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Original Article

Linear measurements of human permanent dental development stages using Cone-Beam Computed Tomography: A preliminary study

Carlos Estrela*, José Valladares Neto**, Mike Reis Bueno***, Orlando Aguirre Guedes****, Olavo Cesar Lyra Porto****, Jesus Djalma Pécora*****

Abstract

Objective: To determine the linear measurements of human permanent dentition development stages using Cone-Beam Computed Tomography. **Methods:** This study was based on databases of private radiology clinics involving 18 patients (13 male and 5 female, with age ranging from 3 to 20 years). Cone-Beam Computed Tomography (CBCT) images were acquired with i-CAT system and measured with a specific function of the i-CAT software. Two hundred and thirty-eight teeth were analyzed in different development stages in the coronal and sagittal planes. The method was based on delimitation and measurement of the distance between anatomical landmarks corresponding to the development of the dental crowns and roots. These measurements allowed the development of a quantitative model to evaluate the initial and final development stages for all dental groups. **Results and Conclusions:** The measurements acquired from different dental groups are in agreement with estimates of investigations previously published. CBCT images of different development stages may contribute to diagnosis, planning and outcome of treatment in various dental specialties. The dimensions of dental crowns and roots may have important clinical and research applications, constituting a noninvasive technique which contributes to in vivo studies. However, further studies are recommended to minimize methodological variables.

Keywords: Tooth development. Incomplete root formation. Apexogenesis. Cone-Beam Computed Tomography. Computed tomography.

* Chairman and Professor of Endodontics, Federal University of Goiás, Goiânia, GO, Brazil.
** Professor of Orthodontics, Federal University of Goiás, Goiânia, GO, Brazil.
*** Professor of Oral Diagnosis, Department of Oral Diagnosis, University of Cuiabá, Cuiabá, MT, Brazil.
**** Post-graduate student, Federal University of Goiás, Goiânia, GO, Brazil.
***** Chairman and Professor of Endodontics, University of São Paulo, Ribeirão Preto, SP, Brazil.

INTRODUCTION

Knowledge of the development stages of permanent teeth is essential for clinical practice in several dental specialties, since it may have influence on diagnosis, treatment planning and treatment outcome.

Several studies have evaluated calcification and development of human teeth using various methodologies.[16,19,20,21,24,26,27,28,34,35,38-41,44,46,47,49] Radiographic images, although representing two-dimensional aspects of three-dimensional structures, were the most widely used resource to determine the calcification and development stages of human permanent teeth.[20,34,35,39,49] A classical study by Nolla[35] evaluated the stages of development of human permanent teeth using radiographic records selected from the files on the basis of length, which were graded on a scale from 0 to 10 based on development.

Technological advances offer imaging modalities which have brought important contributions to dental radiology, such as viable diagnostic tools, namely digital radiography, densitometry methods, Cone-Beam Computed Tomography (CBCT), magnetic resonance imaging, ultrasound and nuclear techniques,[8] providing detailed high-resolution images of oral structures and permitting early detection of alterations in maxillofacial structures.

Since the introduction of computed tomography,[2,17,37] it has been observed that its clinical application has exerted a significant impact on health care.[1,4,7,10-15,19,22,25,29-31,42,43,45,48] Recently, clinical dentistry and research have benefitted from CBCT application,[3,6,8,18,32,42] which has permitted visualization of three-dimensional images, with additional handling strategies.[6] The higher potential for clinical application and the accuracy compared with periapical radiographs have contributed to treatment planning, diagnosis, therapy and prognosis of different diseases.[1,4,6,7,10-15,19,25,26,29-31,42,43,45]

Another remarkable feature of this technology is the CBCT measurement tool, which enables the determination of linear distances and volume of anatomic structures,[4,22,45] presurgical planning of maxillofacial lesions,[7] root length and marginal bone level during orthodontic treatment,[30,43] reconstruction techniques,[1,29] bone level changes following regenerative periodontal therapy,[15] periodontal defect,[19] periapical lesions,[11,12] and root resorptions.[13]

However, based on the potential of high-resolution image acquisition and the availability of new emerging three-dimensional imaging modalities, it seems appropriate to study the linear measurements of human permanent dentition during development, particularly in the first 20 years of age. Thus, the aim of this study was to determine the linear measurements of human permanent teeth at different development stages using Cone-Beam Computed Tomography.

MATERIAL AND METHODS

Image Selection

This study was structured using databases of private radiology clinics (CIRO, Goiânia, GO, Brazil; RIO, Brasília, DF, Brazil; CROIF, Cuiabá, MT, Brazil) involving 18 patients (n=238 teeth), 13 male, 5 female, with age ranging from 3 to 20 years. The patients were referred to the dental radiology service for different diagnostic purposes. The sample had no history of dental caries, orthodontic treatment or disturbance of dental development.

The study design was approved by the Local Ethics Research Committee (UFG, Proc. #169/2008).

Imaging Methods

CBCT images were acquired with i-CAT Cone-Beam 3D imaging system (Imaging Sciences International, Hatfield, PA, USA). Volumes were reconstructed with 0.2 mm isometric voxel. The tube voltage was 120 kVp and the tube current 3.8 mA. Exposure time was 40 seconds. Images were examined with the scanner's proprietary software (Xoran version 3.1.62; Xoran Technologies, Ann Arbor, MI, USA) in a PC workstation running Microsoft Windows XP professional SP-2 (Microsoft Corp, Redmond, WA, USA), with Intel(R) Core(TM) 2 Duo-6300 1.86 Ghz processor (Intel Corporation, USA), NVIDIA GeForce 6200 turbo cache graphics card

(NVIDIA Corporation, USA) and Monitor EIZO - Flexscan S2000, resolution 1600x1200 pixels (EIZO NANAO Corporation Hakusan, Japan).

Imaging Measurements

The method used to study the development of the permanent teeth with CBCT was based on delimiting and measuring the distance between anatomical landmarks according to the development of the dental crowns and roots. All the measurements on the CBCT images were acquired by two dental radiology specialists using a proprietary measurement tool supplied with the CBCT scanner (Xoran 3.1.62; Xoran Technologies, Ann Arbor, MI, USA). A specific function of the i-CAT software that offers values in millimeters was used to measure teeth images. The measurements were made both in the sagittal and coronal planes (the reference used was the largest measurement extension given by the software). The reference distances used were as follows:

- AB - maximum width between the incisal edge or cusp tip and cementoenamel junction;
- BC - maximum width between the cementoenamel junction and the most apical point of the root;
- AC - maximum width between the incisal edge or cusp tip and the most apical point of the root;
- CD - maximum width of the apical foramen;
- A'B' - maximum width between the incisal edge or cusp tip and the end of dental crown, used in teeth that no root formation was detected;
- B'C' - maximum width of the apical foramen, used in teeth where no root formation was detected.

The calibrated examiners measured all 238 teeth at different development stages using the CBCT images and assessed the dimensions in the directions described above. When a consensus was not reached a third observer made the final decision. Due to peculiarities of distinct dental groups, especially for multirooted teeth, measurements were made specifically for each root. The B'C' reference for teeth with more than one root used the mean distance between roots.

Using these measurements a quantitative model with five scores was suggested for all dental groups (with the exception of the third molar): 0 = absence of dental crypt; 1 = presence of dental crypt; 2 = dental crown partially formed; 3 = dental crown completely formed; 4 = beginning of root formation – open apex; 5 = end of root formation – closed apex) (Fig 1).

RESULTS

Linear measurements (mm) of the dental development stages are shown in Tables 1 to 16. Table 17 presents the mean values (mm) of dental development stages on CBCT scans. Figures 2 to 21 show the images of dental development stages.

DISCUSSION

The formation stages of deciduous and permanent teeth are basically the same, differing only in time periods. The dental lamina of deciduous dentition begins between the sixth and eighth week of embryonic development. Permanent teeth begin their development between the twentieth week of intra-uterine life and the tenth month after birth; permanent molars, between the twentieth week of intra-uterine life (first molar) and the fifth year of life (third molar).[33] Dental development starts during the intra-uterine life and lasts approximately until the second decade of life.

The values found by delimiting and measuring the distances between anatomical landmarks corresponding to human teeth development stages are described in Tables 1 to 16. These results allowed the establishment of a model to quantify the initial and final stages of tooth development for each dental group, based on mean values (Table 17). Figures 2 to 21 illustrate dimensions of dental development stages for maxillary and mandibular central and lateral incisors, canine, premolars and molars in the coronal and sagittal planes.

TABLE 1 - Linear measurements (mm) of dental development stages of maxillary anterior teeth (Coronal view).

Age (years)	Maxillary Central Incisor						Maxillary Lateral Incisor						Maxillary Canine					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	8.50					4.70	5.24					3.90	7.30					6.36
4	11.03					5.47	9.31					4.20	10.22					6.84
5	11.50					4.50	7.85					3.61	9.77					5.77
6		9.30	8.61	17.57	4.24			7.87	5.60	13.10	3.61			9.02	3.06	11.88	4.80	
7		10.90	8.64	18.84	3.22			8.63	5.20	13.72	3.81			10.70	2.81	12.78	5.46	
8		11.19	14.02	24.79	2.81			8.55	9.77	18.00	2.81			11.38	4.37	15.42	5.69	
9		8.66	12.34	19.85	0.00			7.28	11.79	18.43	0.00			8.35	11.22	19.00	2.01	
10		9.85	16.12	25.08	0.00			7.53	14.84	21.65	0.00			9.93	10.32	19.67	2.81	
11		8.74	12.76	21.01	0.00			7.84	13.97	21.01	0.00			9.04	17.03	25.02	0.00	
12		11.06	13.49	24.00	0.00			8.40	14.23	21.93	0.00			10.44	15.69	25.40	2.09	
13		9.18	14.49	22.83	0.00			7.47	15.56	22.17	0.00			9.07	18.05	26.46	0.00	
14		9.63	12.53	21.78	0.00			7.22	15.45	22.17	0.00			7.62	18.58	25.55	0.00	
15		10.33	14.36	24.01	0.00			7.47	13.34	20.50	0.00			8.48	18.75	26.61	0.00	
16		8.83	14.05	21.78	0.00			7.50	13.68	20.53	0.00			8.35	19.50	27.34	0.00	
17		9.33	12.17	20.80	0.00			7.95	13.10	20.54	0.00			8.92	15.18	23.41	0.00	
18		9.57	15.23	23.77	0.00			7.80	14.56	21.40	0.00			9.51	19.94	28.22	0.00	
19		10.31	16.32	25.80	0.00			8.06	15.09	22.15	0.00			7.97	18.87	26.06	0.00	
20		9.11	15.18	23.07	0.00			7.73	13.19	20.00	0.00			8.77	19.26	26.60	0.00	

TABLE 2 - Linear measurements (mm) of dental development stages of maxillary anterior teeth (Sagittal view).

Age (years)	Maxillary Central Incisor						Maxillary Lateral Incisor						Maxillary Canine					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	9.60					5.79	6.30					4.30	7.13					5.41
4	11.40					6.04	10.06					5.53	9.92					6.74
5	13.23					5.52	10.15					5.53	10.24					6.18
6		12.41	7.70	19.57	4.49			10.04	2.67	12.50	5.83			10.63	1.71	12.20	7.62	
7		13.62	9.06	22.07	3.58			12.01	4.12	15.95	5.66			10.44	3.06	13.22	7.30	
8		12.43	13.33	24.80	3.23			11.23	9.04	19.50	5.02			13.00	2.91	15.81	8.77	
9		10.85	11.01	20.87	0.00			10.72	10.88	20.24	0.00			10.10	10.12	19.68	3.80	
10		12.04	15.58	26.44	0.00			10.47	14.49	23.87	1.28			11.77	8.80	20.24	5.02	
11		12.04	12.38	23.24	0.00			10.83	13.00	22.75	0.00			11.51	17.77	27.90	0.00	
12		12.28	15.15	26.27	0.00			11.61	15.70	26.17	0.00			13.01	14.30	26.76	3.79	
13		11.12	14.81	25.05	0.00			9.65	14.85	23.39	0.00			11.61	17.05	27.51	0.00	
14		11.09	14.48	24.96	0.00			10.07	14.37	23.74	0.00			10.05	16.75	26.01	0.00	
15		11.29	13.18	23.68	0.00			9.48	12.88	21.46	0.00			9.95	18.09	26.97	0.00	
16		11.65	13.59	24.56	0.00			9.67	14.78	23.35	0.00			11.29	19.25	29.50	0.00	
17		11.26	10.00	20.32	0.00			10.01	11.17	19.78	0.00			10.59	15.25	24.53	0.00	
18		12.79	13.10	25.44	0.00			11.20	13.21	23.34	0.00			12.61	16.39	28.24	0.00	
19		11.93	15.09	26.42	0.00			9.81	15.33	24.01	0.00			9.65	18.41	27.46	0.00	
20		13.06	14.75	26.58	0.00			10.79	16.24	25.37	0.00			11.41	18.09	28.04	0.00	

TABLE 3 - Linear measurements (mm) of dental development stages of maxillary premolars teeth (Coronal view).

Age (years)	Maxillary First Premolar												Maxillary Second Premolar											
	Buccal Root						Palatal Root						Buccal Root						Palatal Root					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	4.30					4.88	3.31					4.88	PRESENCE OF CRYPT						PRESENCE OF CRYPT					
4	6.85					4.24	5.47					4.24	4.24					4.58	3.66					4.58
5	6.85					5.11	5.77					5.11	3.66					3.66	2.77					2.77
6		7.98	1.81	9.62	4.20			7.40	1.40	8.74	4.20			7.56	1.40	8.82	4.18			7.38	1.22	8.51	4.18	
7		8.54	2.43	10.72	4.44			8.59			4.44			7.78	1.02	8.74	4.60			7.81	1.02	8.75	4.60	
8		8.40	6.07	14.00	3.26			7.07	4.68	11.42	3.26			7.52	3.81	11.02	4.02			7.33	3.41	10.44	4.02	
9		7.97	8.12	15.63	2.21			6.84	7.69	14.21	2.01			7.78	6.80	14.44	3.21			7.40	6.80	14.04	3.61	
10		7.86	11.69	19.01	1.41			6.85	11.61	18.25	1.41			7.53	11.29	18.42	2.01			6.90	10.65	17.46	2.40	
11		8.73	12.91	20.80	1.22			7.67	13.10	20.22	0.00			7.84	13.12	20.42	1.79			7.53	12.70	19.81	1.22	
12		8.85	12.81	20.60	1.26			7.81	12.37	19.64	0.82			7.52	11.51	18.27	0.63			7.97	11.71	19.22	0.63	
13		7.15	14.76	21.40	0.00			7.15	12.73	19.40	0.00			6.77	15.89	22.01	0.00			6.32	15.85	21.61	0.00	
14		6.96	14.16	20.45	0.00			6.84	14.32	20.63	0.00			6.77	15.16	21.40	0.00			6.32	14.80	20.60	0.00	
15		7.66	15.67	22.43	0.00			7.38	14.96	22.01	0.00			7.40	14.12	21.01	0.00			7.15	14.12	20.80	0.00	
16		7.72	14.63	21.80	0.00			7.18	14.56	21.26	0.00			7.72	16.36	23.43	0.00			6.99	16.06	22.51	0.00	
17		7.35	12.33	18.81	0.00			7.16	11.07	17.61	0.00			6.49	11.47	17.51	0.00			6.41	11.04	16.71	0.00	
18		8.03	14.12	21.40	0.00			7.38	13.14	20.52	0.00			7.78	15.07	22.42	0.00			7.17	15.25	21.86	0.00	
19		7.47	14.37	21.20	0.00			7.15	14.01	20.60	0.00			7.15	15.82	22.40	0.00			7.40	16.51	23.21	0.00	
20		8.17	17.42	24.61	0.00			7.02	16.02	22.09	0.00			8.16	16.41	24.00	0.00			7.34	16.60	23.40	0.00	

TABLE 4 - Linear measurements (mm) of dental development stages of maxillary premolars teeth (Sagittal view).

Age (years)	Maxillary First Premolar												Maxillary Second Premolar											
	Buccal Root						Palatal Root						Buccal Root						Palatal Root					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	4.51					5.98	2.28					5.98	PRESENCE OF CRYPT						PRESENCE OF CRYPT					
4	6.85					7.97	6.33					7.97	4.54					6.61	3.35					6.61
5	6.58					7.60	5.47					7.60	3.79					2.47	3.01					2.47
6		8.20	1.22	9.34	7.40			7.27	1.34	8.41	7.40			6.84	1.22	7.96	8.02			7.27	1.08	8.02	8.02	
7		9.14	2.15	11.03	7.96			8.40			7.96			6.99	2.15	8.84	9.02			7.35	1.41	8.60	9.02	
8		9.22	4.22	13.05	8.26			7.73	4.56	12.00	8.26			9.22	2.34	11.02	9.00			7.62	2.34	9.65	9.00	
9		7.97	7.89	15.45	5.43			7.40	7.77	15.07	5.43			7.59	6.65	13.89	6.48			7.82	6.55	14.02	6.48	
10		8.75	12.15	20.39	3.54			6.91	10.45	17.20	3.54			8.66	9.31	17.66	4.00			7.03	9.73	16.63	4.00	
11		8.98	11.94	20.60	0.80			7.82	12.48	20.22	0.00			8.29	12.03	19.90	2.41			7.73	12.24	19.63	2.41	
12		9.41	11.51	20.60	0.82			7.62	11.81	19.25	0.80			8.52	10.44	18.38	2.01			8.41	10.88	18.41	2.01	
13		8.80	12.66	21.27	0.00			7.07	13.21	19.90	0.00			7.57	14.95	22.06	0.00			6.68	15.37	21.54	0.00	
14		7.73	12.83	20.22	0.00			7.22	12.86	19.80	0.00			7.86	13.30	20.76	0.00			6.94	14.04	20.39	0.00	
15		8.16	14.14	21.80	0.00			7.50	13.75	21.02	0.00			7.25	14.26	20.91	0.00			7.47	14.21	20.82	0.00	
16		8.26	14.31	22.35	0.00			7.53	14.41	21.66	0.00			7.86	14.60	21.84	0.00			7.33	14.87	21.50	0.00	
17		7.52	10.31	17.26	0.00			7.16	10.61	17.32	0.00			7.29	10.68	17.64	0.00			7.11	10.85	17.11	0.00	
18		9.42	12.42	21.56	0.00			7.67	12.28	19.89	0.00			8.46	15.05	22.95	0.00			7.67	14.99	22.04	0.00	
19		8.10	13.19	20.62	0.00			7.23	14.20	21.01	0.00			7.53	16.54	23.57	0.00			7.03	17.28	23.50	0.00	
20		9.43	15.76	24.45	0.00			7.67	13.94	21.54	0.00			8.63	17.15	24.96	0.00			7.84	16.83	24.39	0.00	

TABLE 5 - Linear measurements (mm) of dental development stages of maxillary first molar tooth (Coronal view).

Age (years)	Maxillary First Molar																	
	Mesiobuccal Root						Distalbuccal Root						Palatal Root					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	7.50					7.22	7.50					7.22	10.06					7.85
4		7.59	2.72	10.26	6.64			7.52	2.28	9.72	6.64			9.02	1.90	10.92	6.64	
5		7.71	3.06	10.57	6.63			7.35	3.06	10.24	6.63			8.88	2.85	11.44	6.63	
6		6.85	8.91	15.61	2.20			8.77	8.66	16.80	2.01			6.79	8.68	15.01	3.35	
7		7.86	9.85	17.80	1.08			7.96	9.42	17.23	1.00			8.29	11.18	18.42	3.01	
8		6.94	11.74	18.40	1.61			7.53	11.64	18.84	1.41			8.44	10.96	18.82	3.22	
9		6.84	12.36	18.80	0.00			7.03	11.91	18.83	0.00			8.22	13.49	20.82	0.00	
10		6.36	14.74	20.81	0.00			7.64	13.80	21.42	0.00			8.35	15.77	23.27	0.00	
11		6.60	14.31	20.32	0.00			7.57	12.06	19.40	0.00			8.22	14.95	22.03	0.00	
12		7.81	13.18	20.60	0.00			8.01	13.10	20.94	0.00			8.30	16.02	23.50	0.00	
13		6.36	12.99	19.02	0.00			6.48	12.53	18.82	0.00			7.23	14.60	21.26	0.00	
14		6.26	12.03	18.03	0.00			6.68	11.44	18.00	0.00			7.47	13.22	20.00	0.00	
15		6.99	14.04	20.62	0.00			7.81	12.21	20.02	0.00			7.47	13.82	20.42	0.00	
16		6.79	13.85	20.22	0.00			7.24	13.64	20.80	0.00			7.98	16.07	22.86	0.00	
17		6.32	11.47	17.05	0.00			6.91	9.58	16.25	0.00			7.60	11.96	18.54	0.00	
18		7.03	14.04	20.62	0.00			7.30	12.56	19.63	0.00			7.54	13.74	20.22	0.00	
19		7.28	14.84	21.46	0.00			7.81	12.96	21.46	0.00			8.36	14.51	22.01	0.00	
20		7.67	14.29	21.14	0.00			8.40	12.96	21.00	0.00			8.36	17.09	24.27	0.00	

TABLE 6 - Linear measurements (mm) of dental development stages of maxillary first molar tooth (Sagittal view).

Age (years)	Maxillary First Molar																	
	Mesiobuccal Root						Distalbuccal Root						Palatal Root					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	6.63					11.16	6.60					11.16	7.74					11.16
4		9.60	1.90	11.24	10.01			7.50			10.01			8.30	2.72	10.90	10.01	
5		7.79	2.10	9.83	10.80			7.71	2.12	9.72	10.80			8.36	2.18	10.19	10.80	
6		6.71	9.23	15.81	2.00			7.34	9.93	16.41	1.65			8.54	9.70	17.84	2.72	
7		7.92	9.63	17.41	4.42			7.62	9.34	16.84	3.49			8.35	10.40	18.58	2.67	
8		7.96	10.41	18.01	4.08			7.47	10.80	17.56	2.34			6.84	11.00	17.69	2.61	
9		7.21	12.08	18.83	0.00			7.23	11.74	18.43	0.00			7.42	13.92	21.00	0.00	
10		7.42	14.08	21.31	0.00			7.80	12.48	20.25	0.00			8.14	13.88	21.95	0.00	
11		7.10	12.23	18.91	0.00			7.73	12.36	19.81	0.00			8.06	13.08	20.91	0.00	
12		7.96	13.35	20.72	0.00			7.42	13.65	20.22	0.00			8.93	15.07	23.62	0.00	
13		6.71	12.66	19.20	0.00			6.48	12.04	18.40	0.00			7.43	13.67	20.46	0.00	
14		6.85	12.13	18.71	0.00			6.71	10.95	17.41	0.00			7.79	11.57	19.10	0.00	
15		7.28	13.25	20.22	0.00			7.38	12.06	19.40	0.00			8.03	12.61	20.42	0.00	
16		7.30	13.22	20.24	0.00			6.87	14.31	21.02	0.00			7.52	15.03	22.37	0.00	
17		7.29	10.85	17.25	0.00			7.04	9.71	16.25	0.00			7.76	11.03	18.54	0.00	
18		8.86	12.03	20.52	0.00			8.24	11.30	19.28	0.00			7.07	13.81	20.63	0.00	
19		7.81	13.45	20.82	0.00			7.28	14.12	21.00	0.00			8.22	14.81	22.69	0.00	
20		8.93	12.18	20.41	0.00			7.86	14.14	21.60	0.00			9.14	15.42	23.99	0.00	

TABLE 7 - Linear measurements (mm) of dental development stages of maxillary second molar tooth (Coronal view).

Age (years)	Maxillary Second Molar																	
	Mesiobuccal Root						Distalbuccal Root						Palatal Root					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	ABSENCE OF CRYPT						ABSENCE OF CRYPT						ABSENCE OF CRYPT					
4	5.11					7.00	3.01					7.00	4.84					7.00
5	4.26						3.31						4.26					
6		7.57			6.85			7.22			6.85			7.98			6.85	
7		8.66			7.07			8.04			7.07			8.79			7.07	
8		7.09	2.43	9.26	7.10			6.81	1.65	8.40	7.10			7.42	3.03	10.06	7.10	
9		7.47	6.21	13.21	4.40			7.22	4.90	12.01	4.40			7.84	5.10	12.50	3.80	
10		6.91	8.22	14.67	2.04			6.65	6.60	13.21	2.47			7.53	8.29	15.01	3.49	
11		7.25	9.41	16.21	1.02			7.60	6.71	14.14	1.00			7.72	9.63	16.51	3.21	
12		7.47	10.31	17.34	2.21			6.99	7.86	14.62	2.04			8.20	9.49	17.04	2.61	
13		6.46	11.61	17.60	0.00			6.45	11.30	17.29	0.00			7.28	13.03	19.25	0.00	
14		6.14	12.32	17.82	0.00			6.36	11.69	17.64	0.00			7.07	14.99	21.00	0.00	
15		7.23	11.76	18.29	0.00			7.44	10.25	17.60	0.00			7.40	13.27	20.22	0.00	
16		7.28	14.52	20.72	0.00			7.03	13.42	20.45	0.00			7.84	16.02	22.87	0.00	
17		6.43	13.46	19.07	0.00			6.33	12.21	18.29	0.00			6.91	11.94	18.17	0.00	
18		7.78	13.98	20.72	0.00			7.60	11.64	19.22	0.00			8.14	14.95	22.00	0.00	
19		7.21	13.26	19.80	0.00			7.21	13.06	20.12	0.00			7.43	14.71	21.95	0.00	
20		7.86	14.02	21.25	0.00			7.57	12.61	19.67	0.00			8.41	17.85	24.80	0.00	

TABLE 8 - Linear measurements (mm) of dental development stages of maxillary second molar tooth (Sagittal view).

Age (years)	Maxillary Second Molar																	
	Mesiobuccal Root						Distalbuccal Root						Palatal Root					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	ABSENCE OF CRYPT						ABSENCE OF CRYPT						ABSENCE OF CRYPT					
4	5.32					7.81	3.06					7.81	5.18					7.81
5	4.54						3.00						4.74					
6		7.80			10.19			7.02			10.19			9.06			10.19	
7		8.42			9.87			8.40			9.87			9.22			9.87	
8		8.23	1.26	9.18	12.01			7.15	1.71	8.55	12.01			7.88	1.22	8.92	12.01	
9		7.78	5.88	13.01	8.24			7.28	5.53	12.43	8.24			7.28	5.41	12.50	8.24	
10		7.34	7.57	14.41	2.81			7.28	6.23	13.27	2.83			7.77	6.03	13.64	4.08	
11		8.49	9.01	16.43	2.01			7.50	7.00	14.82	1.08			7.66	8.55	16.16	1.97	
12		8.03	8.66	16.28	2.72			7.78	6.85	14.56	3.68			8.16	9.43	17.50	2.24	
13		6.99	11.60	18.19	0.00			6.58	10.25	16.71	0.00			7.47	12.50	19.60	0.00	
14		6.21	11.61	17.41	0.00			6.48	10.82	17.27	0.00			7.97	13.62	21.26	0.00	
15		7.67	11.64	18.49	0.00			7.62	10.01	17.20	0.00			8.41	12.13	19.68	0.00	
16		7.62	12.81	20.24	0.00			7.03	14.01	20.94	0.00			8.12	14.41	22.42	0.00	
17		6.80	11.95	18.04	0.00			6.88	10.85	17.01	0.00			8.31	12.12	19.06	0.00	
18		9.67	11.68	21.20	0.00			7.33	12.50	19.60	0.00			8.51	13.22	21.42	0.00	
19		7.47	13.06	20.01	0.00			6.60	13.60	19.40	0.00			7.86	13.80	21.49	0.00	
20		8.54	13.16	20.85	0.00			7.54	12.46	19.33	0.00			7.78	15.93	23.43	0.00	

TABLE 9 - Linear measurements (mm) of dental development stages of mandibular anterior teeth (Coronal view).

Age (years)	Mandibular Central Incisor						Mandibular Lateral Incisor						Mandibular Canine					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	8.45					3.35	7.50					3.35	7.31					4.80
4	9.97					3.31	10.36					3.91	9.90					5.71
5	10.90					3.00	10.65					3.61	9.30					5.32
6		8.19	8.72	16.81	2.18			8.16	7.26	15.07	2.77			9.02	2.42	11.21	6.00	
7		8.63	12.64	21.02	0.00			7.87	13.65	21.15	0.00			8.88	9.43	18.05	3.21	
8		9.37	13.06	22.60	0.00			9.18	14.51	23.40	0.60			9.95	8.09	17.66	3.61	
9		9.12	14.52	23.51	0.00			8.73	15.57	24.01	1.50			9.10	12.25	21.12	3.50	
10		8.10	15.85	23.76	0.00			9.10	16.02	24.81	1.03			8.46	13.06	21.05	3.25	
11		8.59	12.53	20.80	0.00			8.60	15.26	23.43	0.00			9.49	17.47	26.44	1.60	
12		8.88	13.66	22.20	0.00			8.74	15.00	23.52	0.00			8.92	15.93	24.39	0.00	
13		6.71	12.68	19.01	0.00			6.84	14.47	20.82	0.00			7.53	14.26	21.05	0.00	
14		7.92	13.67	21.40	0.00			7.42	15.42	22.41	0.00			8.54	14.85	23.03	0.00	
15		8.74	9.81	18.31	0.00			8.91	10.72	19.40	0.00			8.79	13.39	21.65	0.00	
16		8.59	12.68	21.00	0.00			8.83	14.40	22.61	0.00			9.62	16.16	25.41	0.00	
17		8.20	13.50	21.40	0.00			8.94	15.47	23.90	0.00			9.67	20.52	28.81	0.00	
18		7.23	14.60	21.61	0.00			7.53	15.06	22.01	0.00			7.86	18.68	25.89	0.00	
19		7.28	14.14	21.00	0.00			7.78	14.71	22.20	0.00			7.66	18.95	26.00	0.00	
20		7.57	14.34	21.60	0.00			7.73	12.66	20.20	0.00			9.23	19.67	28.43	0.00	

TABLE 10 - Linear measurements (mm) of dental development stages of mandibular anterior teeth (Sagittal view).

Age (years)	Mandibular Central Incisor						Mandibular Lateral Incisor						Mandibular Canine					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	8.40					4.85	8.19					4.85	7.11					4.80
4	10.90					5.53	10.55					6.63	9.53					6.41
5	11.89					5.43	11.16					5.18	9.31					5.11
6	10.44	8.24	18.09	5.13				10.26	5.41	15.49	6.36		11.80					8.54
7	10.14	12.03	21.41	0.00				10.63	11.88	21.65	2.34			11.74	6.91	18.27	6.02	
8	11.07	12.52	22.62	0.00				11.32	13.15	23.84	2.60			11.76	6.03	17.46	7.42	
9	10.59	14.98	24.50	0.00				11.00	13.73	23.80	1.75			12.18	10.69	22.09	6.50	
10	10.36	15.10	24.50	0.00				10.64	13.61	23.36	1.82			12.10	10.44	21.82	6.17	
11	10.45	14.14	23.53	0.00				10.72	15.03	24.56	0.00			13.05	14.45	26.08	2.83	
12	10.34	13.07	22.82	0.00				10.66	14.52	24.05	0.00			11.79	13.59	24.09	0.00	
13	9.43	10.58	19.46	0.00				8.60	13.24	21.02	0.00			9.77	14.23	22.60	0.00	
14	9.46	12.97	21.40	0.00				9.75	14.48	23.27	0.00			11.61	15.21	25.55	0.00	
15	10.00	10.88	20.06	0.00				10.80	12.26	22.01	0.00			11.84	13.09	24.11	0.00	
16	9.80	13.72	22.29	0.00				10.33	15.12	23.94	0.00			12.28	15.29	26.65	0.00	
17	9.85	13.61	22.67	0.00				11.29	12.70	22.99	0.00			13.44	17.27	29.47	0.00	
18	9.57	14.45	23.19	0.00				9.40	15.98	24.56	0.00			11.85	15.58	26.19	0.00	
19	8.99	13.58	21.60	0.00				9.49	14.81	23.22	0.00			9.95	16.83	25.81	0.00	
20	8.55	13.74	21.47	0.00				9.51	13.91	22.49	0.00			11.22	18.72	28.60	0.00	

TABLE 11 - Linear measurements (mm) of dental development stages of mandibular premolars teeth (Coronal view).

Age (years)	Mandibular First Premolar						Mandibular Second Premolar					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	4.88					5.18			PRESENCE OF CRYPT			
4	6.31					5.43	4.58					4.51
5	5.69					5.43			PRESENCE OF CRYPT			
6	8.25					5.41	8.19					5.53
7		8.17	5.20	13.15	3.88			7.40	2.34	9.62	3.38	
8		8.66	5.06	13.35	3.62			8.36	3.98	11.74	5.00	
9		8.07	7.91	15.25	2.06			7.75	4.37	11.63	4.01	
10		8.38	7.11	15.05	3.26			8.07	3.88	11.57	3.51	
11		8.61	14.20	22.04	2.21			7.84	15.03	22.20	2.72	
12		9.30	13.42	21.90	0.60			8.08	13.07	20.70	0.90	
13		7.25	14.36	20.40	0.00			6.39	15.10	20.82	0.00	
14		6.80	15.97	21.81	0.00			6.39	16.51	22.22	0.00	
15		8.35	12.76	20.65	0.00			8.05	13.42	21.00	0.00	
16		8.14	15.09	22.31	0.00			7.97	15.73	23.01	0.00	
17		8.54	18.29	25.83	0.00			7.66	18.44	25.10	0.00	
18		7.84	15.92	23.01	0.00			7.43	16.48	23.00	0.00	
19		7.54	15.97	22.61	0.00			7.21	16.64	23.04	0.00	
20		8.10	17.23	24.27	0.00			7.40	16.48	23.21	0.00	

TABLE 12 - Linear measurements (mm) of dental development stages of mandibular premolars teeth (Sagittal view).

Age (years)	Mandibular First Premolar						Mandibular Second Premolar					
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	4.37					4.81			PRESENCE OF CRYPT			
4	6.93					5.73	4.69					5.60
5	5.41					4.81			PRESENCE OF CRYPT			
6	8.47					8.11	7.82					8.53
7		9.28	3.42	12.63	5.46			7.07	2.67	9.31	6.01	
8		9.39	4.00	13.16	6.91			8.84	3.22	11.73	5.44	
9		9.30	6.50	15.26	6.50			8.40	3.04	10.91	6.58	
10		8.94	6.79	15.10	6.29			7.50	3.78	10.96	6.96	
11		9.21	13.61	21.67	1.79			9.30	12.41	21.11	4.08	
12		9.14	13.28	22.00	1.20			9.26	11.94	20.16	0.90	
13		8.33	13.93	21.00	0.00			7.62	13.97	20.60	0.00	
14		8.44	15.05	22.60	0.00			6.58	16.75	22.80	0.00	
15		8.94	12.29	20.42	0.00			9.11	12.96	21.42	0.00	
16		9.11	14.76	22.91	0.00			8.80	15.69	23.24	0.00	
17		10.63	17.46	27.22	0.00			9.12	16.49	24.85	0.00	
18		8.99	14.95	23.00	0.00			8.43	15.92	23.40	0.00	
19		7.69	15.78	22.43	0.00			7.53	16.12	23.02	0.00	
20		9.22	16.83	25.02	0.00			7.96	16.88	23.90	0.00	

TABLE 13 - Linear measurements (mm) of dental development stages of mandibular first molar tooth (Coronal view).

Age (years)	Mandibular First Molar																						
	Mesial Root - Mesiobuccal Root Canal						Mesial Root - Mesiolingual Root Canal						Distal Root - Buccal Side						Distal Root - Lingual Side				
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	8.11					8.24	7.26					8.24	8.08					8.24	6.98					8.24
4		7.85	2.01	9.60	7.52			8.08	2.42	10.26	7.52			7.20	1.82	9.00	7.52			7.06	1.82	8.88	7.52	
5		8.11	3.13	11.12	8.83			7.51	3.42	10.87	8.83			8.90	2.42	11.14	8.83			8.08	3.00	10.75	8.83	
6		7.79	8.40	16.00	3.01			8.00	8.72	16.54	2.70			8.45	7.35	16.24	3.31			7.79	9.04	16.77	3.35	
7		7.92	10.49	18.20	1.41			7.80	11.41	19.10	1.52			8.49	9.48	17.96	2.21			7.57	10.32	17.89	1.90	
8		8.71	10.79	19.21	2.15			7.57	12.04	19.21	1.34			8.62	9.95	18.53	2.79			8.25	10.75	18.87	1.34	
9		7.20	14.86	21.26	0.79			7.22	15.65	22.32	1.06			7.76	13.75	21.32	0.79			6.91	14.01	20.77	1.03	
10		7.67	14.87	21.40	1.60			7.04	14.94	21.15	0.71			7.67	13.76	21.10	1.52			6.80	14.39	20.75	0.75	
11		6.65	16.48	22.61	0.00			7.09	16.50	23.20	0.00			7.67	14.27	21.61	0.00			7.21	14.89	22.03	0.00	
12		7.21	15.89	22.52	0.00			7.71	15.89	23.13	0.00			8.66	13.88	22.49	0.00			7.59	14.78	22.24	0.00	
13		6.55	12.37	18.47	0.00			6.68	12.71	19.10	0.00			7.69	11.80	18.91	0.00			6.99	12.48	19.20	0.00	
14		6.32	14.74	20.60	0.00			6.71	15.90	22.20	0.00			7.35	13.81	20.74	0.00			6.75	15.01	21.61	0.00	
15		6.99	12.76	19.25	0.00			7.64	12.52	19.90	0.00			7.67	11.21	18.76	0.00			6.32	12.76	17.63	0.00	
16		7.15	15.75	21.95	0.00			7.03	16.26	22.57	0.00			7.86	13.62	21.38	0.00			7.40	14.60	21.61	0.00	
17		6.32	17.26	23.02	0.00			6.79	16.08	22.44	0.00			6.16	15.61	21.62	0.00			6.99	15.02	21.81	0.00	
18		6.91	14.25	20.65	0.00			6.96	14.85	21.42	0.00			7.62	12.63	20.02	0.00			6.87	13.06	19.80	0.00	
19		7.28	14.14	20.81	0.00			6.90	15.37	21.63	0.00			6.71	14.81	21.26	0.00			6.90	15.34	21.63	0.00	
20		6.71	13.74	19.97	0.00			6.48	16.60	20.74	0.00			7.66	13.81	20.55	0.00			6.98	13.41	19.77	0.00	

TABLE 14 - Linear measurements (mm) of dental development stages of mandibular first molar tooth (Sagittal view).

Age (years)	Mandibular First Molar																						
	Mesial Root - Mesiobuccal Root Canal						Mesial Root - Mesiolingual Root Canal						Distal Root - Buccal Side						Distal Root - Lingual Side				
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	7.52					9.18	7.22					9.18	7.92					9.18	6.91					9.18
4		8.05	1.50	9.42	7.50			7.65	2.72	10.27	7.50			8.32	2.77	10.63	7.50			6.30	2.34	8.24	7.50	
5		7.92	2.77	10.41	7.55			7.00	2.72	9.64	7.55			7.79	2.77	10.31	7.20			7.52	2.95	10.22	7.20	
6		8.75	9.92	18.20	2.77			7.35	9.18	16.20	2.47			8.54	8.11	16.38	2.16			7.00	8.54	15.07	2.01	
7		8.48	10.10	18.05	4.24			7.44	11.76	18.81	4.24			8.49	9.42	17.67	4.04			7.40	10.77	17.81	4.04	
8		9.21	10.58	19.34	2.15			6.44	13.38	18.67	2.15			8.60	10.31	18.64	2.79			7.47	11.65	18.40	2.79	
9		7.94	15.00	21.77	1.25			7.04	14.25	20.74	1.50			7.83	14.30	21.37	2.02			7.00	15.21	21.67	2.02	
10		8.31	12.50	19.51	1.75			6.86	12.13	18.58	1.75			8.25	13.48	21.26	2.55			6.62	15.04	20.93	2.55	
11		8.49	14.56	22.61	0.00			8.16	15.78	23.02	0.00			7.62	14.95	22.04	0.00			6.25	16.27	21.98	0.00	
12		9.40	14.71	22.93	0.00			7.59	16.61	23.22	0.00			8.66	15.18	22.96	0.00			7.94	16.16	23.56	0.00	
13		7.52	12.61	19.00	0.00			6.65	13.96	19.75	0.00			7.62	11.64	18.51	0.00			6.48	13.11	18.98	0.00	
14		7.33	14.54	21.03	0.00			6.65	15.83	21.25	0.00			7.47	13.50	20.42	0.00			6.00	15.12	20.68	0.00	
15		8.60	10.92	19.03	0.00			6.99	12.81	19.27	0.00			7.62	12.43	19.61	0.00			6.60	13.89	20.19	0.00	
16		8.35	15.14	22.66	0.00			7.53	16.51	23.02	0.00			8.00	14.18	21.51	0.00			7.53	15.12	22.03	0.00	
17		6.91	16.76	22.53	0.00			7.02	16.24	23.03	0.00			6.85	14.93	21.34	0.00			6.91	15.16	21.40	0.00	
18		7.73	13.61	20.60	0.00			6.75	15.56	21.30	0.00			7.53	13.67	20.82	0.00			6.01	15.57	20.94	0.00	
19		7.62	15.30	22.00	0.00			5.66	17.46	22.42	0.00			7.84	13.78	21.00	0.00			6.83	15.31	21.54	0.00	
20		7.62	13.85	20.24	0.00			6.91	14.79	20.56	0.00			7.17	13.82	20.20	0.00			6.08	14.70	20.39	0.00	

TABLE 15 - Linear measurements (mm) of dental development stages of mandibular second molar tooth (Coronal view).

Age (years)	Mandibular Second Molar																						
	Mesial Root - Mesiobuccal Root Canal						Mesial Root - Mesiolingual Root Canal						Distal Root - Buccal Side						Distal Root - Lingual Side				
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	PRESENCE OF CRYPT						PRESENCE OF CRYPT						PRESENCE OF CRYPT						PRESENCE OF CRYPT					
4	4.80					8.45	4.51					8.45	4.58					8.45	4.08					8.45
5	3.31						3.31						2.42						4.20					
6	8.53					10.36	7.30					10.36	8.47					10.36	7.13					10.36
7		8.24	1.84	9.65	7.59			7.05	1.98	8.68	7.59			7.66	1.61	9.13	7.59			6.88	1.60	8.24	7.59	
8		8.10	5.10	12.86	2.61			7.86	5.50	12.80	3.41			8.14	4.22	11.98	3.31			7.25	3.80	10.82	3.50	
9		8.14	6.64	14.27	2.55			7.04	6.32	13.06	3.01			7.62	5.88	13.44	3.16			7.27	5.02	12.10	3.02	
10		8.14	6.41	14.04	2.61			7.02	6.41	13.12	2.55			7.52	5.40	12.89	3.35			7.38	5.64	12.91	3.16	
11		7.98	11.22	18.42	2.28			6.96	11.85	18.20	2.68			7.73	10.00	17.64	2.60			6.94	10.01	16.83	2.83	
12		7.87	12.26	19.02	1.27			7.42	12.43	19.05	1.50			8.37	9.64	17.74	1.80			7.13	10.52	17.44	1.80	
13		7.53	12.29	18.78	0.00			6.99	12.46	18.73	0.00			7.42	11.25	18.05	0.00			7.03	11.45	18.01	0.00	
14		6.83	14.67	20.22	0.00			6.51	12.71	18.09	0.00			7.21	13.00	19.74	0.00			6.99	13.72	20.40	0.00	
15		8.29	11.98	18.98	0.00			8.43	10.28	18.66	0.00			7.69	12.09	18.47	0.00			8.03	10.25	18.16	0.00	
16		7.60	16.64	22.53	0.00			7.89	13.60	21.45	0.00			7.87	16.32	22.47	0.00			6.75	14.40	21.05	0.00	
17		7.67	16.20	22.88	0.00			7.96	15.52	22.59	0.00			7.09	16.12	22.61	0.00			7.78	15.13	22.40	0.00	
18		7.80	14.46	21.21	0.00			7.10	14.82	21.22	0.00			7.86	12.66	20.22	0.00			8.22	11.80	19.80	0.00	
19		7.35	13.45	20.00	0.00			7.17	13.89	20.20	0.00			7.50	12.24	19.60	0.00			7.47	13.02	20.24	0.00	
20		6.99	15.43	21.41	0.00			6.58	15.62	21.45	0.00			7.86	13.05	20.25	0.00			7.86	12.86	20.05	0.00	

TABLE 16 - Linear measurements (mm) of dental development stages of mandibular second molar tooth (Sagittal view).

Age (years)	Mandibular Second Molar																						
	Mesial Root - Mesiobuccal Root Canal						Mesial Root - Mesiolingual Root Canal						Distal Root - Buccal Side						Distal Root - Lingual Side				
	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'	A'B'	AB	BC	AC	CD	B'C'
3	PRESENCE OF CRYPT						PRESENCE OF CRYPT						PRESENCE OF CRYPT						PRESENCE OF CRYPT					
4	4.74					7.81	4.08					7.81	4.85					7.81	3.71					7.81
5	2.68						2.56						2.16						1.62					
6	7.52					10.20	6.55					10.20	7.80					10.20	6.77					10.20
7		6.54	1.80	8.22	8.01			6.01	2.15	8.01	8.01			7.96	2.61	10.31	8.01			7.40	1.71	9.01	8.01	
8		8.51	4.47	12.47	9.04			6.32	5.14	11.03	9.04			8.41	3.68	11.22	7.60			7.33	4.33	10.85	7.60	
9		8.72	5.76	14.01	3.54			6.79	5.77	12.29	3.29			8.05	6.02	13.84	3.51			7.00	5.77	12.62	3.26	
10		8.96	5.27	13.83	3.29			6.05	6.97	12.79	2.50			8.08	5.59	13.15	3.25			6.27	5.64	11.77	3.82	
11		8.41	10.32	18.63	2.53			7.72	9.77	17.00	3.01			7.67	10.85	18.23	5.46			6.51	10.91	17.06	5.46	
12		8.82	11.13	19.20	3.60			8.00	11.50	18.94	3.60			8.00	9.77	17.40	3.30			6.36	10.63	16.63	3.30	
13		8.16	11.63	18.75	0.00			6.99	12.47	18.89	0.00			7.28	11.72	17.85	0.00			6.45	11.90	17.99	0.00	
14		6.53	14.89	20.65	0.00			5.89	16.19	20.94	0.00			7.28	12.86	19.67	0.00			5.80	14.05	19.42	0.00	
15		8.93	8.60	17.37	0.00			6.80	9.84	16.21	0.00			8.23	10.21	18.05	0.00			6.87	12.12	18.51	0.00	
16		8.62	14.81	22.22	0.00			6.87	16.20	22.52	0.00			7.78	14.60	21.80	0.00			7.18	15.52	21.81	0.00	
17		8.59	13.52	21.26	0.00			7.20	14.59	21.12	0.00			7.27	15.40	21.90	0.00			7.03	15.23	21.62	0.00	
18		8.05	13.74	20.82	0.00			6.54	15.25	20.68	0.00			7.69	12.97	20.06	0.00			6.08	14.56	20.22	0.00	
19		7.96	13.24	20.39	0.00			6.05	15.75	20.72	0.00			7.52	12.23	19.46	0.00			6.25	14.65	20.24	0.00	
20		7.88	14.87	21.28	0.00			7.54	15.01	21.16	0.00			7.17	14.55	20.48	0.00			6.41	14.97	20.91	0.00	

TABLE 17 - Dimensions (mm) of dental development stages measured with CBCT.

Score	MAXILLARY TEETH						
	Central Incisor	Lateral Incisor	Canine	First Premolar	Second Premolar	First Molar	Second Molar
0							
1							
2	>9.60-11.41	>6.30-8.84	>7.13-9.10	>2.28-5.34	>3.01-3.67	>6.60-6.99	>3.00-4.31
3	>10.85-11.99	>9.48-10.51	>9.65-11.15	>6.91-8.04	>6.68-7.66	>6.48-7.69	>6.21-7.71
4	>7.70-10.03	>2.67-7.58	>1.71-6.82	>1.22-7.25	>1.08-6.31	>1.90-7.25	>1.22-6.02
5	>10-13.59	>10.88-13.86	>15.25-17.45	>10.31-13.14	>10.68-14.69	>9.71-12.90	>10.01-12.47
Score	**MANDIBULAR TEETH**						
	Central Incisor	Lateral Incisor	Canine	First Premolar	Second Premolar	First Molar	Second Molar
0							
1							
2	>8.40-10.40	>8.19-9.97	>7.11-9.44	>4.47-6.30	>4.69-7.82	>6.91-7.39	>1.62-4.59
3	>8.55-9.94	>8.60-10.29	>9.77-11.76	>7.69-9.04	>7.07-8.25	>5.66-7.47	>5.89-7.34
4	>8.24-10.88	>5.41-11.56	>6.03-9.70	>3.42-7.93	>2.67-6.18	>1.50-9.15	>1.71-6.57
5	>10.58-13.24	>12.26-14.21	>13.09-15.53	>12.29-15.13	>12.96-15.60	>10.92-14.65	>8.60-13.69

0 – Absence of dental crypt; 1 – Presence of dental crypt; 2 – Dental crown partially formed; 3 – Dental crown totally formed; 4 – Beginning of root formation – open apex; 5 – End of root formation – closed apex.

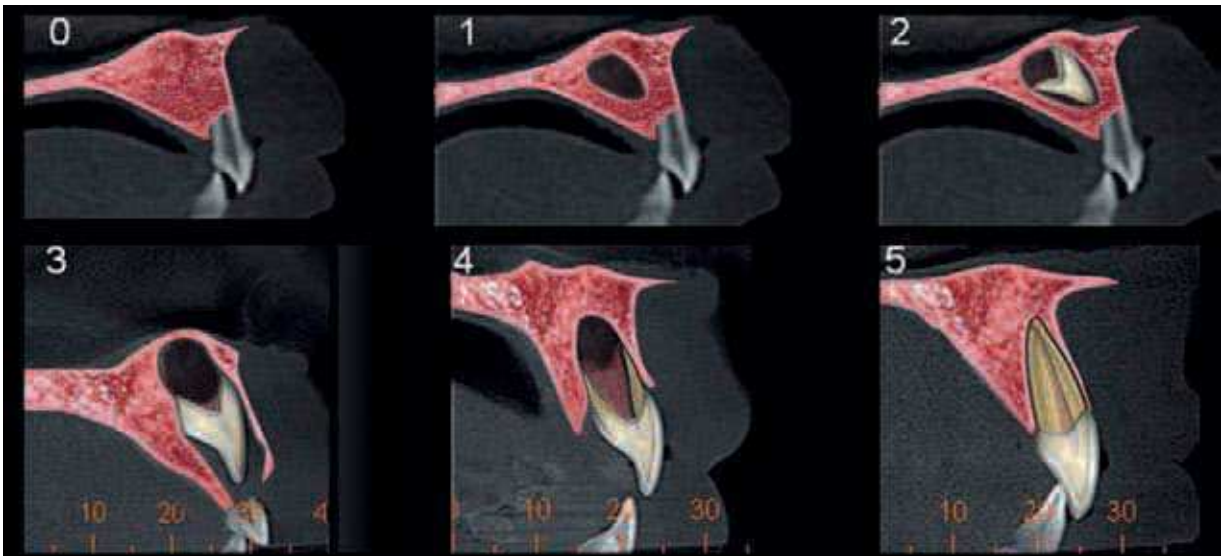

FIGURE 1 - Human permanent dental development stages using CBCT (Sagittal view).

Considering this research is a preliminary essay, the determination of the anatomical landmarks of human teeth with clinical importance may be an initial reference for a dental anatomy study based on the CBCT imaging method.

Growth and development may be estimated using parameters of chronological and biological age. The indicators of biological age are: stature, weight, mental, sexual, skeletal and dental ages.[23] Dental age may be determined by eruptive chronology and by dental mineralization stages. A high correlation is observed between dental age and chronological age. The measurements obtained in the present study corresponding to different stages of dental

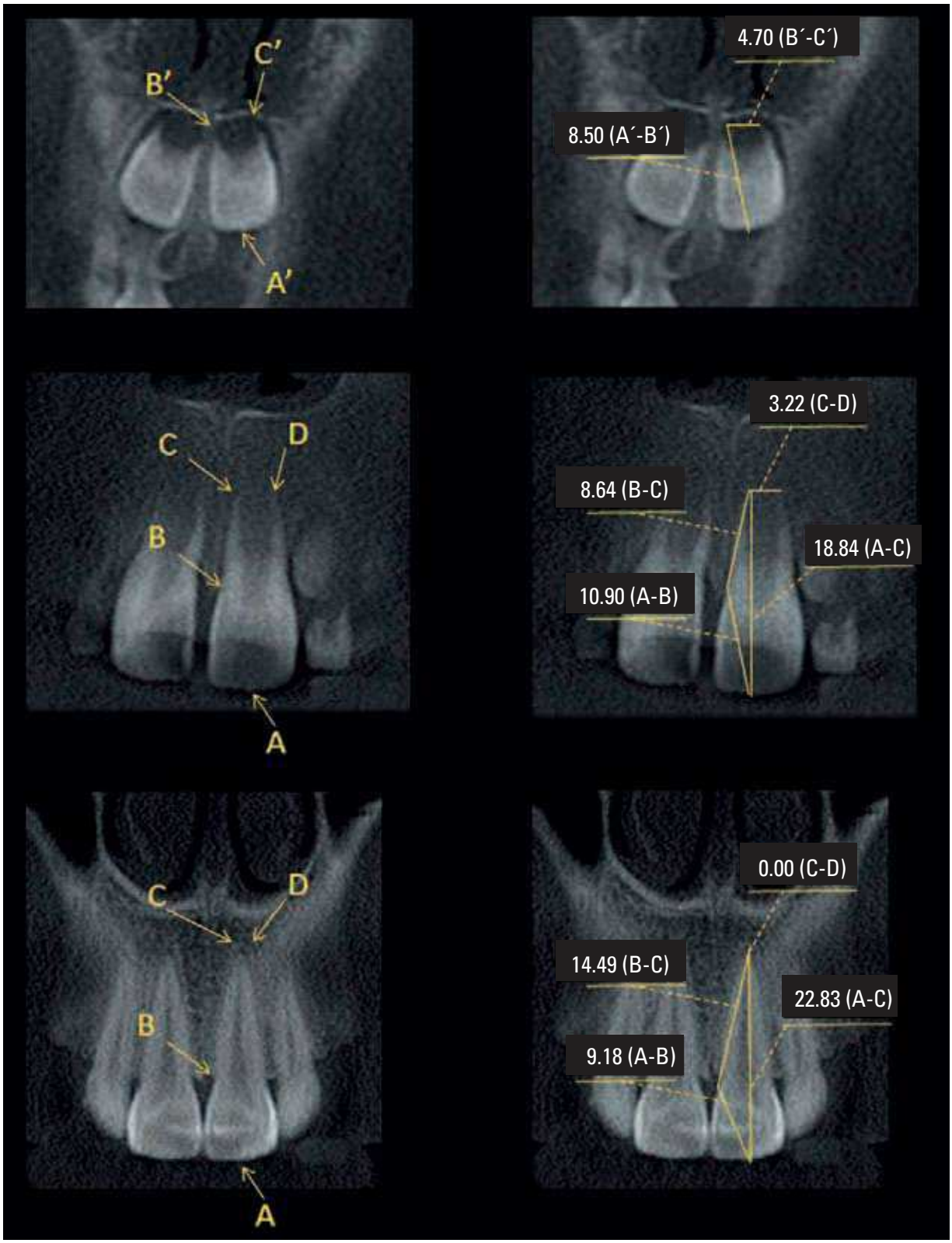

FIGURE 2 - Linear measurements of dental development stages of maxillary central incisor using CBCT (Coronal view).

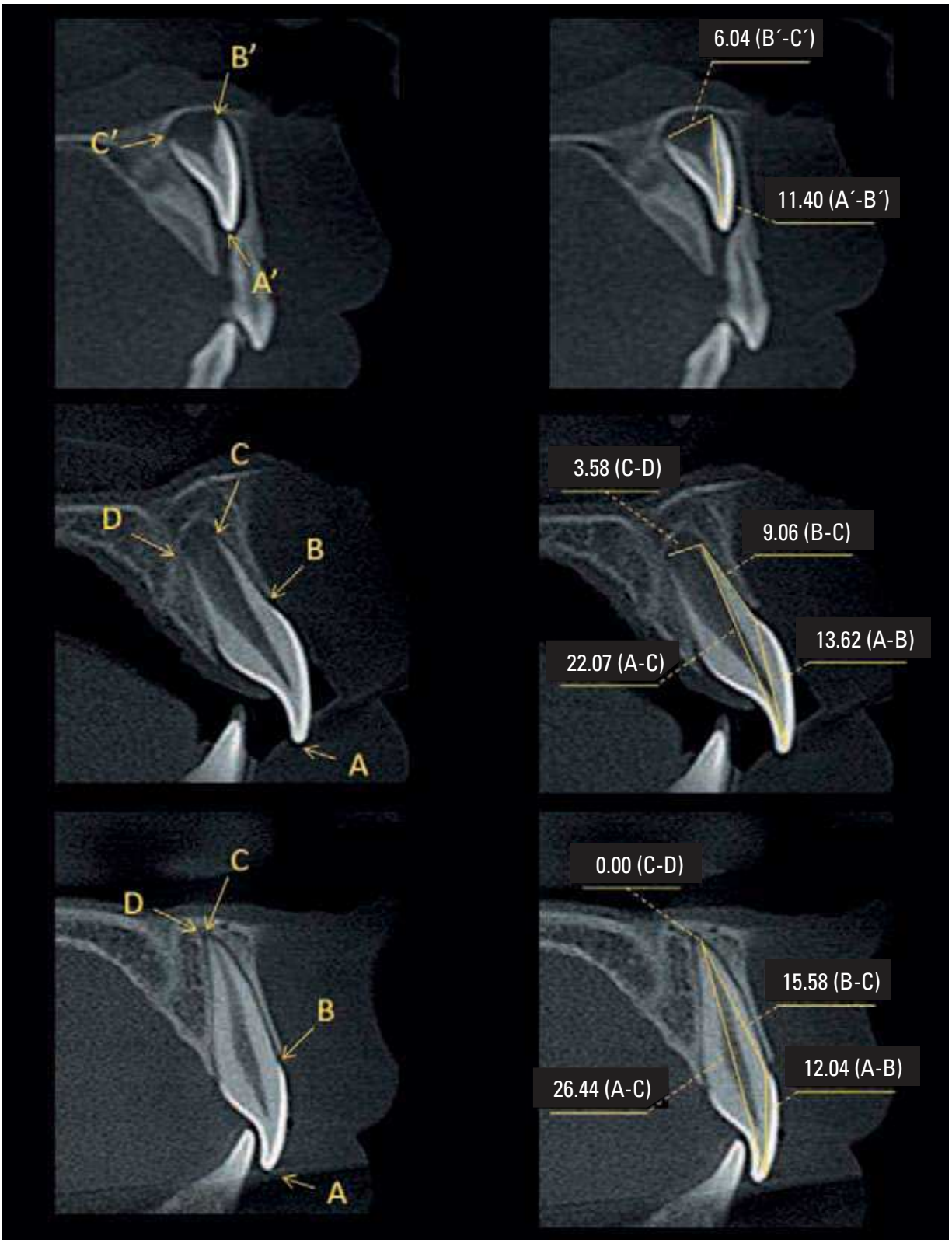

FIGURE 3 - Linear measurements of dental development stages of maxillary central incisor using CBCT (Sagittal view).

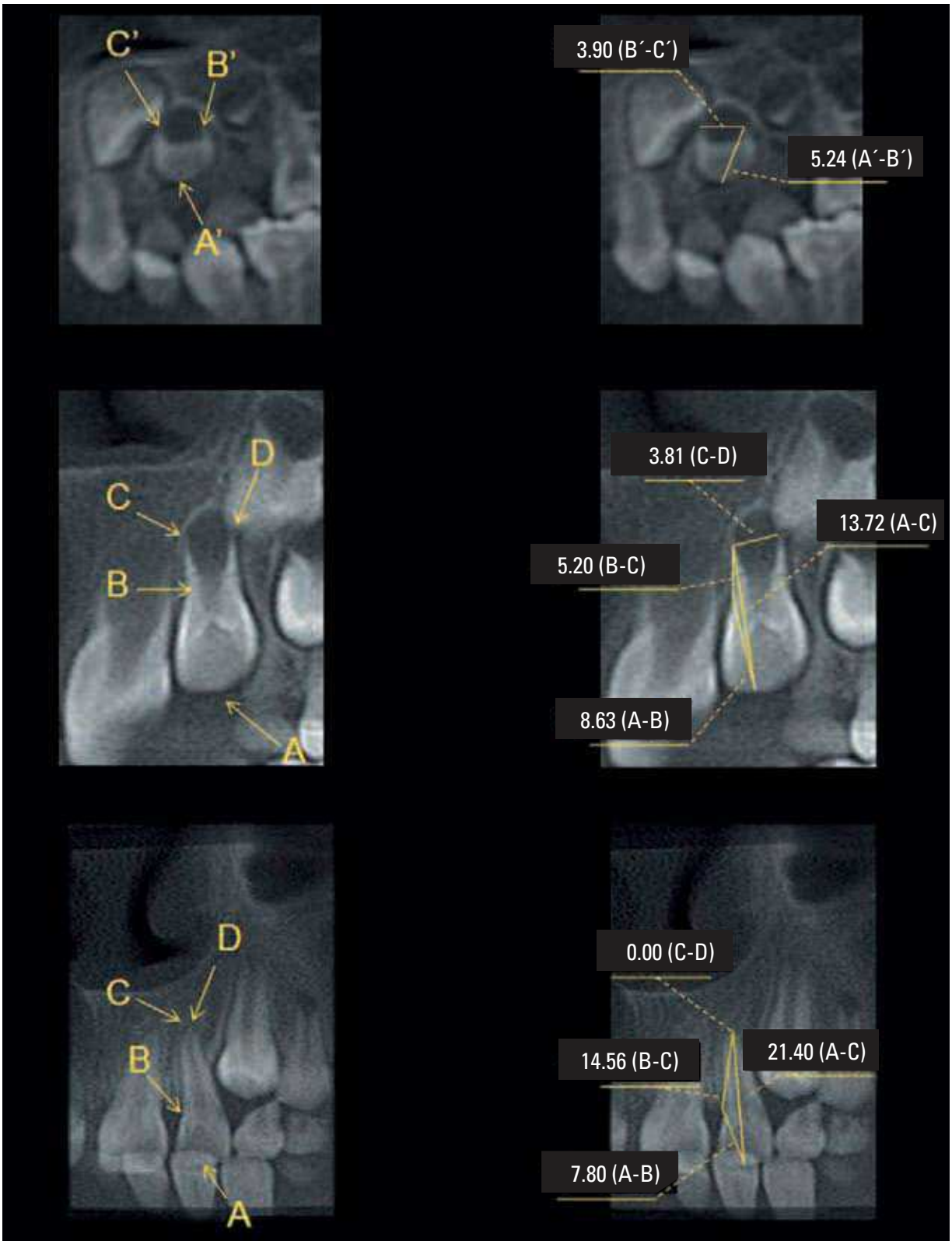

FIGURE 4 - Linear measurements of dental development stages of maxillary lateral incisor using CBCT (Coronal view).

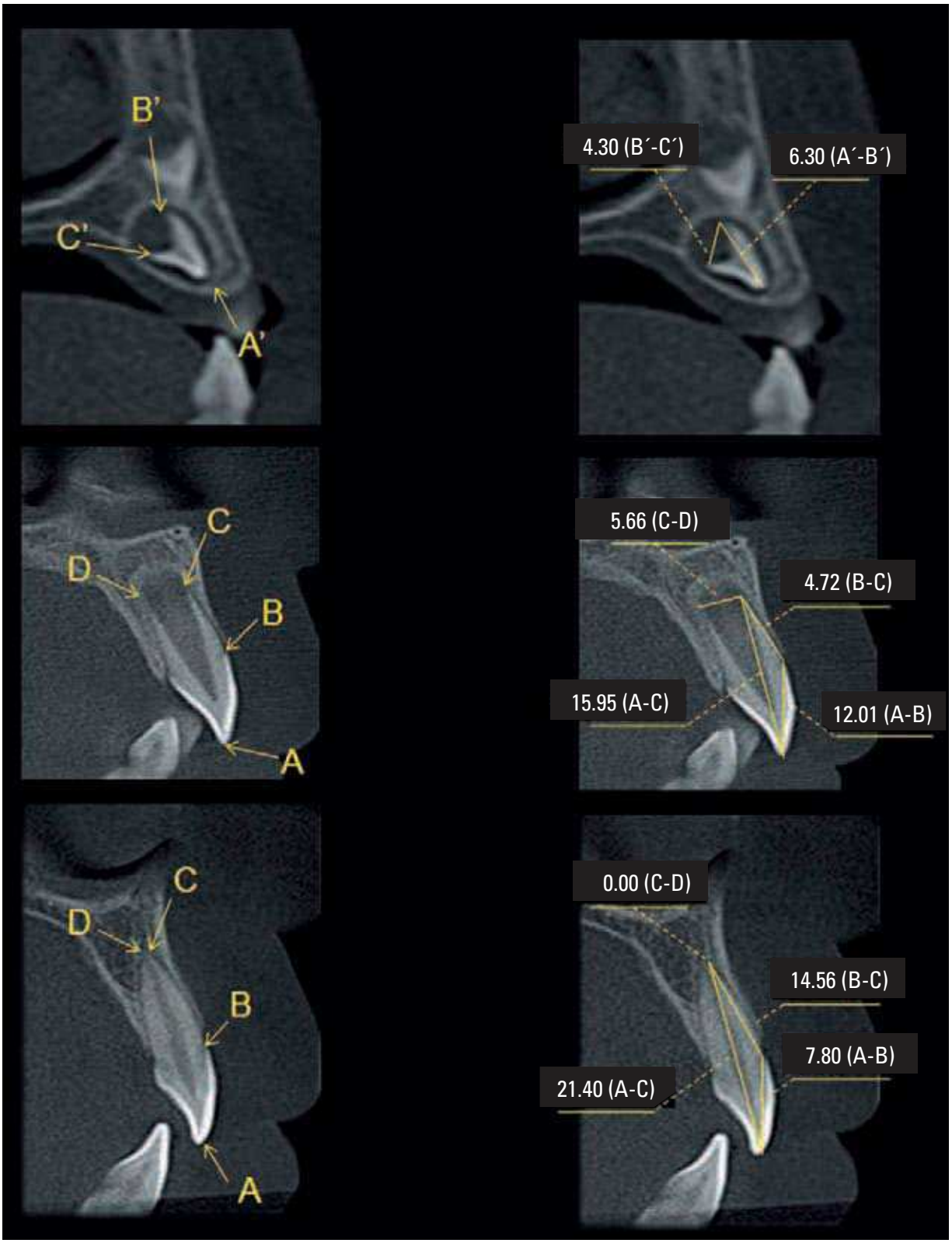

FIGURE 5 - Linear measurements of dental development stages of maxillary lateral incisor using CBCT (Sagittal view).

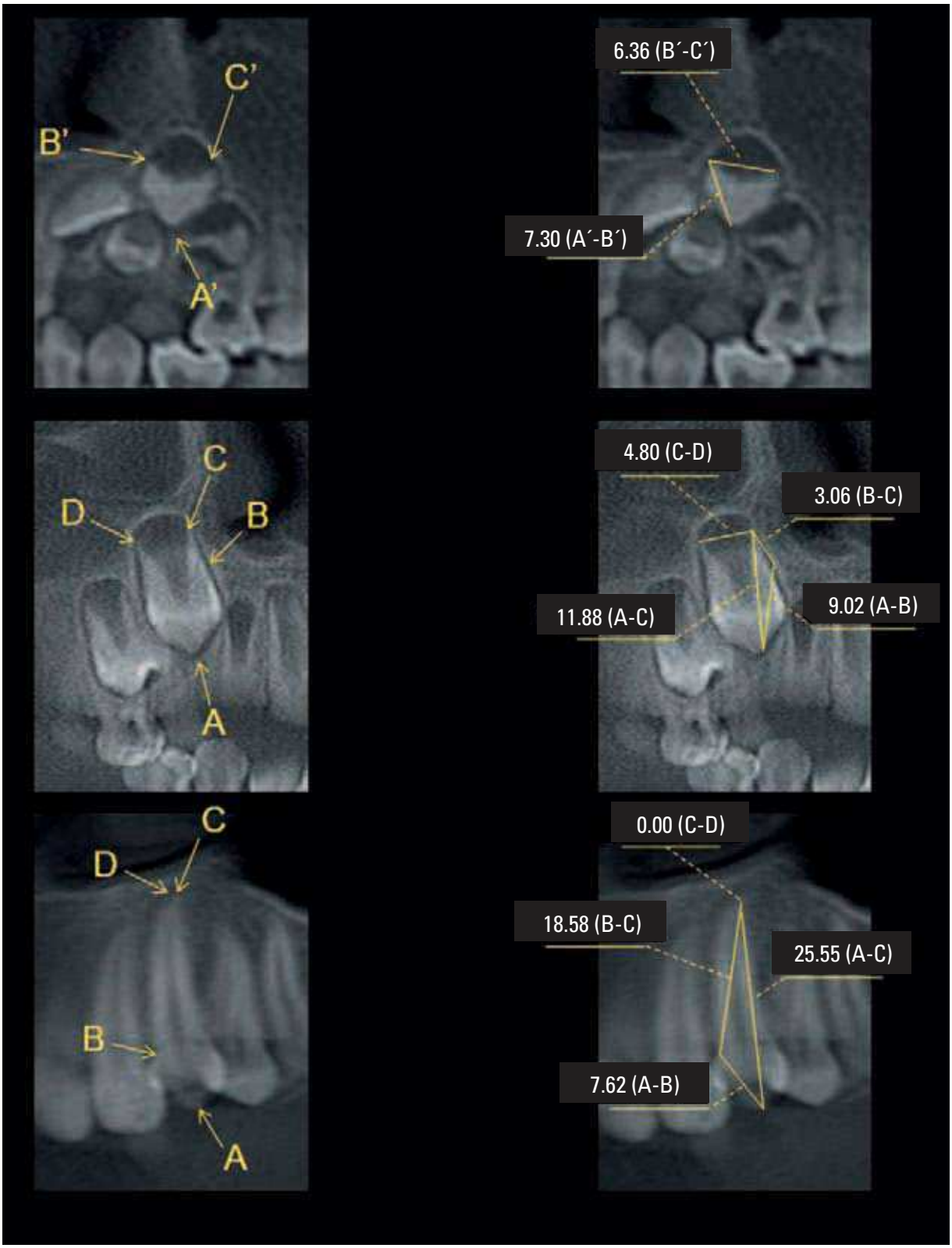

FIGURE 6 - Linear measurements of dental development stages of maxillary canine using CBCT (Coronal view).

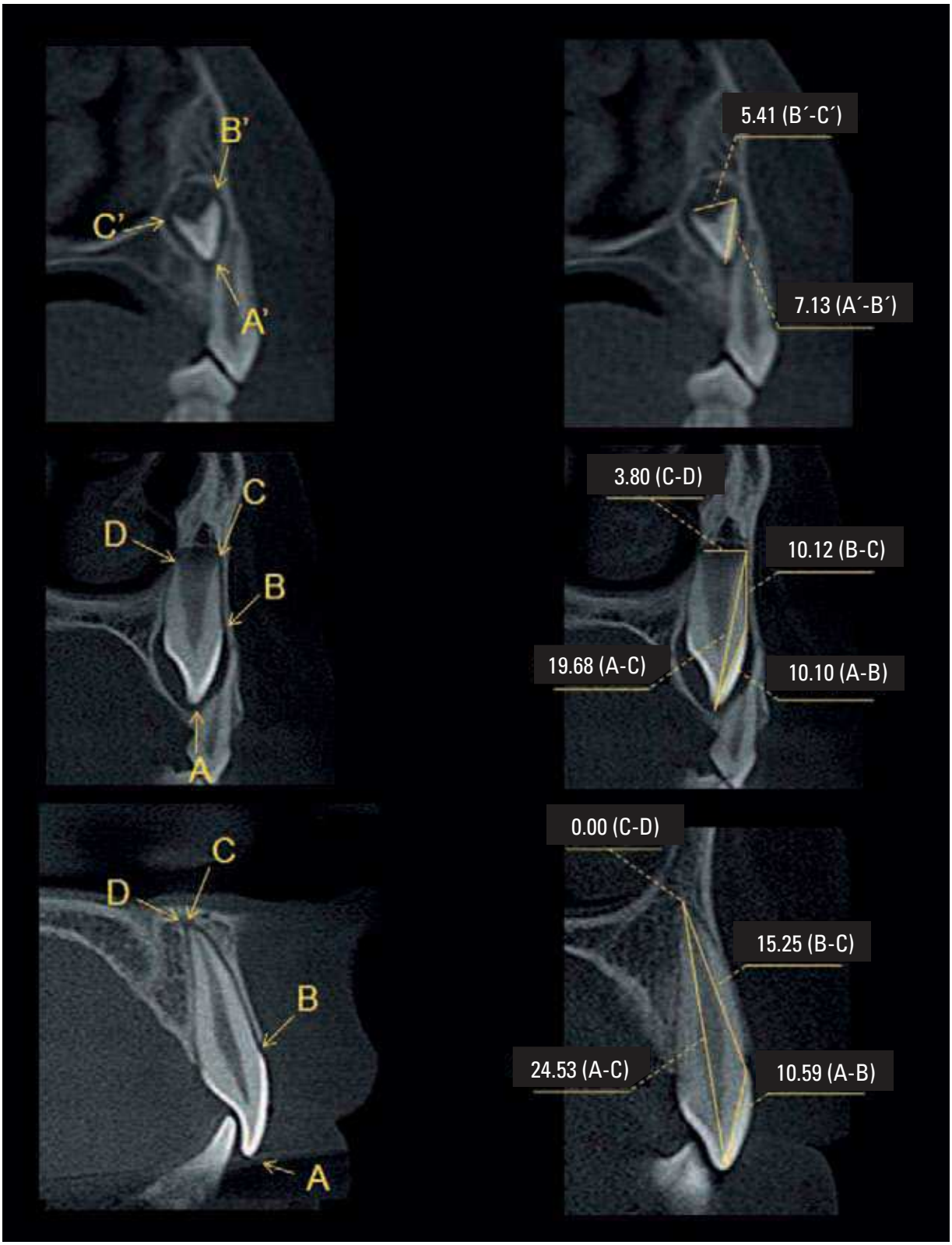

FIGURE 7 - Linear measurements of dental development stages of maxillary canine using CBCT (Sagittal view).

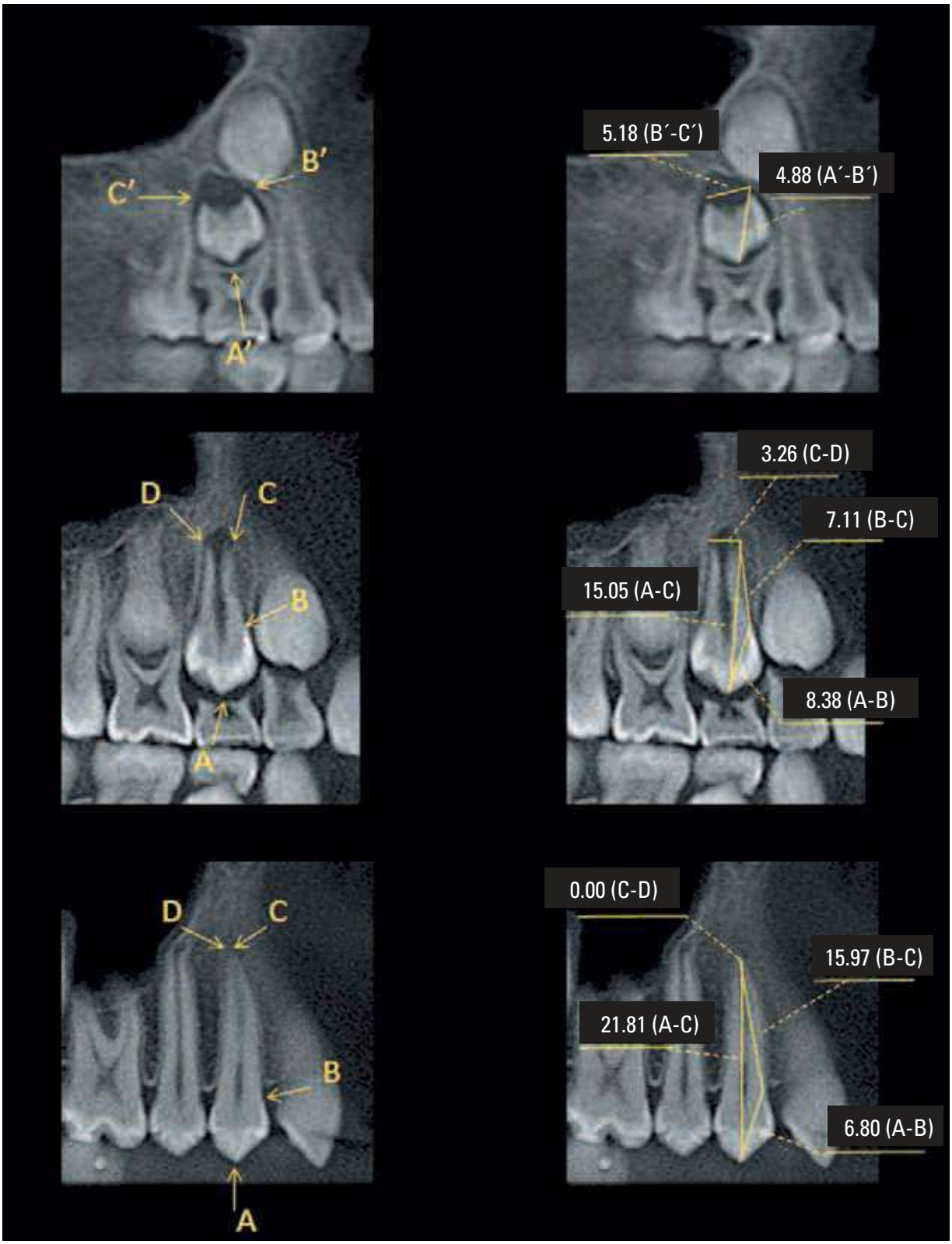

FIGURE 8 - Linear measurements of dental development stages of maxillary first premolar using CBCT (Coronal view).

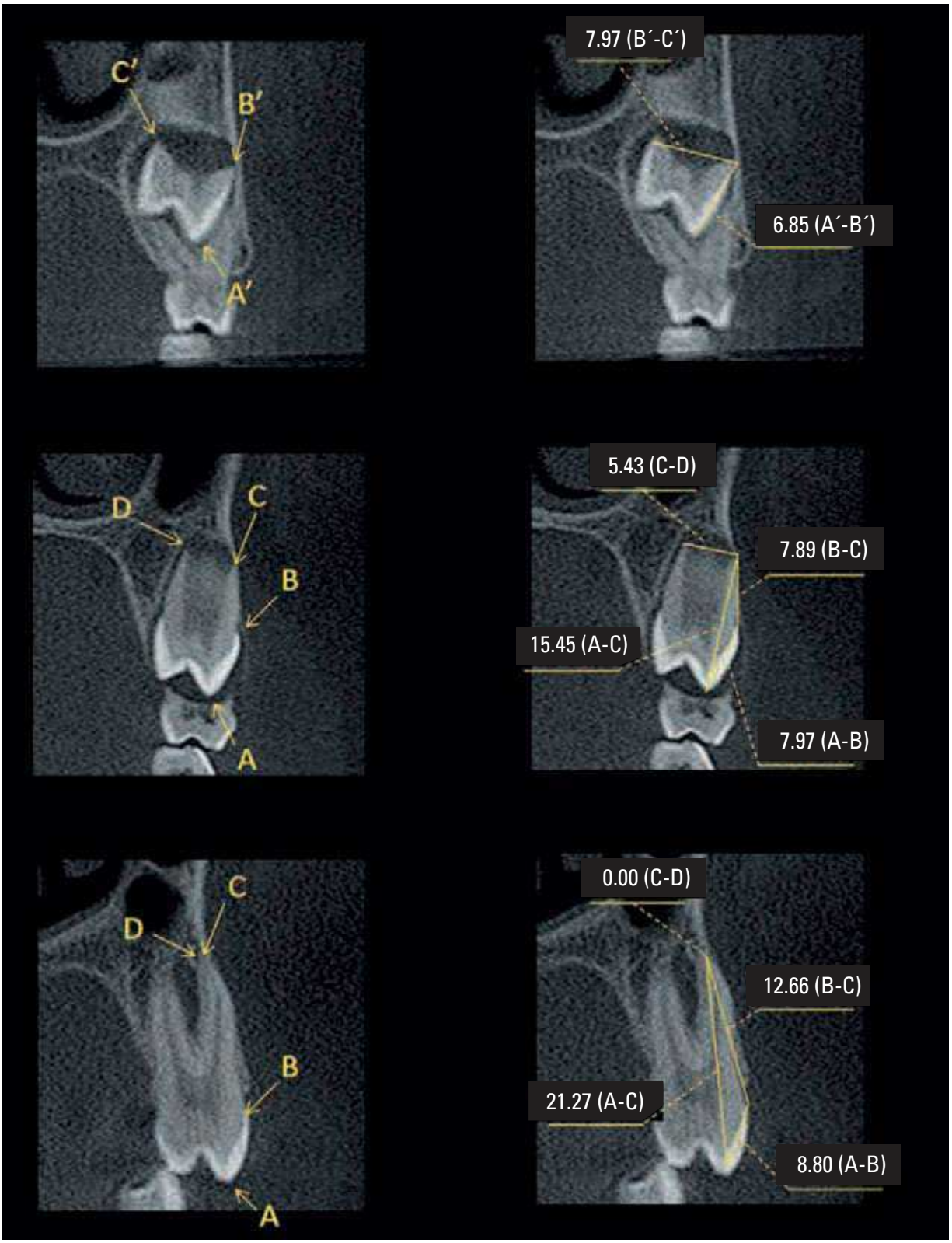

FIGURE 9 - Linear measurements of dental development stages of maxillary first premolar using CBCT (Sagittal view).

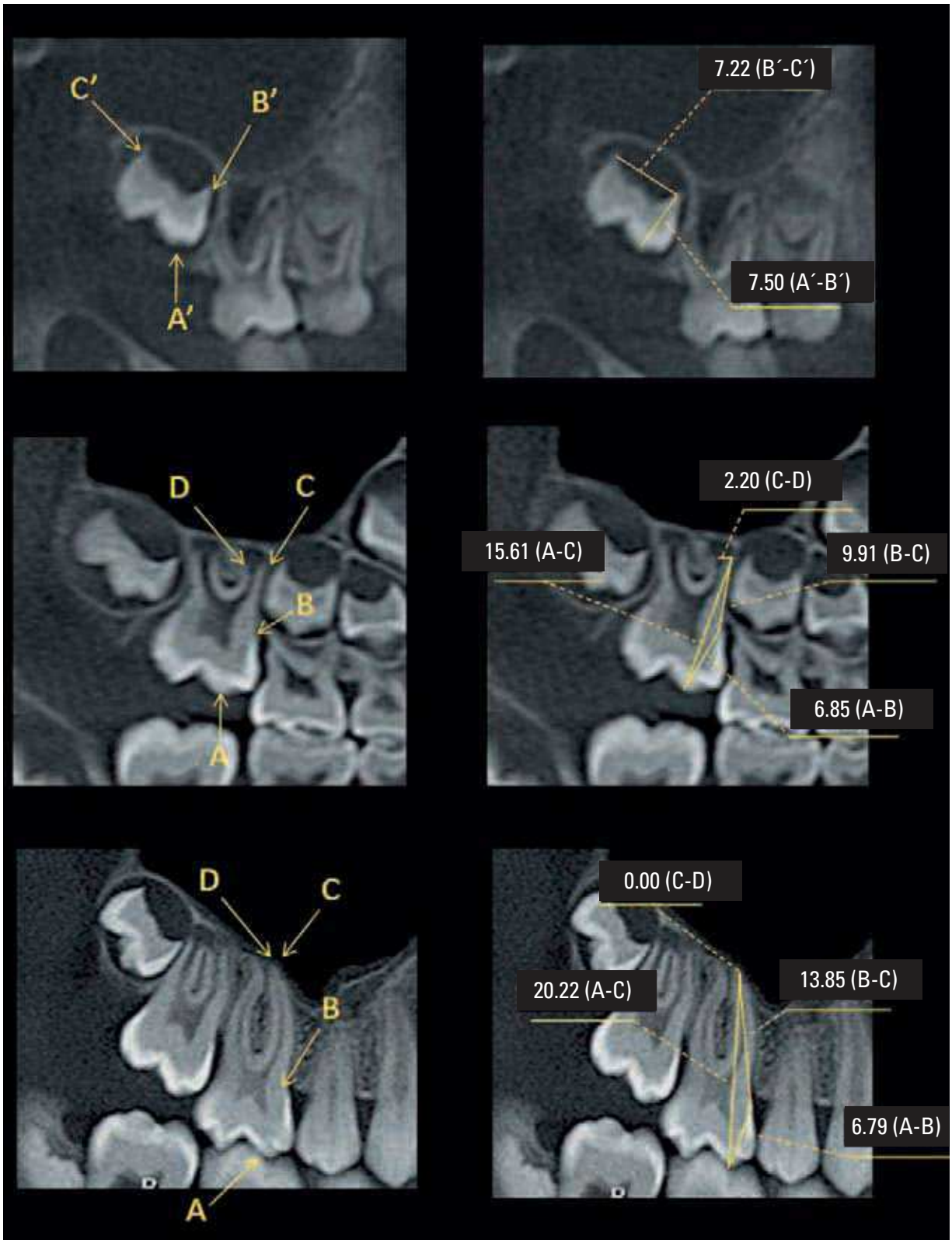

FIGURE 10 - Linear measurements of dental development stages of maxillary first molar using CBCT (Coronal view).

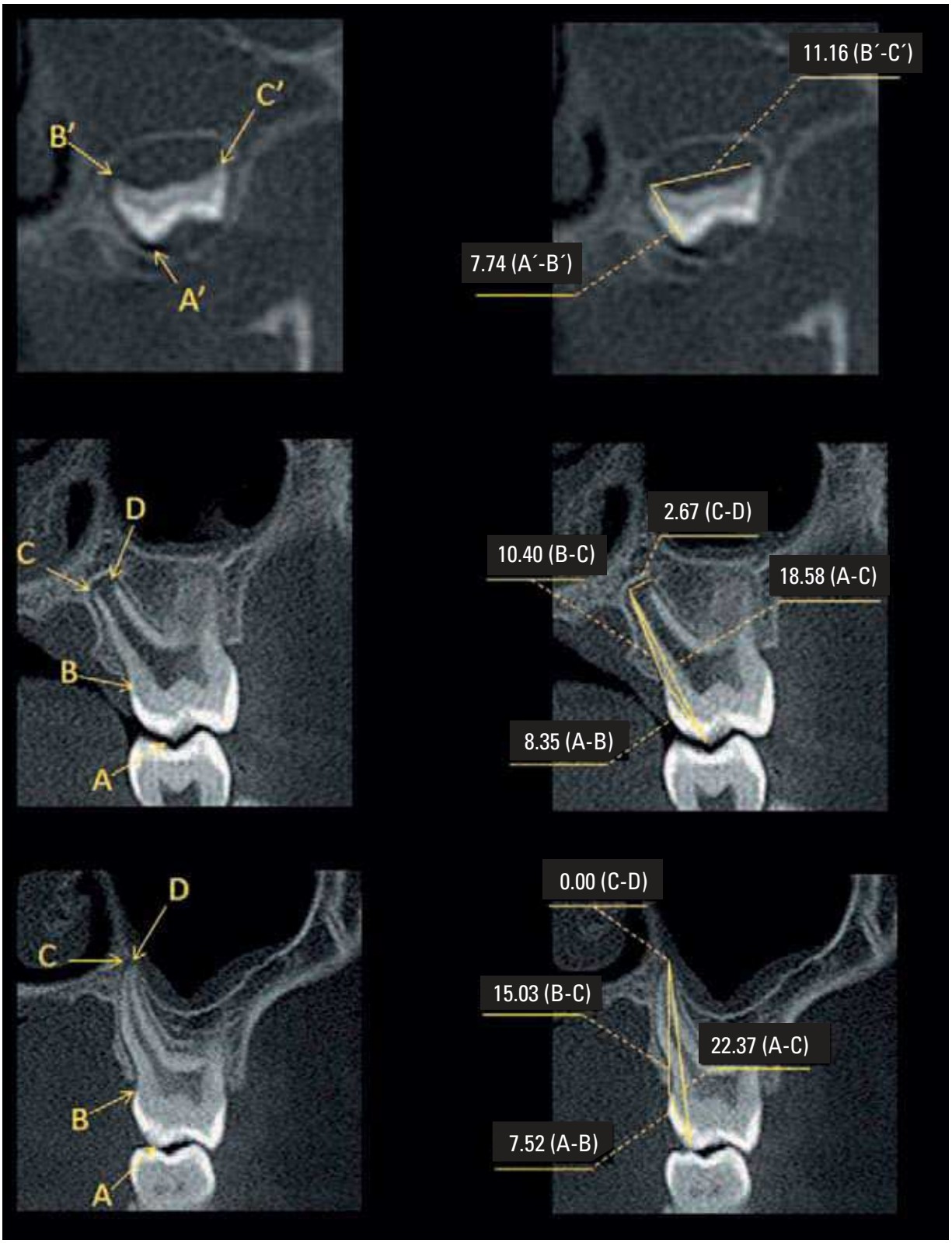

FIGURE 11 - Linear measurements of dental development stages of maxillary first molar using CBCT (Sagittal view).

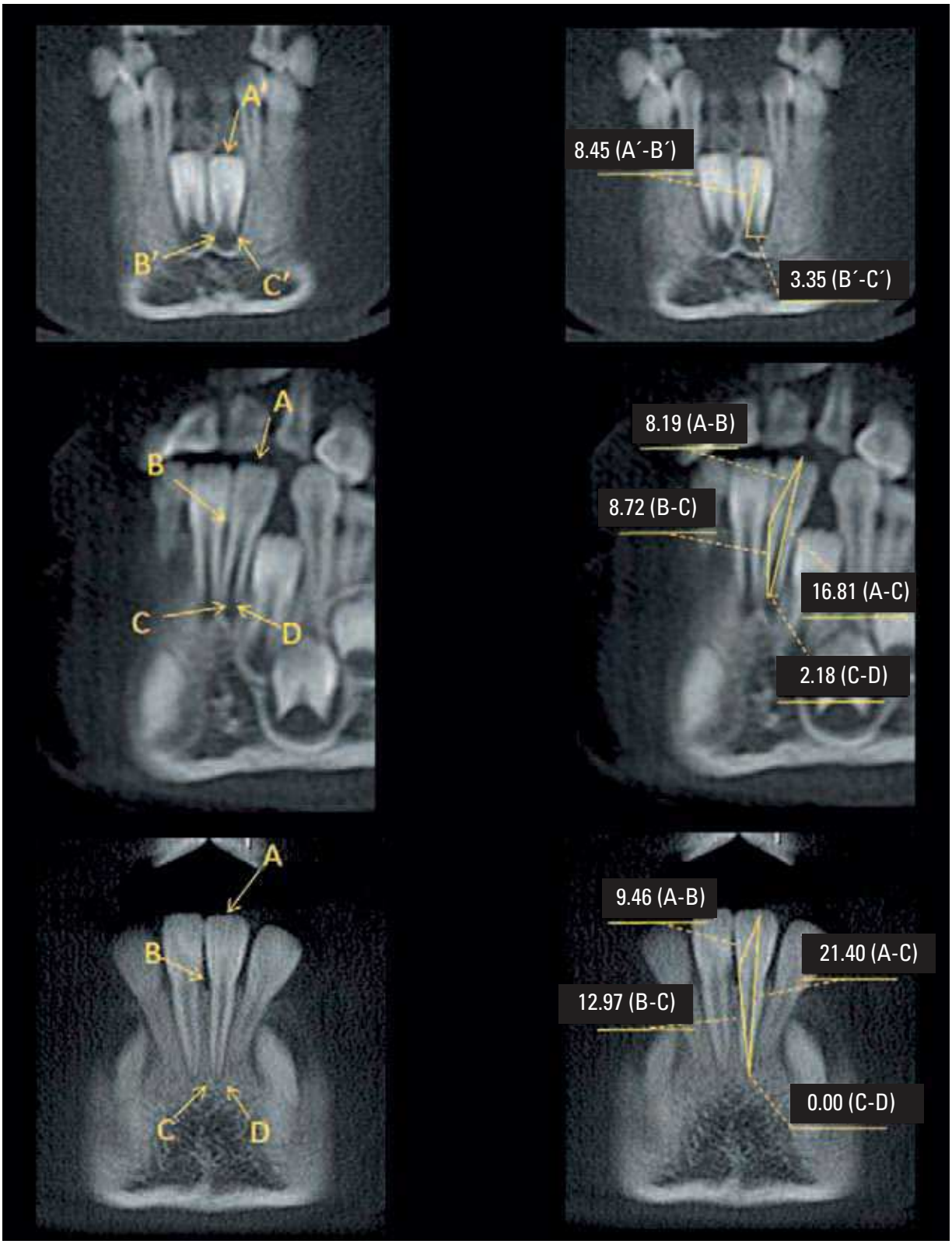

FIGURE 12 - Linear measurements of dental development stages of mandibular central incisor using CBCT (Coronal view).

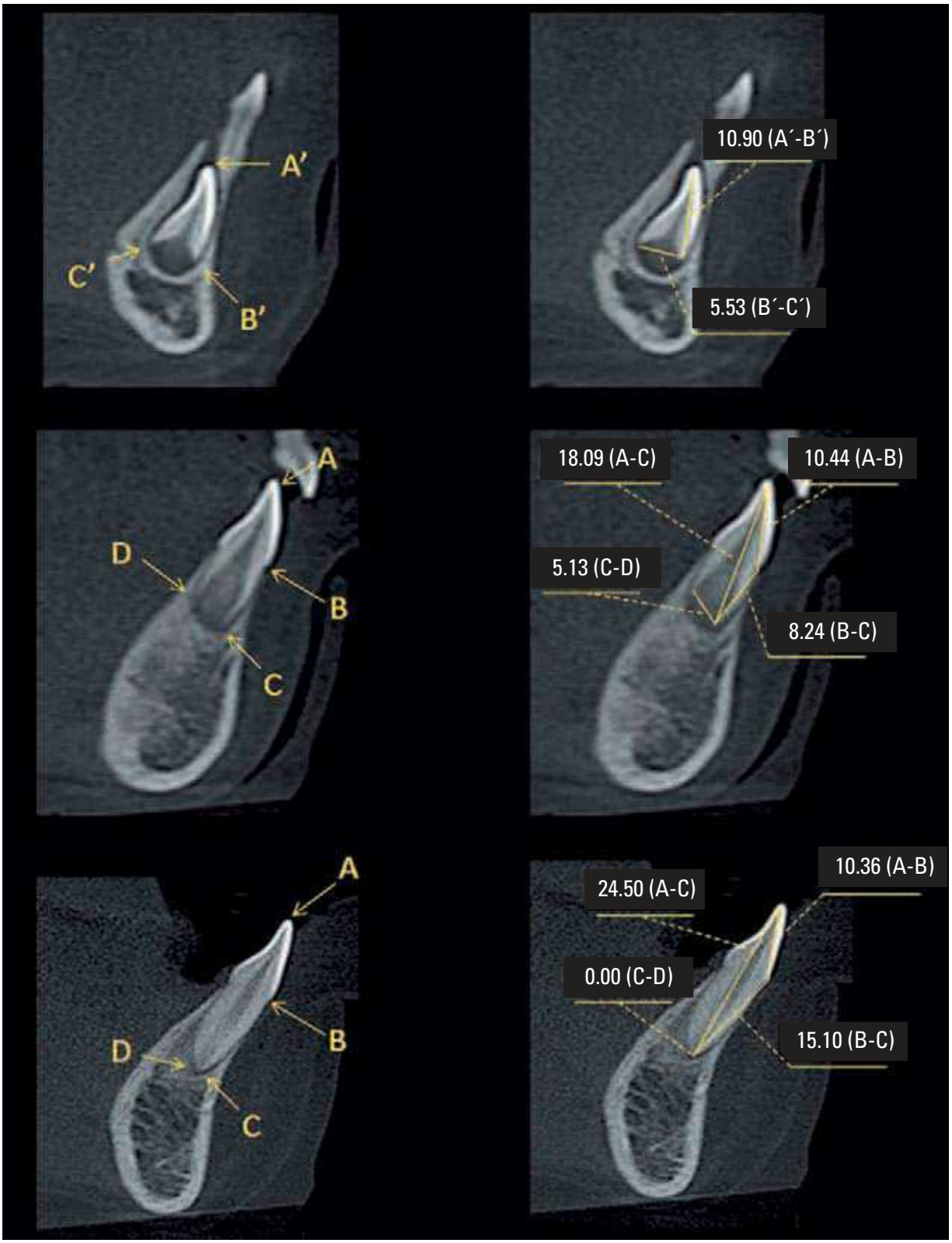

FIGURE 13 - Linear measurements of dental development stages of mandibular central incisor using CBCT (Sagittal view).

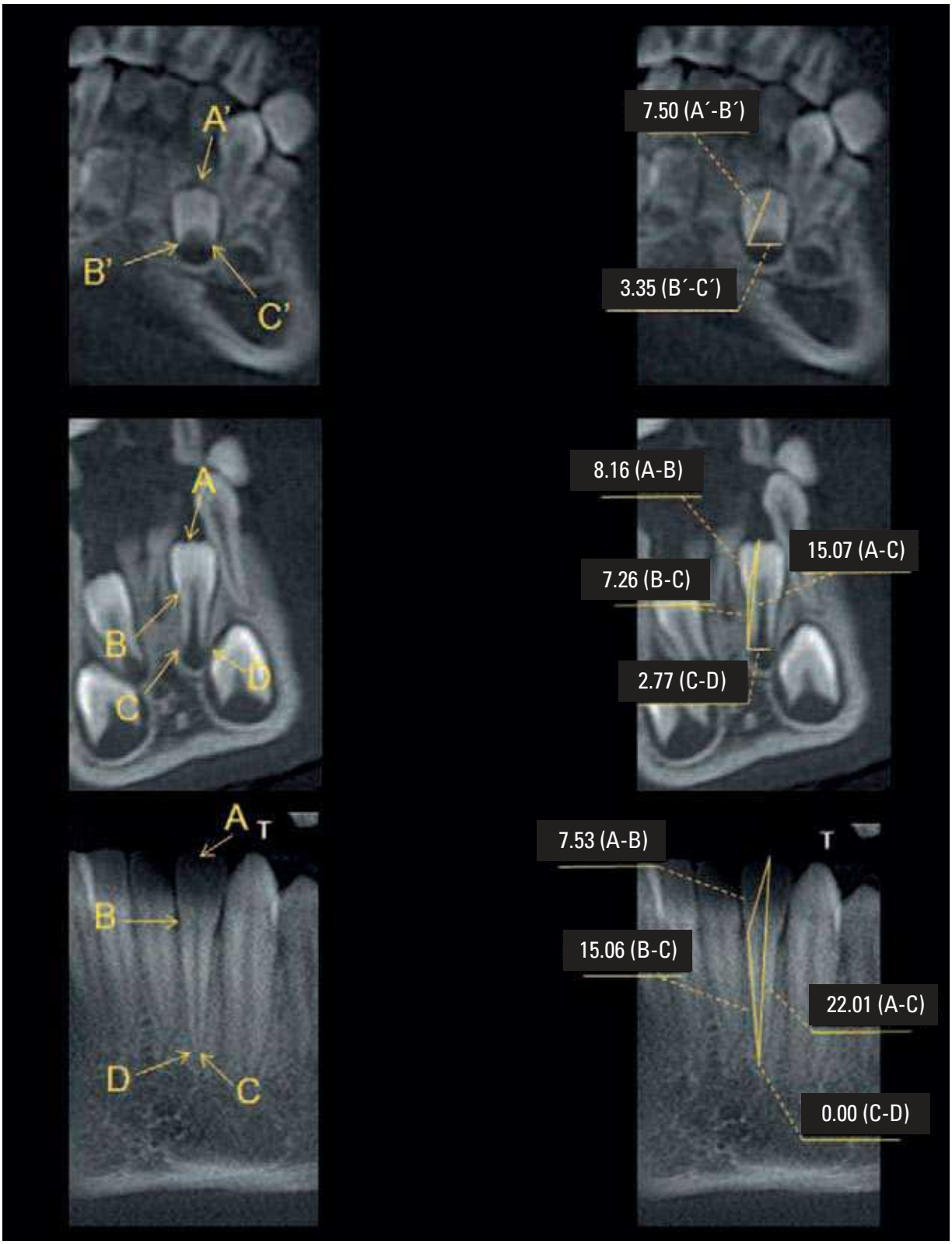

FIGURE 14 - Linear measurements of dental development stages of maxillary lateral incisor using CBCT (Coronal view).

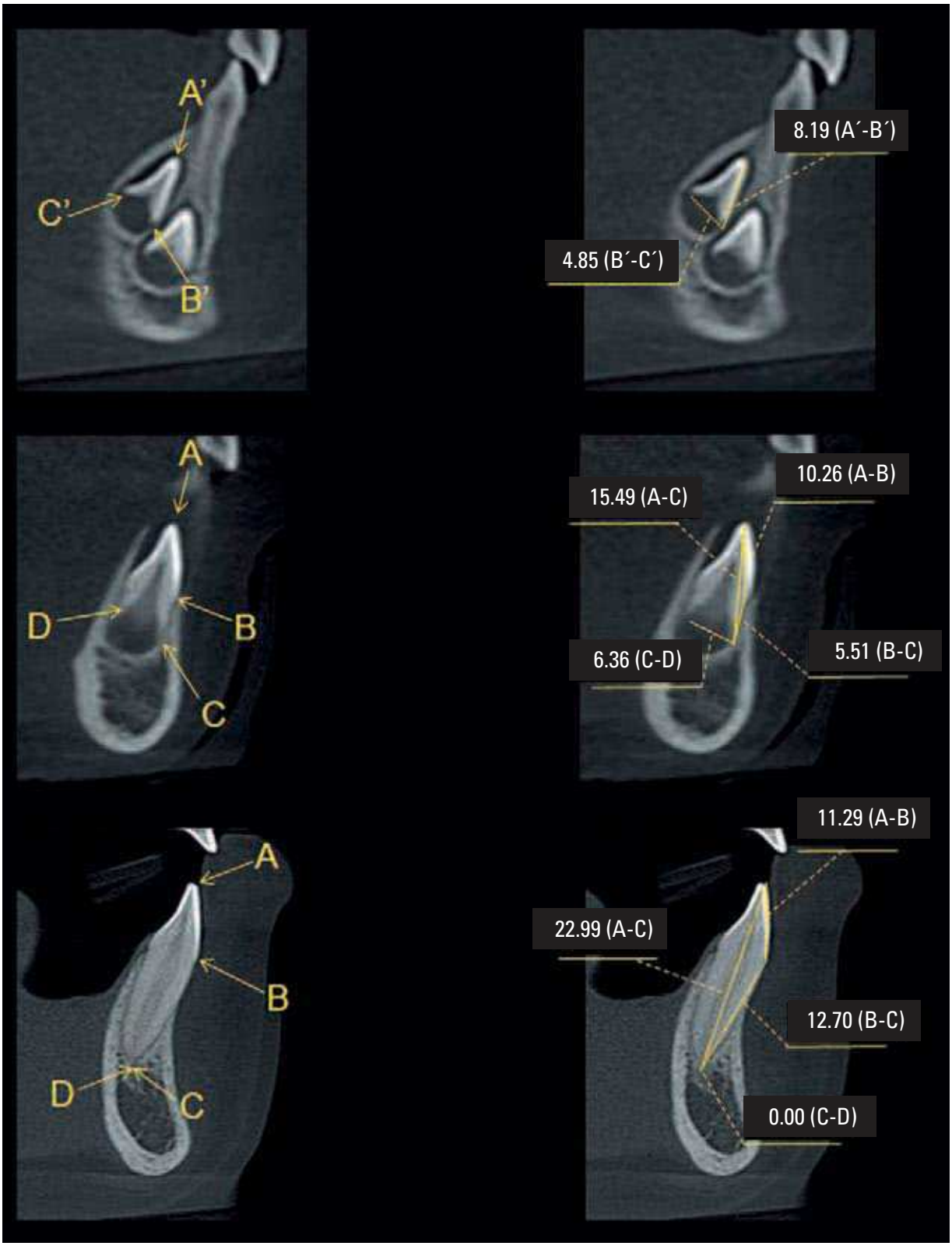

FIGURE 15 - Linear measurements of dental development stages of maxillary lateral incisor using CBCT (Sagittal view).

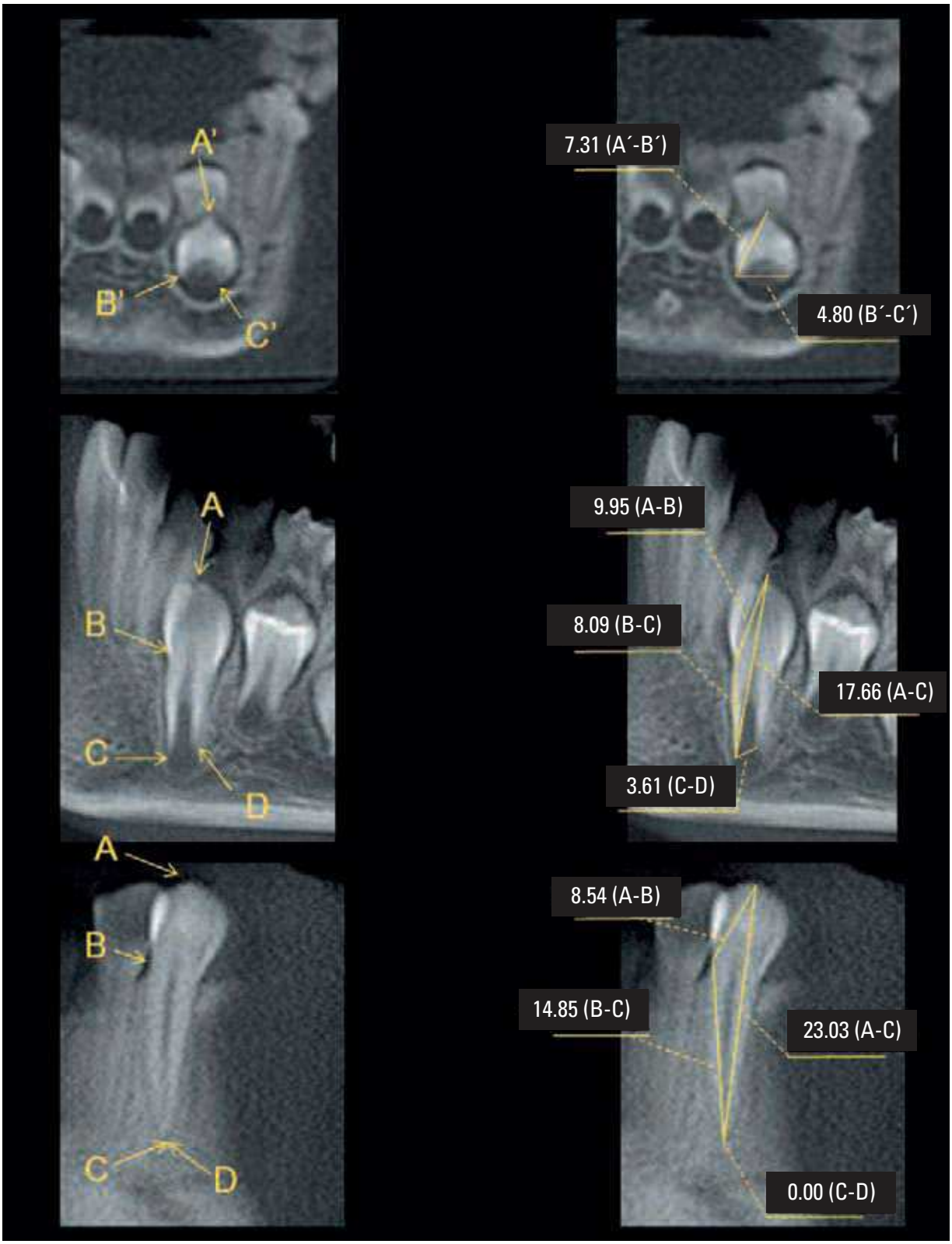

FIGURE 16 - Linear measurements of dental development stages of mandibular canine using CBCT (Coronal view).

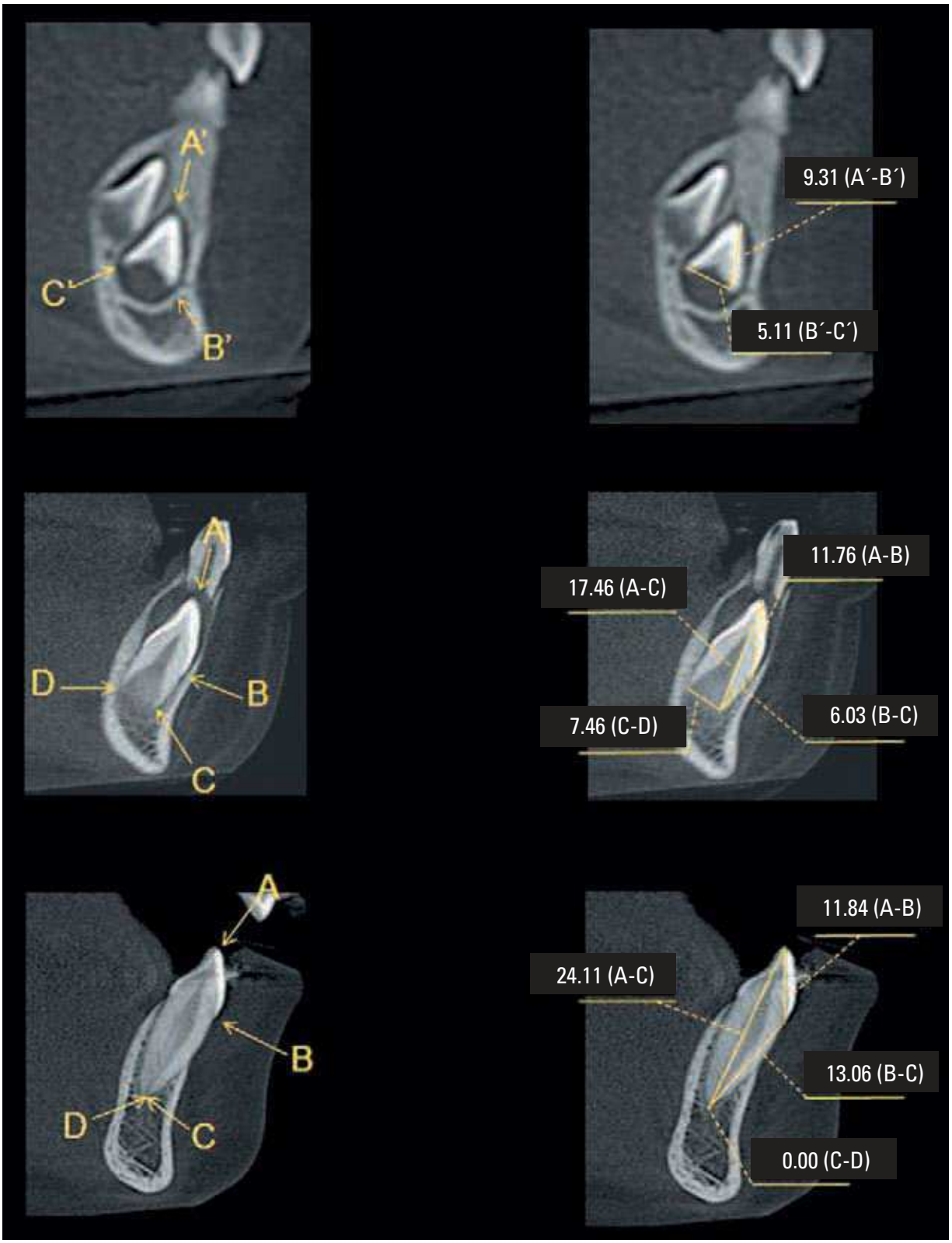

FIGURE 17 - Linear measurements of dental development stages of mandibular canine using CBCT (Sagittal view).

FIGURE 18 - Linear measurements of dental development stages of mandibular first premolar using CBCT (Coronal view).

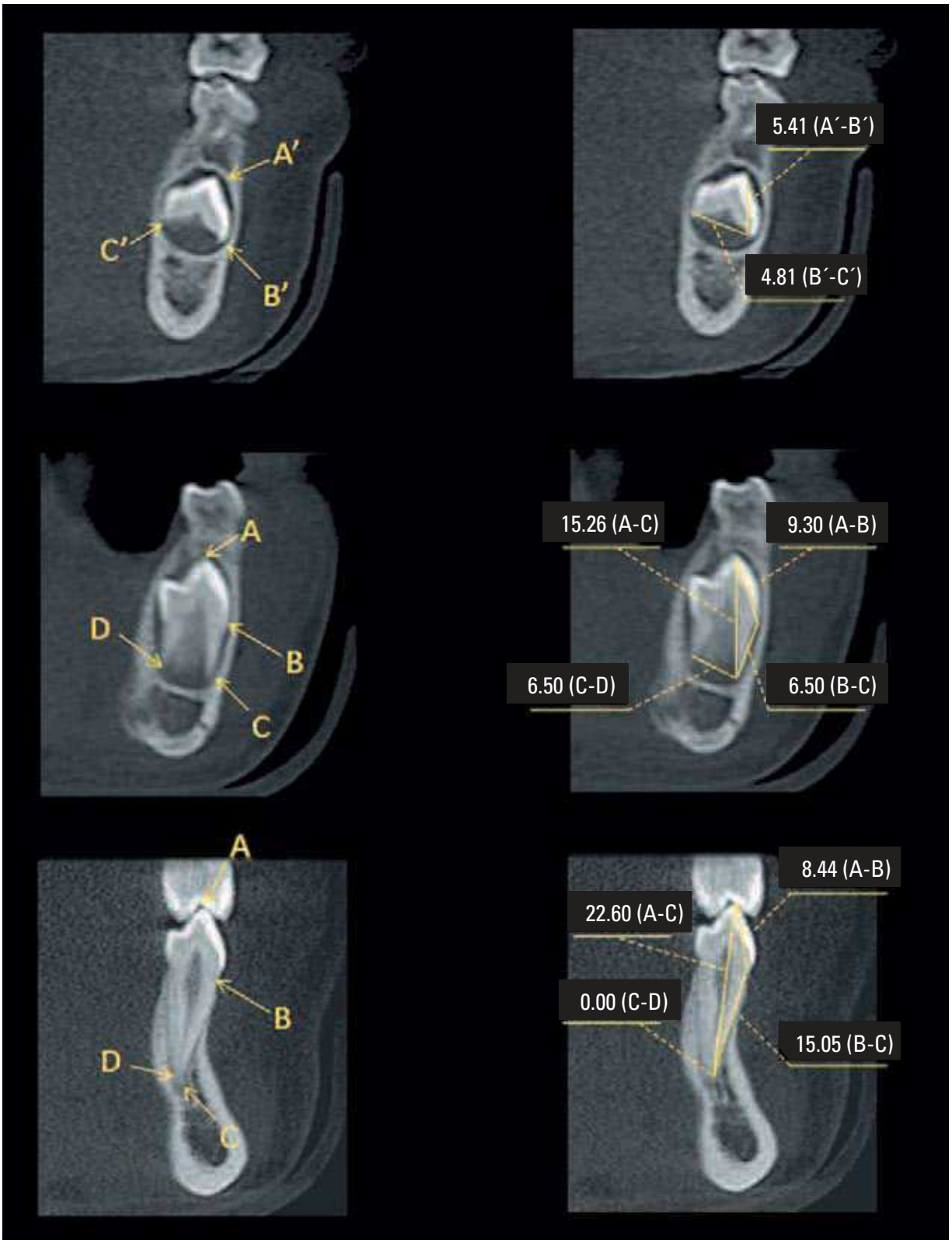

FIGURE 19 - Linear measurements of dental development stages of mandibular first premolar using CBCT (Sagittal view).

FIGURE 20 - Linear measurements of dental development stages of mandibular first molar using CBCT (Coronal view).

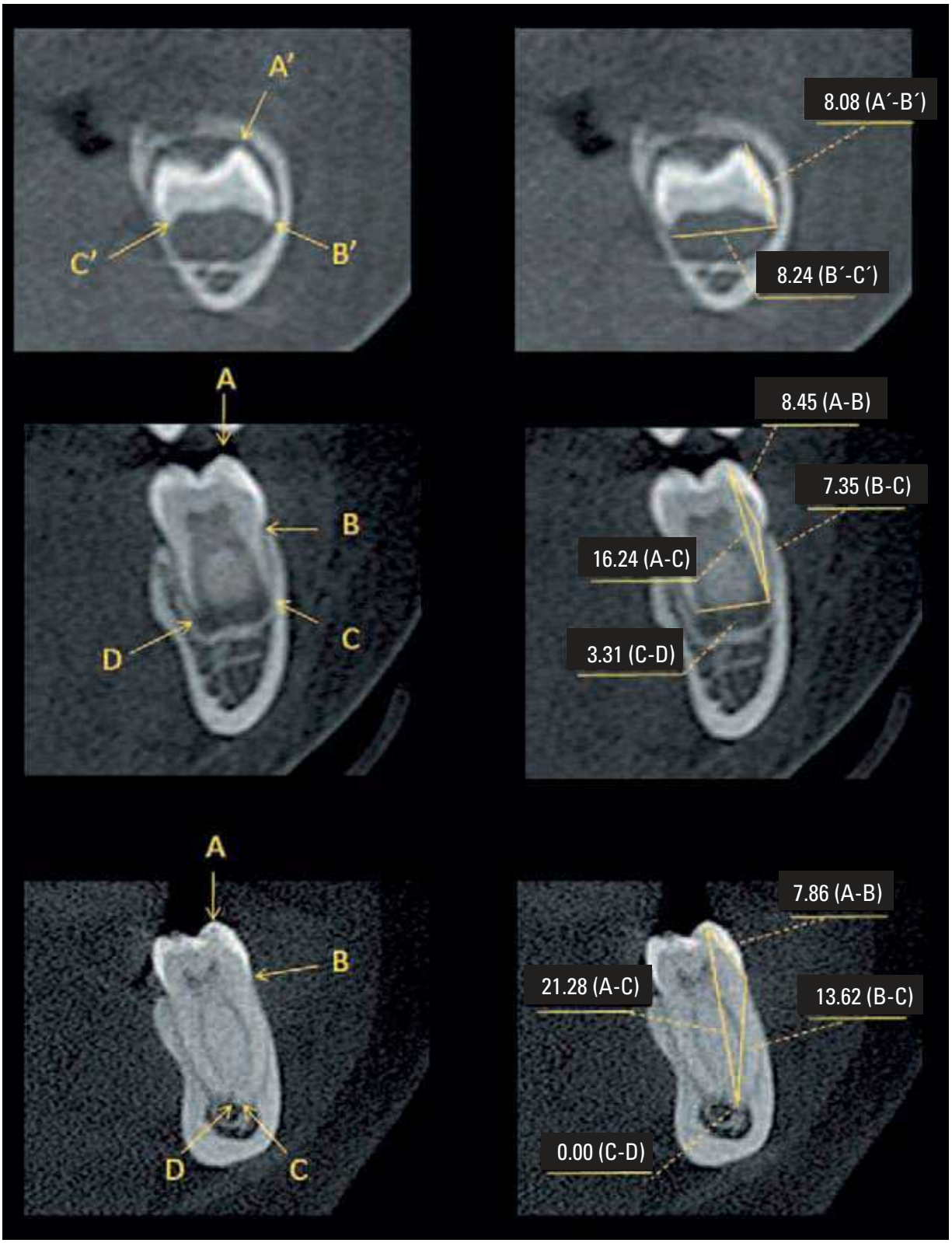

FIGURE 21 - Linear measurements of dental development stages of mandibular first molar using CBCT (Sagittal view).

development (3 to 20 years of age) represent a reference value of length, which should be associated with caution to maturation stage or skeletal age.

The present study was conducted using databases from private radiology clinics, in subjects whose genetic, nutritional, physiologic, pathologic, socioeconomic, and housing patterns were not standardized. The measurements acquired on dental groups are in accordance with estimates from previously published investigations.[9,36,50] However, this tool constitutes a noninvasive technique which permits in vivo studies. Investigations with observation methods using conventional radiographs to evaluate the development of human permanent teeth, chronology and sequence of eruption represent the most widely employed study models.[20,21,34,35,44,49]

A classical study by Nolla[35] reported that every dentist treating children must have a good understanding of the development of the dentition. The variability in tooth development may indicate differences between mean values. The author used serial oral radiographs of twenty-five boys and twenty-five girls, and suggested stages of development of human permanent teeth, which were graded on a scale from 0 to 10 (0- absence of crypt; 1- presence of crypt; 2- start of calcification; 3- one-third of crown completed; 4- two thirds of crown completed; 5- crown almost completed; 6- crown completed; 7- one-third of root completed; 8- two-thirds of root completed; 9- root almost completed - open apex; 10- apical end of root completed). Mean differences in the general sequence of development were not apparent between genders and few development differences were found between right and left teeth.

The possibility of obtaining information on three-dimensional anatomic structures in vivo with image handling has great potential and constitutes an achievement for all dental areas.[6] Liu et al[25] determined the accuracy of volumetric analysis of teeth in vivo using CBCT. The volume of 24 bicuspid teeth extracted for orthodontic purposes were determined. The measurements slightly deviated from the volumes within -4% to 7%. Smoothing operations reduce volume measurements. Currently, no requirements for accuracy of volumetric determinations of tooth volume have been established. Baumgaertel et al[4] investigated the reliability and accuracy of dental measurements made on CBCT reconstructions. Thirty human skulls were scanned with dental CBCT, and 3-dimensional reconstructions of the dentitions were generated. Ten measurements (overbite, overjet, maxillary and mandibular intermolar and intercanine widths, available arch length, and required arch length) were made directly on the dentitions of the skulls with a high-precision digital caliper and on the digital reconstructions with commercially available software. Dental measurements from CBCT volumes can be used for quantitative analysis. A small systematic error was found, which became statistically significant only when combining several measurements. An adjustment for this error allowed improved accuracy.

Several studies have used the CBCT measurement tool to determine distances between maxillofacial anatomical structures.[1,4,7,19,25,29-31,45] CBCT measurements have more important applications and reliability than conventional imaging methods.[5,11-13,15,45]

CONCLUSIONS

Under the tested conditions and within the limitations of this preliminary study, one can conclude that CBCT images of different development stages may contribute to treatment diagnosis, planning and outcome. The dimensions of dental crowns and roots may have good clinical and research application. However, further studies are recommended to minimize variables in the methodology.

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Contact address
Carlos Estrela
Rua C-245, Quadra 546, Lote 9, Jardim América
CEP: 74.290-200 - Goiânia / GO, Brazil
E-mail: estrela3@terra.com.br