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Altered passive eruption diagnosis and treatment: a cone beam computed tomography-based reappraisal of the condition

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Abstract

Aim: To characterize anatomical features of altered passive eruption (APE)-affected teeth using cone beam computed tomography (CBCT) and to present a novel combined surgical approach to its correction.

Clinical Innovation Report: Eighty-four teeth from 14 subjects affected by APE were subjected to CBCT. Periodontal variables were recorded before surgery, and anatomical variables were measured on CBCTs. Clinical crown length was measured on study casts. Surgical treatment was carried out based on the lengths of the anatomical crowns transferred to a surgical guide that served as a reference for the incisions. The mean distance between the CEJ and the bone crest was on average <1 mm, facial bone thickness was ≥ 1 mm and soft tissue thickness was >1 mm for every tooth analysed; no association between the soft and the hard tissue thicknesses was observed.

Conclusion: The CBCT can be used in the diagnosis and treatment planning of APE cases. Anatomically, the APE cases described often presented a thick facial bone plate.

Key words: altered passive eruption; computed tomography; cone beam; crown; aesthetic; lengthening; surgeries; tooth eruption

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Conflict of interests and source of funding:

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Passive eruption has been described as the apical displacement of the periodontium, until the dentogingival junction reaches the cemento-enamel junction (CEJ) (Coslet et al. 1977, Weinberg & Eskow 2000). In altered passive eruption (APE), the tooth crown exposure may not resume entirely, clinically depicting short clinical crowns, often accompanied by excessive gingival display. As a result, the margin of the gingiva assumes a more coronal position on the anatomical crown, and it does not approximate the CEJ (Dolt & Robbins 1997). In these cases, the CEJ is very close or levelled with the bone crest (BC), with little if any room for the dentogingival structures to attach to the root surface.

Altered passive eruption treatment has relied on the management of periodontal tissues, in a surgically driven exposure of tooth crown (Garber & Salama 1996, Hempton & Esrason 1999). The diagnosis and treatment planning of APE have been carried out with the aid of radiographic analysis (Levine & McGuire 1997) and transgingival probing (De Rouck et al. 2009).

Recent advances in computed imaging have enabled a striking improvement of image resolution allowing the analysis of periodontal hard and soft tissues. Most clinical investigations employing cone beam computed tomography (CBCT) published thus far focused on more descriptive approaches to periodontal soft and hard tissues dimensions (Januario et al. 2008, Fu et al. 2010), with little direct application of the technique as a tool in the management of periodontal aesthetic problems. Here, we used CBCT to diagnose and characterize the hard and soft tissue anatomical features of APE-affected teeth. Noteworthy, a clinical approach to enable proper planning of the ressective surgery based on CBCT-gathered biometric information is presented.

Clinical innovation report

Study population and CBCT protocol

Retrospective data were gathered from 84 teeth (14 subjects, mean age 29 ± 3.2 years; 12 females, 2 males), the subjects' chief complaint was "gummy smile." The subjects were treated regularly by the primary author (ELBJr.) in the private environment. This study was approved by the Science and Ethics Committee of the Pontifícia Universidade Católica do Rio Grande do Sul-PUCRS. CBCT (i-CAT; Image Sciences International, Hatfiled, PA, USA) scans (0.2 mm voxel, KV 120, ma 5, image acquisition 26.9 s) of the areas of interest were obtained with a plastic retractor avoiding superimposition of the upper lip with the gingival margin, as previously described (Januario et al. 2008); the CBCT examination included sections of the whole facial aspect of the target teeth, 1 mm apart from one another. Clinically, patients were evaluated through a baseline periodontal examination, and probing depth (PD), relative clinical attachment level (rCAL), visible plaque (VP) and bleeding on probing (BOP) were recorded with the aid of a calibrated constant pressure periodontal probe system (Disc Probe/Pocket Probe; Florida Probe, Gainesville, FL, USA). Subjects who presented plaque and/or gingival bleeding at the target teeth or elsewhere in the mouth were first treated. Study casts were obtained for all subjects, and soft and hard tissue periodontal variables were recorded on CBCT-generated DICOM files and analysed (Osirix HD; Pixmeo, Geneva, Switzerland). After primary reconstruction, the CBCT-based volumetric data were analysed using the two-dimensional orthogonal multiplanar reformatting (MPR). Secondary reconstruction of the images was obtained, and using the coronal view pane, the image was rotated by repositioning the horizontal reference line (Fig. 1). Then, using the axial view pane, the vertical reference line was rotated to bisect the centre of target teeth in the faciopalatal direction. This approach reduced the artifacts related to alterations in tooth positioning within the arch and enabled proper selection of the sagittal plane slice for analysis. The target teeth were rotated facially, so the long axis was perpendicular to the incisal plane. The corresponding sagittal view was used to carry out the measurements as reported by others (Roe et al. 2012). To ensure accuracy, the lengths of the crowns were also measured with a digital calliper (L.S. Starret, Athol, MA, USA) on the study casts and were compared with the measurements obtained through the analysis of the CBCT. The patients' teeth widths measured directly on study casts were divided by the mean tooth width/height ratio of that tooth as previously reported by Sterrett et al. (1999). The variables analysed are depicted in Fig. 2. Before surgery, the width of the keratinized tissue (KT) was measured in situ with a periodontal probe (PCPUNC 15; Hu-Friedy Instruments, Chicago, IL, USA) to the nearest millimetre. A single examiner carried out all the measurements in triplicates during routine consultations. The thickness of the bone crest (BCT) and the soft tissue thickness of the gingival margin (STT) were also measured in a single point, 1 mm apical to the BC and 2 mm apical to the edge of the gingival margin respectively.

Surgical approach to correction of APE

The actual anatomical crown length measured in the CBCT was used as a reference to determine the amount of tooth structure to be exposed. The distance between the gingival margin and the CEJ and the anatomical crown length comprised important references about the amount of soft tissue that could be removed without exposing the cementum, thus avoiding undesired harvesting of tissue. These reference points were located on the study casts with the aid of a digital calliper, and the respective positions of the anatomical crown lengths were marked to determine the scalloped contour of the crown (Fig. 3). The actual anatomical crown lengths estimates were directly waxed up on the study casts according to the markings, which served as references for vacuum-formed silicon templates that were used as surgical guides (Fig. 4). Every subject had the canines, lateral incisors and central incisors treated during the same surgical procedure. To this end, internally bevelled scalloped incisions were performed with a #15c surgical blade, and a full thickness flap raised to expose at least 5 mm of alveolar bone. No scaling and root planing was carried out on the denuded root surfaces, and care was taken to ensure proper levelling of the bone relative to the CEJ of adjacent teeth to avoid discrepancies in the gingival architecture. Osteotomy and osteoplasty were carried out with chisels and rotary instruments under copious irrigation so as to establish a distance of 3.0 mm between the CEJ and the BC. Flaps were replaced with interrupted, internal mattress sutures using 5–0 resorbable material (Ethicon Vicryl 5–0; Johnson & Johnson, Sao Paulo, SP, Brazil) and remained coronally positioned relative to the CEJ. A single measurement of the distance between the alveolar crest and the gingival margin at the zenith of every tooth was carried out to the nearest millimetre with a manual periodontal probe immediately after suturing. The distance from the incisal edge of the teeth to the gingival margin position after surgery was also recorded. Patients were maintained under Chlorhexidine 0.12% (Periogard

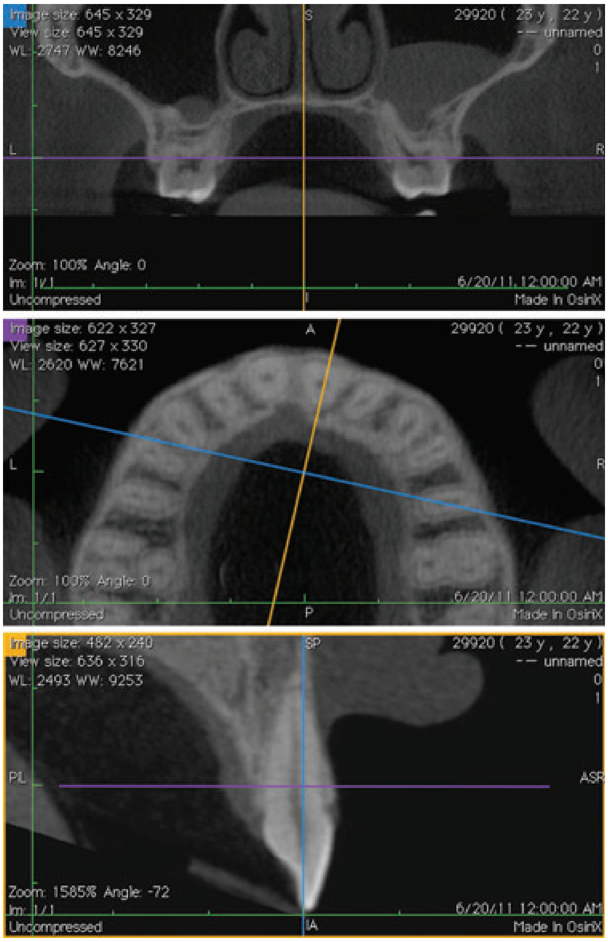

Fig. 1. CBCT analysis. After primary reconstruction, the data were analysed using a two-dimensional orthogonal multiplanar reformatting viewer. The coronal pane (upper panel) was rotated, and in the axial view (middle panel), the centre of the target tooth was bisected in the faciopalatal direction by the reference line to select the slice of interest in the sagittal view. Measurements were carried in the sagittal view pane as described in the text.

Colgate, Sao Paulo, SP, Brazil) twice a day for 7 days. Soft tissues conditions and plaque control were monthly assessed, and clinical variables were collected again 6 months after surgery.

Statistical analysis

Normality was assessed through the Kolmogorov–Smirnov test. Treatment outcome was analysed through the Student's *t*-test for paired observations. The Pearson correlation was used to assess intra-examiner agreement and associations between soft and hard tissue thicknesses. Statistical analysis was carried out using a statistical analysis pack (Graphpad Prism 4 for Mac, La Jolla, CA, USA). Differences were regarded significant if $p < 0.05$.

Surgical outcome

Treated regions healed uneventfully, and the surgical planning using CBCT enabled an efficient assessment of the anatomical features involved. Comparisons of the crown lengths directly measured on the study casts with the electronic calliper and those obtained directly from CBCT revealed high agreement (mean difference = 0.015 mm, $r = 0.99$). Likewise, intra-examiner accuracy was high (mean difference = 0.011 mm $r = 0.99$). No dentin apical to the CEJ remained visible immediately after suturing, and no post-operatory sensitivity was reported. VP and BOP were not detected throughout the 6-month post-operatory period (data not shown). There was a significant improvement of all treated regions, with increased and stable crown length gain up to 6 months of evaluation. Patient satisfaction with the outcome was very high, and no complimentary procedures had to be performed to achieve the desired results.

Changes in the clinical variables

There was a fair amount of soft tissue covering the clinical crowns of all treated teeth diagnosed with APE (Table 1). Table 2 shows the vertical and horizontal dentogingival anatomical variables analysed by CBCT distributed by tooth type. Clinically, the pre-operative periodontium of all treated cases presented features of a thick biotype with a flat gingival architecture (Fig. 3). The CBCT revealed that the mean distance between the CEJ and the BC was on average <1 mm, with a mean bone thickness ≥ 1 mm. The mean soft tissue thickness was ≥ 1 mm for every tooth type analysed, with a mean width of KT relatively even among teeth groups, that is, incisors and canines. No association between the soft and the hard tissue thicknesses was observed (Pearson $r = 0.267$, $p = 0.521$, $R^2 = 0.071$). As shown in Table 3, after 6 months the PD measurements resembled those recorded at baseline ($p = 0.072$), while the rCAL and the gingival margin position underwent a significant change as a response to surgical crown lengthening ($p < 0.05$). A mean general gingival rebound of 0.51 ± 0.28 mm was observed after 6 months of evaluation (data not shown, $p > 0.05$).

Width/length ratio and actual anatomical crown length

The overall correlation between the estimated anatomical crown length based on the width/length method and the actual anatomical crown length measured on CBCT was high ($r = 0.79$), depicting proportional variation between both methods. However, the observed grand mean

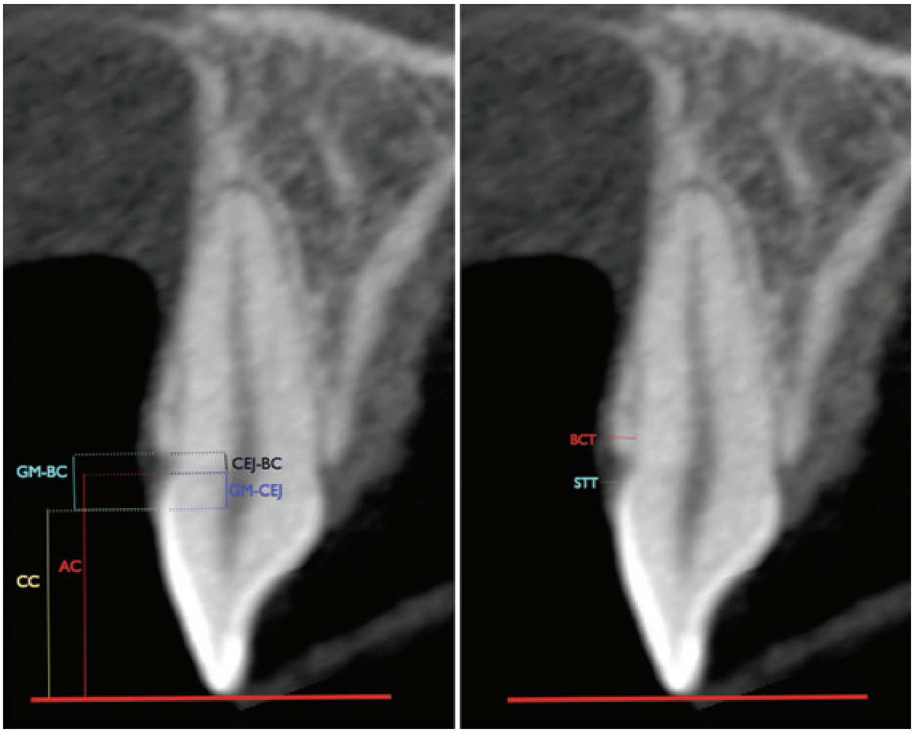

Fig. 2. Variables measured directly on CBCT. The vertical dimensions (a) clinical crown length, that is, the distance from the incisal edge to the gingival margin (CC), anatomical crown length, that is, the distance from the incisal edge to the cemento-enamel junction (CEJ) (AC), the distance from the CEJ to the bone crest (CEJ–BC), the distance from the gingival margin to the bone crest (GM–BC) and the distance from gingival margin to the CEJ (GM–CEJ) were considered. (b) Horizontal dimensions of the periodontium recorded included the thicknesses of the soft tissue (STT) and bone crest (BCT).

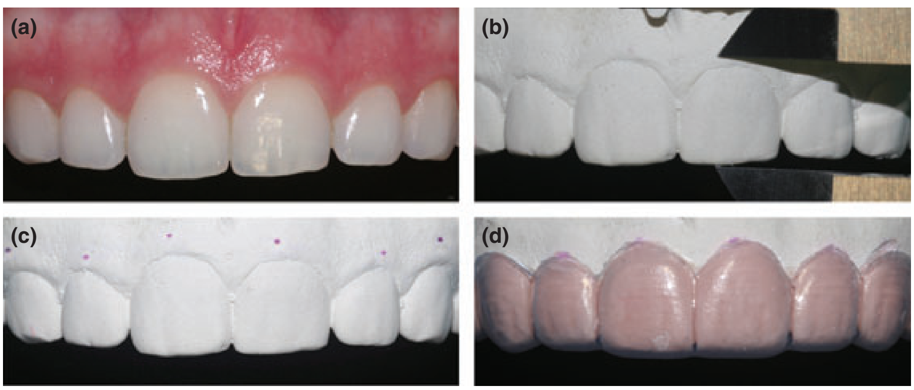

Fig. 3. Case planning approach for APE surgical treatment. (a) Pre-operatory clinical view of a 23-year-old woman; crowns are squared and short, and the periodontium is mildly scalloped with a wide band of attached gingiva. (b) The length of the anatomical crowns measured on the CBCT was transferred to the study cast with the aid of an electronic calliper and (c) pencil marked. (d) The markings served as references for the wax up and preparation of the vacuum-formed silicon surgical guide.

of the difference between the width/length estimation and the actual crown length was 0.72 ± 0.28 mm (p = 0.02). Tooth-type detailed comparisons are depicted in Table 4.

Discussion

Altered passive eruption has been characterized as an entity by many, but little is known about its precise aetiology (Coslet et al. 1977, Evian et al. 1993, Weinberg & Eskow 2000). Crown lengthening requires proper planning to avoid excessive or less than optimal tissue harvesting (Herrero et al. 1995). Likewise, stability of the results seems to depend on technical issues related to soft and hard tissues (Deas et al. 2004). Diagnosis and treatment planning of APE have relied on clinical and radiographic assessment (Evian et al. 1993, Levine & McGuire 1997, Alpiste-Illueca 2004), both being somewhat limited in furnishing the clinician with a great deal of information about the anatomical features. Sterrett et al. (1999) proposed an elegant approach using the width/length ratios of anterior teeth to estimate the actual anatomical crown length, with potential applications in

Fig. 4. Surgical approach to APE correction. (a) The surgical guide reproducing the planned position of the gingival margin was positioned, and (b) an internal bevelled incision was performed without involving the gingival papillae. (c, d) A full thickness flap was raised, which depicted the labial thick bone and reduced distance from the cemento-enamel junction (CEJ) to the bone crest (BC). (e, f, g) After osteoplasty to remove osseous ledges, the bone was reduced to establish 3 mm between the CEJ and the BC. Note that the anatomical crown of tooth #9 is slightly shorter than tooth #8. (h) The flap was coronally replaced with internal mattress sutures, depicting an immediate improvement of the crown length. (i) Pre- and (j) post-operatory view after 6 months, depicting improved aesthetics and positive gingival architecture.

the surgical treatment planning of APE. This method, at least in our study population, was not very accurate to predict the actual anatomical crown length due probably to other population/site-specific related factors.

Although transgingival bone probing measurements seem to be very close to the histometric bone level (Kim et al. 2000, Yun et al. 2005), information about the anatomical crown length, soft and hard tissue thicknesses, as well as the location of the CEJ, may be subjected to discrepancies. Particularly in the case of APE, CBCT has enabled a precise diagnostic of the reduced distance between the CEJ and the BC, as well as the precise determination of the anatomical crown length, a key reference for surgical treatment. CBCT is a recently incorporated tool in dental specialties that has yet to be explored in full. Recently, it has been demonstrated that CBCT-measured periodontal soft and hard tissues, as well as tooth and root lengths, seem to be accurate within certain limits (Fu

Table 1. Descriptive statistics (mm) of anatomical and clinical crown lengths as measured by CBCT

Tooth	Crown	Mean ± SD	Max	Min	Median
Canine	Anatomical	8.64 ± 0.92	10.8	7.15	8.58
	Clinical	6.90 ± 0.83	8.68	6.01	6.71
Lateral	Anatomical	7.64 ± 0.54	8.32	6.79	7.8
	Clinical	5.64 ± 0.52	6.9	4.98	5.73
Central	Anatomical	9.24 ± 0.89	10.8	8.2	9
	Clinical	6.94 ± 0.82	8.5	5.35	7

Table 2. Means ± SD (mm) of dentogingival variables as observed by CBCT

	CEJ–BC	GM–BC	GM–CEJ	STT	BCT	KG
Canine	0.43 ± 0.34	1.74 ± 0.51	1.7 ± 0.7	1.1 ± 0.11	1.1 ± 0.17	5.32 ± 0.87
Lateral	0.39 ± 0.23	1.71 ± 0.31	2.0 ± 0.6	1.0 ± 0.16	1.0 ± 0.21	5.67 ± 0.98
Central	0.95 ± 0.21	1.35 ± 0.2	2.3 ± 0.7	1.0 ± 0.17	1.08 ± 0.22	5.44 ± 0.78

BC, bone crest; BCT, bone crest thickness; CEJ, cemento-enamel junction; KG, width of keratinized gingival; STT, soft tissue thickness; X, GM, gingival margin.

et al. 2010, Sherrard et al. 2010, Benninger et al. 2012). In the approach proposed herein, the anatomical crown lengths measured by CBCT were directly transferred to study casts that served as references for surgical guides. Our results showed that this approach was reliable and enabled adequate clinical outcome in all treated cases. Nevertheless, in many instances, CBCT-based measurements can be prone to inconsistencies related to technical issues. It has been shown that the voxel size is critical when dealing with bone height around teeth (Sun et al. 2011) and crown/root lengths (Sherrard et al. 2010). Also critical, areas of thin facial bone may be susceptible to discrepancies (Ballrick et al. 2008), which seem to be more evident for facial bone thickness than facial bone height, especially regarding inter/intrarater agreement (Timock et al. 2011). The latter was not so critical for us, as all the cases treated had a thick facial bone. Nevertheless, the position of the tooth within the arch may also impact the accuracy of the bone image, unless a detailed prospection of the area of interest is carried out by adequate orientation of the image planes (Molen 2010). Therefore, clinicians must be aware of these technical pitfalls when considering CBCTs for diagnosis and treatment planning. Also noteworthy, despite the advantages of CBCT, presently, it can only be justified when low doses of radiation are used and no additional diagnostic and/or treatment options are available.

It has been claimed that there is a limited room for the dentogingival structures to attach to the root surface of APE-affected teeth, so care must be taken to avoid damage to the periodontal ligament fibres exposed after osteotomy. Differently from our procedure, others have advocated planing of the root exposed by osteotomy as part of the crown lengthening procedure (Pontoriero & Carnevale 2001, Deas et al. 2004). Our choice of not severing the periodontal ligament around the newly exposed root surface relied on the fact that it could produce additional, uncontrolled attachment loss (Bergl-undh et al. 1991), with potential impact on the aesthetic outcome. Noteworthy, to ensure an adequate aesthetic outcome, this approach should be carried also in the neighbouring teeth, something that was performed as all subjects presented APE in all upper anterior teeth. All cases had the post-operative gingival margin positioned 3-mm coronal to the surgically reduced BC. It has been shown that less soft tissue rebound occurs when the gingival margin is positioned coronally to the BC as opposed to flaps repositioned at or below it (Deas et al. 2004). Corroborating these findings, we observed a mean rebound of 0.51 ± 0.28 mm of the gingival margin after 6 months, which was very similar to the results of others (Deas et al. 2004), regardless of the fact that no root planing was carried out in our cases. It is important to note, however, that soft tissue changes may last for up to 1-year post-surgery (Pontoriero & Carnevale 2001).

Recently, Cook et al. (2011) used CBCT to evaluate the differences in labial plate thicknesses of patients clinically identified as having thin *versus* thick/average periodontal biotypes. These authors compared the thicknesses of the facial bone plate in upper incisors and canines; at 4 mm from the CEJ, that is, approximately 1 mm apical to the BC, the mean bone thicknesses found for central incisors, lateral incisors and canines with the thick/average periodontal biotype were 0.65, 0.79 and 0.81 mm, whereas the mean thicknesses of the bone plates found herein were 1.08, 1.0 and 1.1 mm respectively. Regardless of the fact that no statistical test could be applied to compare both studies, it seems that individuals presenting APE may fall into a third category,

Table 3. Means ± SD (mm) of periodontal variables changes after crown lengthening

	PD			rCAL			GMP		
	Baseline	6 months	Δ	Baseline	6 months	Δ	Baseline	6 months	Δ
Canine	1.8 ± 0.12	1.66 ± 0.09	0.14 ± 0.13	8.0 ± 0.12	9.04 ± 0.09	−1.37 ± 0.03*	6.19 ± 0.72	7.93 ± 0.32	−1.74 ± 0.22*
Lateral	1.64 ± 0.09	1.60 ± 0.06	0.04 ± 0.03	6.49 ± 0.09	7.45 ± 0.06	−0.95 ± 0.03*	4.84 ± 0.66	6.31 ± 0.25	−1.47 ± 0.25*
Central	1.72 ± 0.13	1.70 ± 0.09	0.06 ± 0.05	8.27 ± 0.13	9.23 ± 0.09	−0.96 ± 0.05*	6.5 ± 0.79	8.4 ± 0.21	−1.90 ± 0.19*

GMP, gingival margin position; PD, probing depth; rCAL, relative clinical attachment level; Δ, change.
*$p < 0.05$.

Table 4. Mean ± SD (mm) of anatomical crown lengths estimated by the width/ratio approach compared with cone beam computed tomography (CBCT) in APE cases

Tooth	Width	Estimated	CBCT	Difference	*r*
Canine	7.49 ± 0.41	9.25 ± 0.73	8.64 ± 0.92	0.61 ± 0.34*	0.755
Lateral	6.35 ± 0.32	8.39 ± 0.34	7.64 ± 0.5	0.75 ± 0.33*	0.712
Central	8.60 ± 0.31	10.0 ± 0.38	9.24 ± 0.89	0.76 ± 0.32*	0.81

r = *Pearson* for anatomical crown length through the width/ratio approach and CBCT.
*$p < 0.05$.

that is, a very thick periodontal biotype. Individuals who presented a flat periodontal architecture, with short clinical crowns, reduced gingival scalloping and reduced distance between the CEJ and the alveolar crest comprised the totality of our sample. Therefore, only a minimum distance between the CEJ and the alveolar crest was present, with no obvious room for attachment structures according to previously established dimensions (Ingber et al. 1977, Vacek et al. 1994). Several investigators explored the anatomical issues related to the biological width, showing that the dimensions of the dentogingival unit are prone to significant variations (Vacek et al. 1994, Perez et al. 2008). The aforementioned studies suggested that variables such as tooth type, tooth position and the surface analysed might play a role in the supraosseous height of the gingiva. The periodontal biotype also seems to play a relevant role as it has been shown that the CEJ–BC distance is increased in the thin periodontal biotype compared with the thick/average one (Cook et al. 2011). Our findings seem to support this premise as the average CEJ–BC distance for canines, lateral incisors and central incisors was only 0.43, 0.39 and 0.95 mm respectively. In other words, there seemed to be an inverse relationship between the thickness of the periodontium and the CEJ–BC distance in these individuals.

The facial gingival thickness and width of KG in APE cases were very similar to those reported by others who used either direct measurements or CBCT (Kan et al. 2010, Cook et al. 2011). Noteworthy, although all individuals fell into the thick periodontal biotype and flat periodontium, the very thick osseous facial plate was not associated with a thick gingival margin ($R = 0.267$, $p = 0.52$). This lack of association may be an APE-related feature as others (Fu et al. 2010), in contrast, observed a moderate association ($R = 0.429$, $p = 0.000$) between the labial gingiva thickness and the underlying bone, both measured by CBCT. This difference could be explained by a reduced number of APE cases in their sample population and/or the fact that the authors used cadavers in their analysis, and recent evidences suggest that in some situations, CBCT protocols may be sensible to postmortem changes (Takahashi et al. 2010, Ishida et al. 2011).

Conclusion

As proper treatment depends on the adequate diagnosis and knowledge of the periodontal anatomy, the CBCT approach described herein could be useful in the management of APE. Within the limitations of the restricted sample size, the anatomical features of APE based on this first report using CBCT suggests that this entity is very peculiar, which often falls into a thick periodontal biotype that requires proper management for improved aesthetics.

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Clinical Relevance

Scientific rationale for the study: Observational study of altered passive eruption (APE) cases where cone beam computed tomography (CBCT) was used to characterize anatomical features, enabling a novel proposed surgical approach to its correction.

Principal findings: APE-affected teeth presented reduced distance between the CEJ and the alveolar crest and thick periodontal biotype. No association between the gingival and the alveolar bone thicknesses was observed. The crown width/length ratio did not predict the actual anatomical crown length.

Practical implications: APE cases require a detailed evaluation of soft and hard tissues dimensions before surgical planning. CBCT can be used as a tool in the correction of APE, and the novel surgical planning approach proposed herein was effective and predictable.