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Review Article

Defining and Measuring Periodontal Readiness for Tooth Movement after Regenerative Surgery: A Scoping Review of Healing Criteria, Treatment Timing, and Interdisciplinary Decision Processes

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ABSTRACT

Periodontal regeneration can preserve teeth with advanced attachment loss and intrabony defects, but the point at which a treated tooth is biologically and clinically ready for orthodontic movement remains insufficiently defined. Recommendations based only on elapsed postoperative time risk conflating healing chronology with periodontal stability, tissue maturation, mechanical tolerance, and interdisciplinary treatment readiness. This scoping review mapped clinical, regenerative, orthodontic, and methodological evidence relevant to determining readiness for tooth movement after regenerative periodontal surgery. A PRISMA-ScR- and JBI-compatible approach was used to identify literature published from 2017 through 2024 concerning treated periodontitis, regenerative healing, post-treatment stability, orthodontic movement, timing, and decision criteria. Sixty-eight records were identified through the executed search routes, six duplicates were removed, 13 records fell outside the predefined publication window, and 49 records underwent domain screening. Eighteen were excluded, leaving 31 evidence units for the review map. Direct evidence was concentrated in a small number of Stage IV periodontitis studies, including a randomized comparison of orthodontic initiation 4 weeks versus 6 months after regenerative surgery and longitudinal practice-based programmes using approximately 3-month sequencing. The broader literature supplied evidence on attachment gain, probing-depth reduction, pocket closure, defect morphology, inflammatory and molecular healing, radiographic changes, tooth retention, maintenance, and long-term stability, but no validated universal readiness score, biomarker cutoff, radiographic threshold, or postoperative waiting period was identified. The evidence therefore supports treating periodontal readiness as a conditional multidomain clinical state rather than a fixed chronological milestone. Clinical timing should remain contingent on periodontal control, healing trajectory, defect and patient characteristics, planned biomechanics, maintenance capacity, and interdisciplinary reassessment.

Keywords: Periodontal regeneration, Orthodontic tooth movement, Stage IV periodontitis, Intrabony defects, Periodontal stability, Interdisciplinary treatment

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Introduction

Advanced periodontitis can leave a dentition with substantial attachment loss, reduced periodontal support, pathologic tooth migration, impaired function, and complex restorative or orthodontic needs. The contemporary classification system distinguishes the severity and complexity of periodontitis from its future

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progression risk and provides the terminology required to describe patients whose treatment extends beyond infection control alone [1]. Staging is particularly important when tooth position, masticatory dysfunction, secondary occlusal problems, or rehabilitation needs make multidisciplinary treatment necessary [2]. At the same time, periodontal health is not restricted to an intact periodontium: a clinically healthy state may exist on a reduced periodontium after successful therapy, provided that inflammatory disease is controlled [3]. This distinction is fundamental to any attempt to define readiness for orthodontic movement because reduced support, previous regeneration, and current periodontal stability are related but non-equivalent concepts.

Evidence-based periodontal treatment is structured around infection control, correction of residual disease, and subsequent supportive care rather than around a single procedural endpoint [4]. For Stage IV periodontitis, the treatment problem becomes still more explicitly interdisciplinary. The European Federation of Periodontology guideline recognizes that periodontal therapy may need to be integrated with orthodontic, prosthetic, restorative, or other rehabilitative interventions and that treatment sequencing requires repeated clinical reassessment [5]. Consequently, the decision to move a tooth after regenerative surgery cannot be reduced to whether a prescribed number of weeks or months has elapsed. The relevant question is whether sufficient biological and clinical conditions have been achieved for controlled force application without undermining periodontal stability or misinterpreting incomplete healing as therapeutic readiness.

The available combined periodontal–orthodontic literature suggests that orthodontic treatment can be useful in selected patients with advanced periodontal destruction, particularly when pathologic migration compromises function or rehabilitation. A systematic review and meta-analysis of patients with severe periodontitis and pathologic tooth displacement found evidence of periodontal and orthodontic improvement after combined treatment, while also emphasizing heterogeneity and limitations in the underlying studies [6]. A separate systematic review addressing tilted teeth and teeth with intrabony or furcation defects similarly found that the direct evidence base was small and methodologically uneven [7]. Clinical data nevertheless indicate that orthodontic movement can be undertaken in carefully selected periodontally compromised patients when inflammation is controlled and treatment is integrated with periodontal management [8].

These findings create a clinically important interpretive problem. A study may report when orthodontics was initiated, but a reported interval is not necessarily a biologically validated readiness threshold. A regenerated defect may show radiographic fill, attachment gain, reduced probing depth, or pocket closure, yet none of these measures has automatically been validated as a standalone indicator that the tooth can tolerate a particular orthodontic loading strategy. Conversely, requiring long postoperative delays without reference to actual periodontal status may unnecessarily prolong treatment or allow pathologic tooth position to persist. The literature therefore needs to be mapped according to what was actually measured, when tooth movement was initiated, which clinical conditions were present, and how confidently those observations can be translated into a readiness decision.

The purpose of this scoping review was to identify and organize the evidence relevant to defining and measuring periodontal readiness for orthodontic tooth movement after regenerative surgery. The review specifically examined the characteristics of the available evidence base, reported postoperative timing strategies, periodontal and regenerative healing indicators, contextual modifiers, and interdisciplinary decision processes. Particular attention was given to distinguishing direct evidence concerning post-regenerative orthodontic movement from indirect evidence concerning periodontal regeneration or long-term stability, and to separating observed clinical outcomes from proposed criteria that still require prospective validation.

Materials and Methods

The review was conducted using a scoping-review design aligned with the PRISMA Extension for Scoping Reviews, which provides reporting guidance for transparent identification, selection, charting, and presentation of heterogeneous evidence [9]. Methodological decisions followed updated JBI guidance for scoping reviews, including specification of the review question through Population–Concept–Context logic, iterative evidence charting, and descriptive synthesis appropriate to a field in which study designs and outcome definitions are too heterogeneous for a single pooled estimate to answer the principal question [10]. Protocol-level decisions were specified before synthesis in accordance with JBI best-practice guidance for scoping-review protocols [11].

The population domain comprised people with treated periodontitis or periodontal defects relevant to

regenerative treatment and subsequent orthodontic movement. The concept domain included periodontal readiness, regenerative healing, periodontal stability, timing of orthodontic movement, post-treatment clinical indicators, and multidisciplinary decision processes. The context domain included combined periodontal–orthodontic care and closely related regenerative-periodontology evidence capable of informing the interpretation of healing or stability after therapy. Evidence was restricted to the substantive publication interval from 2017 through 2024. Human clinical trials, observational studies, longitudinal follow-ups, clinically relevant exploratory studies, systematic evidence syntheses, and practice guidelines were eligible when they contributed directly to post-regenerative orthodontic decision-making or supplied clinically meaningful evidence on healing, stability, or measurement. Methodological and classification references were retained separately as contextual sources rather than counted as included review evidence.

The review did not use journal quartile as an eligibility criterion for evidence units. Study relevance was determined by the clinical and methodological review question rather than by journal prestige. Evidence was also coded by directness. Studies evaluating the initiation or consequences of orthodontic movement after regenerative periodontal treatment were considered direct evidence. Studies addressing regenerative healing, periodontal stability, defect morphology, biomaterials, inflammation, molecular healing, supportive care, or long-term tooth retention were considered contextual evidence unless orthodontic movement formed part of the studied intervention. This distinction prevented regenerative efficacy from being treated automatically as proof of orthodontic readiness.

The executed search was performed on 20 October 2026 using reproducible PubMed-indexed retrieval routes covering: periodontal regeneration combined with orthodontic tooth movement; Stage IV periodontitis and orthodontic treatment; intrabony-defect healing and stability; periodontal classification; and evidence concerning treatment timing. Targeted PMID, DOI, publisher-metadata searches, and backward and forward citation chaining supplemented the primary retrieval. Because the executable search environment returned bounded indexed result sets rather than a conventional institutional MEDLINE export, the recorded numerical flow represents the searches actually executed for this review and is not interpreted as a database-wide PubMed hit total.

Eligibility, evidence-layer coding, and charting were applied to the deduplicated record set. Extraction fields included study design, clinical setting, patient or biological population, periodontal state, intervention or exposure, comparator where applicable, sample size when reported, periodontal and orthodontic condition, measured endpoints, healing or timing interval, principal finding, study limitations, biological plausibility, competing or null evidence, generalizability, and whether a claim represented direct evidence or proposed synthesis. Missing information was retained as not reported rather than inferred.

The operational review rules are summarized in **Table 1**. These rules deliberately separate evidence that can describe healing from evidence capable of supporting a decision about tooth movement.

Table 1. Operational eligibility rules and evidence-mapping domains for post-regenerative periodontal readiness

Review element	Operational rule	Article-specific application
Population	Treated periodontal patients or periodontal defects clinically relevant to subsequent orthodontic treatment	Priority to Stage IV periodontitis, intrabony defects, reduced periodontal support, and regenerated teeth
Core concept	Readiness for orthodontic tooth movement following periodontal therapy or regeneration	Clinical stability, healing trajectory, treatment timing, biomechanics, and interdisciplinary reassessment
Context	Periodontal–orthodontic care and relevant regenerative-periodontology settings	Direct combined-treatment evidence separated from indirect healing evidence
Publication interval	2017–2024	Later evidence excluded from the substantive review set
Direct evidence	Studies in which orthodontic movement followed or interacted with periodontal/regenerative treatment	Timing studies, combined-treatment cohorts, long-term combined-care follow-up
Contextual evidence	Evidence capable of informing healing or stability but not directly testing orthodontic movement	Regeneration trials, defect-healing studies, stability studies, maintenance evidence

Eligible designs	Trials, cohorts, longitudinal studies, clinically relevant exploratory studies, systematic syntheses, guidelines	No requirement that all designs estimate an intervention effect
Clinical endpoints	Measures actually reported by the source	Probing depth, clinical attachment, pocket closure, radiographic change, tooth retention, inflammatory or molecular variables
Timing information	Post-treatment or post-surgical intervals as actually reported	An interval is charted as a study characteristic, not automatically interpreted as a threshold
Measurement validity	Evidence must support the meaning assigned to an indicator	Surrogate outcomes are not treated as equivalent to functional readiness
Evidence quality	Assessed according to study design and reported limitations	No journal-rank proxy and no fabricated composite risk score
Exclusion	Wrong clinical concept, unrelated population/context, or evidence without usable healing/stability relevance	Technical or regenerative material studies were excluded when they could not inform the review question
Missing data	No inference from absence of reporting	Entries remain “not reported” or are omitted from quantitative interpretation
Synthesis	Structured qualitative mapping rather than pooled readiness estimation	Evidence organized by directness, healing domain, timing, context, and decision relevance

Results and Discussion

Characteristics of the evidence base

The executed search routes identified 68 records. Six exact duplicate records were removed, leaving 62 unique records. Thirteen fell outside the locked 2017–2024 evidence window, and 49 records entered title, abstract, and domain screening. Eighteen were excluded because they addressed an unrelated clinical concept, lacked usable healing or stability information, represented background material without an eligible evidence contribution, involved an unsuitable population or context, or duplicated secondary treatment discussion without additional extractable evidence. Thirty-one evidence units were retained for mapping.

The most directly relevant evidence was concentrated in a small cluster of studies evaluating combined regenerative periodontal and orthodontic treatment. A multicenter randomized trial compared initiation of orthodontic treatment 4 weeks after regenerative surgery with initiation after 6 months in patients with Stage IV periodontitis [12]. Forty-three participants were randomized, and the reported 12-month clinical attachment gain was 5.4 ± 2.1 mm in the early group and 4.5 ± 1.7 mm in the delayed group, without a statistically significant between-group difference. Pocket closure was also frequent in both groups. The trial therefore provides direct evidence that an early 4-week strategy can be feasible in selected, intensively managed patients, but its design does not establish 4 weeks as a universal biological threshold.

A practice-based retrospective cohort used a different treatment sequence, with orthodontic therapy initiated approximately 3 months after regenerative periodontal surgery, and reported favorable periodontal outcomes during integrated treatment [13]. A later long-term analysis of the same clinical programme found that periodontal improvements and tooth stability could be maintained over approximately 10 years in the retained cohort [14]. These studies are clinically valuable because they extend the evidence beyond a single short-term timing comparison, but their observational nature and specialist treatment setting limit generalization. A systematic review of orthodontic treatment in periodontally compromised patients likewise concluded that the number and quality of directly informative clinical studies remained limited [15].

The broader regenerative literature was substantially larger than the direct timing literature. Defect morphology has been investigated as a potential determinant of regenerative healing. A systematic review found that intrabony-defect configuration, including depth and number of residual bony walls, may influence clinical healing after regenerative surgery [16]. Clinical closure of residual periodontal pockets has also been examined as an outcome after regenerative procedures; a systematic review and meta-analysis of randomized studies found that substantial pocket resolution can occur following regenerative treatment using papilla-preservation approaches [17]. Longer-horizon network evidence indicates that regenerative or reconstructive procedures can provide sustained improvements in probing-depth and

attachment outcomes compared with less regenerative approaches, although comparative certainty varies across techniques and follow-up periods [18].

Long-term primary studies further demonstrated that regenerative success cannot be represented by a single early postoperative measure. A retrospective case series found that favorable attachment outcomes after regenerative treatment of infrabony defects could remain stable for years under supportive care [19]. A five-year analysis similarly showed that clinical attachment could remain stable after regeneration, while recurrence and patient-level modifiers such as smoking remained relevant [20]. Twenty-year follow-up of intrabony defects treated by guided tissue regeneration or open-flap debridement documented high tooth retention but also demonstrated that long-term survival and early regenerative response are not interchangeable outcomes [21]. Another 20-year randomized-trial follow-up reported favorable long-term tooth-retention and recurrence patterns after periodontal regeneration compared with access-flap surgery [22]. A 10-year follow-up of a minimally invasive randomized trial found durable periodontal results across treatment approaches, while suggesting that the incremental contribution of regenerative materials may be smaller than that of the overall treatment and maintenance pathway in some settings [23]. Long-term enamel-matrix-derivative data likewise showed maintenance of clinical improvements but identified tooth- and patient-related modifiers of prognosis [24].

Evidence concerning regenerative adjuncts and minimally invasive therapy increased the biological breadth of the evidence base but did not directly answer the orthodontic timing question. A best-evidence systematic review and network meta-analysis found that biologic agents can influence outcomes in periodontal infrabony defects, although comparative effects vary by material and endpoint [25]. In a randomized trial of minimally invasive nonsurgical therapy with or without enamel matrix derivative, additional benefit from the biologic was not uniform across all measured outcomes, providing important null-sensitive evidence against assuming that a regenerative adjunct necessarily produces a qualitatively different readiness state [26]. A double-blind randomized trial examining locally delivered doxycycline before regenerative treatment showed that the inflammatory molecular environment of an intrabony defect can be modified, but these molecular observations were not validated as orthodontic clearance criteria [27]. An exploratory analysis of defect morphology after minimally invasive nonsurgical therapy also failed to support a simple deterministic relationship between morphology and healing, challenging the idea that anatomy alone can function as a readiness gate [28]. Evidence concerning recombinant fibroblast growth factor-2 similarly focused principally on defect bone fill and regenerative outcomes rather than functional tolerance to orthodontic force [29].

The definition of periodontal stability itself was heterogeneous. A systematic review of patients in supportive periodontal care found substantial variation in how “stable” or “successfully treated” periodontitis was operationalized across studies, even though several definitions were associated with subsequent tooth-loss risk [30]. This variability is directly relevant to readiness research: if periodontal stability lacks a single consistently applied operational definition, it cannot be assumed that studies using the term are measuring the same biological or clinical state.

Contemporary clinical studies added further evidence concerning the temporal and procedural heterogeneity of periodontal healing. A pilot molecular investigation of intrabony defects demonstrated marked early changes in gingival crevicular fluid mediators after nonsurgical therapy, with later movement toward a more quiescent profile [31]. A prospective multicenter cohort of minimally invasive nonsurgical treatment documented clinically and radiographically favorable healing of intrabony defects over follow-up [32]. A randomized trial of a flapless approach with or without enamel matrix derivative reported clinical and radiographic improvement in both groups, with adjunctive benefits confined to selected outcomes [33]. A multicenter randomized comparison of Er,Cr laser therapy with a minimally invasive surgical technique supplied additional evidence that multiple procedural routes can produce 12-month periodontal improvement [34]. Clinical and radiographic evaluation of platelet-rich fibrin, concentrated growth factor, and autogenous bone further illustrated the heterogeneity of regenerative strategies used to treat intrabony defects [35].

Taken together, the included evidence base was characterized by a narrow set of studies directly examining when orthodontic movement followed regenerative surgery and a much wider set of studies examining periodontal healing, regeneration, stability, anatomy, inflammation, biomaterials, and long-term prognosis. The direct evidence principally involved selected Stage IV periodontitis populations managed in specialist interdisciplinary settings, whereas indirect evidence covered a broader range of intrabony defects and regenerative approaches. Follow-up ranged from

early molecular observations to decades-long tooth-retention studies. The dominant clinical endpoints were probing depth, clinical attachment level, pocket closure, radiographic defect change, and tooth retention; none was prospectively validated as a standalone measure of orthodontic readiness.

The evidence-selection arithmetic is summarized in **Figure 1**. The reported counts reflect the executed search routes rather than conventional database-export totals and should not be interpreted as universal PubMed retrieval totals.

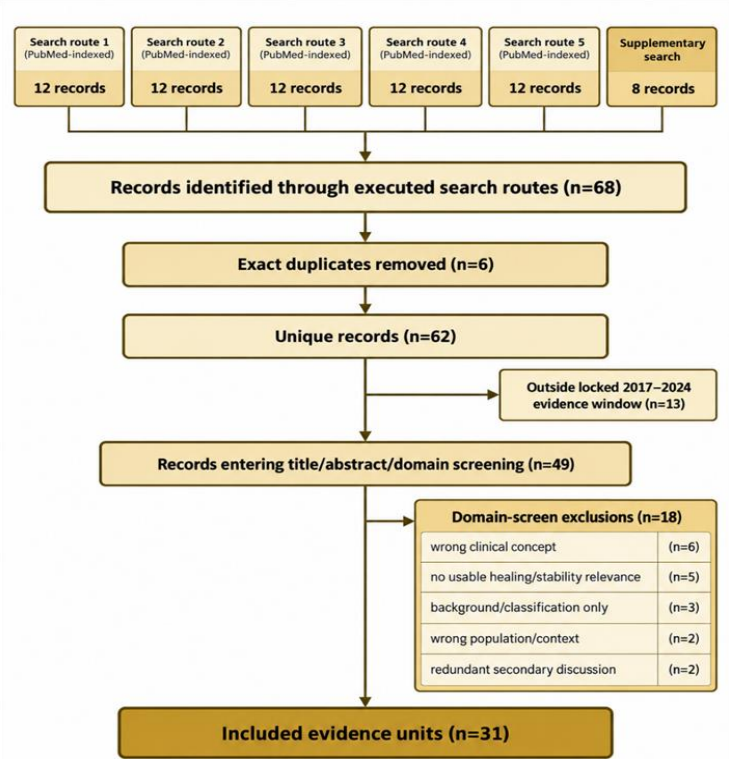

Figure 1. Verified selection pathway for evidence on periodontal readiness after regenerative surgery

The 31 included evidence units are characterized in **Table 2** according to design, clinical context, timing horizon, and their directness to the readiness question.

The table deliberately retains contextual regenerative evidence rather than disguising it as direct evidence of post-surgical orthodontic tolerance.

Table 2. Characteristics of the included evidence units relevant to periodontal readiness after regenerative therapy

Evidence unit	Design/context	Principal clinical domain	Timing or follow-up	Directness to orthodontic readiness
Stage I–III treatment guideline, 2020	Evidence-based clinical guideline	Periodontal control and treatment endpoints	Sequential treatment pathway	Contextual
Stage IV treatment guideline, 2022	Evidence-based interdisciplinary guideline	Complex periodontal rehabilitation	Sequential reassessment	High contextual relevance
Pathologic migration review, 2022	Systematic review/meta-analysis	Combined periodontal–orthodontic treatment	Heterogeneous	Direct synthesis
Intrabony/tilted-tooth review, 2022	Systematic review	Combined periodontal–orthodontic care	Heterogeneous	Direct synthesis
Periodontally compromised orthodontic cohort, 2022	Clinical study	Orthodontics under periodontal control	Treatment course	Direct
Early-versus-delayed timing trial, 2021	Multicenter randomized trial	Regeneration followed by orthodontics	4 weeks vs 6 months	Direct

Practice-based combined-treatment cohort, 2021	Retrospective cohort	Regeneration plus orthodontics	Approx. 3-month initiation	Direct
Ten-year combined-treatment follow-up, 2023	Long-term retrospective cohort	Periodontal stability after combined care	Approx. 10 years	Direct
Orthodontic treatment systematic review, 2023	Systematic review	Periodontally compromised patients	Variable	Direct synthesis
Defect-morphology synthesis, 2021	Systematic review	Intrabony regenerative healing	Mainly approximately 12 months	Contextual
Pocket-resolution synthesis, 2021	Systematic review/meta-analysis	Post-regenerative pocket closure	Mainly approximately 12 months	Contextual
Regenerative network meta-analysis, 2021	Network meta-analysis	Medium/long-term regeneration	3–20 years	Contextual
Long-term regenerative case series, 2017	Retrospective case series	Attachment stability	Long term	Contextual
Five-year regenerative stability study, 2019	Comparative follow-up	Clinical attachment stability	5 years	Contextual
Twenty-year GTR/OFD follow-up, 2019	Long-term controlled follow-up	Tooth retention and defect outcomes	20 years	Contextual
Twenty-year regenerative RCT follow-up, 2017	Randomized-trial follow-up	Retention, recurrence, cost	20 years	Contextual
Ten-year minimally invasive RCT follow-up, 2022	Randomized-trial follow-up	Regenerative stability	10 years	Contextual
Long-term enamel-matrix cohort, 2022	Retrospective cohort	Regenerative outcome durability	Mean approximately 10 years	Contextual
Biologics network meta-analysis, 2022	Systematic review/network meta-analysis	Regenerative biologic effects	Variable	Contextual
MINST±EMD randomized trial, 2022	Randomized clinical trial	Minimally invasive defect healing	12 months	Contextual
Doxycycline molecular trial, 2023	Double-blind randomized trial	Local inflammatory environment	Early/preoperative	Contextual
Morphology exploratory analysis, 2023	Exploratory cohort analysis	Defect anatomy and healing	Approximately 12 months	Contextual/rival evidence
rhFGF-2 systematic review, 2023	Systematic review	Defect bone fill	Variable	Contextual
Periodontal stability systematic review, 2023	Systematic review/meta-analysis	Definitions of successful treatment	Longitudinal	High contextual relevance
Molecular-healing pilot study, 2024	Exploratory clinical study	Gingival crevicular fluid biology	Days to 3 months	Contextual
Multicenter MINST cohort, 2024	Prospective multicenter cohort	Intrabony-defect healing	12 months	Contextual
Flapless±EMD randomized trial, 2024	Randomized clinical trial	Clinical/radiographic regeneration	12 months	Contextual
Laser-versus-MIST randomized trial, 2024	Multicenter randomized trial	Intrabony-defect treatment	12 months	Contextual

Autologous-product regenerative study, 2024	Clinical/radiographic comparative study	Intrabony-defect regeneration	Study follow-up	Contextual
Periodontal-status operationalization study, 2024	Measurement-framework study	Definition of periodontal status	Cross-sectional/epidemiologic application	Contextual
Supportive-care stage/grade study, 2024	Longitudinal clinical/economic analysis	Maintenance and retreatment	Longitudinal	Contextual

The distribution shown in **Table 2** clarifies why the review cannot infer a universal readiness threshold. Only a minority of included evidence directly evaluated orthodontic treatment after regeneration; most studies addressed biological or clinical conditions that may influence a readiness judgment but did not test that judgment itself. The next stage of the review therefore requires a separate synthesis of which healing indicators and treatment intervals were actually reported, which were merely inferentially relevant, and where the evidence does not support conversion of a surrogate outcome into an orthodontic clearance criterion.

Results: readiness criteria and clinical decision processes

The included literature did not identify a single validated test that determined whether a regenerated tooth was ready for orthodontic movement. Instead, studies reported different combinations of elapsed postoperative time, probing-depth reduction, clinical attachment gain, pocket closure, radiographic defect change, inflammatory control, and longitudinal periodontal stability. The most direct evidence concerned treatment timing. In the multicenter randomized trial, orthodontic movement initiated 4 weeks after regenerative surgery produced periodontal outcomes that were not statistically inferior to those observed when treatment began after 6 months [12]. In the practice-based programme, orthodontic therapy was initiated approximately 3 months after regenerative treatment and was associated with favorable periodontal outcomes [13], with long-term follow-up demonstrating stability within the treated cohort [14]. These intervals demonstrate that successful combined treatment has been undertaken using substantially different schedules. They do not establish 4 weeks, 3 months, or 6 months as a universal biological threshold.

The distinction between a reported treatment interval and a readiness criterion was reinforced by the wider evidence. Periodontal guidelines emphasize control of active disease and achievement of treatment goals before progression to complex rehabilitative phases [5]. Evidence concerning orthodontic care in periodontally compromised patients similarly indicates that movement should occur within a controlled periodontal environment rather than during uncontrolled inflammation [8]. Thus, elapsed time has clinical meaning only when interpreted alongside the condition of the periodontal tissues and the broader treatment pathway.

Clinical attachment level, probing depth, and pocket closure were among the most consistently reported measures of periodontal response. Regenerative treatment can produce substantial attachment gains and pocket reduction [17], and long-term studies demonstrate that favorable clinical outcomes may remain stable for many years [19]. However, attachment gain does not directly measure the mechanical behavior of a tooth during subsequent orthodontic loading. Likewise, pocket closure indicates improvement in the periodontal environment but does not independently demonstrate maturation of regenerated tissues or define the magnitude and direction of force that a particular tooth can tolerate.

Defect morphology represented another potential source of clinical information. Synthesis evidence suggested that deeper, narrower defects or defects retaining more bony walls can display different regenerative responses [16]. Yet morphology was not consistently associated with healing in an exploratory analysis of minimally invasive nonsurgical treatment [28]. Anatomy therefore appears relevant to prognosis and regenerative potential without functioning as a deterministic clearance criterion. Its clinical interpretation must remain conditional on the treatment delivered, the inflammatory environment, tooth support, and the response observed during follow-up.

Inflammatory and molecular evidence further showed that healing is temporally dynamic. Modification of the local inflammatory environment before regenerative treatment can influence measured molecular conditions [27], while exploratory gingival crevicular fluid data demonstrated substantial early biological changes followed by later movement toward a more quiescent state [31]. These findings make biological plausibility for time-dependent readiness strong, but no included

study validated a molecular concentration or biomarker pattern as a threshold for initiating orthodontic force.

Radiographic improvement was similarly insufficient as an isolated criterion. Studies of regenerative materials, minimally invasive treatment, flapless approaches, and surgical techniques frequently reported radiographic defect fill or related structural changes [25]. Favorable radiographic and clinical outcomes were also documented after nonsurgical treatment of intrabony defects [32] and after flapless regenerative strategies [33]. Nevertheless, radiographic fill is an anatomical surrogate. It does not establish the organization, maturation, or load-bearing properties of the regenerated periodontal attachment apparatus, and it cannot by itself define orthodontic readiness.

Long-term periodontal stability added another dimension. Regenerated teeth can remain functional for many years [21], and randomized long-term evidence supports sustained tooth retention after periodontal regeneration [22]. Yet long-term survival addresses prognosis after treatment rather than the earliest appropriate point for initiating tooth movement. Similarly, maintenance of favorable results after minimally invasive regenerative procedures [23] and enamel matrix derivative therapy [24] demonstrates durability without identifying an early functional loading threshold.

Table 3 therefore distinguishes indicators that are clinically informative from indicators that have actually been validated as readiness criteria.

Table 3. Healing observations and postoperative intervals relevant to decisions about orthodontic movement after periodontal regeneration

Readiness-related domain	What the literature actually reports	How it may inform a decision	Why it cannot currently function as a standalone readiness threshold
Postoperative interval	Orthodontic initiation has been reported at approximately 4 weeks, 3 months, and 6 months in direct combined-treatment pathways	Establishes that different sequencing strategies can succeed in selected patients	No interval has been prospectively validated across different defects, patients, force systems, or regenerative procedures
Probing depth	Reduction following periodontal and regenerative treatment	Indicates reduction in residual periodontal pocketing	Does not directly measure regenerated-tissue maturation or orthodontic load tolerance
Clinical attachment level	Attachment gain is commonly reported after successful regeneration	Demonstrates improvement in periodontal support	Gain magnitude has not been validated as a clearance cutoff
Pocket closure	Frequently achieved after successful regenerative therapy	Supports control of residual periodontal disease	Pocket closure alone does not establish functional readiness for tooth movement
Bleeding/inflammatory control	Reduced inflammatory activity is expected after successful treatment	Helps distinguish controlled from active disease	Absence of clinical inflammation does not quantify tissue maturation
Defect morphology	Defect depth, angle, and wall configuration may modify regenerative response	Contributes to prognosis and interpretation of healing	Morphology does not consistently predict healing and cannot determine readiness by itself
Radiographic defect change	Bone fill or reduction in defect depth may occur during healing	Provides structural information over time	Radiographic change is a surrogate and does not measure periodontal ligament function or force tolerance
Molecular healing	Early inflammatory and healing mediators change with treatment and time	Demonstrates biological phase dependence	No molecular marker or combination has validated clinical decision thresholds
Tooth stability and support	Long-term retention and attachment stability are achievable after successful regeneration	Indicates sustainability of periodontal treatment	Long-term prognosis does not identify the earliest appropriate time for orthodontic initiation
Supportive periodontal care	Maintenance influences long-term periodontal stability	Determines whether a favorable tissue state is likely to be maintained	Maintenance participation cannot compensate for unresolved active disease

Planned orthodontic biomechanics	Reduced support changes the clinical meaning of force application	Requires individualized force planning and monitoring	The reviewed literature does not validate a universal force magnitude for regenerated teeth
Interdisciplinary reassessment	Periodontal and orthodontic findings can be reviewed before progression to active movement	Integrates multiple clinical dimensions	No validated composite decision instrument or weighted score currently exists

The evidence therefore maps readiness more convincingly as a conditional state than as a discrete measurement. Periodontal control, the trajectory of healing, residual defect characteristics, remaining support, treatment modality, maintenance behavior, and the intended orthodontic mechanics may all alter the meaning of the same postoperative interval. This multidimensional interpretation is compatible with the direct timing studies while avoiding conversion of their treatment schedules into unsupported universal rules.

This review identified a fundamental difference between when orthodontic treatment has been started successfully and when a regenerated periodontal site can be said to be biologically ready for orthodontic movement. The first question has limited direct clinical evidence. The second remains incompletely operationalized. The randomized comparison of 4-week and 6-month initiation provides the strongest evidence that prolonged waiting is not necessarily required in every carefully managed Stage IV patient [12]. The approximately 3-month sequencing used in the practice-based cohort provides another clinically successful approach [13]. Neither finding justifies automatic initiation at the corresponding interval. Rather, the studies indicate that chronological delay is only one component of a decision that also depends on periodontal control, defect response, patient adherence, planned mechanics, and continued professional monitoring.

The review synthesis is represented in **Figure 2** as a conditional convergence rather than a sequential timer. The central decision state is reached only when information from healing, periodontal control, tooth-support conditions, planned orthodontic loading, and maintenance can be interpreted together.

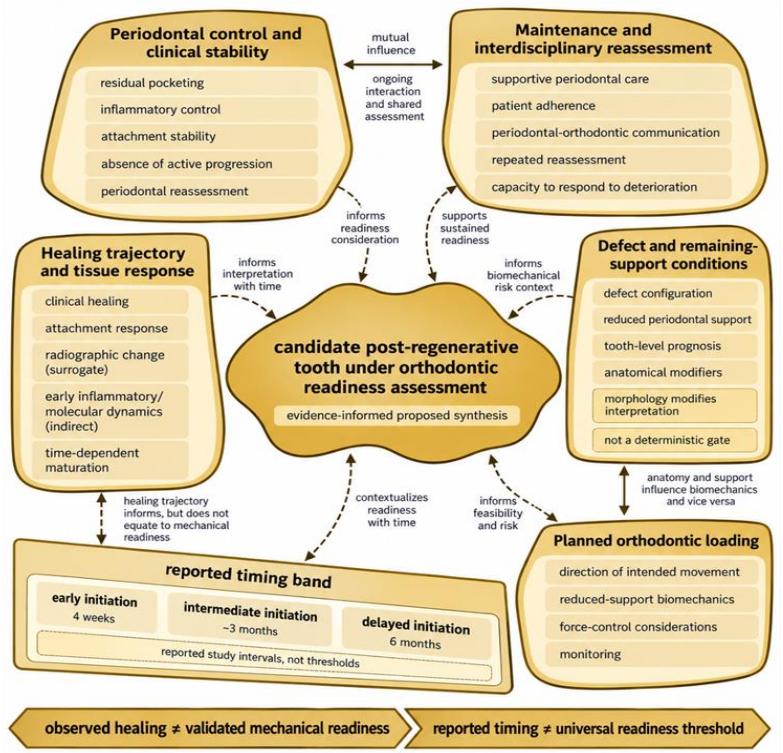

Figure 2. Conditional convergence of periodontal healing, treatment timing, and orthodontic decision readiness

The biological plausibility for such a multidomain interpretation is strong but remains indirect in important respects. Periodontal wound healing and regeneration are governed by interacting inflammatory,

cellular, vascular, matrix, and patient-level processes rather than by a single chronological event [36]. Contemporary regenerative biology likewise shows that growth-factor-mediated hard- and soft-tissue responses vary with the local environment and intervention [37]. These mechanisms explain why elapsed time alone is unlikely to capture every clinically relevant dimension of healing, but mechanistic plausibility should not be confused with clinical validation of a readiness instrument.

A second limitation concerns measurement. Periodontal-status classifications can produce different operational interpretations depending on the definitions applied to clinical datasets [38]. Comparable variability was evident in the literature on treated periodontal stability. Consequently, a future readiness instrument would first require precise operational definitions of the variables it intends to combine. It would also need to demonstrate that those variables predict clinically meaningful outcomes under orthodontic loading rather than merely describing prior periodontal improvement.

Maintenance creates an additional boundary condition. Long-term periodontal outcomes depend partly on supportive periodontal care, and the benefit associated with regular maintenance can vary with the underlying stage and grade of periodontitis [39]. The favorable combined-treatment cohorts included structured specialist care and follow-up, which may limit transportability to settings with less consistent periodontal maintenance. Readiness should therefore not be viewed as permanent clearance. A tooth judged appropriate for movement at one point can require renewed periodontal reassessment if inflammation, hygiene, mobility, attachment status, or treatment mechanics change.

Table 4 summarizes what can reasonably be incorporated into clinical judgment now and what remains unvalidated.

Table 4. Evidence-supported readiness domains and unresolved validation gaps

Decision domain	What can currently be justified	What remains uncertain	Priority for future validation
Periodontal disease control	Active inflammation should be controlled before complex orthodontic progression	Exact combination of clinical findings required for clearance	Prospective operational definition of periodontal control before movement
Postoperative timing	Successful movement has been reported using markedly different initiation intervals	Whether an optimal interval exists for specific regenerative procedures or defects	Comparative trials stratified by healing state rather than time alone
Clinical attachment and probing depth	Useful measures of periodontal response and residual disease	Whether particular values predict mechanical tolerance	Evaluate predictive value for periodontal deterioration during movement
Pocket closure	Supports a favorable periodontal treatment response	Whether closure is necessary or sufficient for movement	Prospective testing as one component of a multivariable assessment
Radiographic healing	Provides structural information about defect resolution	Relationship between radiographic change and functional periodontal maturation	Correlation with clinically meaningful orthodontic outcomes
Molecular/inflammatory healing	Demonstrates time-dependent biological change	No validated biomarker profile defines readiness	Longitudinal biomarker studies linked to subsequent tooth movement
Defect morphology and remaining support	Modifies prognosis and biomechanical context	Cannot independently determine treatment timing	Stratified studies incorporating support geometry and planned movement
Orthodontic mechanics	Reduced support requires controlled individualized biomechanics	Evidence does not define universal force magnitudes after regeneration	Trials reporting movement type, force systems, support, and periodontal response together
Supportive periodontal care	Essential to maintaining treatment stability	Minimum monitoring schedule and adherence required during combined care	Pragmatic studies across routine clinical settings

Interdisciplinary reassessment	Clinically defensible because readiness depends on several interacting domains	No validated structured decision instrument exists	Development and external validation of a clinically usable readiness assessment
Composite readiness construct	Evidence supports multidomain reasoning	No weighting, score, probability, or threshold has been validated	Prospective model development followed by independent external validation

The main implication is therefore not that clinicians should substitute a new unvalidated framework for existing periodontal judgment. Rather, the evidence argues against treating elapsed time, radiographic fill, pocket depth, attachment gain, or any other isolated measure as synonymous with readiness. In patients resembling those studied, earlier orthodontic initiation may be reasonable when periodontal treatment goals have been achieved and the clinical trajectory is favorable. The confidence of that decision should diminish when active inflammation persists, tissue response is uncertain, periodontal support is severely compromised, planned movement imposes unfavorable biomechanical demands, maintenance is unreliable, or the patient differs substantially from the populations studied.

Future research should move beyond comparing calendar intervals alone. Prospective studies should document periodontal status immediately before orthodontic initiation, characterize defect anatomy and regenerative treatment, describe the planned tooth movement and mechanics, measure inflammatory and structural healing where appropriate, and then relate these variables to periodontal outcomes during orthodontic treatment. Such work could determine whether a reproducible multidomain assessment predicts outcomes better than time since surgery. Until that validation exists, a readiness construct should remain a transparent clinical synthesis rather than a numerical score.

Conclusion

The available evidence does not support a universal postoperative waiting period or a single clinical, radiographic, anatomical, or molecular threshold for orthodontic tooth movement after regenerative periodontal surgery. Direct studies show that successful movement has been initiated at substantially different postoperative intervals in carefully selected and intensively managed patients, including earlier than traditional prolonged delays. These findings establish feasibility, not a universal timing rule.

Periodontal readiness is therefore best understood as a conditional multidomain state in which disease control, healing trajectory, residual periodontal support, defect characteristics, planned orthodontic mechanics, supportive care, and interdisciplinary reassessment are interpreted together. Clinical attachment gain, probing-depth reduction, pocket closure, radiographic fill, molecular change, and elapsed time can inform that judgment, but none has been validated as an independent clearance criterion. Prospective validation is required before any composite readiness score, numerical cutoff, or universal timing recommendation can be justified.

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