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Systematic Review

Clinical Outcomes of Skeletal Anchorage Versus Conventional Anchorage in the Class III Orthopaedic Treatment in Growing Patients: A Systematic Review and Meta-Analysis

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Main Points

In the orthopaedic treatment of Class III malocclusion in growing patients:

- Skeletal anchorage showed greater improvements in ANB and Wits.
- Fewer dental side effects with skeletal anchorage (less incisive protrusion).
- Better vertical control with skeletal anchorage
- BAMP protocol was the most effective for maxillary advancement with minimal side effects.

ABSTRACT

The aim of this systematic review was to evaluate the clinical outcomes of skeletal anchorage, compared to conventional anchorage, in the treatment of skeletal Class III malocclusion in growing patients. A systematic review was conducted following PRISMA guidelines. A specific search strategy was developed for PubMed, Web of Science, Embase, and Cochrane searching for randomized controlled trials and non-randomized clinical trials. Eleven interventions were assessed, three employing conventional anchorage (group A) and eight skeletal anchorage (group B). Nine pre-treatment (T0) and post-treatment (T1) mean cephalometric outcomes were statistically polled (SNA, SNB, ANB, Wits, Overjet, Overbite, SNMP, IMPA, U1PP). In total, 196 studies were identified, 17 studies were included in the qualitative and quantitative analysis. In the skeletal anchorage group, a greater increase in both ANB (+2.511°) and Wits (+4.691 mm) were observed and the increase in SNMP resulted well-controlled (+0.758°). The conventional anchorage group showed higher dentoalveolar side effects: increase in U1PP (+5.624°), decrease in IMPA (-0.866°) and increase in overjet (+5.255 mm). Treatments exploiting skeletal anchorage determined a better correction of skeletal Class III, thanks to a combination of greater advancement of the maxilla and more enhanced retrusion of the mandible. In all treatment protocols exploiting dental anchorage, the increase in the inclination of the central incisor resulted significantly greater. Further longitudinal studies are required to evaluate the long-term effects of skeletal anchorage in growing patients.

Keywords: Class III malocclusion, orthodontic anchorage procedures, orthodontic appliances, interceptive treatment, bone anchored maxillary protraction (BAMP)

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INTRODUCTION

Skeletal Class III malocclusion is a complex dentofacial deformity caused by a discrepancy in the three-dimensional growth of the upper and lower jaws.[1] It is regarded by many as the most arduous malocclusion to treat, representing a true challenge for clinicians. Etiologically, skeletal Class III may derive from a retrognathic maxilla, a prognathic mandible or a combination of both.[2] According to literature, its prevalence varies amongst different ethnical groups, affecting 1-4% of Caucasians,[3] 5-8% of Afro-Americans,[4] and 4-14% of Asians.[5] The clinical manifestation of skeletal Class III may be very heterogenous, comprising several different dental and skeletal morphological variants. The patient's age and individual growth pattern represent two decisive factors to consider in the establishment of the optimal treatment strategy.[6,7] In growing patients, interceptive treatment is aimed at preventing irreversible changes in the skeletal structures and associated soft tissues, thus restoring a more favourable growth environment and facial aesthetics.[8,9] A variety of treatment strategies are accurately reported in literature and may be distinguished in two main subtypes: treatment plans that employ dental or conventional anchorage and ones that make use of skeletal anchorage. The latter has the objective of maximizing orthopaedic effects in growing patients whilst minimizing undesired dentoalveolar changes.[10-12] To date, not many studies have analysed the comparative effectiveness of maxillary protraction with or without the use of skeletal anchorage systems. Furthermore, according to the recent reviews published in literature,[13-18] there is still insufficient evidence to support the advantages and beneficial clinical outcomes of maxillary protraction using skeletal anchorage compared to traditional treatments, such as facemask therapy. Nevertheless, the implementation of skeletal anchorage continues to spread and new scientific evidence is being produced. These reviews have examined the clinical effectiveness of different anchoring protocols in the treatment of skeletal Class III, but without a detailed evaluation of the different types of interventions and with a reduced range of cephalometric results.[13-18]

Therefore, the aim of this systematic review was to evaluate the clinical outcomes of skeletal anchorage, compared to conventional anchorage, in the treatment of skeletal Class III malocclusion in growing patients.

METHODS

Search Strategy

The systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines[19] to ensure exhaustiveness and transparency. A specific search strategy was developed for PubMed, Web of Science, Embase, and Cochrane. English literature was searched with no time limit. A rigorous electronic search was carried out for randomized controlled trials (RCTs) and non-randomized clinical trials (CCTs) on patients affected by skeletal Class III, treated with protocols employing dental anchorage [rapid maxillary expansion (RME) combined with face mask (FM); Alternate RME and Constriction (Alt-RAMEC) combined with FM] and skeletal anchorage (mini-implants and/or mini-plates). All previous systematic reviews were carefully screened until July 2023 to identify potentially useful articles.

Eligibility Criteria

In order to be included in the systematic review, articles had to meet the following inclusion criteria: (a) population: patients affected by skeletal Class III malocclusion; (b) intervention: patients submitted to orthodontic treatment through the use of skeletal or dental anchorage appliances; (c) comparisons: availability of pre-treatment (T0) and post-treatment (T1) lateral cephalograms to compare cephalometric outcomes; (d) outcomes: availability of angular and millimetric cephalometric outcomes, pre and post-treatment, to evaluate treatment effectiveness; (e) study design: RCTs and CCTs in the English language, with full-text availability. The following exclusion criteria were implemented: (a) studies conducted on patients affected by syndromes or craniofacial deformities; (b) studies conducted on patients who received a previous orthodontic or surgical treatment; (c) studies in which patients were treated using a combination of skeletal and dental anchorage systems, without a clear distinction between data related to the two different types of anchorage; (d) case reports, systematic reviews, meta-analysis and finite element analysis were excluded.

Selection Process

Two independent authors (RP and FI) screened the titles and abstracts of articles identified through the electronic search. When the articles fulfilled the inclusion criteria, the full text was achieved; when the abstract did not contain sufficient information to allow the article's selection, the full text was visioned. The authors read and assessed the full-text articles to verify the attainment of all inclusion criteria; the identification of exclusion criteria led to the rejection of the article. In case of disagreement between the two authors (RP and FI) a third and fourth reviewer (ADS and MH) were appointed to reach the final decision.

Data Items

Data extraction from the articles was performed by the same two authors (RP and FI). The following data were recorded for each article: author/s, year of publication, study type, inclusion and exclusion criteria, treatment strategy, sample size, number of drop-outs, patients' mean age, clinical and cephalometric out-comes reported in the study, direction and intensity of the applied force, mean force application time, mean treatment duration, mean follow-up time, radiographic examinations. Specifically, pre-treatment and post-treatment cephalometric out-comes were classified as follows: (a) sagittal measurements: SNA (°), SNB (°), ANB (°), Wits (mm), overjet (mm); (b) vertical measurements: SNMP (°), overbite (mm); dental relationships: IMPA (°), U1PP (°).

Methodological Quality Assessment

A quality assessment of the articles included in this review was performed. Ten distinct characteristics were evaluated for each article and were assigned an individual score. The overall score, deriving from the sum of the ten individual ones, represented the quality of the article. Quality was expressed as low (total score ≤7), medium (total score >7 e ≤10), medium-high (total score >10 e ≤14) and high (total score >14).

Risk of Bias Assessment

Following the Cochrane risk of bias assessment tool,[20] the risk of bias was individually evaluated for each article by taking into consideration six distinct domains: selection bias, attrition bias, performance bias, reporting bias, detection bias and other bias.

RESULTS

Characteristics of Eligible Studies

A specific search strategy, reported in Table 1, was developed for PubMed, Web of Science, Embase, and Cochrane. In total, 196 studies were identified through the electronic search and submitted to screening, after which 109 studies were immediately excluded (98 duplicates, 11 not written in English). The 87 remaining studies were attentively assessed by the same two reviewers (RP and FM) who determined the exclusion of 70 studies for the following reasons: 47 were case reports, 4 were systematic reviews or meta-analysis, 10 included patients affected by craniofacial deformities or syndromes, 2 included patients previously treated orthodontically and finally, 4 were excluded for other reasons. Hence, the selection process, summarized in the PRISMA flow diagram in Figure 1, led to the inclusion of 17 studies in the qualitative and quantitative analysis, 5 were RCTs and 12 were CCTs.

Ten studies compared the effects of a conventional anchorage therapeutic protocol, represented by RME associated with FM, to a skeletal anchorage therapeutic protocol, represented by the following options: bone anchored maxillary protraction (BAMP) (2 studies),[21,22] zygomatic mini-plates associated with FM (2 studies),[23,25] zygomatic mini-screws associated with FM (1 study),[25] mini-plates inserted laterally to the pyriform aperture associated with FM (3 studies),[26-28], hybrid-hyrax expansion associated with face (2 studies).[29,30] One study compared treatment with a conventional palatal arch associated with FM to treatment with a skeletally anchored palatal arch using 2 miniscrews associated with FM.[31] The remaining 6 studies evaluated the effectiveness of specific treatment protocols in the absence of a reference control group. In particular, two studies assessed the effects of Hybrid-hyrax expansion associated with FM;[32,33] one study evaluated the effects of the BAMP protocol,[12] one study assessed the Alt-RAMEC expansion associated with facemask,[36] one study analysed zygomatic mini-plates associated with FM[28] and, lastly, one study assessed

Table 1. Search strategy

Database	Research Concept	Research Strategy
Pubmed	Concept 1: Patients with class III malocclusion	Class III malocclusion OR Angle class III OR skeletal class III OR retrognathia OR maxillary hypoplasia OR maxillary retrusion OR mandibular hyperplasia OR mandibular protrusion OR Hapsburg jaw
	Concept 2: Orthopedic treatment	Removable orthodontic appliance OR functional orthodontic appliance OR activator device OR reverse-pull headgear OR extra-oral traction appliance OR orthodontic chincup OR facemask
	Concept 3: Skeletal anchorage	Orthodontic anchorage OR skeletal anchorage OR temporary anchorage devices OR miniscrew OR miniplate OR bone anchors OR bone anchored maxillary protraction
Cochrane database	Concept 1: Patients with class III malocclusion	Class III malocclusion OR Angle class III OR skeletal class III OR retrognathia OR maxillary hypoplasia OR maxillary retrusion OR mandibular protrusion
	Concept 2: Orthopedic treatment	Removable orthodontic appliance OR functional orthodontic appliance OR activator device OR reverse-pull headgear OR extra-oral traction appliance OR orthodontic chincup OR facemask
	Concept 3: Skeletal anchorage	Orthodontic anchorage OR skeletal anchorage OR temporary anchorage devices OR miniscrew OR miniplate OR bone anchors OR skeletal maxillofacial protraction
Embase	Concept 1: Patients with class III malocclusion	Class III malocclusion OR Angle class III OR skeletal class III OR retrognathia OR maxillary hypoplasia OR mandibular hyperplasia OR jaw occlusion disorder
	Concept 2: Orthopedic treatment	Removable orthodontic appliance OR functional orthodontic appliance OR activator device OR reverse-pull headgear OR extra-oral traction appliance OR orthodontic chincup OR facemask
	Concept 3: Skeletal anchorage	Orthodontic anchorage OR skeletal anchorage OR temporary anchorage devices OR miniscrew OR miniplate OR bone anchors OR skeletal maxillofacial protraction
Web of Science	Concept 1: Patients with class III malocclusion	Class III malocclusion OR Angle class III OR skeletal class III OR retrognathia OR maxillary hypoplasia OR maxillary retrusion OR mandibular hyperplasia OR mandibular protrusion
	Concept 2: Orthopedic treatment	Removable orthodontic appliance OR functional orthodontic appliance OR activator device OR reverse-pull headgear OR extra-oral traction appliance OR orthodontic chincup OR facemask
	Concept 3: Skeletal anchorage	Orthodontic anchorage OR skeletal anchorage OR temporary anchorage devices OR miniscrew OR miniplate OR bone anchors OR bone anchored maxillary protraction

the effectiveness of the Alt-RAMEC expansion associated with miniplates inserted in the pyriform aperture and FM.[35]

Overall, out of the 17 studies assessed, the authors extrapolated 11 distinct treatment protocols of which 3 made use of conventional anchorage (RME associated with FM, Alt-RAMEC maxillary expansion associated with FM, palatal arch associated with FM) and 8 made use of skeletal anchorage treatment protocols (Hybrid-hyrax associated with FM, BAMP protocol, zygomatic miniplates associated with FM, zygomatic miniscrews associated with FM, skeletally anchored palatal arch associated with FM, miniplates inserted in the pyriform aperture associated with FM, Alt-RAMEC Hybrid-hyrax associated with FM, Alt-RAMEC expansion associated with miniplates inserted in the pyriform aperture and FM). The number of treated case groups and the associated treatment protocols were attentively recorded for each article and are summarized in Table 2. Specifically, a total of 29 case groups were identified, of which 12 were treated with conventional anchorage (group A) and 17 were treated with skeletal anchorage (group B). The detailed description of all the assessed therapeutic protocols is reported and data extracted from the selected articles were displayed in Appendix A to allow synthesis and clarity.

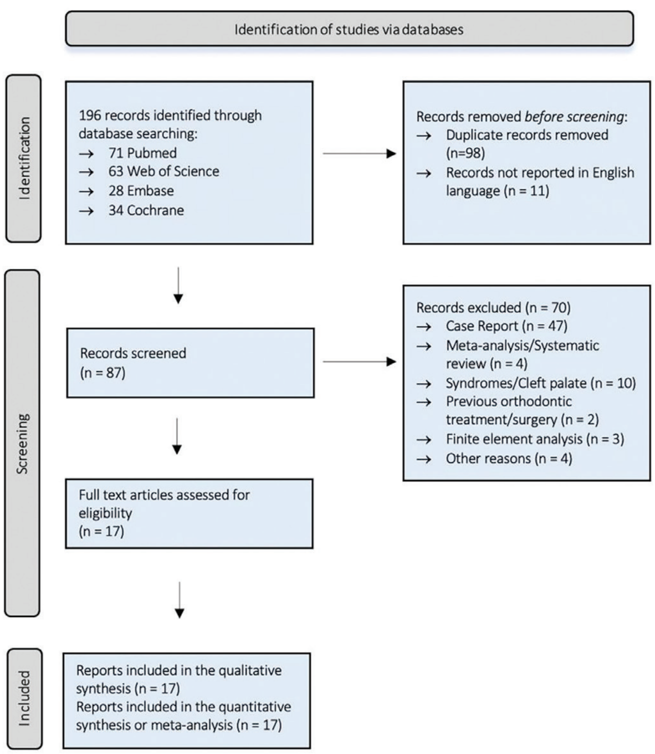

Figure 1. Prisma flow diagram

Methodological Quality Assessment

A quality assessment of the articles included in this review was performed. Ten distinct characteristics, reported in Table 3, were evaluated for each article, and were assigned an individual score. The overall score, deriving from the sum of the ten individual ones, represented the quality of the article, with a maximum score of 16. Overall, six studies resulted of medium quality, ten studies of medium-high quality and no study attained a high-quality score. The summary of the scores established in the quality assessment is reported in Table 4.

Risk of Bias Assessment

Following the Cochrane risk of bias assessment tool, the risk of bias was individually evaluated for each article by taking into consideration six distinct domains. The attribution of the scores corresponding to each domain is reported in Table 5. Overall, the greatest bias was attributed to performance and detection, since no blinding was performed in the process of patient selection and outcome analysis respectively. On the other hand, attrition bias and reporting bias were both regarded as low since all articles attentively reported all data related to the outcomes assessed in the studies.

Statistical Analysis

All statistical analyses were performed using a computer software (The Jamovi Project, 2023, edition 2.3) and all tables were displayed using Excel database (Microsoft Corporation, Washington, 2018). According to the statistical analysis, mean

Table 2. Summary of treatment protocols and number of case groups

Type of anchorage	Levels	N° Case groups	% of total
Conventional	RME + Facemask	10	34.5%
	Palatal Arch + Facemask	1	3.4%
	RME Alt-RAMEC + Facemask	1	3.4%
Skeletal	Hybrid Hyrax + Facemask	4	13.8%
	BAMP Protocol	3	10.3%
	Zygomatic Miniscrews + Facemask	1	3.4%
	Zygomatic Miniplates + Facemask	3	10.3%
	Miniplates Pyriform Apertura + Facemask	3	10.3%
	Palatal Arch + Miniscrew + Facemask	1	3.4%
	Alt-RAMEC + H-Hyrax + Mandibular Miniscrews	1	3.4%
	RME Alt-RAMEC + Miniplates + Facemask	1	3.4%
	Total	**29**	**100.0%**

treatment time was greater in the conventional anchorage treatment protocols when compared to the skeletal anchorage ones, with an average duration of 11.15 months and 9.59 months respectively. In both anchorage groups, the maximum treatment duration resulted in 21 months, whereas the minimum treatment duration was reported as 6.24 months for conventional anchorage protocols and 5.8 months for skeletal anchorage protocols.

Particular attention was paid to the patient's mean age in the conventional and skeletal anchorage treatment protocols. The mean patient age was 9.99 years in the first group and 10.68 years in the second group; the mean patient age refers to the age of the patients at the start of the treatment protocol. The minimum age was recorded as 6.5 years and 8.74 years in the conventional and skeletal treatment protocols respectively. The maximum age, instead, was registered as 11.7 years in the conventional anchorage group and 12.5 years in the skeletal anchorage group.

Pre-treatment (T0) and post-treatment (T1) mean cephalometric outcomes in the conventional and skeletal anchorage treatment protocols were compared. On the sagittal plane, the ANB showed a greater increase in the skeletal anchorage group (+2.511°) with respect to the conventional anchorage group (+2.094°): this increase was the result of both a larger increase in the angle SNA (2.511° compared to 2.094°) and a larger decrease

Table 3. Parameters assessed in the qualitative analysis and method of score attribution

Pre-established characteristics	Code	Score
Adequacy of sample selection description based on age and sex across the groups	A	Full: 2 points; partial: 1 point
Study design for the inclusion of the treated group	B	Prospective: 1 point; retrospective or not declared: 0 points
Description of the Class III (full, skeletal, and/or dental parameters; partial, only dental parameters)	C	Full: 2 points; partial: 1 point
Distribution of the different maturational stages among the investigated subjects	D	Full: 2 points; partial: 1 point
Adequacy of treatment description based on: (a) orthodontic appliance; (b) description of TADs and their placement (miniscrews, miniplates); (c) treatment duration	E	Full: 2 points; partial: 1 point
Withdrawals declared or derivable	F	No/Yes: 1 point; not declared: 0 points
Description of the method error analysis	G	Yes: 2 points; no: 0 points
Blinding for measurements	H	Yes: 1 point; no: 0 points
Adequacy of statistics based on the comparisons of the intragroup changes over time among/between group	I	Yes: 2 points, no: 1 point
Prior estimation of sample size or a posteriori power analysis	J	Yes: 1 point, no: 0 points

Table 4. Summary of scores attributed in the qualitative analysis of the articles

Author	A	B	C	D	E	F	G	H	I	J	Total score	Article quality
de Souza et al.[22]	2	1	2	1	2	0	2	1	2	1	14	Medium/High
Lee et al.[36]	2	0	2	1	2	0	2	0	2	0	11	Medium/High
Willmann et al.[29]	2	0	2	1	2	0	0	0	2	0	9	Medium
Seiryu et al.[31]	2	1	2	1	2	0	2	1	2	1	14	Medium/High
Bozkaya et al.[23]	2	0	2	1	2	0	0	0	2	0	9	Medium
Ngan et al.[30]	2	0	2	1	2	0	2	0	2	0	11	Medium/High
NienKemper et al.[32]	2	0	2	1	2	0	2	0	2	0	11	Medium/High
Ge et al.[25]	2	0	2	1	2	0	2	0	2	0	11	Medium/High
Nienkemper et al.[33]	2	0	2	1	2	0	2	0	2	1	12	Medium/High
Papadopoulou et al.[34]	2	1	2	1	2	0	2	0	2	0	11	Medium/High
Kaya et al.[35]	2	1	2	1	2	0	0	0	2	0	10	Medium
De Clerck et al.[12]	1	0	2	1	1	0	0	0	1	0	6	Low
Buyukcavus et al.[26]	2	0	2	1	2	0	2	0	2	1	12	Medium/High
Ağlarcı et al.[21]	2	1	2	1	2	1	2	0	2	1	14	Medium/High
Koh and Chung[24]	2	0	2	2	2	0	0	0	2	0	10	Medium
Sar et al.[27]	2	1	2	1	2	0	0	0	2	0	10	Medium
Tripathi et al.[28]	2	0	2	1	2	0	0	0	2	0	9	Medium

in the angle SNB (-1.058° compared to -0.914°) in patients treated with skeletal anchorage systems. These data agree with Wits' index, which underwent a more substantial increase in the skeletal anchorage group compared to the traditional anchorage group (+4.691 mm and +3.781 mm respectively). In the vertical plane, the SNMP angle between the Sella-Nasion plane and the mandibular plane was assessed. The increase of this angle resulted less enhanced in patients treated with skeletal anchorage (+0.758°) with respect to patients submitted to conventional treatment protocols (+1.221°). Respectfully to dental parameters, in the dental anchorage group the mean increase in overjet was greater compared to the skeletal anchorage group (+5.255 mm and +4.797 mm respectively), whereas overbite showed a similar mean decrease in both treatment protocols (-0.671 mm and -0.758 mm respectively). The mean decrease in the IMPA angle resulted more enhanced in the conventional anchorage protocols (-2.866°) compared to the skeletal anchorage protocols (-2.518°). However, the more outstanding result was achieved by the angle between the axis of the central upper incisor and the palatal plane, which underwent a substantially higher increase in the conventional anchorage protocols (+5.624°) compared to the skeletal anchorage protocols (+1.193°).

Meta-Analysis

A statistical meta-analysis was conducted to compare the effects of the following treatment protocols:

1. RME + FM
2. BAMP
3. Hybrid-Hyrax + FM
4. Zygomatic miniplates + FM
5. Miniplates in the pyriform aperture + FM

The protocol RME + FM was considered as landmark for conventional anchorage treatment strategies. Pre-treatment and post-treatment mean cephalometric outcomes were statistically compared. The objective of the following meta-analysis was to evaluate the relative effectiveness of each individual skeletal anchorage protocol compared to the conventional anchorage reference protocol (RME + FM). The standardized mean difference (SMD) was used to quantify the effect size. The SMD corresponded to the standardized value of the difference between the mean values of cephalometric outcomes in the conventional and skeletal anchorage treatment protocols. The meta-analysis allowed to identify compelling results, which are reported as follows. In all treatment protocols, exploiting both skeletal and dental anchorage, the increase in the angle SNA resulted as statistically significant and was particularly enhanced in 2 protocols: BAMP and Miniplates in the pyriform aperture + FM. The decrease in angle SNB resulted statistically significant in only 2 protocols: RME + FM and Zygomatic miniplates + FM. With respect to angle ANB, its increase was statistically significant in all protocols and distinctly emphasized in 2 of them: Miniplates in the pyriform aperture + FM and BAMP. The increase in the Wits index was, again, statistically significant in only 2 protocols: BAMP and RME + FM. The increase in the angle SNMB did not result statistically significant. Regarding the dental parameters, the increase in overjet resulted statistically significant only in the treatment protocol employing dental anchorage, RME + FM. The decrease in overbite did not result statistically significant in any of the protocols examined. At last, the increase in the angle

Table 5. Risk of bias evaluation

Author	Selection bias	Attrition bias	Performance bias	Reporting bias	Detection bias	Other bias
de Souza et al.[22]	Low	Low	Low	Low	Low	Low
Lee et al.[36]	High	Low	High	Low	High	Low
Willmann et al.[29]	Low	Low	High	Low	High	Low
Seiryu et al.[31]	High	Low	Low	Low	Low	Low
Bozkaya et al.[23]	Low	Low	High	Low	High	Low
Ngan et al.[30]	Low	Low	High	Low	High	Low
NienKemper et al.[32]	High	Low	High	Low	High	Low
Ge et al.[25]	Low	Low	High	Low	High	Low
Nienkemper et al.[33]	Low	Low	High	Low	High	Low
Papadopoulou et al.[34]	High	Low	High	Low	High	Low
Kaya et al.[35]	High	Low	High	Low	High	Low
De Clerck et al.[12]	Unclear	Low	High	Low	High	Low
Buyukcavus et al.[26]	Low	Low	High	Low	High	Low
Ağlarcı et al.[21]	Low	Low	High	Low	High	Low
Koh and Chung[24]	High	Low	High	Low	High	Low
Sar et al.[27]	High	Low	High	Low	High	Low
Tripathi et al.[28]	High	Low	High	Low	High	Low

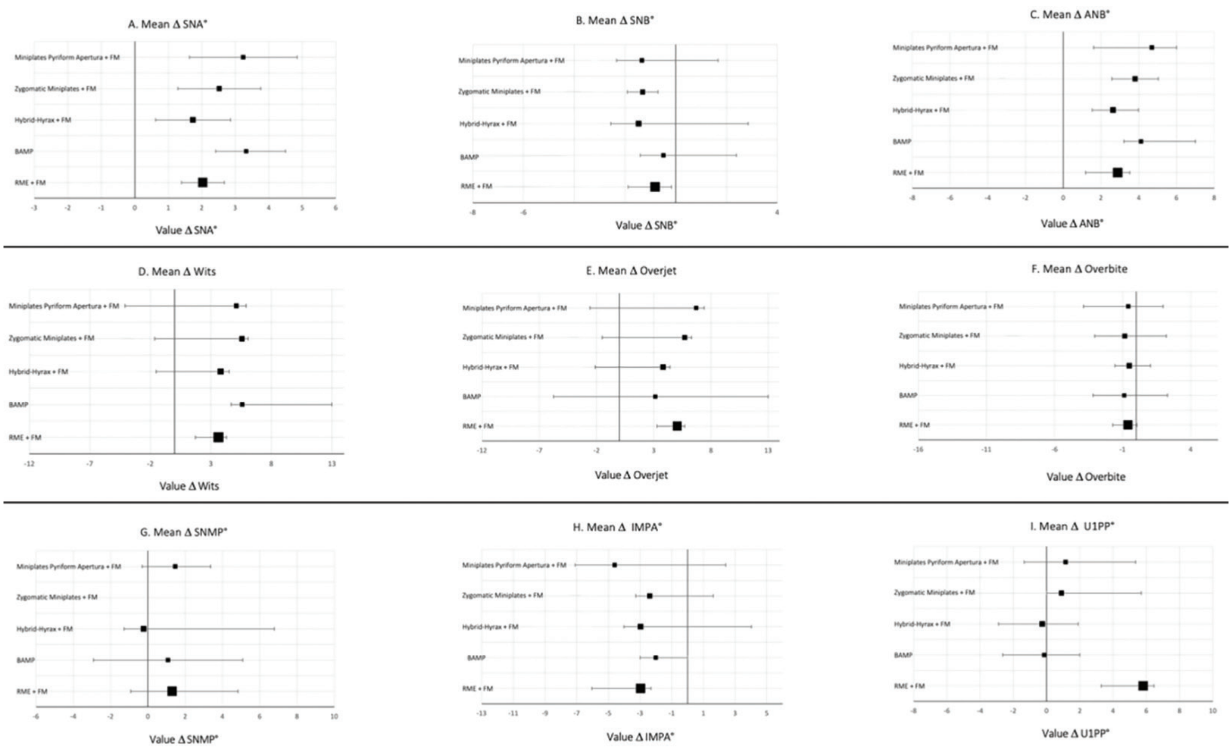

Figure 2. Forest plots of the effects of the treatment protocols. A. Effect in SNA°; B Effect in SNB°; C. Effect in ANB°; D. Effect in Witts; E. Effect in Overjet; F. Effect in overbite; G. Effect in SNMP°; H. Effect in IMPA°; I. Effect in U1PP°

U1PP and the decrease in the angle IMPA resulted statistically significant only in the dental anchorage treatment protocol. The forest plots of interventional treatments included in the meta-analysis are available in Figure 2.

DISCUSSION

A variety of distinct strategies are reported in literature with respect to orthopaedic treatment of skeletal Class III.[36-39] What may be asserted with certainty is that the earlier the orthopaedic approach is employed, the greater the skeletal changes that may be appreciated. With advancing age, skeletal correction may be surmounted by dental adjustments.[6,36] Hence, treatment results and their long-term stability represent a current research topic which orthodontists are scrupulously investigating.

To date, early treatment of skeletal Class III malocclusion is regarded as a valid strategy to improve the patients' aesthetics and to reduce the future need of combined surgical and orthodontic treatments.[40] The clinician's choice of the best timing of intervention should also take into consideration that, amongst the objectives of orthodontic treatment, the improvement of facial aesthetics represents a key component, along with the resolution of dental and skeletal discrepancies.[41,42] According to Alhammadi et al.[43] the age of the patient and the severity of the malocclusion represent the two decisive factors to assess in the decision of the best treatment timing. The results of this research highlight that the mean patient age was higher in treatments exploiting skeletal anchorage protocols compared to conventional ones.

There is a vast amount of existing research supporting the effectiveness of bone-anchored devices in the treatment of Class III malocclusion. The key advantages of skeletal anchorage are represented by the predictability of the biomechanical forces and the stability of the clinical outcomes,[37] allowing the clinician to contrast the adverse effects of facemask therapy, such as the increase in the lower anterior facial height, the proclination of the maxillary incisors and the retroclination of the mandibular incisors.[15,18,38]

The analysis of the results shows that treatments that exploited skeletal anchorage determined on average a better correction of skeletal Class III. This was made possible by of increased maxillary advancement and improved mandibular retrusion. Nevertheless, the results of the meta-analysis show that even in the conventional anchorage protocol, represented by RME + FM, the increase in angles SNA and ANB resulted statistically significant. Thus, the employment of a dental anchorage protocol does allow the correction of class III but not without any drawbacks. In fact, dental movements appeared to be significantly more enhanced in the conventional anchorage treatment protocols, in which the increase in overjet was predominantly achieved by accentuating the buccal inclination of the upper central incisors. As the results of the meta-analysis demonstrate, the increase in the angle U1PP and the decrease in the IMPA angle resulted statistically significant exclusively in the RME + FM protocol, implicating a lower long-term stability of the Class III correction. With respect to vertical changes, overall, the increase in the angle SNMP resulted less enhanced in patients treated with skeletal anchorage but, according to the meta-analysis, the difference in vertical changes between skeletal and dental anchorage treatment protocols may not be considered as statistically significant.

Along with the choice of which anchorage type to implement, the clinician also faces the choice of the most appropriate treatment timing.

Study Limitations

The main limitation of the present study is represented by the restricted sample size examined for each of the distinct treatment protocols employing skeletal anchorage. Hence, the results achieved do not allow the establishment of evidence-based conclusions with respect to the effects of skeletal anchorage in interceptive Class III treatment. Another key limitation is represented by the lack of data regarding the long-term effects of therapies exploiting skeletal anchorage as very few studies included a long-term follow-up of the patients submitted to treatment.

The ultimate goal of this review was to identify which therapeutic approach yields the best results in correcting maxillary deficiency in skeletal Class III children with minimal adverse effects. In the short term, according to the assessment of the results of the present study, it seems that the most promising treatment protocol employing skeletal anchorage is the BAMP. In fact, in patients treated with such protocol, the following were observed: highest increase in the angle SNA, lowest increase in the proclination of the upper incisors, lowest retroclination of the lower incisors and good control of the vertical dimension. Clearly, this study presents insufficient evidence to support the encouraging results observed but it raises awareness on the need of future studies that may assess the auspicious outcomes of the BAMP protocol in the interceptive treatment of skeletal Class III.

CONCLUSION

The conventional treatment protocol, comprising RME associated to facemask, allows the correction of Class III malocclusion through a combination of skeletal and dentoalveolar effects. More specifically, in all treatment protocols exploiting dental anchorage, the increase in the inclination of the central incisor resulted significantly greater compared to bone anchorage protocols. The application of skeletal anchorage, instead, allows to convey the employed forces directly to the skeletal components and circum-maxillary sutures, thus maximizing skeletal changes whilst minimizing undesired dental movements. Furthermore, the employment of skeletal anchorage enhances the sagittal advancement of the maxilla and reduces the unwanted vertical changes. It should be noted that there has been insufficient long-term research, thus conclusions should be drawn cautiously. These conclusions do not ensure any direct therapeutic success; rather, the clinician should exercise caution when using skeletal anchorage invasively in Class III children, as increasing bone conditions and stability are vulnerable to many circumstances.

Ethics

Informed Consent: A systematic review and meta-analysis.

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Footnotes

Author Contributions: Concept - R.P., G.G.; Design - G.G.; Data Collection and/or Processing - F.I., A.A.D.S. M.H., R.A.V.; Analysis and/or Interpretation - A.A.D.S. M.H.; Literature Search - R.P., F.I., R.A.V.; Writing - R.P., A.A.D.S. M.H.

Conflict of Interest: All the authors declare no conflict of interest in connection with this article.

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Appendix: https://d2v96fxpocvxx.cloudfront.net/90a4190a-90d9-41a4-a9c9-d78d3fa8efda/content-images/9ef152b8-dbab-45ea-b88b-cdb4c39dff03.pdf