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Precision early intervention in growth and developing dentition: A cohort study

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Abstract:
Early intervention may help intercept malocclusion in the developing dentition, but treatment selection and timing remain challenging. Therefore, it is of interest to evaluate the risk-stratified approach in 100 children with mixed dentition (mean age, 8.8 years) using surveillance or targeted appliances. Mean PAR scores decreased from 26.6 to 15.9 (37.7%; $p<0.001$), with greater improvement after active treatment than surveillance (45.6% vs. 1.8%; $p<0.001$). PAR reduction increased with appliance compliance (15.2% to 51.9%; $p<0.001$), while treatment timing within the mixed-dentition phase showed no significant effect. Thus, data shows that risk stratification and treatment compliance as key determinants of predictable outcomes in early orthodontic intervention.

Keywords: Early orthodontic intervention, mixed dentition, malocclusion, peer assessment rating, precision dentistry, risk stratification

Background:
Malocclusion is common in children and includes Class I, II and III relationships, crowding, crossbite and increased overjet **[1].** Early orthodontic intervention may harness growth and simplify later treatment, but appropriate patient selection and treatment timing remain challenging **[2]**. Skeletal and dental maturity assessments provide biological indicators that can improve the timing of interceptive treatment **[3]**. The Peer Assessment Rating (PAR) index provides a validated measure for quantifying occlusal severity and treatment-related improvement **[4]**. Risk-based treatment planning can integrate occlusal, skeletal, behavioural and oral-health factors to guide surveillance or active intervention, while emerging digital and AI tools may further support orthodontic risk assessment **[5].** Therefore, it is of interest to evaluate the whether a precision, risk-stratified model of early intervention improves occlusal outcomes and how these outcomes relate to risk tier, appliance compliance and treatment timing.

Methodology:
This analysis used a structured cohort of 100 children in the mixed dentition, aged between six and twelve years, characterised across demographic, growth, skeletal, occlusal and behavioural and oral-health domains. It should be noted at the outset that the dataset is a simulated cohort generated for methodological and teaching purposes; the values are modelled rather than drawn from identifiable patients and the analysis is therefore intended to show a precision-intervention framework rather than to report clinical trial results. For each child, chronological age was recorded together with dental age estimated by the Demirjian method and skeletal maturity expressed as a cervical vertebral maturation stage from CS1 to CS6. Anthropometric growth markers (height, weight and body-mass-index percentile), Angle molar classification, baseline overjet and overbite, crossbite type, arch-length crowding, parafunctional or airway habits, tonsillar grade, family history of malocclusion and caries and oral-hygiene indices were also captured. Each child was assigned to a low, moderate or high risk tier using a composite severity model that integrated the occlusal, skeletal, behavioural and oral-health variables and was then managed by an intervention matched to the risk tier and the presenting malocclusion. Modalities ranged from active surveillance, in which growth was monitored without an appliance, to space maintenance, rapid palatal expansion for transverse deficiency or posterior crossbite, functional (Twin Block) appliances for Class II growth modification, facemask or reverse-pull headgear for Class III maxillary protraction, habit-breaking appliances and myofunctional therapy. Intervention was further categorised by the phase of the mixed dentition at which it commenced (early versus late) and appliance or protocol compliance was graded from poor to excellent. Occlusal severity was quantified using the Peer Assessment Rating (PAR) index at baseline and again at a 12-month review and the percentage reduction in PAR was taken as the primary outcome, with a reduction of at least 30% denoting a meaningful improvement and at least 70% a substantial improvement.

Overjet and overbite at follow-up were recorded as secondary occlusal measures and each child was assigned a summary clinical outcome. Statistical analysis compared paired baseline and follow-up scores using the Wilcoxon signed-rank test, two-group comparisons using the Mann-Whitney test and comparisons across risk tiers and compliance categories using the Kruskal-Wallis test, while associations between categorical variables were examined using the chi-square test. The level of significance was set at 5%.

Results:

The cohort comprised 100 children with a near-even sex distribution (53 male, 47 female) and a mean chronological age of 8.8 years, closely matched by a mean dental age of 8.8 years; the two measures were strongly correlated, consistent with a broadly typical pattern of dental maturation. At baseline, Angle Class I was the most common relationship (40%), followed by Class II division 1 (28%), Class III (19%) and Class II division 2 (13%) and just over half of the children (52%) presented with a crossbite. The mean overjet were 3.2 mm and the mean arch-length crowding 4.5 mm and the composite risk model distributed the cohort almost evenly across the low, moderate and high tiers **(Table 1)**. Across the whole cohort, occlusal severity improved markedly over the 12-month interval, with the mean PAR score falling from 26.6 at baseline to 15.9 at follow-up, a statistically significant change ($p<0.001$) corresponding to a mean reduction of 37.7%. When children who received active appliance therapy were compared with those managed by surveillance alone, the difference was pronounced: treated children achieved a mean PAR reduction of 45.6% against only 1.8% in the surveillance group ($p<0.001$), while the mean overjet showed only a small, non-significant change over the same period **(Table 2)**. PAR reduction differed significantly across the precision risk tiers ($p<0.001$). Children in the moderate and high tiers, who were more likely to receive active intervention, achieved mean reductions of 49.2% and 43.2% respectively, whereas low-risk children, most of who were monitored, showed a smaller mean reduction of 20.5% **(Table 3)**. A clear gradient was also seen with appliance compliance: mean PAR reduction rose from 15.2% in children with poor compliance, through 30.9% and 43.5% for fair and good compliance, to 51.9% in those with excellent compliance ($p<0.001$), indicating a strong dose-response relationship between adherence and occlusal improvement **(Table 4)**. By contrast, the phase of the mixed dentition at which treatment began did not significantly influence the outcome, with early-phase and late-phase intervention producing comparable mean reductions of 35.5% and 39.9% respectively ($p=0.30$). The distribution of assigned interventions reflected the mixed pattern of malocclusion in the cohort, with rapid palatal expansion the most frequently used modality, followed by facemask therapy, active surveillance, functional appliances, myofunctional therapy, habit-breaking appliances and space maintenance **(Table 5)**. Overall, most children showed a favourable response: 58% were classified as improved and a further 9% as greatly improved, while 18% remained stable under surveillance and 15% showed no significant change; among actively treated children, 82% were improved or greatly improved. The association between risk tier and clinical outcome was statistically significant ($p<0.001$) **(Table 6)**.

Table 1: Demographic and baseline clinical characteristics of the cohort (n = 100)

Characteristic	Value
Sex, male : female	53 (53%): 47 (47%)
Mean chronological age (years)	8.8 ± 1.8 (range 6.1–11.9)
Mean dental age (years)	8.8 ± 1.8
Angle Class I	40 (40%)
Angle Class II division 1	28 (28%)
Angle Class II division 2	13 (13%)
Angle Class III	19 (19%)
Any crossbite present	52 (52%)
Mean overjet (mm)	3.2 ± 3.2
Mean crowding (mm)	4.5 ± 3.0
Risk tier (low : moderate : high)	33:33:34

Values are n (%) or mean ± standard deviation.

Table 2: Change in occlusal severity (PAR index) over the 12-month interval

Comparison	Baseline	Follow-up	p-value
Mean PAR score (whole cohort)	26.6 ± 7.6	15.9 ± 6.2	<0.001*
Mean overjet (mm)	3.2 ± 3.2	2.9 ± 1.8	0.43
PAR reduction, treated (n=82)	—	45.6 ± 17.8%	<0.001*
PAR reduction, surveillance (n=18)	—	1.8 ± 3.9%	

Wilcoxon signed-rank test for paired scores; Mann-Whitney test for treated versus surveillance
** indicates a significant difference at $p \leq 0.05$.*

Table 3: Mean PAR reduction by precision risk stratification

Risk tier	Mean PAR reduction (%)	SD	n
Low	20.5	24	33
Moderate	49.2	17	33
High	43.2	19	34

Kruskal-Wallis test, $p < 0.001$ across tiers

Table 4: Mean PAR reduction by appliance / protocol compliance

Compliance	Mean PAR reduction (%)	SD	n
Poor	15.2	7.3	12
Fair	30.9	9.4	34
Good	43.5	26	32
Excellent	51.9	29	22

Kruskal-Wallis test, $p < 0.001$ across compliance categories

Table 5: Distribution of assigned early-intervention modalities

Intervention modality	n (%)
Rapid palatal expander	29 (29%)
Facemask / reverse-pull headgear	18 (18%)
Active surveillance	18 (18%)
Functional appliance (Twin Block)	12 (12%)
Myofunctional therapy	11 (11%)
Habit-breaking appliance	8 (8%)
Space maintainer	4 (4%)

Active surveillance denotes monitoring without an active appliance

Table 6: Distribution of clinical outcomes at 12 months

Outcome category	n (%)
Improved	58 (58%)
Monitored – stable	18 (18%)
No significant change	15 (15%)
Greatly improved	9 (9%)

Association between risk tier and outcome, chi-square test, $p < 0.001$

Discussion:

The present analysis showed substantial improvement in occlusal severity over 12 months, with greater PAR reduction among actively treated children than those under surveillance.

This supports the principle that early orthodontic treatment should be directed toward children with a clear potential for benefit rather than applied uniformly **[6].** The progressive improvement across risk tiers further supports risk-based treatment selection, with moderate- and high-risk children showing greater benefit than low-risk children managed conservatively. Such an approach is consistent with evidence that treatment effectiveness depends on the type and severity of the developing malocclusion **[7]**. The strong association between appliance compliance and PAR reduction emphasizes adherence as an important determinant of orthodontic treatment response. Patient cooperation and appliance wear remain particularly relevant during removable-appliance therapy, where inadequate compliance can substantially compromise treatment effectiveness **[8].** Treatment timing within the mixed-dentition phase was not significantly associated with outcome in this cohort. Evidence from Class II malocclusion indicates that early two-phase treatment provides limited additional occlusal benefit compared with later single-phase treatment, although early intervention may reduce the risk of incisor trauma **[9]**. Conversely, timing may be more important for specific skeletal discrepancies. Early facemask therapy for Class III malocclusion can improve skeletal and occlusal relationships, showing that treatment timing should be individualized according to malocclusion characteristics and growth potential **[10]**. The frequent use of rapid palatal expansion in the present cohort is consistent with its established role in managing transverse maxillary deficiency and posterior crossbite. Orthopedic expansion during growth can produce favorable transverse changes, although treatment response varies with skeletal maturity and clinical presentation **[11]**. The findings also support the increasing role of personalized and data-driven orthodontics. Artificial intelligence and digital orthodontic technologies are increasingly being investigated for diagnosis, treatment planning, growth assessment and prediction of treatment outcomes, potentially improving consistency in clinical decision-making **[12,13]**. Given the substantial prevalence of malocclusion among children, structured risk assessment may help prioritize patients who are most likely to benefit from early intervention while avoiding unnecessary treatment in low-risk individuals **[14, 15]**. Several limitations should be considered. The dataset was a simulated cohort developed for methodological and teaching purposes; therefore, the reported effect sizes should be considered illustrative rather than definitive clinical evidence. The 12-month follow-up also prevents assessment of long-term stability, subsequent comprehensive treatment requirements and relapse. In addition, risk categories and compliance levels were predefined rather than externally validated and residual confounding between risk, treatment selection and compliance cannot be excluded.

Conclusion:

Risk-stratified early orthodontic intervention was associated with meaningful improvement in occlusal severity, particularly among actively treated children. Treatment response was greater in moderate- and high-risk children and increased progressively with appliance compliance, whereas treatment timing within the mixed dentition showed limited influence. Thus, data support individualized, compliance-focused intervention as a potential strategy for predictable outcomes, although prospective clinical validation is required.

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