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RESEARCH ARTICLE

Assessment of lower third molar space: A comparative radiographic study

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Objective: The aim of this study was to assess lower third molar space using four different radiographic reconstructed Cone Beam Computed Tomography (CBCT) images: orthopantomogram, lateral cephalogram, multiplanar CBCT and a newly introduced three-dimensional (3D) simulation technique.
Methods: The CBCT scans of 32 individuals (20.97 ± 2.152 years) with a total of 50 lower third molars were collected and analyzed. The ratio between the necessary space and available space for lower third molars was calculated on each radiographic reconstructed image. Repeated-measure analysis of variance followed by multiple comparison tests were used.
Results: The mean ratio was significantly smaller with cephalograms (0.611 ± 0.263), followed respectively by orthopantomograms (0.756 ± 0.221), multiplanar CBCT (0.789 ± 0.191) and 3D simulation technique (0.807 ± 0.193) ($p < 0.001$). The lowest mean difference was recorded between multiplanar CBCT and 3D simulation technique (0.017). Intraclass correlation coefficient was strong (>0.90) for all techniques except cephalograms.
Conclusions: The assessment of the lower third molar space differs according to the adopted imaging technique. Three-dimensional simulation technique is a useful novel technology that allows an exploration of the crown in many different dimensions and orientations, giving more predictable results than the conventional methods.
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Introduction

The decision regarding the fate of impacted lower third molars is typically controversial. While some factors including cyst formation, root resorption of the adjacent second molars[1] and orthodontic molar distalisation movements may impose the extraction decision,[2] other factors such as age, medical status,[1] space closure cases[3] and sufficient eruption space[4] might favour the conservation decision. In some pathological circumstances, retained third molars are accompanied with quite serious risk factors. Of these, pericoronitis is the most common occurrence, as it appears with 20–30% of partially erupted and 10% of completely subgingival third molars, followed by dental caries.[2] External root resorption of adjacent second molar roots is another risk factor with varying incidence. Also, dentigerous cysts and odontogenic keratocysts can occur in 1.2 to 2.3% of the cases around the dental follicular tissue of the impacted tooth.[2]

In orthodontics, the decision of extracting or keeping lower third molars is usually made at the end of treatment where the orthodontist have to measure the distal

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space and compare it to the third molar crown diameter for better decision making process. Following an orthodontic treatment involving premolars extraction, 5 to 6 mm of retromolar space can be formed, giving the third molar a chance to erupt and become functional whenever it presents a favorable angulation.[5]

Regarding the aetiology of third molars impaction, insufficiency of the available retro-molar space has long been considered the main reason of this occurrence.[4,6,7] This variable measured from the distal surface of the second molar to the ascending ramus was used in numerous studies as a major predictor.[7–9] Björk et al showed that this space was remarkably reduced in 90% of the cases of impacted third molars.[6] They proved that the lack of space, indeed, was a result of a combination of various skeletal and developmental factors.

Later on, researchers investigated other predictors for third molar impaction such as angulation of the tooth[10,11] and its stage of mineralisation.[6,12] Olive and Basford assessed the third molar space by estimating the space/width ratio (SWR); which is equal to the retromolar space divided by the mesio-distal third molar crown diameter.[7] When this ratio was equal or greater than 1, it is likely that 70% of the third molars will erupt.[4]

In order to assess the space for the third molars, different radiographic techniques, using only two-dimensional measurements, were documented in the literature.[7,13,14] Panoramic radiography and lateral cephalographs were widely used. Even more so, the reproducibility and validity of the estimates performed on these radiographs along with intraoral bitewings and 60-degree rotated cephalograms were compared to each other and to those measured directly on dried skulls.[7]

However, the fact that projection errors emerged with these techniques, more recently the use of Cone Beam Computed Tomography (CBCT) became popular.[15] Bearing in mind the important anatomical variations that a lower third molar can present and its complex relationship to the surrounding structures especially in the sagittal aspect,[16,17] several studies assessed the retromolar space and the width of the third molar crown using CBCT scans.[15,18]

Nevertheless, the main focus was based essentially on linear dimensions without considering the three-dimensional position of the impacted tooth. Relying only on two-dimensional measurements will not provide sufficient information to accurately measure the SWR, particularly when the tooth is angulated buccally or lingually.

To our best knowledge, no studies until present-day had integrated the segmentation technology in evaluating the SWR. Hence, this study aimed to compare lower third molar space using four radiographic images reconstructed from CBCT scans and to validate a novel 3D simulation technique. The null hypothesis is that there is no difference between the latter technique and the other reconstructed images.

Methods and materials

This retrospective study has been reviewed and accepted by the Saint Joseph University of Beirut Institutional Review Board, reference number USJ-2021–27.

Initial sample selection

1051 previously taken CBCT scans between January 2019 and September 2021 were randomly selected from the archives of the dental hospital at the university where patients in need of miscellaneous dental inquiries signed a detailed informed consent allowing the use of their data for the purpose of scientific research. The CBCTs were acquired in the same conditions using Newtom VGI CBCT machine 15 × 15 field of view and 0.3 mm voxel size (QR s.r.l via Silverstrini, 20–37135-Verona, Italy). Projection data were collected with a device rotating 360 degrees around patients over a total acquisition time of 18 seconds.

Inclusion and exclusion criteria

Patients included in the study had:

- Impacted lower third molar(s) embedded in a bony crypt and positioned below the cementoenamel junction (CEJ) of the adjacent second molar.
- Full permanent dentition.
- No missing or extracted permanent teeth.
- Complete mineralisation of the third molar crown.
- Absence of previous orthodontic or orthognatic surgical treatment.

Patients excluded from the study had:

- Pathological conditions at the molar region (cysts, tumours or extensive caries).
- Craniofacial malformations.
- Erupted lower third molar(s).
- Presence of artefacts that might distort the measurements in the retro-molar area.

Final sample selection

Following the inclusion and exclusion criteria, 1019 CBCT scans were excluded and thirty-two scans were included, as shown in the sample selection flow chart (Figure 1). The selected patients had one or two impacted lower third molars with a total of 50 examined teeth.

Statistical power analysis was applied to determine if the sample size was large enough to detect significant difference between groups for the mean ratio measurements. The power post-test obtained was 0.997 indicating a lower type II error.

Image evaluation and head orientation

Images were evaluated using the Blue Sky Plan® 4.7.55 (Blue Sky Bio, LLC, Grayslake, IL, USA). In order to prevent distortion, images were re-oriented according to

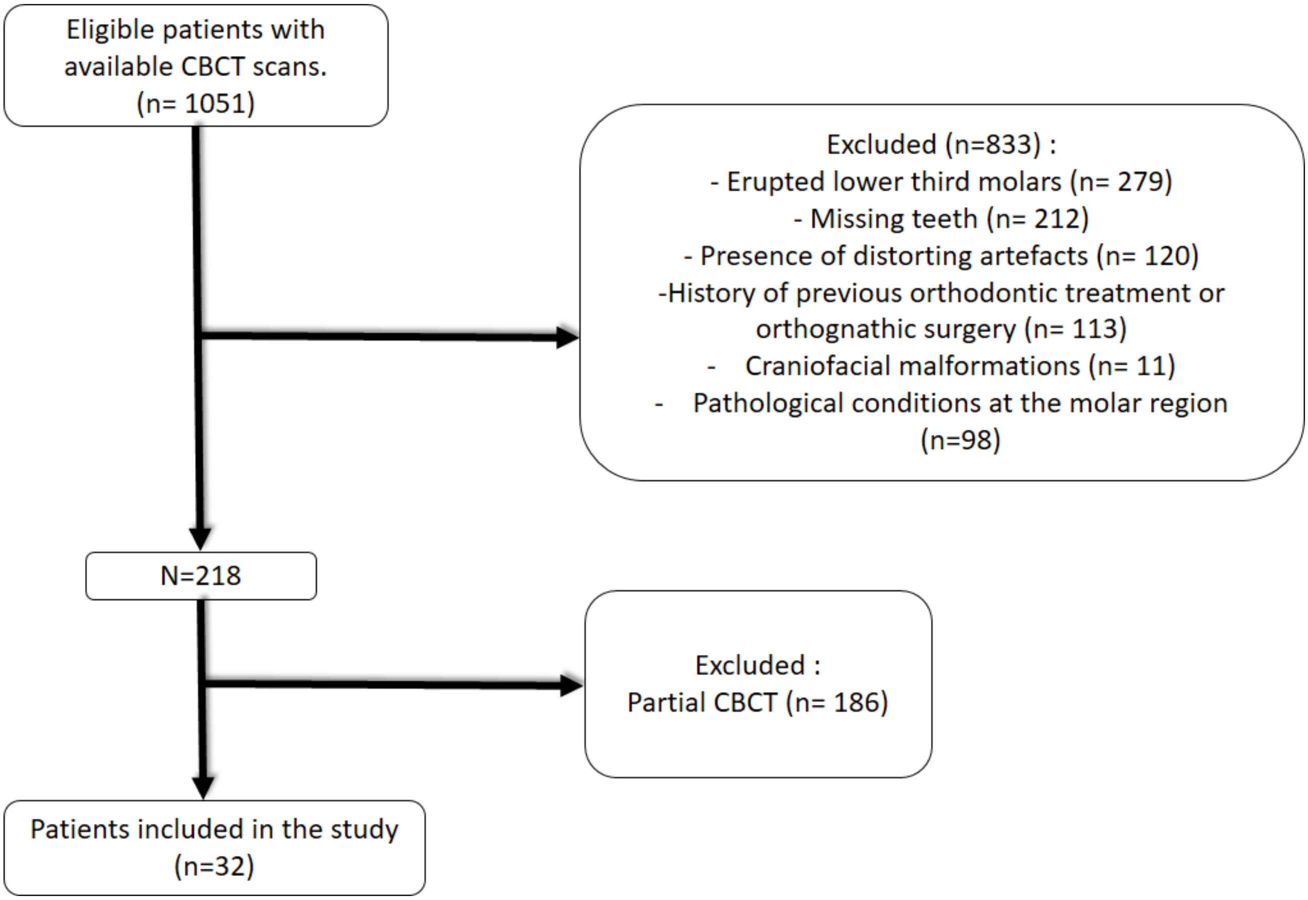

Figure 1 Flow chart showing sample selection

the occlusal plane in the sagittal and frontal view. In the axial view, the plane was reoriented to the line joining the distal surfaces of the right and left lower second molars.

Measurements
In order to achieve linear measurements, two planes were defined:

- Occlusal plane (OP): a horizontal line passing through molars and premolars cusps.
- Tangent plane (TP): a line tangent to the distal surface of the mandibular second molar and perpendicular to the OP.

CBCT-generated orthopantomogram (CBCT-OPG): Panoramic images were reconstructed from imported CBCT DICOM files. A panoramic curve was drawn on the axial image passing through the middle of each tooth in the bucco-lingual direction at the level of the CEJ. A 2D panoramic image was generated and two linear measurements were recorded according to the methodology used by Niedzielska et al.[9] (Figure 2):

- Available space (AS): distance between TP and the anterior border of the ascending ramus along the OP.
- Necessary space (NS): mesio-distal width of the impacted third molar measured from the most mesial to the most distal point of the crown.

Then the ratios of the two recorded measures (AS/NS) were calculated.

CBCT-generated lateral cephalogram (CBCT-Ceph): Cephalometric images were reconstructed from imported CBCT DICOM files and cephalometric mode was chosen. The cephalometric assessment technique employed was adopted from Behbehani et al[10] study. The same parameters (AS and NS) were taken with the corresponding definitions as described on the panoramic mode (Figure 3). The obtained ratios of the retro-molar space to the width of the third molar were also calculated.

Multiplanar CBCT (MPR-CBCT): As Marchiori et al[15] described a recent technique concerning the CBCT based assessment for the lower third molar space, the same technique was adopted in this study where AS and NS were measured as:

- AS: distance between the distal border of the second molar and the anterior border of the ascending ramus. The latter line was fixed on the panoramic view

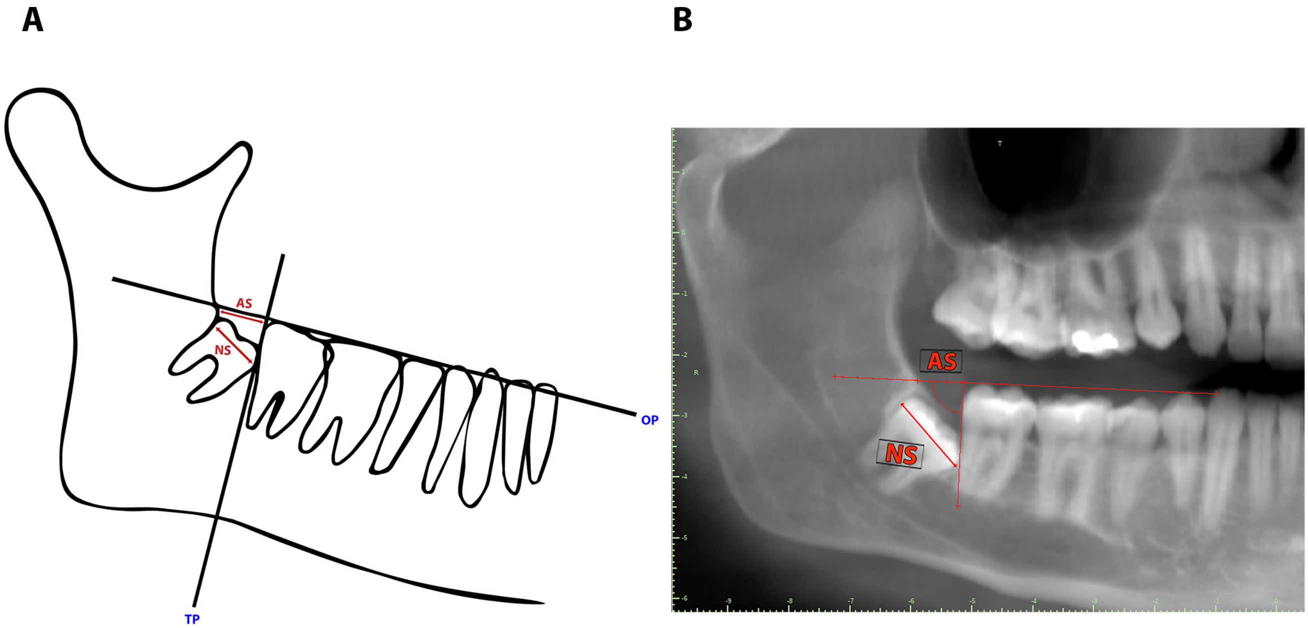

Figure 2 Cone beam computed tomography (CBCT)-generated orthopantomographic measures: (**A**) schematic drawing showing the NS (Necessary space), AS (Available space), OP (Occlusal plane) and TP (Tangent plane). (**B**) Radiographic representation of the measures.

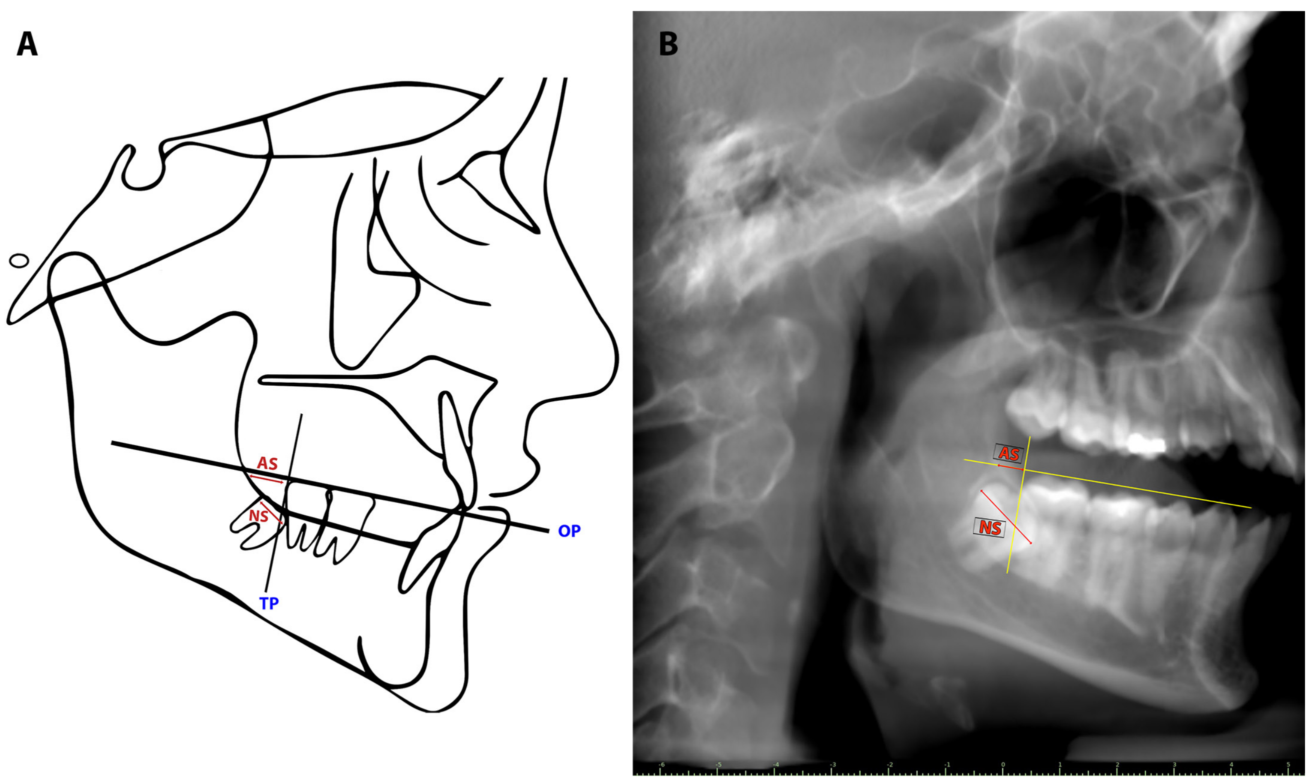

Figure 3 Cone beam computed tomography (CBCT)-generated lateral cephalometric measures: (**A**) schematic drawing showing the NS (Necessary space), AS (Available space), OP (Occlusal plane) and TP (Tangent plane). (**B**) Radiographic representation of the measures.

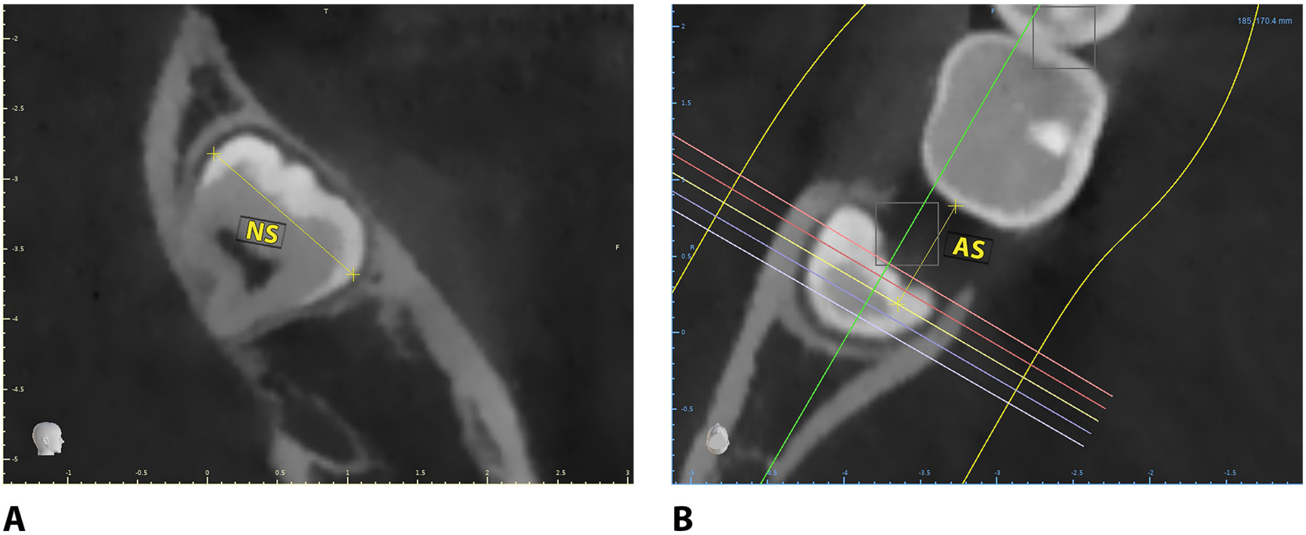

Figure 4 Multiplanar Cone beam computed tomography (CBCT) measures: (**A**) radiographic representation showing the NS (Necessary space) and (**B**) AS (Available space).

and then the distance was measured on the axial view (Figure 4A).

- NS: mesio-distal width of the impacted third molar measured from the most mesial to the most distal point of the crown on the sagittal view (Figure 4B).

Ratios between these two measures were subsequently evaluated to assess the sufficiency of space for the lower third molar.

3D simulation technique: After loading the DICOM files into the Blue Sky Plan® 4.7.55 software, the model editing option was used in order to perform the segmentation procedure.

First, the impacted crown was segmented separately by delimiting it automatically and then rechecking it manually. The region of interest covered the whole crown where the cusps of the crown represented the upper limit and the CEJ represented the lower limit. The segmented crown was then saved in STL (Stereolithography) format. Second, the whole mandible was segmented and saved as a CT surface in the software (Figure 5A). Later, the STL file was added to the segmented mandible and the crown was moved upwards in order to simulate an ideal eruption: the horizontal dimension corresponded to an alignment of the principal groove with the first and second molars. As for the vertical aspect, the marginal ridge of the occlusal surface of the third molar was positioned at the same height as the second molar's distal marginal ridge. (Figure 5B and C).

In order to evaluate the available space, an artificial line was placed at the conjunction point between the occlusal plane and the ascending ramus (Figure 5D). This line served as a guide where the space occupied by the segmented crown anteriorly presented the available space. As for the necessary space, it was measured from the most mesial to the most distal point of the segmented crown (Figure 6A and B).

Statistical analysis

The IBM SPSS statistics (version 25.0) was used to perform the statistical analyses. The level of significance was set at 5.0%.

The main outcome variable of the study was the ratio between AS and NS. The same investigator applied measurements twice on 10 wisdom teeth chosen arbitrarily. Reproducibility of the measurements was assessed using the intraclass correlation coefficient (ICC) with its 95% confidence interval. The ICC was greater than 0.90 for all radiographic techniques indicating a good reproducibility except for cephalometric technique (0.75).

Repeated-measure analysis of variance followed by Bonferroni multiple comparison tests were performed to compare the mean ratio between the four radiographic techniques.

Results

Description of the study population

The lower wisdom teeth of 32 subjects (12 males and 20 females) were measured. The mean age was 20.97 ± 2.152 years (Range: 18 to 25 years). The mean age of males was 20.45 ± 2.207 years and the mean age of females was 21.25 ± 2.124 years. 50 mandibular wisdom teeth (38: 22 teeth; 48: 28 teeth) were analysed. The demographic description is shown in the table below (Table 1).

Comparison of the mean ratio

The minimum, maximum, mean and standard-deviation of the ratio are displayed in the following table (Table 2). In addition, a graphic illustration of the mean ratios obtained with the four different radiographic reconstructed images is displayed in Figure 7.

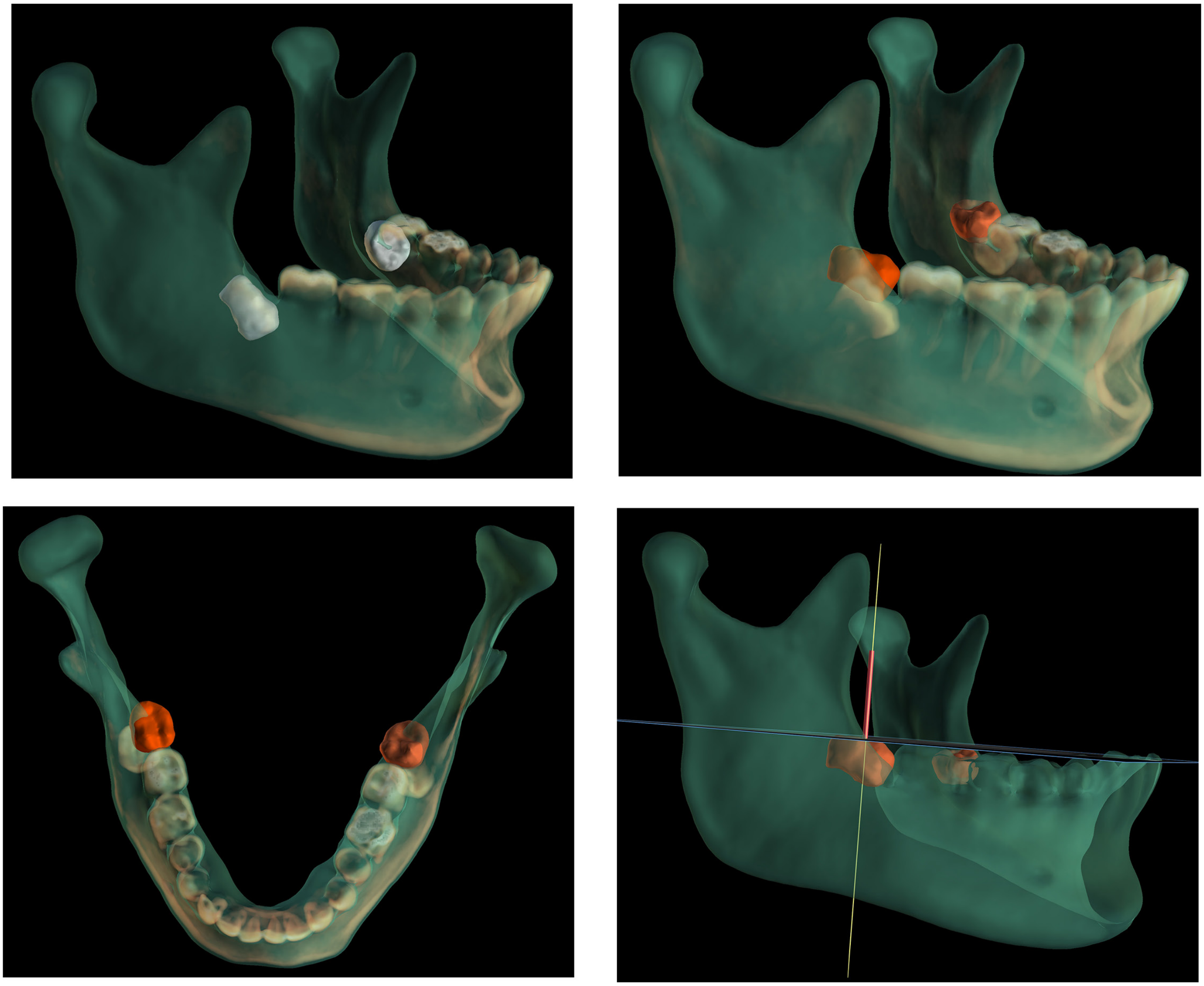

Figure 5 Three-dimensional simulation technique: (**A**) Digitally reconstructed image showing the segmented mandible and wisdom teeth (lateral view). (**B**) Image showing the virtually erupted crown (in orange) aligned in the ideal position in the lateral view and (**C**) occlusal view. (**D**) Image showing the intersection between the occlusal horizontal plane and the artificial vertical line representing the anterior border of the ascending ramus (lateral view).

This study revealed that the mean ratio was significantly different between the four radiographic imaging techniques (-p-value<0.001); it was significantly smaller with CBCT-Ceph (0.611 ± 0.263), followed by CBCT-OPG (0.756 ± 0.221) and MPR-CBCT (0.789 ± 0.191). It was significantly greater with 3D simulation technique (0.807 ± 0.193).

The results of the multiple comparison tests are represented in the following table (Table 3). According to these results, the null hypothesis was rejected.

Discussion

It is well known that the eruption of the lower third molars can be affected by the crown's dimension and retro-molar space.[9] Among other several factors, it was ascertained that retromolar space represents a key factor in predicting the eruption of lower third molars. This was reflected by the fact that a gain of one millimetre in the eruption space, decreases by 29% the risk of impaction, while a gain of one degree in the angulation of the third molar relative to the occlusal plane, improved by 11% the risk of impaction.[10] Indeed, although the angulation assessment is much easier to measure, third molars in vertical position will stay impacted when facing an insufficient retromolar space. In an opposing manner, a severely angulated tooth will not erupt despite any space management.

The space assessment was usually done using different 2D techniques such as cephalometric,[10] panoramic[9] and different CBCT views.[15] Several articles have studied and compared the accuracy of these techniques in predicting

Figure 6 Cone beam computed tomography (CBCT) images showing the measures on the virtually aligned crown: (**A**) Red line representing the necessary space and yellow line representing the available space in the frontal view. (**B**) Bucco-lingual position of the virtually aligned crown in the axial view.

the mesio-distal space-based ratio.[7,14] However, all of them focused on linear measurements without taking into consideration either the whole volume of the crown or its position on the jaw.

Recently, the evolution of radiographic assessment software has allowed the usage of further innovative options in dentistry. Virtual simulation and threshold-based segmentation has been recently adopted in many clinical circumstances thus avoiding decision making errors arising with the conventional methods.[19] In fact, digital simulation is being frequently used in many situations regarding the surgical planning and prognosis of the third molars.[20] The present study's purpose was to compare the accuracy of a CBCT based orthopantomogram, lateral cephalogram, axial and sagittal views and a novel assessment technique based on threshold segmentation in determining the SWR of the lower third molar.

The obtained results revealed a significant statistical difference between all studied imaging techniques. CBCT-Ceph measurements recorded the lowest ratio followed respectively by CBCT-OPG, MPR-CBCT and 3D simulation technique. Thus, it can be hypothesised that some techniques underestimate the available and necessary space of the lower third molar particularly when considering a single linear measurement instead of taking into account the whole volume of the crown.

Concerning the OPG measurement outcomes, the current results can be elucidated by Brasil et al who pointed out an underestimation of the accommodation space for the lower third molars with the conventional panoramic images compared to CBCT scans.[13] The authors justified such results by the fact that the external oblique ridge, that is anatomically a continuation of the anterior border of the ramus, is located posteriorly on the panoramic image causing a biased measurement. In addition, the superposition of the ascending ramus over the impacted tooth might have negatively influenced the evaluated space. Despite the difference with the latter study concerning the origin of panoramic images, it has been shown that with the new generation of CBCT machines, panoramic reconstructions from CBCTs can provide similar image quality and clear identification of anatomical structures when compared to standard panoramic images.[21] A recent study, comparing the linear measurements between reformatted panoramic slices and dry skulls, confirmed the accuracy of the former imaging technique taking into consideration the software and the voxel size.[22] In another radiographic evaluation of the tilting of third molars, Lupi et al found a significant difference between 3D (as CBCT) and 2D (as panoramic reconstructions from CBCT) images, due to geometric distortion of the latter images.[23] However, the authors explained the use of panoramic reconstructions instead of normal panoramic images, as the ultimate image results not from a single layer, but a sum of many layers parallel to the fixed panoramic line, in which only objects in the focal layer are shown. Thus,

Table 1 Demographic description of patients included in the study

Gender	*N*	*Mean age*
Male	12	20.45 ± 2.207
Female	20	21.25 ± 2.124

Table 2 Mean ratio in different radiographic reconstructed images

	Minimum	*Maximum*	*Mean*	*Std. Deviation*	*N*
CBCT-OPG	0.27	1.39	0.76	0.22	50
CBCT-Ceph	0.26	1.70	0.61	0.26	50
MPR-CBCT	0.49	1.30	0.79	0.19	50
3D Simulation	0.49	1.32	0.81	0.19	50

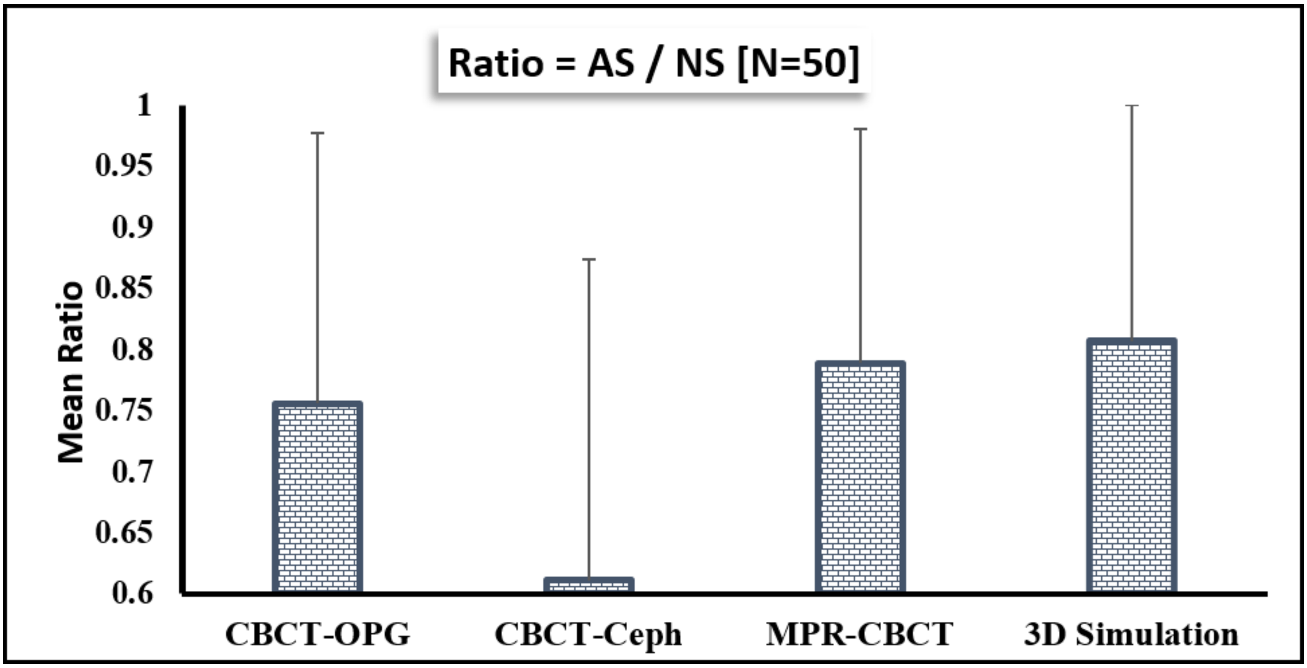

Figure 7 Graph showing the comparison of mean ratios among different radiographic techniques.

magnification and distortion errors because of tomographic movement, associated with panoramic X-rays, are bypassed. They concluded that while 3D to 2D reconstructions carry some geometric distortion, this was only a part of the total distortion acquired with the standard panoramic radiography.[23]

Concerning the CBCT-Ceph, although no studies have investigated the SWR using CBCT generated cephalographs, and due to the high reproducibility between the conventional and reconstructed techniques as shown in a systematic review,[24] the obtained results can be explained by Olive and Basford findings.[7]

The authors found that the least accurate results appeared with lateral cephalograms when compared to other radiographic techniques in terms of intra examiner reliability, reproducibility and validity of estimates. In fact, the non-reproducibility observed was due to structures superposition that may lead to difficulty in locating strategic landmarks such as the ascending ramus and the impacted teeth particularly when they are bilaterally impacted.

The significant difference detected between panoramic radiographs and lateral cephalographs can be elucidated by the fact that on panoramic images the two sides of the jaw can be clearly defined, which enables a more precise measurement on each side-without superimposition.[11]

Due to the mentioned assessment errors related to the conventional techniques, the present paper proposed a novel approach that relies on threshold segmentation and virtual simulation. The proposed method allows the clinician to properly investigate the SWR in terms of ideal position in a three-dimensional setting predicting the prognosis of the lower third molar. The comparison between all studied images illustrated in Table 3 showed that the simulation technique was the closest to MPR-CBCT since the lowest mean difference was recorded between these two imaging techniques (0.017).

Although there is limited data about the accuracy of CBCT assessment technique in estimating the SWR, this technique provides a detailed millimetric viewing of the requested zone in many orientations giving it a superior status in comparison to other 2D images.[25] Nevertheless, the difference detected between both imaging techniques (CBCT and digital simulation) might be due to the additional option provided by the simulation technique with regard to crown positioning and orientation.

Table 3 Multiple comparison tests between groups

(I) Radio	*(J) Radio*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*
CBCT-OPG	CBCT-Ceph	0.145	0.031	0.000
	MPR-CBCT	−0.034	0.013	0.015
	3D Simulation	−0.051	0.016	0.003
CBCT-Ceph	CBCT-OPG	−0.145	0.031	0.000
	MPR-CBCT	−0.178	0.033	0.000
	3D Simulation	−0.196	0.031	0.000
MPR-CBCT	CBCT-OPG	0.034	0.013	0.015
	CBCT-Ceph	0.178	0.033	0.000
	3D Simulation	−0.017	0.009	0.050
3D Simulation	CBCT-OPG	0.051	0.016	0.003
	CBCT-Ceph	0.196	0.031	0.000
	MPR-CBCT	0.017	0.009	0.050

Clinical relevance

In the era of digital dentistry, the current study came to provide the dentist with valuable additional information needed in establishing his treatment plan. The decision regarding the fate of the lower third molar presents an important matter in the treatment strategy, as its state depends on the accommodation space and position. In case of retention, the practitioner should be able to predict the potential position of the third molars based on the simulation technique, thus avoiding the possible pitfalls of the conventional 2D imaging techniques.

Study limitations

This study presented some limitations. First, it included a limited population. Second, the proposed simulation technique requires a learning curve and a fair knowledge of imaging software. Finally, SWR ratio is one of many predicting factors of third molar eruption, therefore further studies must consider the axial inclination of the tooth, in addition to the introduction of the soft tissue parameter as adjunctive predictors of eruption.

Conclusion

Based on the current results, the clinician should be aware of the potential mistakes made using the conventional CBCT generated images. Hence, a convenient assessment of the mandibular posterior space requires a special attention regarding the three-dimensional position of the lower third molar by adopting the simulation technique.

Contributors

YA: Writing, interpretation of data, BH: Project administration, critical revision, RY: Resources, validation, supervision, NG: Design of the work, software and methodology, JB: Conceptualisation, validation.

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