Conventional Braces and Clear Aligners: An Evaluation of Outcome and Treatment

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I. Introduction

Conventional orthodontic treatment to treat a variety of malocclusions using wires, brackets, or ligatures has been around since 1770. Orthodontic materials were first developed in 1887 by Dr. Edward Angle, who used nickel alloy for its flexibility in wires. Different materials like copper, zinc, and 14-karat gold became more prominent and widely used for traditional orthodontic treatment. Stainless steel was introduced in 1929 and it gained popularity for its fracture resistant property under stress, and less costly than gold(1). In 1944, removable appliances started being used for mild and moderate tooth movements. Development of new research and technology in the late 20th and early 21st century brought CAD/CAM manufacturing, which has allowed the development of plastic orthodontics including Invisalign. ALIGN technologies, the proprietary company of Invisalign, was founded in 1997 and the FDA approval for Invisalign was presented in 1999(2).

There are many options of clear aligners available currently. Invisalign is the most popular clear aligner company and is unique due to their Smart track polymer system. This multi-layered polymer system replaces traditional aligner materials with a more elastic material, enhancing fit, comfort, efficiency. Invisalign aims to speed up tooth movement by 50% and increase precision by 75% compared to other materials(3). Furthermore, Invisalign also claims to resolve rotations of 40 degrees in upper and lower central incisors, 45 degrees in canines and premolars, 30 degrees in lateral incisors, and 20 degrees in molars. SureSmile, another aligner brand, uses Essix ACE Plastic, a thinner, singled layered material (4). SureSmile has shown studies that illustrate a reduced treatment time than the traditional, wire approach with improved quality. Another aligner brand is ClearCorrect, made out of a tri-layer material, two layers of polymers with an elastomeric inner layer. ClearCorrect aligners have shown force retention overtime, have kept its shape throughout the wear, and have exhibited durability and demonstrated 4x better tear resistance than single layer polymers(5).

Traditional orthodontic treatment usually consists of NiTi (nickel titanium) and Stainless steel wires. Stainless steel alloys offer resistance to corrosion, greater rigidity, and reduced friction. Stainless steel alloys also come in multi-stranded variations, which exhibit lower rigidity that allows them to be used in the early stages of treatment. NiTi alloys differ from stainless steel in their flexibility and shape memory, which allows them to revert to their original shape even with significant force(6). Thermodynamic NiTi alloys become activated under a certain temperature so it becomes easier to insert NiTi wires into bracket slots during application. Many activations under a specific temperature provide different advantages. For example, alloys activated under 27°C exert greater loads, working well in the oral cavity, where the temperature is around 36-37°C. Wires activated at 40°C are well-fit for patients with high sensitivity, as the wires undergo minimal activation during warm salt water mouth rinses(7).

Braces and clear aligners, both effective in orthodontic treatment, use different approaches to get desired outcomes.Orthodontic treatment seeks to correct malocclusions or bite problems. There are 2 common types of malocclusion, overbite and underbite. Overbite is a clinical condition where the maxillary teeth are angled forward covering the mandibular teeth(8). In an underbite, the mandible is extended out covering the tip of the maxillary teeth(9). Intrusion and extrusion are additional malocclusion issues that can be present. Intrusion refers to the downward movement of the tooth into the alveolar bone, and extrusion displacement of a tooth out of its alveolar housing(10). Additionally, there are 3 different types of malocclusion classes. Class 1 is crowding around

or spacing issues around the teeth. Class 2 is an overbite when the maxillary front teeth are positioned too forward protruding over the lower incisors. Class 3 is an underbite where the lower front teeth are positioned in front of the top front teeth(11). Figure 1 below demonstrates the three malocclusion classes discussed above. Overall gingival health is a big reason why orthodontic treatment is needed, as gingivitis and periodontal disease are common in patients before getting treatment (12) . In extreme cases orthognathic jaw surgery is needed for malocclusions, facial asymmetry, and problems with jaw growth(13).

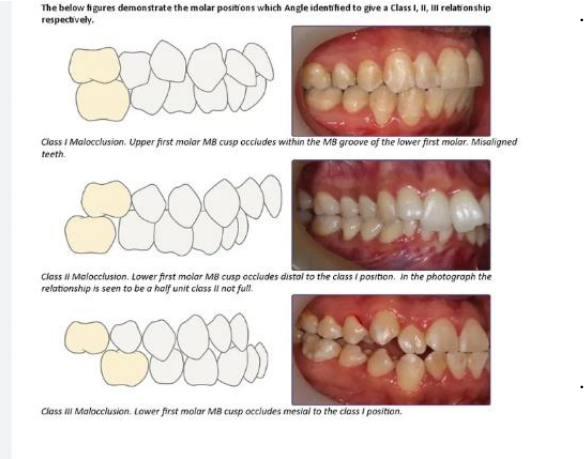

Figure 1- Illustration of class I, class II, and class III malocclusions. In Class II, maxillary teeth are positioned more anteriorly in comparison to mandibular teeth. In Class III, maxillary teeth are positioned more posteriorly in comparison to mandibular teeth.

During orthodontic movement the body goes through biological changes. During the initial phase, the teeth begin to shift, affecting the tissue around it and forcing the periodontal ligament surrounding the tooth to stretch and compress, which causes the blood vessels to leak, attract inflammatory cells, and recruit cells that help with bone remodeling(14). Throughout this process, gingival inflammation is present because of plaque build-up as wearing orthodontic devices makes it difficult to clean, especially in interproximal spaces. (15). Additionally, the dental pulp is affected during orthodontic treatment as pulpal tissue sits in hard tooth structure that is dependent on blood vessels passing through, any problem with blood flow and tissue pressure can affect dental pulp (16). As a result of orthodontic force, the periodontal ligament is affected as it undergoes a remodel with the breakdown of bone on the compressed side and the buildup of bone on the tension side (17). The metabolic state of the bone is influenced during orthodontic treatment, as bone turnover affects the rate of tooth movement(18).

II. Materials/Methods

This systematic review focused on the following question: In young adults in need of orthodontic treatment, which orthodontic appliance, traditional braces or clear aligners, will have the best outcome and treatment in the most effective way possible?

The definitions of population, intervention, comparison, and outcome (PICOs) were developed based on the focused question as follows:
Population: Young adults needing orthodontic treatment
Intervention: Traditional braces
Comparison: Clear aligners
Outcomes: Best outcome in the most effective way possible

Search strategies
An electronic search without time or language restrictions was conducted using Pubmed, Google Scholar, and other published articles. The reference lists of included studies and relevant reviews were also searched for other potential studies. The detailed search strategies were as follows: Orthodontics AND wires, wires AND brackets, clear aligners AND braces, Invisalign AND efficiency, periodontal status AND aligners, braces AND force, cost WITH clear aligners, oral hygiene AND traditional braces, mechanism AND clear aligners, ‘Quality of life’ with braces AND aligners, treatment AND braces,

III. Discussion

Orthodontic treatments, including clear aligners and braces use distinct mechanisms to straighten teeth. A major difference in mechanism between clear aligners and traditional wire is the force, elasticity, and angulation used. The force used with traditional orthodontic wire and clear aligners differs significantly. Clear aligners have two different systems, the displacement driven system and the force-driven system, as shown in figure 2. The displacement driven system is a method orthodontics uses to create a custom set of aligners to apply gentle pressure and shift the teeth overtime. The system guides simple movements of the teeth such as minor rotations or tipping. The system is less effective in complex movements and root adjustments. The force-driven system designs the aligners so they are able to apply force in targeted areas. In certain cases, the aligners will be altered with pressure points for more difficult tooth movements, such as intrusion and uprighting. In some cases, power ridges, which are strategically placed bumps on the aligner to exert precise forces on specific teeth will be used to control root torque and to get desired force on the specific area (19) (20). Additionally, the force and magnitude is determined on the configuration of the aligners, with each tooth receiving a certain magnitude and a type of force. Aligners designed with specific intrusion patterns show force exerted on different types of teeth such as, incisors, canines, and premolars. This variety of force application is helpful in correcting deep bite issues, as it affects how effectively aligners achieve the desired outcome for the teeth. Most aligners are made from a polyurethane plastic material which severely influences their mechanical properties and force distribution(21). Comparing elasticity, clear aligner materials have viscoelastic properties which have viscous and elastic materials. Invisalign uses a polymer called SmartTrack, which gives the aligners elasticity and produces constant forces which improves overall efficiency.

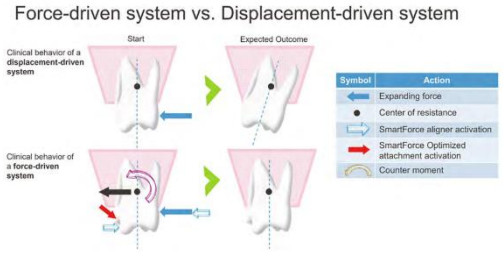

Figure 2: An illustration describing clear aligner force systems, the force driven system and displacement-driven system. The displacement driven system relies on physically moving teeth into new positions. The force driven system uses precise forces to move teeth in the desired position.

Orthodontic wires such as Nickel-Titanium and Stainless steel exert a great amount of force once applied. Friction is very influential on the force applied because it can determine the amount of force the wires exert. For example, stainless steel wires have lower friction rates which allows greater force to be released. Additionally, the low friction rates for stainless steel wires allows them to be less resistant to tooth movement compared to other alloys(22). Orthodontic treatment utilizes NiTi wires to achieve optimal results, considering factors like the degree of deflection, ligation techniques, and frictional forces to ensure the most effective force application for desired outcomes(21). A study done by Garner et al (22) observed that frictional forces between brackets and wires are greater with NiTi wires compared to stainless steel wires, but lower than those with beta-titanium wires, especially in zero torque or angulated brackets. Orthodontic wires like Niti and stainless steel have lower stiffness, making them flexible and more elastic. Due to the high yield strength and elasticity of stainless steel, stresses can severely impact the wire's elastic properties after bending. Therefore, heat treatment is used to relieve stress in stainless steel wires bent into arches, loops, or coils, thereby enhancing their elasticity. In NiTi the most beneficial characteristics are its springback and flexibility. NiTi's high springback is used in cases that need low forces but large elastic deflections. Also, it is commonly observed that NiTi wires exhibit more pronounced springback and higher revocable energy compared to

stainless steel or beta-titanium wires(22). Zirconia brackets are a type of orthodontic bracket made from zirconium oxide and gained its popularity because of its durability and appearance. They are mainly used when strong movements are needed but patients would like a more aesthetic treatment option. Zirconia brackets are highly resistant to staining and discoloration, making them a good option for patients who want them to be more discreet. They also exhibit superior mechanical properties such as higher fracture toughness and better performance under stress compared to ceramic brackets. Although, one of the challenges with zirconia brackets is their higher friction with orthodontic wires which can affect the efficiency of tooth movement(41).

During orthodontic treatment, the quality of life and pain throughout is a key factor orthodontists need to look for. For patients who need orthognathic surgery, studies show that clear aligners have a better quality of life outcome, and lower amount of pain after surgery than traditional braces. In the study by Patricia de Leyva (23), 2023, patients with dental deformities who underwent orthognathic surgery randomly received post-orthodontic treatment of either traditional braces or clear aligners. Quality of life was assessed through the Orthognathic Quality of Life Questionnaire and the Oral Health Impact Profile (23). Additionally, another study by Paula Coutinho Cardoso had a group of patients use invisalign and traditional braces(24). This study agrees with the most recent studies showing a greater incidence of pain when fixed appliances are used.

A key factor in orthodontics is the time the treatment takes to get the desired outcome. In many cases, aligners were effective in rapid orthodontic treatment. Rapid orthodontic treatment is an accelerated approach to straighten teeth and fix misalignments. A study by Dr. Edmund Khoo (25) shows a case of 3 patients who got micro-osteoperforation (MOPs) done, a technique to accelerate ortho movement. MOPs are created with tiny openings in the alveolar bone requiring movement typically under local anesthesia, without the necessity of lifting a tissue flap. These patients were treated with Invisalign. All three patients were satisfied with the outcome and stated that there was very little pain and felt mild gingival inflammation a day after the procedure(25). Three clinical studies showed that PAOO resulted in faster leveling and alignment compared to traditional orthodontic treatment, with accelerated percentages of 39%(246 days versus 402), 46% (171.9 versus 314 days), and 47% (74.5 versus 141.7 days) respectively for each study. Furthermore, two investigations demonstrated that PAOO accelerated the retraction of upper interior teeth, with acceleration rates of 44% (156 versus 441 days) and 61% (130.5 versus 234.1 days) (26) respectively. To achieve the desired outcome, it is very important to know which treatment with time efficiency is better. In cases not requiring rapid orthodontic movement, similar results are found in terms of timing for case completion. A study by Buschanga et al showed that during traditional treatment aligners took 11.5 months to achieve desired outcome while traditional braces took 17 months to fix malocclusions in the teeth (27). The factors included chair time, doctor time, and overall patient compliance. The time for the clear aligners was most likely shorter as it does not need a detailing or finishing phase, while traditional braces take up to 6 months for it. However, the American Board of Orthodontics objective grading system showed that the aligners did not correct malocclusions as well as braces did.

During orthodontic treatment it is very common for overall oral hygiene to be affected. In clear aligners compared with traditional braces, clear aligners facilitate better oral hygiene which improves periodontal status, decreases bleeding on probing and gingival inflammation(19). Traditional braces make it harder to clean those hard to reach spaces causing more problem areas(28). Clear aligners are significantly better at improving gingiva health, and more specifically periodontal disease, as patients have a greater ability to clean their teeth when the appliance is removed. However, traditional braces affect plaque removal, gingival heath, and makes gingivitis more prominent. The bands, elastics, brackets and wires in traditional orthodontic treatment carry bacteria which can then cause periodontal disease.

Studies have shown it is best to perform orthodontic movement after active periodontal disease has been treated. Orthodontic movement can enhance bacteria and cause periodontal inflammation. In clear aligners, caries can be affected as well. The biomaterials in clear aligners can result in a growth of bacteria associated with caries and the emergence. In traditional braces as stated before braces make it harder to clean the teeth, which causes caries to become more prominent from the bacteria in the mouth. White spot lesions are common to show up during orthodontic treatment in both clear aligners and traditional braces. Again comparing the two, many cases show that patients who have traditional braces get white spot lesions because fixed appliances promote bacteria, plaque build up and limit the ability to clean the teeth. Compared to aligners they have a much better success rate with white spot lesions, since they are more accessible to clean and bacterial plaque doesn't get missed while brushing. A study by de Leyva et al (23) compared bleeding on probing and probing depth. Clear aligners had significantly lower probing depth compared to traditional braces, and comparing bleeding on probing clear aligners only had 1 where traditional braces had 8 (23). Another study by Luca Levrini et al (28) compares bleeding on probing between clear aligners and traditional braces, which concluded that clear aligners had less bleeding on probing compared the fixed appliances(28).

After orthodontic treatment, patients with malocclusions treated with aligners showed significantly better results in treating the malocclusions compared to traditional braces. However, in a 6-month post-treatment period for aligners, more relapse was shown compared to traditional braces. Data gathered by Kaklamanos et al (29) showed that aligners for treatment may offer further advantages to the improved Oral Health-Related Quality of Life (OHRQoL) seen with orthodontic correction, compared to traditional treatment using conventional metal fixed appliances. These advantages could include enhanced comfort during sleep, eating, and social interactions, as well as increased self-esteem and overall satisfaction with oral health(29).Another study was done by Qiuying Li et al, yielding similar results on the Qol of braces and aligners(30). A study done by Di Spirito et al (31) showed after a 6 month period, clear aligners had a better periodontal status compared to traditional braces(31). Studies about rebound percentage of clear aligners and traditional braces are very limited. However, a study done by Papadimitriou et al,(32) shows how teeth alignment with clear aligners deteriorate quicker than with braces.This implies that the rebound rate would be higher in aligners than in braces(32).

The total material cost for clear aligners is calculated differently. The price range for aligner systems in the United States range from $2,650 and $7,000. More specifically, in Invisalign, the cost varies depending on how long the treatment will be. If the patient's treatment plan is 6-12 months, the average cost would be $2,650 – $6,000 (33). Traditional braces on the other hand are calculated with more specifics. For example, a big part in the cost is what type of braces the patient needs, traditional metal braces average cost is $3000-$5000, for ceramic braces average cost is $4000-$7000, and for lingual braces the average cost is $5000-$8000. In addition, home care throughout orthodontic treatment is essential to the success of treatment. In this study by Peter H. Buschang et al (27), he compared the time efficiency of aligners and braces. Aligners had 14 total appointments while braces had 19 (27). In the same study, the aligners group averaged one emergency visit while traditional braces averaged 3.5. In another study traditional braces took more chair time compared to aligners. And keeping in mind during this chair time the material costs also increase. On the other hand, total doctor time was more in aligners than traditional braces. As 25% of doctor time was over 33 minutes while traditional braces had 26 minutes. After finishing treatment, the corrections in the teeth were the patients who had aligners(19). Post Treatment after 3 years show how the alignment of teeth were worsening in the patients with clear aligner treatment compared to traditional braces(34).

IV. Conclusion

Clear aligners and traditional braces yield many differences in outcomes. In orthognathic surgery clear aligners demonstrated superior quality of life (Qol) outcome and reduced pain levels compared to braces(23). Regarding time efficiency, clear aligners had quicker results than braces, although after post treatment the alignment of teeth tended to deteriorate in patients who underwent clear aligner treatment (27)(34). In overall hygiene clear aligners had better outcomes with periodontal status, bleeding on probing, and inflammation(19). Traditional braces also promoted white lesions during treatment(23). In treating malocclusions clear aligners tend to yield better results than braces(29). Periodontal status was achieved in both braces and clear aligners, but clear aligners yielded better results. Caries were more prominent in traditional braces compared to clear aligners. Both braces and clear aligners offer effective solutions for orthodontic treatment, although clear aligners have several advantages. Clear aligners provide greater comfort, are less visible and are easier to maintain. Additionally, they result in quicker treatment times with better periodontal status compared to traditional braces. Also complying with patients' satisfied outcome. Therefore, those seeking a convenient and aesthetic orthodontic solution, clear aligners are the preferable choice.

A new method for making clear aligners by 3D printing them offers many benefits.3D printing allows for highly precise aligners, better fit, higher efficacy, and reproducibility.The process includes high-process 3D models creating aligners with a smooth surface finish, which is important for transparency and patient comfort. Companies like Modern Clear utilize advanced 3d printing technology to maintain quality and consistency. To add on, the ability to control the thickness and design of aligners allow for more customized treatment plans, which leads to better orthodontic outcomes(35). A study by Gianluca M. Tartaglia et al shows that 3D printed aligners offer superior accuracy, load resistance, and reduced deformation compared to traditional thermoformed aligners(37). A study by James Grant et al measures the amount of force and movement with 3D printed aligners(38). The study proposes one of the key benefits of 3D printed aligners is increased precision in manufacturing, allowing for better predictability of movement. Also, agrees with the previous study that 3D printed aligners achieved greater accuracy and load resistance(37). Despite the advantages of 3D printing aligners, there is not enough technical and clinical data regarding these aligners(38).

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