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Predictability of Arch Expansion with Clear Aligners: A Systematic Review of the Literature

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Abstract

Introduction: Clear aligners are an aesthetic alternative to fixed appliances, yet their predictability in arch expansion is still debated. This systematic review evaluates the efficiency of aligners in achieving planned expansion and identifies factors influencing outcomes. ***Materials and Methods:*** A systematic review was conducted following the PRISMA guidelines. Electronic searches were performed in PubMed, Cochrane Library, and ScienceDirect using a PICOS-based strategy. Methodological quality and risk of bias were assessed using standardized tools (AMSTAR 2, NHLBI/NIH). ***Results:*** Nine studies were included in the final analysis, consisting of two systematic reviews and seven cohort studies. The review found that arch expansion predictability is highest in the premolar region (reaching up to 93.53%) but decreases progressively toward the posterior segments, with the lowest accuracy observed at the first molar level (approximately 55-68%). Expansion is primarily achieved through coronal tipping rather than true bodily translation. ***Conclusion:*** Aligners effectively manage mild crowding but often result in uncontrolled tipping. To improve predictability, clinicians should utilize overcorrection strategies and pre-program negative torque. Higher-quality randomized clinical trials are necessary to establish standardized protocols.

Keywords: Orthodontics; Invisible orthodontics; Clear aligners; Predictability.

INTRODUCTION

Transverse arch deficiencies are frequently encountered in orthodontic practice and are commonly associated with dental crowding, posterior crossbite, and altered smile width. Arch expansion is often used to increase arch dimensions and create space without extractions. With the growing use of clear aligner therapy, transverse expansion has become a routinely planned movement in digitally guided orthodontic treatments.

Despite continuous advancements in aligner materials and software-driven biomechanics, the predictability of arch expansion with clear aligners remains uncertain. The accuracy of transverse changes appears to vary according to tooth position, arch location, and the level at which expansion is assessed.

Given the widespread clinical use of aligners for managing transverse discrepancies and the variability reported in treatment outcomes, a clearer understanding of expansion predictability is required. The aim of this

study is to evaluate the accuracy of arch expansion achieved with clear aligners by comparing planned and achieved transverse changes.

1. MATERIALS AND METHODS

We carried out this systematic review of the literature according to the criteria published by the international PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) recommendations. Ethical approval for carrying out the study was given by the "Thesis Committee" of the Faculty of Dental Medicine of Monastir in March 2024.

1.1 Objective of the Study:

The purpose of this review was to answer the following question:

- In patients with dental malocclusion, does orthodontic treatment with aligners, compared to the planned virtual set-up model, yield predictable results in terms of arch expansion?

1.2 Eligibility Criteria:

The PICOS (population, intervention, comparison, outcome, study design) format was used to formulate the clinical question with defined inclusion and exclusion criteria (Table 1). All articles included in this systematic review met the following criteria:

Table 1: Eligibility criteria

Domains	Inclusion Criteria	Exclusion Criteria
Participants	Humans with permanent dentition	Children, Animals, In vitro study, Computer simulations
Intervention	Orthodontic treatment with clear aligners using aligner-specific auxiliaries.	Orthodontic treatment with appliances other than aligners and/or using auxiliaries not associated with aligners (Mini-screws, palate expander, elastics...).
Comparaison	The virtual model built using simulation software, representing the ideal outcome.	Absence of data from the virtual setup model
Outcome	The amount of transversal movements achieved versus those programmed (in mm or degrees) and the degree of arch expansion precision. Factors influencing the predictability of expansion (use of attachments, wear time, materials, etc.).	Other results.
Study design	Systematic review (with or without meta-analysis), Randomized or non-randomized controlled trial, Cohort study (retrospective or prospective)	Non-original article, Narrative review, Letter to the editor, Case report, Case series, Expert opinion

1.3 Information Sources and Search:

Two reviewers independently conducted a comprehensive search using a combination of controlled vocabulary (MeSH) and free text terms. PubMed, Cochrane Library and ScienceDirect were searched from January 2014 to august 2024 (period of ten years). Other than publication date, the search restrictions included only English and French articles as well as full text and references availability. MeSH keywords were selected and combined with Boolean operators AND/OR to obtain the following search equation used on the different electronic databases:

orthodontic* AND (clear aligners OR aligners) AND (predictability OR efficiency OR efficacy) AND tooth movement

1.4 Study Selection:

The process of selecting studies was conducted independently and in duplicate. All pertinent articles were imported into Zotero, a bibliography generator. Initially, duplicate articles were eliminated. Subsequently, titles and abstracts were scrutinized for eligibility. Full-text reports were consulted for articles that appeared to meet the inclusion criteria. Ultimately, relevant articles were subject to comprehensive analysis. Disagreements regarding inclusion were resolved by discussion between the two authors.

1.5 Data Collection Process and Items:

Data from the chosen articles for this study were extracted using a predefined standardized form by two independent reviewers. The collected information included author, year, number of participants, intervention, outcomes, and author conclusions. In cases of doubt or disagreement between the two reviewers, resolution was achieved through discussion.

1.6 Risk of Bias of Individual Studies:

The assessment of the risk of bias (RoB) of the included studies was performed by several tools depending on the type of each study:

*** The AMSTAR 2 test:**

(AMSTAR revised), was used to assess the quality of systematic reviews, as well as the search strategy, presentation of results, bias, sources of conflicts of interest and funding and the bias of the authors. This assessment grid was found to be reliable, valid, precise and easy to use [1]. It consists of a series of 16 questions with 3 possible answers: “Yes”, “Partial yes” and “No”. If the systematic review is not accompanied by a meta-

analysis, then we write "No meta-analysis". For the calculation of the total score, one point is assigned to each "Yes" response, half a point is assigned to each "Partial Yes" response, and no points are assigned to the "No" and "No meta-analysis" responses. For each study, the number of points obtained is transformed into a grade A, B or C, according to the protocol described below:

- Grade A: 11 to 16 points out of 16: high quality study.
- Grade B: 7 to 10 points out of 16: study of average quality.
- Grade C: 0 to 6 points out of 16: low quality study.

*** The NHLBI, NIH quality assessment tool:**

this is a tool developed by the NIH (National Institutes of Health) [2] and used in our review to assess the methodological quality of cohort studies and case-control studies with control group. Each type of study has a very specific scale to assess its risk of bias. For cohort studies, the scale is made up of 14 questions to which 3 answers are possible: "Yes", "No" or "Unsure". A "yes" response indicates that the criterion is met and a point is thus awarded. For the answers "No" and "Unsure" no points are awarded. The total score is calculated as follows:

- High quality study: 12 to 14 points out of 14.
- Average quality study: 8 to 11 points out of 14.
- Low quality study: 0 to 7 points out of 14.

2. RESULTS

3.1 Study Selection:

The results of the electronic search and the subsequent article selection process were visualized in the PRISMA flow diagram, aligning with PRISMA guidelines. Initially, 1299 studies were identified through both database and manual searches. Following the elimination of duplicates, 1245 studies persisted, and only 43 advanced beyond the stage of title and abstract screening. Ultimately, 9 articles were included in the final selection, as depicted in the PRISMA flow diagram (Figure 1).

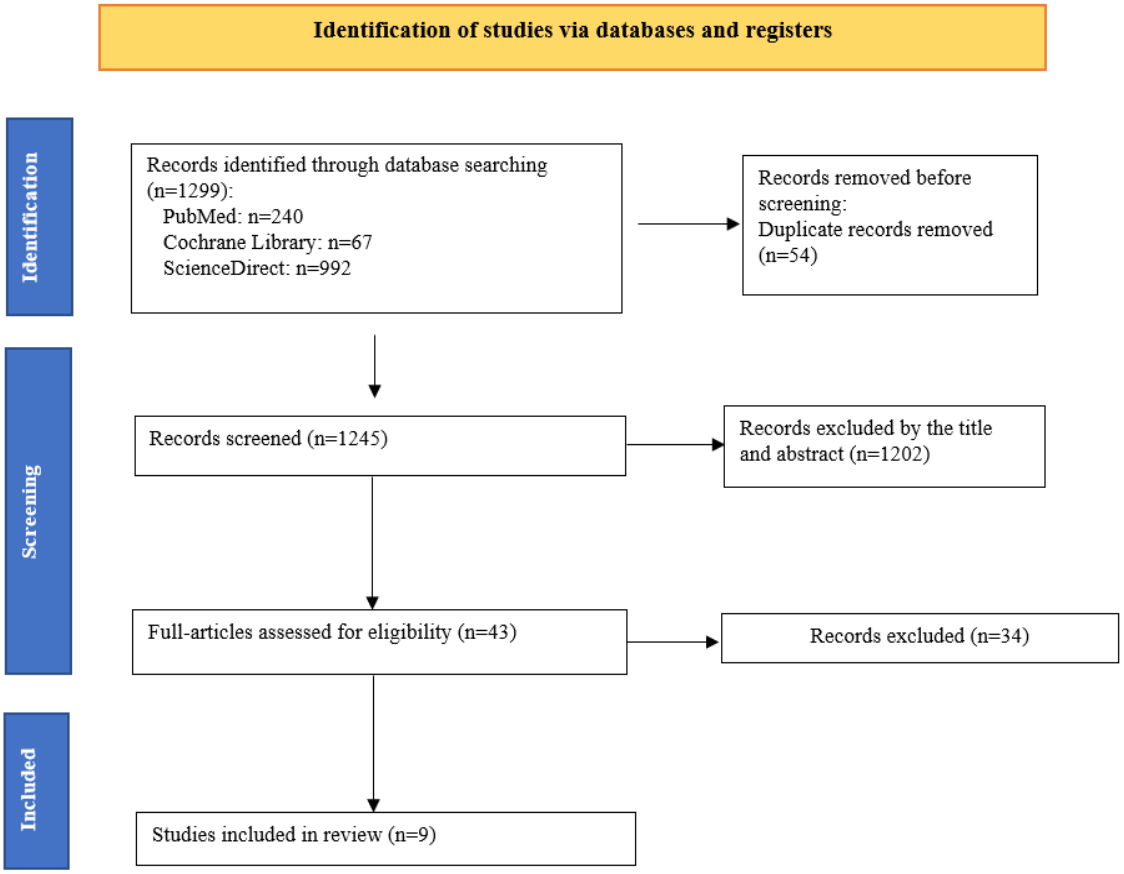

Fig-1: Flow chart according to the PRISMA statement

3.2 Study Characteristics:

9 relevant publications were identified as eligible according to the predefined inclusion criteria for this review: 2 articles were systematic reviews and 7 were cohort studies (2 retrospective and 5 prospective). Studies were collected with a publication date limited to 10 years, from 2014 to 2024.

3.3 Data Extraction and Synthesis

The 9 articles included in this systematic review and the data extracted from each study are shown in Table 2.

Table 2: Overview of included studies

Authors and Collaborators	Year	Study Design	Participants	Intervention	Primary Outcomes	Conclusion
Aikaterini Papadimitriou (3)	2018	Systematic review	22 studies; mean age 30.	Global review of movement accuracy using Invisalign aligners	Sufficient for anterior crowding. Insufficient for posterior expansion	Invisalign can treat simple non-extraction cases faster than fixed appliances; limited in controlling tooth axes and occlusal seating[1].
Ning Zhou (4)	2020	Prospective cohort study	20 adult patients.	Evaluation of maxillary expansion efficacy.	Crown Expansion Predictability: Canines (79.75%), 1st premolars (76.10%), 2nd premolars (73.27%), and 1st molars (68.31%)[10]. Translation Efficacy: 36.35 ± 29.32% for the 1st maxillary molar.	Maxillary expansion is primarily due to tipping. It is necessary to pre-program sufficient buccal root torque to improve bodily movement efficacy.
Vincenzo D'Antò (5)	2023	Prospective cohort study	30 patients; Ordoline aligners.	Analysis of expansion accuracy at cuspid and gingival levels.	Total Accuracy: 67% (upper) and 64% (lower). Highest Accuracy: Canine cuspids (83% upper, 79% lower). Lowest Accuracy: 1st molar gingival level (55% upper, 57% lower)[16].	Expansion is mainly due to crown tipping rather than translation; regular monitoring and over-expansion are recommended.
Gabriella Galluccio (6)	2023	Prospective cohort study	28 patients; Smart-Track material.	Transversal expansion accuracy without auxiliaries.	Global Accuracy: 70.88%. Cuspid level accuracy: 70–82%. Gingival level accuracy: ~50%[21]. Most precise: 1st premolar inter-cuspid (93.53%). Least precise: canine gingival level (43%).	Movement is predominantly tipping rather than translation.
Songyang Ma (7)	2023	Systematic review	15 trials; adult patients.	Review of Invisalign expansion efficacy and ClinCheck predictability.	Significant expansion achieved, especially in premolars; less effective for canines and 2nd molars. Efficacy decreased from front to back in the maxilla.	Efficacy is maximal in the premolar region. Overcorrection should be planned. SmartTrack material provides good efficacy.

Authors and Collaborators	Year	Study Design	Participants	Intervention	Primary Outcomes	Conclusion
Ana Sofia Rocha (8)	2023	Retrospective cohort study	75 participants; age 11-49.	Expansion predictability in both arches.	Predictability: 54.75% to 113% (maxilla) and 95.9% to 134% (mandible). 100% accuracy at lower premolars.	Aligners allow effective expansion in both arches, primarily in the premolars. The movement is generally predictable despite some inaccuracies.
Luis Huanca Ghislanzoni (9)	2024	Prospective cohort study	21 Caucasian subjects (Invisalign Lite).	28-week study on expansion and angular movements.	Expansion is precise, sometimes over-expressed at molars.	Invisalign Lite predicts linear expansion effectively.
Raquel Bueno MEDEIROS (10)	2024	Retrospective cohort study	65 patients; EX30 vs. SmartTrack materials.	Comparison of expansion accuracy between materials.	Overall Accuracy: EX30® (37-38%); SmartTrack® (56.62-68.72%)[47]. Most Precise: EX30® (maxillary 1st premolar 55.7%); SmartTrack® (mandibular 1st molar 83.3%).	No statistically significant difference found between materials, though SmartTrack showed higher overall accuracy. torque and overcorrection are recommended.
Marco Migliorati (11)	2024	Prospective cohort study	17 patients; 3D printed aligners.	Efficacy of in-office printed aligners.	Transversal dimension accuracy: 99.6%.	3D printed aligners are a viable alternative for mild crowding with high transverse precision.

3.4 Risk of Bias in Included Studies:

➢ **Systematic reviews:**

Using AMSTAR 2 test, 1 study presented a low risk of bias (Grade A), 1 study was classified as moderately at risk of bias (Grade B) while 0 studies were assessed as low-quality reviews (Table 3).

➢ **Cohort studies:**

Using the NHLBI, NIH tool, 2 cohort studies were judged to be of high quality and 5 were rated as of moderate quality (Table 4).

Table 3: Risk of bias assessment according to AMSTAR 2.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Grade
Papadimitriou et al	Y	PY	Y	Y	Y	Y	N	Y	Y	N	NM	NM	Y	Y	NM	N	B
Ma et al	Y	Y	Y	Y	Y	Y	PY	Y	Y	N	NM	NM	Y	Y	NM	Y	A

Y: Yes ; PY: Partially Yes ; N: No ; NM: No Meta-analysis.

Table 4: Risk of bias assessment according to NHLBI, NIH.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Quality
N. Zhou	Y	Y	U	Y	N	Y	Y	Y	Y	Y	U	Y	Y	Y	**Moderate**
V. D'Antò	Y	Y	U	Y	Y	Y	Y	U	Y	Y	U	U	Y	Y	**Moderate**
G. Galluccio	Y	Y	U	Y	Y	Y	Y	U	Y	Y	U	U	Y	Y	**Moderate**
A. Rocha	Y	Y	Y	Y	N	Y	Y	U	Y	Y	U	Y	Y	Y	**Moderate**
L. Ghislanzoni	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	**High**
R. MEDEIROS	Y	Y	U	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**High**
M. Migliorati	Y	Y	U	Y	N	Y	Y	Y	Y	U	Y	Y	Y	Y	**Moderate**

Y: Yes; N: No; U: Uncertain.

3.5 Certainty Assessment:

The level of scientific evidence is assigned to each of the included studies according to the criteria outlined by the Oxford Center for Evidence-based Medicine [24] and presented in Table 5. All of the included articles were of grade B recommendation. Consequently, conclusions of a moderate level of evidence could be drawn from the review process.

Table 5: level of scientific evidence

Reference	Level of evidence	Grade of recommendation
[3]	2a	B
[4]	2b	B
[5]	2b	B
[6]	2b	B
[7]	2a	B
[8]	2b	B
[9]	2b	B
[10]	2b	B
[11]	2b	B

4. DISCUSSION

4.1 Summary of Evidence:

Expansion is a complex movement that combines translation and buccal tipping of the lateral segments, allowing the gain of space required for the management of crowding. It has been reported that expansion achieved with aligners should range between 2 and 4 mm [12]. Ali *et al.,*[13] recommend limiting expansion to 2–3 mm per quadrant in order to minimize the risk of gingival recession.

Papadimitriou *et al.,*[3] stated that the accuracy of movements is insufficient for maxillary posterior tooth expansion, but remains adequate to manage mild to moderate crowding without extraction and without significant changes in mandibular incisor position/inclination (crowding < 6 mm). Zhou *et al.,*[4] investigated the accuracy of maxillary expansion by measuring intercuspid distances at the level of the canines, first premolars, second premolars, and first molars. They reported decreasing predictability from anterior to posterior: 79.75% for the canine, 76.10% for the first premolar, 73.27% for the second premolar, and 68.31% for the first molar, confirming the observations of Houle *et al.,*[15]. This reduction in efficiency may be explained by root morphology, cortical bone thickness, greater occlusal load in the posterior region, soft-tissue resistance, and reduced mechanical capacity of the aligner in the posterior part of the arch. For the first molar, translational expansion reached only 36.35% (± 29.32%) accuracy, with a root-to-crown movement ratio of 2:5, indicating that the expansion achieved was mainly due to tipping. The addition of preprogrammed negative torque in ClinCheck is therefore recommended [7].

D'Antò *et al.,* (5) reported an accuracy of 57–79% in the mandible and 54–83% in the maxilla, with the best results at the canine cusps (79% in the mandible, 83% in the maxilla) and the lowest at the gingival margins of the first molars (57% and 55%, respectively). The higher predictability at the cuspal level is explained by the coronal tipping induced by the aligner. Movement of canines and premolars is generally easier, as they are aligned on a straight line without occlusal interferences. However, canines are often less accurate than premolars because they lie on a circular arc and are therefore more influenced by the configuration of the anterior teeth. Anatomical limitations of the mandible, its greater mineralization, and increased occlusal stability may limit the success of mandibular expansion [16]. Similar to Zhou *et al.,*[4], when the planned expansion relies mainly on tipping, high predictability is observed, with an accuracy of 83.6%. Conversely, when root-buccal torque is prescribed, movement predictability decreases markedly. Galluccio *et al.,*[6] reported a mean accuracy of maxillary expansion of 70.88%, with higher predictability at the first premolar (93.53%) and lower at the first molar (70.55%). Expansion was also greater in the intermolar region than in the intercanine region, with mean values of 55% at the intermolar gingival level and 43% at the intercanine gingival level. Rocha *et al.,*[8] reported a wider predictability range, from 54.75% to 113% in the maxilla and from 95.9% to 134% in the mandible. The greatest expansions were observed at the first and second premolars in both arches, in agreement with the previous study. In the maxilla, overexpansion was noted at the first molar and underexpansion at the canine. In the mandible, only the first molar showed an expansion significantly greater than planned. These discrepancies did not result from planned bodily movement but rather from uncontrolled tipping of the teeth. These findings were confirmed by Ghislanzoni *et al.,*[9], who also reported that molar expansion is sometimes overexpressed. Indeed, they observed a statistically significant expansion at the maxillary and mandibular first molars, even though no expansion had initially been planned.

Medeiros *et al.,*[10] compared the predictability of dental expansion achieved with EX30® (PETG) and SmartTrack® (PU). Overall accuracy was 56.62% in the maxilla and 68.72% in the mandible with SmartTrack®, compared with 37% and 38%, respectively, with EX30®. The most accurate regions differed: the

maxillary second premolar (76%) and the mandibular first molar (83.3%) for SmartTrack®, versus the maxillary first premolar (55.7%) and the mandibular canine (69.9%) for EX30®. The poorest performance concerned the gingival margin of the canines (25% for EX30® and 40.8% for SmartTrack®). The pilot study by Migliorati *et al.,*[11] reported an expansion accuracy of 99.6% with printed aligners; however, it should be noted that only small expansions were required to resolve crowding.

Factors influencing predictability

- **Materials**

The study by Medeiros *et al.,*[10] showed no statistically significant difference between EX30® and SmartTrack® in terms of expansion accuracy, with significant discrepancies between planned and achieved movements for both materials. In the EX30® group, overall accuracy was 37% in the maxillary arch and 38% in the mandibular arch, in agreement with the results reported by Kravitz *et al.,*[14] and Solano-Mendoza *et al.,*[18]. The SmartTrack® group showed higher accuracy rates (56.62% in the maxilla and 68.72% in the mandible). Align Technology attributes this improvement to the SmartTrack® material [22]. However, the authors consider this interpretation to be misleading, as it does not account for the effect of the new G8 protocols [17]: a 0.5 mm threshold to activate expansion, balanced posterior forces, automatic root torque, and optimized attachments. Software sequencing has also evolved, prioritizing expansion in the order of movements. Therefore, any comparison between materials should be made with caution due to inherent sampling biases. Furthermore, the study evaluated the accuracy of transverse movements by comparing two landmarks: the cusp tip (reflecting coronal tipping) and the gingival margin (indicating radicular or bodily movement). The results showed that, for both materials, tipping movements were significantly more accurate than translational movements. These data confirm the general tendency of aligners to produce more tipping than bodily movement, and that planned bodily movements are often overestimated in ClinCheck® [4, 15, 21, 23]. The findings are consistent with previous studies (4, 19, 20) and suggest that overcorrection is necessary in all cases of transverse expansion, regardless of the material used. The addition of posterior crown-lingual torque is recommended to limit tipping movements.

4.2 Limitations:

This review presents several limitations that should be acknowledged. One of the main limitations lies in the heterogeneity of the included studies, which differ in their protocols, thereby making direct comparisons difficult and limiting the feasibility of robust meta-analyses. The overall level of evidence remains moderate, as the majority of the included studies are retrospective or prospective cohort studies, with a non-negligible risk of methodological bias. Moreover, certain complex movements and factors influencing predictability remain insufficiently investigated, which restricts the scope and generalizability of the conclusions.

In addition, the article selection was limited to studies available online and accessible free of charge, as well as those published or translated into French or English. This approach may have led to the exclusion of relevant scientific studies published in other languages, potentially introducing a selection bias. However, in the field of medical sciences, research is generally more likely to be translated into English when it reports significant findings, which may partially mitigate this limitation. Furthermore, the review was restricted to studies published within the last ten years, which may also represent an additional source of selection bias.

5. CONCLUSION

Dental expansion with aligners is generally effective for space creation and management of mild to moderate crowding. Predictability decreases from anterior teeth toward the molars, mainly due to anatomical and mechanical factors that limit effectiveness in the posterior part of the arch, with maximum predictability at the premolar level. Aligners tend to induce primarily crown tipping rather than bodily movement, which often requires programmed overcorrection with appropriate negative torque to improve outcomes. The thermoplastic materials used (SmartTrack® and EX30®) do not provide statistically significant differences in accuracy, although SmartTrack® generally shows better performance. Accuracy is also influenced by the location of the movement and by the anatomical and occlusal configuration of the arch.

Nevertheless, the current lack of randomized clinical trials does not allow definitive conclusions to be drawn regarding the true predictability of arch expansion movements and the factors influencing them. Additional clinical and experimental research therefore remains essential to strengthen these findings.

Declarations Section:
Ethics approval and consent to participate: Not applicable.
Consent for publication: Not applicable.
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Authors' contributions:
MAB: study conception and design and data collection
RG: analysis and interpretation of results
DI and WA: draft manuscript preparation
ST and AA: revised the text
All authors reviewed the results and approved the final version of the manuscript

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