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Optimizing Contemporary Orthodontic Treatment using the 2×4 Appliance: A Narrative Review of the Techniques and Outcomes

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Abstract

With the new emphasis on timely management of malocclusions to avert the consequences of untreated malocclusion, interceptive orthodontics has both simplified, and eliminated the need for future intervention. The 2×4 appliance is a kind of fixed orthodontic appliance that is specifically indicated in the period of mixed dentition to address transitional dental problems such as anterior crossbites, open bites, deep bites, crowding, and rotations. This narrative review describes the uses, advantages, disadvantages, and the modifications of the 2×4 appliance. The databases of PubMed, Scopus, Cochrane Library, Google Scholar, and grey literature databases were searched for clinical trials, observational studies, and case reports/series looking in English using multiple searching terms. Out of 64 articles, 35 were relevant articles that screened, appraised and summarized in this review. The 2×4 appliance is indicated for mixed dentition patients who present with either mild or moderate malocclusions, especially when removable appliance compliance is a significant concern. Owing to their advantages, the usage of such appliance is recommended by orthodontists and pedodontists.

Keywords: 2×4 appliance, interceptive orthodontics, mixed dentition treatment, paediatric dentistry, orthodontic appliances.

Introduction

The mixed dentition phase occurs when the primary teeth develop into permanent teeth. This includes a consideration for the difference between malocclusions that need correction and those which can correct themselves naturally. The posterior and anterior crossbites, rotations, crowding, spacing, midline diastema, etc. are some of the most frequent malocclusions encountered at this stage (1).
To reduce the impact of a potential malocclusion, preventive intervention is imperative. One such case is cross-bite which is both self-perpetuating and progressive. If not corrected, it could lead to a skeletal malocclusion which may require comprehensive orthodontic and surgical intervention. Addressing these issues at an earlier stage could aid a child with self-esteem difficulties and eliminate the need for complex orthodontic treatment later in life (2).

Simple instances might require the use of fixed or moveable appliances for treatment. It might not be possible to bond fixed appliances to primary teeth, thus the 2×4 fixed appliance is utilized in their place. It includes buccal tubes or bands on the first permanent molars, orthodontic brackets attached to the erupted maxillary incisors, and continuous archwires. As it enables 3D control of the affected teeth throughout the treatment of anterior crossbites or aligning ectopic incisors, it presents more efficient and effective tooth positioning. This adaptable device can consequently be used to treat rotations, diastemas, and improper tooth inclinations and angulations in a short amount of time. Moreover, it could lessen the difficulty and length of any subsequent treatments in addition to immediately restoring anterior esthetics (3). Therefore, this narrative review aims to synthesize the current evidence on the uses, efficacy, and modifications of the 2x4 appliance, providing a clear rationale for its application in interceptive orthodontic care.

The 2×4 appliance

Definition

This fixed appliance consists of an archwire, brackets on the erupted permanent incisors, and bands or buccal tubes on the first permanent molars (4) (Figure 1).

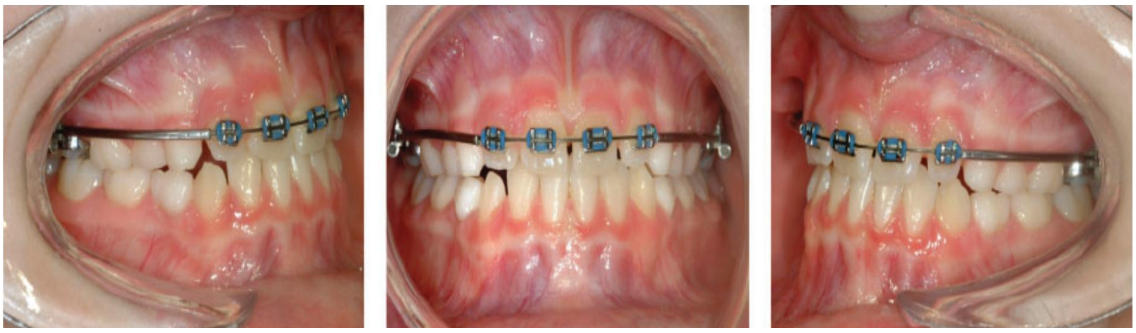

Figure. 1: The components of 2×4 appliance. Brackets on the anterior teeth, bands on the molars, archwire and supporting metal tube (4)

Advantages of 2×4 appliance

1. It effectively regulates the anterior dentition's three-dimensional tooth movement (tipping, translation, rotations, and torque) and helps to maintain a proper arch form (5,6).
2. It is simple to use, adaptable, and enables a quick and more predictable result in a single brief phase (4).
3. The patient or the parents do not need to alter this device because it is well-tolerated (7).
4. It could be modified, for example, by adding wire loops for supporting band elastics (particularly helpful for later traction of ectopic or impacted permanent maxillary cuspids), or by adding open-coil springs to the dental arch to create space (8).
5. Needs only a single visit (4,9).
6. No laboratory facilities are involved in many cases (5,10,11)

7. Does not negatively influence the patients' normal speech (12).
8. It reduces teasing and bullying, resulting in enhanced self-esteem along with psychosocial health and self-image of the patient (9).

Disadvantages of 2×4 appliance

Many studies listed down the following disadvantages (4,8,9,13-15):

1. In the future, the patient might require a second stage of orthodontic treatment.
2. Limited anchorage.
3. Brushing or eating could cause the distally extended archwire behind the molar tubes to become loose.
4. Skeletal malocclusions and improper intermaxillary connections cannot be fixed with this approach.
5. In contrast to orthopedic removable appliances, it cannot change insufficient oral muscle patterns.
6. It is unfitting for primary dentition.
7. Compared to the removable appliance, it takes longer chairside time for fitting (such as bracket bonding and enamel etching).
8. Development of carious and white spot lesions due to poor oral hygiene.
9. It might be difficult to place the molar band if the permanent molar has not fully erupted or if the clinical crown height is too short.
10. When the band is put on, a few children might feel uncomfortable and refuse further treatment.

Indications of 2×4 appliance

The major uses of 2×4 appliances could be summarized as followed (4,8,13,16):

1. Treatment of crossbites both anteriorly and posteriorly.
2. Managing ectopically erupted or impacted permanent incisors.
3. Closing median diastemas or abnormal spacing.
4. Correcting anterior teeth crowding and mild rotation.
5. Correction of vertical problems.
6. Torquing of anterior teeth.

1- Treatment of anterior/ posterior crossbites

Throughout the early years of a child's oral development, anterior crossbite is frequently a significant functional and aesthetic problem (17). According to an axiom in orthodontics, "the best time to treat a crossbite is the first time it is seen" (18,19)

In order to prevent the problem from developing into a true class III malocclusion in future, early intervention of anterior crossbites was strongly advised. (12,20) Several wire-bending and force-delivery techniques can be employed with the 2x4 appliance, with the choice depending on the specific malocclusion and anchorage needs (1)

Because it permits the protrusion of upper incisors, the 2×4 appliance is widely used to address crossbites in mixed dentition (12). In cases of functional crossbites, it is essential to first remove any early contacts between opposing teeth (11,14).

In comparison to traditional removable devices, it has a strong action and could deliver lighter continuous forces to correct anterior crossbites (13,19). Thus, it could produce good results in a short period of therapy (5,10,20). The procedure was involved inserting

a series of straight Nickel-Titanium (NiTi) and stainless steel archwires with a bite raiser (4,21) as shown in Figure 2.

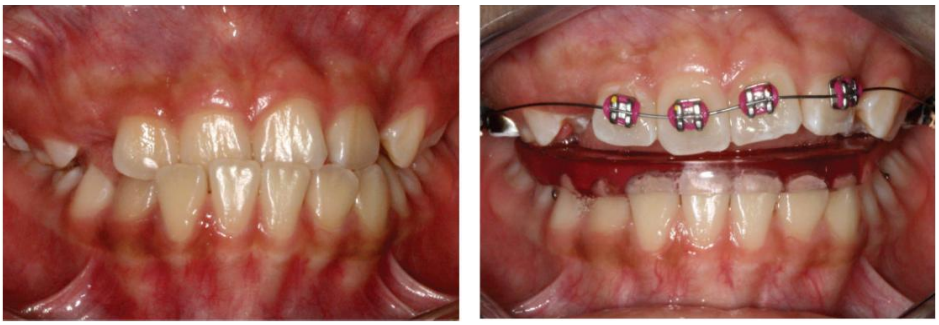

Figure. 2: Management of anterior cross bite of the maxillary incisors using 2×4 appliance and bite plane. The left photo is before treatment and the right photo is during treatment (21)

Alternatively, the orthodontist can use the wires in the manner that follows: The starting phase is tooth alignment with the NiTi archwire, followed by insertion of a 0.016 or 0.018 inch stainless steel archwire housing omega loops mesial to the first molars. These loops may be activated in order to procline anterior teeth (22,23) as seen in Figure 3.

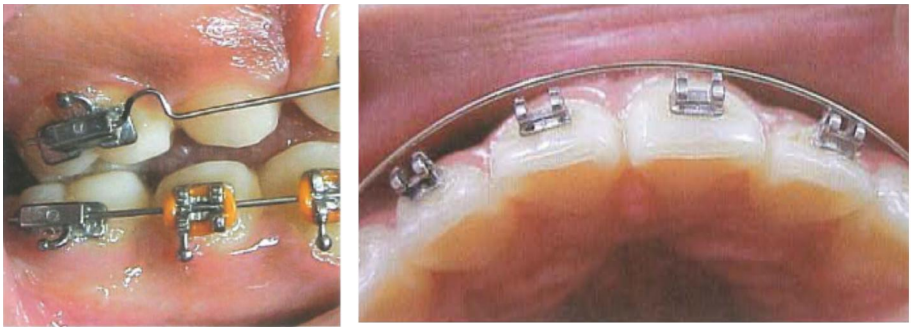

Figure. 3: Management of anterior cross bite of the maxillary incisors using 2×4 appliance. The photo in the left side shows the omega loop in front of the first molar. The photo in the right shows the active form of the wire (22)

Metal stoppers can be used with an NiTi archwire, placed mesial to the permanent molars, so that the archwire will be 1-2 mm anterior to the brackets of the anterior teeth and will be tied into the slots either by elastic or metal ligation (23).

Omega loops or helices can be also be bent bilaterally just distal to the lateral incisors and the activation would be the same as previously described by pulling the wire until it is located 1-2mm in front of the incisor brackets, and then secured into the slots and ligated with ligature elastics (24,25). An open coil spring would be placed between the molars and incisors, or into the 2-3 mm space of the steel or plastic tube and the incisors, if more space is required for incisor proclination as clearly illustrated in Figure. 4 (26). While omega loops provide controlled proclination, the use of open coil springs is indicated when significant space creation is required prior to alignment.

Class III elastics could also be used with a 2×4 appliance to retrocline the mandibular anterior teeth and procline the maxillary anteriors to assist correct an anterior crossbite (Figure. 5). A quadhelix might be added to the 2×4 appliances in situations of posterior crossbites in the case when maxillary expansion is necessary (Figure. 6). If simultaneously correcting a posterior crossbite is necessary, it could be soldered to molar bands or palatal sheaths that have been welded to provide a removable quadhelix (4,27).

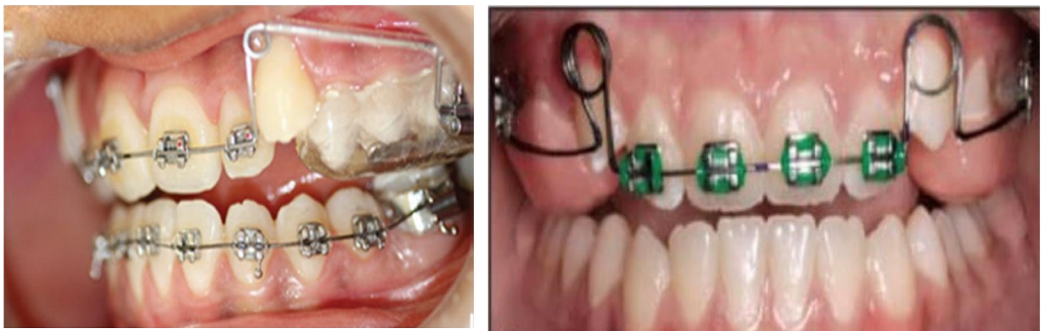

Figure. 4: Treatment of anterior cross bite with 2×4 appliance. A 0.017×0.025-inch beta Titanium archwire with bilateral helices in addition to bonded hyrax (24) in the left photo, or posterior bite plane (25) in the right photo.

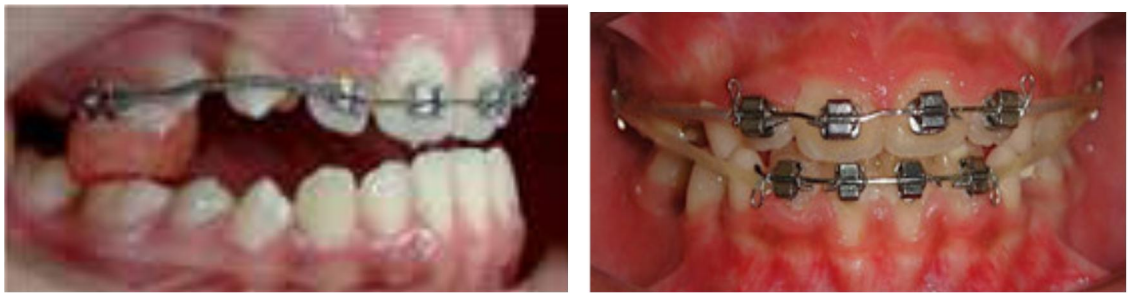

Figure. 5: Treatment of anterior cross bite with 2×4 appliance and active NiTi push coil spring on the left side (26), or using class III elastics on the right side.

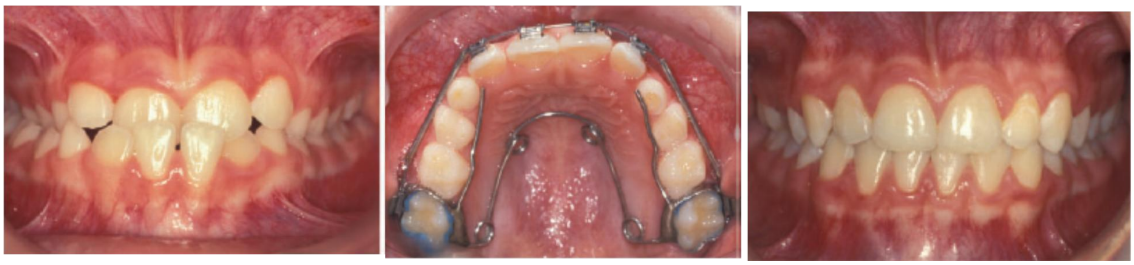

Figure. 6: Management of anterior and posterior cross bites using 2×4 appliance. The left photo is before treatment, the middle photo is during treatment showing the 2×4 appliance and the quadhelix, the right photo is after treatment completion (4)

2- Managing ectopic or impacted upper permanent central incisors

The correction of ectopic or impacted permanent incisors is another early sign of the 2×4 appliance usage. Once the etiological component was determined, it might be essential to make the space for the impacted tooth to be properly repositioned in its proper position in the dental arch (4) .Following space creation with an open coil spring, a heavy stainless steel archwire is inserted to provide anchorage. Traction is then initiated using a power chain from the impacted tooth's attachment to the archwire.

In comparison to removable appliances, the 2×4 appliances could readily execute a careful space opening by precisely controlling the amount and vector of the traction force (27). In this regard, Das and colleagues (28) have identified the determining factors that must be taken into consideration for the effective alignment of an impacted incisor with the appliance namely: the direction and position of the impacted tooth, the severity of root dilacerations, the level of root development, and the presence of enough space for the impacted incisor.

When enough space was created and prior to the traction of the incisors, heave gauge stainless steel archwire was tied back to retain arch shape and space for the impacted incisor was opened using push coil spring. Light elastics such as elastic power chain, metal ligatures, and auxiliary wire can be applied to achieve traction (4) as shown in Figure 7.

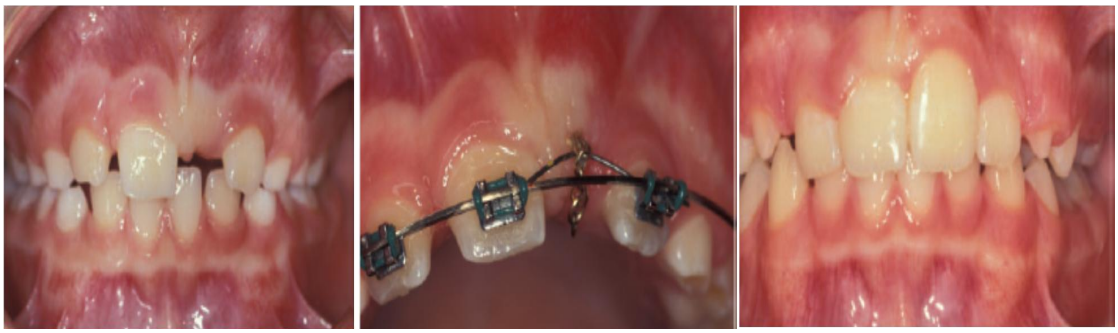

Figure. 7: Management of impacted maxillary left central incisor using 2×4 appliance. The left photo is before treatment, the middle photo is during treatment showing traction of the impacted tooth with piggy-back technique, the right photo is after treatment completion (4)

3-Closing median diastemas or abnormal spacing

After the local cause of diastema has been removed, a sectional 2×4 appliance could be inserted to better manage space closure as well as the leveling and alignment of the upper incisors. As indicated in Figure 8, closing loop wire, elastomeric chains between brackets, push coil springs, and micromagnetic devices are occasionally included to help with space closure (22,29).

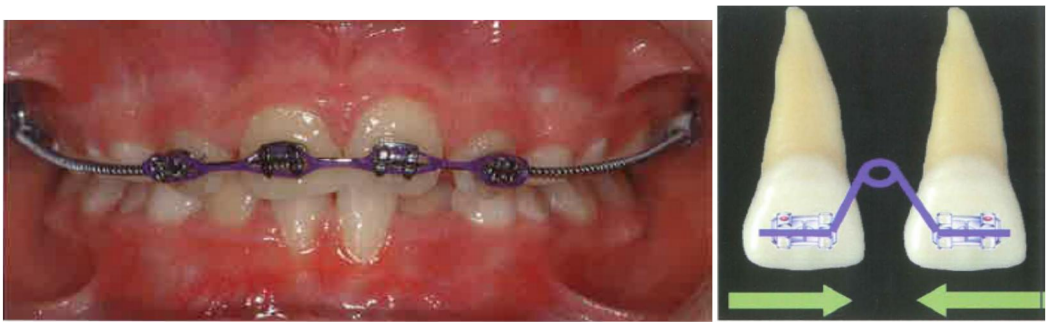

Figure 8: Closure of anterior spaces and median diastema using power chain and push coil as shown in the left photo or closing loop wire as shown in the right photo (22)

The orthodontic treatment for closing the midline diastema in mixed dentition was divided into three categories: treatment which involved bodily movements of the two central incisors, treatment which involved mesial tipping of incisors' crowns only, treatment involving a reduction of increased overjet and overbite by retraction and intrusion of the upper teeth (30).

The treatment option would depend on the initial angulation of the incisor, ugly duckling stage, degree of overjet and overbite. Distally angulated incisors' crowns are indicated for removable orthodontic appliance as tipping movement is provided in contrary to the mesially angulated incisors' crowns. On the other hand, ugly duckling stage needs no treatment as it is a usual phenomenon. The degree of overjet will determine the choosing of the traction method (power chain or push coil spring) (23).

With consideration to the erupting maxillary canines to mitigate a root resorption issue during space closure, swabbing the brackets of the lateral incisors to create mesial movement of the roots, is a recommended step (31).

Managing the anterior spacing with minimal to no overjet will certainly be more challenge. In this situation, a push coil spring which is inserted between the brackets of the lateral incisors and the bands on the molars is indicated. On the other hand, if there is a pronounced overjet, then a power chain may be used to close the space. Spacing with excessive overjet and/or overbite can be treated with double-helical loops in either steel or beta titanium arch wire of 0.017×0.025-inch with or without a step (22).

4- Correcting anterior teeth crowding and mild rotation

The 2×4 appliance can be used to manage mild anterior teeth crowding and rotation by delivering sequential NiTi then steel archwires (Figure 9), other cases may also involve interproximal enamel stripping to create a space for movement. The most important element in treating this type of malocclusion is exerting light forces (4).

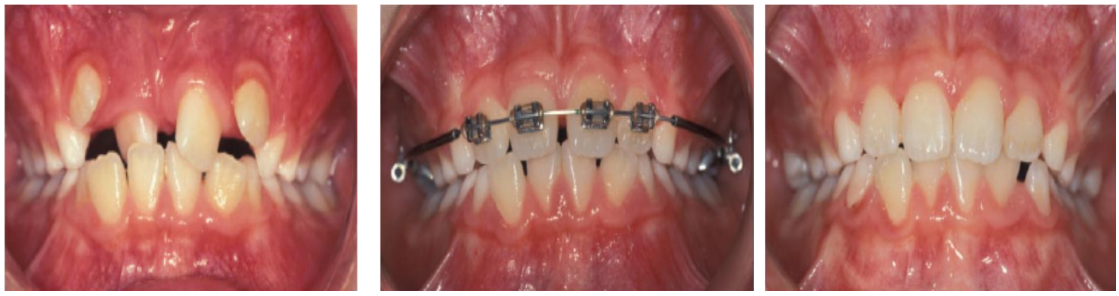

Figure. 9: Management of irregular and rotated incisors using 2×4 appliance. The left photo is before treatment, the middle photo is during treatment, and the right photo is after treatment completion (4)

5- Deep bite/ open bite correction

The vertical correction of the front teeth could be performed by 2×4 appliances called utility arch, continuous intrusion arch and Connecticut intrusion arch (32).

A. The utility arch

Dr. Robert Ricketts in the early 1950s developed the utility arch using 0.016×0.016-inch or 0.016×0.022-inch Blue Elgiloy wire to construct a lever system that will exert a constant force to the incisors. In spite of whether loops are present or absent, all utility arches share a common architecture that includes the incisal segment, posterior vertical segment, vestibular segment, and molar segments (33,34) as shown in Figure 10.

The utility arch is specifically indicated for deep bite correction requiring significant incisor intrusion and molar distalization, but its use is cautioned in cases with already proclined lower incisors.

Tip-back, cinch back and toe-in bends in the molar segment or an occlusally oriented gable bend in the posterior vestibular segment are used to activate it. On all anterior teeth, the utility arch will produce between 50 and 75 grams. This amount of force is thought to be perfect for incisor intrusion.

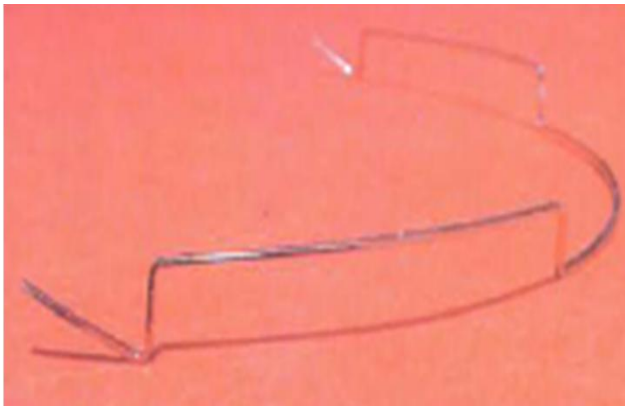

Figure. 10: Utility arch (22)

The combined result is a protrusion of the lower incisors, which may be torqued, along with a tipping back of the mandibular molars. In short face cases, the lower incisors' intrusion will help to rectify the deep bite and the molar's distal tipping, which will help to open the bite. A labial crown torque will be exerted as the wire engages the incisor brackets through the active arch as the force is applied anteriorly to the center of resistance (Figure 11).

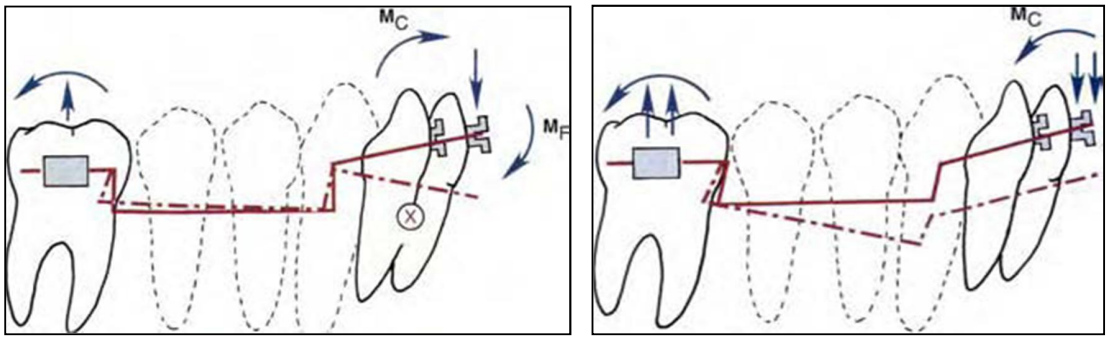

Figure. 11: Activation of the utility arch will cause distal crown tipping and extrusion of the first molar and intrusion of the mandibular anterior teeth with proclination (left photo). To overcome this proclination either bend the wire behind the last molar or apply lingual crown torque on the mandibular anterior teeth (23)

This is desirable with proclined incisors, yet not with retruded lower incisors, thus compensating lingual crown torque must be added to the archwire to prevent this unwanted side effect. The molar part of the arch could be activated to cause molar rotation and to increase or decrease molar width (23).

Modifications made to this arch are somewhat useful in moving the mandibular incisors either forward or backward (Figure 12). Incorporating simple loops into the basic utility arch increases its utility as a force application system which outlines the 3D movement of the incisors and molars (34).

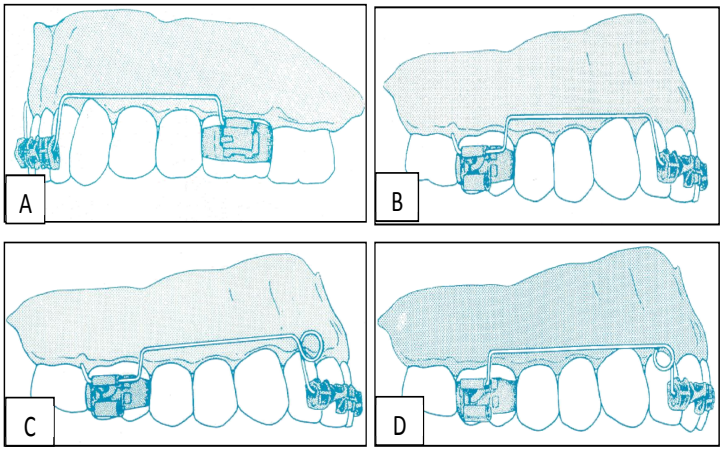

Figure. 12: Types of utility arch. A. Passive utility arch with posterior vertical step fitting snugly against the auxiliary tube of the maxillary first molar, B. Intrusion utility arch with posterior vertical step 5-8mm anterior to auxiliary tube on upper first molar, allowing slight retrusive activation, C. Retrusion utility arch with the loop anterior to the anterior vertical step is activated while the molar segment is retruded, and D. Protrusion utility arch with posterior vertical step fitting flush against auxiliary molar tube (34)

B. Burstone's continuous intrusion arch

It is either 0.016×0.022 or 0.017×0.025 inches beta titanium archwire which extends from an auxiliary molar tube to incisors, bypassing the premolars and canines to exert an apical (intrusive) force on the front teeth. This wire has a step bend located just distal to the lateral incisors and mesial to the molar tube (band). Only intrusive force is applied as the wire is carried down to the central or lateral incisors. A fairly strong anchorage unit, typically a 0.018×0.025-inch steel archwire or trans-palatal arch, connected the teeth of the posterior segment to control anchorage posteriorly (Figure 13). The cuspid is skipped by not bonding the cuspid bracket or by adding a tiny step in its area. The anterior teeth are held together for the incisor segment wire (35,36).

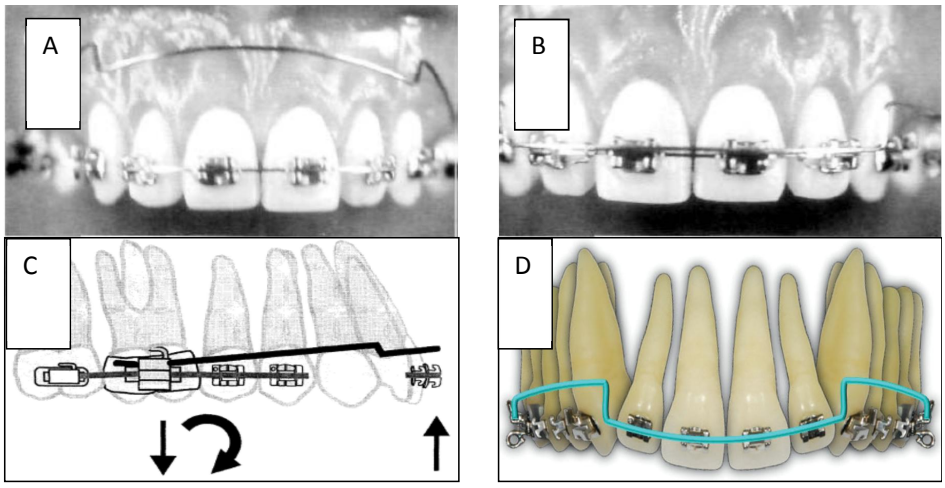

Figure. 13: Burstone's continuous intrusion arch. A. Frontal view in the passive form, B. Frontal view in the active form, C. and D. Biomechanical effects on the molar and incisors (34,35)

Control of the force system is essential for an intrusion to be effective. In particular, force magnitude, consistency, usage of only a single point application, control of force direction, and choice of an appropriate site for the force application must be carefully planned and provided. A force gauge could be used to calculate the magnitude of the force. The quantity and size of teeth affect how much force is applied. For instance, approximately 60 grams of force is applied for the four upper incisors during intrusion. The initial plane of occlusion must be maintained with using modest force and a stable anchorage device (32,35). Assuring that this arch will not be inserted into the incisor brackets to deliver pure intrusion force, but rather that a separate segment is implanted, is a particularly crucial factor in intrusion. The roots of incisors will move mesially, flare (due to palatal root torque), and intursion when the intrusion arch is inserted directly into the bracket slot. Therefore, the wire needs to be tied off at the lateral incisor brackets or pulled back toward the molar tube. To encourage incisor flare, the intrusion arch may be tied off between the central incisors in cases of class II division 2 where the maxillary incisors are retroclined. This helps repair deep bites and opens the bite in low angle cases. To prevent this adverse effect, trans-palatal arch or heavy gauge archwire engaging the second bicuspid bracket and both molar tubes is required since the moment created on the molars will be clockwise and lead to distal crown tipping and extrusion along with palatal crown tipping (35).

C. Connecticut intrusion arch

NiTi alloys were used to create the Connecticut intrusion arch (CIA), which Ravindra Nanda first described in 1998. This could be utilized to treat situations of occlusal canting, open bites, and deep bites. Beta Titanium archwire is used to create a modified Connecticut intrusion arch (37,38). According to Amasyali et al. (39), this wire combines utility arch and traditional intrusion arch properties. They are prefabricated wires that have the proper bends for simple insertion and use. The maxillary and mandibular variants of two wire sizes—0.016×0.022 and 0.017×0.025 inches—have anterior dimensions that are 34 mm and 28 mm, respectively (Figure 14).

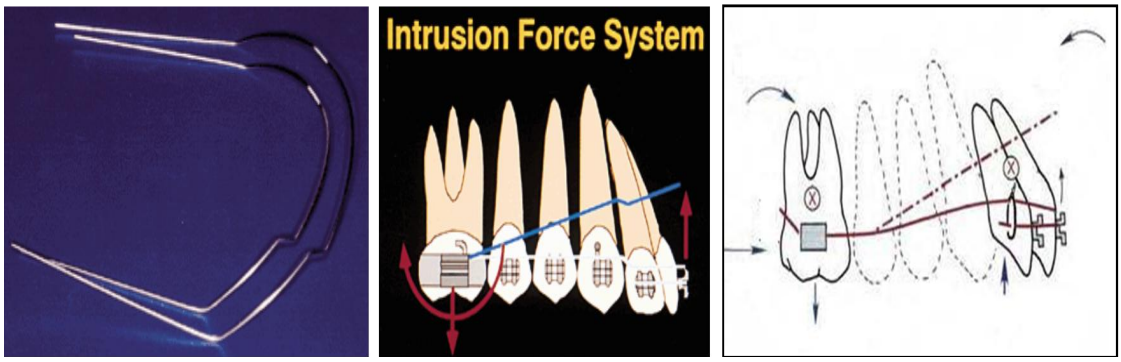

Figure. 14: The Connecticut intrusion arch in the left. The biomechanical effect of Connecticut intrusion arch on the molar and anterior teeth in the middle and right photos (23,37)

In order to accommodate for a variety of cases like extraction, non-extraction, and mixed dentition cases, the by-pass that is distal to lateral incisors is offered in two distinct lengths (32,37). A V-bend that is tuned to deliver between 40 and 60 grams of force serves as the fundamental force delivery mechanism. The V-bend is placed such that it is immediately in front of the molar brackets. A straightforward force system that consists of a vertical (intrusive) force in the anterior area and a moment in the posterior section will be created when the arch is triggered (37,38) as shown in Figure 14. The wire could be tightened behind the first molar to prevent this from happening. In the case when the intrusion arch is ligated in the area of lateral incisors, an intrusive force will be exerted. Under some circumstances, though, when it is tied between the central incisors, it will provide a downward intrusive force with concomitant incisor crown flaring (this is favorable when treating class II division 2 or upright incisors). It will permit long appointments as the wire will remain functional at a consistent force, for a very long time approximately removing the need for adjustments (37).

6- Torquing of anterior teeth

Placing torquing archwire is one technique for delivering torque to the anterior teeth. A 2×4 appliance with a V-bend located slightly distal to the lateral incisors' bracket serves as the torquing archwire (16). The extended span that results from placing the wire into the incisor and molar brackets, yet not the cuspid or bicuspid brackets gives a torquing arch its desired low load deflection rate feature. In the case when employing beta Titanium archwire, the V-bend does not need a helix, making the procedure more

contented for the patient. In the case when the wire has been tightened posteriorly, the anterior portion of the wire lies above to incisors, yet the force at the incisors is extrusive with palatal torque of the roots. As a result of cinching, the incisors' palatal torque will cause their extrusion and distal movement, as well as the molars' intrusion and mesial movement (Figure 15).

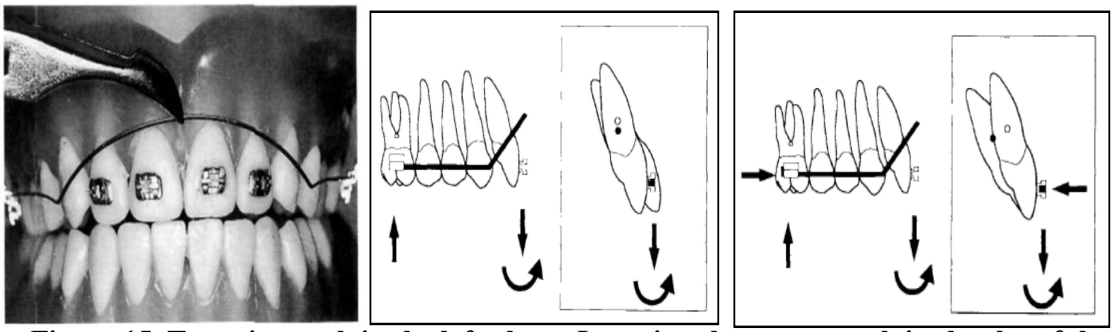

Figure. 15: Torquing arch in the left photo. Inserting the torque arch in the slot of the incisor brackets will cause palatal root torque, extrusion and advancing of the incisors with intrusion of the molar as shown in the middle photo. Cinching the wire behind the molar tube will cause palatal root torque, extrusion and distal movement of the incisors, with intrusion and mesial movement of the molar as shown in the right photo (16)

Certain incisor second-order rotations also take place as the torquing arch is kept in place for several months, and the roots will diverge distally. Once the torquing arch is eliminated, this is a result of the torsion in a 3D wire and may be fixed with a regular continuous arch wire (16).

Clinical recommendations and precautions

The initial diameter of the straight orthodontic wires used in the 2×4 technique should be thin to properly apply gentle, well-controlled, and continuous force across the incisors. These wires could slip or fracture, inflicting harm to the cheek. This issue could be fixed by (4):

1. A long, durable, stainless-steel tube or plastic sleeve that fills the entire gap between the first molar and the incisors is placed on the archwire. This tube protects the wire's lengthy, unsupported span from deformation brought on by occlusal forces.
2. The excess of the wire is annealed distal to the molar tubes and cinched against the tube, yet this technique averts the wire from sliding forward, potentially causing the first permanent molar to move forward unintentionally.

Supportive evidence for the 2×4 appliance

Three RCTs comparing the effectiveness of the 2×4 appliance and alternative appliances have been conducted. Collectively, these RCTs suggest the 2×4 appliance is a highly efficient and effective interceptive tool, achieving results comparable to other modalities, though primarily through dental rather than skeletal changes.

Gu et al. (40) examined the results of using a face mask and a 2×4 appliance to treat cases of false class III. They concluded that the level of overjet correction was comparable between the 2×4 and reverse headgear groups. While the reverse headgear group's overjet correction was caused by both dental and skeletal changes, the basic fixed appliance's overjet correction was caused by dental modifications.

Other study (20) examined the efficacy of removable and 2×4 appliances in treating cases with anterior cross bite associated with functional shift in mixed dentition and discovered that either appliances are successful, with the 2×4 appliance requiring much less time to treat patients.

da Silva et al. (41) have compared the performance and effectiveness of clear aligners and 2×4 fixed appliances to treat irregularities in the position of the maxillary incisors in mixed dentition. They concluded that for maxillary incisor position changes in the mixed dentition, there is similar efficiency and effectiveness between clear aligners and 2×4 mechanics. The selection of appliance must ultimately be made by the specialist and parents.

Two other clinical trials that were non-randomized aimed to compare efficiency of NiTi CIA with the utility arch (39) and with Beta Titanium CIA (38), and both studies demonstrated that all were effective to intrude the anterior teeth.

Amendments of 2×4 appliance

There are 2 modifications reported in the literature. One was described by Isaacson et al. (42) and Rebellato (43) and the called a 2×6 appliance as they utilized cuspids and the other was designated by Tsui et al. (44) , and referred to just the molars and the cuspid only to move the cuspid bodily, they pertained to the appliance as a 1×2 appliance (Figure 16).

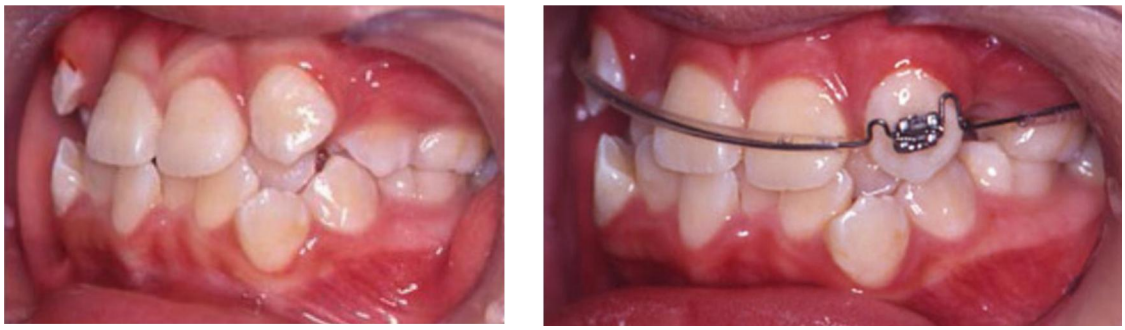

Figure 16. The modified 1×2 appliance (44)

Limitations

Still few studies exist regarding 2×4 appliances, so future high-quality studies with longer follow-up are needed to compare long-term stability against clear aligners and to quantify its impact on reducing comprehensive treatment needs. Also, national and international surveys comparing orthodontists, pediatricians, and general dentists similar to Quinzi et al. (45) can observe the prevalence of the use of the 2×4 appliance among those practitioners, and why, how they used it and their treatment length.

Conclusions

Accomplishing successful orthodontic treatment results depends upon the parents as well as orthodontist. Having parents recognize malocclusions at an early stage and diagnosing malocclusions at the correct age can create stability in treatment results. Parents should not wait until all permanent teeth to erupt anytime since many simple malocclusions can be corrected proactively. The 2×4 appliance is versatile, simple and effective and can intercept simple malocclusions as early as possible with sooner treatment duration compared to the traditional approaches. By not having to wait for all the permanent teeth to erupt, one can not only treat the malocclusions early but also can help the child improve their self-esteem at an earlier stage.

Declarations

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Ethics statement

The authors declare that the author approved that this research follows the journal's Attach Ethic Approval guidelines as appeared on the journal's author guidelines page.

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Author contributions
RAA and MN provided the concepts, data analysis, and writing of the manuscript; MN worked with data collection and analysis; RAA worked with data collection and analysis; MN revised the manuscript and analyzed the data.

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