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Two- versus three-dimensional imaging in subjects with unerupted maxillary canines

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SUMMARY The aim of this study was to evaluate whether there is any difference in the diagnostic information provided by conventional two-dimensional (2D) images or by three-dimensional (3D) cone beam computed tomography (CBCT) in subjects with unerupted maxillary canines.

Twenty-seven patients (17 females and 10 males, mean age 11.8 years) undergoing orthodontic treatment with 39 impacted or retained maxillary canines were included. For each canine, two different digital image sets were obtained: (1) A 2D image set including a panoramic radiograph, a lateral cephalogram, and the available periapical radiographs with different projections and (2) A 3D image set obtained with CBCT. Both sets of images were submitted, in a single-blind randomized order, to eight dentists. A questionnaire was used to assess the position of the canine, the presence of root resorption, the difficulty of the case, treatment choice options, and the quality of the images. Data analysis was performed using the McNemar–Bowker test for paired data, Kappa statistics, and paired *t*-tests.

The findings demonstrated a difference in the localization of the impacted canines between the two techniques, which can be explained by factors affecting the conventional 2D radiographs such as distortion, magnification, and superimposition of anatomical structures situated in different planes of space. The increased precision in the localization of the canines and the improved estimation of the space conditions in the arch obtained with CBCT resulted in a difference in diagnosis and treatment planning towards a more clinically orientated approach.

Introduction

In subjects with delayed eruption of maxillary canines, the diagnostic procedure can, in the majority of cases, be limited to clinical inspection and palpation of the alveolar process, considering also occlusal development and somatic maturity. However, according to Ericson and Kurol (1986 a,b), 8–10 per cent of patients older than 10 years also require a radiographic examination to obtain sufficient information regarding the position and angulation of the canine and its relationship with the neighbouring structures.

A study describing the routines of orthodontists and oral surgeons revealed that 78 per cent used more than two, and 23 per cent four or more radiographs (Southall and Gravely, 1989) to describe the position of an ectopic canine and for treatment planning. Clinicians tend to choose the techniques that they are most familiar with (Bishara, 1992). Not considering the cost–benefit ratio between information provided and radiation exposure might lead to an unjustified radiation dose to the patient.

Localization of impacted canines can be challenging with conventional radiographic methods, due to distortion, superimposition of three-dimensional (3D) structures, and imaging artefacts. Conventional radiographs such as dental pantomographs (DPT) and periapicals (Clark, 1909) provide information regarding the vertical and mesio-distal relationship of the unerupted canine with neighbouring teeth and adjacent anatomical structures (Gratt, 1994). DPTs are affected by a certain degree of distortion in the horizontal plane (Mckee *et al.*, 2001, 2002; Yeo *et al.*, 2002). Periapicals provide improved visualization of the interdental relationship, but information in the bucco-lingual direction can only be obtained by combining different projections. DPT and periapicals may be integrated with other two-dimensional (2D) images: occlusal radiographs, lateral, and postero-anterior head films. As images routinely used to identify impacted teeth all suffer from errors implicit in the technique, the application of medical computed tomographic (CT) scanning has been suggested. This method allows for a more precise visualization of the relationship with the neighbouring teeth, but its use has been limited to specific indications since the cost and the irradiation dose are high (Ericson and Kurol, 1987, 1988; Elefteriadis and Athanasiou, 1996; Ericson and Bjerklin, 2001; Ericson *et al.*, 2002).

With the introduction of cone beam computed tomography (CBCT; Mozzo *et al.*, 1998), the advantages of the CT scan could be obtained with reduced scanning time, lower irradiation dose, and cost. CBCT utilizes a 2D, or panel detector, which allows generation of a 3D data set of the head of the patient using a single rotation of the X-ray source and detector. This technique differs from fan-beam CT scanners, where multiple 'slices' are stacked to obtain a complete 3D image. The value

of CBCT in dento-maxillofacial imaging has been recognized by a number of researchers (Mah and Hatcher, 2003; Ludlow *et al.*, 2006) and different scanners have been introduced.

The aim of this study was to assess the difference in the diagnosis and treatment approach to unerupted maxillary canines based on conventional 2D images and 3D CBCT image sets.

Subjects and methods

Twenty-seven patients (17 females and 10 males, mean age 11.8 years) undergoing orthodontic treatment at the Department of Orthodontics, School of Dentistry, University of Aarhus, Denmark, were included in this study. In total, 39 ectopic canines were examined. The subjects were selected from patients already enrolled for an additional CBCT examination because of ectopic position of the tooth or because of other indications for 3D evaluation. The CBCT examination was considered supplemental to conventional radiographic examination during the period of gradual implementation of the machine at the Department of Orthodontics. Therefore, this material was considered unique for further comparative studies. Consent to undergo the additional radiographic examination and to use the material for the present investigation was obtained from all patients.

Two different sets of images were available for each canine. One set comprised a DPT, a lateral head film, and the available periapical radiographs with different projections, as routinely used in orthodontic treatment planning. The 2D digital images (Figure 1) were obtained with the Digora Optime System (Soredex, Tusuula, Finland). The second set of images was created from CBCT scans generated with a NewTom 3G scanner (Quantitative Radiology s.r.l., Verona, Italy). This group included a series of static images produced elaborating the CBCT raw data with dedicated software. Six to eight different 3D reconstructions were generated with the maximum intensity projection and volumetric rendering methods, 12–20 axial images, one curved planar reformation (panorex), a series of multiplanar reconstructions (cross-sections), two oblique planar reformation recording the bucco-lingual and mesio-distal dimension of the tooth (Figure 2). Each image set was assembled in a Power Point® presentation.

Each set, either of conventional radiographs or CBCT-generated images, was assigned a numerical code and, in a randomized order, submitted for evaluation to eight different dentists (three at the beginning of their orthodontic education; two with a moderate degree of experience at the end of their postgraduate education and three specialists with more than 5 years of experience).

The image sets were sent in small batches to ensure that no dentist had access to both 2D and 3D images of the same canine at any time. The evaluators were asked to fill in a questionnaire regarding, in the first part, the position of the canine expressed by different parameters (Stivaros and Mandall, 2000) and to assess the presence of root resorption on the lateral incisors. In the second part of the questionnaire, the operators were asked to estimate the difficulty of the case and the quality of the images visualized on a visual analogue scale, and to choose a treatment strategy among given alternatives.

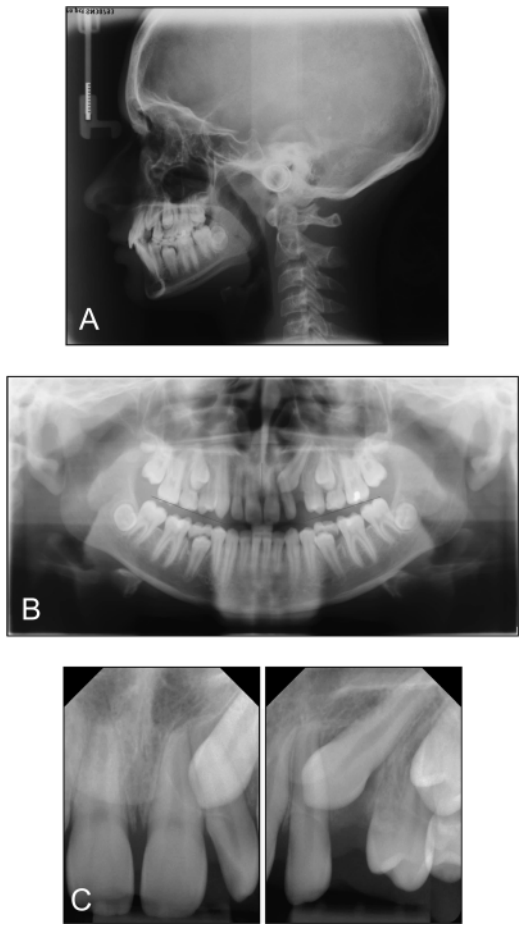

Figure 1 Example of a two-dimensional data set composed of digital radiographs: (A) lateral head film, (B) dental pantomograph, (C) periapical radiographs with different projections.

The influence of the radiographic method was assessed by means of a McNemar–Bowker test for paired data, Kappa statistics, and a paired *t*-test. The differences were considered significant at the 5 per cent level. The Statistical Package for Social Sciences, version 12.0 (SPSS Inc., Chicago, Illinois, USA), was used.

Results

Considering a data set as composed of both 2D and 3D image sets, the total number of data sets for the 39 canines submitted to the eight operators was 312. The results of this investigation divided for parameters are summarized in Table 1. The agreement among the 2D and 3D methods and the description of the systematic difference are described.

Localization of the canine

The inclination measured to the midline did not differ significantly when evaluated using the two methods (Figure 3).

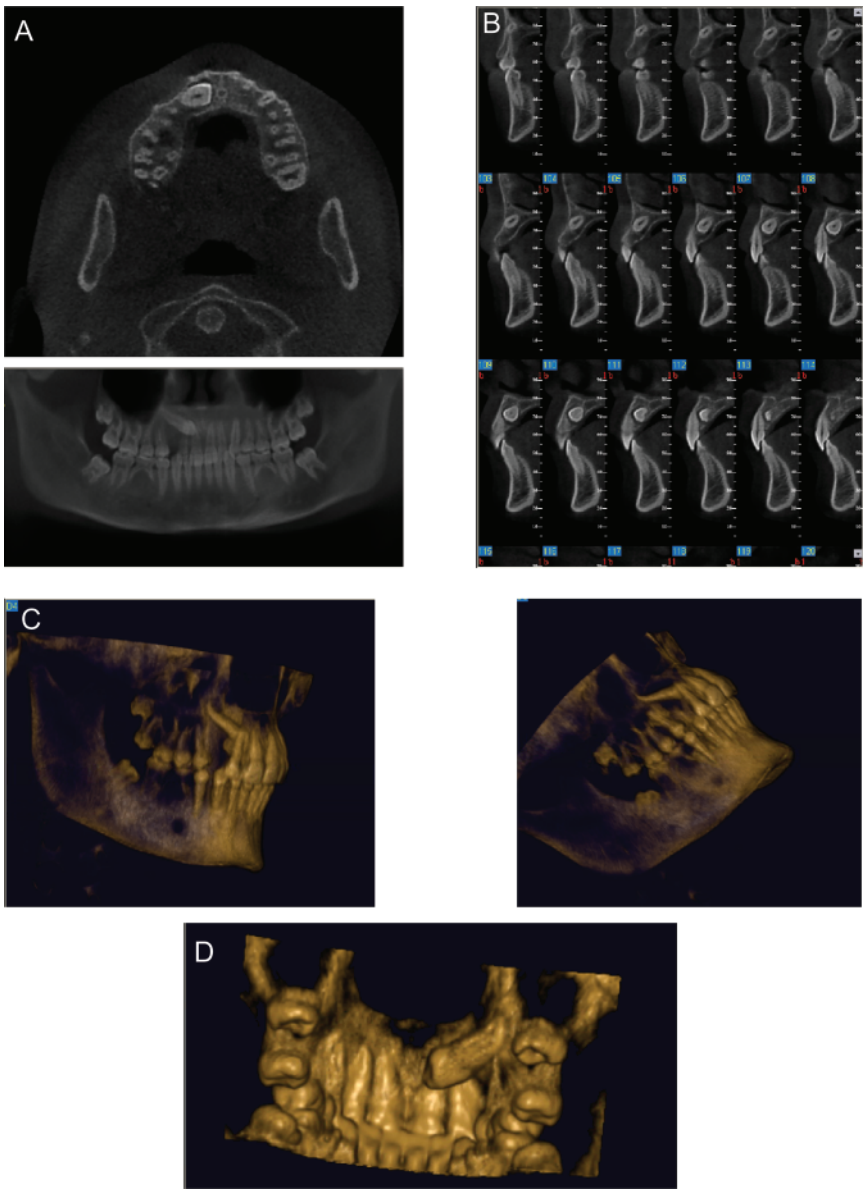

Figure 2 Example of the types of images delivered as a three-dimensional (3D) data set: (A) axial view, (B) curved planar reformation (panorex), (C) transplanar reformation (cross-sections), (D) 3D reconstructions. Several 'cuts' from the axial and the cross-section view were provided.

Table 1 Summary of the results: agreement among the two (2D) and three-dimensional methods for the parameters considered. Significance calculated with the McNemar–Bowker test, the Student's *t*-test, and description of the systematic difference.

Parameter	Percentage of agreement	*P*	Description of systematic difference
Inclination to the midline	74	>0.05	/
Mesio-distal position of the apex	64	0.001	2D indicated less variation in apex position
Vertical level of the clinical crown	66	0.013	2D indicated higher vertical level
Overlap with the lateral incisor	70	0.001	2D indicated less overlap
Labio-palatal position of the crown	68	0.001	2D indicated more palatal position of crown
Labio-palatal position of the apex	65	0.001	2D indicated more palatal position of apex
Root resorption of neighbouring incisor/s	82	0.001	2D indicated less root resorption
Treatment strategy	70	0.008	2D lead to observational strategy
Assessment of difficulty	46	<0.05	2D indicated less difficult treatment
Assessment of image quality	51	<0.05	2D was judged less positively with respect to image quality

When assessing the mesio-distal localization of the apex, a significant difference was found for the two methods. The tendency of the 2D data set, to score in the region of the first premolar was higher, while on the 3D data set, a larger spread was observed. The vertical level of the clinical crown differed significantly with a tendency towards a higher position based on the 2D images. The definition of overlap with the lateral incisor was congruent for the two methods in 70 per cent of cases. The statistically significant disagreement reflected the larger overlap when evaluated on the 3D images.

With respect to labio-palatal localization of the crown and the apex, paired data analysis revealed significantly larger labial localization with the 3D method (Table 2).

Root resorption

Significantly more root resorption was found (P = 0.001) when using the 3D data set (Table 3).

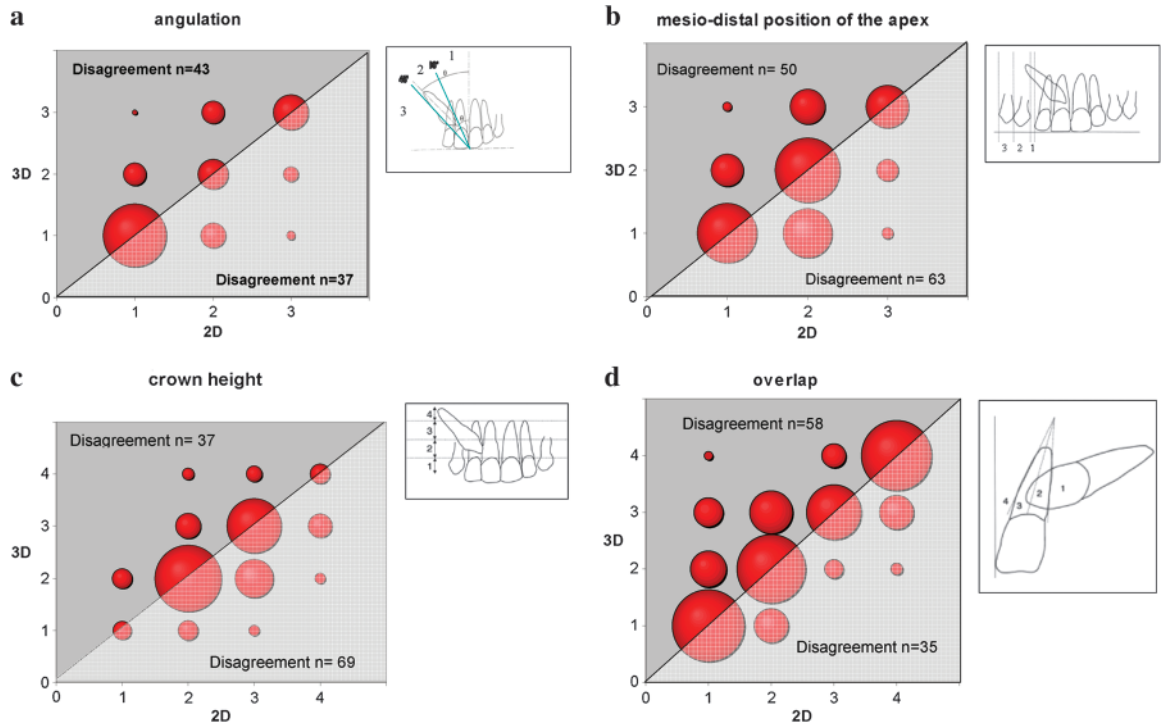

Figure 3 Bubble graphs showing the level of agreement when evaluating: (a) inclination with respect to the midline, (b) mesio-distal position of the apex, (c) vertical level of crown height, (d) overlap with the neighbouring incisor defined within categories. The spheres' size is proportional to the number of data sets (total = 312). The spheres lying on the diagonal line depict the total agreement between the two methods. (a) The distribution of the disagreement is equal in the 2D and 3D areas of the graph. (b) The apex is seen more in the area of the first premolar following 2D evaluation, while a larger spread is observed on the 3D area of the graph. (c) The crown is seen more apical following 2D evaluation, as shown by the distribution of larger spheres in the 2D area of the graph. (d) The overlap is seen as larger following 3D evaluation, as described by the skewed distribution of larger spheres towards the 3D area of the graph.

Table 2 Number of data sets (N = 312) scored as labial or palatal in the evaluation of the crown and apex labio-palatal position.

		Labio-palatal position of the crown			Labio-palatal position of the apex		
		3D			3D		
		Labial	Palatal	Total	Labial	Palatal	Total
2D	Labial	143	16	**159**	56	27	**83**
	Palatal	85	68	**153**	81	148	**229**
Total		**228**	**84**	**312**	**137**	**175**	**312**

The canine crowns and apices were classified as labial more frequently after three-dimensional (3D) evaluation with respect to two-dimensional (2D; P = 0.001) as shown in bold.

Table 3 Number of data sets (N = 312) scored as with or without root resorption of the adjacent teeth.

		Resorption		
		3D		Total
		No	Yes	
Resorption 2D	No	236	40	**276**
	Yes	14	22	**36**
Total		**250**	**62**	**312**

A more frequent diagnosis of root resorption was identified after three-dimensional (3D) evaluation, P = 0.001, shown in bold.

Treatment choice

When asked to make a treatment choice, agreement was found for 70.5 per cent of the cases (Table 4). The lack of congruence was statistically significant. A more frequent choice of an observational–interceptive approach was based on the 2D evaluation, while a more active intervention, with special focus on expansion and space maintenance, was recommended based on the 3D examination.

Difficulty of the case

The assessment of the difficulty of a case differed significantly. The paired sample *t*-test showed a difference at the 95 per cent confidence level, rendering treatment more difficult based on 3D examination.

Quality of the images

When finally asked whether they found the images appropriate for the given diagnostic purpose the respondents preferred the 3D images. The paired sample *t*-test showed a difference at the 95 per cent confidence level; the mean score was higher when evaluating the 3D image sets.

Discussion

Comparison of the findings of this study, based on conventional and CBCT-generated images, demonstrated a difference with respect to localization of the canine apex mesio-distally and of both the apex and crown bucco-palatally, vertical localization of the crown, overlap with the lateral incisor, and perception of root resorption. The agreement among the two methods with respect to inclination of the canine to the midline could be explained by the classification distinguishing only between three categories, each comprising a large range of angulations.

In agreement with Chaushu *et al.* (2004), the present study demonstrated significant differences with respect to localization of the apex in a mesio-distal direction, with a higher tendency for a score in the intermediate category (first premolar region) following 2D examination. This might be explained by the horizontal distortion, which affects the image of objects located behind or in front of the focal trough on an DPT image (Yeo *et al.*, 2002). Anatomical structures located within the focal trough of a panoramic radiograph would appear undistorted, while other objects located in front or behind the sharp line are blurred, magnified, or constricted and sometimes not clearly recognizable (Gratt, 1994).

Clinically, the difference between the two methods concerning the vertical level of the clinical crown would have an influence on the estimated outcome of treatment; the higher the canine position with respect to the occlusal plane, the longer and more difficult treatment. A more cranial localization was identified following 2D evaluation with respect to 3D. This is in accordance with the findings of Chaushu *et al.* (1999) who reported that palatally located canines will be projected higher than labially located canines on a DPT as the central ray in panoramic radiography is directed from a slight negative angulation of −7 degrees.

The method of examination also influenced the estimation of overlap with the adjacent lateral incisor. A larger overlap was scored on the 3D images. This could be due to the horizontal deformation that affects the DPT, resulting in an increased dispersion of objects in the horizontal plane (Gratt, 1994). Clinically, in subjects where the overlap is larger, such as in upper anterior crowding, the overlap will appear less severe in two-dimensions.

A difference in the perception of the canine position and the space conditions in the arch will influence the treatment plan. This is confirmed by the findings, where the evaluators suggested active orthodontic treatment more frequently based on the 3D image set. Several evaluators completed the questionnaire specifying the need for expansion or other procedures targeted at maintenance of the leeway space. This treatment approach has been shown to be more successful than simple observation (Baccetti *et al.*, 2008). In the present research, observation was chosen more frequently following 2D evaluation. It can therefore be speculated that the use of CBCT allows for a treatment choice with a better prognosis.

Lack of congruence among the two examinations with respect to labial or palatal localization of the crown and apex is of clinical importance. The majority of the canines in this sample were localized labially or centrally. The incorrect diagnosis based on the 2D images can be ascribed to the fact that several teeth were localized approximately in the middle of the alveolar crest. The 3D image set allowed more precise localization with respect to the lateral incisor since axial sections were provided. Information on the exact position of the crown is relevant when performing surgical exposure, while the orthodontist needs to localize the apex to define the vector of traction.

The present study demonstrated that root resorption was more frequently diagnosed on the 3D image set. However, the resolution of the images obtained with the NewTom does not allow for clear depiction of resorption craters either at the

Table 4 Distribution with respect to choice of treatment based on two (2D) and three-dimensional (3D) evaluation.

Treatment choice	2D	3D
Extraction of primary canine only	26	12
Observation-no treatment	63	50
Extraction of the permanent canine	6	15
Surgical exposure/orthodontic treatment	211	230
Surgical transplantation of the canine	6	5

Less observational and more surgical exposure and orthodontic traction were suggested after 3D evaluation. Lack of congruence between the two methods was statistically significant ($P = 0.008$).

cement or dentine level. Therefore, the evaluators were asked not to measure root resorption but to assess its presence or absence. CBCT allows determination of close proximity between teeth: this might not change evaluation of the prognosis of the resorbed teeth but influences the treatment plan in terms of determination of the direction of orthodontic traction.

The greatest amount of overlap was also scored on the 3D images and could explain the higher grade of difficulty assigned after 3D evaluation. The quality of the images was, as anticipated, assessed positively for the 3D image set. Further improvements in CBCT are occurring both at the hard- and software level. It is however already possible to ameliorate the volumetric data exported in DICOM format by elaboration with other software dedicated to dento-maxillo-facial imaging. The quality of the voxels, basic unit in the image, is still inferior when compared with a conventional CT scan.

The main advantage of CBCT with respect to a CT scan is the reduction in the radiation dose. Ludlow *et al.* (2006) reported values of effective dose of 36.3 Sv for the NewTom 3G corresponding to four DPTs. In comparison, the radiation dose of a lateral and postero-anterior cephalogram can be up to 166 Sv (Mah and Hatcher, 2003).

In order to understand the associated radiation/cancer risk, the dosimetric cost has to be interpreted in terms of background equivalent radiation time compared with daily light irradiation in a sunny place. The NewTom 3G corresponds to 4–6 days compared with 18 days for a CT scan. The results of this study showed that the 3D image set obtained with CBCT provides additional information with respect to the 2D images. This information, mainly in the position of the unerupted canine and its relationship with neighbouring structures, has a strong clinical relevance, which appears to justify the risks of the radiation dose.

Conclusions

When comparing the diagnosis of unerupted maxillary canines based on 2D and 3D images, the findings showed a difference between the two techniques. Using the 3D image set, the crown of the canine was perceived to be more occlusally positioned than on the 2D images. Furthermore, the 3D images allowed determination of the mesio-distal position of the apex, while the bucco-palatal position could be assessed with less uncertainty. The overlap with the lateral incisor was perceived as more severe after 3D evaluation. The same was true concerning the presence of root resorption. In accordance with these findings, a higher degree of difficulty of the case was judged on the basis of the 3D image set.

These differences can be explained by factors affecting the conventional 2D radiographs such as distortion, magnification, and superimposition of anatomic structures situated in different planes. The treatment plan was different using 2D and 3D image sets. 3D examination more often led to an approach of expansion and orthodontic traction. The CBCT gives a perception of the intra-osseous position of the impacted tooth, which improves diagnosis and provides useful information for treatment consultation.

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