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Randomized Controlled Trial (RCT)

The skeletal and dental effects of Hanks Herbst versus twin block appliances for class II correction in growing patients: a randomized clinical trial

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Summary

Background: Despite the popularity of the Twin Block (TB) and the Hanks Herbst (HH) functional appliances, there is limited prospective research comparing these removable and fixed designs, respectively.

Objectives: To evaluate and compare the skeletal and dental effects associated with TB and HH functional appliances as well as to detect factors that might influence the success or failure of treatment in adolescents with Class II malocclusion.

Design and setting: A parallel-group randomized controlled trial was undertaken in a single-centre hospital in the United Kingdom.

Methods: A total of 80 participants (aged 10–14 years) with overjet of 7 mm or more were randomized to receive either the HH or TB appliance. Cephalometric radiographs were collected at the start of the study and immediately after the withdrawal of the functional appliances and measured using Pancherz analysis. Participants were allocated to the TB or HH group, based on an electronic randomization, stratified for gender and allocation concealed. Blinding to the allocated arm was not possible. However, all data were coded and anonymized to ensure that assessors were blinded to the group allocation. The main outcome was the anterior–posterior skeletal and dento-alveolar changes at the end of the functional phase.

Results: Fifteen (37.5%) participants from the TB group and 7 (15.5%) from HH failed to achieve full overjet reduction (<4 mm) after 12 months of treatment. Overjet reduction was 2 mm greater with HH compared to TB ($P = .05$; 95% CI: 0.2, 3.2). No significant differences regarding skeletal and dental changes were reported, with the exception that participants in HH group experienced greater lower molar protraction ($P = .002$; 95% CI: −2.8, −0.8) and mandibular incisors advancement ($P = .001$; 95% CI: −2.9, −1), indicating greater dental than skeletal effects.

Conclusion: The TB appliance was associated with a higher rate of treatment discontinuation. No significant clinical differences were observed in the skeletal and dental effects, although the HH may be associated with more pronounced effects on the mandibular dentition.

Clinical Trial Registration: The protocol was registered online before the start of the trial (ISRCTN11717011).

Keywords: Functional appliance; Fixed; Removable; Trial; adolescents

Introduction

The Twin Block (TB) and the Herbst are popular removable and fixed functional appliances, respectively [1, 2]. The original Herbst design was rigid, making chewing and hygiene measures difficult. In addition, fabrication and fit were both time- and cost-intensive. Hence, many modifications have been introduced aiming to overcome those limitations. The Hanks Telescoping Herbst (HH) design has been developed (American Orthodontics, Sheboygan, WI, USA), to reduce the risk of breakages associated with traditional Herbst design. It includes prefabricated Rollo bands which have ¾ occlusal coverage to increase retention and stability. On the buccal surfaces of the Rollo bands, there are threaded attachments into which the telescoping arms are screwed. The prefabricated telescoping arm allows easy replacement in case of emergency, reducing the dependence on laboratory support. It is also intended to obviate the risk of disengagement of the telescoping arms, to increase the range of mandibular excursive movements and associated comfort. These arms are available in different lengths (21, 24, 27, and 31mm) based on the requirement for forward posture. These may be combined with a trans-palatal arch or rapid expander in the maxilla and a lingual arch in the mandible to minimize unwanted side effects and to facilitate transverse correction as required.

There is limited prospective research comparing removable and fixed designs, with a previous systematic review concluding that most comparative studies were subject to performance bias and heterogeneity in relation to treatment protocols [3]. Overall, both removable and fixed functional appliances have shown success in reducing the overjet to the range of 5 mm, with similar proportional correction in terms of skeletal and dental effects in the sagittal plane [4]. However, there was no significant clinical evidence to suggest the superiority of one design over the other [3, 5]. Furthermore, previous clinical trials have combined the functional phase of treatment with the use of multibracket fixed appliances before and/or after the functional phase, potentially contaminating direct comparison [6–9].

A prospective study comparing the effects of the combined Headgear-Activator appliance versus the Herbst found that overjet reduction in the Headgear-Activator group was greater than in the Herbst group, which might relate to the adjunctive use of the headgear [10]. Baysal *et al.* reported that the TB resulted in greater skeletal effects than the Herbst appliance with the latter producing more mandibular molar and incisal advancement [8]. O'Brien *et al.* found that overjet reduction was mainly dento-alveolar in nature, with minor skeletal change and of similar magnitude with both appliances [6]. A further limitation in the published studies was the inclusion of the labial bow in the TB design, which might have accentuated the dento-alveolar effects.

The removable nature of the TB appliance and the catastrophic breakages with the Herbst design have been implicated in the failure of functional therapy [5]. Moreover, morphological factors contributing to the success of functional therapy have previously been assessed based on cephalometric studies. For example, skeletal and dental dimensions, including mandibular length, ramus height, anterior facial height ratio, and the magnitude of overbite depth, have been linked to the success of functional treatment [11–13]. In contrast, other prospective studies have failed to find a relationship between skeletal morphology and response to functional treatment [6, 14]. O'Brien *et al.*, however, found that the use of a TB appliance was associated with a greater chance of failure to complete the functional phase of treatment compared to Herbst, in which girls achieved a greater skeletal II correction compared to boys, regardless of the type of functional appliance [6]. It would be intuitive to expect that this increased non-compliance rate might reduce the efficiency and relative predictability of TB therapy.

The current study thus aimed to compare the skeletal and occlusal effects associated with TB and HH functional appliances and to detect factors that might influence the success or failure of treatment. Other outcomes related to treatment duration, patient experiences, complications, and the impact of functional appliance wear on the oral health-related quality of life have been reported recently [15] and are not within the scope of the current paper.

Materials and methods

Trial design

A parallel-group randomized clinical trial (RCT) with a 1:1 allocation ratio was undertaken. The protocol was registered online before the start of the trial (ISRCTN11717011). Ethical approval was obtained from the U.K. Health Research Authority (IRAS project ID: 208408) along with local approval by Research and Development Department. Written informed consent and assent forms were also obtained from participants and their parents/guardians.

Participants

Participants were recruited at the Institute of Dentistry between February 2017 to September 2019. Treatment was carried out by one specialist orthodontist (M.M.P.) who had, prior to study commencement, gained further training in the use of both appliances. The following selection criteria were applied: (i) Class II division 1 incisor relationship, with an overjet of 7 mm or greater, (ii) aged 10–14 years. Those with a history of previous orthodontic treatment, missing teeth, relevant medical conditions, and/or hyper-divergent facial type (Mandibular plane to palatal plane > 40°) were excluded.

Interventions

A modified Clark Twin Block (TB) appliance was used with the bite registration taken in edge-to-edge or in maximum comfortable mandibular advancement. The following components were incorporated in the TB design: (i) Adam's clasps on all first premolars (or first deciduous molars) and first permanent molars, (ii) ball-ended clasps on the mandibular incisors, (iii) midline expansion screw in the maxillary component, (iv) blocks intersecting at 70°C, with an approximate height of 6 mm in the first premolar region (Fig. 1). Participants were instructed to wear the appliance full time, except for eating and during contact or water sports.

In the comparison group, the Hanks Telescoping Herbst (HH; American Orthodontics, Sheboygan, WI, USA) was fabricated from stainless steel Rollo bands on the first permanent molars only with buccally positioned threaded attachments, connecting a lingual arch in the mandible and trans-palatal arch (cantilever design; Fig. 2). If maxillary expansion was required, a rapid maxillary expander was incorporated in the upper component. The appliance was cemented with light-cured glass ionomer material (3M Unitek™, USA). The bite was registered with mandibular advancement of 4–6 mm. Later activation was carried out by incrementally advancing the mandible using bespoke 1 or 2 mm crimpable stops. Once the overjet was reduced to < 4 mm, the telescoping arms were removed for 4–6 weeks to check the stability and retention of the overjet. If the overjet was still stable, the HH was removed, and the need for the multi-bracket fixed appliance phase considered.

Participants in both groups were reviewed on a 6- to 8-weekly basis and those who failed to attend an appointment were offered another. Once the overjet was clinically corrected (<4 mm) and deemed stable, the functional appliance was removed, and the treatment was considered complete. No treatment with multi-bracket appliance was undertaken before or during the functional therapy to allow for measuring the effects of functional appliances in isolation. In line with the study protocol, non-compliance with the treatment (treatment failure) was characterized as follows:

1) Overjet not reduced by at least 10% after 6 months.
2) Failure to achieve a normal overjet (<4 mm) after 12 months of active treatment.
3) Severe complications (e.g. catastrophic fracture of appliance or embedment in the soft tissue) more than three times within the first 6 months.
4) Persistent poor oral hygiene preventing the continuation of the treatment.

Outcomes

The main outcome of the current study was the anterior–posterior skeletal and dento-alveolar change at the end of the 12-month functional phase, based on Pancherz cephalometric analysis [16]. Other outcomes relevant to the duration of treatment, as well as other secondary outcomes (e.g. complications, cost effectiveness and impact on quality of life) have

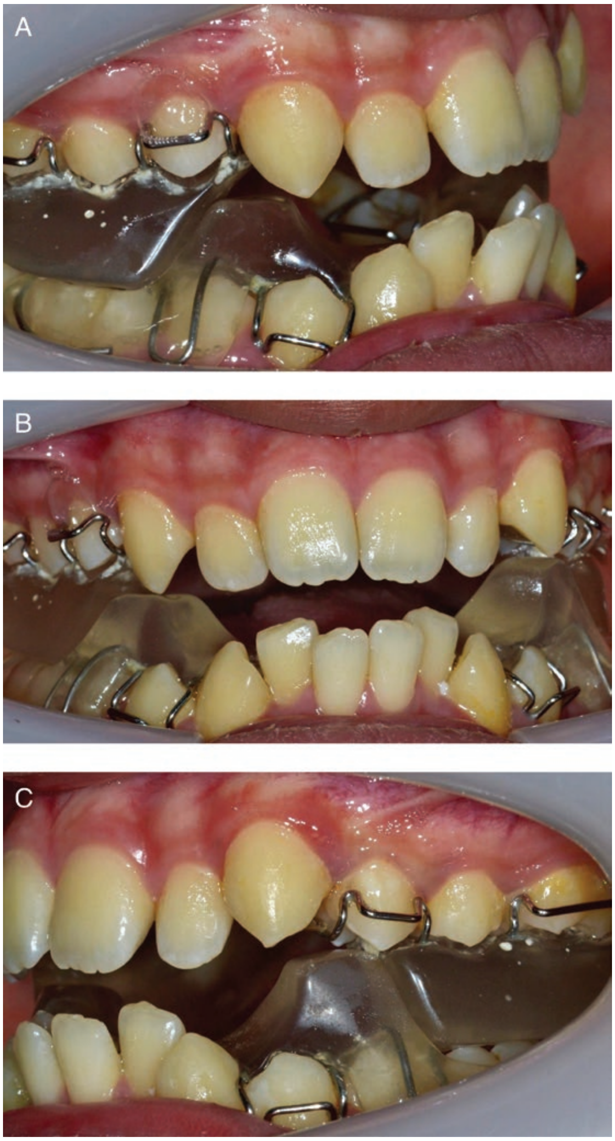

Figure 1. (a–c) Twin Block design.

been reported recently [15] and are not within the scope of the current paper.

Overjet and occlusal measurements were taken from cephalometric radiographs at the start of the study (T0) and immediately after the withdrawal of the functional appliance (T1). The cephalograms were corrected for magnification and traced manually and analysed by a single examiner (M.S.) using the Pancherz analysis (16; Fig. 3). The reliability of cephalometric landmark identification was evaluated with repeat measure undertaken on 15 randomly selected cephalograms, with a 2-week intervening period. For all the linear measurements, the occlusal line (OL) and the occlusal line perpendicular (OLp) from the T0 cephalogram were used as a reference grid. The grid was then transferred from the T0 tracing to the T1 by superimposition on the nasion-sella line (NSL) registering on sella (S). Sagittal changes including changes in relation to OLp, occurring during the functional treatment were measured by calculating the difference (*d*) in landmark position (Table 1). Additionally, vertical changes were assessed by evaluating changes in the lower anterior facial height percentage (LAFH%).

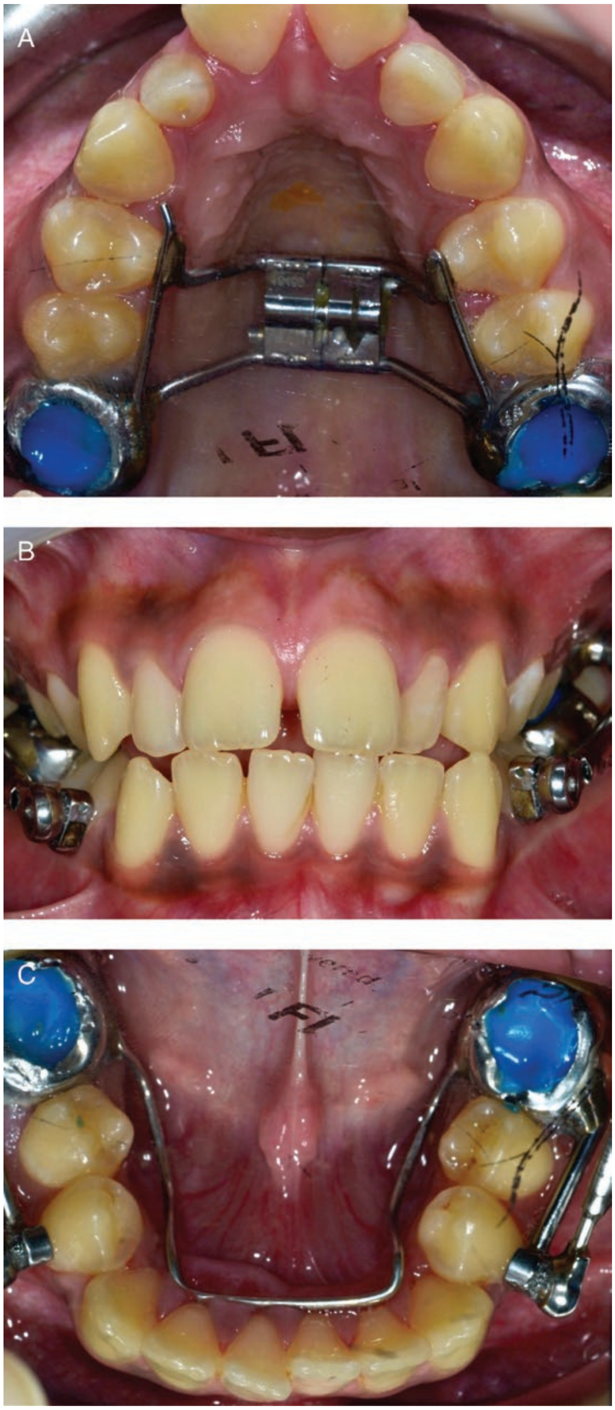

Figure 2. (a–c) Hanks Herbst appliance.

Sample size

The sample size was calculated based on a previous study using the difference in treatment duration required to correct the overjet during treatment with the TB and HH appliances [3]. This indicated that a 4-month (SD = 4.6) difference was regarded as clinically significant, and therefore, a sample size of 40 participants per group was recruited, which allowed for a non-compliance rate of 30%, with a power of 85% and a significance level of 0.05. However, we acknowledge that treatment duration is not within the scope of the current paper, and results relevant to this outcome were published in our allied paper related to this body of research [15].

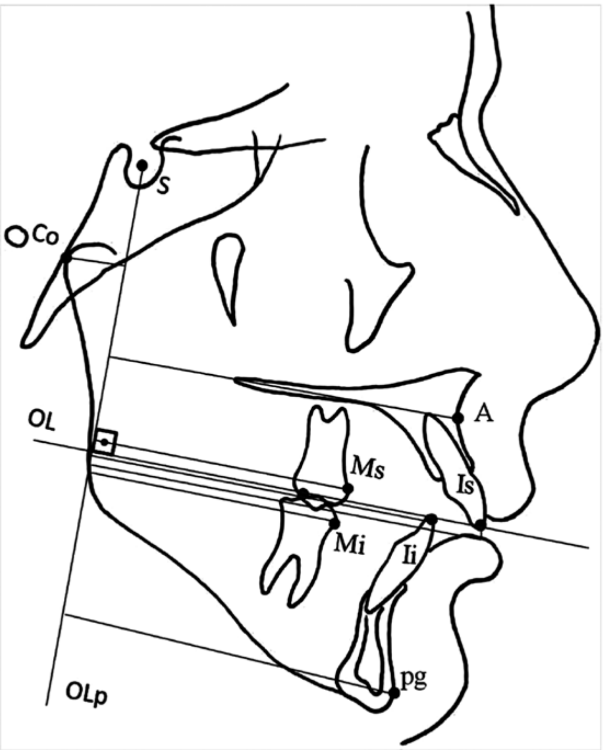

Figure 3. Modified Pancherz analysis, with measurement landmarks added.

Randomization and allocation concealment

Participants fulfilling the selection criteria were recruited from new patient clinics. Information leaflets were provided to both participants and their parents/guardians. Those agreeing to participate were provided information leaflets and rescheduled for both assent and consent process, with the collection of baseline records. Each participant was then randomly allocated to the TB or HH group, based on an electronic randomization, stratified for gender, and performed by an independent statistician. Allocation was concealed from both the participant and treating clinician using sequentially numbered, opaque sealed envelopes.

Blinding

The visibility of the functional appliances precluded the blinding of either the clinician or the participants to the allocated arm during treatment. However, all used participants' data were coded and anonymized to ensure that assessors and statisticians were blinded to the group allocation.

Statistical methods

Descriptive statistics were used to assess baseline demographic and clinical data. The reliability of cephalometric landmarks was assessed using the intra-class correlation coefficient and judged as good to excellent for all cephalometric variables (>0.7). A Wilcoxon–Mann–Whitney test was used to assess cephalometric data.

Regression models were constructed to detect factors that might have influenced final overjet (Is/OLp minus Ii/OLp), final skeletal discrepancy (A/OLp minus Pg/OLp), and failure of treatment. Tested covariates included gender, age, initial overjet, initial skeletal discrepancy, and initial lower anterior facial height ratio.

Statistical analyses were performed using JMP®, Version 14.2 (SAS Institute, Inc., Cary) with the level of statistical significance predefined at $P < .05$. The data were analysed on an intention-to-treat basis, and all participants' records included according to their original allocation, regardless of the outcome of treatment.

Results

Overall, 127 participants were assessed for potential participation in the trial. Of these, 47 were found to be ineligible and excluded (Fig. 4). Eighty participants (40 per group) were allocated to TB and HH treatment, with equal distribution of males and females. Baseline demographic and clinical characteristics, including age, gender, ethnicity, initial overjet, and peer assessment rating score are presented in Table 2, with no meaningful clinical differences observed between the groups.

Two participants from the TB group failed to reduce their overjet after 6 months of treatment and were lost to follow up. A further 13 participants in the TB group also failed to have full overjet reduction (<4 mm) increasing the total number of failures in the TB group to 15 (37.5%). In the HH group, no dropouts were reported. However, seven participants (17.5%) discontinued their treatment due to poor oral hygiene, frequent breakages and/or complications and were deemed failures.

Before treatment, there were no significant differences between the treatment groups for any of the cephalometric landmarks, with favourable changes during treatment reflecting Class II correction in both groups (Table 3). Data from the Pancherz analysis (Table 4) showed that overjet reduction in the HH group (−6.9 mm) was approximately 2 mm greater than the TB (−5.1), which was statistically significant ($P = .05$; 95% CI: 0.2, 3.2). Similarly, the HH was more effective than TB in correcting the molar relationship which was again statistically significant ($P = .02$; 95% CI: 0.2, 3.4).

Dentally, both appliances had a similar effect on maxillary incisor retraction and maxillary molar distalization. However, the HH was associated with significantly greater mandibular molar advancement ($P = .002$; 95% CI: −2.8, −0.8) and incisor protrusion ($P = .001$; 95% CI: −2.9, −1). Skeletally, no significant differences were found between both groups in relation to the final position of the maxilla. More pronounced forward movement of the mandibular base was observed in both groups (2.7–3.5 mm), although the between-group difference was not statistically significant ($P = .54$; 95% CI: −0.8, 2.5). Overall, there was a similar improvement in the skeletal discrepancy and an increase in overall mandibular length in both TB (3.4 mm) and HH (2.9 mm) groups, with no statistically significant difference detected ($P = .8$; 95% CI: −1.2, 2; Table 4). Based on the regression models (Table 5), treatment with TB was a significant predictor for higher final (residual) overjet [$\beta = 1.7$, 95% CI, 0.35–3.18, $P = .02$]. Furthermore, increased pre-treatment overjet was found to be a predictor for higher residual overjet, regardless of the type of appliance used ($\beta = 0.43$, 95% CI, 0.05–0.82, $P = .03$]. Similarly, the final skeletal discrepancy was positively influenced by the pre-treatment discrepancy ($\beta = 0.77$, 95% CI, 0.57–0.97, $P = 001$), as well as pre-treatment lower anterior height ratio ($\beta = 30.8$, 95% CI, 4.66–57, $P = .02$, Table 5).

Discussion

In the current study, we found that both appliances partially or completely reduced the overjet and contributed to the

Table 1. Definition of angular and linear measurements according to Pancherz analysis.

Definition	Pancherz measurement
Overjet (negative values indicate reduction and correction)	Is/OLp(d) minus Ii/OLp(d)
Molar relationship (a distal relationship: positive value; a mesial relationship: negative value)	Ms/OLp(d) minus Mi/OLp(d)
Sagittal position of the maxillary base	A point/OLp (d)
Sagittal position of the mandibular base	Pg/OLp (d)
Skeletal discrepancy	A point/OLp(d) minus Pg/OLp(d)
Sagittal position of the condylar head	Co/OLp(d)
Composite mandibular length	Pg/OLp(d) plus Co/OLp(d)
Sagittal position of the maxillary central incisor within the maxilla	Is/OLp(d) minus A point/OLp(d)
Sagittal position of the mandibular central incisor within the mandible	Ii/OLp(d) minus Pg/OLp(d)
Sagittal position of the maxillary permanent first molar within the maxilla	Ms/OLp(d) minus A point/OLp(d)
Sagittal position of the mandibular permanent first molar within the mandible	Mi/OLp(d) minus Pg/OLp(d)

improvement of the skeletal discrepancy in the short term. The HH appliance was more effective than the TB in correcting the overjet, which is in keeping with previous prospective studies [6–9]. Generally speaking, the mandibular contribution was greater than the maxillary for both dental and skeletal changes. In particular, the HH produced greater mandibular molar protraction and incisor advancement compared with the TB, which might explain its greater efficiency and predictability in reducing the overjet.

The lower incisors advanced more appreciably during HH treatment. Similar considerable proclination of mandibular incisors was also reported during treatment with fixed Class II correctors, including Forsus, Twin Force Bite Corrector as well as Herbst appliance [7–9]. This change may need to be factored into space requirements during the subsequent multi-bracket fixed appliance phase. In particular, excessive proclination has been suggested to risk instability and deleterious effects on the periodontium [17–20]. The differential effects introduced to the mandibular dentition may relate to the presence of occlusal acrylic coverage associated with the TB design, providing anchorage to restrain lower incisal advancement. Alternatively, the reduced wear time and limited associated force transmission during the TB phase may well be contributory [21]. These findings are in keeping with the majority of previous prospective research detailing the effects of functional appliances [3, 4, 22, 23].

In terms of the skeletal correction, based on Pancherz analysis, no statistical difference was observed with both appliance groups achieving approximately 3 mm of correction over treatment. This was found to be in broad agreement with previous studies [6, 8], although Baysal *et al.* reported correction of up to 4.2 mm with the TB. In the current study, the increase in the LAFH% was minimal with both appliances, although slightly greater in the TB group. This was anticipated with the height of the blocks potentially contributory, whereas the HH has telescoping arms permitting forward mandibular posture with limited vertical opening.

A significant clinical difference was observed in treatment discontinuation, with higher failure rates in the TB (37%) compared to the HH (17%). This is related to either lack of overjet reduction, frequent breakages, or persistent poor oral hygiene. These findings were in keeping with previous research [5] and can be attributed to the enforced nature of full-time wear with the HH, leading to adaptation and acceptance of the appliance sooner than might be the case with the TB appliance. Furthermore, the regression model suggested that older children are more likely to find the appliances difficult to adapt to, regardless of their appliance design. However, these findings should be interpreted with caution as the study was not powered to evaluate the effects of demographics, in isolation.

The regression model suggested that there was a significant positive correlation between pre-treatment overjet, antero-posterior skeletal discrepancy, and lower anterior facial height, and post-treatment residual overjet, regardless of the appliance design. Moreover, we found a significant positive association between the lower anterior facial height ratio at baseline and the final skeletal discrepancy. Therefore, it may be reasonable to suggest that adolescents with reduced anterior facial height, milder skeletal discrepancies, and lower overjet might be more likely to experience efficient overjet reduction with functional appliance therapy. Conversely, O'Brien *et al.* [6] did not find a correlation between pre-treatment skeletal and dental measurements and the success of functional therapy but suggested that correction in girls was 1.6 times greater compared to boys, with no impact of the initial vertical proportion on the final skeletal discrepancy. This variation could be explained by the imbalanced gender distribution and attrition bias in the previous study [6]. Nevertheless, the findings of the current study should be interpreted with caution as significantly increased skeletal discrepancy was excluded from the sample.

Limitations

We used the Pancherz analysis with superimposition to evaluate morphological changes, an approach that has been widely used in previous studies [6, 8, 24, 25]. However, this analysis lacks norms or reference values in which participants can be compared to evaluate the severity of malocclusion, as well as the magnitude of correction. Nevertheless, the Pancherz analysis comprises only linear measurements, which may be more reliable being constructed from only two landmarks, compared to three or four landmarks that are required to construct angular measurements [26]. Another potential challenge with the Pancherz analysis is that it is confined to horizontal changes and alterations in the sagittal plane only; however, in the present study, this was addressed with evaluating changes in the lower anterior facial height ratio (LAFH%).

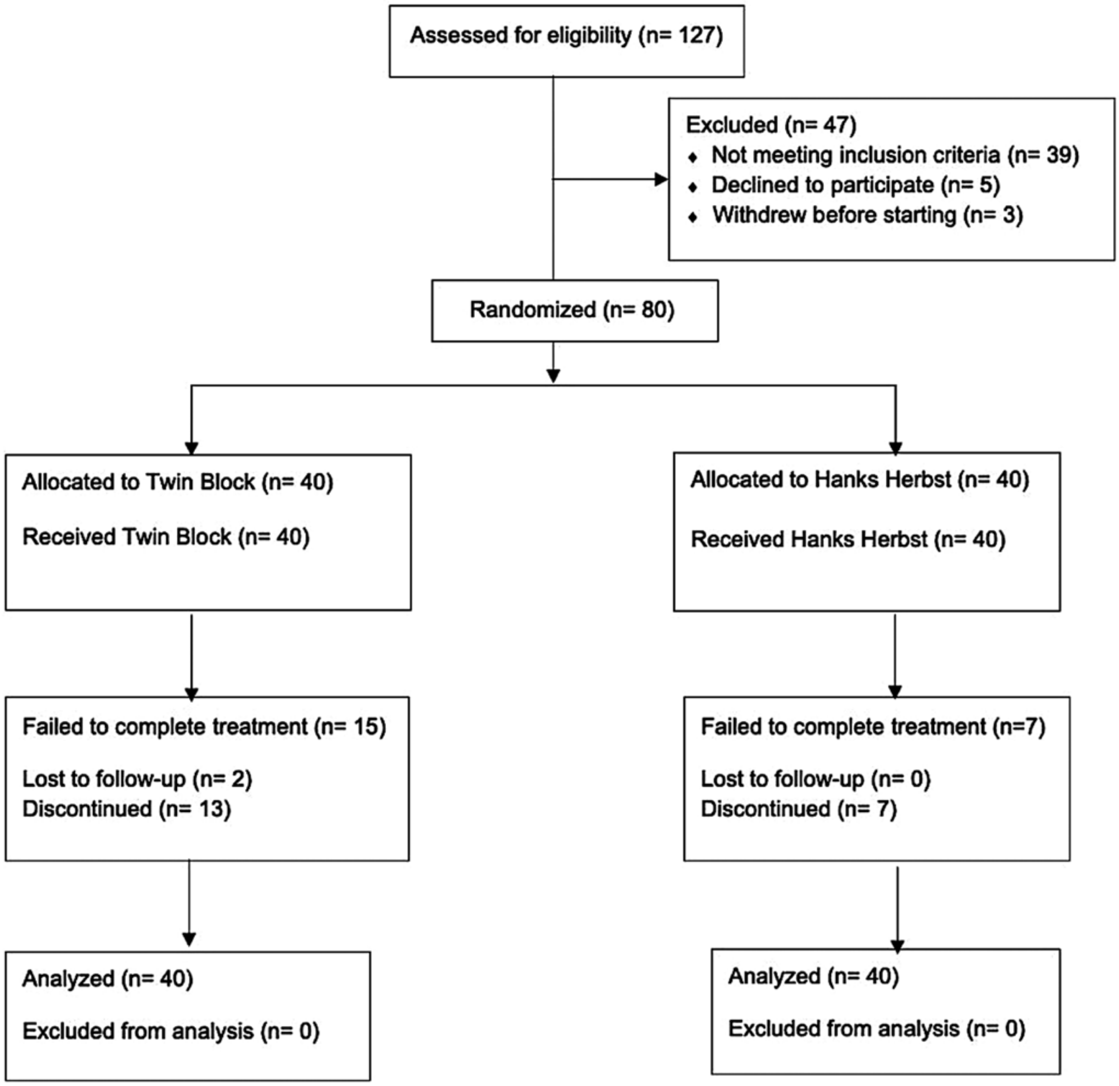

Figure 4. CONSORT flowchart of participants in the study.

Table 2. Comparison of baseline (T0) participant characteristics.

Variable	Twin Block group (n = 40) Mean (SD) or N (%)	Hanks Herbst group (n = 40) Mean (SD) or N (%)
Gender	20 Female, 20 Male	20 Female, 20 Male
Age range (years)	10–14	10–14
Mean age (years)	12.8 (1.3)	12.7 (1.2)
Ethnicity		
South Asian	21 (52.5%)	25 (62.5%)
White	14 (35%)	10 (25%)
Afro-Caribbean	5 (12.5%)	5 (12.5%)
Overjet (mm)	10.3 (2.1)	10.4 (2.3)
Peer Assessment Rating score	39.6 (8.6)	39.9 (6.4)

In the current study, we did not include the stage of maturity of the cervical spine as a surrogate measure of growth and maturity. This approach is in keeping with other well-designed RCTs with the outcomes of growth modification typically not correlated with skeletal maturation [6, 25]. The age range was therefore arbitrarily determined to be between 10 and 14 years old, for both males and females, matching the age of participants in similar previous studies [3] based on the assumption that growth modification is ineffective beyond this age.

The present RCT was confined to a single-centre teaching hospital setting, involving patients treated within a publicly funded healthcare system. It is known that compliance may be influenced by a range of factors including payment for treatment [27]. As such, the findings may overstate the difference in compliance between the fixed and removable alternatives, affecting the generalizability of the results.

Conclusions

- Based on the present clinical trial, the HH may be more effective than the TB in terms of overjet reduction and molar relationship correction.

Table 3. Comparisons of Pancherz variables at baseline (T0) and end of functional treatment (T1) within each group.

Variable (mm)	Hanks Herbst (*n* = 40)		Twin Block (*n* = 40)	
	T0	T1	T0	T1
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Maxillary incisor (Is/OLp)	83.2 (4.1)	82 (5.8)	83.3 (6.1)	82.8 (6.3)
Mandibular incisor (Ii/OLp)	72.8 (4.8)	78.4 (6)	73.1 (6.6)	77.6 (7)
Overjet (Is/OLp minus Ii/OLp)	10.4 (2)	3.6 (2.2)	10.3 (2)	5.2 (3.9)
Maxillary molar (Ms/OLp)	49.4 (4.8)	48.3 (5.9)	49.3 (4.8)	49 (4.9)
Mandibular molar (Mi/OLp)	47.9 (4.8)	53.2 (5.9)	48.2 (5.7)	52.6 (5.4)
Molar relationship (Ms/OLp minus Mi/OLp)	+1.5 (2)	−5 (3.2)	+1.1 (2)	−3.6 (3.5)
Maxillary base (A/OLp)	72.4 (3.8)	72.8 (5.3)	71.7 (5)	72.7 (5.6)
Mandibular base (Pg/OLp)	71.4 (4.2)	74.1 (5.5)	71.1 (5.6)	74.6 (5.6)
Skeletal discrepancy (A/OLp minus Pg/OLp)	+1 (2.9)	−1.4 (3.5)	+0.6 (4.3)	−2 (4.8)
Condylar head (Co/OLp)	13.4 (3.5)	13.6 (3.7)	14.9 (4.5)	14.8 (4)
Mandibular length (Pg/OLp + Co/OLp)	84.9 (4.4)	87.7 (5)	86 (6.7)	89.4 (5.7)
Lower anterior facial height (%)	54.4 (3)	55.8 (2.7)	54 (2.7)	55.7 (2.1)

+ indicate distal molar relationship and Class II skeletal relationship.
– Indicate normal molar relationship and normal skeletal relationship.

Table 4. Pancherz analysis of dental and skeletal relationships before and after treatment (mm).

Variable (mm)	Hanks Herbst (*n* = 40) Mean (95% CI)	Twin Block (*n* = 40) Mean (95% CI)	Difference in Mean (95% CI)	*P* value*
Occlusal changes				
Overjet Is/OLp(d) minus Ii/OLp(d)	−6.9 (−7.7, −5.9)	−5.1(−6.3, 3.9)	1.8 (0.2, 3.2)	.05
Molar relationship Ms/OLp(d) minus Mi/OLp(d)	−6.5 (−7.5, −5.5)	−4.7 (−5.9, −3.5)	1.8 (0.2, 3.4)	.02
Skeletal changes				
Maxillary base A/OLp(d)	0.3 (−0.4, 1.1)	1 (0.5, 1.5)	0.7 (−0.2, 1.6)	.22
Mandibular base Pg/OLp(d)	2.7 (1.9, 3.4)	3.5 (0.2, 1.6)	0.9 (−0.8, 2.5)	.54
Skeletal discrepancy A/OLp(d) minus Pg/OLp(d)	−2.4 (−3.2, −1.4)	−2.5 (−3.7, −1.3)	−0.2 (−1.6, 1.3)	.67
Condylar Head Co/OLp(d)	0.2 (−0.5, 0.9)	−0.1(−0.7, −0.5)	−0.3 (−1.2, 0.6)	.82
Mandibular Length Pg/OLp(d) + Co/OLp(d)	2.9 (1.8, 3.9)	3.4 (2.1, 4.8)	0.5 (−1.2, 2.3)	.80
Dental changes				
Maxillary incisor Is/OLp(d) minus A/OLp(d)	−1.5 (−2.2, −0.8)	−1.6 (−2.2, −0.9)	−0.05 (−1, 0.9)	.77
Mandibular incisor Ii/OLp(d) minus Pg/OLp(d)	3 (2.2, 3.8)	1 (0.5, 1.5)	−2 (−2.9, −1)	.001
Maxillary molar Ms/OLp(d) minus A/OLp(d)	−1.5 (−2.2, −0.7)	−1.3 (−1.9, −0.6)	0.2 (−0.8, 1.2)	.56
Mandibular molar Mi/OLp(d) minus Pg/OLp(d)	2.7 (1.9, 3.4)	0.9 (0.2, 1.6)	−1.8 (−2.8, −0.8)	.002

*Wilcoxon Mann–Whitney test.

- No significant differences were observed between the TB and HH in terms of skeletal and dental effects, although the HH may be associated with more pronounced effects on the mandibular dentition.
- Although further research is required to specifically address this, overjet reduction may be more efficient in adolescents with reduced facial height, less severe skeletal discrepancy, and lower baseline overjet.

Table 5. Regression analysis after adjustment for baseline (T0) data.

Variable	Treatment failure		Final skeletal discrepancy		Final overjet after	
	β [95% CI]	*P* value	β [95% CI]	*P* value	β [95% CI]	*P* value
Treatment group (Twin Block)	0.53 [0.31, 0.9]	.021	1.7 [0.35, 3.18]	.02	0.03 [−1.39, 1.45]	.96
Gender (male)	0.60 [0.22, 1.63]	.32	−0.65 [−2.06, 0.77]	.36	1.2 [−0.26, 2.58]	.11
Age	0.83 [0.56, 1.23]	.36	−0.17 [−0.77, 0.44]	.58	0.2 [−0.46, 0.75]	.63
Lower anterior facial height ratio (T0)	1.1 [0.92, 1.31]	.30	17.6 [−8.41, 43.68]	.18	30.8 [4.66, 57]	.02
Overjet (T0)	1.11 [0.86, 1.42]	.43	0.43 [0.05, 0.82]	.03	−0.06 [−0.45, 0.32]	.74
Skeletal discrepancy (T0)	0.89 [0.77, 1.03]	.13	−0.08 [−0.28, 0.12]	.40	0.7 [0.57, 0.97]	< .0001

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Author contributions

Moaiyad Pacha (Data curation [Equal], Formal analysis [Equal], Investigation [Equal], Methodology [Equal], Project administration [Equal], Writing—original draft [Equal], Writing—review & editing [Equal]), Padhraig Fleming (Conceptualization [Supporting], Formal analysis [Supporting], Methodology [Supporting], Supervision [Supporting], Writing—review & editing [Supporting]), Muftah Shagmani (Data curation [Supporting], Methodology [Supporting], Validation [Equal], Writing—original draft [Supporting]), and Ama Johal (Conceptualization [Equal], Data curation [Equal], Formal analysis [Equal], Funding acquisition [Equal], Investigation [Equal], Methodology [Equal], Project administration [Equal], Resources [Equal], Software [Equal], Supervision [Equal], Validation [Equal], Writing—original draft [Equal], Writing—review & editing [Equal])

Conflict of interest

The authors declare that there is no conflict of interest.

Data availability

The data underlying this article cannot be shared publicly due to the privacy of individuals that participated in the study. The data will be shared on reasonable request to the corresponding author

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