Radix paramolaris and radix distomolaris in Danish permanent maxillary molars

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The School of Dentistry in Copenhagen possesses a collection of 96 human permanent maxillary molars (M sup) with a root complex, the macromorphology of which includes a facially located supernumerary root known as radix paramolaris (RP) and/or a distally located supernumerary root called radix distomolaris (RD). Systematic analysis of these teeth enabled the authors to establish precise criteria for the identification of RP and RD on M sup; 91.5% out of a total of 70 RP identified occurred on M3 sup, 7.2% on M2 sup, and 1.4% on M1 sup. The corresponding percentages for 29 RD identified were: 96.5% on M3 sup, 3.4% on M2 sup, and 0.0% on M1 sup; 50.0% of the 70 RP were separate in relation to the 2 facial root components and 31.5% non-separate; in 18.6% of the RP observed, it was impossible to establish whether or not they were separate. Corresponding frequencies for the 29 RD in relation to the distofacial and lingual root components were 41.3% separate and 37.9% non-separate; 20.7% of the roots could not be categorized. The following clinically relevant macromorphological variables regarding RP and RD were also observed: degree of separation in relation to the respective neighboring root components, degree of divergence in relation to the same macrostructures, apical bend, apical gracility, and pattern of fusion. □ *Maxillary molars; permanent teeth; supernumerary roots*

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A facially located supernumerary root is found on permanent maxillary molars (*M sup*) in humans. This macrostructure, *radix paramolaris: RP* (1), was first mentioned in dental literature in 1914. Since then, relatively few authors have paid any attention to RP on these tooth types (2–16). Their observations are typically few in number, and none of them has provided a proper macromorphological characterization of the root structure. A characterization of that nature has simply been impossible based on such sporadic observations.

The same tooth group also contains a supernumerary root located distally in the root complex. As far as can be ascertained, this root has only been observed/illustrated a few times (9, 11, 12, 16). The authors of this article suggest the designation *radix distomolaris: RD* for the root.

The extensive Copenhagen Tooth Collection includes a significant number of M sup, the root complex of which contains an RP or an RD. This material enabled the authors to conduct a systematic analysis of the morphological variation of RP and RD in the relevant tooth group. In the light of the above, the authors planned a study, the aim of which was: (i) to establish precise criteria for the identification of RP and RD on M sup, (ii) to map occurrences of these supernumerary roots on M1 sup, M2 sup, and M3 sup, (iii) to record other clinically relevant macromorphological variables regarding RP and RD, e.g. degree of divergence, apical bend, and apical gracility.

The present article is part of a larger combined research project regarding supernumerary roots on human permanent molars. In two previous studies (17, 18), the authors conducted similar macromorphological analyses of supernumerary roots located lingually and facially, respectively, on mandibular molars.

Materials and methods

Materials

The Department of Dental Morphology and Forensic Odontology at the School of Dentistry in Copenhagen has a substantial collection of extracted teeth. The teeth have been sent unsorted to the department by practising dentists in Denmark between 1963 and 1998. On receipt, the teeth are adequately cleaned. At the moment (December 1998), the collection includes 96 permanent maxillary molars with root complexes containing an RP and/or an RD; 52 are from the right side, 44 from the left side. The teeth and the supernumerary roots were identified by both authors independently of each other. This survey was conducted on those teeth.

Definitions

The dental morphological definitions, which in this context are required knowledge, are presented below.

Root cone. Constantly present macromorphological unit or element involved in the build-up of the root complex.

Supernumerary root. Inconstantly present macromorphological element.

Root component. Root cone combination that contributes to the build-up of the root complex of molars.

Root structure. Joint designation for root cone, supernumerary root, root component, etc.

Separation (in this context). The phenomenon that root structures are separate.

A root structure that at a given level is separate from one or several other root structures is designated as separate. A root structure that at a given level is connected to one or several other root structures is designated as non-separate.

Furcation. The part of the root complex that is located between separate root structures.

Degree of separation. The maximal furcoapical extension in relation to the maximal cervicoapical extension.

Degree of divergence. The angle formed by the height axes in the cervical two-thirds, approximately, of 2 root structures.

The degree of divergence may be larger than zero, i.e. positive, equal to zero, or smaller than zero, i.e. negative. A positive degree corresponds to divergence between the above-mentioned height axes. A degree at zero corresponds to parallelism between the axes mentioned. Negative degree corresponds to convergence between the axes.

Apical bend. The phenomenon that the apical third, approximately, of a root complex or a root structure deviates from the direction of the corresponding, cervical two-thirds.

Apical gracility. The phenomenon that the apical part of a root complex or a root structure is especially fragile.

Fusion. The phenomenon that root structures are in contact apically, but are separate further cervically.

Methods

All the observations registered were based on the above definitions. The observations were made on completely dry teeth in a stereo-microscope (Wild M 8 zoom) with a magnification of maximum ×15. Reflected light was used.

Results

Identification

By way of introduction, it must be pointed out that M sup always has 3 root components in the structure of its root complex: a mesiofacial, a distofacial, and a lingual (19). Taking strict account of these 3 components, the presence and identity of RP and RD were established. The criteria for the identification of RP and RD on the permanent maxillary molars are described in the following paragraph.

Radix paramolaris, type A. The *mesial* part of the root complex consists of 3 macrostructures which are, in principle, cone-shaped: a facial, a central, and a lingual (Fig. 1). The degree of separation between the facial and the central root structure is 0; the border between them is constituted by a groove running in a cervicoapical direction. A distinct cingulum derivative—tuberculum paramolare—is found in the crown with direct relation to the facial root structure. Under these conditions, the facial macrostructure is identified as RP and the central macrostructure as the mesiofacial root component, while the lingual root structure represents the mesial part of the lingual root component.

Fig. 1. M3 sup, mesial aspect; facial to the left. Radix paramolaris, type A: RP non-separate from mesiofacial root component. Horizontal arrows show supernumerary root; vertical arrows point toward tuberculum paramolare.

Radix paramolaris, type B. The *facial* part of the root complex consists of 3 macrostructures which are, in principle, cone-shaped. The cervical part of these structures, or the structures as a whole, is located centrally, mesially, and distally. The central structure is: (i) separate in relation to both the other root structures (Fig. 2), (ii) non-separate in relation to one and separate from the other of the approximal root structures (Fig. 3), or (iii) non-separate in relation to both the mesial and the distal macrostructure (Fig. 4). In cases where the central structure is non-separate in relation to one or both of the approximal root structures, the border between the respective structures is constituted by a fairly deep groove running in a cervicoapical direction. Under these conditions, the central 1 of the 3 facial root structures is identified as RP. The mesial and distal macrostructure is

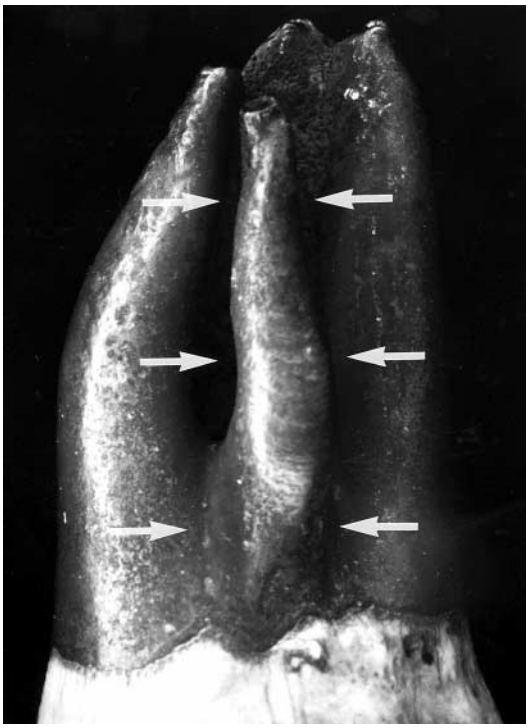

Fig. 2. M3 sup, facial aspect; mesial to the left. Radix paramolaris, type B: RP separate from mesiofacial and distofacial root components. Arrows show supernumerary root.

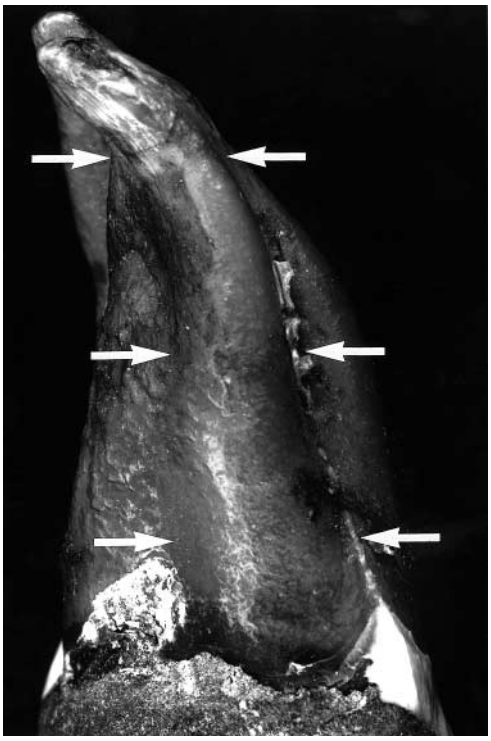

Fig. 4. M3 sup, facial aspect; mesial to the right. Radix paramolaris, type B: RP non-separate from mesiofacial and distofacial root components. Arrows show supernumerary root.

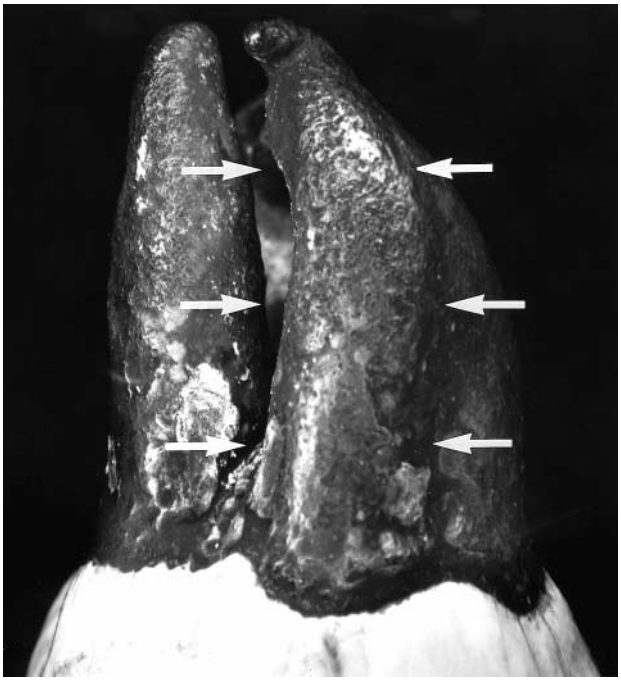

Fig. 3. M3 sup, facial aspect; mesial to the right. Radix paramolaris, type B: RP non-separate from mesiofacial root component, separate from distofacial component. Arrows show supernumerary root.

identical with the mesiofacial and distofacial root component. RP's central position may be modified by a more or less pronounced mesial or distal displacement.

Radix distomolaris. The *distal* part of the root complex consists of 3 macrostructures which are, in principle, cone-shaped. The cervical part of these structures, or the structures as a whole, is located centrally, facially, and lingually. The central structure is: (i) separate in relation to both the other root structures (Fig. 5), (ii) non-separate in relation to one and separate from the other of the root structures, or (iii) non-separate in relation to both the macrostructures mentioned. The border between the central non-separate macrostructure and the other structures is constituted by a fairly deep groove running in a cervicoapical direction. Under these conditions, the central structure is identified as RD, while the facial structure is identical with the distofacial root component; the lingual macrostructure represents the distal part of the lingual root component. RD's central position may be modified by a fairly pronounced facial or lingual displacement.

The distribution in the material of RP and RD on M1 sup, M2 sup, and M3 sup is given in Tables 1 and 2, respectively. RP and RD were both present on 3 of the teeth studied (Fig. 6).

In Table 1, *type B separate* covers the variants on which RP was separate in relation to both the mesiofacial and the

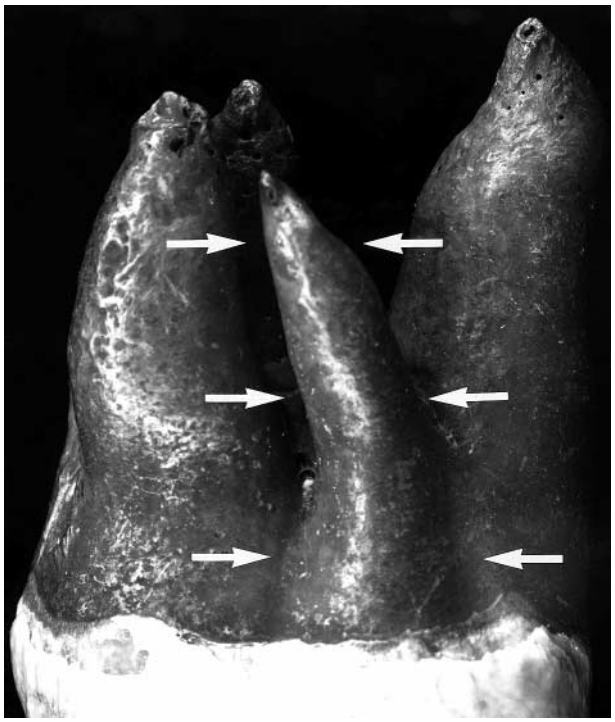

Fig. 5. M3 sup, distal aspect; facial to the left. Radix distomolaris: RD separate from distofacial and lingual root components. Arrows show supernumerary root.

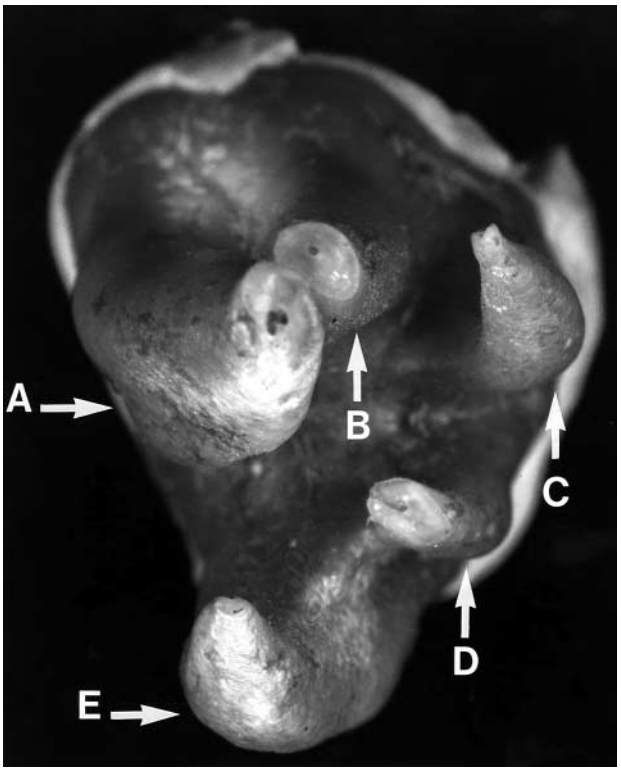

Fig. 6. M3 sup, oblique apical aspect; facial upwards, mesial to the left. A: mesiofacial root component, B: radix paramolaris, C: distofacial root component, D: radix distomolaris, E: lingual root component.

Table 1. Distribution of 70 radix paramolaris on the permanent maxillary molars according to root types

	M1 sup		M2 sup		M3 sup		Total	
	*n**	%	*n*	%	*n*	%	*n*	%
Type A								
Non-separate	0	0.0	0	0.0	3	4.3	3	4.3
Separate/non-separate	0	0.0	0	0.0	2	2.9	2	2.9
Type B								
Separate	0	0.0	2	2.9	33	47.1	35	50.0
Non-separate	1	1.4	2	2.9	16	22.9	19	27.2
Separate/non-separate	0	0.0	1	1.4	10	14.3	11	15.7
Total *n*%	1	1.4	5	7.2	64	91.5	70	100.1

* Absolute frequency.

Table 2. Distribution of 29 radix distomolaris on the permanent maxillary molars according to root types

	M1 sup		M2 sup		M3 sup		Total	
	n	%	*n*	%	*n*	%	*n*	%
Separate	0	0.0	1	3.4	11	37.9	12	41.3
Non-separate	0	0.0	0	0.0	11	37.9	11	37.9
Separate/non-separate	0	0.0	0	0.0	6	20.7	6	20.7
Total *n*%	0	0.0	1	3.4	28	96.5	29	99.9

distofacial root component; *type B non-separate* covers the variants on which RP was non-separate in relation to one or both of the facial root components. Similarly, in Table 2 *separate* covers the variants on which RD was separate in relation to both the distofacial and the lingual root components; *non-separate* covers the variants on which RD was non-separate in relation to one or both of the root components just mentioned. On the variants described in the tables as *separate/non-separate*, it was impossible to determine whether separation would occur or had occurred (see Discussion).

Macromorphology

The following clinically relevant macromorphological variables regarding RP and RD were also observed.

Relative size. On the individual tooth, RP could have a cervicoapical extension greater or lesser than the corresponding extension of both the mesiofacial and the distofacial root components. Variants have also been observed on which RP was larger than one of the facial root components, but smaller than the other. The smallest of RPs had a cervicoapical extension which was approximately 1/2 of the corresponding extension of the facial root components.

Similarly, RD often had a smaller cervicoapical

extension than both the distofacial and the lingual root components. Variants were also observed on which RD was larger than one of the neighboring root components, but smaller than the other. The smallest RD had a cervicoapical extension which was approximately 2/3 of the corresponding extension of the distofacial and the lingual root components. In none of the examined teeth was RD larger than both the relevant neighboring structures.

Frequency of separation. As a supplement to the data presented in Tables 1 and 2, the following points are worthy of note.

On 2 of the 3 radix paramolaris type A non-separate variants, RP was non-separate in relation to both the mesiofacial and distofacial root components; on the third tooth, RP was non-separate in relation to the mesiofacial root component, but separated from the distofacial component.

The total of 19 radix paramolaris type B non-separate variants were distributed as follows: RP was non-separate in relation to both the facial root components on 12 of the teeth; on 3 of the teeth, RP was non-separate in relation to the mesiofacial root component and separated from the distofacial component; finally, RP was non-separate in relation to the distofacial root component, but separated in relation to the mesiofacial component on 4 of the teeth.

Radix distomolaris non-separate was identified on 11 teeth, distributed as follows: RD was non-separate in relation to both the distofacial and the lingual root components on 3 of the teeth; on 7 of the teeth RD was non-separate in relation to the distofacial root component but separated from the lingual component; on the final tooth, RD was non-separate in relation to the lingual root component and separated from the distofacial component.

Degree of separation. The degree of separation measured in pairs varied from 0.0 to approximately 0.8. On one and the same tooth—where at least one degree of separation was greater than 0—the degree of separation between RP and the mesiofacial root component was relatively often greater or lesser than the degree of separation between RP and the distofacial component. On one and the same tooth—where at least one degree of separation was greater than 0—the degree of separation between RD and the lingual root component was often greater than the degree of separation between RD and the distofacial component.

Degree of divergence. RP's degree of divergence in relation to both the mesiofacial and distofacial root components was often either slightly positive, 0, or slightly negative. Pronounced divergence was rarely observed, and the maximum was approximately 40°. RD's degree of divergence compared to the distofacial and lingual root component was usually either slightly positive, 0, or slightly negative. On the individual tooth, RD's degree of divergence in relation to the lingual root component was often greater than the degree of divergence in relation to the distofacial component. On 1 tooth, a divergence of approximately 80° between RD and the lingual root component was observed.

Apical bend. RP and RD often had an apical bend, especially when the root structures were separate. Bends of over 90° were measured. The direction of the bend varied.

Apical gracility. RP and RD often exhibited apical gracility, especially the separate roots. The degree of gracility was occasionally highly pronounced.

Fusion. RP could be fused with both the mesiofacial and distofacial root components, or only with 1 of these components. RD was only observed to fuse with the distofacial root component.

Discussion

Materials

As previously mentioned, the Copenhagen Tooth Collection—the source of the material examined—consists of extracted teeth. The composition of the material may be influenced by different—and partially uncontrollable—factors; associated with the nature of the extraction and/or collection processes, for example. There is, thus, no 100% guarantee that the collection is representative in *quantitative* terms. As a result, the authors do not think it is justifiable in the given context to quote frequencies for RP and RD occurrences in the Danish population.

It is worth noting that neither RP nor RD were observed in a Dutch survey (20) of 2,861 M1 sup, 2,871 M2 sup, and 2,431 M3 sup.

The material consisting of M sup with an RP or an RD at the authors' disposal is, however, sufficiently large to make it representative as far as *qualitative* conclusions are concerned. As far as variation is concerned, it is unlikely that any significant Danish RP or RD variants have been omitted from the material.

No information is provided about whether the individual tooth in the Collection is extracted from females or males. Thus, it has been impossible to identify potential gender differences.

On the existing basis, it is also impossible to map any population differences in the macromorphology of RP and RD. A lack of comparable data makes it impossible at present to conduct such an otherwise relevant analysis.

When observing variables manifested in the macromorphology of the root complex, it is, in principle, necessary to differentiate between teeth from younger and older persons. For example, root grooves which were originally less deep can be covered completely by age-related cement deposits. Accordingly, non-separate supernumerary roots can be overlooked. In the Copenhagen Tooth Collection, the vast majority of M1 sup and M2 sup variants are older teeth, while the M3 sup variants are typically extracted from young/younger people. The registered distribution of the supernumerary roots over the 3 tooth types may, therefore, deviate slightly from the real distribution.

Under certain conditions, it was impossible to decide whether an identified supernumerary root should be

registered as separate or non-separate. This was the case on variants where large cement deposits apically in the root complex had totally obscured the original macromorphology. On root-open teeth with a demonstrated non-separate supernumerary root, it was also impossible to decide whether the root would have remained non-separate or whether separation would have occurred later in the root formation period. The RP and RD variants in question were, therefore, registered as separate/non-separate (see the tables). Nor was it possible on those teeth to observe, for example, degree of separation, apical bend, and apical gracility for the supernumerary roots concerned.

Ontogenesis

By way of introduction, it must be stressed that relationships regarding supernumerary teeth, which are fused with the crown and/or the root complex on an otherwise normal tooth, are not included in this work and will not, therefore, be discussed here.

On the permanent molars, supernumerary roots vary considerably. To avoid an unnecessary complicated classification of these roots, the present authors have chosen to refer a supernumerary root to its *location* in the root complex.

In the attempt to give as simple an explanation as possible for the etiology of supernumerary roots, it must first be underlined that tooth germs—like other organs—possess great ontogenetic plasticity, a characteristic that allows modifications during the formation of both the crown and the root complex.

As far as the molars are concerned, the shape of tooth germs is modified from the original oval cross-section during the root formation process, as bulges appear corresponding to the basal prominences in the crown. Each of these coronal swellings will later be supported by a root component.

Growth units are formed in the dental papilla, each of which has its own vascular system. During root formation, Hertwig's root sheath grows in between clearly separate growth units, while units located close to or relatively close to each other remain incompletely separated and are delineated by root grooves (21).

A common feature in the formation of supernumerary radicular structures is the establishment of a new, extra/supernumerary growth unit in the dental papilla. Often, this growth unit is established before root formation begins. Macromorphologically, the growth zone will then manifest itself cervically on the crown and on the root complex. It is not yet known what initiates the formation of an extra growth unit, but once it is organized it appears to be self-regulated and continues its growth, differentiation, and mineralization at the same rate as other independent growth centers, which are established when the occlusal surface is formed.

Supernumerary growth units occur mainly in areas where coronal macrostructures vary the most: on M sup this partly corresponds to the basal cingulum facially, where the paramolar structure is formed, partly in relation to the distal structures of the crown where the marginal tuberculum, designated as c5 (22), and/or the distolingual lobe, may be atypically large in relation to the other crown structures.

Owing to the very considerable variation among M2 sup and M3 sup, a tuberculum paramolare, a large c5 or a strikingly well-defined distolingual lobe is not always associated with a supernumerary root after all. The presence of a continuous morphological series of variants instead of consisting of a few discrete variants indicates that tooth formation is a multifactorial process.

The identification of separate supernumerary roots is of particular clinical importance, for example, during extraction because of the risk of fracture. Detection can be facilitated by analysing the cervical morphology of the crown whenever the tuberculum paramolare is present or whenever the occlusal distal or distolingual macrostructures on M2 sup and M3 sup are larger than expected. If the structures in question are accompanied by a cervical prominence or convexity, then the coronal macrostructure is probably supported by a supernumerary root. The cervical prominence can, thus, serve as a diagnostic aid.

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