



Rapid Volume Measurement of Ameloblastoma Using the ABC/2 Technique

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Abstract

Objective To estimate tumour volume in patients with unilocular and multilocular ameloblastoma using computed tomography (CT) and cone beam computed tomography (CBCT) images by applying the ABC/2 estimation technique, and to compare these measurements with volumes obtained using MITK Workbench software (version 2016.11.0).

Materials and Methods Medical records of patients with histopathologically confirmed benign ameloblastoma from January 2008 to January 2018 were retrospectively reviewed. A total of 29 patients (18 males and 11 females) were included. Radiographic images were analysed, and tumour volumes were calculated using the ABC/2 estimation technique and compared with volumes derived from the open-source MITK Workbench software. The Wilcoxon signed-rank test was used to compare paired tumour volumes obtained using the two methods. Agreement between ABC/2 and MITK measurements was additionally assessed using Bland–Altman analysis, with calculation of the mean bias and 95% limits of agreement.

Result The mean age of the patients was 28.10 years (range 6–52 years). After screening for adequate image quality, CT and CBCT scans from 10 patients were included for volumetric comparison. The distribution of multilocular and unilocular ameloblastoma was similar. No statistically significant difference was observed between tumour volumes measured using the ABC/2 estimation technique and those calculated using MITK software ($p=0.58$, $z=-0.56$). Bland–Altman analysis demonstrated a mean bias of +0.16 mL (95% CI -2.05 to $+2.38$ mL), with 95% limits of agreement from -5.90 to $+6.22$ mL. Nine of the ten paired measurements were within the estimated limits of agreement.

Conclusion The ABC/2 estimation technique provides a rapid preliminary estimate of ameloblastoma volume, particularly for regularly shaped lesions. Bland–Altman analysis demonstrated minimal average systematic bias; however, the observed limits of agreement and their uncertainty do not establish interchangeability with MITK-based segmentation. These findings are preliminary because of the small sample size, pooled CT and CBCT data, and single-observer measurements.

Keywords Ameloblastoma · Cone-beam computed tomography · Image-based volume measurement · Lesion size

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Introduction

Ameloblastoma is the most common locally invasive benign odontogenic tumour of the jaw, generally affecting the posterior mandibular region and accounting for 11% of all odontogenic tumours in the head and neck region [1–4]. Precise radiographic assessment of lesion size and extent is important for effective treatment planning [5, 6].

Conventionally, radiographs such as orthopantomograms (OPGs) are used to measure these parameters. However, these methods are less sensitive to the extent of bone and soft-tissue invasion [5]. As an alternative, medical imaging techniques such as computed tomography (CT) and cone beam computed tomography (CBCT) have proven reliable for dimensional evaluation of well-defined radiolucent lesions in three-dimensional images. Additionally, the ability to visualize normal and abnormal anatomical structures can inform surgical planning [7].

The ABC/2 technique was designed to approximate the volume of round or ellipsoid masses, both regular and irregular, and has been used successfully to assess cerebral neoplasms and intracranial hemorrhage with similar dimensions [8, 9]. Coincidentally, ameloblastomas are round-to-ellipsoid, regular-to-irregular, similar to intracranial hemorrhage, and the ABC/2 technique could also be applied to measure ameloblastoma volume [10]. Therefore, the current study was conducted to measure ameloblastoma volume from CT and CBCT data using the ABC/2 technique. For comparison, the open-source Medical Imaging Interaction Toolkit (MITK) software, developed by the German Cancer Research Centre, was used as a reference [11]. It should be noted that the software was designed specifically for interactive segmentation and volumetric evaluation of neoplasms, and the source values can serve as a reliable control for the current study [12].

Materials and Methods

The study was approved by the Human Research and Ethics Committee at Universiti Sains Malaysia (USM) [USM/JEPeM/19010025]. Patient data from January 2008 to January 2018 were obtained from the Medical Record Unit at Hospital Universiti Sains Malaysia. The study included CT and CBCT data from patients diagnosed with unilocular or multilocular ameloblastoma. Metastatic cases were excluded. Additional details on patient gender, age at diagnosis, type of ameloblastoma, and tumour location were also reviewed. CT and CBCT images were retrieved from the Radiological Department at USM for patients with ameloblastoma prior to surgical intervention. Age groups were classified by decade. No formal sample size calculation was

performed due to the retrospective nature of the study and the limited availability of eligible imaging data. Therefore, the final sample size was determined by data availability, and the study should be interpreted as a preliminary exploratory analysis.

CT and CBCT images were retrieved retrospectively from the institutional radiology archive. Imaging parameters were extracted from available DICOM metadata where recorded. For CT datasets, slice thickness and reconstruction parameters were documented where available. For CBCT datasets, voxel size was recorded where available depending on the acquisition protocol used at the time of imaging.

CT and CBCT datasets were reviewed independently, and imaging acquisition parameters were recorded where available. Differences in voxel size, slice thickness, spatial resolution, and reconstruction characteristics between the two modalities were considered during volumetric assessment. Given the retrospective nature of the study and limited sample size, separate statistical comparisons between CT and CBCT datasets were not feasible. Therefore, the findings should be interpreted with consideration of potential imaging-related heterogeneity. All volumetric measurements using both the ABC/2 estimation technique and MITK Workbench software were performed by a single calibrated observer to ensure consistency in measurement. Coronal and sagittal reconstructions were used for confirmation of anatomical boundaries where required.

The collected CT and CBCT data were opened using MITK Workbench 2016.11.0. MITK Workbench was used as a reference method for volumetric analysis because it is a widely used open-source medical image segmentation platform that enables detailed slice-by-slice manual tumour segmentation. It has been employed in previous imaging studies as a reliable tool for volumetric assessment when manual segmentation is required. In this study, MITK was used as a reference segmentation method rather than a gold standard. The tumour was segmented slice by slice in the axial view using the “Add,” “Subtract,” and “Correction” functions. The coronal and sagittal views were used as controls to detect over- or under-segmentation. After all slices were segmented, the volume was displayed in the “Statistics” menu. A 3D model of the tumour was created using the same software to visually evaluate the extent of the defect. Two readings were taken one week apart, and the mean estimated tumour volume was recorded. All measurements were performed by a single observer and repeated after one week. The tumour volume was calculated using the ABC/2 estimation technique, following the formula $V = ABC/2$ [9]. Measurements were performed as follows: (A) Maximal tumour diameter: identified on the axial view as the greatest linear dimension of the tumour in any plane; (B)

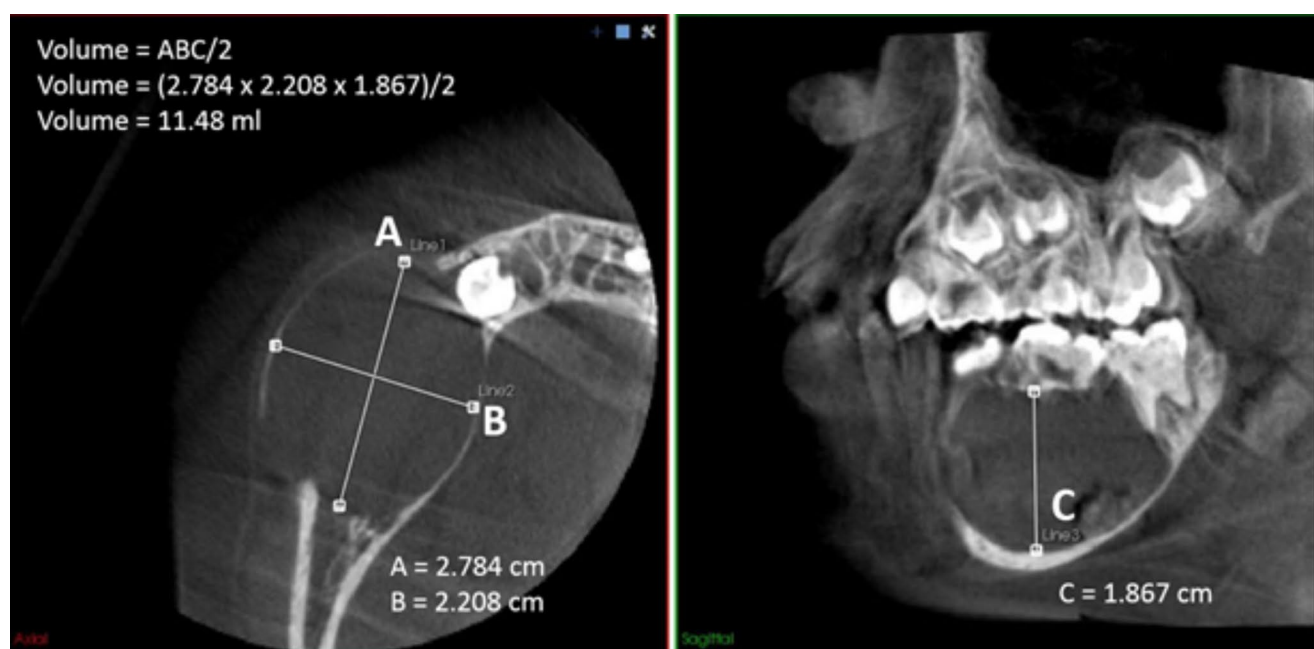


Fig. 1 Method used for calculating tumour volume using the ABC/2 technique

Table 1 Age distribution of the patients with ameloblastoma

Age group (years)	Decade of life	Frequency (%)
<10	1st decade	1 (3.45)
11–20	2nd decade	6 (20.69)
21–30	3rd decade	14 (48.28)
31–40	4th decade	0 (0.00)
41–50	5th decade	7 (24.14)
51–60	6th decade	1 (3.45)
Total		29 (100)

(N=29, Age range=6–52)

Perpendicular diameter: measured on the same axial slice as dimension A, taken perpendicular to A at its midpoint; (C) Depth (height): measured on the coronal view as the maximal craniocaudal extent of the tumour. All measurements were performed on the slice showing the largest cross-sectional area of the tumour. Coronal and sagittal views were used for verification. CT and CBCT voxel dimensions and slice thicknesses were recorded and standardized where possible. No image standardization or reslicing was applied to preserve original clinical data. Figure 1 illustrates the measurement technique.

The volume data from both the MITK Workbench 2016.11.0 software and the ABC/2 estimation technique were entered into a statistical software package (SPSS v24.0, IBM Corporation). Descriptive statistics were used to calculate the frequency and percentage of the variables. The Wilcoxon Signed Rank Test was used to compare differences in tumour volume. Agreement between ABC/2 and MITK measurements was assessed using Bland–Altman analysis based on the patient-level average volumes.

Differences were calculated as ABC/2 minus MITK and plotted against the mean of the two measurements. The mean difference (bias) and 95% limits of agreement were calculated as the mean difference $\pm$ 1.96 standard deviations of the paired differences. The mean bias and limits of agreement were reported with 95% confidence intervals. Distributional and potential magnitude-related patterns were also examined graphically. The Wilcoxon signed-rank test was retained as a test of paired differences and was not interpreted as a measure of agreement.

Results

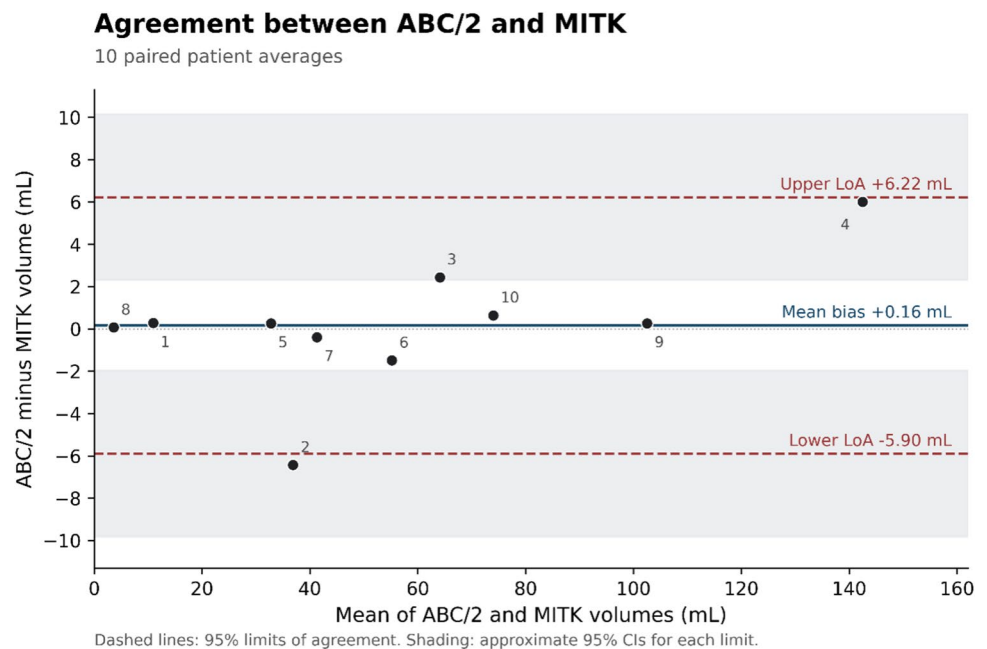
A total of 29 ameloblastoma cases were identified, including 18 males and 11 females (M:F=1.6:1). Of these, 19 cases were excluded due to incomplete or inadequate imaging data, leaving 10 cases with suitable CT or CBCT datasets for volumetric analysis. The mean age of the study population was 28.10 ± 12.17 years (range 6–52 years). The most common decades of diagnosis were the 3rd, 5th, and 2nd, in descending order (Table 1). Of the 29 patients, only 10 had clear, well-preserved imaging data. Table 2 presents the patient's gender and age, tumour location, and volume. All 10 subjects had mandibular ameloblastoma, with 20% anterior and 80% posterior cases. 50% of the cases were diagnosed with unilocular ameloblastoma, while the rest had a multilocular variant. For the purpose of subgroup analysis, tumour morphology was classified as either “regular” or “irregular.” Regularly shaped ameloblastomas were defined as lesions

Table 2 Gender, age, location, radiographic appearance, and the differences of tumour volume measured using MITK software and the ABC/2 technique of patients with ameloblastoma

Case	Gender	Age (years)	Radiographic appearance	Volume measurements (ml) ^a		
				MITK	ABC/2	Difference
1	F	6	Unilocular	10.85	11.13	-0.28
2	M	23	Multilocular	40.1	33.67	+6.43
3	M	22	Unilocular	62.9	65.34	-2.44
4	M	20	Multilocular	139.45	145.45	-6.00
5	M	16	Unilocular	32.65	32.91	-0.26
6	M	21	Unilocular	55.95	54.46	+1.49
7	M	42	Multilocular	41.5	41.11	+0.39
8	F	30	Unilocular	3.60	3.68	-0.08
9	F	29	Multilocular	102.4	102.66	-0.26
10	M	44	Multilocular	73.7	74.34	-0.64

^aWilcoxon's signed rank test for volume comparison: significant at <0.05. Mean volume, MITK=56.31±41.18. Mean volume, ABC/2=56.47±42.96. Z=-0.56. P=0.58, F: Female, M: Male

Fig. 2 Bland–Altman plot showing agreement between tumour volumes estimated using the ABC/2 technique and MITK segmentation in ten patients. Differences were calculated as ABC/2 minus MITK and plotted against the mean volume obtained by the two methods. The solid line represents the mean bias (+0.16 mL), and the dashed lines represent the 95% limits of agreement (−5.90 to +6.22 mL). Shaded areas indicate the approximate 95% confidence intervals for the limits of agreement



demonstrating relatively uniform, rounded or ellipsoid contours with well-defined borders and minimal asymmetric expansion. Irregular lesions were defined as those showing multilocular architecture, asymmetric growth patterns, cortical expansion extending beyond a single mandibular region, or involvement of multiple anatomical zones with non-uniform borders. Intra-observer reliability was excellent for both methods (ICC=0.96 for MITK; ICC=0.94 for ABC/2). Volumetric measurements showed that ABC/2 and MITK generated volumes of ameloblastoma did not differ significantly (Table 2).

Bland–Altman analysis was performed to assess agreement between the ABC/2 and MITK measurements. For the ten paired patient-level averages, the mean bias (ABC/2 minus MITK) was +0.16 mL (95% CI, −2.05 to +2.38 mL), with a standard deviation of the differences of 3.09 mL. The

95% limits of agreement ranged from −5.90 to +6.22 mL. The approximate 95% confidence intervals were −9.81 to −1.98 mL for the lower limit and +2.31 to +10.14 mL for the upper limit. Nine of the ten paired measurements were within the estimated limits of agreement. One case showed an ABC/2 estimate 6.43 mL lower than the corresponding MITK measurement (Fig. 2).

Discussion

In this study, the volume of ameloblastoma was successfully measured using the ABC/2 technique and compared with the MITK software. The current study on the Malaysian population found that the mean age of diagnosis of ameloblastoma was 28.10 years, which, in comparison, was much

lower than previous findings (30.3–35.1 years) [13–15]. This could be due to the presence of one patient, a 6-year-old, and the limitation on the number of patients attending the centre over the past ten years.

However, gender evaluation showed a male: female ratio of 1.6:1, which is in agreement with documented similar studies [16, 17]. Furthermore, the locations and predominance of mandibular ameloblastoma also agree with previous studies of 80.5% [17] 80% [18] and 92% [19]. The distribution of unilocular and multilocular ameloblastoma was also consistent with studies conducted by Chapelle et al., ($n = 19$, 52% multilocular, 48% unilocular) and Reichart et al., ($n = 1245$, 51% multilocular, 49% unilocular) [20, 21].

The performance of the ABC/2 method is influenced by tumour morphology due to its underlying geometric assumption of an approximately ellipsoid shape. In regularly shaped ameloblastomas with more uniform and rounded contours, this assumption is better satisfied, resulting in closer approximation to volumetric measurements obtained using manual segmentation. However, in irregular or multilocular lesions, the presence of asymmetric growth, cortical expansion, and non-uniform boundaries deviates from this assumption, leading to greater discrepancies between ABC/2 and segmentation-based volumetric assessment.

The ABC/2 technique is fundamentally based on a geometric approximation of lesion volume using an ellipsoid model. Consequently, its accuracy decreases as tumour morphology deviates from a regular rounded or ellipsoid configuration. Multilocular ameloblastomas and lesions with asymmetric expansion, scalloped borders, or complex anatomical extension may therefore be associated with greater measurement error. Although no statistically significant difference was observed between ABC/2 and MITK measurements in the present study, this finding should not be interpreted as evidence that the two methods are interchangeable. Rather, the results suggest that ABC/2 may serve as a rapid preliminary estimation tool in selected cases, whereas software-based segmentation remains preferable when accurate volumetric assessment is required.

The Bland–Altman analysis further characterized agreement between the two methods. The mean bias of +0.16 mL indicates minimal systematic difference on average between ABC/2 and MITK measurements. However, individual differences extended from approximately –6 to +6 mL, and the confidence intervals surrounding the limits of agreement were relatively wide. Thus, although the average bias was small, individual ABC/2 estimates may differ appreciably from segmentation-based measurements. Furthermore, no clinically acceptable difference between the two methods was prespecified. Therefore, the present findings should not

be interpreted as demonstrating interchangeability between ABC/2 and MITK segmentation.

The precision of the agreement estimates is limited by the small sample size of ten cases. In addition, CT and CBCT datasets were pooled, potentially introducing heterogeneity related to voxel size, slice thickness, spatial resolution, and reconstruction characteristics. The sample size was insufficient to perform reliable modality-specific Bland–Altman analyses. Finally, all measurements were performed by a single observer; therefore, the present agreement analysis represents the averaged measurements of that observer and does not establish inter-observer reproducibility. Larger studies using standardized imaging protocols, multiple observers, and predefined clinically acceptable limits are required.

In the MITK software, manual tumour segmentation yielded accurate results regardless of tumour shape. However, slice-by-slice tumour segmentation was considered laborious and time-consuming. In contrast, the ABC/2 estimation technique accurately estimated intracerebral hemorrhage in less than 1 min [10]. The rapid calculation of ameloblastoma volume using the ABC/2 technique has clinical advantages for prognosis and initial preoperative discussions among oral and maxillofacial surgeons.

The ABC/2 technique offers a fast estimate of ameloblastoma volume. Additionally, the shape and calculated volume of a regular tumour were more accurate than those of an irregular tumour using the MITK software, consistent with previous research [22–24]. For instance, in patients No. 2 and No. 4, the tumour shape is irregular, as it has extended from the right ramus to the right body of the mandible. This caused a bigger difference in tumour volume (± 6.00 ml) when compared to other regular-shaped tumours.

Tumour volume does not directly determine surgical margins in ameloblastoma, volumetric assessment may still have important clinical utility. It can assist clinicians in estimating overall lesion burden during preoperative evaluation, support planning of reconstructive requirements following resection, and provide a quantitative parameter for monitoring tumour progression or recurrence over time. However, volumetric estimation should be interpreted in conjunction with other clinical and radiographic features, including cortical perforation, soft tissue involvement, and anatomical extension.

Although volumetric assessment may provide useful quantitative information for preoperative evaluation, it should be regarded as a supportive tool rather than a primary determinant in surgical decision-making for ameloblastoma. Treatment planning is mainly guided by established clinical and radiographic factors, including cortical bone perforation, soft tissue involvement, anatomical extent of the lesion, and relationship to adjacent vital structures. Tumour

volume may assist in estimating lesion burden and reconstruction requirements, but it does not independently dictate surgical margins or definitive management strategies.

It is important to emphasize that tumour volume does not directly determine or guide surgical margins in ameloblastoma management. Surgical decision-making is primarily based on established clinical and radiographic factors, including the extent of cortical bone perforation, soft tissue involvement, anatomical spread, and relationship to adjacent vital structures. Volumetric assessment should therefore be regarded as a supportive adjunct in preoperative evaluation rather than a determinant of definitive surgical margins.

ABC/2 method is a simplified geometric estimation technique and is not interchangeable with manual segmentation-based volumetric analysis. While it may provide reasonable approximations in regularly shaped, approximately ellipsoid lesions, it does not measure true tumour volume in the same manner as voxel-based segmentation. Therefore, ABC/2 should be considered an estimation tool rather than an equivalent replacement for segmentation methods such as MITK, particularly in irregular or multilocular ameloblastomas.

The final sample size was limited by the availability of high-quality archived imaging data in this retrospective study. As a result, only 10 cases were included for analysis, and a formal sample size calculation was not feasible. This limitation reduces the statistical power and generalizability of the findings, and the results should therefore be interpreted as preliminary exploratory data.

Another limitation of this study is the inclusion of both CT and CBCT datasets. Although both modalities are suitable for evaluating osseous lesions of the jaws, differences in voxel size, slice thickness, image resolution, and reconstruction algorithms may influence segmentation accuracy and volumetric measurements. The retrospective design prevented complete standardization of imaging acquisition parameters across all cases. Consequently, a degree of measurement heterogeneity may have been introduced, which should be considered when interpreting the results. The small sample size ($n=10$) limits statistical power and generalizability. Therefore, the findings should be interpreted cautiously as preliminary exploratory data.

Conclusion

The ABC/2 technique may provide a rapid preliminary estimate of ameloblastoma volume, particularly for lesions with relatively regular, round-to-ellipsoid morphology. Bland–Altman analysis demonstrated a small mean systematic bias between ABC/2 and MITK measurements; however,

the observed limits of agreement and their uncertainty do not establish interchangeability between the two methods. Manual segmentation remains preferable when precise volumetric assessment is required, particularly for irregular or complex lesions. These findings should be considered preliminary because of the small sample size, inclusion of both CT and CBCT datasets, and use of a single observer. Larger prospective multicentre studies with standardized imaging protocols and predefined clinically acceptable limits of agreement are warranted.

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Declarations

Conflict of interest The authors have no financial or personal relationships that could inappropriately influence or bias the content of this paper.

Ethics approval this study has been ethically approved by the ethical review board, Jawatankuasa Etika Penyelidikan Manusia Universiti Sains Malaysia (USM/JEPeM/19010025).

Informed consent N/A.

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