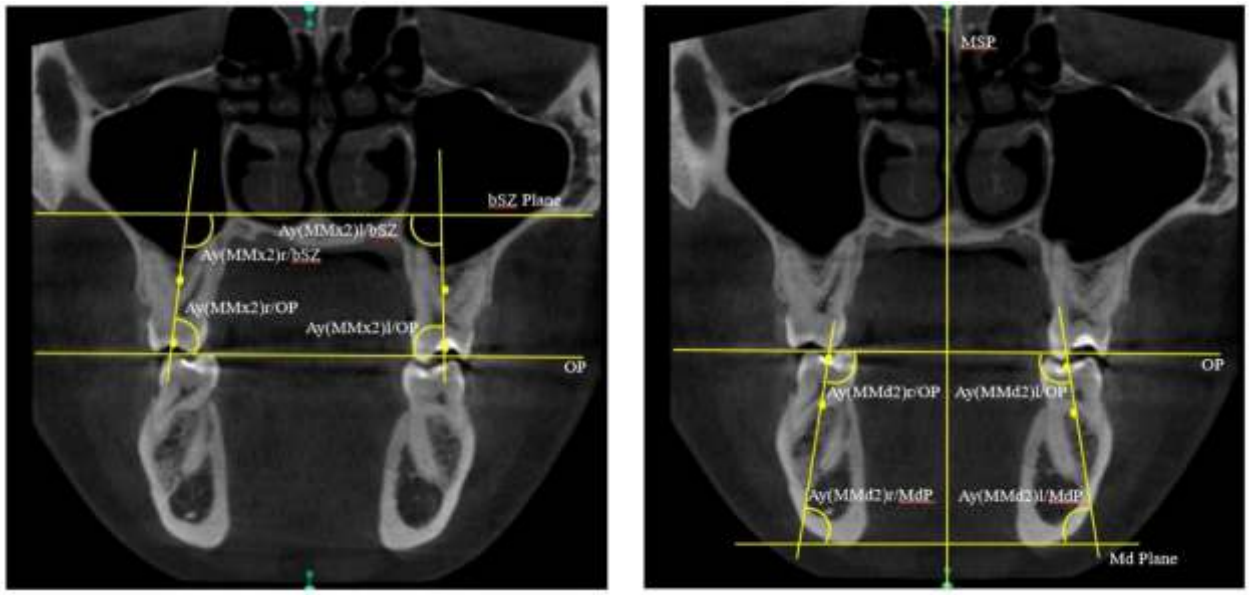
Table 1: *Landmarks, reference planes and angular measurements*

	Definition
Landmark	
Fu-MMx2r and Fu-MMx2l	Furcation of the maxillary second molar (right and left)
Sc-MMx2r and Sc-MMx2l	Central fissure of the maxillary second molar (right and left)
Fu-MMd2r and Fu-MMd2l	Furcation of the mandibular second molar (right and left)
Sc-MMd2r and Sc-MMd2l	Central fissure of the mandibular second molar (right and left)
Reference lines and planes	
Ay(MMx2)r and Ay(MMx2)l	Long axis of the maxillary molar (Longitudinal axis of the maxillary second molar) = Line drawn between the deepest concavity between palatal and vestibular cusps and the furcation of the maxillary second molar roots.
Ay(MMd2)r and Ay(MMd2)l	Long axis of the mandibular molar (Longitudinal Axis of the second mandibular molar)
Sub-Bizygomatic Plane (bSZP)	Line joining the lower borders of both left and right zygoma (left and right).
Mandibular Plane (MdP)	Line joining the border of bilateral second molars alveolar bone.
Occlusal Plane (OP)	Line passing by cusps of both left and right sides second molars
Median Sagittal Plane (MSP)	Line that involves the Nasion point and Chin point.
Angular measurement	
Ay(MMx2)r/bSZP and Ay(MMx2)l/bSZP	Angle formed by the maxillary second molar and the bi-sub-zygomatic plane
Ay(MMx2)r/OP and Ay(MMx2)l/OP	Angle formed by the maxillary second molar axis and the occlusal plane.
Ay(MMd2)r/OP and Ay(MMd2)l/OP	Angle formed by the mandibular second molar axis and the occlusal plane
Ay(MMd2)r/MdP and Ay(MMd2)l/MdP	Angle formed by the mandibular second molar axis and the mandibular plane.



a b

Figure 1 : *Cephalometric Points and Planes (a and b)*



a b

Figure 2: *Angular measurements (a: maxilla; b : mandible)*

adjusted on the axial and sagittal split window respectively. All angular measurements were carried out on the coronal split window of the imaging software using the built-in angle measuring tool. Dental reference points were used to evaluate buccolingual inclinations of permanent maxillary and mandibular second molars.

Statistical Data Processing

All measurements were performed by the same operator (S.O.K.)

Data was statistically analyzed using the SPSS (Statistical Package for Social Sciences) 22.0 for Windows (IBM). We used the normality test (Kolmogorov-Smirnov) to check the normality of the investigated variables distribution.

Twenty-five randomly selected subjects were measured again by the same examiner after 2 weeks to test for intraexaminer reproducibility. A paired t-test was carried out for tooth inclination measurements. The test of Kruskal-Wallis was used to compare more than 2 means in case the variances were different. The significance was predetermined at $p < 0.05$

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Table 2 : *Distribution of first molar absence*

Arch	Maxillary arch		Mandibular arch		Total
	Right side	Left side	Right side	Left side	
Absence of the first molar	14 (17.5%)	11 (13.75%)	43 (53.75%)	12 (15%)	80 (100%)

Results

The sample population included 101 untreated adults among with 47 males (mean age 50.32 years ± 13.94 years) and 54 females (mean age 47.46 years ±11.60 years) who all met inclusion requirements. No statistically significant difference (p =0.26) was found between age and both genders.

Intraclass coefficients were between 0.883 and 0.997, indicating that the operator was consistent during repeated measurements. the intraexaminer reliability test showed no significant differences between tooth inclination measurements.

We selected two subgroups of patients: fully dentate patients and patients with an absent first molar. *(Table 2)*

The distribution of absent molars shows that the right mandibular hemi-arcade is the most affected. In more than half of the cases (53.75%), the first right mandibular molar is absent.

While for the other sectors, the first molar is absent at the same frequency. *(Table 2)*

The inclination of the second right mandibular molar shows a significant difference between the group of fully dentate patients and the group of patients with a first molar absent (p=0.001); the angle Ay(MMd2)r/MdP being more closed in partially toothed subjects (86.7°). In otherwords, only the second right mandibular molar has a more pronounced bucco-lingual inclination. *(Table 3)*

Table 3: *Comparison of cephalometric variables according to dentition.*

Parameters	Patient dentate (n=21)	Patient with a first molar absent (n=80)	
	Mean (°)	Mean (°)	*p*
Ay(MMx2)r/bSZP	118.47	118.16	0.123
Ay(MMx2)l/bSZP	122.47	119.46	0.850
Ay(MMd2)r/MdP	103.42	86.7	0.001*
Ay(MMd2)l/MdP	103.32	100.14	0.458
Ay(MMx2)r/OP	61.26	62.42	0.840
Ay(MMx2)l/OP	58.68	59.04	0.576
Ay(MMd2)r/OP	77.42	76.43	0.982
Ay(MMd2)l/OP	76.89	77.00	0.791

The mean values of the angle of inclination of the second molars with respect to the three reference planes (bSZP, MdP and OP) do not show statistically significant differences by gender for any edentulousness.

Table 4: *Comparison of inclination differences in dental measurements according to gender*

Patient Cephalometric Parameter	Dentate Female (n=11)	Dentate Male (n=10)	Female with a first molar absent (n=43)	Male with a first molar absent (n=37)	
	Mean (°)	Mean (°)	Mean (°)	Mean (°)	*p*
Ay(MMx2)/bSZP	0.23	2.66	5.50	1.42	0.22
Ay(MMd2)/MdP	5.00	-1.66	0.83	-0.42	0.28
Ay(MMx2)/OP	-3.30	-3.45	-4.75	1.14	0.76
Ay(MMd2)/OP	-1.00	0.83	0.58	-2.42	0.82

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Discussion

Using the CBCT in the present study, we mainly found out that there were statistically significant differences in the buccolingual inclination of molars between the group of partial edentulous and the group of non-edentulous. The loss of the first mandibular molar generally leads to a lingualisation of the second mandibular molars.

The buccolingual inclination of the 2nd mandibular molar in patients with partial edentulism was more pronounced on the right than on the left, whereas these inclinations would invariably be similar on both sides in subjects with fully dentate, regardless of the typology according to Grosso[22]

In addition to changes in the position of the unopposed tooth following loss of an antagonist, a number of positional changes of teeth adjacent to the site of tooth loss may also take place. These spontaneous movements are clinically useful in some situations that may be beneficial to an orthodontic outcome[23]. They usually take the form of drifting and tipping of teeth adjacent to an extraction site. We may define drifting as the bodily horizontal movement of a tooth within the alveolar bone, which can be in a mesial, distal, lingual or buccal direction, whereas tipping may be defined as the rotational movement of a tooth within bone about an axis located on its root length.

A number of authors[24,25] have described tipping and drifting, but have not attempted to quantify these positional changes. More recent evidence[26,2] demonstrates that tipping, particularly at sites distal to the site of tooth loss, is very common following posterior tooth loss and is particularly extreme in the lower arch where tipping of such a tooth may be up to 43°, with a mean tip of 20°.

The loss of one or several teeth, if unreplaced, leads to troubles of the whole dental system. This loss may result in a real imbalance of forces and gradually affect the dental occlusion. Teeth support themselves. Thus, a tooth that loses its opposing tooth, will clarify the occlusal contact, and this less firmly stable tooth will remain in such new available space. Once one of them is lost, adjacent teeth are no longer stable in their original position, and may tilt in the available space.

A tooth that loses its distal or mesial tooth, will also migrate to that available space. These new patterns may constitute the causes of malocclusions and tooth decay.

Thilander and Skagius[28] found that residual spaces after first molar extraction are distributed mainly at the posterior and partially at the anterior dental arches in both jaws. On the other hand, Laine and Hausen[29] found that residual spaces after first molar extractions are distributed over the whole of the dental arch in the mandible, whereas in the maxillary arch these spaces are limited between canines and second permanent molars. In the anterior maxillary area, a correlation has been found between spacing and extractions of permanent teeth mesial to first molars.

Our results suggest that the second position of the mandibular molar on the edentulism side was more buccal, which would require high chewing forces.

However, the alternated bilateral chewing is the ideal pattern to stimulate structures that support the masticatory function, allowing wide excursions, physiological occlusal contacts, a synchronous bilateral muscular activity, and a uniforme force to chew food[30].

These results suggest that people with missing unilateral posterior teeth had a greater preference for chewing than those with fully serrated teeth, and that missing unilateral posterior teeth could be a risk factor for excessive prevalence of chewing. These results are consistent with those of Yatamasaki[31].The unilateral loss of posterior teeth unconsciously affects chewing prevalence.

The chewing force or masticatory function caused by the jaw muscles impacts not only on dental positions and shapes of dental arch, but also on mandibular shapes and structures[32,33].

Structural and functional changes that result from the loss of one or several teeth, may be considered on the one hand as an adjustment to the new situation, and as a pathological condition on the other hand. There are important variations between individuals following the loss of one or several teeth.

Buccolingual crown inclination is one of the six keys to normal occlusion[34]. Optimum inclination of anterior teeth is necessary for obtaining normal overbite and posterior occlusion, whereas optimum inclination of posterior teeth is necessary for obtaining a proper occlusion with maximum intercuspation and for avoiding functional interferences[20]. In addition, the upright positioning of teeth in the center of the alveolus is essential for stable occlusion and better periodontal conditions[35].

Therefore, orthodontists must know the anatomical limits of tooth movement to secure proper torque control.

In order to reach this goal, it is necessary that the patient exhibits an optimal transverse dimension of maxillary dentoalveolar bone, as well as appropriate buccolingual inclinations of the posterior teeth[36-41].

This is necessary for both functional and esthetic occlusion. Thus, the torque values of the posterior brackets are important in achieving this goal and must interface favorably with the lateral and protrusive forces

The determination of the smile components in a patient is very important in designing a successful orthodontic treatment plan[42]. Posterior components of the smile include the inclinations of the posterior teeth, which have an important effect on esthetics and proper function.

However, we found no significant differences related to gender.

Marcus and al[43] reported that the prevalence of edentulousness was not related to gender, while Hoover and Mc Dermount[44] noted that the edentulous effect was higher in males than females.

In the present study, coronal slices of maxillary and mandibular CT scan were used to measure the inclination of the molar longitudinal axis as suggested by Tsumori and al[14], and Masumoto and al[45].In the partial edentulous group, permanent mandibular first molars have a higher prevalence of loss due to decay[46].

The high frequency of first molar loss may be due to its early eruption and the complex nature of its occlusal surface. When it is lost, neighboring teeth drift with changes in magnitude and types of movements.

Second and third mandibular molars usually feature a mesial and marked lingual latch while bicuspids are distal[11,46,47].

Changes in tooth inclination may represent a key factor of tooth stability. Mandibular molars naturally tend to lingually tilt.

Alkhtib et al[48] found that there was an orientation of first molars inclinations in untreated adults whose maxillary molars feature a slight buccal inclination, and whose mandibular molar feature a slight lingual inclination.

According to Dawson,[49] there are two reasons for the existence of the curve of Wilson. The first is for optimal resistance to loading, whereby the buccolingual inclination of the posterior teeth parallels the inward pull and orientation of the internal pterygoid muscle contraction to produce the greatest resistance to masticatory forces. Secondly, inward inclination of the occlusal table allows open access to food as it is being chewed, facilitating the masticatory process. Okeson[50] explained that the occlusal curvature exists to have the most effective use of cuspal contacts, while avoiding nonfunctional contacts known as balancing interferences.

Nanda[51] stated that a small curve of Wilson between the buccal segments allows for proper occlusal function, but that "an accentuated curve will result in balancing interferences, especially in the second molar area." It is important to find out what an appropriate amount of buccolingual tooth inclination is for adequate function, and to quantify it so that we can have treatment goals that are well-supported by evidence. Given the orientation of anatomic structures described by Dawson[49], it would be expected that the bone inclination would also be oriented this way for optimal masticatory loading.

A potential link between buccolingual inclination of molars and vertical facial type has been studied, but the results are scattered and inconsistent [45,52,53,54,14,55,56.]

Orthodontic philosophies have varied in the irrationale of an occlusal curvature and molar torque.

Andrews[55] explained, in his six-element philosophy, that "each crown must be inclined so that the occlusal surface can interface and function optimally with the teeth in the opposing arch." McNamara[56] suggested that one of the goals of orthodontic treatment should be to flatten the occlusal plane and level the curve of Wilson. Conversely, Dawson[49] stated that when the curve of Wilson is made too flat, ease of masticatory function may be impaired.

These authors used CBCT images before treatment to evaluate teeth inclination.

One of the advantages of using CBCT is the ability to visualize the whole tooth, thus removing some of the uncertainty in long-axis inclination that can result from using casts with uneven cusp wear or tooth morphology[57,34,58,53]. In this study, the whole anatomic crown was used to determine the long axis of the second molars.

Tooth inclination seems to be influenced by tooth adaptation or skeletal differences, and their evaluation could help to achieve a more detailed treatment program. Other studies are required to bring to light more accurate and conclusive data.

Our study sample included only subjects who have attained full growth. In this sample the absence of the first molar is mainly observed at the mandible on the right side. Curtis et al[59] pointed out that removable mandibular prosthesis were more frequently needed. Malocclusions may be complex due to migration of bicuspids into the former site or extraction area. In such conditions, aesthetic and functional results can only be achieved through an interdisciplinary approach including orthodontics, implantology and prosthodontics[60].

It is known that 30% of adults in orthodontics need an interdisciplinary patient care to achieve best

results[61].

It would therefore be logical to consider maintaining some degree of a curve of Wilson after orthodontic treatment, to be consistent with the physiologic needs of masticatory function and to encourage stability of treatment by remaining consistent with natural findings.

Besides, we obtained our sample from a private dental office in which patients were admitted for diagnostic and the planning of various dental care. They didn't therefore, represent all the adults as a whole since this convenience sample was built up retrospectively, by taking into account only patients who had a tomographic check-up.

So, this study was limited by the convenience sampling method used. Despite this, the findings are useful in providing insight on impact of tooth loss. The study did not investigate reasons why subjects didn't use dental prostheses despite having missing teeth, although it could be implied that they do not perceive the need for a prosthesis. A qualitative study may be undertaken to understand a lot of thing else. Gaps remain as to whether one should continue to provide prosthodontic treatment for partially dentate patients if their missing teeth do not significantly affect their lives.

Furthermore, the cause and duration of a number of posterior teeth loss have not been stated, so missing teeth were evaluated through a panoramic reconstruction by analyzing the occlusion discontinuity.

A deeper investigation, involving a greater number of cases should be carried out.

Conclusion

Buccolingual inclination is part of the evaluation of orthodontic results since years. We have used the CBCT to measure this inclination on the basis of the major axis of the tooth. It appears that there is a significant increase in the lingual switching of mandibular molars adjacent to the partial edentulous sites. Right mandibular second molars of the subjects with the first mandibular molar absent appeared to be approximately 14° more incline in lingual direction than those of the other subjects. These changes in molars inclination may represent a key factor in stabilizing the orthodontically redesigned, provided that the lack of teeth is prosthetically compensated.

Contributors

All authors contributed to the design, data collection, analysis and writeup of the manusctipt.

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Self

Conflict of Interests

Nil

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