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Evaluation of mandibular trabecular bone by fractal analysis in pediatric patients with hypodontia of the mandibular second premolar tooth

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Abstract

Background It is still unclear whether the trabecular structure of the jaw is different in individuals with hypodontia than in those without hypodontia; this is important for clinicians. The aim was to determine whether the mandibular trabecular bone structure of children and adolescents with hypodontia differs from the control group by using the fractal analysis (FA) method in this study.

Methods A total of 138 panoramic radiographs of 69 cases and 69 control subjects (mean age 13.2 ± 10.1) were evaluated. The age and gender of subjects in the case and control groups were matched. Three regions of interest (ROIs) were selected from the panoramic radiographs. ROI1 refers to the center of the ramus rising above the mandibular foramen. ROI2 refers to the area between the apical level of the mandibular molar and the upper border of the mandibular canal. ROI3, the missing tooth region, refers to the apical third of the mesial side of the erupting or fully erupted permanent mandibular first molar. Mann-Whitney U and Wilcoxon tests were used. $p < 0.05$ was accepted for the significance value.

Results The mean fractal dimension (FD) values of ROI1, ROI2, and ROI3 were 1,25, 1,20, and 1,13, respectively. The means FD values obtained from the ramus region were higher than the other regions ($p < 0.05$). The FD values did not differ significantly according to gender and age ($p > 0.05$). The FD values of the case group were lower than the control group for ROI3 ($p < 0.05$).

Conclusion The results of this study showed that the mandibular trabecular bone quality of pediatric patients with one missing tooth was different from the healthy group. The difference in the mean FD values from the ROIs indicates that the ramus has a denser structure than the mandibular corpus. Clinicians should factor this into their dental treatment planning process.

Keywords Fractals, Panoramic radiography, Hypodontia, Child, Adolescent

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Introduction

Hypodontia is defined as the agenesis of one or more teeth in primary or permanent dentition [1]. Tooth agenesis is more prevalent in females, with the most frequently affected tooth being the mandibular second premolar, followed by the maxillary lateral incisor and maxillary second premolar (excluding the third molar) [2].

The etiology of tooth agenesis is complex, and both environmental and hereditary factors are reported to be effective [3]. Environmental factors leading to tooth agenesis include infectious diseases (e.g., rubella), various traumas in the tooth region, surgical procedures, chemotherapy or radiotherapy, or impairments in the innervation to the jaw, and factors linked to fetal development in the uterus [4–6]. In addition, it is known that tooth agenesis is accompanied by various syndromes, such as Down syndrome, cleft lip and palate, ectodermal dysplasia, van der Woude syndrome, oral-facial-digital syndrome type I, Rieger syndrome, and holoprosencephaly [7]. Although epigenetic and environmental factors contribute to tooth agenesis's etiology, there is convincing evidence that genetic factors prevail in the pathogenesis of the disease [8].

Today, FA is a popular method that quantitatively expresses the quality of bone tissue [9–11]. The FD values calculated by the box-counting method in trabecular bone are expected to be between 1 and 2. Values close to 2 represent a more complex bone microstructure, while values close to 1 refer to simpler bone microstructures highlighting the porosities of bone [12] .

In hypodontia patients, it is valuable for the clinician to know the bone quality in treatments such as dental implant applications and orthodontic treatments [13, 14]. It has been reported that permanent tooth agenesis may cause insufficient alveolar bone development [15–17]. On the other hand, the relevant literature reports that the effect of hypodontia on trabecular bone structure is not clear [18].

Determining whether the mandibular trabecular bone structure of children and adolescents with hypodontia differs from that of a control group can enhance the effectiveness of orthodontic, prosthetic, and implant treatments and help in the early detection of potential issues during the growth process. Additionally, this study can contribute valuable scientific data to the literature, expand the existing knowledge on dental anomalies, and aid clinicians in planning more effective treatment strategies.

For these reasons, it was aimed to determine whether the mandibular trabecular bone structure of children and adolescents with hypodontia is different from the control group by the fractal analysis method.

Materials and methods

The Sütçü İmam University Non-Interventional Ethics Committee of the Faculty of Medicine granted the ethical approval to the present study (approved no. 2021-04). The presented study was retrospectively carried out in the Sütçü İmam University, School of Dentistry, Department of Pedodontics. The radiological records of the child and adolescent individuals who applied to the Sütçü İmam University, Pedodontics Outpatient Clinic for various dental treatment reasons were analyzed. Informed consent was obtained from all participants and from the parents of those under the age of 16 before the study began. To ensure standardization in the study, we included only the pediatric patient with agenesis of the mandibular second premolar in the study group.

According to the analysis of 95% confidence (1-α), 80% test power (1-β) and d=0.77 effect size, the number of samples to be taken in each group was determined as 6 according to the one-tailed independent samples t test analysis [19]. However, in order to increase the power of the sample, 67 people were included in each group in our study.

Sixty-nine child and adolescent individuals with agenesis of the mandibular second premolar consisted of the study group, while 69 child and adolescent individuals without hypodontia, matched with the study group for age and gender, consisted of the control group. Both groups were selected from child and adolescent individuals with mixed dentition periods. Each individual in the case and control group were matched for age and gender.

In both groups, radiographs with insufficient image quality, diagnosis of disease and drug use affecting bone metabolism, presence of syndrome, genetic disease, dental caries in the missing tooth region, apical and periodontal pathology were excluded from the study.

All panoramic radiographs were obtained by the same technician on the GENDEX GDP-700 device (Kavo Kerr, Biberach, Germany) at 66 kVp, 6.3 mA and 14 s acquisition procedures according to the manufacturer's reference values.

A total of 138 panoramic radiographs, 69 of the study group and 69 of the control group, were saved to the lab computer is 2441×1149 pixel, 300 dpi resolution, 8-bit color depth, and Joint Photographic Experts Group (JPEG) format. In this study, the box-counting algorithm, which is primarily preferred in the FA method, was used [11] .

All the image processing and fractal analysis procedures were conducted via the ImageJ v1.52 (NIH, Bethesda, MD, USA) program. The first step for FA was to select the region of interest manually. In all panoramic radiographs, trabecular bone structures in ROIs located on the left side of the mandible (the quadrant with agenesis teeth) were measured.

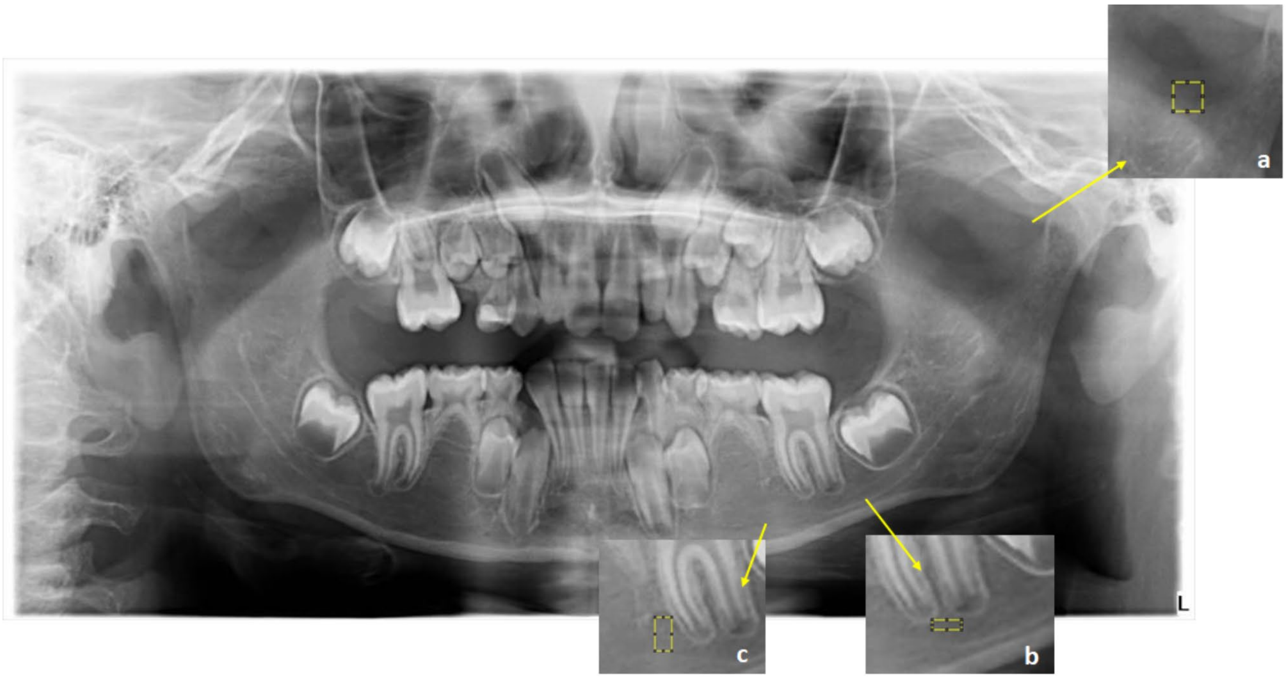

Fig. 1 Selection of ROI on a panoramic radiograph, (**a**): The center of the ramus rising above the mandibular foramen, (**b**): The area between the apical level of the mandibular molar and the upper border of the mandibular canal, (**c**): The missing tooth region; the apical third of the mesial side of the erupting or fully erupted permanent mandibular first molar

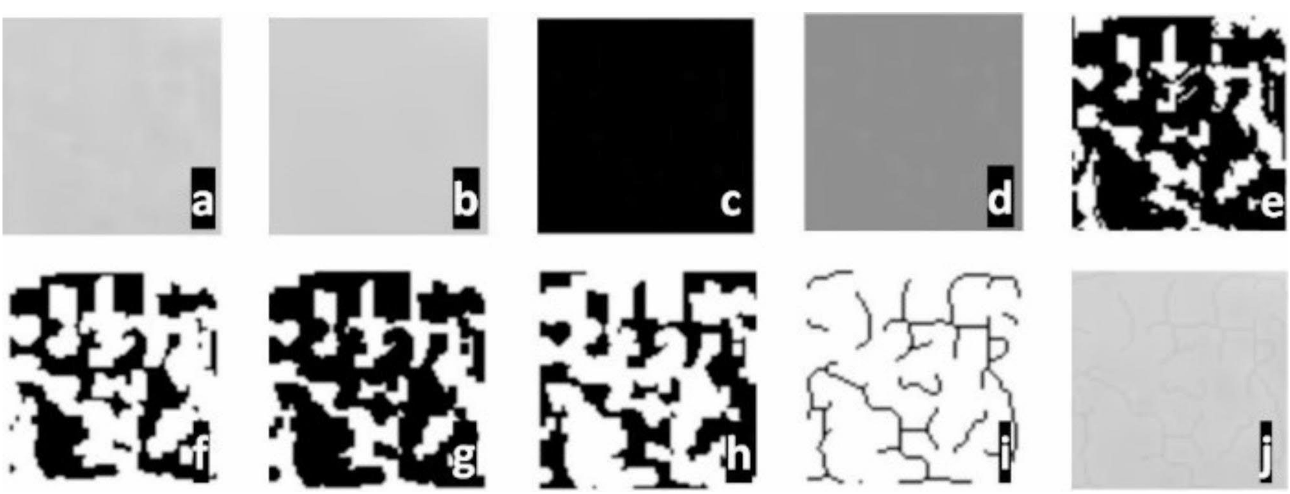

Fig. 2 (**a**): Duplicated, (**b**): Blurred, (**c**): Subscription, (**d**): Grayscale offset, (**e**): Binarized, (**f**): Eroded, (**g**): Dilatation, (**h**): Invert, (**i**) and (**j**): Skeletonize

ROIs in the mandibular left posterior region were selected from:

(1) The center of the ramus rising above the mandibular foramen (Fig. 1a),
(2) The area between the apical level of the mandibular molar and the upper border of the mandibular canal (Fig. 1b),
(3) The missing tooth region was in the apical third of the mesial side of the erupting or fully erupted permanent mandibular first molar (Fig. 1c).

ROI1 was selected as a 20×20 pixel square, while ROI2 was a 30×10 pixel rectangle and ROI3 was a 40×20 pixel rectangle (Fig. 1). The selected ROIs were duplicated (Fig. 2a). The duplicated images were blurred with Gaussian filter (Sigma 35). The purpose of this step is to eliminate the large-scale brightness changes that may occur due to different object thicknesses and the presence of overlapping soft tissues and to preserve only density differences (Fig. 2b). The images obtained with the Gaussian filter were subtracted from the original images (Fig. 2c). One hundred twenty-eight gray pixel

Table 1 The mean fractal dimension values according to total sample, gender, age and case-control groups

	ROI1	*p* value	ROI2	*p* value	ROI3	*p* value
Total	1.25 (1.00–1.49)		1.20 (1.00–1.37)		1.13 (0.81–1.35)	**0.000***†‡
Gender						
Female	1.26 (1.01–1.49)	0.629	1.20 (1.00–1.35)	0.448	1.14 (0.88–1.35)	0.203
Male	1.24 (1.00–1.43)		1.19 (1.00–1.37)		1.11 (0.81–1.29)	
Age Groups						
4–10 years	1.26 (1.00–1.49)	0.578	1.19 (1.00–1.35)	0.604	1.14 (0.90–1.35)	0.619
11–17 years	1.24 (1.00–1.44)		1.20 (1.00–1.37)		1.12 (0.81–1.35)	
Case-Control Groups						
Case	1.24 (1.00–1.49)	0.589	1.20 (1.00–1.34)	0.854	1.04 (0.80–1.23)	**0.000***‡
Control	1.25 (1.00–1.44)		1.20 (1.00–1.37)		1.14 (0.71–1.35)	

*$p<0.01$, ‡Wilcoxon test, ǂ Mann-Whitney U test

values to each pixel location in the images were added (Fig. 2d). The images were binarized as the next step to secure two parts representing bone marrow and trabeculae. (Fig. 2e). The resulting images were eroded; thus, the noise was reduced (Fig. 2f). In the next step, dilatation was applied to the image to make the structures more apparent (Fig. 2g). The colors of the regions denoting the bone marrow and trabecular bone were changed to the opposite colors (Fig. 2h). The final images were skeletonized using the 'Skeletonize' option (Fig. 2i **and** Fig. 2j). Using the software's box-counting algorithm, the images were divided into 2, 3, 4, 6, 8, 12, 16, 32, and 64 pixel-sized squares, and the number of frames containing trabeculae and the total number of frames was calculated. The values obtained in the logarithmic scale chart were included. The slope of the line aligned to points on the chart yields the FD value.

In the present study, two oral and maxillofacial radiologists performed the measurements blindly and independently. The mean FD value of each region of interest was calculated and used for statistical analysis. For evaluating the intra and inter-observer reliability, the measurements of were repeated two weeks after the first measurements.

Statistical analysis

Data analyses were performed using IBM SPSS Statistics 26.0 (Statistical Package for Social Science) package program. Kolmogorov Smirnov test was used to evaluate whether the data were normally distributed. Since the data did not show normal distribution ($p<0,05$), Mann-Whitney U and Wilcoxon tests were used. Also, reliability analysis was performed for intra-observer and inter-observer agreement. $p<0.05$ was accepted for the significance value.

Results

A total of 138 panoramic radiographs of 69 individuals with hypodontia (36 females, 33 males) and 69 control subjects (36 females, 33 males) were evaluated. Since age and gender were matched in the patient and control groups, the mean age of the individuals in both groups was 13.2±10.1. There was no statistically significant difference in the distribution of age and groups according to gender, $p>0.05$).

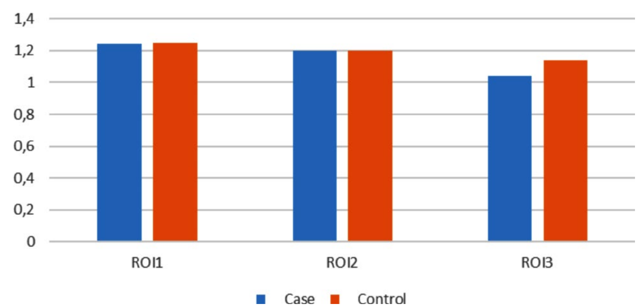

Fig. 3 The diaphragm of mean fractal dimension values according to case-control groups

The intra-rater reliability coefficients for ROI1, ROI2, and ROI3 were 0.898, 0.875, and 0.902 for rater 1, and 0.912, 0.921, and 0.885 for rater 2, respectively. Interobserver Cronbach's alpha values for ROI1, ROI2, and ROI3 were also 0.928, 0.896, and 0.901, respectively. Intra-observer and inter-observer consistency was nearly perfect.

The mean FD values of ROI1, ROI2, and ROI3 were 1,25, 1,20, and 1,13, respectively. Table 1 shows the mean FD values of ROIs by total sample, gender, age, and case-control groups. According to Wilcoxon test, there was a statistically significant difference between FD values obtained from ROIs. While the mean FD value obtained from the ramus region was the highest, the FD value obtained from the edentulous area was the lowest ($p<0.05$) (Table 1). The FD values obtained from all ROIs did not differ significantly according to gender and age ($p>0.05$) (Table 1). When the FD values of the case-control groups were compared, the values obtained from ROI1 and ROI2 did not differ according to the groups, while ROI3 showed a significant difference ($p<0.05$) (Table 1) (Fig. 3). The FD values of the case group were lower than the control group.

Discussion

Hypodontia treatment requires a multidisciplinary as a combination of orthodontics, fixed and removable prosthesis, and oral surgery approach and treatment includes different approaches according to the age of the child and the dentition period [20, 21]. If orthodontic treatment and dental implants are to be applied in the early period in order to preserve the bone structure in hypodontia patients, it is recommended to wait for the completion of growth and development, that is, approximately 16–20 years of age [22, 23]. In the literature, early placement of dental implants in children with hypodontia has only been applied in severe tooth deficiency, and these are case reports [24–26]. One the other hand, in orthodontic treatment, it is reported that the speed of tooth movement increases as the bone density decreases, and that the anchorage should be increased according to the need in the regions where the bone density is low [27]. Therefore, it will be beneficial for the clinician to know the status of the bone tissue in the patient group with hypodontia.

In the literature, the effects of many systemic diseases on the jaw were investigated using the fractal method [9, 28–31]. Lower FD values have been associated with lower bone density [9, 30, 31].

The most important finding of this study is that the FD values obtained from the edentulous area (ROI3) were significantly lower in the case group compared to the control group. This indicates that trabecular bone quality may be adversely affected in patients with hypodontia. The significant difference observed in ROI3 and the lower FD values in the case group highlight the impact of hypodontia on bone structure. There was only one study in the literature evaluating the effect of hypodontia on trabecular bone and this study included an older age group [18]. On the contrary, in this study, children and adolescents were evaluated. Creton et al. [18]. investigated possible bone structure changes due to hypodontia with fractal analysis and other radiographic measurements and reported that there was no significant difference between the groups. However, they observed a greater FD values when the number of missing teeth increased. The difference between Creton et al. [18] and us may be due to the fact that they used the caliper method when calculating FD values in their study and classified tooth deficiency as hypodontia, oligodontia or dental agenesis. Although the timing of dental implant applications is recommended to be after the completion of growth and development, our results may provide important insights into mandibular trabecular bone structure for both orthodontic treatment and dental implant patients. Low bone quality in edentulous areas can negatively impact long-term dental health and the stability of the jaw structure. During orthodontic treatment, tooth movements in areas with low bone quality may differ, affecting the speed and stability of treatment. If dental implants are planned, low bone quality should be considered, and supportive treatments such as bone grafts, regenerative therapies, and anchorage devices should be considered.

There are many recent studies related to bone quality through fractal analysis and dental radiology in the literature [9, 11, 12, 30]. In the calculation of FD values, methods such as power, caliper and box counting methods are used [31]. It has been stated that the methods to be used in the analysis of mandibular and maxillary bones should differ. Although there are many methods to calculate, the most preferred is the box counting method [32]. Therefore, this method was used in this study.

Most studies evaluated the FD on periapical, bitewing, and panoramic radiographs. Recently, the number of studies working FD on Cone Beam Computed Tomography (CBCT) images has been increasing. However, the number of studies is still limited [33]. Magat et al. [34] compared DPR and CBCTs in the evaluation of trabecular bone by fractal analysis and stated that it would be more feasible and appropriate to choose panoramic radiographs because of the disadvantages of CBCTs such as higher radiation and lower image resolution. DPR was the method of choice due to its advantages in the presented study, considering the pediatric patient group.

It has been reported that the FD values is affected by the parameters of ROI selection, size, shape, and the region where it is placed. It has been stated that the use of linear ROIs is insufficient to evaluate the trabecular structure, therefore, a planar ROI selection should be made [35]. Planar ROIs were selected in this study. The size of the selected ROIs differed by region, as individuals were in the mixed dentition period and were studied in a limited area.

According to the literature, it is seen that the mean fractal values vary between 1.10 and 1.83 in healthy individuals [36]. In this study, mean fractal values ranged from 1.04 to 1.26. The results we obtained were within the limits of the literature. In studies, FD values were generally evaluated in individuals over the age of 18 [29, 37–41]. There were a limited number of studies evaluating the trabecular bone structure of children and adolescents with FA [28, 42, 43]. The mean age (11.67 ± 2.53 years.) and FD values (1.29 ± 0.06) of the individuals in Yagmur et al.'s study [42] were quite close to those in this study. The reason for the differences in FD values stated in the studies may be due to the difference in the number of samples, FD values calculation method, gender and age distributions.

It is known in the literature that FD values are lower in females and in the older age group [39]. However, FD values did not differ according to age and gender in this study. There is not a limited number of studies in the literature in which these findings can be directly compared.Similar to this study, in a study evaluating the FD values of children's condyles [43], it was emphasized that trabecular structure did not change according to age, except for those aged 6 years. In another study [44], it is stated that trabecular bone scarcity is more pronounced in individuals under the age of 20. Kavitha et al. [45] reported that FD values of trabecular bone were lower in females than males all ages. Hormonal problems, the number of systemic diseases and the increase in drug use with age in females may cause this situation [46]. As far as we know, there was no study in the literature evaluating the effect of gender in this age group.

In this study, the FD values of different ROIs of individuals on the same side were significantly different from each other. When the FD values of all individuals were examined, it was seen that the FD values calculated from the ramus region were the highest and the FD values calculated from the regions with missing teeth were the lowest. A larger FD values indicates a denser and less porous trabeculae [32]. According to this information, it can be said that among the regions examined in this study, the trabecular complexity in the ramus region is higher than in other areas. In addition, Yaşar and Akgünlü [38] observed that the differences in occlusal forces occurring in the dental and edentulous areas during chewing caused some changes in the trabecular bone structure, resulting in lower FD values in the dental areas. In this study, fractal values obtained from structures adjacent to the dentulous regions were lower. Consistent with our result, there are studies in the literature that indicate that there are differences in FD values of ROIs evaluated on the same side, as well as in studies conducted in the same regions [38, 40, 41, 45].

This study is one of the first to demonstrate differences in mandibular trabecular bone quality in children and adolescents with hypodontia and provides an important foundation for future research. Additionally, the data obtained using the fractal analysis method provides an objective approach to assessing bone quality.

The limitation of the current study is that only one missing tooth was evaluated in the study groups and the sample size was small. In future studies, the number of patients should be increased and edentulous status should be evaluated. In addition, studies that include both cortical bone and trabecular bone in a wider age range can be done by categorizing missing tooth cases.

Conclusion

The results of this study showed that the mandibular trabecular bone quality of pediatric patients with one missing tooth was different from the healthy group. The difference in the mean FD values from the ROIs indicates that the ramus has a denser structure than the mandibular corpus. Clinicians are advised to evaluate the bone status carefully when devising dental treatment plans for these patients.

Author contributions

K.T.T, G.M.: conceptualization-methodology-software-formal analysis-writing–original draft A.C.: conceptualization-methodology-software A.S.O.: conceptualization, data collection, S.O.: supervision-review and editing.

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Data availability

The data that support the finding of this study are available from the corresponding author upon reasonable request.ng author upon reasonable request.

Declarations

Ethics approval and consent to participate

The Sütçü İmam University Non-Interventional Ethics Committee of the Faculty of Medicine granted the ethical approval to the present study (number: 2021-04). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all participants and from the parents of those under the age of 16 before the study began.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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