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Risk Factors of Relapse in Orthodontics: A Systematic Review

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Abstract

Aim: This systematic review aimed to identify and synthesize the risk factors associated with orthodontic relapse. **Methods:** A comprehensive electronic search was conducted in PubMed, MEDLINE, Embase, Cochrane Library, Google Scholar, Scopus, and Web of Science to address the research question. The methodological quality of the selected articles was assessed using STROBE-based criteria. **Results:** The analysis of the eighteen studies included, identified several major risk factors associated with orthodontic relapse. These factors were categorized into general and local factors. General factors included age and gender. Local factors comprised treatment mechanics, therapeutic approach, quality of orthodontic finishing, extraction protocol, functional environment and its rehabilitation, presence of third molars, retention protocol, facial type, initial crowding, incisor inclination, curve of Spee, and presence of diastema. **Conclusion:** Multiple general and local factors contribute to orthodontic relapse. A comprehensive understanding of these determinants may assist clinicians in optimizing treatment planning, retention strategies, and long-term stability.

Subject Areas

Dentistry

Keywords

Recurrences, Relapse, Risk Factors, Orthodontics, Corrective Orthodontics, Malocclusion

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1. Introduction

One of the primary objectives of orthodontic treatment is not only to correct dental and skeletal discrepancies but also to ensure the long-term stability of these corrections, as achieving an ideal occlusal balance is meaningful only if the results are maintained over time [1].

However, long-term studies have shown that relapse occurs in approximately 70% of cases, making the maintenance of treatment outcomes particularly challenging [2]. According to other authors, only 10% of cases maintained satisfactory alignment after 20 years, compared with 30% to 50% of cases after 10 years [3]. These findings emphasize the importance of informing patients about the realistic long-term expectations of orthodontic treatment. They also highlight the inherent instability of orthodontic outcomes and the limited understanding of the mechanisms underlying post-treatment relapse [3].

In this context, relapse—defined as "the return, following correction, of the original features of the malocclusion" by the British Standards Institute (BSI) in 1983 [4], and more recently described as "unfavorable changes from the final tooth position at the end of orthodontic treatment" [4]—remains a major concern in orthodontic practice.

Multiple risk factors have been associated with the recurrence of malocclusion. It is therefore essential for clinicians to identify and understand these determinants to optimize treatment planning and enhance long-term stability. Factors such as patient compliance, age, growth pattern, type of malocclusion, and retention protocol must be carefully evaluated and clearly discussed with patients [5].

The present systematic review aims to identify and synthesize the principal risk factors associated with orthodontic relapse, thereby providing evidence-based insights to support clinical decision-making and improve long-term treatment stability.

2. Materials & Methods

2.1. Protocol and Registration

The protocol for this systematic review was registered on 5 March 2025 in the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) under the registration number INPLASY202530019.

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6].

2.2. Search Strategy

2.2.1. Identification of Electronic Databases

A systematic literature search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6] to identify relevant studies investigating risk factors associated with orthodontic relapse.

The electronic search was performed between September 2024 and January

2026. The following databases were systematically explored: MEDLINE, MEDLINE In-Process, the Cochrane Central Register of Controlled Trials (CENTRAL), EMBASE, and the Cochrane Library.

2.2.2. Keywords and Boolean Equations

A search strategy was developed using Boolean operators to combine predefined keywords into structured search equations. These equations were designed to be interpreted by each database search engine in order to retrieve relevant articles.

The development of the search equations followed three sequential steps:

1) Identification of potential keywords relevant to the research question;

2) Combination of these keywords using Boolean operators (AND, OR) and additional database-specific features such as wildcards and quotation marks;

3) Iterative testing and refinement of the search equations to achieve optimal sensitivity while minimizing irrelevant results (noise).

The first step consisted of identifying candidate keywords representing the main concepts of the research topic. Five keywords were defined:

- Risk Factors
- Recurrences
- Relapse
- Orthodontics, corrective
- Malocclusion

The next step involved combining these keywords and their synonyms into structured search equations. Both free-text terms and controlled vocabulary (e.g., MeSH terms in PubMed) were used whenever available.

Different equations were tested for each database to maximize sensitivity and reduce the risk of omitting relevant studies. The objective of the search strategy was to minimize irrelevant references while ensuring comprehensive identification of eligible studies.

The following Boolean equations were retained:

- ((orthodontics, corrective[MeSH Terms]) AND (recurrences[MeSH Terms])) AND (risk factors[MeSH Terms])
- ((orthodontics, corrective[MeSH Major Topic]) AND ((relapse[MeSH Terms])) OR (recurrences[MeSH Terms]))
- ((((recurrences[MeSH Terms]) OR (relapse[MeSH Terms]))) AND (orthodontics, corrective[MeSH Major Topic])) AND (risk factors[MeSH Terms])
- (orthodontics, corrective[MeSH Terms]) AND (recurrences[MeSH Terms])

2.2.3. The Search Procedure

The search strategy was structured according to the PICOS framework (Population, Intervention/Indicator, Comparison, Outcome and Study Design), as summarized in Table 1.

Research question:

What are the potential risk factors associated with relapse following orthodontic treatment?

The electronic search yielded a total of 106,258 records. After the removal of

Table 1. Description of the PICO elements.

PICOS Component	Description
Population	Patients who received orthodontic treatment
Intervention/Indicator	Identification of potential risk factors for orthodontic relapse
Comparison	Control group
Outcomes	Occurrence and identification of potential risk factors for relapse after orthodontic treatment
Study Design	Retrospective studies, cohort studies, case-control studies, and randomized controlled trials (RCTs)

duplicates and the application of predefined filters (publication date and type of article), 52,988 records remained.

Titles and abstracts were then screened to exclude irrelevant studies that did not meet the inclusion criteria. In cases of uncertainty, studies were retained for full-text assessment to determine eligibility.

2.3. Criteria for Study Selection

2.3.1. Inclusion Criteria

Studies meeting the following criteria were included:

- Studies investigating risk factors associated with orthodontic relapse following corrective orthodontic treatment.
- Articles addressing relapse in the transverse, vertical, and anteroposterior dimensions, as well as across different skeletal classes in orthodontics.
- Observational studies, including retrospective, cohort, and case-control designs.
- Articles published between 2016 and 2026.

2.3.2. Exclusion Criteria

The following studies were excluded:

- Case reports, expert opinions, letters to the editor, commentaries, and editorials.
- Articles that did not meet the objectives of the review after screening of the title, abstract, and full text.
- Articles published in languages other than French or English.
- Studies investigating relapse following orthopedic or orthognathic surgical treatment.
- Studies evaluating external factors influencing orthodontic relapse, such as periodontal conditions.

2.4. Selection of Studies

After applying the predefined inclusion and exclusion criteria, 18 studies were retained for qualitative synthesis and served as the basis for the systematic analysis. The methodological quality of the included studies was assessed using the

STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist [7]. The STROBE Statement is a reporting guideline designed to improve the transparency and completeness of reporting in observational studies, including cohort, case-control, and cross-sectional designs. It provides a structured checklist that addresses key methodological components necessary for clear and comprehensive reporting. The STROBE checklist consists of 22 main items encompassing essential elements of study design, methodology, analysis, and interpretation [7].

3. Results

A total of 18 studies were included in the final qualitative synthesis following the selection process (**Figure 1**). The identified risk factors associated with orthodontic relapse were categorized into general and local factors. General factors included age and gender. Local factors comprised treatment-related and dentofacial variables, including: the mechanics used, the therapeutic approach, the quality of orthodontic finishing, extraction protocol, functional environment and its rehabilitation, presence of third molars, type of retention protocol, facial type, initial crowding, incisor inclination, curve of Spee, and presence of diastema.

All included studies underwent structured data extraction, as detailed in **Table 2**. Methodological quality assessment was performed using the STROBE checklist, allowing evaluation of the completeness and transparency of reporting of the included studies. The detailed quality assessment is presented in **Table 3**.

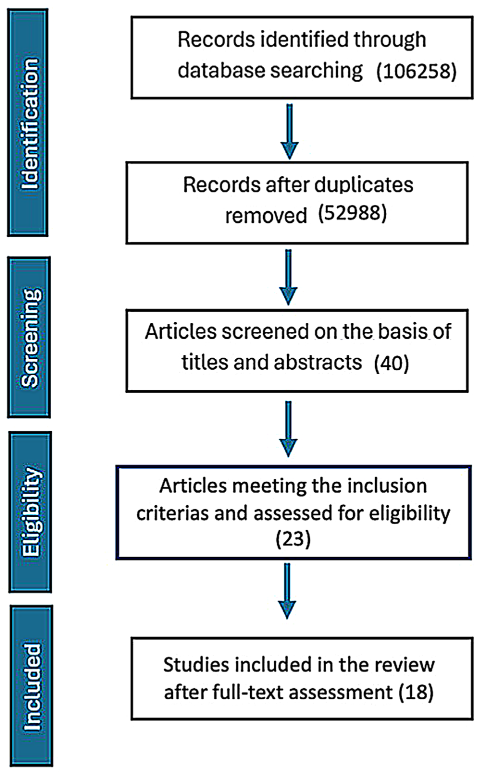

Figure 1. Flow chart for article selection.

Table 2. The general characteristics of selected studies.

Title	Author/ Year	Study Design	Means of Acquisition	Sample	Gender	Potential Risk Factors	Statistical Analysis	Main Findings/ Conclusion
Orthodontic treatment stability predictors: A retrospective longitudinal study [3]	Gonzalez-Gil de Bernabé *et al.*, 2016	Retrospective longitudinal study	Patient records, dental casts	70	46 F/24 M	Age at start, treatment length, retention duration, years without retention, gender, premolar extraction, presence of wisdom teeth, type of retainer	Odds ratios (ORs) with 95% CI	Overbite and lower anterior segment alignment deteriorated most. Fixed retainers protective; years without retention increased mandibular alignment instability.
Evaluation of post-treatment stability after orthodontic treatment in mixed and permanent dentitions [8]	Oh *et al.*, 2016	Retrospective longitudinal study	Clinical exams, cephalometric radiographs, dental casts	42	30 F/12 M	Retainer use, natural growth	Paired/unpaired t-tests; ANOVA; regression; Pearson correlation	Mandibular incisor alignment maintained with fixed retainers. Age-related relapse mimicked untreated subjects. Arch width/depth decreased slightly (~1 mm).
Evaluation of Outcome of Orthodontic Treatment in Context to Post-treatment Stability [9]	Kanuru *et al.*, 2016	Retrospective analysis	Dental casts, clinical records	100 (Angle Class I)	54 M/46 F	Initial malocclusion severity, retention duration, posttreatment follow-up, relapse tendency	Descriptive statistics; Pearson correlation; $p < 0.05$	Relapse occurred despite ideal treatment → highlights importance of long-term retention.
Relapse of anterior crowding 3 and 33 years postretention [10]	Freitas *et al.*, 2017	Retrospective longitudinal study	Dental casts, clinical records, occlusal indices	28 (4 premolar extractions)	9 M/19 F	Aging, posttreatment duration, mandibular anterior crowding, initial malocclusion type, limited fixed retention	Descriptive stats; Kolmogorov–Smirnov; repeated-measures ANOVA; Tukey post-hoc; t-tests; chi-square	Maxillary anterior crowding stable long-term; mandibular anterior crowding relapsed continuously → lifelong retention required.
Stability of orthodontic treatment outcome in relation to retention status: An 8-year follow-up [11]	Steinnes *et al.*, 2017	Retrospective longitudinal observational follow-up	Clinical exams, dental casts, patient records, questionnaires	67	43 F/24 M	Retainer absence/loss, posttreatment duration, aging, mandibular anterior crowding, retention type, retainer failure/non-compliance	Descriptive stats; t-test; chi-square; Wilcoxon; ICC	Occlusal relapse occurs despite long-term fixed retainers. Fixed mandibular retainers effective; maxillary retainers less influential.
Comparison of anterior crowding re-	Mahmoudzadeh	Retrospective cohort	Clinical exams, dental	120	99 F/21 M	Extraction vs nonextraction, in-	Paired t-test; ANOVA;	Anterior crowding may recur post-treat-

lapse tendency in patients treated with incisor extraction, premolar extraction, and nonextraction treatment [2]	*et al.*, 2018	study	casts			itial incisor crowding	Tukey; Pearson & Spearman	ment; original crowding level predicts relapse.
Teeth movement 12 years after orthodontic treatment with and without retainer [12]	Abdulraheem *et al.*, 2019	Retrospective longitudinal study	Linear measurements via digital caliper (TDI)	92 (groups by retainer use)	–	Retainer use, natural growth	Kolmogorov–Smirnov; t-tests; chi-square	25% of incisor misplacement due to growth, not relapse. TDI index distinguishes relapse from natural changes.
Evaluation of the Influence of Mandibular Third Molars on Mandibular Anterior Crowding Relapse [13]	Cotrin *et al.*, 2019	Retrospective cohort study	Dental casts, panoramic radiographs	60	30 F/30 M	Presence/absence of mandibular third molars	t-tests; chi-square; Kolmogorov–Smirnov	Mandibular anterior crowding relapse unaffected by third molars.
Long-term stability of curve of Spee levelled with continuous archwires [14]	Rozzi *et al.*, 2019	Retrospective longitudinal observational	Digital dental casts, lateral cephalograms	60 nonextraction patients; mean age 19.8 ± 1.4 y	32 F/28 M	Skeletal vertical pattern, dental movement, incisor inclination, overbite relapse, growth, muscular forces	Kolmogorov–Smirnov; ANOVA; paired t-test; Bland–Altman; regression	Stability influenced by vertical skeletal pattern: low-angle → greater relapse; high-angle → better stability.
Factors associated with stability of compensatory orthodontic treatment of Class III malocclusion [15]	Marco Nassar Blagitz *et al.*, 2020	Retrospective longitudinal study	Clinical exams, cephalometric analysis, dental casts	36	21 M/15 F	Mandibular premolar extraction, treatment finishing, maxillary incisor inclination	Multivariate Poisson regression	Extractions and optimal occlusion reduced relapse; higher initial maxillary incisor inclination increased relapse risk.
Relapse 1 week after bracket removal: a 3D superimpositional analysis [16]	Papagiannis *et al.*, 2020	Prospective cohort study	3D superimposition of dental casts	38	19 M/19 F	No retention post-debonding	Shapiro-Wilk test; non-parametric statistics	Maxillary arch showed relapse within 1 week; first molars reverted; canines rotated toward pre-treatment positions.
Development of a novel orthodontic alignment index & effect of residual overjet [17]	Devine *et al.*, 2022	Retrospective cohort study	Clinical exams, dental casts	82	–	Residual overjet	Intraclass correlation coefficient	Amount of overjet at treatment end had no effect on relapse severity.
Mandibular morphometric analysis in open bite early treatment relapse	Paoloni *et al.*, 2022	Retrospective longitudinal study	Clinical exams, dental casts, cephalometric	23	7 M/16 F	Initial deep bite severity, treatment technique	Paired t-test; Procrustes analysis	In growing open bite subjects, early treatment relapse was significant; skeletal char-

subjects [18]			radiographs					acteristics were potential risk factors.
Does quality of orthodontic treatment outcome influence post-treatment stability? [19]	Gera *et al.*, 2022	Retrospective longitudinal observational	Digital dental models, clinical retention records	287	101 M/186 F	Treatment quality (PAR, LII), overjet, correction amount, aging, retainer failure	Descriptive; linear & ordinal regression; mixed models; Bonferroni correction; ICC	Short-term stability very good with fixed retainers; high-quality outcomes predicted better stability.
Factors Influencing Post-Treatment Relapse in Diastema Closure [20]	Mei *et al.*, 2022	Retrospective cross-sectional observational study	Orthodontic records, recall exams, panoramic radiographs	40	10 M/30 F	Retainer type, retention absence/interruption, aberrant labial frenum, incisor proclination, growth	ICC; descriptive; chi-square; Mann–Whitney U; Kruskal–Wallis	Diastema closure showed high stability (>80%); relapse not significantly associated with gender or retainer type.
Long-Term Stability of Curve of Spee Depth [21]	Busenhart *et al.*, 2024	Retrospective longitudinal study	Clinical exams, dental casts	157	89 F/68 M	Extraction vs non-extraction, initial curve depth	Shapiro-Wilk; t-tests	Mild/deep curves straightened; seven years post-treatment, curves remained stable. Premolar extractions associated with lower relapse.
Long-term stability of dental arch widths after extraction and non-extraction orthodontic treatment [22]	Giannakopoulou *et al.*, 2025	Retrospective longitudinal cohort study	Digital 3D measurements of intercanine, interpremolar, intermolar widths	104	62 F/42 M	Transverse expansion magnitude, extraction vs non-extraction, follow-up duration, sex differences, aging	Descriptive; t-tests; Wilcoxon; independent t-tests; Mann–Whitney; chi-square; multivariable regression; Bland–Altman	Modest transverse expansion stable long-term; greater expansion → higher relapse; extraction itself not a major factor.
Long-term relapse of anterior teeth with and without premolar extractions [23]	Aras *et al.*, 2025	Retrospective longitudinal cohort study	3D surface mesh, conventional 2D measurements, long-term postretention (≥10 y)	62	NG: 16 F/13 M; EG: 20 F/13 M	Extraction vs non-extraction, arch expansion, postretention duration, mandibular lingual incisor movement, initial incisor irregularity	Shapiro-Wilk; Levene; chi-square; independent t-tests; MANCOVA; ICC; Bland–Altman	Long-term anterior relapse clinically small in both groups. 3D analysis showed comparable stability; non-extraction group showed slightly more mandibular relapse.

Methodological Quality Assessment

The methodological quality assessment performed using the STROBE checklist (Table 3) revealed an overall satisfactory level of reporting among the included studies [2] [3] [8]-[23]. The majority of the selected articles [2] [3] [8] [10]-[17]

Table 3. Quality assessment using the Strobe tool.

I	Studies	[3]	[8]	[9]	[10]	[11]	[2]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]
STROBE Item:	1-a	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1-b	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	6-a	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
	6-b	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1
	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	9	1	1	0	1	1	0	1	1	1	1	0	1	0	1	0	1	1	1
	10	1	0	0	1	0	1	0	1	1	0	1	0	1	0	1	0	0	1
	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	12-a	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0
	12-b	1	1	0	1	1	0	0	1	1	1	0	1	0	1	0	1	1	0
	12-c	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	1	1	0
	12-d	1	1	0	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0
	12-e	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	13-a	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	13-b	1	1	0	1	1	0	1	1	1	1	0	1	0	1	0	1	1	1
	13-c	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
	14-a	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	14-b	1	1	0	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0
	14-c	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	16-a	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	16-b	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1
	16-c	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	17	1	1	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1
	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	19	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	21	1	1	0	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1

Continued

22	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Total	30	31	18	32	31	25	30	31	32	15	26	30	23	31	23	30	31	31
Percent	88.2	91.2	52.94	94.1	91.2	73.5	88.2	91.2	94.1	44.11	76.5	88.2	67.6	91.2	67.6	88.2	91.2	91.2
Methodological quality grade	Good	Good	Average	Good	Good	Good	Good	Good	Good	Poor	Good	Good	Average	Good	Average	Good	Good	Good

[19] [21]-[23] were classified as having good methodological quality, with scores exceeding 85%, indicating adequate description of study design, participant selection, statistical analysis, and interpretation of results. A smaller number of studies demonstrated average quality [9] [18] [20], mainly due to incomplete reporting of potential sources of bias, confounding factors, or missing data management. One study [15] was categorized as having poor methodological quality, reflecting substantial deficiencies in transparency and reporting completeness.

4. Discussion

A systematic literature review was conducted to highlight the risk factors for orthodontic relapse.

By examining a wide variety of clinical studies, this study aimed to provide a thorough summary of the factors that can affect long-term treatment stability. The identified risk factors are examined in two main categories: general factors—such as age, gender, and genetic background—and local factors, including treatment mechanics, finishing quality, extraction choices, functional environment, and retention strategies.

Patient age at the start or end of orthodontic treatment has been studied as a potential factor for relapse, with mixed results. Gera *et al.* found that older age at treatment completion was associated with greater post-treatment alignment changes two years after debonding, despite fixed retainers [19]. Lang *et al.* identified a potentially optimal treatment window (9 - 12 years), with lower relapse rates, while treatment before 9 or between 13 and 17 years showed higher relapse, particularly for mandibular irregularity and overbite [24]. Conversely, several studies did not find a significant effect of age on post-treatment stability: Devine *et al.* [17], Papagiannis *et al.* [16], and Busenhart *et al.* [21] reported no association between baseline age and relapse, whether short- or long-term. Overall, these findings suggest that age may influence orthodontic stability in a non-linear way, but it does not consistently act as an independent predictor.

Regarding gender, evidence suggests that sex-related differences in post-orthodontic stability may exist, although findings are not entirely consistent. In multivariable analyses, Gera *et al.* [19], Devine *et al.* [17], and Busenhart *et al.* [21] found no significant effect of gender on alignment changes or curve of Spee relapse, and Giannakopoulou *et al.* reported similar stability in transverse arch width between males and females [22]. However, some studies indicate gender-specific relapse patterns over longer follow-up periods. Lang *et al.* observed more frequent relapses in males for most measures, especially irregularity indices and upper intercanine width, while overbite and mandibular intermolar relapse were greater in females ($p < 0.05$) [24]. Similarly, Zinad *et al.* reported gender-specific dentoalveolar changes: in untreated individuals, PAR scores increased in males during adolescence (12 - 22 years) and in females between 19 - 39 years, whereas in treated patients, late post-retention PAR increases (10 - 15 years) were significantly greater in females ($p = 0.007$), suggesting that part of female relapse may reflect normal maturational changes rather than treatment instability [25]. Overall, gender does not consistently act as an independent predictor of relapse, but physiological gender-specific dentoalveolar changes may modulate long-term stability, particularly for vertical and transverse occlusal parameters.

Facial type and skeletal pattern are important general determinants of post-orthodontic stability, particularly in cases with vertical discrepancies such as open bite and deep bite. Rozzi *et al.* demonstrated that patients with a hyperdivergent facial pattern experienced significantly greater relapse of the curve of Spee after leveling with continuous archwires compared with normodivergent subjects [14], highlighting the inherent instability associated with vertical facial types. Paoloni *et al.* further showed that specific mandibular morphologies were linked to higher relapse risk after early open-bite treatment [18], suggesting that such cases remain biologically unstable even after apparent correction. Similarly, Busenhart *et al.* reported that facial type remained a significant predictor of long-term curve of Spee changes, independent of treatment-related factors [21].

Although Lang *et al.* did not classify patients by facial type, their findings indicated that relapse patterns varied with developmental stage and growth characteristics at treatment onset, indirectly supporting the influence of skeletal maturation on stability [24]. Broader analyses also emphasize the vulnerability of vertical malocclusions: Chacón-Moreno *et al.* noted that open bite corrections are particularly prone to recurrence when underlying skeletal discrepancies persist [26], and Najjar *et al.* highlighted the roles of vertical growth pattern, mandibular rotation, and occlusal force imbalance in relapse of both open and deep bite cases [27]. Overall, hyperdivergent and open-bite facial types represent a significant intrinsic risk for orthodontic relapse. Unlike treatment mechanics or retention protocols, skeletal morphology is non-modifiable, limiting the long-term ability of dentoalveolar compensation to maintain correction. Patients with vertical skeletal discrepancies therefore require careful finishing and long-term retention strategies.

The functional environment, closely linked to facial type and skeletal pattern, is a key determinant of post-orthodontic stability, especially in malocclusions with vertical discrepancies. Evidence from open-bite studies indicates that persistent functional disturbances can undermine long-term outcomes. Paoloni *et al.* found that relapse after early open-bite treatment was strongly associated with unfavorable mandibular morphology and ongoing growth tendencies, reflecting the influence of functional factors such as mandibular posture and muscular balance [18]. Busenhart *et al.* similarly reported that post-treatment occlusal changes may continue over time, highlighting the importance of neuromuscular adaptation and functional equilibrium for long-term stability [21].

Direct evidence on oral function comes from Long and Lee, who emphasized that balanced perioral musculature and tongue posture are essential for maintaining dental alignment [28]. Untreated functional habits—including mouth breathing, low tongue posture, and atypical swallowing—contribute significantly to relapse [28]. Their analysis also showed that combining orthodontic treatment with orofacial myofunctional therapy significantly reduced relapse rates, particularly in anterior open-bite cases, compared with orthodontic treatment alone [28].

These findings align with Chacón-Moreno *et al.*, who noted that post-orthodontic instability is multifactorial and often influenced by growth-related changes and soft tissue pressures, even in patients with fixed retainers [29]. Fixed retention alone does not neutralize functional forces, and ongoing muscular imbalance may drive relapse and unwanted tooth movements. Collectively, this evidence indicates that failure to identify and rehabilitate dysfunctional oral habits is a major risk factor for recurrence. Functional rehabilitation—including airway management and orofacial myofunctional therapy when indicated—should be considered a core component of orthodontic treatment planning and long-term retention strategies rather than a secondary measure [29].

Initial crowding severity is a consistently identified and reproducible predictor of post-orthodontic relapse [2]. Mahmoudzadeh *et al.* reported that greater pre-treatment mandibular crowding was significantly associated with increased anterior alignment relapse, regardless of extraction protocol [2], and Kanuru *et al.* similarly found that higher baseline irregularity index values predicted greater post-treatment changes [9]. Aras *et al.*, in a large long-term cohort, confirmed that baseline anterior crowding remained a significant predictor of relapse in both extraction and non-extraction groups, even after multivariable adjustment [23], while Gera *et al.* showed that initial alignment quality strongly influenced subsequent stability [19]. Quantitative analyses further support this relationship: Lang *et al.* documented substantial relapse in both arches, particularly in mandibular irregularity, using Little's Irregularity Index [24], and Bezawada *et al.* found that mandibular crowding had the highest relapse rate (35%, $P = 0.015$), with greater initial malocclusion severity significantly increasing the odds of recurrence ($OR = 2.8$, $P = 0.004$) [30]. Overall, these findings indicate that the magnitude of pre-treatment crowding directly affects long-term stability. Greater initial displacement requires extensive dentoalveolar correction, increasing the biological tendency for teeth to return toward their original positions. The mandibular anterior region is particularly susceptible, likely due to anatomical constraints and ongoing maturational changes, highlighting the need for reinforced and prolonged retention strategies in cases of severe baseline crowding [31].

In contrast to the challenges posed by initial crowding, Midline diastema closure is inherently unstable. Mei and Jiang [20] and Morais *et al.* [32] reported substantial relapse rates, with lateral diastemas more stable. Greater initial diastema width, family history, and multiple anterior spaces further increase recurrence risk [33] [34]. Soft tissue and periodontal factors play major roles, highlighting the need for prolonged or permanent retention.

Incisor inclination (position) is a key mechanical determinant of post-treatment stability, particularly in cases requiring significant sagittal correction or anterior alignment changes [17]. Devine *et al.* reported that residual sagittal discrepancies and maxillary incisor position were associated with anterior alignment relapse [17], and Blagitz *et al.* observed that greater dentoalveolar compensation involving incisor inclination increased relapse risk [15]. Long-term studies [24] [31], consistently highlight that large therapeutic incisor movements may exceed the adaptive capacity of surrounding periodontal and muscular tissues, increasing the likelihood of relapse. Even in patients with fixed retainers, unwanted rotational and inclination changes can occur if incisors lie outside the neutral muscular zone [28]. Overall, careful torque control and maintenance of favorable interincisal angles are critical for long-term stability.

In addition to the influence of incisor inclination on anterior alignment stability, vertical occlusal parameters, particularly the curve of Spee, represent another critical aspect of long-term post-treatment stability. Correction and maintenance of the curve of Spee are particularly sensitive to vertical skeletal patterns [14]. Rozzi *et al.* demonstrated greater relapse in hyperdivergent patients compared with normodivergent individuals [14], and Busenhart *et al.* confirmed that skeletal pattern remains a significant covariate in long-term curve of Spee changes [21]. Lang *et al.* also observed vertical relapse influenced by age and retention duration [24], while broader reviews emphasize the vulnerability of deep bite and open bite corrections to recurrence [26] [27]. Vertical relapse reflects ongoing skeletal and dentoalveolar adaptation, necessitating careful vertical control and reinforced retention [27].

Treatment strategy influences long-term stability. Approaches relying on dentoalveolar compensation, incisor proclination, or camouflage mechanics are associated with higher relapse risk [15] [17] [19] [22]-[24]. Extraction versus non-extraction protocols do not consistently affect relapse magnitude; rather, treatment mechanics, baseline characteristics, and retention protocols play more significant roles [2] [13] [22] [24]. Individualized planning integrating skeletal diagnosis, biomechanical control, and realistic stability goals is therefore essential.

Orthodontic mechanics affect both immediate mechanical rebound and long-term dentoalveolar adaptation. Early relapse can occur within days due to viscoelastic tissue properties [16]. Aras *et al.* [23], and Lang *et al.* [24] showed that mechanics governing incisor displacement, transverse expansion, and vertical control significantly influence long-term stability. Controlled force application, careful torque management, and precision in biomechanical execution are critical.

High-quality finishing reduces short-term relapse but does not guarantee long-term stability. Devine *et al.* [17] and Gera *et al.* [19] reported that residual malalignment predicted instability, while Mecenas *et al.* [35] highlighted that vertical and sagittal relationships may outweigh finishing quality in determining long-term outcomes. Finishing must align with occlusal objectives, skeletal considerations, and retention strategy [35].

Retention remains the cornerstone of relapse prevention. Steinnes *et al.* [11] and Abdulraheem *et al.* [12] demonstrated that discontinuing retainers increases relapse, particularly in the mandibular anterior region. Gera *et al.* [19] confirmed retention type as an independent protective factor, and Littlewood *et al.* [36] emphasized that lifelong tooth movement occurs due to periodontal fiber reorganization, occlusal forces, soft tissue pressures, and age-related changes. Retention should be considered a long-term management strategy rather than a guarantee of permanent stability [36].

Current evidence indicates that third molars are not a significant independent factor in mandibular anterior relapse.[37] Cotrin *et al.* [13], Zawawi and Melis [37], Lyros *et al.* [38], Cheng *et al.* [39], and long-term cohort studies [22]-[24] showed no consistent association between third molar status and relapse once growth, treatment mechanics, and retention are considered. Relapse is more strongly influenced by biological maturation, dentoalveolar adaptation, and retention compliance, rather than erupting third molars.

5. Conclusions

The aim of this review was to synthesize the current body of evidence concerning the determinants of post-orthodontic relapse and to distinguish between intrinsic and modifiable factors influencing long-term stability.

The literature consistently indicates that relapse is a multifactorial phenomenon arising from the complex interaction among patient-related characteristics, skeletal pattern, initial dental severity, treatment mechanics, quality of finishing, and retention strategy. Vertical skeletal discrepancies, pronounced initial crowding, large diastemas, and extensive dentoalveolar compensations appear to be associated with an increased susceptibility to relapse.

Conversely, variables such as age, sex, extraction protocol, and the presence of third molars do not demonstrate consistent evidence as independent predictive factors. Retention remains the primary protective measure for maintaining treatment outcomes; however, it does not entirely counteract physiological age-related changes.

Consequently, achieving long-term stability necessitates individualized, biologically grounded treatment planning integrated with meticulously designed and monitored retention protocols.

Conflicts of Interest

The authors declare no conflicts of interest.

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