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# Application of Skeletal Anchorage Devices in Growth Modification Treatments: A Literature Review

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**Abstract**

**Background:** One of the most important orthodontic treatments is the correction of maxillary and mandibular malformations in growing patients by guiding the patient's growth with the help of various appliances.

**Objective:** This study aimed to review the application of Temporary Anchorage Devices (TAD) in growth modification treatments.

**Methods**: A comprehensive search was conducted on PubMed, Scopus, Science Direct, Web of Science, and other relevant databases, using specific keywords and criteria to identify studies that evaluated the skeletal and dentoalveolar effects of skeletal anchorage devices in growth modification treatments.

**Results**: Studies were divided into four categories of application of TAD in the Treatment of Class II malocclusion, Class III malocclusion, sagittal, and vertical problems. The results of this study showed that treatment of most of the growing Class II patients was done by using mini-plates with fixed functional appliances like Herbst and Forsus. In some studies of treatment of Class III with maxillary deficiency, mini-plates were used with Class III elastics, in some other studies, the face mask was used with mini-plates. All these methods showed good results at the end of the treatment.

**Conclusion**: Bone anchors are effective for modifying jaw growth in young patients with sagittal and transverse issues, particularly for maxillary deficiencies. TADs can be used for growth modification at older ages than traditional methods. However, TADs are not recommended for vertical problems.
**Keywords**: Temporary Anchorages Devices, Growth Modification, Success rate

## Introduction

### 1. Background

Orthodontic treatment aims to correct misaligned teeth and jaw issues by influencing patient growth. Facial growth patterns are set early in life and seldom change later without intervention. Jaw growth can be modified in all dimensions through growth inhibition or stimulation [1-3]. Orthodontic treatment uses forces on teeth to modify growth, with the Growth Modification (GM) method effectively treating skeletal discrepancies by altering the growth process [4]. For Cl III malocclusion, it involves impeding lower jaw growth, promoting upper jaw growth, or a mix, while Cl II malocclusion follows the opposite [5]. Stress and strain from force application induce tissue shape changes and functional adjustments. Force removal eliminates abnormal effects, allowing normal growth and tissue function restoration, leading to secondary tissue shape adaptation [2, 6-8].

Conventional GM methods involve applying force to the jaw bone, affecting tooth movement and treatment efficiency [9]. For example, in rapid maxillary expansion (RPE), force reduction before reaching growth sites can impact maxillary growth. Implants now allow direct force application to the jaw, potentially reducing the need for heavy force to influence growth [1, 2, 10]. GM effectiveness with orthopedic appliances varies based on the patient's age and skeletal pattern [11]. Cl III patients with maxillary deficiency and Cl II patients with mandibular deficiency benefit most from GM treatments [10, 12, 13]. Skeletal anchorages revolutionized orthodontic treatment by enabling direct force application to bones, enhancing skeletal movements, reducing dental shifts, and ensuring optimal treatment outcomes through proper anchorage [1, 2, 12].

Various studies have shown the success of GM treatment in TAD-based expansions [14-18]. MARPE effectively corrects upper jaw transverse issues without surgery, as shown in a study on skeletal and dentoalveolar changes due to mini screws [19]. On the other hand, palatal expansion using a mini-plate directly anchored in the palate had a better maxillary expansion. Examining the number of changes in the zygomaticomaxillary horizontal plane with palatal expander micro-implants with CBCT in another study showed a significant change in the intertemporal distance and zygomaticotemporal angle and in the horizontal plane, the maxilla and zygoma and the entire zygoma arch were significantly displaced [20]. It was found that comparing bone anchors with maxillary face masks for treating class III malocclusion in adolescents, bone anchors showed increased SNA and decreased ANS-Me, WITS, and U1-PP [21].

## 2. Objectives

Therefore, the present study aimed to highlight the importance of skeletal anchorage devices in achieving skeletal changes and improving occlusal parameters, particularly in the treatment of skeletal class II malocclusion during the preadolescent stage. The review includes studies that used various skeletal anchorage devices, such as bi-maxillary mini plates and mini-screws, and evaluated their effects on skeletal and dentoalveolar changes.

## 3. Method

### *3.1. Search strategy*

This research was a review study and the main method of data collection was through searching the scientific websites. The data required for this research were collected through searching in Cochrane, MEDLINE by way of PubMed, Embase (via Ovid), Lilacs, Science Direct, Scopus, and Clinicaltriala.Gov between January 2010 and June 2021. The following phrases were searched as keywords, and all keywords were placed in quotation marks to explore the databases. Boolean operators “AND” and “OR” were used: Temporary orthodontic device, Skeletal anchorage, Mini-screw, Mini-plate, Mini-implant, Growth modification, Skeletal Class II, Skeletal Class III, Maxillary deficiency, Mandibular deficiency, Palatal constriction, Expansion, Open bite, Deep bite

### *3.2. Inclusion / Exclusion criteria*

The inclusion criteria for this universal systematic review were; a) English language published articles. Also, key regional languages were checked for records that have no English title or abstract. b) The records should be available in full text on the mentioned databases. c) clinical trial studies, prospective and retrospective studies, case reports, and case series with complete descriptions of treatment processes and details of treatment results on Temporary Anchorage Device (TAD) in Orthodontic Treatment. d) systematic review studies and meta-analysis, and e) articles published between 2010 and 2021. Unrelated articles and review studies and low-quality studies in the hierarchy of scientific evidence (such as Ph.D. dissertations, expert opinions, letters, editorials, histological and biomechanical studies), animal and laboratory studies, and studies related to patients with systemic conditions were excluded from our review study.

### *3.3. Screening and selection process*

In this review study, the acceptance of studies to enter the research was done by a series of inclusion and exclusion criteria. At first, the title and abstract of the studies obtained from the search were checked by two people in terms of having the inclusion criteria. Selected articles were evaluated from two dimensions: The scientific principles and the conditions for entering the study and the accuracy of the methodology. The references of these articles were also evaluated manually so that the related articles were also evaluated and included in this study if they had the conditions to be mentioned.

The included studies were divided into the following four groups:

1- Application of TAD in the growth modification treatment of Class II malocclusion

2- Application of TAD in the growth modification treatment of Class III malocclusion

3- Application of TAD in the growth modification treatment of vertical skeletal problems

4- Application of TAD in the growth modification treatment of transverse problems

Due to the review nature of this study, there was no need for statistical analysis, and had no special ethical consideration. Only honesty and truthfulness have been observed in presenting the content.

## 4. Results

After the search through the databases, 137 articles were found, of which 13 were not from the period between 2010-2021, and 4 articles could not be accessed in full text, and 4 articles did not have English text, and 81 articles were not relevant and 102 articles were deleted in total. A total of 35 articles were approved, which were placed in the following sub-groups according to the subject (**Figure1 and Table 1**):

1. Class II Malocclusion: 7 articles

2. Class III Malocclusion: 9 articles

3. Transversal problems: 8 articles

4. Vertical problems: 11 articles

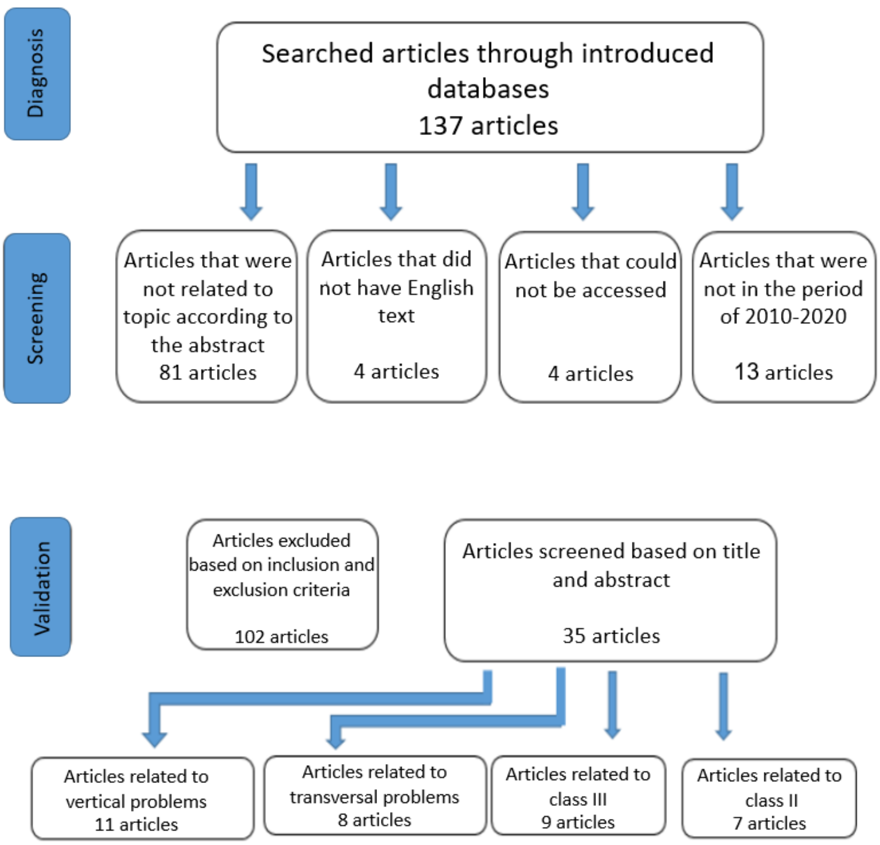


**Figure 1. Search results**

**Table 1 – Selected studies**

| Number | Name | Authors | Journal | Study design | Year | Category of problem |
|---|---|---|---|---|---|---|
| 1 | A novel approach for treatment of skeletal Class II malocclusion: Miniplates-based skeletal anchorage | Al-Dumaini AA, Halboub E, Alhammadi MS, Ishaq RAR, Youssef M | American Journal of Orthodontics and Dentofacial Orthopedics | Clinical trial | 2018 | Cl II |
| 2 | Severe skeletal Class II Division 1 malocclusion in postpubertal girl treated using Forsus with miniplate anchorage | Patil HA, Kerudi VV, Rudagi B, Sharan JS, Tekale PD | journal of orthodontic science | Case report | 2017 | Cl II |
| 3 | Three-Dimensional Evaluation of Pharyngeal Airway Volume Following Treatment of Post-Pubertal Patients with Skeletal Class II Malocclusion via Miniplate-Anchored Herbst Appliance | ElHabbak KS, Hussain F, Al-Dany A-DA | Al-Azhar Journal of Dental Science | Randomized clinical trial | 2020 | Cl II |
| 4 | Evaluation of the miniplate-anchored Forsus Fatigue Resistant Device in skeletal Class II growing subjects: A randomized controlled trial | Elkordy SA, Abouelezz AM, Fayed MM, Aboulfotouh MH, Mostafa YA | The Angle Orthodontist | Randomized controlled trial | 2019 | Cl II |
| 5 | Treatment of skeletal class II malocclusion using miniplate anchorage with fixed functional appliance | Gorantla S, Thokala M, Maru D, Veginadu P, Konathala SS | Journal of Indian Orthodontic Society | Case report | 2019 | Cl II |
| 6 | Effects of miniplate anchored and conventional Forsus Fatigue Resistant Devices in the treatment of Class II malocclusion | Turkkahraman H, Eliacik SK, Findik Y | The Angle Orthodontist | Clinical trial | 2016 | Cl II |
| 7 | Can the use of skeletal anchors in conjunction with fixed | Elkordy SA, Aboelnaga AA, Fayed MMS, | European Journal of Orthodontics | systematic review and | 2016 | Cl II |

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| | functional appliances promote skeletal changes? A systematic review and meta-analysis | AboulFotouh MH, Abouelezz AM | | meta-analysis | | |
| 8 | A novel method for treatment of Class III malocclusion in growing patients | Al-Mozany SA, Dalci O, Almuzian M, Gonzalez C, Tarraf NE, Ali Darendeliler M | Progress in orthodontics | Case series analytical study | 2017 | Cl III |
| 9 | Zygomatic miniplates for skeletal anchorage in orthopedic correction of Class III malocclusion: A controlled clinical trial | Bozkaya E, Yüksel AS, Bozkaya S | The Korean Journal of Orthodontics | Controlled clinical trial | 2017 | Cl III |
| 10 | Dentoalveolar and arch dimension changes in patients treated with miniplate-anchored maxillary protraction | Elnagar MH, Elshourbagy E, Ghobashy S, Khedr M, Evans CA | American Journal of Orthodontics and Dentofacial Orthopedics | Clinical trial | 2017 | Cl III |
| 11 | Maxillary protraction with intermaxillary elastics to miniplates versus bone-anchored face-mask therapy in cleft lip and palate patients | Jahanbin A, Kazemian M, Eslami N, Pouya IS | Journal of Craniofacial Surgery | Clinical trial | 2016 | Cl III |
| 12 | The short-term treatment effects of face mask therapy in Class III patients based on the anchorage device: miniplates vs rapid maxillary expansion | Lee N-K, Yang I-H, Baek S-H | The Angle Orthodontist | Cross sectional | 2012 | Cl III |
| 13 | Dentofacial effects of two facemask therapies for maxillary protraction: Miniscrew implants versus rapid maxillary expanders | Ge YS, Liu J, Chen L, Han JL, Guo X | The Angle Orthodontist | Randomized clinical trial | 2012 | Cl III |
| 14 | Maxillary protraction with miniplates providing skeletal anchorage in a | Cha B-K, Choi D-S, Ngan P, Jost- | American journal of orthodontics and dentofacial orthopedics | Case report | 2011 | Cl III |

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| | growing Class III patient | Brinkmann P-G, Kim S-M | | | | |
| 15 | Skeletal Anchorage for Orthopedic Correction of Growing Class III Patients | Cha B-K, Ngan P | Seminars in Orthodontics | Clinical trial | 2011 | Cl III |
| 16 | The effects of miniscrew with Class III traction in growing patients with maxillary deficiency | Jamilian A, Haraji A, Showkatbakhsh R, Valaee N | International Journal of Orthodontics | Case-control | 2011 | Cl III |
| 17 | Short-term impact of microimplant-assisted rapid palatal expansion on the nasal soft tissues in adults: A three-dimensional stereophotogrammetry study | Lee S-R, Lee J-w, Chung D-H, Lee S-m | Korean journal of orthodontics | Clinical trial | 2020 | Transverse |
| 18 | Zygomaticomaxillary modifications in the horizontal plane induced by micro-implant-supported skeletal expander, analyzed with CBCT images | Cantarella D, Dominguez-Mompell R, Moschik C, Sfogliano L, Elkenawy I, Pan HC, et al. | Progress in orthodontics | Case-control | 2018 | Transverse |
| 19 | Skeletal and dentoalveolar changes after miniscrew-assisted rapid palatal expansion in young adults: A cone-beam computed tomography study | Park JJ, Park Y-C, Lee K-J, Cha J-Y, Tahk JH, Choi YJ | The Korean Journal of Orthodontics | Cross-sectional | 2017 | Transverse |
| 20 | The easy driver for placement of palatal mini-implants and a maxillary expander in a single appointment | De Gabriele O, Dallatana G, Riva R, Vasudavan S, Wilmes B | J Clin Orthod. 2017;51(11):728-37 | Case report | 2017 | Tranverse |
| 21 | Mini-implant assisted rapid palatal expansion: new perspectives | Montigny M | Journal of Dentofacial Anomalies and Orthodontics | Review | 2017 | Transverse |
| 22 | Dentoskeletal effects of a temporary skeletal anchorage device–supported rapid maxillary | Vassar JW, Karydis A, Trojan T, Fisher J | The Angle Orthodontist | Cross-sectional | 2016 | Transverse |

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| | expansion appliance (TSADRME): a pilot study | | | | | |
| 23 | Orthopedic expansion with orthodontic mini-implants: Case report | Vázquez AH, Núñez EG | Revista Mexicana de Ortodoncia | Case report | 2014 | transverse |
| 24 | Application and effectiveness of a mini-implant-and tooth-borne rapid palatal expansion device: the hybrid hyrax | Wilmes B, Nienkemper M, Drescher D | World J Orthod | Clinical trial | 2010 | transverse |
| 25 | Dentoskeletal changes following mini-implant molar intrusion in anterior open bite patients | Hart TR, Cousley RR, Fishman LS, Tallents RH | The Angle Orthodontist | Cross - sectional | 2015 | Vertical (open bite) |
| 26 | Mini-implant-anchored Mesialslider for simultaneous mesialisation and intrusion of upper molars in an anterior open bite case: a three-year follow-up | Wilmes B, Katyal V, Willmann J, Stocker B, Drescher D | Australasian Orthodontic Journal | Case report | 2015 | Vertical (open bite) |
| 27 | Orthodontic treatment of anterior open bite: a review article—is surgery always necessary? | Reichert I, Figel P, Winchester L | Oral and maxillofacial surgery | Review | 2014 | Vertical (open bite) |
| 28 | Camouflage of a high-angle skeletal Class II open-bite malocclusion in an adult after mini-implant failure during treatment | Sant’Anna EF, da Cunha AC, Brunetto DP, Sant’Anna CF | American Journal of Orthodontics and Dentofacial Orthopedics | Case report | 2017 | Vertical (open bite) |
| 29 | Orthodontic treatment of anterior open-bite malocclusion: stability 10 years postretention | Zuroff JP, Chen S-H, Shapiro PA, Little RM, Joondeph DR, Huang GJ | American journal of orthodontics and dentofacial orthopedics | Cross - sectional | 2010 | Vertical (open bite) |
| 30 | Skeletal open-bite correction with mini-implant anchorage and minimally invasive surgery | Uribe F, Azami N, Steinbacher D, Janakiraman N, Nanda R | J Clin Orthod | Case report | 2018 | Vertical (open bite) |

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|---|---|---|---|---|---|---|
| 31 | Vertical control of a Class II deep bite malocclusion with the use of orthodontic mini-implants | Jung M-H | American Journal of Orthodontics and Dentofacial Orthopedics | Case report | 2019 | Vertical (deep bite) |
| 32 | Treatment effects of intrusion arches and mini-implant systems in deepbite patients | Şenışık NE, Türkkahraman H | American journal of orthodontics and dentofacial orthopedics | Clinical trial | 2012 | Vertical (deep bite) |
| 33 | Effectiveness of miniscrew-supported maxillary incisor intrusion in deep-bite correction: A systematic review and meta-analysis | Sosly R, Mohammed H, Rizk MZ, Jamous E, Qaisi AG, Bearn DR | The Angle Orthodontist | Systematic review and meta-analysis | 2020 | Vertical (deep bite) |
| 34 | Mini-implant assisted gummy smile and deep bite correction | Reddy SR, Jonnalagadda VNS | Contemporary Clinical Dentistry | Case report | 2021 | Vertical (deep bite) |
| 35 | Comparison of intrusion effects on maxillary incisors among mini implant anchorage, j-hook headgear and utility arch | Jain RK, Kumar SP, Manjula W | Journal of clinical and diagnostic research: JCDR | Clinical trial | 2014 | Vertical (deep bite) |

*4.1. Application of TAD in the growth modification treatment of Class II malocclusion*

Functional appliances are widely used in the treatment of Class II malocclusion in growing patients with mandibular deficiency to protrude mandible, however, they have unwanted side effects on teeth in the way that the mandibular incisors move forward. This is especially true about fixed functional appliances. They may even intrude on the posterior upper teeth. To avoid these unwanted dental side effects exerting the force directly to the bone rather than teeth has been suggested. Fixed functional appliances have been used in combination with these skeletal anchors to reduce the movement of mandibular incisors, either with the help of mini-screws or mini-plates [22].

In one method, mandibular mini-plates are placed in the posterior buccal areas between the first and second mandibular molars and above the external oblique ridge. The maxillary mini-plates are placed in the anterior labial areas in such a way that its arm is more distal than the maxillary lateral incisor and the orthopedic force is applied using a class II intermaxillary elastic [23] (**Figure 2**).


**Figure 2 . Mini-plates after the repair phase (A) initial malocclusion (B) use of intermaxillary elastic (C) placement of elastic between maxillary canine and mandibular first molar**

In another method, functional appliances are used along with TADs. Forsus Fatigue Resistance device (FFRD) with mini-plate (FMP) was used for class II malocclusion treatment in three studies (**Figure 3**). This method was used as an alternative treatment method for orthognathic surgery in a 17-year-old girl with mandibular retrognathism, deep bite, and concave profile. It was concluded that Forsus with mini-plates can be used as a powerful method in growing and post-pubertal patients [24]. The use of mini-plates in the FFRD group in another study with 48 patients (with a mean age of 12.3 ± 0.9) increased the mean length of the mandible significantly only in the FMP group. Mandibular incisors showed significant proclination in the FFRD group while no protrusion was reported in the FMP group [25]. However, in another study on 45 patients slight protrusion in mandibular incisors in the FFRD group was shown, but in the FMP group, they were retruded [26]. Generallyو in all three studies in the FMP group, the mandible had counterclockwise rotation but in the FFRD group had no change, and overjet and overbite showed a decrease in the FFRD group. Mandibular growth rehabilitation and maxillary growth inhibition were seen in both groups. There were more advantages in dentoalveolar dimensions in the FMP group.

**Figure 3. Forsus fatigue resistance device (FFRD) with mini-plate anchorage**

In another study, Powerscope was used instead of FFRD for treatment. The difference between the treatment of class II skeletal malocclusion using anchored mini-plates and fixed functional appliances was evaluated. A powerscope was placed on the mini-plates after placing the mini-plates bilaterally in the symphysis of the mandible. skeletal and dental changes of the mandible were favorable at the end of the treatment [27].

In another study that used Herbest for the treatment of class II malocclusion, the effects on the airway were also evaluated. Fourteen post-puberty girls with skeletal class II malocclusion with mandibular retrognathism were treated by functional Herbest type 4 appliance, which was anchored with two regenerating plates and bilaterally in the mandible between the canine and the first premolar teeth. The results showed that the volume of the nasopharyngeal passage had no significant increase in patients before and after treatment, but velopharyngeal, glossopharyngeal, and total airways had a significant increase after Herbest treatment. Also, mandibular retrognathism showed a significant improvement in these patients, and the SNB angle increased and the ANB angle decreased significantly [28].

In a systematic review, the use of skeletal anchorages with fixed orthodontic appliances on skeletal changes was evaluated. In this review, the results of 7 studies showed that the evaluation of in total 157 class II patients (Fixed Functional Appliance (FFA) and skeletal anchorage and only FFA didn't show a significant difference in the amount of random effect between mandible length and the SNB angle changes. There was no significant difference in the changes in the inclination of the upper and lower incisors. However, the results of the reviewed studies showed insufficient evidence to achieve a definite conclusion about the effect of using skeletal anchorage with FFA [29]. **Table 2** mentions the studies that were reviewed above in the growth modification treatment of Class II malocclusion.

**Table 2. Changes of skeletal parameters in growth modification treatment of class II malocclusion with the help of TAD**

| First Author | SNA changes | SNB changes | ANB changes | WITS changes |
|---|---|---|---|---|
| Al-Dumaini | -1.40 | 2.90 | -4.00 | Not available |
| Patil | -1° | +2° | -3° | - 6 mm |
| El- habbak | -0.16° | +3.95° | -3.7° | Not available |
| Elkordy | -0.79° | +0.7° | Not available | Not available |
| Gorantla | -1° | +3° | - 4° | Not available |
| Turkkharaman | -0.5° | +0.5° | - 1° | Not available |

*4.2. Application of TAD in the growth modification treatment of Class III malocclusion*

A facemask is the most practical treatment method in treating patients with class III malocclusion due to maxillary deficiency. However, the use of indirect forces limits its favorable orthopedic results and has adverse effects in some cases. Recently, protocols related to skeletal anchorages have been used to apply orthopedic forces directly to the maxillofacial skeleton. There are 2 methods to create orthopedic force directly to the maxilla without wasting forces from the teeth and as a result, the maxilla moves forward. One method is to anchor the facemask with a curved mini-plate fixed to the zygomatic arch and place a heavy elastic between the mini-plates and the facemask [30, 31] (**Figures 4 & 5**). Another method is to use a direct mini-plate fixed to the infrazygomatic crest and symphysis in the mandible and connect them with class III elastics [31] (**Figures 6 & 7**).

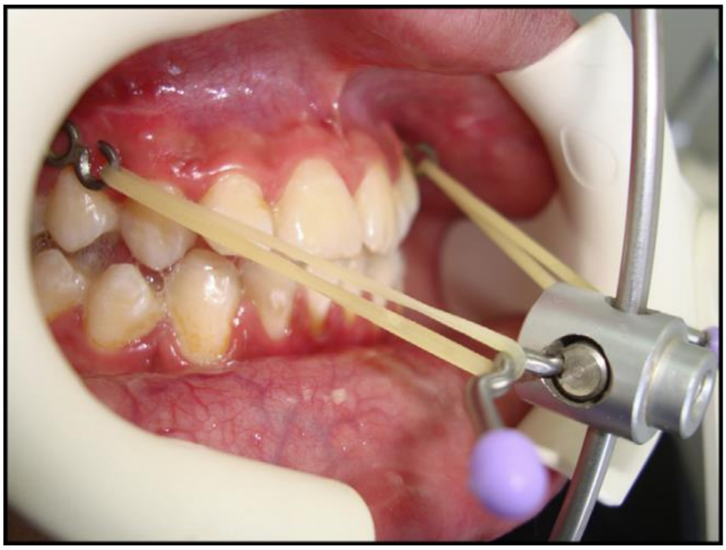

**Figure 4. Application of facemask to mini-plates**

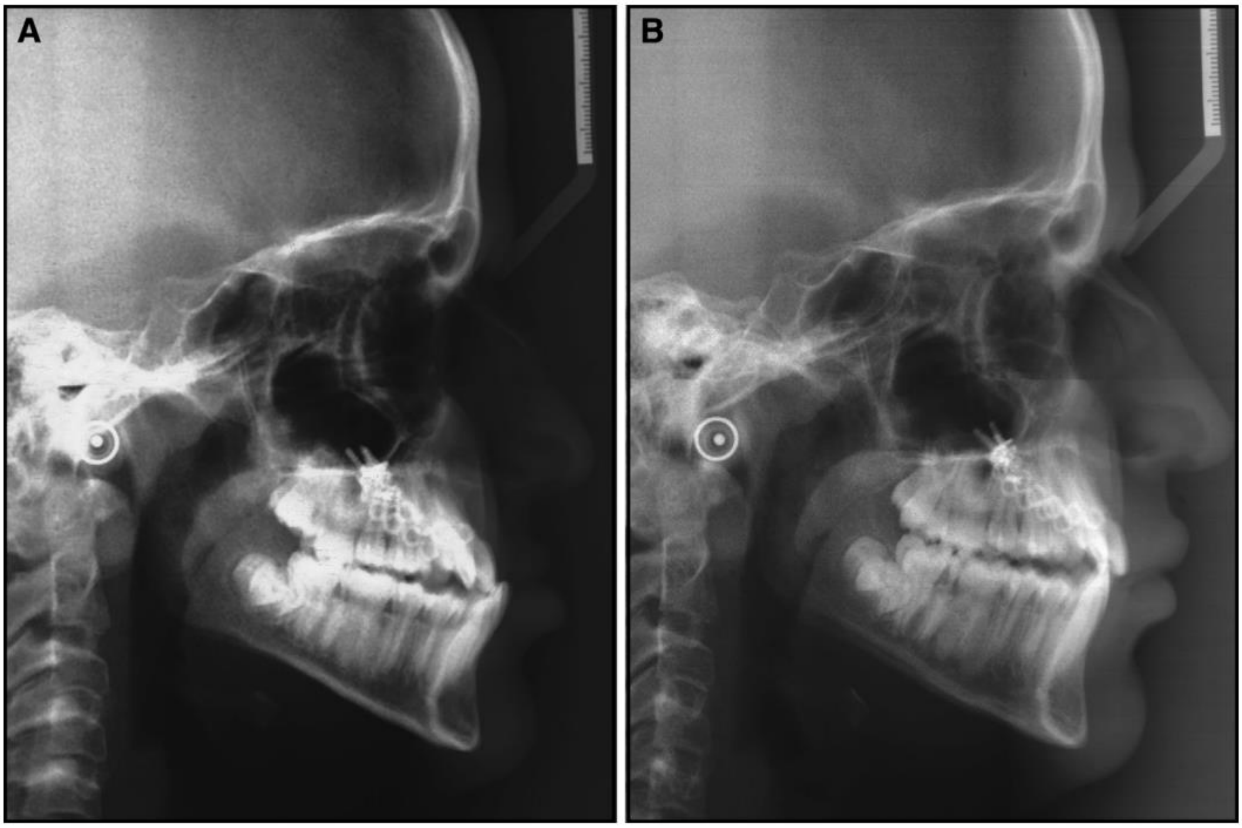


**Figure 5. Cephalograms: A, before and B, after maxillary protraction using skeletally anchored facemask with mini-plates**

**Figure 6. Application of Class III elastics extending from infrazygomatic mini-plates in the maxilla to symphyseal mini-plates in the mandible**

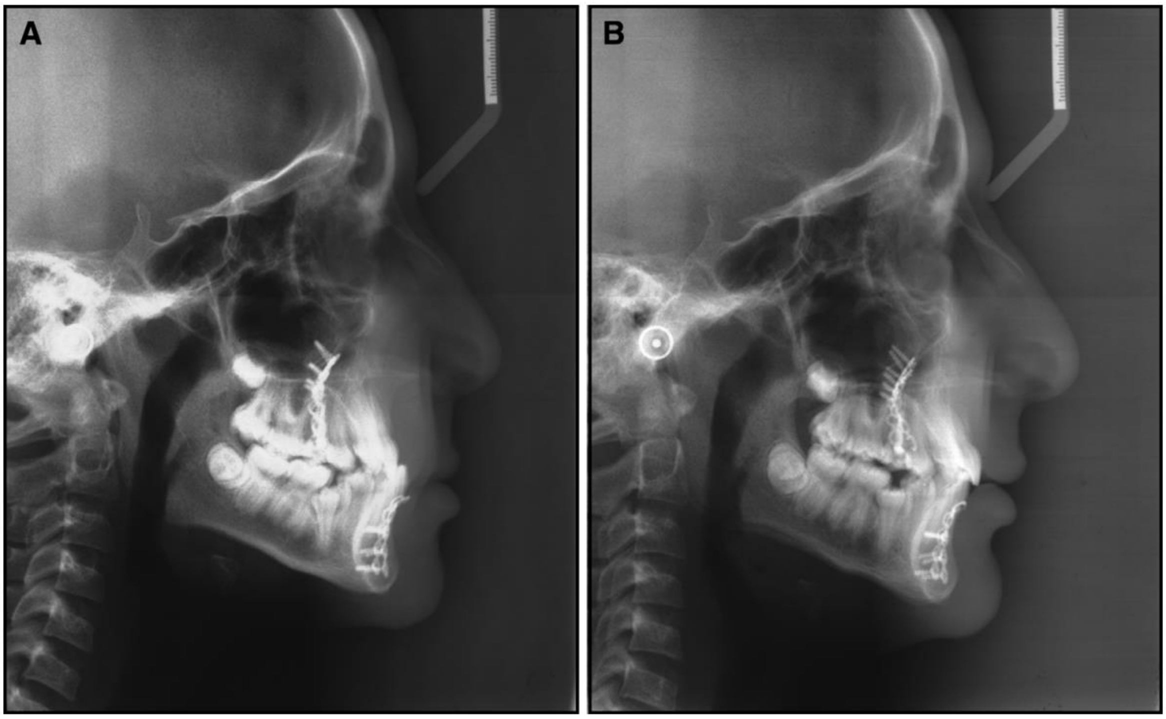


**Figure 7. Cephalograms: A, before and B, after maxillary protraction by Class III elastics extending from infrazygomatic mini-plates to symphyseal mini-plates**

Various studies have been conducted in the field of comparing face mask treatment with RME (FM-RME) to face mask with mini-plate (FM-MP) in the treatment of class III malocclusion. As a result, treatment with FM-MP on 20 patients with a mean age of 11.2 years on FM-MP and 10.7 in the FM-RME group caused more maxillary advancement and less displacement and rotation during the opening of the mandible, as well as proclamation of the maxillary incisors [30]. Even in one study that compared FM-RME and FM-MP, no significant movement in the maxilla was seen in the former group [32]. In comparison with treatment by facemask alone, the treatment with FM-RME and face mask with mini-screw (FM-MS) on 43 patients caused less protrusion of skeletal connections and soft tissue profile and reduced the effects of dentoalveolar complications [33]. Eventually, the vertical increase in the height of the maxilla in the FM-MP group was less than in the FM-RME group, which has an important role in the height of the lower third of the face [32]. In another study, significant anterior rotation was seen in the palatal plane after treatment with a facemask with and without a mini-plate. Furthermore, the changes in the sagittal position of the upper jaw and incisors and molars were similar in both groups [34].

In a 2016 study, Al-Mozany et al. investigated the effectiveness of a new method in the treatment of 14 growing patients with class III malocclusion and retrognathic maxilla. All participants received the MARPE appliances activated with the Alt-RAMEC (Alternative Rapid Maxillary Expansion and Constriction) protocol. Class III elastics were used for jaw protrusion. The maxilla was significantly protruded and the base of the mandible moved backward significantly (the Y-axis angle also increased significantly). The maxillary and mandibular incisors were significantly proclined and reclined respectively. A combination of dental and skeletal effects significantly improved overjet and soft tissue harmony [10].

The efficiency of intermaxillary elastics attached to mini-plates compared to bone-anchored face masks in the treatment of 11 pre-pubescent patients with lip and palate cleft disorders was evaluated. The results showed that there was no significant difference between the two groups in terms of dental skeletal and soft tissue parameters. Based on the preliminary findings of this study, intermaxillary elastics to mini-plates have a significant effect as an alternative to face mask therapy in the protraction of the maxilla in patients with lip and palate cleft [35]. In another study on non-cleft patients (10 in the facemask group and 10 in the mini-screw group), both groups were successfully treated while the mean IMPA increased in the mini-screw group and decreased in the facemask group [36]. Cha et al. showed that maxillary protraction methods with bone anchorages have better results in the soft tissue of the upper lip and the middle third of the face. Also, this method causes the soft tissue of the lower lip to move in a sagittal plane, which creates a concave appearance in the lateral view of the face [37]. Generally, it was observed that Class III elastics attached to mini-plates provide better vertical closure of the mandibular plane compared to facemasks anchored with mini-plates [33, 35]. **Table 3** mentions the studies that were reviewed above in the growth modification treatment of Class III malocclusion.

**Table 3. Changes of skeletal parameters in growth modification treatment of class III malocclusion with the help of TAD**

| First author | SNA changes | SNB changes | ANB changes | WITS changes |
|---|---|---|---|---|
| Al-Monzay | +1.87° | -2.2° | +3.95° | +5.16mm |
| Bozakaya | +2.2° | -1.3° | +3.8° | +5.44mm |
| Elnagar | Not available | Not available | Not available | Not available |
| Jahanbin | +4.2° | -1.4° | +3° | +5.6mm |
| Lee | +2.73° | -0.7° | +3.8° | +2.87mm |
| Ge | +3.3° | +2.5° | + 1.45° | +3.98mm |
| Cha | +3.2° | + 8.01° | + 4.3° | -1.8mm |
| Cha | +7.3° | -1.6° | +8.9° | Not available |
| Jamilian | +3° | -3° | Not available | 0mm |

*5.2. Application of TAD in the growth modification treatment of transverse problems*

Mini-screw-assisted rapid palatal expansion (MARPE) has been an acceptable treatment for expansion in teenagers and adults in recent years. The use of orthodontic mini screws for maxillary orthopedic expansion can have the least unwanted effects on dental movements. Maxillary skeletal expansion is a device that relies on bone anchorage and transfers the expansion force directly to the maxillary bone, and this operation is performed with the help of placing mini-screws in the place of the palatal and nasal cortical bones.

The effects of maxillary expansion with mini-screws have been evaluated in several studies. The short-term impact of micro-implant-assisted rapid palatal expansion (MARPE) in the soft tissue of 30 adolescents showed that 7 mm of expansion and alar base width, alar width, and alar concavity were changed by 1.214, 0.912, and 0.987 mm, respectively. Most soft tissue landmarks showed positional changes around the nasal region after MARPE in young adults. The nose became wider and moved forward and down. The volume of the nose after the treatment showed a significant increase compared to the initial volume [38].

The results of skeletal and dentoalveolar changes of rapid palatal expansion caused by mini-screws in 14 patients with a mean age of 20.1 made it clear that MARPE was an effective method in correcting maxillary transverse problems with and without surgery [19] (**Figure 8**). Another study showed this anchorage was placed directly on the palate, which was closer to the resistance center of the maxillary midline had better maxillary expansion, and reduced the dimensions of the vestibular cortex to a very thin size [39]. In a similar study on 25 patients, a significant increase in all linear measurements except the buccal width of the maxilla in the canine area was observed. However, the greatest palatal expansion was in the area of the first premolar. All adolescent patients aged 8 to 16 years had less tooth tipping and more expansion compared to adults. More variations were in the tipping of the first molar, which indicated the less uprighting of these teeth. Therefore, the results showed that the use of these appliances is effective in the clinical aspect and can cause slight tipping of the molars and even a positive effect on the expansion of the temporary skeletal anchorage device (TSAD) area [40]. In another two studies by De Gabriele et al. and Vazquez et al., it was concluded that orthopedic forces are directly applied to the nasomaxillary complex and mini-screws are a reliable source for anchorage and make acceptable skeletal changes with changes on teeth [41, 42].

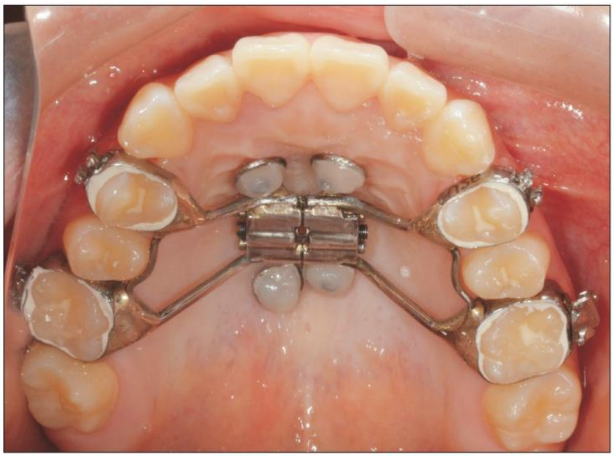

**Figure 8. Clinical application of miniscrew-assisted rapid palatal expansion**

The zygomaticomaxillary changes in 15 patients with a mean age of 17.2 years, the horizontal plane with micro-implant skeletal expanders (MSE) in CBCT images showed that the change in intertemporal distance and zygomaticotemporal angle was significant. In the horizontal plane, the maxillary and zygomatic bone and the entire arch of the zygoma were moved significantly. It was mentioned that the center of rotation of the zygomaticomaxillary complex was near the proximal part of the zygomatic process of the temporal bone, which was more posterior and lateral than what was reported in the articles for dental expanders. Bending of the bone in the zygomatic process of the temporal bone during maxilla expansion was seen with the help of the mini-screw [20]. Wilmes et al. examined the effect of mini-implants and palatal expander tools called hybrid hyrax on 13 patients with a mean age of 11.2 years in 2010. The hybrid hyrax device was effective for RPE treatment and It could be used especially in patients with reduced anchorage of anterior teeth. Because most teeth do not participate in this appliance, regular orthodontic treatment should be started early. A combination of hybrid hyrax and face masks can be used to protract the maxilla and effectively minimize the mesial shift of the teeth [43].

*4.6. Investigating the application of TAD in the growth modification treatment of vertical skeletal problems*

In cases of open bite, some articles were reviewed using TAD intrusion of posterior teeth, and the bite was closed, but in all cases the movement was dental and the patients were adults without the possibility of GM [44-49]. Also, in cases of deep bite, some articles were reviewed that intrusion of anterior teeth was done using TAD, and the deep bite was relieved, but all movement was dental and the patients were adults in all cases, so they could not be considered as GM cases too [50-54].

## 5. Discussion

The use of bone anchorages in growing patients is usually with favorable clinical success in beauty, function, and stability [1, 2]. The best period to use bone anchorages for GM is the growing age; children who are in the growth period and before the growth spurt are good candidates for class II and class III treatments; Because at this age, it is possible to modify maxillary protrusion or mandibular retrusion easily. For this reason, suitable candidates for these studies are children under 12 years old [55, 56]. In this study, the average age of the patients was 10.8 years. In some studies, the study was also conducted on people over 20 years of age, and usually, the patients had anteroposterior and class II abnormalities, the reason for which is the effectiveness of treating this abnormality after puberty and completion of the growth spurt [57].

Bone or temporary anchorages are usually in the form of mini-implants mini-screws or mini-plates. Based on the results of the present study, most of the studies used mini-plates as anchorage. The use of mini-plates has advantages over mini-implants and mini-screws; Among them, it can be mentioned that they have less risk of failure and less risk of damage to anatomical landmarks such as tooth root and tooth bud in mixed dentition period which is the most appropriate age for GM treatment due to not using self-drilling and self-tapping screws. Also, some reports indicate the occurrence of infection and inflammation around the mini-screws, which has created the need for a mini-implant to remove the load and inflammation in clinical practice. Also, in some studies, mini-implant breakage due to a child's non-cooperation and trauma to the area has been reported, which has challenged clinicians to remove it [1, 57].

In this review, most of the available studies were case reports with a short-term follow-up period (mostly less than 1 year) because TADs are emerging tools. Therefore, it is difficult to judge their clinical success. Their success rate in similar studies is 80% to 90% in the 1-month follow-up period and 66% to 80% have been reported in 3 months. Among the factors that reduce their success, we can mention peri-implantitis in mini-implants, implant fracture, damage to anatomical areas, dentoalveolar recurrence, and patient non-cooperation [58, 59].

A review of studies on GM treatments by TADs showed that bone anchorages can be used to treat class II malocclusion successfully. The plate in the mandible and Functional device has been mainly used in the treatment of Class II malocclusion. The mini-plate was placed between the canine and the first premolar in some studies [28] and it was placed in the symphysis in some other studies [25, 27]. The most used devices were Forsus [24-26], Powerscope [27] and Herbst [28].

The skeletal and dental changes were different in the studies that compared the two methods; there was an increase in the proclamation of the incisors in the conventional FFRD group without mini-plate, while in the mini-plate anchor FFRD group not only an increase was not present, but also a slight decrease was seen. Also, an increase in the effective length of the mandible and counter-clockwise rotation of the mandible was observed in the latter group [25, 26]; as well as the reduction of SNB and ANB angles [28]. Another advantage of this method is the increase in the volume of airway spaces [28]. The noteworthy point was that the average age of the patients was higher than what was said in the past for the appropriate age for growth modification treatment.

In general, the treatment of class II malocclusion with the help of TAD was used more in cases of mandibular deficiency rather than maxillary excess. TAD was used in the mandible to directly transfer the force of the functional device to the mandible. Although this method had an inhibitory effect on the maxilla, in general, there was no used TAD in the maxilla to directly inhibit the growth of the maxilla. TAD in the maxilla was mainly to correct dental problems and distalizing the maxillary dental arch, and this is not an example of growth modification treatment. The use of bone anchorages to treat Class III skeletal malocclusion has been also successful; mainly in cases with maxillary growth deficiency and not in cases of patients with the large mandible. Maxillary protrusion methods with bone anchorages had better results in the soft tissue of the upper lip and middle third of the face. Also, this method causes soft tissue movement in the lower lip and mandible in the sagittal plane, which relives a concave appearance in the lateral view of the face[27].

In some studies, evaluating the efficiency of intermaxillary elastics connected to mini-plates in comparison with bone-anchored face masks showed that there was no significant difference between the two groups in terms of dental skeletal and soft tissue parameters. However, in other studies, connecting class III elastics to mini-plates causes better vertical closure of the mandibular plane than facemasks anchored with mini-plates [33, 35]. Facemask is one of the auxiliary tools, especially in patients with class III disorders, which with the lever force it applies, causes the maxillary bone to be pulled forward in the long term and solves class III problems as a result. Also, using a facemask helps to correct the relationship between centric relation and centric occlusion [30].

When bone anchors are used with a facemask, they usually direct the incoming force to the circum-maxillary sutures, which facilitate the performance of the facemask in the protruding maxilla by creating a cellular reaction of bone modeling and remodeling. The amount of maxillary forward movement has been varied between 3.8 and 5.4 mm with bone anchorages in similar studies [60].

In the reviewed studies, there is a slight change in the incisal relations and the angle of rotation of the upper and lower incisors in the use of these bone anchorages. The use of elastics which connect the bone anchorages from the infrazygomatic region to the distal canine surface of the lower jaw limits the movement of teeth and prevents them from unwanted movements due to the fixation of skeletal anchorages to the alveolar bone [61,62].

In several studies, we have seen an increase in the SNA angle. The use of bone anchorage in the anterior region causes the anchorage to move downward and forward by pulling the upper jaw forward, which increases the SNA and decreases the SNB. The reduction of SNB can also be due to the backward and downward rotation of the mandible following the maxillary forward movement, which is justified by the increase in the palatal plane angle in the study group [22, 27]. Also, a significant increase in orbital protraction was seen. The results of Shi et al.'s meta-analysis study also showed that SNA changes increase when using bone anchors [63]. In other studies, we saw an improvement in overjet after using skeletal anchors. Using bone anchorages connected to the facemask or without it compensated the overgrowth of the mandible in class III patients by pulling the maxilla forward and as a result, overjet was eliminated [30, 32, 34, 35].

The decrease in S-Go length in most studies and the increase in A-S on the other hand show that the bone anchorages cause forward rotation of the maxillary bone which results in mandibular autorotation [62,64]. Examination of soft tissue parameters showed that in most studies, the distance between the upper lip and plane E decreased and vice versa the distance between the lower lip and plane E increased. This finding showed that the use of bone anchorages improved the appearance of the face and created beauty in people by changing the concavity of the lips, which is one of the positive points of using this method. This finding has been confirmed in similar studies [22, 25, 27, 30, 33, 35].

Summarizing the results of several studies on the treatment of maxillary transverse problems, it could be said that maxillary skeletal expansion methods, which rely on bone anchorage and transfer the expansion force directly to the maxillary bone, have favorable results. This operation is performed by placing mini-screws in the palatal bone. The review of these studies showed favorable changes in skeletal indices. Also, paranasal, subnasal soft tissue, and right and left alars had significant movement in the Y-axis. Remarkable points were that 4 mini-screws were often used to insert the rapid palatal expansion device. In this method, it is highly recommended to use CBCT images to choose the best area to place the screws and evaluate the appropriate bone [20,38,65]. Another noteworthy point was the high age of the patients; even in one study the average age of the patients was 20.1 years old [19]. As a result, the use of this method can reduce the need for surgical treatment for rapid palatal expansion in adult patients.

Due to the limited number of available articles and the fact that most of them are case reports, the statistical analysis of results was not possible and no definitive conclusions can be made. Clinical trial studies are suggested with a sufficient number of samples and specific classification of patients in terms of age and the type of treatment that should be done so that a systematic review can be done in this category and reach more definite results.

## 6. Conclusion

The review of studies on the application of skeletal anchorage devices in growth modification treatments reveals that temporary skeletal anchorages can be successfully used in the treatment of growing patients with various dentofacial deformities, including class II malocclusion, class III malocclusion with maxillary deficiency, and posterior crossbite. Temporary anchorage devices (TADs) have been shown to increase the success of orthopedic treatment by reducing dental movements and increasing skeletal movements, particularly in cases of growth stimulation, such as maxillary or mandibular deficiency correction. However, the use of skeletal anchorage devices in cases of vertical dimension problems has mainly been studied in adult patients for dental movements, which is not an example of growth modification treatment. The prevalence of using skeletal anchorage devices in the treatment of transverse problems and class III malocclusion with maxillary deficiency is higher than in the treatment of class II malocclusion based on the number of studies. Furthermore, growth modification treatment is also promising in older ages by using skeletal anchors, which can provide a more efficient and effective method for achieving skeletal changes and improving occlusal parameters. Overall, the findings of the review suggest that skeletal anchorage devices have the potential to overcome the limitations of conventional orthopedic and orthodontic mechanics in growth modification treatments, particularly in cases of growth stimulation, and highlight the importance of further research in this area.

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**Author’s contribution**

All authors listed have significantly contributed to the development and the writing of this article.

**Conflict of interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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