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Effects of intrusion combined with anterior retraction on apical root resorption

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SUMMARY This study evaluated the influence of intrusion mechanics combined with anterior retraction on root resorption of the maxillary incisors. A sample of 56 patients was divided into two groups: group 1 comprised 28 patients (12 females and 16 males), presenting with an increased overjet and deep overbite (6.48 and 4.78 mm, respectively) treated with reverse curve of Spee intrusion mechanics and group 2 comprised 28 patients (12 females and 16 males) with an increased overjet of 5.67 mm and a normal overbite of 1.12 mm. The initial mean ages for groups 1 and 2 were 13.41 and 13.27 years, respectively. Pre- (T1) and post- (T2) treatment periapical radiographs were used to evaluate root resorption. The groups were compared using the Mann–Whitney *U*-test. Correlation between root resorption and tooth movement was investigated with Spearman's correlation coefficient.

The subjects in group 1 had statistically greater root resorption ($P < 0.05$) than those in group 2. The initial overbite severity and the amount of correction had significant positive correlations with root resorption ($r = 0.324$ and $r = 0.320$, respectively). The combination of anterior retraction with intrusive mechanics causes more root resorption than anterior retraction of the maxillary incisors alone.

Introduction

Orthodontic treatment is frequently related to the occurrence of apical root resorption. The concentration of orthodontic forces on the root, especially on the apex, can cause biological changes in the cementum and periodontal ligament, resulting in root resorption (Brezniak and Wasserstein, 1993; Faltin *et al.*, 2001).

Malocclusions presenting a deep overbite are frequently associated with the occurrence of an accentuated curve of Spee. In these cases, levelling the curve of Spee becomes a desirable orthodontic treatment goal (Shannon and Nanda, 2004). In edgewise mechanics, levelling archwires with an accentuated and reverse curve of Spee are frequently used to correct a deep overbite (AlQabandi *et al.*, 1999; Clifford *et al.*, 1999). This procedure usually produces intrusion and flaring of the incisors and these teeth appear to be most susceptible to resorption because of root characteristics that concentrate greater stress on the apex (Rudolph *et al.*, 2001; Shaw *et al.*, 2004).

Among dental movements, incisor intrusion and anterior retraction seem to cause the greatest resorption during orthodontic treatment (McFadden *et al.*, 1989; Mirabella and Årtun, 1995; McNab *et al.*, 2000; Faltin *et al.*, 2001). This combination of movements and the amount of initial overjet have been correlated in Class II treatment with the occurrence of apical resorption (Brin *et al.*, 2003).

Although many authors agree that intrusion and retraction forces are strongly related to root resorption,

some controversy exists (DeShields, 1969; Dermaut and De Munck, 1986; Baumrind *et al.*, 1996; Costopoulos and Nanda, 1996). Probably, this controversy results from uncontrolled methodologies in the literature. Many variables can compromise the results, due to the difficulty in distinguishing which factor is involved in the resorption process (Brezniak and Wasserstein, 1993). Additionally, no study has demonstrated the role of each movement to the degree of root resorption, when acting simultaneously.

Therefore, the purpose of this research was to evaluate the following null hypothesis: root resorption is similar in deep overbite extraction treatment with anterior retraction combined with intrusive mechanics and in normal overbite extraction treatment with only incisor retraction. Correlations between resorption, treatment time, and the amount of initial overjet and overbite were also investigated.

Subjects and methods

The files of 56 patients (24 females and 32 males) with ages ranging from 9.42 to 21.5 years were retrospectively selected from the archive of the Orthodontic Department at Bauru Dental School, University of São Paulo. Only patients that had undergone two maxillary or four premolar extractions and retraction of the anterior teeth with standard fixed edgewise appliances were selected. Subjects with root resorption, endodontic treatment, a history of trauma impacted canines, or dental anomalies of a number of teeth

before treatment were excluded. Those with incomplete orthodontic records and poor quality radiographs were also not included.

Sample selection was primarily based on patients that presented an initial overjet of at least 3 mm, observed on the study casts. The sample was divided into two groups: group 1 included 28 bilateral Class II malocclusion patients (12 females and 16 males) with an initial mean age of 13.41 ± 2.38 years (range, 9.42–21.5 years) and an initial overjet of 6.48 ± 2.52 mm (minimum, 3.2; maximum, 12.8 mm) and an overbite of 4.78 ± 1.18 mm (minimum, 3.5; maximum, 8.7 mm). The patients were treated with two maxillary (17 patients) or four premolar (11 patients) extractions and treatment was performed with continuous archwire intrusive mechanics with an accentuated and reverse curve of Spee. Treatment time was 27.95 (SD = 9.35) months for this group.

Group 2 included 28 patients (12 females and 16 males) with an initial mean age of 13.27 ± 1.85 years (range, 11.16–19.33 years), an initial overjet of 5.67 ± 2.73 mm (minimum, 3.0; maximum, 14.3 mm), and a normal overbite of 1.12 ± 0.97 mm (minimum, 0.1; maximum, 3.8 mm). These patients were treated with two maxillary (three patients) or four premolar (25 patients) extractions, without intrusive mechanics. Fourteen patients had a Class I and 14 a Class II malocclusion. Treatment time was 29.43 (SD = 7.16) months.

Orthodontic mechanics included fixed edgewise appliances, with 0.022×0.028 inch conventional brackets and a wire sequence characterized by an initial 0.015 inch twist-flex or a 0.016 inch nitinol, followed by 0.016, 0.018, 0.020, and 0.021×0.025 or 0.018×0.025 inch stainless steel archwires (Unitek, Monrovia, California, USA). The deep overbite in group 1 was corrected with an accentuated and reverse curve of Spee both in the round and rectangular archwires. Extraoral headgear was used to maintain and/or correct a Class II molar relationship in the groups and, whenever necessary, Class II elastics were also used. The intrusion forces delivered by the archwires were 100–150 g.

The pre- (T1) and post- (T2) treatment periapical radiographs were obtained with the DABI 70 Spectro 1070X X-ray machine (Dabi Atlante, Ribeirão Preto, Brazil), set up for 70 kV, 10 mA, and an exposure time of 1 second, with the long-cone paralleling technique. Kodak Ektaspeed EP 21 films (Eastman Kodak, Rochester, New York, USA) were used, and the angles were obtained by an intraoral XCP positioner (Rinn-Dentisply, Elgin, Illinois, USA). All radiographs were processed automatically.

Root resorption evaluation was blindly performed by one author (DT) on the final periapical radiographs, which were scanned with the Sprint Scan 35 Plus scanner (version 2.7.2; Polaroid, Cambridge, Massachusetts, USA), with a resolution of 675 dpi at a scale of 1:1. The initial radiographs were also scanned to be used as a parameter of the resorption

severity during this evaluation. The images were analysed with Photoshop software (version 6.0; Adobe System, San Jose, California, USA) at 300 per cent enlargement, without image quality loss.

The method of Malmgren *et al.* (1982) was used to evaluate the severity of apical root resorption, ranking it into 5 degrees (Figure 1). Four scores, corresponding to each maxillary incisor, for each patient were obtained, a total of 112 scores per group.

The cephalometric characteristics studied consisted of changes in overbite and overjet and vertical and horizontal displacements of the maxillary central incisor apices (MxIapex vert and MxIapex hor; Figure 2). The T1 and T2 treatment lateral cephalograms were traced by the same examiner (DT), and the landmarks were digitized (model

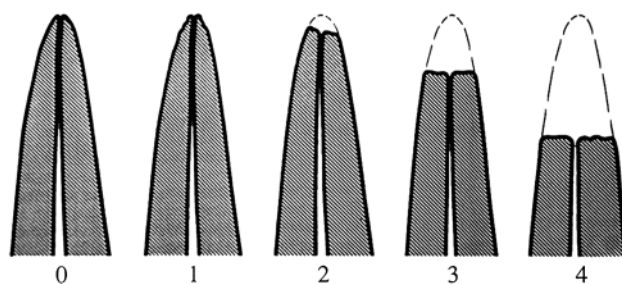


Figure 1 Scoring system of Malmgren *et al.* (1982): grade 0, no root resorption; grade 1, mild resorption, root with a normal length and only displaying an irregular contour; grade 2, moderate resorption, small area of root loss with the apex exhibiting an almost straight contour; grade 3, accentuated resorption, loss of almost one-third of root length; grade 4, extreme resorption, loss of more than one-third of the root length. This figure was published in the *American Journal of Orthodontics and Dentofacial Orthopedics*, Beck, Harris, 1994 Apical root resorption in orthodontically treated subjects: analysis of edgewise and light wire mechanics, 105: 350-361, Copyright Elsevier.

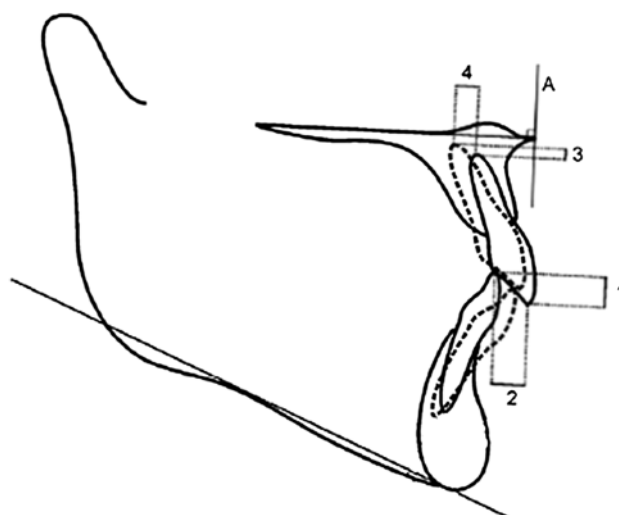


Figure 2 Cephalometric characteristics evaluated: 1, overbite; 2, overjet; 3, MxIapex vert-vertical displacement of maxillary incisor apex, measured perpendicularly to palatal plane (PP); 4, MxIapex hor-horizontal displacement of maxillary incisor apex, measured perpendicularly to line A, which is perpendicular to the PP, through anterior nasal spine.

30TL.F; Numonics, Montgomeryville, Pennsylvania, USA). Landmark coordinates were stored using the Dentofacial Planner software (version 7.02; Dentofacial Planner, Toronto, Ontario, Canada). This software corrected the magnification factors of the radiographs; these were 6.0 (FNX-Cefalo 90, Rio de Janeiro, Brazil) and 9.8 per cent (model MR05; Villa Sistemi Medicali, Milan, Italy), according to the cephalostat used. The patients were positioned with the Frankfort plane horizontal (Manson-Hing, 1985). The length of the average central incisor on the T1 headfilm was assigned to the T2 headfilm to eliminate interference of the amount of apical resorption in the calculation of apical displacements. Treatment changes were calculated as T1–T2.

Error study

Thirty randomly selected patients, 15 from each group, had the amount of any root resorption re-evaluated and their radiographs were retraced, redigitized, and remeasured by the same examiner after a 30 day interval. For root resorption evaluation, intraexaminer agreement was calculated with Kappa statistics (Landis and Koch, 1977). For the cephalometric evaluation, the casual errors were estimated using the formula of Dahlberg (1940) $Se^2 = \Sigma d^2/2n$, where Se^2 is the error variance and d is the difference between two determinations of the same variable. Systematic errors were evaluated with dependent t -tests at $P < 0.05$ (Houston, 1983).

Statistical analyses

The initial ages, treatment times, amounts of initial overjet, and overbite of the groups, as well as the cephalometric treatment changes were compared with t -tests. Intergroup root resorption was compared with the Mann–Whitney U -test. Descriptive statistics were used to show the distribution of the teeth among the scores of root resorption according to the method of Malmgren *et al.* (1982). Correlations of the initial and extent of overbite and overjet correction, treatment time, inclination of the maxillary incisors, and vertical and horizontal displacements of the maxillary incisor apices with the amount of root resorption were studied with Spearman's correlation coefficient. For the first five variables (initial and treatment changes in overbite and overjet and treatment time), all incisors were considered in the correlation, whereas the vertical and horizontal displacements of the maxillary central incisors were correlated with resorption of the corresponding teeth only. The results were considered significant at $P < 0.05$. Statistical analyses were performed with Statistica software (Statistica for Windows 6.05; Statsoft, Tulsa, Oklahoma, USA).

Results

Kappa statistics showed almost perfect agreement between the first and second root resorption intraexaminer evaluation.

There were no statistically significant systematic errors and the casual errors were within acceptable limits (Table 1).

The groups were matched regarding the initial ages, treatment time, and the amount of initial overjet. However, group 1 had a statistically greater initial overbite and a greater number of patients were treated with two maxillary premolar extractions than those in group 2 (Table 2). Group 1 also had greater overbite treatment changes (Table 3). Group 1 treated with intrusion and anterior retraction mechanics had a greater degree of root resorption (mean 2.37, mean rank 36.05) than group 2 (mean 1.69, mean rank 20.94) with a normal overbite treated with anterior retraction without intrusive mechanics (Mann–Whitney U -test 180.5; $P < 0.05$).

The distribution of teeth in the groups, scored according to Malmgren *et al.* (1982), showed that group 1 had 16.96 per cent of the teeth classified with scores of 0 and 1 and the remaining 83.04 per cent had root resorption scores of 2, 3,

Table 1 Results of the systematic and casual error evaluation.

Variable	Measurement 1		Measurement 2		P	Dahlberg
	Mean	SD	Mean	SD		
Pre-treatment						
Overjet (mm)	5.97	2.09	5.89	1.99	0.55	0.36
Overbite (mm)	4.5	0.85	4.49	1.11	0.97	0.5
Mx1.PP	113.04	7.81	112.82	7.41	0.50	0.84
Mx1-vert (mm)	3.96	2.14	3.02	1.83	0.86	0.51
Mx1-hor (mm)	8.85	2.22	8.38	2.44	0.12	0.83
Post-treatment						
Overjet (mm)	2.60	1.25	2.70	1.29	0.32	0.27
Overbite (mm)	1.81	0.84	1.86	0.91	0.56	0.21
Mx1.PP	113.68	6.95	114.07	7.33	0.23	0.88
Mx1-vert (mm)	4.44	1.98	4.51	1.92	0.46	0.24
Mx1-hor (mm)	12.34	2.39	12.12	2.45	0.10	0.37

Table 2 Intergroup data comparison for initial ages, treatment time, initial overjet and overbite, and for number of patients in each extraction protocol (t - and chi-square tests).

Variables	Group 1 ($n = 28$), deep overbite		Group 2 ($n = 28$), normal overbite		P
	Mean	SD	Mean	SD	
Initial age (years)	13.41	2.38	13.27	1.85	0.8098
Treatment time (months)	27.95	9.35	29.43	7.16	0.5117
Initial overjet (mm)	6.48	2.52	5.67	2.73	0.2502
Initial overbite (mm)	4.78	1.18	1.12	0.97	*
Extraction protocol (chi-square tests)	Two maxillary premolar extractions 17	Four premolar extractions 11	Two maxillary premolar extractions 3	Four premolar extractions 25	*

* $P < 0.05$.

and 4. Group 2 had 38.39 per cent of the teeth with scores of 0 and 1 and 61.61 per cent with scores of 2, 3, and 4 (Table 4).

As the number of patients in the groups was not matched regarding the extraction protocols and since this could influence the amount of root resorption, some patients were eliminated from both groups, and the subgroups were again compared with the Mann–Whitney *U*-test. Similar resorption results were obtained in the subgroups with a four premolar extraction protocol: subgroup 1 ($n = 11$) with a deep overbite (mean 2.54, mean rank 27.45) and subgroup 2 ($n = 25$) with a normal overbite (mean 1.61, mean rank 14.56). Mann–Whitney *U*-test 39; $P < 0.05$. Root resorption had a statistically significant positive

Table 3 Comparison of intergroup treatment changes (*t*-test).

Variables	Group 1 ($n = 28$), deep overbite		Group 2 ($n = 28$), normal overbite		<i>P</i>
	Mean	SD	Mean	SD	
Overjet (mm)	3.90	2.35	2.66	2.73	0.073
Overbite (mm)	2.84	1.12	−0.16	1.34	*
Mx1.PP (°)	1.72	8.87	1.71	9.25	0.996
Mx1apex vert (mm)	0.07	1.65	0.04	1.26	0.935
Mx1apex hor (mm)	−2.89	2.43	−2.43	2.16	0.464

* $P < 0.05$.

Table 4 Distribution of teeth with apical root resorption according to the scoring system of Malmgren *et al.* (1982).

Score	Group 1 ($n = 112$), deep overbite		Group 2 ($n = 112$), normal overbite		Total ($n = 224$)
	<i>n</i>	%	<i>n</i>	%	
0	0	0.00	0	0.00	0
1	19	16.96	43	38.39	62
2	39	34.83	58	51.78	97
3	47	41.96	11	9.83	58
4	7	6.25	0	0.00	7

Table 5 Correlation of root resorption with the studied variables of both groups (Spearman).

Variable	<i>R</i>	<i>P</i>
Resorption × initial overbite	0.324	*
Resorption × overbite changes	0.320	*
Resorption × initial overjet	0.184	0.173
Resorption × overjet changes	0.219	0.104
Resorption × treatment time	0.127	0.349
Resorption Mx1apex × Mx1.PP changes (°)	0.186	0.169
Resorption Mx1apex × Mx1-vert changes (mm)	−0.176	0.193
Resorption Mx1apex × Mx1-hor changes (mm)	−0.043	0.75

* $P < 0.05$.

correlation with initial overbite and the amount of its correction (Table 5).

Discussion

Study design

Factors related to orthodontic treatment are primarily responsible for the prevalence of root resorption (McFadden *et al.*, 1989; Blake *et al.*, 1995; Mirabella and Årtun, 1995; Baumrind *et al.*, 1996). However, studies differ significantly regarding design, methodology, control group, and treatment characteristics. An inadequate or unstandardized radiographic technique and a small sample size are common problems that can lead to questionable results. Additionally, several studies do not distinguish the variables related to patients and treatments and how they can influence resorption (Mirabella and Årtun, 1995; Baumrind *et al.*, 1996). Most correlated resorption with intrusive forces (Dermaut and De Munck, 1986; McFadden *et al.*, 1989; Mirabella and Årtun, 1995), retraction (Levander and Malmgren, 1988), and with different types of techniques (Blake *et al.*, 1995; Janson *et al.*, 2000) but did not identify specific movements. In this retrospective study, root resorption was investigated in an homogeneous sample, treated with and without accentuated and reverse curve of Spee intrusion mechanics combined with anterior retraction.

Sample selection and methodology

In samples consisting of patients treated by different professionals, several variables should be considered. It is difficult to obtain a sufficiently large group with adequate records treated by a single operator to evaluate root resorption. It has been thought that the diversity of clinicians undertaking treatment prevents biased clinical procedures, which may be systematically incorporated in treatment due to the performance of a single professional. Furthermore, while other studies in the literature were conducted with samples from various sources, the authors stated that this factor should not interfere with the results (Baumrind *et al.*, 1996; Sameshima and Sinclair, 2001).

Subjective methods, such as that of Malmgren *et al.* (1982), are predominantly used in root resorption studies performed after tooth movement, presenting a primary advantage in that they do not depend on standardization of the initial radiographs (DeShields, 1969; Levander and Malmgren, 1988; Janson *et al.*, 2000; McNab *et al.*, 2000). In contrast, there are other methods that calculate resorption by comparing measurements obtained on radiographs before and after treatment, which demand a standardized radiographic method (Dermaut and De Munck, 1986; McFadden *et al.*, 1989; Linge and Linge, 1991; Blake *et al.*, 1995; Mirabella and Årtun, 1995; Baumrind *et al.*, 1996; Costopoulos and Nanda, 1996). Therefore, the subjective method used in the present seems to be reliable, showing

almost perfect intraexaminer agreement and confirming the precision of the evaluation. Additionally, there were no significant systematic errors and the casual errors were within acceptable levels (Table 1).

Compatibility of the groups

The groups were not compatible regarding initial overbite, with group 1 presenting a statistically greater overbite and consequently requiring greater overbite correction, which is a requirement in a study intended to compare groups with differences in intrusion mechanics (Tables 2 and 3). Additionally, group 1 also had a greater number of patients treated with two maxillary premolar extractions. This issue was addressed by comparing subgroups only with four premolar extractions.

Intergroup comparison

The patients treated with retraction and intrusion mechanics (group 1) had statistically greater root resorption than those in group 2 (Table 4). However, it could be argued that the greater number of patients with two maxillary premolar extractions in group 1 could have accounted for the greater resorption in this group. For this reason, the patients with two maxillary premolar extractions were excluded from each group and a new root resorption comparison was performed. Again, subgroup 1 demonstrated statistically greater apical root resorption. Therefore, it seems that the intergroup difference in the amount of resorption is due to the intrusive mechanics as previously suggested (McFadden *et al.*, 1989; Costopoulos and Nanda, 1996), combined with anterior retraction. Costopoulos and Nanda (1996) also found greater resorption in intruded teeth than in teeth treated without intrusion. Harris and Butler (1992) also observed root resorption in patients undergoing intrusion, but there was no non-intrusion control group for comparison.

An accentuated and reversed curve of Spee is used in deep bite correction because it provides anterior tooth intrusion (AlQabandi *et al.*, 1999; Shannon and Nanda, 2004). Actually, what occurs in deep bite treatment is the sum of factors involving incisor flaring, vertical alveolar growth restriction, and tooth intrusion (McFadden *et al.*, 1989; AlQabandi *et al.*, 1999; Clifford *et al.*, 1999; Shannon and Nanda, 2004). Incisor flaring due to levelling of the curve of Spee is a common effect since the intrusion force is applied labially to the centre of resistance, creating a moment that labially tips the teeth (AlQabandi *et al.*, 1999; Clifford *et al.*, 1999; Shannon and Nanda, 2004). Thus, the root apex moves posteriorly, concurrent with intrusion. This proclination effect is even more critical in the maxillary incisors because the intrusive force vector is usually farther from the centre of resistance.

It can be inferred from these results that one of the factors that contributed to the larger degree of resorption of the

incisors in group 1 was the presence of intrusive mechanics, causing a larger force on the apices from the movement of the incisors during the same period in which considerable retraction forces were used (Costopoulos and Nanda, 1996; Rudolph *et al.*, 2001).

Correlation

Considering the total sample, there was a positive statistically significant correlation of root resorption with the initial deep bite and the amount of its correction (Table 5). Although statistically significant, this correlation can be considered low but is in agreement with several other studies in the literature demonstrating that intrusion can be considered a predictive factor for resorption, in cases with (Harris and Butler, 1992; Sameshima and Sinclair, 2001; Brin *et al.*, 2003) and without (Chiqueto *et al.*, 2008) extractions. The force magnitude during the initial period of intrusion can determine the final degree of root resorption (Costopoulos and Nanda, 1996). This variable was reasonably controlled because the force magnitude used was in the range of 100–150 g. In addition, the variety of professionals involved in treating the patients minimized the risk of systematic application of intensive forces.

Treatment time is important when intrusive forces are used (McFadden *et al.*, 1989; Costopoulos and Nanda, 1996). Treatment time did not have a significant correlation with resorption, as found in other studies (Linge and Linge, 1983; Dermaut and De Munck, 1986; Costopoulos and Nanda, 1996; Table 5). Even though some authors have related resorption to treatment time (McFadden *et al.*, 1989; Baumrind *et al.*, 1996; Brin *et al.*, 2003; Shaw *et al.*, 2004), DeShields (1969) considered that this variable was not the primary cause of loss of root length. If patients who require greater tooth movements also demand more time, the contributory factor is not only treatment duration. In these cases, it is speculated that the amount of tooth movement is the most important factor (Harris and Butler, 1992; Brin *et al.*, 2003; Shaw *et al.*, 2004). The amount of movement is not directly proportional to treatment time because the appliances can be in place with reduced action on the teeth (Mirabella and Årtun, 1995) as patients sometimes miss appointments, and some professionals adopt longer intervals between activations. In this study, there was a wide range of treatment times in both groups. However, because the mean treatment times were similar between the groups, it is reasonable to assume that the factors affecting treatment duration were similar and did not contribute to the difference in root resorption.

This research confirms that a larger degree of resorption and a greater percentage of resorbed teeth are expected when intrusion mechanics are associated with extractions and retraction mechanics. For this reason, intrusion should be carefully applied, particularly in patients who require significant intrusion–retraction movements.

Conclusions

The null hypothesis was rejected because patients with a deep overbite treated with intrusion mechanics with the aim of accentuating and reversing the curve of Spee, combined with anterior retraction, had statistically greater maxillary incisor root resorption than patients with a normal overbite treated with anterior retraction without intrusion. There was a statistically significant positive correlation of root resorption with initial overbite severity and with the amount of correction.

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