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Research Article

Comparative Effectiveness of Clear Aligners Versus Fixed Appliances for Mild to Moderate Crowding

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Abstract: Clear aligner therapy (CAT) has rapidly expanded as an aesthetic alternative to fixed orthodontic appliances (FA) in treating mild to moderate dental crowding. Despite increasing clinical use, comparative experimental evidence evaluating treatment effectiveness, duration, and patient-centered outcomes remains limited. The objective of this randomized clinical trial was to determine whether clear aligners achieve comparable alignment correction to fixed appliances in adults with mild to moderate crowding and to assess associated differences in treatment duration, pain experience, and oral health changes.

A total of 120 adult participants (18–35 years; Little Irregularity Index 3–7 mm) were randomized equally to CAT or FA groups. The primary outcome was reduction in irregularity measured from baseline to treatment completion. Secondary outcomes included treatment duration, pain at 14 days assessed by a Visual Analogue Scale (VAS), and periodontal indices. Data were analyzed using independent-samples t-tests and chi-square tests with $\alpha = 0.05$.

Mean reduction in irregularity was statistically similar between groups (4.30 ± 0.88 mm vs 4.39 ± 0.91 mm; $p > 0.05$), indicating comparable effectiveness. Clear aligner treatment showed significantly shorter mean treatment duration (8.4 ± 1.7 months vs 12.1 ± 2.3 months; $p < 0.001$), lower early pain scores (3.4 ± 1.2 vs 6.2 ± 1.8; $p < 0.001$), and improved periodontal indices at interim assessments.

These results suggest that clear aligners are as effective as fixed appliances in correcting mild to moderate crowding while providing advantages in patient comfort and treatment efficiency. **Keywords**: clear aligners, fixed appliances, dental crowding, orthodontic treatment, treatment effectiveness.

Introduction: Dental crowding — a discrepancy between tooth size and dental arch length — is one of the most common malocclusions encountered in clinical orthodontic practice worldwide. This condition can compromise oral function, exacerbate plaque retention, contribute to gingival inflammation, and negatively

influence esthetics and psychosocial well-being. Traditionally, fixed orthodontic appliances (FA), consisting of bonded brackets and archwires, have served as the gold standard for aligning crowded dentition. FA enables three-dimensional control of tooth movement, allowing precise biomechanics for a variety of malocclusion severities. Over decades, refinements in bracket design, wire alloys, and auxiliary mechanics have optimized the capacity of FA to correct crowding and other malocclusion components with predictable outcomes.[1-4]

Despite the robust track record of FA, several limitations have been identified. Fixed appliances are often associated with greater discomfort due to bracket-wire irritation, challenges in maintaining oral hygiene, and increased incidence of enamel decalcification during prolonged treatment. These factors can adversely affect patients' quality of life and compliance. Furthermore, FA requires frequent clinical adjustments, potentially increasing chair time and appointments. In response to demands for more aesthetic and patient-friendly options, clear aligner therapy (CAT) has become increasingly popular, particularly among adults and treatment-seeking individuals who prioritize discretion and comfort.[5-8]

Clear aligners are a series of custom-fabricated, removable thermoplastic trays designed to apply controlled forces to teeth in a planned sequence of movements. Their design leverages digital scanning, computer-aided treatment planning, and incremental aligner fabrication to achieve incremental tooth movement. Although initially introduced primarily for mild to moderate crowding cases, accelerations in material science and digital planning software have expanded the indications for CAT. Nevertheless, rigorous experimental evidence comparing clear aligners to fixed appliances in real-world clinical settings remains limited, particularly for adult populations with mild to moderate crowding.[9-12]

Recent clinical trials and comparative studies suggest that CAT might achieve alignment outcomes comparable to FA in mild to moderate crowding cases, with potential advantages in comfort, periodontal health, and treatment efficiency. For example, recent randomized trials in adult cohorts reported similar improvements in tooth irregularity indices between clear aligners and fixed appliances, indicating that both modalities can effectively correct mild to moderate crowding when properly selected and executed. In those studies, clear aligners demonstrated shorter overall treatment durations, reduced early pain perception, and higher patient satisfaction scores compared with FA, while maintaining similar endpoint alignment measures. These observations, though promising, underscore the necessity for rigorously designed clinical trials with adequate sample sizes and standardized outcome measures to definitively elucidate comparative effectiveness and ancillary benefits.

The growing body of evidence also highlights important considerations in evaluating orthodontic effectiveness. Measures such as Little's Irregularity Index and Peer Assessment Rating (PAR) provide quantitative assessments of arch alignment and occlusal outcomes that can be used to compare different treatment modalities objectively. Secondary outcomes including treatment duration, pain experience, periodontal health changes, and early complications (such as enamel decalcification) offer critical insights into the broader impact of appliance choice on patient experience and clinical efficiency.

Despite advances in digital technology and aligner materials, debate persists regarding the relative performance of clear aligners versus fixed appliances. Some clinical data indicate that clear aligners may offer superior hygiene outcomes due to removability, potentially reducing plaque accumulation and associated gingival inflammation. Conversely, FA may provide superior control over complex tooth movements, such as torque expression or rotational adjustments of cylindrical teeth, prompting continued reliance on FA for more demanding cases. These biomechanical distinctions underscore the importance of case selection and the need for evidence that defines the boundaries within which each modality performs optimally.

Given this context, the present study was designed as a parallel-group, randomized clinical trial comparing the effectiveness of clear aligners and fixed appliances in treating mild to moderate crowding in adults. By focusing on clinically relevant outcomes — including alignment correction, treatment duration, pain perception, and periodontal indices — this investigation aims to contribute meaningful, practice-oriented evidence to guide clinical decision making. The central hypothesis was that clear aligners would achieve alignment outcomes comparable to fixed appliances while providing advantages in secondary patient-centered outcomes.

This study is situated within the landscape of recent research that questions and refines traditional treatment paradigms. As technology evolves and patient preferences for aesthetic and comfortable treatment grow, it is essential to rigorously evaluate how novel modalities such as clear aligners measure up against established standards. High-quality experimental evidence addressing these comparative outcomes is critical not only for clinicians and researchers but also for patients making informed choices about orthodontic care.

In summary, the correction of dental crowding remains a cornerstone of orthodontic treatment planning. While fixed appliances have historically been the mainstay of therapy, clear aligner systems have emerged as a compelling alternative, particularly for mild to moderate crowding. Thorough experimental comparisons — grounded in quantitative metrics and meaningful patient outcomes — are essential to delineate the relative merits and limitations of these treatment options, and to optimize appliance selection in line with individual needs and clinical objectives. The following sections outline the methodology and results of a randomized clinical trial designed to advance this evidence base.

Methodology: This study employed a parallel-arm, randomized clinical trial design to compare the effectiveness of clear aligner therapy and fixed appliance treatment in adult patients presenting with mild to moderate dental crowding at Killa Abdullah, Balochistan. Eligible participants were adults aged 18–35 years with permanent dentition and a baseline Little Irregularity Index between 3 and 7 mm in the mandibular anterior segment. Exclusion criteria included prior orthodontic treatment, systemic conditions affecting bone metabolism or periodontal health, active periodontal disease, missing or impacted permanent teeth, requirement for tooth extraction, craniofacial anomalies, or inability to comply with study protocols. Sample size estimation was performed using Epi Info software, targeting 80% power to detect a clinically meaningful difference of 0.5 mm in irregularity index reduction between groups with a 5% alpha error, yielding a required total sample of 120 participants (60 per

group). After obtaining verbal and written informed consent from all participants, baseline records were collected including intraoral scans, dental casts, periodontal indices, and pain assessment baselines. Participants were randomized to either the clear aligner group or fixed appliance group using computer-generated random sequences with concealed allocation. Clear aligner therapy consisted of digitally planned sequential aligners worn 20–22 hours per day with fortnightly tray changes, while the fixed appliance group received standardized pre-adjusted edgewise brackets with initial leveling and alignment followed by progressive wire sequences according to established clinical protocols. Outcomes were assessed at treatment completion by clinicians blinded to group assignment when feasible. The primary outcome measure was the change in Little Irregularity Index from baseline to post-treatment. Secondary measures included total treatment duration recorded in months, pain experienced at 14 days post-placement assessed via a 10-cm visual analogue scale, and periodontal indices including plaque and gingival bleeding at interim appointments. Data were analyzed using independent-samples t-tests for continuous variables and chi-square tests for categorical outcomes with significance set at $p < 0.05$. All ethical considerations including verbal consent procedures were documented in accordance with institutional review board guidelines, and participants retained the right to withdraw without penalty. The design ensured robust comparison of clinically relevant outcomes while maintaining standardized clinical protocols across groups.

Results

Table 1. Demographic and Baseline Characteristics (n=120)

Characteristic	Clear Aligners (n=60)	Fixed Appliances (n=60)	p-value
Age (years), mean ± SD	25.4 ± 4.1	24.9 ± 4.3	0.48
Gender (F/M)	32/28	30/30	0.68
Baseline Little Index (mm), mean ± SD	5.12 ± 1.15	5.16 ± 1.04	0.82
Baseline Plaque Index, mean ± SD	1.25 ± 0.36	1.27 ± 0.39	0.78

Table 2. Primary and Secondary Outcomes

Outcome	Clear Aligners	Fixed Appliances	p-value
LII Reduction (mm), mean ± SD	4.30 ± 0.88	4.39 ± 0.91	0.56

Outcome	Clear Aligners	Fixed Appliances	p-value
Treatment Duration (months), mean ± SD	8.4 ± 1.7	12.1 ± 2.3	<0.001*
Pain VAS (14 days), mean ± SD	3.4 ± 1.2	6.2 ± 1.8	<0.001*

Table 3. Periodontal Indices at Interim (6 weeks)

Index	Clear Aligners	Fixed Appliances	p-value
Plaque Index, mean ± SD	1.12 ± 0.30	1.45 ± 0.41	<0.001*
Gingival Bleeding Score, mean ± SD	0.85 ± 0.22	1.12 ± 0.29	<0.001*

*Statistically significant ($p < 0.05$)

LII reduction was similar between the aligner and fixed appliance groups, indicating equivalent alignment effectiveness. Treatment duration was significantly shorter and early pain scores were significantly lower in the clear aligner group. Periodontal indices at 6 weeks favored the aligner group, suggesting better early periodontal response.

Discussion: The present randomized clinical trial demonstrates that clear aligner therapy provides alignment outcomes comparable to fixed appliances in adults with mild to moderate dental crowding. The similarity in Little Irregularity Index reduction between the groups confirms that both modalities are capable of achieving clinically significant improvements in anterior crowding when planned and executed according to standardized protocols. This equivalence reinforces the notion that clear aligners are a viable alternative to fixed appliances for appropriate patient presentations, especially where cosmetic considerations are paramount.[13-14]

A significant finding of this study was the shorter mean treatment duration in the clear aligner group. This observation suggests that clear aligner protocols, with digital planning and planned incremental movements, may streamline the alignment phase compared to the conventional wire sequence adjustments characteristic of fixed appliances. Reduced treatment duration is an important clinical advantage, as it can lower the burden of prolonged orthodontic care, decrease cumulative risk for decalcification, and improve patient adherence.[15-17]

Early treatment pain, as measured by VAS scores at 14 days, was markedly lower in the clear aligner group. This reduced discomfort may be attributed to the gentler, more distributed forces applied by aligners compared with the initial heavy force events associated with bracket bonding and wire engagement in fixed appliances. Lower pain experience is likely to enhance patient satisfaction and compliance, contributing to a more favorable perception of orthodontic therapy.

Periodontal indices at interim assessment exhibited superior scores in the aligner group, which likely reflects the benefit of removable appliances on hygiene maintenance. The ability to remove aligners for brushing and flossing appears to mitigate plaque accumulation and gingival bleeding compared to fixed appliances, which inherently complicate effective hygiene practices. Improved periodontal health during early treatment phases may have long-term implications for oral health outcomes.[18-20]

Despite these advantages, it is crucial to acknowledge that the biomechanical capabilities of clear aligners may be limited in more complex tooth movements requiring torque control or significant rotational adjustments. In cases with higher complexity or extraction requirements, fixed appliances may still be preferred due to established capabilities in delivering intricate force systems. Accordingly, clear aligners should be considered within the context of case selection and specific movement requirements.

The current findings align with emerging clinical evidence that positions clear aligners as an effective option for mild to moderate crowding while offering ancillary benefits such as shorter treatment duration, reduced pain, and enhanced early periodontal outcomes. Such evidence helps refine clinical decision making in contemporary orthodontic practice, where patient preferences and quality-of-life factors increasingly influence treatment planning.

In summary, this study fills an important gap in comparative clinical evidence by providing robust experimental data on the performance of clear aligners relative to fixed appliances for mild to moderate crowding. The favorable outcomes associated with clear aligner therapy in this context support its integration into evidence-based practice, while underscoring the need for continued research on complex cases and long-term stability.

Conclusion Clear aligners and fixed appliances achieve equivalent alignment outcomes in mild to moderate dental crowding. Clear aligners offer shorter treatment duration and improved early comfort and periodontal status. This study supports clear aligner use for appropriately selected cases and highlights the need for future research on complex movements.

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