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Original Research Paper

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REVIEW ON THE SCIENCE AND CLINICAL PRACTICE OF IN-OFFICE ALIGNER

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ABSTRACT In-office aligner treatment has transformed from simple manual setups to a complex, practitioner-led digital discipline driven by advancements in CAD/CAM technology and 3D printing. This review article summarizes the mechanical and clinical methods of in-house fabrication, right from diagnosis to intraoral scanning and planning for a treatment including staging and emphasizing the shift toward a "combined shape- and force-driven" working principle of attachments and aligners. Biomechanical control is evaluated through moment-to-force ratios and the strategic application of composite attachments to overcome the inherent limitations of the plain thermoformed aligners.

KEYWORDS :

1. INTRODUCTION: The Evolution of Aligner Therapy

The use of removable appliances to guide tooth movement is rooted in the early 20th century, with Remensnyder (1926) and Kesling (1945) laying the conceptual groundwork. Kesling's "tooth positioning appliance" utilized manual setups,that was later streamlined by Sheridan's "Essix Tooth Moving System," which introduced thermoplastic foils for mild crowding.

The founding of Align Technology in 1997 integrated these concepts with CAD/CAM technology, allowing for the first virtual treatment planning via ClinCheck software. While outsourced systems dominated for decades, the advent of high-resolution 3D printing and sophisticated software like OnyxCeph has enabled a return to in-office fabrication since 1999. This shift allows the clinician to maintain complete control over the treatment path, providing immediate flexibility to modify staging or attachment design.

2. Biomechanical Principles of Aligner Therapy

Shape-Driven vs. Force-Driven Movement

Aligners primarily function through a shape-driven approach. The internal geometry of the aligner is slightly different from the current position of the dental arch (the setup increment). When seated, the appliance's shape forces the teeth into the predefined target position. Modern aligners augment this with composite attachments, moving toward a "combined shape- and force-driven" principle.

Mechanotransduction and PDL Response

When force is applied at the tooth-aligner interface, the roots deflect within the periodontal ligament (PDL). This creates mechanical strains that trigger mechanotransduction, a cascade of molecular reactions that leads to bone apposition and resorption. Optimal orthodontic force is estimated between 0.2 and 0.3 N/cm^2; forces exceeding this can cause hyalinization, which halts tooth movement and can lead to root resorption.

The Center of Resistance (CR) and Moments

To move a tooth bodily (translation), the applied force must pass through the Center of Resistance (CR). However, aligners apply force to the crown, which is eccentric to the CR. This naturally creates a tipping moment. To simulate bodily movement of tooth, attachments are placed are various locations which enable the aligner to provide counter-moment on the tooth and thus helping in translation.

3. Steps Involved for In-office Aligners Production

Figure 1

I. Intraoral Scanning

It helps to create a digital model by recording the teeth, gums, and bite of the patient using a handheld optical scanner. It replaces conventional alginate or silicone impressions and produces a highly accurate 3D model of the patient's dentition. These scans are then imported into treatment-planning software.

These scans provide high accuracy replication with immediate visualization facility and better storage options. Commonly used intra-oral scanners are 3Shape TRIOS, iTero, Medit i700 / i900, etc.

II. Digital Treatment Planning

This is the most important step involved, since the aligners will be fabricated according to the planning done in the software. A thorough knowledge of different types of attachments and staging is required for this.

Staging in aligner treatment is the planned sequencing of tooth movements into different steps to achieve efficient and predictable results. Compatible movements are performed together, while conflicting movements are separated into different stages. Proper staging improves aligner fit, anchorage control, and root movement, and reduces unwanted tipping or tracking errors. Well-planned staging shortens treatment time and increases the stability and accuracy of the final result. Fig.2 describes the movement synergistic and conflicting to each other..

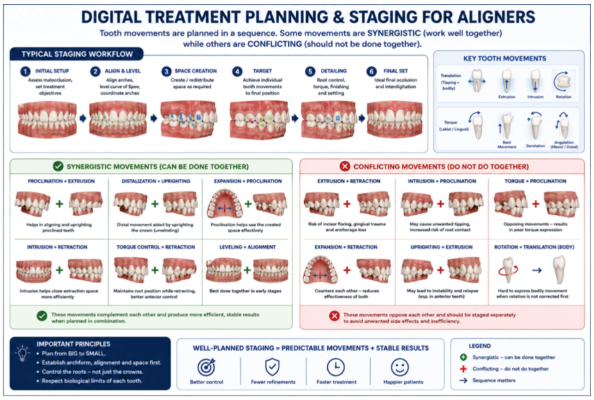

Figure 2

Attachments are composite resin bulks bonded to the enamel to increase the "grip" of the aligner and provide surfaces perpendicular to the desired direction of movement.

Cutouts are gaps in the aligner trays that serve specific purpose like bonding of buttons or auxillaries in the tooth or engagement of elastics. These are often required in the aligners to increase the surface area of the aligners and provide efficient tooth movement since aligners do not replicate the exact movements by itself in the oral cavity as it does in the software. Fig. 3 shows the list of attachments and cutouts along with their uses commonly used along with aligners.

Bonding of Attchments

- **Direct Bonding:** Attachments are modeled manually on the teeth before scanning, ensuring the aligner recognizes the attachment as part of the tooth geometry for a perfect fit.
- **Template Bonding:** A virtual attachment is designed, and a 3D-printed model is used to create a 0.4 mm thermoplastic template (e.g., Copyplast) to transfer the composite to the patient's teeth. Research suggests that high-viscosity composite provides the most accurate reproduction with minimal "flash".

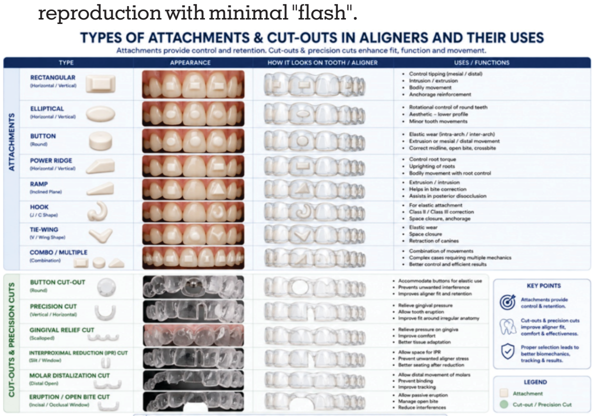

Figure 3

III. Printing 3D Models

After digital treatment planning and staging, the final tooth movements are exported as STL (Standard Tessellation Language) files. Each stage of movement is converted into a separate 3D model, which is printed and later used for thermoforming the aligners.

In orthodontic practice, DLP (Digital Light Processing) and LCD/MSLA resin printers are most commonly used because they provide high accuracy and smooth surface detail.

The usual printing materials are biocompatible model resins. They are dimensionally stable and suitable for vacuum or pressure thermoforming.

Printing time depends on the number of models and layer height. A single arch model usually takes 15–30 minutes, while 8–12 models for a full aligner series can often be printed together in 30–60 minutes on modern DLP printers (fig. 4). After printing, models are washed in isopropyl alcohol, dried, and post-cured for 5–15 minutes before aligner fabrication.

Figure 4

IV. Thermoforming the Aligners

After cleaning and drying the models, they are ready to receive the thermoforming sheets (fig.5) that will act as aligner trays in the thermoforming machines (fig. 6) The clinical success of an in-office system depends on the mechanical characteristics of the chosen polymer. The two most common materials are PET-G (Polyethylene terephthalate glycol) and PU (Polyurethane).

- **PET-G:** Featured in systems like Duran (Scheu Dental) and Biolon (Dreve), it is recognized for high transparency, ductility, and an E-modulus of approximately 2020–2200 MPa.
- **PU:** Used in systems like Invisalign (TPU) and Zendura, these materials often offer a different balance between stiffness and resistance to physical aging.
- **Multilayer Foils:** Newer materials like CA Pro (Scheu) combine hard and soft layers to provide a more constant force delivery.

Viscoelasticity and Stress Relaxation

Thermoplastic aligner materials are viscoelastic, meaning they exhibit properties of both fluids and solids. This leads to two critical phenomena:

1. **Stress Relaxation:** When a material is kept at constant strain (seated on the teeth), the force it exerts decays over time. Studies show a 50–80% force reduction within the first 24 hours of loading.
2. **Creep:** This is the gradual deformation of the aligner material under constant stress.

The rapid decay of force is significantly accelerated by the intraoral environment, specifically water immersion (saliva) and constant mechanical loading. This biomechanical reality necessitates a "restoring force" approach, where the aligner is changed every 7 to 10 days to maintain therapeutic force levels.

Physical Aging

As amorphous structures, these polymers exist in a non-equilibrium state. Over time, polymer chains rearrange to reach a lower energy state, a process called physical aging. Initially, saliva absorption can have a plasticizing effect, making the material softer; however, long-term exposure can lead to the material becoming harder and more brittle, increasing the risk of cracking.

Figure 5

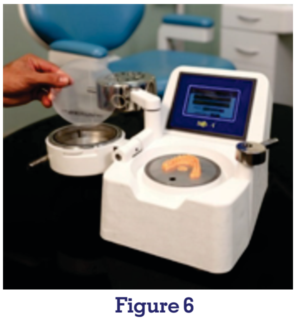

Figure 6

V. Case Selection and Planning Algorithm

Successful treatment begins with a comprehensive diagnostic algorithm:

1. **Functional Analysis:** Assessing the craniomandibular/musculoskeletal system. If TMD is present, treatment starts with established COPA (Craniomandibular Orthopedic Positioning Appliance) splints to find a therapeutic condyle position.
2. **Esthetic Analysis:** "Backward planning" where the finishing smile line and gingival levels are designed first.
3. **Biological Analysis:** Evaluation of periodontal and endodontal status.
4. **Structural Analysis:** Determining the final tooth positions to achieve a stable Class I relationship.

VI. Staging Strategies and Complex Movements

Small vs. Large Setup Increments

Two primary staging concepts exist:

- **Small Increments:** Movements of 0.1–0.2 mm per stage using aligners of uniform thickness (e.g., 0.75 mm).
- **Large Increments:** Movements of 0.5–0.75 mm per setup model using a graduated sequence of aligner thicknesses.

The 0.4/0.5/0.75 mm Sequence

Traditional sequences (0.5/0.625/0.75 mm) were found to risk periodontal overloading. Research now recommends a novel sequence:

- **0.4 mm (Soft):** Serves as a "leveling" aligner, reducing initial loads by 35–45%.
- **0.5 mm (Medium):** Continues the movement.
- **0.75 mm (Hard):** Finalizes the expression of the setup increment.

Sequential Distalization and the "Caterpillar" Design

To manage extraction spaces or Class II corrections:

- **Sequential Distalization:** Moving the second molar 50%, then starting the first molar, and so on, using Class II elastics for anchorage.
- **Caterpillar Motion Design:** In extraction cases, this sequentially moves canine segments then incisor segments to maintain anchorage and avoid the "bowing effect".

VII. Managing Tooth Size and Space: IPR

Interproximal Enamel Reduction (IPR) is a critical tool for creating space and managing Bolton discrepancies. Aligner software allows for the precise prediction of the required IPR amount. Clinically, it is used to:

- Treat mild to moderate crowding.
- Reduce "black triangles" by bringing contact points apically, allowing the papilla to fill the space.
- Improve anterior esthetics by reshaping teeth.

VIII. Functional Integration: Centric Relation and TMD

A unique strength of the in-office approach is the integration of the temporomandibular joint (TMJ) health into the digital plan.

- **Centric Relation (CR) Integration:** By using the DMD-System for real-time 3D tracking of condylar pathways, clinicians can visualize the functional joint space.
- **Virtual Mandibular Jump:** In growing patients, software can simulate the advancement of the mandible (similar to a Fränkel appliance) within the aligner stages.
- **COPA on Aligner:** For patients with acute TMJ pain, fixed splints (COPA onlays) are bonded to mandibular molars to maintain a therapeutic condyle position during the first phase of aligner treatment.

IX. Laboratory Fabrication: 3D Printing and Trimming

3D Printing Principles

- **DLP/SLA (Digital Light Processing):** Preferred for high accuracy and fine feature resolution.
- **FDM (Fused Deposition Modeling):** Cheaper but produces rougher surface finishes.
- **Resolution:** A vertical resolution of 50 μm is sufficient for aligner fabrication and attachment transfer.

Trimming and Retention

In-office aligners are typically left with a 2–3 mm straight margin above the gingival border. Studies show that this design significantly increases retentive force compared to scalloped margins. Thermoforming should be performed at a pressure of 6 Bar for optimal adaptation.

X. SUMMARY AND CONCLUSION

In-office aligner orthodontics provides the modern practitioner with unparalleled control over the biomechanical and functional aspects of treatment. Success depends on mastering the viscoelasticity of thermoplastic materials, implementing graduated staging sequences, and designing movement-specific attachments. By integrating functional joint analysis into the digital workflow, clinicians can ensure that "beautiful is what functions," prioritizing the long-term health of the temporomandibular and musculoskeletal systems alongside dental esthetics.

REFERENCES

1. Meikle MC. The tissue, cellular, and molecular regulation of orthodontic tooth movement. *Eur J Orthod* 2006.
2. Kesling HD. The philosophy of the tooth positioning appliance. *Am J Orthod Oral Surg* 1945.
3. Schupp W, Haubrich J. *Aligner Orthodontics and Orofacial Orthopedics.* Berlin: Quintessence Publishing, 2023.
4. Elkholy F, Lapatki BG. Recommendation of a novel film-thickness sequence (0.4, 0.5 and 0.75 mm). *J Aligner Orthod* 2018.
5. Cowley DP, et al. The effect of gingival-margin design on retention. *J Clin Orthod* 2012.
6. Simon M, et al. Forces and moments generated by removable thermoplastic aligners. *Am J Orthod Dentofacial Orthop* 2014.
7. Lapatki BG, Elkholy F. Biomechanical Aspects of Tooth Movement with Aligners. *In: Schupp/Haubrich Textbook.*
8. Nakao K, et al. Molecular mechanisms in human periodontal ligament after intermittent force. *J Dent Res* 2007.
9. Krey K, et al. Behaviour of monolayer and multilayer foils in the thermoforming process. *JAO* 2019.
10. Chang S, et al. Aligner therapy in treating bimaxillary dentoalveolar protrusion. *JAO* 2019.