UNIVERSIDADE FERNANDO PESSOA

HORIZONTAL ALVEOLAR OSTEOGENIC DISTRACTION FOR RECONSTRUCTION OF THE ALVEOLAR PROCESS IN CLEFT PATIENTS: SYSTEMATIC REVIEW

[Distração osteogénica alveolar horizontal na reconstrução da apófise alveolar em doentes fissurados: Revisão sistemática]

Dissertação de Mestrado Integrado em Medicina Dentária

Nuno Alexandre dos Santos Gil

Orientador:

Doutor Jorge Pereira

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Dedicated to:

- Pedro and Sofia, the joy of my life
- Ana, my life companion
- The cleft patients, true life heroes

Acknowledgments

I acknowledge the support of those who supported me in this path:

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- My children and my wife, for being the pillars of my life

Abstract

Clefts of lip and palate are among the most common congenital anomalies. The alveolar process is frequently affected, secondary alveolar bone graft (ABG) being the gold standard treatment for its reconstruction. However, failures do occur, with the dimension and morphology of the alveolar cleft being an important factor. Alternative and/or complementary techniques to address the limitations of secondary ABG in cases of wide alveolar clefts (WAC) have been reported, horizontal alveolar distraction osteogenesis (HAOD) being the most used.

This study aims to provide an overview of the technical variations of HAOD to reconstruct alveolar clefts and compare their outcomes in terms of oronasal fistulas closure, bone reconstruction quality, and complications rate, accordingly with the available evidence.

Studies on human individuals with congenital cleft lip/palate having alveolar clefts treated with any type of HAOD were selected. The search strategy was developed using Medical Subject Headings (MeSH) and applied to the PubMed, Web of Science (core collection), Embase, and Scopus databases. Demographic, clinical baseline, intervention, and clinical outcomes information were extracted, and the risk of bias was assessed. The selection process, data extraction and risk of bias evaluation, were conducted by two independent researchers with divergences solved through discussion and, if necessary, by mediation of a third researcher.

A total of 313 studies were identified, and 21 (9 case series and 12 clinical cases) were eligible for final analysis, involving 67 patients (mean cleft dimension of 12.5 mm; 53 unilateral, 14 bilateral clefts), 74 HAOD (66 bifocal; 8 trifocal), and 92 transport discs. Among the included studies, numerous technical variations were observed, although common points existed. These included 17 distractor models, six distraction protocols, seven flap types, and six osteotomy types. Of the studies that reported relevant information, 92% indicated a significant reduction of oronasal fistulas, with an average reduction in size of 82%. In at least 56 sites of osteogenic distraction, the quality of new bone was presumed to be good, although no specific data on volume was provided. The most common complication was issues related to the distraction vector.

Although the studies included present important risk of bias, the available data suggest that HAOD can be an important tool in dealing with alveolar process reconstruction in WAC. It appears that the technique can reduce the dimension of oronasal fistulas and alveolar clefts. Most cases were treated with tooth-borne distractors, but the evidence collected points towards a better control of the distraction vector with hybrid fixation and TPB utilization.

Key-words: Cleft lip and palate, Alveolar cleft, Alveolar process, Distraction osteogenesis, Bony transport.

Resumo

As fendas labiopalatinas estão entre as anomalias congénitas mais comuns. O processo alveolar é frequentemente afetado, sendo o enxerto ósseo alveolar secundário (EOA) o tratamento *gold standard* para a sua reconstrução. No entanto, podem ocorrer falhas, sendo a dimensão e a morfologia da fenda alveolar um fator importante. Têm sido relatadas técnicas alternativas e/ou complementares para abordar as limitações do EOA secundário em casos de fendas alveolares extensas, sendo a distração osteogénica alveolar horizontal (DOAH) a mais utilizada.

Este estudo tem como objetivo fornecer uma visão global das variações técnicas do DOAH para reconstrução de fendas alveolares e comparar os seus resultados em termos de encerramento de fístulas oronasais, qualidade da reconstrução óssea e taxa de complicações, de acordo com as evidências disponíveis.

Foram selecionados estudos em indivíduos humanos com fenda labiopalatina congénita, com fendas alveolares tratadas com qualquer tipo de DOAH. A estratégia de pesquisa foi desenvolvida com recurso ao *Medical Subject Headings* (MeSH) e aplicada às bases de dados PubMed, Web of Science (*core collection*), Embase e Scopus. Foram extraídos dados demográficos, relativos ao *status* clínico inicial, à intervenção realizada, aos resultados da reconstrução, e avaliado o risco de viés. Os processos de seleção, extração de dados e avaliação do risco de viés foram conduzidos por dois investigadores independentes, tendo as divergências sido resolvidas através de discussão e, se necessário, pela mediação de um terceiro investigador.

Foram identificados um total de 313 estudos, e 21 (9 séries de casos e 12 casos clínicos) foram elegíveis para análise final, envolvendo 67 doentes (dimensão média da fenda de 12,5 mm; 53 fendas unilaterais, 14 bilaterais), 74 DOAH (66 bifocais; 8 trifocais) e 92 discos de transporte. Entre os estudos incluídos, foram observadas inúmeras variações técnicas, embora existissem pontos em comum. Estes incluíram 17 modelos de distratores, seis protocolos de distração, sete tipos de retalhos e seis tipos de osteotomias. Dos estudos que reportaram a informação relevante, 92% indicaram uma redução das fístulas oronasais, com uma redução média do tamanho da fenda alveolar de 82%. Em pelo menos 56 locais de distração osteogénica, presumiu-se que a qualidade do neo-osso era adequada, embora não tenham sido fornecidos dados específicos sobre o volume. A complicação mais comum foram os problemas relacionados com o vetor de distração.

Embora os estudos incluídos apresentem importantes riscos de viés, os dados disponíveis sugerem que a DOAH pode ser importante no tratamento das fendas alveolares extensas. Esta técnica poderá reduzir a dimensão das fístulas oronasais e das fendas alveolares. Os distratores dento-suportados foram os mais usados, mas as evidências recolhidas apontam para um melhor controlo do vetor de distração com fixação híbrida e utilização de TPB.

Palavras-chave: Fenda lábio-palatina, Fenda alveolar, Apófise alveolar, Distração osteogénica e Transporte ósseo

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List of abbreviations, initialisms and acronyms

ABG	Alveolar Bone Graft
Ar-D	Aravindaksha distractor
AW-D	Archwise distractor
BCLP	Bilateral Cleft Lip and Palate
Bi	Bilateral
Bs-D	Bousdras distractor
CBCT	Cone Beam Computed Tomography
Cef.	Cephalic
CT	Computed Tomography
Cx	Surgery
DALYs	Disability-Adjusted Life Years
DP-D	Dolomanz/Pichelmayer distractor
GPP	GengivoPeriosteoPlasty
HAOD	Horizontal alveolar osteogenic distraction
HAOD	Horizontal Alveolar Osteogenic Distraction
Hg-D	Hegab distractor
HU	Hounsfield Unit
LF 1	Le Fort I osteotomy
Li-B	Liou distractor
Max.	Maximum
Md-B	Modus distractor
MeSH	Medical Subject Headings
Min.	Minimum
mm	Millimetres
Mod.	Modified
N/R	Not reported
OD	Osteogenic Distraction
OPG	OrthoPantomoGraphy

P.	Palatine
pAW-D	Pre-Archwise distractor
PICOS	Population; Intervention; Comparator; Outcome; Setting
Plt.	Palatal
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
RCT	Randomized Controlled Trials
Sk1-D	Sakamoto 1 distractor
Sk2-D	Sakamoto 2 distractor
Sk3-D	Sakamoto 3 distractor
Sk4-D	Sakamoto 4 distractor
Sz-D	Suzuki distractor
TMR-D	Tripathi/Mohanty/Rai distractor
TPB	Trans Palatal Bar
Uni	Unilateral
US	UltraSonography
V.	Vestibular
WAC	Wide Alveolar Cleft
Zg-H	Zhang distractor
ZP-H	Zemann/Pichelmayer distractor
Zrch-B	Zurich pediatric distractor

Introduction

Congenital orofacial clefts are among the most common congenital anomalies and clefts of lip and palate are the most common orofacial congenital anomalies.(Stallings et al., 2024)

In 2019, the global prevalence of orofacial clefts was estimated to be 59,68/100.000 (95% UI: 48.63 – 73.32 per 100,000), while its global burden, measured in disability-adjusted life years (DALYs), was estimated to be 6,85/100.000 (95% UI: 4.68 – 10.32). (Kantar et al., 2023)

Cleft patients have multiple types of reconstructive challenges. Although the final goal is a full and comprehensive rehabilitation, the whole process is complex, multidisciplinary, and divided into multiple steps that can present variations according to the specific characteristics of each patient, and even between centres.

The alveolar process, when affected, is usually reconstructed just before the eruption of the permanent canine tooth with the gold standard technique – secondary alveolar bone graft (ABG) collected from iliac bone.(Bergland et al., 1986) Although this technique has high success rates, in an important number of cases failures do occur. This can be related to a multiplicity of factors, the size/morphology of the alveolar cleft being one. Mostly because of limited soft tissue availability to cover the graft, wide alveolar clefts (WAC) are challenging both to surgeons and orthodontists.(Liou et al., 2000; Long et al., 1995; Van Der Meij et al., 2003) So, other techniques have been described for this purpose, namely tongue and myofascial flaps to provide an adequate quantity of soft tissue to properly cover a traditional alveolar graft, segmental orthognathic surgery, free flaps, and alveolar osteogenic distraction, which is the most commonly used. The recently published systematic review by Mordukhovich et al. (2025) designed to compare treatment efficacies and patient populations on the setting of WAC is a reflex of the relevance of this clinical challenge.

According to Liou et al. (2000), horizontal alveolar osteogenic distraction (HAOD) presents important advantages over the other techniques described to repair WAC. It is a simple surgical procedure usually done in an outpatient setting that creates new alveolar bone and adjacent soft tissues biologically similar to the native ones. This is particularly important to the gingiva, as this specialized soft tissue is essential to maintain healthy supportive teeth structures, as well as prosthetic solutions. Theoretically, it has no limits on the amount of new tissue that can be created, so it can be a solution no matter how wide the alveolar cleft is. It can help solving dental crowding without dental extractions, as new edentulous alveolar bone is created. It can also be used in cases of alveolar bone graft failure.

Generically, this technique consists of performing two continuous osteotomies (one vertical and one horizontal) in the maxilla, so that a dento-alveolar bone segment adjacent to the alveolar cleft becomes individualized. This segment - the disc – is stabilized with a specific device - the distractor – placed at the same surgical time, which allows gradual displacement of the disc towards the final desired position. This way, new bone and soft tissue will be created distally to the disc, at the site of the vertical osteotomy, usually between two teeth. However, in most cases, despite bone contact achievement, a residual cleft persists due to the anatomic incompatibility of the two sides of the cleft. So, HAOD allows reduction of the cleft size but does not completely exclude the need of a final small surgical procedure – the docking site surgery. This is usually a gengivo-periosteoplasty (GPP) with or without a small bone graft. For this reason, alveolar osteogenic distraction can also be seen as a complementary procedure to ABG in the alveolar cleft reconstruction process.(Liou et al., 2000)

The utilization of HAOD to reconstruct the alveolar process in cleft patients was first published by Liou et al. (2000). Since then, multiple variations of this technique have been reported, but no publication has yet synthesized or tried to compare them. Given this unmet need, a systematic review was conducted to identify the variations of the HAOD (I/C) used to treat cleft patients with alveolar component (P), and to investigate the differences in the reconstruction outcomes (O).

Methods

Based on the research question and according to PRISMA guidelines (Page et al., 2021), the systematic review protocol has been designed to address the following objectives: identify and characterize the HAOD technical variations for alveolar process reconstruction in cleft patients, and to determine which achieve better reconstructive results, based on success rates of oronasal fistula closure, bone reconstruction quality, and complications rate.

Eligibility criteria and study selection

Table I details the inclusion criteria following the PICOS methodology. The only exclusion criteria identified were studies conducted in animals, books, and unpublished data. The selected studies went through a screening process to ensure that only those entirely meeting the eligibility criteria were included.

Table I - Inclusion criteria according to PICOS methodology

Population	Human individuals with congenital lip/palate cleft in need for alveolar process repair
Intervention	HAOD
Comparator	HAOD technical variations
Outcomes	Resolution of oro-nasal fistulas, quality of the new bone created and complications rate
Setting	Randomized clinical trials, non-randomized clinical trials, case series/ reports published in English, Portuguese, Spanish, or French and no date limits

HAOD – Horizontal Alveolar Osteogenic Distraction

Search Strategy

The search strategy was developed using Medical Subject Headings (MeSH) terms and structured through the application of the search equation ***((cleft palate) OR (cleft lip) OR (alveolar cleft)) AND ((alveolar distraction) OR (interdental distraction) OR (dentoalveolar distraction) OR (((distraction osteogenesis) OR (bony transport)) AND (alveolar process)))*** to the databases PubMed, Web of Science (core collection), Embase and Scopus. In PubMed, Web of Science (core collection), and Embase, the query was performed for all fields, while in Scopus it was performed just for the fields article title, abstract, and keywords. No filters were applied, and the last search was conducted on the 29th of March 2025.

Data extraction

The studies included were fully analysed for data extraction using specific forms. This data was then subjected to synthesis and qualitative analysis. Authors of the included studies were not contacted to obtain further details.

Risk of bias evaluation

Quality assessment and risk of bias evaluation were planned accordingly to the type of study and the quality of the information reported (tables II and III). Studies deemed to be of insufficient quality or with a high risk of bias should be excluded from the final analysis.

Table II - Method of risk of bias evaluation per type of study

Type of study	**Risk of bias evaluation toll**
RCT	RoB 2 (Cochrane Foundation)
non-RCT	ROBINS I (Cochrane Foundation)
Case series	Checklist for Case Series (Joanna Briggs Institute)
Case report	Checklist for Case Reports (Joanna Briggs Institute)

RCT – Randomized Controlled Trial

Table III - Risk of bias according to the quality of the reported information

Bias risk	**Criteria**
■ High risk	> 50% "not reported"
	> 50% "unclear"/"intermediately reported"
■ Intermediate risk	≤ 50% "unclear"/"intermediately reported" and/or "not reported"
	50% - 75% "reported"
■ Low risk	> 75% "reported"

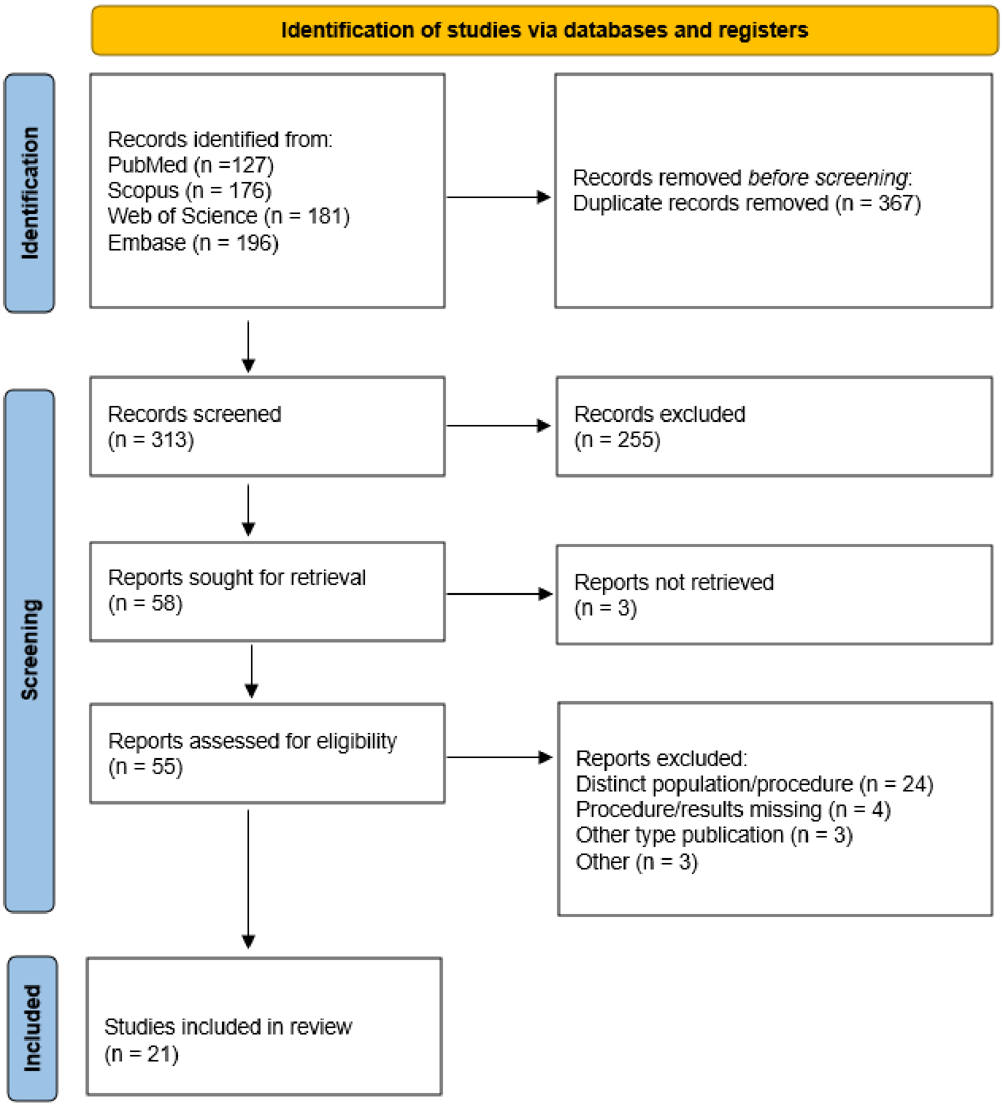
Reviewers

The selection process, data extraction, quality assessment, and risk of bias evaluation were conducted by two independent researchers. Discrepancies were solved through discussion and, if necessary, by the mediation of a third researcher.

Results

The search performed yielded 313 studies. After title and abstract screening 58 studies were selected for full analysis. Three were not retrievable and 33 were excluded as they didn´t meet the eligibility criteria. The main reason was "distinct population or procedure" (n=24). Four studies met the eligibility criteria, but they have been excluded as the procedure description and/or the results were not reported for all the included patients. Three studies were excluded because of the type of publication. Moreover, three studies were excluded because they reported cases already published in other included studies, different techniques were sequentially used in the same case, or the description of the technical variation was unintelligible, making it unreproducible. In total, 21 studies were included, all being either case series or case reports (Figure 1).

Figure I - PRISMA flow diagram



Quality assessment and risk of bias evaluation revealed important concerns. Besides the fact that only case series and case reports were available, almost 50% of the included studies presented a high risk of bias, with less than 5% presenting a low risk of bias (graphics I and II). Regarding the various domains evaluated, it is important to refer that the post-intervention clinical condition/outcomes were the most under-reported items (graphics III and IV).(Aromataris et al., 2024; Munn et al., 2020)

Graphic I - Risk of bias per included clinical case

Study	1	2	3	4	5	6	7	8		Overall appraisal
Alkan 2007	Green	Green	Yellow	Red	Green	Red	Green	N/A		Yellow
Aravindaksha 2014	Green	Green	Yellow	Red	Red	Red	Red	N/A		Red
Binger 2003	Green	Green	Red	Red	Green	Red	Green	N/A		Yellow
Bousdras 2014	Green	Green	Yellow	Green	Green	Yellow	Green	N/A		Yellow
Erverdi 2012	Green	Red	Green	Red	Red	Red	Green	N/A		Red
Erverdi 2013	Green	Red	Red	Red	Green	Red	Green	N/A		Red
Erverdi 2014	Green	Green	Red	Red	Green	Red	Green	N/A		Yellow
Neha 2018	Green	Red	Yellow	Green	Green	Yellow	Green	N/A		Yellow
Pektas 2008	Green	Green	Red	Red	Red	Red	Red	N/A		Red
Pichelmayer 2008	Green	Red	Yellow	Red	Red	Red	Green	N/A		Red
Shahab 2019	Green	Red	Yellow	Green	Green	Yellow	Red	N/A		Red
Suzuki 2006	Green	Green	Green	Green	Green	Yellow	Green	N/A		Green

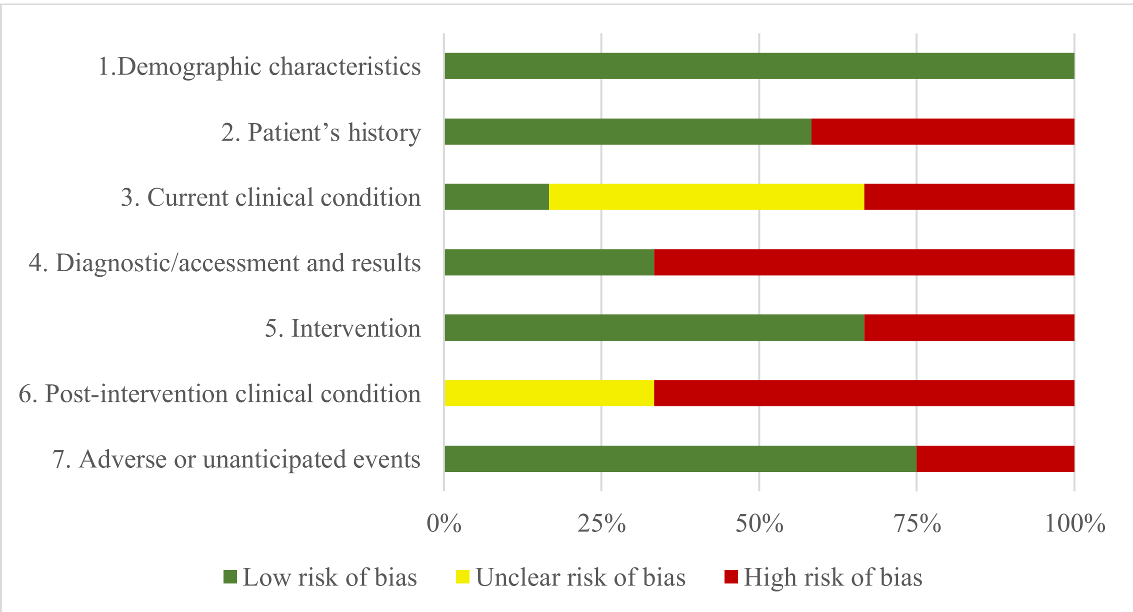
JBI checklist for case reports: 1. Were patient's demographic characteristics clearly described? 2. Was the patient's history clearly described and presented as a timeline? 3. Was the current clinical condition of the patient on presentation clearly described? 4. Were diagnostic tests or assessment methods and the results clearly described? 5. Was the intervention(s) or treatment procedure(s) clearly described? 6. Was the post-intervention clinical condition clearly described? 7.Were adverse events or unanticipated events identified and described? 8. Does the case report provide takeaway lessons?

Graphic II - Risk of bias per included case series

Study	1	2	3	4	5	6	7	8	9	10	Overall appraisal
Altawell 2022	● (green)	● (green)	● (green)	● (yellow)	● (yellow)	● (green)	● (green)	● (green)	N/A	● (red)	● (yellow)
Dolomanz 2003	● (yellow)	● (red)	● (green)	● (yellow)	● (yellow)	● (green)	● (green)	● (yellow)	N/A	● (red)	● (red)
Hegab 2012	● (green)	● (red)	● (green)	● (yellow)	● (yellow)	● (green)	● (green)	● (red)	N/A	● (green)	● (yellow)
Sakamoto 2011	● (red)	● (green)	● (green)	● (yellow)	● (yellow)	● (green)	● (green)	● (red)	N/A	N/A	● (yellow)
Singh 2021	● (green)	● (green)	● (green)	● (yellow)	● (yellow)	● (green)	● (yellow)	● (red)	N/A	● (green)	● (yellow)
Titiz 2019	● (red)	● (red)	● (green)	● (yellow)	● (yellow)	● (green)	● (yellow)	● (red)	N/A	N/A	● (red)
Yilmaz 2019	● (red)	● (red)	● (green)	● (yellow)	● (yellow)	● (green)	● (green)	● (red)	N/A	N/A	● (red)
Zemann 2011	● (green)	● (green)	● (green)	● (yellow)	● (yellow)	● (green)	● (green)	● (red)	N/A	● (red)	● (yellow)
Zhang 2018	● (green)	● (green)	● (green)	● (yellow)	● (yellow)	● (green)	● (yellow)	● (red)	N/A	● (red)	● (red)

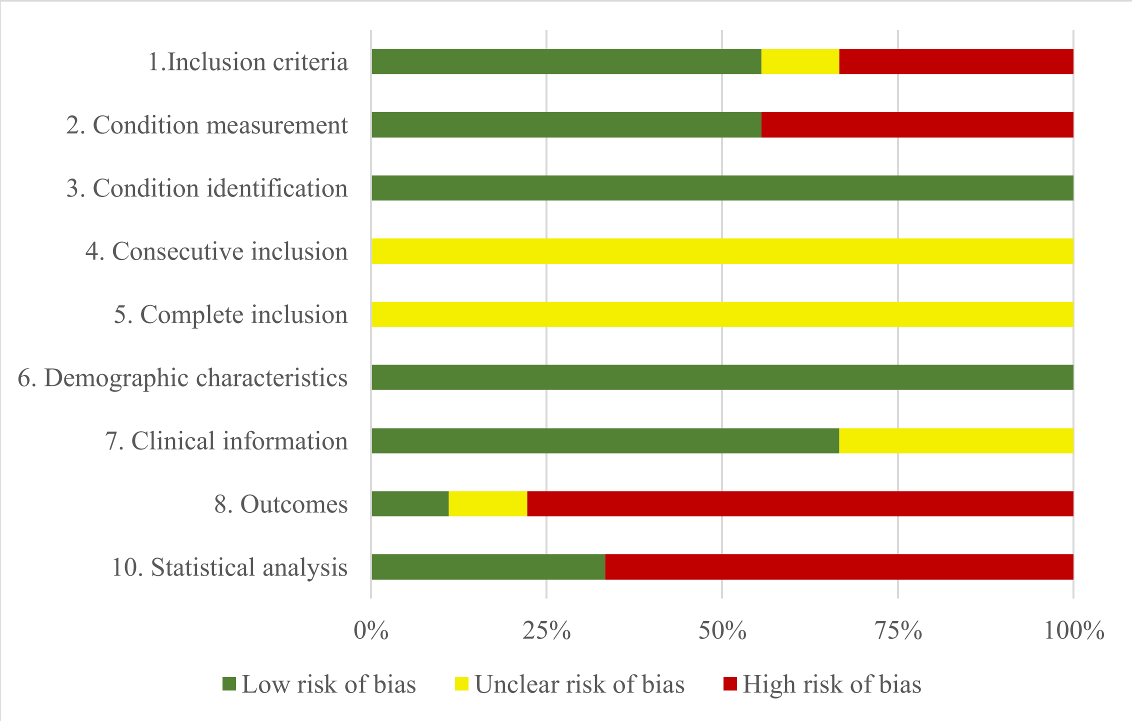
JBI checklist for case series: 1. Were there clear criteria for inclusion in the case series? 2. Was the condition measured in a standard, reliable way for all participants included in the case series? 3. Were valid methods used for identification of the condition for all participants included in the case series? 4. Did the case series have consecutive inclusion of participants? 5. Did the case series have complete inclusion of participants? 6. Was there clear reporting of the demographics of the participants in the study? 7. Was there clear reporting of clinical information of the participants? 8. Were the outcomes or follow up results of cases clearly reported? 9. Was there clear reporting of the presenting site(s)/clinic(s) demographic information? 10. Was statistical analysis appropriate?

Graphic III - Risk of bias per criteria (clinical cases)



JBI checklist for case reports

Graphic IV – Risk of bias per criteria (case series)



JBI checklist for case series

<u>Demographic context</u>:

The included studies totalized 67 patients (36 males, 29 females, 2 N/R) with a mean age of 16,65 (9 to 25 years old).

<u>Baseline clinical status</u>:

All patients had permanent dentition, except one 9-year-old patient, which case was reported by Binger et al. (2003) and whose transport disc had two teeth germs.

Regarding the type of cleft there were 53 unilateral and 14 bilateral cleft patients. In seven studies (39 patients) information about cleft dimension was available and it was possible to calculate that for those the mean alveolar cleft dimension was 12,5 mm (7-19mm) (table IV).

For 38 patients, information regarding previous alveolar cleft reconstruction was reported (table IV), with sixteen having a history of previous reconstruction with other techniques.

Information regarding oro-nasal fistula presence before HAOD was possible to obtain for just 13 patients, of which 12 had oro-nasal fistula (table IV).

Table IV - Characterization of the patients included per study

Study	n	Age (years)	Cleft type		Oro-nasal fistula	Cleft dimension (mm)	Previous reconstruction
			Uni	Bi			
Singh 2021	11; 12; 19	20,91 +/- 2,67 (16-25)	10	1	N/R	11,3 +/- 3,6 (cast) 11,01 +/-2,66 (CT)	3 cases (ABG)
Neha 2018	1; 1; 2	22		1	N/R	9,54 (CT)	N/R
Hegab 2012	10; 10; 10	20,5+/-2,48 (16-24)	10		N/R	N/R	1 case (ABG)
Dolanmaz 2003	5; 8; 8	21,4 +/-2,65 (17-25)	2	3	yes	N/R	N/R
Zemann 2011	6; 6; 6	12,67 +/- 0,75 (12-13)	6		N/R	12 +/- 3,74 (7-19) (Cx)	N/R
Pichelmayer 2008	1; 2; 2	12		1	yes	N/R	N/R
Altawell 2022	10; 10; 10	9,5 +/- 2,5	10		N/R	12,25 +/- 2,54 (9-15)	10 cases (N/R)
Zhang 2018	6; 6; 6	17,83 +/-3,07 (15-24)	6		N/R	15,43 +/- 1,24 (13,3-17,4)	N/R
Binger 2003	1; 1; 1	9		1	N/R	N/R	no
Suzuki 2006	1; 1; 2	15	1		yes	12	no
Aravindaksha 2014	1; 2; 2	18		1	yes	N/R	no
Alkan 2007	1; 2; 2	18		1	yes	N/R	ABG (tongue flap)
Bousdras 2014	1; 1; 1	16	1		yes	N/R	no
Pektas 2008	1; 1; 1	13	1		N/R	N/R	no
Erverdi 2012	1; 1; 2	22	1		no	N/R	N/R
Erverdi 2013	1; 1; 2	16		1	N/R	N/R	N/R
Erverdi 2014	1; 1; 1	16	1		N/R	N/R	ABG
Shahab 2019	1; 1; 2	16		1	yes	N/R	N/R
Titiz 2019	2; 2; 4	20; 13	1	1	N/R	N/R	N/R
Yilmaz 2019	2; 2; 4	20; 21		2	yes	N/R	N/R
Sakamoto 2011	3; 3; 5	14 +/- 1,63 (12-16)	3		N/R	15,33 +/- 0,47 (15-16)	N/R

n (patients; distraction procedures; discs distracted); ABG – alveolar bone graft; Bi – Bilateral; CT – computed tomography; Cx – surgery; N/R – not reported; Uni – unilateral.

<u>HAOD technical variations</u>:

Considering bilateral bifocal distraction as two procedures and trifocal distraction as one, the 67 patients corresponded to 74 distractions (fifty-six bifocal of which seven pairs from the same individual, six of them simultaneously performed; 18 trifocal). It is important to highlight that five patients with bilateral clefts were treated with trifocal distraction, which was related either to premaxillary atresia or agenesia. In total, these 74 procedures involved the distraction of 92 dento-alveolar segments (table IV).

Only five studies reported follow-up time, the range being between 6 and 48 months (table V).

Table V - Follow-up time per study

Study	Follow-up (months)		
	Mean	Min	Max
Neha 2018	8	N/A	N/A
Hegab 2012	33,6	24	48
Dolanmaz 2003	13,2	6	24
Zemann 2011	-	7	36
Altawell 2022	-	6	18
Titiz 2019	12	N/A	N/A

Min. – minimum; Max. - maximum

To achieve a comprehensive analysis of the various HAOD technical variations reported in the literature for alveolar process reconstruction in cleft patients, 17 variables were collected from each study, as far as they were available, and analysed comparatively. Among the included studies, most presented different techniques, although common points existed. Only the groups of Erverdi (Erverdi et al., 2014; N. Erverdi et al., 2012, 2013; Shahab et al., 2019; Titiz et al., 2019; Yilmaz et al., 2019), Pichelmayer/Zemann (Pichelmayer et al., 2008; Zemann & Pichelmayer, 2011a), and Tripathi/Mohanty/Rai (Neha et al., 2018; Singh et al., 2021) had more than one paper included in the final review. Erverdi group papers presented cases of the Archwise technique, except for the oldest paper that presented a technique slightly different, probably a step in the process of development of their technique. Pichelmayer/Zemann group presented different techniques in two different papers, the oldest also being most probably an intermediate step in the development of their technique. Tripathi/Mohanty/Rai presented the same technique in the two papers.

Sixty-one patients had surgery under general anaesthesia and five were operated under local anaesthesia by Dolanmaz et al. (2003).

Information about the type of flap (table VI) was given by 14 studies (47 patients and 56 distraction discs), with the principal incision being vestibular in all of them. In 16 discs, the vestibular incision consisted of two vertical incisions (one near the cleft and the other near the vertical osteotomy, both including mucosa and gingiva, although sparing the marginal gingiva). In 14 discs, the vestibular incision was on the mucosa and described as horizontal. In one patient, corresponding to one disc, the vestibular incision was reported to have been done on the gingival margin. For the remaining 25 discs, there were few details (for 16 discs, just vestibular incision was referred, and for 9 discs, just palatine approach was denied, so it was assumed vestibular approach was done).

Table VI - Type of flap and osteotomies per study

Study	Flap	Osteotomy
Singh 2021	N/R	LF1 5mm + interdental
Neha 2018	N/R	LF1 5mm + interdental
Hegab 2012	2 vestibular vertical incisions (gingiva/mucosa) + tunelization 1 palatine intrasulcular incision + tunelization	LF1 5-10mm + interdental
Dolanmaz 2003	Vestibular incision	Horizontal 4-5mm + interdental
Zemann 2011	Vestibular incision	Horizontal 5mm + interdental
Pichelmayer 2008	N/R	Horizontal + interdental
Altawell 2022	Vestibular horizontal incision (mucosa) + Palatine tunelization	Horizontal 3-5mm + interdental
Zhang 2018	2 vestibular vertical incisions (gingiva/mucosa) + tunelization	Horizontal supra-apical+ interdental
Binger 2003	Marginal gingival incision + Nasal mucosa tunelization	High LF1 + Pterigomaxilary separation
Suzuki 2006	Vestibular incision (bottom of the vestibule)	Horizontal 4-5mm + interdental
Aravindaksha 2014	N/R	Horizontal + interdental
Alkan 2007	Vestibular incision	Horizontal 4-5mm + interdental
Bousdras 2014	Vestibular incision (bottom of the vestibule) Palatine mucoperiosteum minimaly reflection	Horizontal high (45°) + interdental
Pektas 2008	Vestibular incision (bottom of the vestibule)	Horizontal 4-5mm + interdental
Erverdi 2012	N/R	Horizontal supra-apical + interdental
Erverdi 2013	N/R (no palatine approach)	Horizontal supra-apical + interdental
Erverdi 2014	N/R (no palatine approach)	Horizontal supra-apical + interdental
Shahab 2019	N/R (no palatine approach)	Horizontal 5mm + interdental
Titiz 2019	N/R	Horizontal + interdental
Yilmaz 2019	N/R (no palatine approach)	Horizontal supra-apical + interdental
Sakamoto 2011	N/R	Horizontal 5mm + interdental

LF 1 – Le Fort I osteotomy; N/R – not reported

Concerning the design of the osteotomies (table VI), all authors performed horizontal and vertical osteotomies to individualise the distraction disc. Vertical osteotomies were interdental for all patients and discs, except the case published by Binger et al. (2003) that performed it at the pterygomaxillary suture. Regarding horizontal osteotomies, they were described as supra-apical in 84 discs. For 67 discs, further details were given, with the aimed distance from the dental apices varying from 3 to 10 mm. As previously stated, Binger et al. (2003) were the soles that include a patient with mixed dentition, and they described the horizontal osteotomy as a high Le Fort I to prevent lesion of the teeth germs. Other authors described the horizontal osteotomy to be done with an inclination of 45° towards palatine. (Bousdras et al., 2014)

For 11 studies (62 discs) it was possible to obtain information about the set of instruments used to perform the osteotomies. Most frequently, piezoelectric surgery and osteotomes were combined (25 discs in 17 patients from two studies), with bur or saw and osteotomes (23 discs in 18 patients from five studies) being the second most common set of instruments used. Bur and osteotomes (10 discs in 10 patients from one study), saw and osteotomes (eight discs in eight patients from three studies), only saw (five discs in three patients from one study) and only piezoelectric surgery (two discs in one patient from one study) were the other combinations of instruments.

It was possible to determine the size of 49 distraction discs. Most frequently, the disc included two or three teeth (n=45). However, two discs included just one tooth and the other two were bigger, including four teeth or corresponding to the entire lateral segment. For 27 discs, it was also possible to determine the maxillary segment used to create the distraction disc. The 12 discs corresponding to unilateral cleft patients were individualized from the smaller segment (n=7) or from the larger (n=5). The 15 discs relative to bilateral cleft patients were all individualized from the lateral segments.

To achieve a comprehensive analysis of the design of the distractors, five variables were considered: distractor screw type and position, fixation, distractor track, and accessories. A total of 17 different distractor models were identifiable and coded according to the name of the authors who used it, their brand/model, or the name given by the authors (tables VII and VIII). Seven models of distraction devices were used to distract more than five discs (76 discs in total), while the other 10 were used for less than three discs each (five of which just for one disc). Among those seven distractor types, the distractor screw was almost always placed on the vestibular side, and the most common was the hyrax screw (5 devices; 53 discs; 7 studies), followed by the Archwise distractor (1 device; 13 discs; 5 studies) and the intra-oral Liou distractor (1 device; 10 discs; 1 study). The fixation of the distractor was most commonly done through a cemented acrylic tooth cap (1 device; 21 discs; 2 studies), followed by bands, (2 devices; 20 discs; 3 studies), metallic crown caps (1 device; 13 discs; 5 study), bands and bone screws (2 device; 12 discs; 2 study) and just bone screws (1 device; 10 discs; 1 study). The most frequent distractor track was palatine arch + hyrax guidance pin (2 devices; 31 discs; 3 studies), followed by hyrax guidance pin alone (2 devices; 16 discs; 3 studies), horizontal double vestibular arch (1 device; 13 discs; 1 study), the distractor screw (1 device; 10 discs; 1 study) and a palatine arch screwed to the bone (1 device; 6 discs; 1 study). It is also important to highlight that two devices included a transpalatal bar (TPB) (34 discs; 2 studies).

Table VII - Distractors given name, code, and number of discs distracted with

Given name	Code	Distracted discs	Studies
Tripathi/Mohanty/Rai	TMR-D	21	Singh 2021; Neha 2018
Bousdras	Bs-D	1	Bousdras 2014
Dolomanz/Pichelmayer	DP-D	10	Dolomanz 2003; Pichelmayer 2008
Hegab	Hg-D	10	Hegab 2012
Sakamoto 1	Sk1-D	2	Sakamoto 2011
Sakamoto 2	Sk2-D	1	Sakamoto 2011
Sakamoto 3	Sk3-D	1	Sakamoto 2011
Sakamoto 4	Sk4-D	1	Sakamoto 2011
Erverdi (Pré-Archwise)	pAW-D	2	Erverdi 2012
Suzuki	Sz-D	2	Suzuki 2006
Aravindaksha	Ar-D	2	Aravindaksha 2014
Erverdi (Archwise)	AW-D	13	Erverdi 2013, 2014; Shahab 2019; Titiz 2019; Yilmaz 2019
Zhang	Zg-H	6	Zhang 2018
Zemann/Pichelmayer	ZP-H	6	Zemann 2011
Liou distractor	Li-B	10	Altawell 2022
Modus distractor	Md-B	3	Pektas 2008; Alkan 2007
Zurich pediatric distractor	Zrch-B	1	Binger 2003

Based on the predicted trajectory of the transport disc, the distraction vector was classified as curvilinear, linear, or linear modified (table VIII). Vectors were considered linear modified whenever, based on some characteristics of the distractor, it was expected to follow a linear trajectory for the disc but, based on other characteristics, a modification of that trajectory was presumably intended by the authors.

Table VIII - Description of distractor models used in the included studies

Code	Description					
	Distractor screw		Fixation	Distractor track	Acessories	Vector
	Type	Position				
TMR-D	Hyrax screw	V	Acrilic cap	Palatine arch; Hyrax guidance pin	TPB	Linear mod
Bs-D	Hyrax screw	P	Bands	Hyrax guidance pins		Linear
DP-D	Hyrax screw (half)	V	Bands	Hyrax guidance pin		Linear
Hg-D	Hyrax screw (half)	V	Bands	Palatine arch; Hyrax guidance pin		Linear mod
Sk1-D	Fan type expansion screw	P	Bands	Horizontal vestibular arch		Curvilinear
Sk2-D	Expansion screw	P	Bands	Expansion screw guidance pin		Linear
Sk3-D	Zurich type ramos distractor	V	Bands	Distractor screw		Linear
Sk4-D	Zurich type ramos distractor	V	Bands	Distractor screw	TPB	Linear
pAW-D	Archwise distractor(Tasarim Med)	V	Bands/brackets	Orthodontic archwire		Curvilinear
Sz-D	Traction screws and micro-cables	V	Bands/brackets	Horizontal double vestibular arch		Curvilinear
Ar-D	Fan type expansion screw	P	Metalic caps?	Screw structure		Curvilinear
AW-D	Archwise distractor (Tasarim Med)	V	Metalic caps	Horizontal double vestibular arch	TPB	Curvilinear
Zg-H	Hyrax screw (half)	V	Bands/screws	Hyrax guidance pin		Linear
ZP-H	Hyrax screw (with hinge)	V	Bands/screws	Palatine arch (screwed)		Curvilinear
Li-B	Intra-oral Liou distractor (Martin)	V	Screws	Distractor screw		Linear
Md-B	Modus MDO 1.5 distractor (Medartis)	V	Screws	Distractor screw		Linear
Zrch-B	Zurich pediatric distractor (Martin)	V	Screws	Distractor screw		Linear

TMR-D - Tripathi/Mohanty/Rai tooth-borne distractor; BS-D – Bousdras tooth-borne distractor; DP-D – Dolanmaz/Pichelmayer tooth-borne distractor; Hg-D – Hegab toth-borne distractor; Sk1-D – Sakamoto 1 tooth-borne distractor; Sk2-D – Sakamoto 2 tooth-borne distractor; Sk3-D – Sakamoto 3 tooth-borne distractor; Sk4-D – Sakamoto 4 tooth-borne distractor; pAW-D – pre Archwise tooth-borne distractor; Sz-D – Suzuki tooth-borne distractor; Ar-D – Aravindaksha tooth-borne distractor; AW-D – Archwise tooth-borne distractor; Zg-H – Zhang hybrid distractor; ZP-H – Zemann/Pichelmayer hybrid distractor; Li-B – Intra-oral bone-borne Liou distractor (Martin); Md-B – Modus MDO 1.5 bone-borne distractor (Medartis); Zrch-B – Zurich paediatric bone-borne distractor (Martin).

On the other hand, the fixation of the distractor determined its classification as tooth-borne, bone-borne, or hybrid, the first being the most frequently used (table VIII). All the tooth-borne and hybrid distractors used were custom-made, while the bone-borne were standard. Just four types distractors had the distraction screw palataly placed, corresponding to the studies of Aravindaksha et al. (2014), Bousdras et al. (2014), and Sakamoto et al. (2011).

Table IX presents the mean cleft dimension per type of distractor used.

Table IX - Mean cleft dimension per type of distractor used

Type of distractor	Mean cleft dimension (mm)	n
Bone-borne	12,25	10
Hybrid	13,715	12
Tooth-Borne	11,74	17

Regarding the distraction protocol, four variables were analysed – duration of the latency period, rhythm (length distracted and number of activations per day), and duration of the consolidation period. Most discs (n=68; 74%) were distracted 5-7 days after performing the osteotomies, although an important number of discs (n=20; 22%) were distracted after only 3 days (table X).

Table X - Distraction protocol per study

Study	Latency (days)	Rythm (mm/day)	Consolidation
Singh 2021	7	0,5 + 0,5	3 meses
Neha 2018	7	0,5 + 0,5	3 meses
Hegab 2012	7	0,5 + 0,5	2 meses
Dolomanz 2003	3	0,5 + 0,5	1 week
Zemann 2011	5	0,25+0,25	6 weeks
Pichelmayer 2008	7	0,4 + 0,2 + 0,4*	Early mobilization (imediate); N/R
Altawell 2022	5	0,45 + 0,45	Early mobilization (week 2); N/R
Zhang 2018	3	0,4 + 0,4	3 meses
Binger 2003	6	0,5	10 weeks
Suzuki 2006	6	0,5 + 0,5	3 weeks
Aravindaksha 2014	7	N/R	3 meses
Alkan 2007	6	0,5 + 0,5	3 meses
Bousdras 2014	4	0,5 + 0,5	12 weeks
Pektas 2008	4	0,25 + 0,25	Early mobilization (imediate); 10 weeks
Erverdi 2012	4	0,5 + 0,5	2 mounths
Erverdi 2013	5	0,5 + 0,5	2 mounths
Erverdi 2014	5	0,5 + 0,5	2 mounths
Shahab 2019	5	0,5 + 0,5	3 mounths
Titiz 2019	5	0,5 + 0,5	8 mounths
Yilmaz 2019	5	0,5 + 0,5	2 mounths
Sakamoto 2011	7	0,5 + 0,5	1 mounth

* - 0,2+0,2+0,2 mm per day after soft tissue contact; N/R – not reported

Approximately 89% (n=82) of the discs were distracted at a rhythm between 0,8 and 1 mm/day, divided into two or three daily activations, and 70% were distracted at 1 mm/day. The remaining eight discs were distracted at slower rhythms (0,5mm/day divided or not in two daily activations) (table X).

The consolidation period (time between the end of the activation of the distractor and its removal) lasted between zero and 32 weeks, most frequently eight to 12 weeks (54 discs). In 21 discs, the concept of early callus manipulation was presumably used, as the consolidation period was inferior to two weeks. In 13 discs, an intermediate consolidation period – three to six weeks – was used. The remaining four discs had 32 weeks of consolidation (table X).

Information on pre-surgical orthodontics was reported in 17 studies (56 patients), but just nine (27 patients) reported on diastema creation at the site of the vertical interdental osteotomy (table XI). A total of 53 patients had pre-surgical orthodontic treatment and a total of 26 (27 vertical osteotomies) had diastemas created. Three patients were reported as not having had presurgical orthodontics, although one from the study of Titiz et al. (2019) already presented diastemas in the two vertical osteotomy sites.

Five studies reported information on the administration of post-surgical antibiotics, the corresponding 23 patients all having been administered with. However, no further specifications are given (table XI).

Concerning docking site surgery, details were available in 16 studies (51 patients; 59 docking sites), and the most frequent procedure was ABG (n=31), followed by GPP (14). In almost 25% of the docking sites no surgical procedure was performed (table XI).

Table XI - Pre- and post-surgical details per study

Study	Pre-surgical orthodonthics	New bone dental rehabilitation	Antibiotic therapy	Docking site surgery
Singh 2021	yes (diastema ?)	N/R	N/R	N/R
Neha 2018	yes	N/R	N/R	no (soft tissue compression)
Hegab 2012	yes (diastema)	N/R	N/R	8 GPP; 2 ABG (chin)
Dolomanz 2003	yes (diastema?)	Dental fixed prosthesis (4) Orthodontics (1)	yes	no (ABG planned in the 3 BCLP)
Zemann 2011	yes (diastema)	N/R	yes	GPP (simultaneuously with OD)
Pichelmayer 2008	yes (diastema)	Teeth transplantation Orthodontics	N/R	ABG
Altawell 2022	yes (diastema?)	N/R	yes	Soft tissue excision (at contact) ABG (HA)
Zhang 2018	N/R	Prosthetic treatment	N/R	ABG (Iliac)
Binger 2003	N/R	Orthodontics	N/R	ABG
Suzuki 2006	yes (diastema?)	N/R	N/R	N/R
Aravindaksha 2014	yes (diastema?)	N/R	N/R	No
Alkan 2007	no	Orthodontics	yes	Planned (ABG)
Bousdras 2014	yes (diastema)	Dental implant (possible)	yes	ABG
Pektas 2008	yes (diastema?)	Dental implant	N/R	ABG
Erverdi 2012	N/R	N/R	N/R	N/R
Erverdi 2013	yes (no diastema)	Dental implant	N/R	ABG (Iliac block)
Erverdi 2014	yes (diastema?)	Dental fixed prosthesis	N/R	No
Shahab 2019	yes (diastema)	Dental implant	N/R	N/R
Titiz 2019	no* yes (diastema)	Dental fixed prosthesis Dental implant	N/R	N/R
Yilmaz 2019	yes (diastema)	Dental fixed prosthesis Dental implant	N/R	ABG
Sakamoto 2011	N/R	Orthodontics	N/R	ABG

* - diastemas already existed do to dental agenesias; ABG – alveolar bone graft; GPP – gengivoperiosteoplasty; N/R – not reported.

The type of dental rehabilitation of the new alveolar bone was reported by only 13 studies (20 patients). Most patients were treated with some type of dental prosthesis (n=13) although an important number were treated with orthodontic tooth movements towards the new bone (n=7).

Outcomes of the different HAOD technical variations

Concerning oro-nasal fistula resolution no study evaluated this variable systematically. However, Dolanmaz et al. (2003) referred that among the patients included in their study the ones with unilateral clefts got their oro-nasal fistulas completely closed with the alveolar distraction and an associated GPP as docking site surgery, while the ones with bilateral clefts got their fistulas almost closed. Altaweel et al. (2022) reported that almost all the patients treated in their study had their fistulas closed with soft tissue excision on the two sides of the cleft (when they got into contact) as docking site surgery. Alkan et al. (2007) state that the alveolar distraction allowed a 60% reduction in the fistula, which was then completely closed with a von Langenbeck palatoplasty. Bousdras et al. (2014) reported total closure of the fistula when the distraction was associated with ABG. Shahab et al. (2019), in the case they reported, stated that the fistula was almost closed after HAOD, and no information was given regarding docking site surgery.

Aiming to further characterize the alterations in the cleft morphology associated with the HAOD, distraction length, cleft reduction, and residual cleft dimension were also registered. When analysed in conjunction with the original cleft dimension, these variables give similar information and are relatively interchangeable. It was assumed that the initial cleft dimension equals the residual cleft dimension plus the distraction length. Distraction length and cleft reduction will normally correspond to the same value. Given this, the percentage of mean cleft reduction was calculated whenever possible. The global mean reduction of the clefts (30 clefts; 29 patients; five studies) was 82% (table XII). Suzuki et al. (2006) presented a case in which the cleft was completely closed.

Table XII - Mean cleft reduction after HAOD per study

Study	Patients	OD	Mean cleft reduction (%)
Singh 2021	11	12	83,4
Neha 2018	1	1	76,7
Altawell 2022	10	10	81,5
Zhang 2018	6	6	78,1
Suzuki 2006	1	1	100,0

OD – osteogenic distraction

The new bone quality was systematically evaluated by Singh et al. (2021) and Hegab (2012) through bone density (HU) measurement in the CBCT (table XIII), although they made the final evaluation at different times (3- and 6-months post HAOD, respectively). Nevertheless, no information is given about its volume. Other five studies (five patients) evaluated, presumably empirically, the new bone quality (three with OPG and the other with CBCT and US), reporting it as good. In eight other studies (11 patients), although no information was given concerning this specific aspect, it might be reasonable to presume that the bone quality was acceptable, as the dental rehabilitation of the new bone included orthodontic tooth movement towards it or dental implant placement.

Table XIII - New bone quality per study

Study	New bone quality (HU)
Singh 2021	491,2 - 498,23 (3 months)
Hegab 2012	251,78 +/- 36,08 (3 months) 510,27 +/- 51,23 (6 months)

HU – Housfield unit

In terms of complications, distraction vector issues were the most frequently reported. Alkan et al (2007), Altaweel et al (2022), Binger et al (2003), Dolanmaz et al (2003), Erverdi et al (2012), Hegab (2012), Pichelmayer et al (2008), Titiz et al (2019), and Zemann & Pichelmayer (2011) referred its occurrence their studies. On the other hand, Neha et al. (2018) and Erverdi et al (2013; 2014) refer that they had no issues with the distraction vector. In these 12 studies, six different types of distractors (table XIV) were used, although three of them distracted three or less discs.

Table XIV - Incidence of vector issues per distrator model

Distractor	Distractor vector issues				Distracted discs
	Cef migration (n)	Plt migration (n)	Cef/Plt migration (n)	Incidence (%)	
AW-D	0	0	0	0,0	3
DP-D	9	0	0	90,0	10
TMR-D	0	0	0	0,0	2
ZP-H	1	0	0	16,7	6
Li-B	0	0	3	30,0	10
Zrch-B	0	1	0	100,0	1
Total	10	1	3	43,8	32

AW-D – Archwise tooth-borne distractor; DP-D – Dolanmaz/Pichelmayer tooth-borne distractor; TMR-D - Tripathi/Mohanty/Rai tooth-borne distractor; ZP-H – Zemann/Pichelmayer hybrid distractor; Li-B – Intra-oral bone-borne Liou distractor (Martin); Zrch-B – Zurich paediatric bone-borne distractor (Martin).

Table XV presents the incidence of distraction vector issues per fixation type/distractor model. Just orthodontic bands, bone screws and orthodontic bands plus bone screws were used to distract six or more discs.

Table XVI presents the incidence of distraction vector issues per accessories/distractor model with trans palatal bar being the sole identified.

The analyses for the type of distractor screw and track presented the same results as the analysis for the distractors themselves, as each model had different types of distractor screws and tracks. Similarly, no analysis was performed concerning the position of the distractor screw, as just six transport discs were distracted with devices that had the distractor screw placed on the palatal side and those devices presented important heterogeneity.

Table XV - Incidence of vector issues per type of fixation and distractor model

Distractor	Fixation	Distractor vector issues				Distracted discs
		Cef migration (n)	Plt migration (n)	Cef/Plt migration (n)	Incidence (%)	
AW-D	Metalic cap	0	0	0	0,0	3
DP-D	Bands	9	0	0	90,0	10
TMR-D	Acrilic cap	0	0	0	0,0	2
ZP-H	Bands/screws	1	0	0	16,7	6
Li-B; Zrch-B	Screws	0	1	3	36,4	11

AW-D – Archwise tooth-borne distractor; DP-D – Dolanmaz/Pichelmayer tooth-borne distractor; TMR-D - Tripathi/Mohanty/Rai tooth-borne distractor; ZP-H – Zemann/Pichelmayer hybrid distractor; Li-B – Intra-oral bone-borne Liou distractor (Martin); Zrch-B – Zurich paediatric bone-borne distractor (Martin).

Table XVI - Incidence of vector issues per accessory and distractor model

Distractor	Accessory	Distractor vector issues				Distracted discs
		Cef migration (n)	Plt migration (n)	Cef/Plt migration (n)	Incidence (%)	
AW-D; TMR-D	TPB	0	0	0	0,0	5
DP-D; ZP-H	No TPB	10	0	0	62,5	16

AW-D – Archwise tooth-borne distractor; DP-D – Dolanmaz/Pichelmayer tooth-borne distractor; TMR-D - Tripathi/Mohanty/Rai tooth-borne distractor; ZP-H – Zemann/Pichelmayer hybrid distractor.

Distractor failures were reported by Dolanmaz et al. (2003) (one case of fracture) and Altaweel et al. (2022) (two cases of instability). Zhang et al. (2018) and Hegab (2012) clearly stated they had no device failures.

Data regarding potential infectious complications were not reported in any of the included studies. Nevertheless, as stated above, 23 patients were documented to have received antibiotic prescriptions, with no information provided for the remaining cases.

Relapse was systematically evaluated by Hegab (2012) through the measurement of the distance between the two teeth adjacent to the vertical osteotomy immediately after the conclusion of the HAOD and after three and six months. The relapse was minimal both at three (0,2 +/- 0.35mm; 4 out of 10 patients) and six months (0,35 +/- 0,41; 5 out of 10 patients),

Supporting teeth relative position alterations are referred in four papers of those who used tooth-borne distractors, but only three measured it (table XVII). Singh et al (2021), Hegab et al (2012) and Dolanmaz et al (2003), all analysed angular variations in the axis of the teeth used to support the distractor based on pre and post distraction OPG analysis according to the method described by Ursi et al. (1990) although Hegab (2012) did not report the values for the teeth in the anchorage unit. Zemann & Pichelmayer, 2011 referred no anchorage teeth relative position change, although this evaluation was probably just empirical, as no assessment methodology is presented.

Table XVII - Analysis of supporting teeth relative position alterations

Study	Distractor	Transport disc teeth inclination change	Anchorage unit teeth inclination change	Anchorage unit teeth distal displacement
Singh 2021	TMR-D	3,05°	Right: 1,41° Left: 1,91°	-
Hegab 2012	Hg-D	14,02 +/- 2,09°	-	0,9 +/-0,52mm
Dolomanz 2003	DP-D	7,6°(2-17,5°)	3,3° (0-9°)	0,8mm (0-2mm)

DP-D – Dolanmaz/Pichelmayer tooth-borne distractor; Hg-D – Hegab tooth-borne distractor; TMR-D - Tripathi/Mohanty/Rai tooth-borne distractor.

Altaweel et al. (2022) described one case of suture dehiscence that was addressed with saline irrigation. Bousdras et al. (2014), Dolanmaz et al. (2003), Zemann & Pichelmayer, (2011) and Zhang et al. (2018) denied this complication. The calculated incidence was 3,2%.

A lateral root fracture of a premolar tooth (adjacent to a vertical osteotomy site) was reported by Altaweel et al. (2022). On the other hand, Zhang et al. (2018) reported they did not have any root fractures in six interdental osteotomies. The global incidence was 6,25%.

Dolanmaz et al. (2003) described an episode of epistaxis treated successfully with nasal packing in one patient while Zemann & Pichelmayer (2011) and Altaweel et al. (2022) denied haemorrhagic issues in the patients included in their studies. The calculated incidence was 4,8%,

Other complications were referred in the included studies. Hegab (2012) and Pichelmayer et al. (2008) stated the need to change the distractor at the middle of the process in four cases each, as the cleft was wider than the length permitted by the device. Altaweel et al. (2022) reported one case of hypoesthesia in the infraorbital nerve territory that evolved favourably with vitamin B supplements for 10 days, one case of occlusal interference during the active distraction successfully managed with a posterior bite raiser, one case of angular cheilitis due to chronic contact with the distractor body and two cases of mild discomfort at the end of the activation phase, attributed to compression of the soft tissue between the two bony ends. Pichelmayer et al. (2008) also reported that some patients experienced this discomfort.

Cases of transport disc necrosis, soft tissue rupture (excluding suture dehiscence), abnormal callus cicatrisation, oro-antral fistula, sinusitis, or dental pulp necrosis were not reported at all. Similarly, Binger et al. (2003) give no information on eventual specific difficulties or complications such as alteration of the dental germs' relative position or dental eruption problems for the patient with mixed dentition they treated.

Discussion

In what concerns to cleft patients, WAC is a particular setting of the alveolar process defect.

Demographic context:

The 67 patients analysed in this systematic review is a relative small number when compared with the 173 analysed by Mordukhovich et al. (2025). This probably relates with the more restrictive selection criteria applied, which is in line with the different objectives of both studies. Among those 67 patients, there is a relatively balanced ratio between females and males, and although sex is usually considered not relevant in the treatment, its incidence is twofold higher in males. Interestingly, these patients presented a mean age higher than the usual age for treatment with the gold standard treatment (table IV).(Suomalainen et al., 2014)

Baseline clinical status:

In the global cleft population the ratio between uni and bilateral clefts is estimated to be 9:1, which is different from the 4:1 found in this review (table IV).(Fell et al., 2025) This may be related to the fact that bilateral clefts usually present more severe phenotypes, thus needing more often reconstructive strategies other than secondary ABG.

The mean cleft dimension for the 39 patients who had it reported – 12,5mm (7-19mm) (table IV) – is higher than the usual for a general cleft population treated with secondary ABG, as reported in a recent systematic review - 6.80mm (± 1.98 mm). (Chetpakdeechit et al., 2023) However, there was a lack of information concerning the methodology used to make the measurement with just three papers providing information. Singh et al. (2021) made the measurement on dental casts (distance between the teeth adjacent to the cleft defect at the maximum contour) and CT images (distance between the teeth adjacent to the defect at the level of their cementoenamel junction). Neha et al. (2018) measured it on CT images (measured at the cervical zone and 7mm above). Zemann & Pichelmayer, (2011) measured the width on dental cast but provided no information on the specific methodology.

Although information regarding previous alveolar cleft reconstruction attempt was reported just for 38 patients, the fact that 16 had history of previous reconstruction with other techniques (table IV) is in line with the idea that HAOD can be used both as first and second line of treatment for alveolar cleft reconstruction (table IV).

It is well recognised that closing oro-nasal fistulas is an important objective of the alveolar cleft repair, so it is difficult to explain why their presence was reported for less than 20% of the patients and no author evaluated their severity.

HAOD technical variations:

Concerning the focality of the HAOD, both bi and trifocal procedures were used. It is important to refer that the selection between them cloud be related to the dimension of the cleft and thus with the complexity of the reconstruction. This was the case for the study of Singh et al. (2021), that defined a cleft dimension cut-off of 8mm to decide whether to use bi or trifocal HAOD. Nevertheless, in this review, it was possible to calculate the cleft dimension depending on the type of distraction for very few patients, especially those submitted to trifocal distraction (n=2), so it was not adequate to analyse whether the dimension of the cleft had some kind of association with the type of HAOD.

Although almost all patients underwent surgery under general anaesthesia, five were treated under local anaesthesia. No details were given about surgery duration and whether conscious sedation was used, but the fact that five patients had surgery under local anaesthesia favours the idea that the surgical procedure of performing the osteotomies is relatively simple and minimally invasive. Interestingly, of those patients, three had bilateral clefts and surgery performed at the same surgical time on both sides. However, it is also important to refer that the mean age of the patients of this study was the highest among those included in this review (table IV).

As described above, to perform the osteotomies the principal incision was always vestibular and although most were performed through two vestibular vertical incisions plus tunnelization between them, more authors preferred vestibular horizontal incisions (table VI). Some authors also combined the vestibular principal incision with a smaller palatine approach in the area of the vertical osteotomy, apparently to prevent tearing of the palatal mucosa with the cutting instruments. Nevertheless, they give emphasis to the fact that these palatine approaches were minimally invasive, with small mucoperiosteum reflection and based on tunnelization. Interestingly in all this cases the set of instruments used included burs and/or saws but never piezoelectric devices.

Regarding the design of the osteotomies (table IV), there is a clear preference for interdental positioning of its vertical component, which is in line with the described in the original technique. The horizontal component was described as least 3 mm supra-apical, which is also in line with the original technique and might be acceptable as no dental necrosis was reported in any study.(Liou et al., 2000) For the patient that had mixed dentition the author highlighted that care should be taken to put the horizontal component of the osteotomy high enough to avoid the dental germs. This is in line with the described in the original technique and other non-included papers that included mixed dentition patients. Nevertheless, Pichelmayer & Zemann (2012) refer that, in their opinion, the permanent canine should have already or almost erupted at the moment of the HAOD.

Liou & Chen (2009), recommended that the distraction disc should contain at least two teeth to allow adequate blood supply from the adjacent soft tissues. However, in this review two discs included just one tooth and complications were not reported.(Dolanmaz et al., 2003; Pektas et al., 2008)

Most of the cases included in this review were treated with tooth-borne devices, which is in line with other literature.(Mordukhovich et al., 2025) Nevertheless, a considerable number was treated with hybrid and bone-borne devices. Factors like the uncertainty about what is the best technical solution, experience of the cleft team and economic issues could have played a role in the decision. However, analysing the data of the present review (table IX) it is doubtful that it had been influenced by the dimension of the cleft as suggested by Mordukhovich et al. (2025).

Regarding the type of vector associated to each distractor (table VIII), it is important to refer that the definition of linear modified vector might be confusing, as it is not quite clear how a linear distraction device may change the vector of distraction, unless it is admitted that the device has some kind of flexibility in its structure or fixation.(Pichelmayer & Zemann, 2012) However, this was the authors option to distinguish cases like the presented by Pektas et al. (2008) in which, although the distractor was the same used by Alkan et al. (2007) (Modus MDO 1.5, Medartis), elastics and anchorage miniplates were used to try to optimise the trajectory of the distraction disc. The available data did not allow to make any analysis of an eventual association between the type of distraction vector and the HAOD outcomes.

Contrary to what was described in the original technique by Liou et al. (2000) the majority of the discs were distracted after 5-7 days. This might be related with the idea defended later by Liou & Chen (2009) that the duration of the latency period should be determined by the soft tissue healing, as soft tissue dehiscence during the distraction leads to the failure of the process.

The most used rhythm for distraction was between 0,8 and 1 mm/day divided into two or three daily activations (table X). No rationale has been given by the authors using much slower rhythms. However, the literature about distraction osteogenesis in craniofacial area points to the age of the patient as a reason to use higher distraction rhythms, at least in new-borns.(Mao et al., 2023) In fact, while the mean age of the patients treated with rhythms of 0,5 mm/day is 18 years old, for those patients treated with rhythms between 0,8 and 1 mm/day it is 12 years old. This is in line with the report of the original technique in which a rhythm of 1 mm/day was applied to patients with less than 12 years old.

The consolidation period (table X) has two possible approaches: early callus manipulation attempting its manipulation or its consolidation without any attempt to manipulate it. The concept of early callus manipulation is a well-known method to mitigate a non-planned final position of the distraction disc and already described in the original technique.(Liou et al., 2000). This approach was presumably used in the 21 discs that had less than three weeks of consolidation. However, it must be highlighted, that for a callus to heal, structural stability is essential, so shorter consolidation periods were associated with orthodontic stabilization and simultaneous position adjustment. However, Pichelmayer & Zemann (2012) argue that, in their experience, it is not always easy to correct a bad position of the distracted maxillary segment with orthodontic techniques and early callus manipulation.(Pichelmayer & Zemann, 2012) Interestingly, four discs had 32 weeks of consolidation, but no explanation for such a long period was given by the authors.

In the original technique the most favourable interdental septa for the vertical osteotomy should be identified based on radiological images, which was reported to be usually between the first molar and second premolar. However, in this review, 27 interdental osteotomies were preceded by the orthodontic creation of diastemas (table XI). The strategy described by Liou et al. (2000) may be specially interesting in cases where dental crowding is a problem, as it may not be easy to achieve the creation of the diastemas in such a context. Besides, although dental extractions could help in the creation of diastemas in those situations, maintaining all the teeth also has the benefit of moving them orthodontically to the new edentulous alveolar bone after the distraction has been concluded, thus eventually avoiding the need for dental prosthesis.

Some type of surgery was usually performed at the docking site, although it does not appear to be essential in all cases as it was not performed in almost 25% of the cases. This is in line with the idea that the HAOD should be seen more as a complementary procedure to ABG, than an alternative to it.

Although the type of dental rehabilitation of the new edentulous alveolar bone was considerably under-reported, dental prosthesis was the more frequently used (table XI). This may be related with the higher age of the patients included in this review when compared with the reported for the patients treated by Liou et al. (2000) and reported in the description of the original technique, where the chosen treatment was orthodontic tooth movement.

Outcomes of the reconstruction according to the HAOD technical variation:

Analysing the impact of HAOD technical variations in the treatment of oro-nasal fistulae was not possible in a systematic way due to the under-report of this condition at baseline and the outcomes after HAOD. Nevertheless, it appears that HAOD can be an interesting tool in oro-nasal fistulae reduction and/or closure, especially if combined with GPP and small ABG. The calculated mean cleft reduction of 82% after HAOD, meaning that for an alveolar cleft of 10mm, a mean reduction of 8,2mm could be expected, and the residual cleft being only 1,8mm, which is relevant from a clinical point of view, corroborates this idea.

No study referred the new bone quality to be inadequate, so it was also not possible to analyse whether any technical variation presented better outcomes. Nevertheless, its assessment trough the mean bone density measurement in two studies, is compatible with type 3 alveolar bone at least at 6 months post HAOD, which is the usual for the maxilla (table XIII). Importantly, no considerations were made regarding the volume of the new bone quality, which is also an important criterion when evaluating the quality of the neo-bone.

As referred above, distraction vector issues were the most reported complication, although with some distractors the problem was smaller. When trying to understand which characteristics of the devices could be associated with better outcomes, some clues could be found. On one hand it appears that hybrid distractors present less distraction vector issues, although two models of tooth-borne distractors (AW-D and TMR-D) can also be interesting (table XV). These were reported as not having had associated distraction vector issues, and their structural design seems quite solid, but information regarding this topic was only available for respectively three and two transported discs that used them. On the other hand, the inclusion of a TPB on the device also appears to have a positive effect on this outcome (table XVI).

Distractor failures did not present any identifiable tendence, and data was sparse on this topic.

Data regarding infectious complications were not reported in any of the included studies, so it was not possible to evaluate whether antibiotic prescription would offer an advantage in this context. Although 23 patients were documented to have received antibiotic prescriptions, this procedure does not seem to have serious infectious risk.

Singh et al. (2021) presented the smallest variations on the inclination of the supporting teeth on the transportation disc (table XVII), which can eventually be related to a superior structural stability of the device used, namely associated with the TPB and the complete hyrax screw.(Singh et al., 2021) Interestingly, Hegab (2012) considered the inclination change in the most mesial tooth of the distraction disc equal to the inclination of the disc itself.(Hegab, 2012) This might be reasonable if it is assumed that even with tooth-borne distractors, a complete osteotomy allows the forces applied to the teeth to be totally converted into disc movement without any dissipation as dental movement. The inclination change in the teeth of the anchorage unit was also less evident in the study of Singh et al. (2021) than in that of Dolanmaz et al. (2003) (table XVII), which might also be related to the TPB effect. Concerning the linear mesiodistal displacement of the supporting teeth in the anchorage unit measured on dental casts by Hegab (2012) and Dolanmaz et al. (2003) it was similar to that reported in the original technique.(Liou et al., 2000)

Relapse may be theoretically the result of three different mechanisms. First, it can be related to backward dental movement, which would be more likely to happen with bone-borne devices that could maintain the position of the bone to which they are attached, but not of the corresponding teeth if they had not another type of retention. This would have no clinical relevance as no alteration would result for the level of cleft closure. Second, it can be caused by backward movement of the distraction disc (bone and teeth), which could be the case if inadequate retention was done during the consolidation phase, for example, associated with early distractor removal and subsequent inadequate orthodontic technique. Third, it can also affect just the bone, for example, if there is a tooth-borne distractor in place that anchors just the teeth or if a bone-borne distractor is removed very early and the teeth are correctly stabilized from an orthodontic perspective. Presumably, just the second and third would have an impact on the level of cleft closure.(Hegab, 2012) This way, relapse may play an important role in the final outcome. As long as just Hegab (2012) systematically analysed the relapse it was not possible to make a thorough analysis of this topic. Nevertheless, and although the distractor was removed at two months post HAOD and orthodontic treatment started immediately but without application of rapid orthodontic tooth movement towards the regenerated bone, the data presented seem to be in line with the described in the original technique by Liou et al. (2000)

Regarding suture dehiscence, it could be hypothesized that perhaps the type of flap had some impact on it based on the rationale that incisions made perpendicular to the distraction vector cloud be a risk factor for suture dehiscence as the tension on the surgical wound would be perpendicular to it, thus favouring separation of its edges. This idea was based on a recently published paper in which Erverdi et al. (2024) unrecommend performing vertical incisions based on their experience in one case in which a vertical incision was made by error, resulting in wound dehiscence and callus exposure. However, the data collected in this systematic review contradicts this hypothesis, as not only the dehiscence reported happened with an incision parallel to the distraction vector but also Hegab (2012) and Zhang et al. (2018) reported they did not have any suture dehiscence using incisions perpendicular to the distraction vector, even with a latency period of just three days in the last case. It is possible that the complication reported by Erverdi et al. (2024) resulted essentially from the fact that the vertical incision was not planned, and apparently a minimal amount of gingiva was spared.

As stated above, lateral root fractures were rare, although just Altaweel et al. (2022) and Zhang et al. (2018) reported on this topic. The sole case of lateral root fracture was diagnosed just at the end of the distraction, and apparently had no impact on the outcome. However, Erverdi et al. (2024) recommend stopping and reversing the distraction so that the transport segment returns to its original position, and after healing is completed, the distraction should be planned at another site. To perform the osteotomies Altaweel et al. (2022) used bur and osteotomes while Zhang et al. (2018) used a piezoelectric surgery device and osteotomes. So, it is possible to hypothesize that maybe piezoelectric surgery devices combined with osteotomes offer an advantage over burs combined with osteotomes. Altaweel et al. (2022) reported that the patients included in their study were submitted to pre-surgical orthodontics, however, no information was given concerning diastema opening at the vertical osteotomy site. On the other hand, Zhang et al. (2018) did not report any information on this subject. This way, it was not possible to analyse if pre-surgical diastema opening through orthodontics might influence the incidence of tooth root lateral fractures at the interdental osteotomy sites. With the advancements in 3D planning and printing, the fabrication of individualized surgical guides may increase the accuracy and safety of this procedure. (Matsushita et al., 2022)

The incidence of 4,8% minor haemorrhagic events, and although just four studies reported on this complication in a total of 21 patients, is compatible with a low haemorrhagic risk.

Regarding soft tissue rupture during the distraction (excluding suture dehiscence), it is important to refer that although no author reported this type of complication some consider important to orthodontically create diastemas between the two teeth adjacent to the interdental osteotomy site not only to decrease the risk of root fracture but also to avoid root exposure that cloud happen if the interdental osteotomy was not performed entirely between the two adjacent *laminae durae*, which could lead to callus exposure.(Erverdi et al., 2024; Hegab, 2012; Liou et al., 2000; Shahab et al., 2019; Titiz et al., 2019; Yilmaz et al., 2019)

The studies included in this systematic review present important risks of bias associated both with their type and the quality of the information they report. While it is understandable that this is a particular setting of cleft patients, it would be important not only to perform stronger types of studies but also to follow the guidelines for each type of publication more strictly. Nevertheless, this review is important as it not only aggregates and analyses the available published knowledge on HAOD for alveolar cleft reconstruction but also furnishes relevant guidance for new studies.

Conclusion

The available data suggest that HAOD may be an important tool in dealing with WAC repair.

It appears that the technique can reduce the dimension of oronasal fistulas and alveolar clefts, although not completely excluding the need for a docking site surgery, namely a GPP eventually associated with a small ABG.

Most cases were treated with tooth-borne distractors, but the evidence collected points towards a better control of the distraction vector with hybrid fixation and TPB utilization.

Although the AW-D and the TMR-D, both using TPB, have interesting designs and presented no distraction vector issues, it was possible to obtain relevant information on this variable for few distracted discs using them.

Bibliography

Alkan, A., Bas, B., Özer, M., & Bayram, M. (2007). Closure of a large palatal fistula with maxillary segmental distraction osteogenesis in a cleft palate patient. *Cleft Palate-Craniofacial Journal*, *44*(1), 112–115. https://doi.org/10.1597/05-195

Altaweel, A. A., Lababidy, A. S., Abd-Ellatif El-Patal, M., Elsayed, S. A., Eldin, M. S., Dabbas, J., Meneim, M. H. A.-E., & Kharma, M. Y. (2022). Outcomes of Bifocal Transport Distraction Osteogenesis for Repairing Complicated Unilateral Alveolar Cleft. *Journal of Craniofacial Surgery*, *33*(2), E187–E191. Scopus. https://doi.org/10.1097/SCS.0000000000008260

Aravindaksha, S. P., Batra, P., & Sadhu, P. (2014). Bilateral Alveolar Distraction for Large Alveolar Defects: Case Report. *The Cleft Palate-Craniofacial Journal : Official Publication of the American Cleft Palate-Craniofacial Association*. https://doi.org/10.1597/13-058.1

Aromataris, E., Lockwood, C., Porritt, K., Pilla, B., & Jordan, Z. (Eds.). (2024). *JBI Manual for Evidence Synthesis*. JBI. https://doi.org/10.46658/jbimes-24-01

Bergland, O., Semb, G., & Abyholm, F. E. (1986). Elimination of the residual alveolar cleft by secondary bone grafting and subsequent orthodontic treatment. *The Cleft Palate Journal*, *23*(3), 175–205.

Binger, T., Katsaros, C., Rücker, M., & Spitzer, W. J. (2003). Segment Distraction to Reduce a Wide Alveolar Cleft before Alveolar Bone Grafting. *Cleft Palate-Craniofacial Journal*, *40*(6), 561–565. Embase. https://doi.org/10.1597/1545-1569(2003)040<0561:SDTRAW>2.0.CO;2

Bousdras, V. A., Liyanage, C., Mars, M., & Ayliffe, P. R. (2014). Segmental maxillary distraction with a novel device for closure of a wide alveolar cleft. *Annals of Maxillofacial Surgery*, *4*(1), 60–63. https://doi.org/10.4103/2231-0746.133067

Chetpakdeechit, W., Pisek, P., Pitiphat, W., & Rattanakanokchai, S. (2023). Cleft Size and Success of Secondary Alveolar Bone Grafting—A Systematic Review. *The Cleft Palate Craniofacial Journal*, *60*(3), 285–298. https://doi.org/10.1177/10556656211059361

Dolanmaz, D., Karaman, A. I., Durmus, E., & Malkoc, S. (2003). Management of alveolar clefts using dento-osseous transport distraction osteogenesis. *Angle Orthodontist*, *73*(6), 723–729. Scopus.

Erverdi, A. N., Acar, Y. B., & Mert, B. (2024). A novel approach in orthodontics: Archwise distraction osteogenesis. *Seminars in Orthodontics*, *30*(5), 602–622. Scopus. https://doi.org/10.1053/j.sodo.2024.05.011

Erverdi, A. N., Yilmaz, B., Motro, M., Gozneli, R., & Ugurlu, K. (2014). Simultaneous alveolar cleft closure and dental midline correction with curvilinear intraoral distraction. *Cleft Palate-Craniofacial Journal*, *51*(3), 344–349. Embase. https://doi.org/10.1597/12-279

Erverdi, N., Küçükkeleş, N., Şener, C., & Selamet, B. U. (2012). Interdental distraction osteogenesis for the management of alveolar clefts: Archwise distraction. *International Journal of Oral and Maxillofacial Surgery*, *41*(1), 37–41. Embase. https://doi.org/10.1016/j.ijom.2011.09.001

Erverdi, N., Motro, M., Gozneli, R., & Kucukkeles, N. (2013). A Novel Vector Control Device in Horizontal Bone Transport. *Journal of Oral and Maxillofacial Surgery*, *71*(4), 768–774. https://doi.org/10.1016/j.joms.2012.09.013

Fell, M., Bradley, D., Chadha, A., Butterworth, S., Davies, A., Russell, C., Richard, B., Wren, Y., Lewis, S., & Chong, D. (2025). Sidedness in Unilateral Orofacial Clefts: A Systematic Scoping Review. *The Cleft Palate Craniofacial Journal*, *62*(5), 730–743. https://doi.org/10.1177/10556656231221027

Hegab, A. F. (2012). Closure of the alveolar cleft by bone segment transport using an intraoral tooth-borne custom-made distraction device. *Journal of Oral and Maxillofacial Surgery*, *70*(5), e337–e348. Scopus. https://doi.org/10.1016/j.joms.2012.01.013

Kantar, R. S., Hamdan, U. S., Muller, J. N., Hemal, K., Younan, R. A., Haddad, M., Melhem, A. M., Don Griot, J. P. W., Breugem, C. C., & Mokdad, A. H. (2023). Global Prevalence and Burden of Orofacial Clefts: A Systematic Analysis for the Global Burden of Disease Study 2019. *Journal of Craniofacial Surgery*. https://doi.org/10.1097/scs.0000000000009591

Liou, E. J. W., & Chen, P. K. T. (2009). Intraoral Distraction of Segmental Osteotomies and Miniscrews in Management of Alveolar Cleft. *Seminars in Orthodontics*, *15*(4), 257–267. Scopus. https://doi.org/10.1053/j.sodo.2009.07.002

Liou, E. J. W., Chen, P. K. T., Huang, C. S., & Chen, Y. R. (2000). Interdental distraction osteogenesis and rapid orthodontic tooth movement: A novel approach to approximate a wide alveolar cleft or bony defect. *Plastic and Reconstructive Surgery*, *105*(4), 1262–1272. Embase. https://doi.org/10.1097/00006534-200004040-00002

Long, R. E. J., Spangler, B. E., & Yow, M. (1995). Cleft width and secondary alveolar bone graft success. *The Cleft Palate-Craniofacial Journal: Official Publication of the American Cleft Palate-Craniofacial Association*, *32*(5), 420–427. https://doi.org/10.1597/1545-1569_1995_032_0420_cwasab_2.3.co_2

Mao, Z., Tian, G., Shrivastava, M., Zhou, J., & Ye, L. (2023). Complications of Mandibular Distraction Osteogenesis in Infants with Isolated Robin Sequence. *Children*, *10*(10), 1591. https://doi.org/10.3390/children10101591

Matsushita, K., Wakabayashi, Y., Tanaka, S., Seikai, T., & Donen, M. (2022). CAD/CAM surgical guide for precise interdental osteotomy at the site between the crowded teeth in cleft lip and palate patients. *Advances in Oral and Maxillofacial Surgery*, *8*. Embase. https://doi.org/10.1016/j.adoms.2022.100379

Mordukhovich, I., Hill, M., Fragomen, F. R., Meyers, A., Gharb, B. B., & Rampazzo, A. (2025). A systematic review of wide alveolar cleft repair techniques. *Journal of Plastic, Reconstructive and Aesthetic Surgery*, *102*((Mordukhovich I.; Fragomen F.R.; Meyers A.; Gharb B.B.; Rampazzo A., rampaza@ccf.org) Department of Plastic Surgery, Cleveland Clinic, Cleveland, OH, United States), 335–347. Embase. https://doi.org/10.1016/j.bjps.2025.01.053

Munn, Z., Barker, T. H., Moola, S., Tufanaru, C., Stern, C., McArthur, A., Stephenson, M., & Aromataris, E. (2020). Methodological quality of case series studies: An introduction to the JBI critical appraisal tool. *JBI Evidence Synthesis*, *18*(10), 2127–2133. https://doi.org/10.11124/JBISRIR-D-19-00099

Neha, N., Tripathi, T., Mohanty, S., & Rai, P. (2018). A novel minimally invasive technique of using tooth-borne hyrax expansion screw for distraction osteogenesis of large alveolar cleft defects (HYDIS-TB). *Cleft Palate-Craniofacial Journal*, *55*(6), 895–902. Scopus. https://doi.org/10.1597/15-335

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

Pektas, Z. Ö., Kircelli, B. H., Bayram, B., Kircelli, C., & Uckan, S. (2008). Alveolar cleft closure by distraction osteogenesis with skeletal anchorage during consolidation. *International Journal of Oral and Maxillofacial Implants*, *23*(1), 147–152. Medline.

Pichelmayer, M., Mossböck, R., & Droschl, H. (2008). Maxillary segmental distraction in a patient with bilateral cleft lip and alveolus with subsequent tooth transplantation: A preliminary case report. *Cleft Palate-Craniofacial Journal*, *45*(4), 446–451. Embase. https://doi.org/10.1597/07-118.1

Pichelmayer, M., & Zemann, W. (2012). Alveolar cleft closure by osseodistraction: Pitfalls and troubleshooting. *Journal of Craniofacial Surgery*, *23*(2), e72–e75. Medline. https://doi.org/10.1097/SCS.0b013e31824685d3

Sakamoto, T., Ishii, T., Mukai, M., Ueki, A., Sueishi, K., Suga, K., Nakano, Y., & Uchiyama, T. (2011). Application of interdental distraction osteogenesis to unilateral cleft lip and palate patients. *The Bulletin of Tokyo Dental College*, *52*(2), 103–112. Medline. https://doi.org/10.2209/tdcpublication.52.103

Shahab, N., Sar, C., Sarac, M., & Erverdi, N. (2019). Reconstruction of premaxilla with alveolar distraction osteogenesis in a patient with complete cleft lip and palate: A case report. *Cleft Palate-Craniofacial Journal*, *56*(4), 534–537. Embase. https://doi.org/10.1177/1055665618785789

Singh, N., Tripathi, T., Mohanty, S., Rai, P., & Bhutiani, N. (2021). Closure of large alveolar defect by maxillary alveolar distraction using a vector-controlled distractor appliance in cleft patients: A pilot study. *Journal of Oral Biology and Craniofacial Research*, *11*(2), 277–283. https://doi.org/10.1016/j.jobcr.2021.02.008

Stallings, E. B., Isenburg, J. L., Rutkowski, R. E., Kirby, R. S., Nembhard, W. N., Sandidge, T., Villavicencio, S., Nguyen, H. H., McMahon, D. M., Nestoridi, E., & Pabst, L. J. (2024). National population-based estimates for major birth defects, 2016–2020. *Birth Defects Research*, *116*(1). https://doi.org/10.1002/bdr2.2301

Suomalainen, A., Åberg, T., Rautio, J., & Hurmerinta, K. (2014). Cone beam computed tomography in the assessment of alveolar bone grafting in children with unilateral cleft lip and palate. *European Journal of Orthodontics*, *36*(5), 603–611. https://doi.org/10.1093/ejo/cjt105

Suzuki, E. Y., Buranstidporn, B., & Ishii, M. (2006). Simple and inexpensive approach for the management of cleft patients with the twin-track distraction: Case report. *Journal of Oral and Maxillofacial Surgery*, *64*(4), 722–726. Embase. https://doi.org/10.1016/j.joms.2005.12.019

Titiz, S., Çelikkol, O., Ateş, P., Aras, A., & Erverdi, N. (2019). Multidisciplinary treatment of two patients with cleft lip and palate using archwise distraction: A case report. *Journal of Stomatology, Oral and Maxillofacial Surgery*, *120*(1), 61–66. Medline. https://doi.org/10.1016/j.jormas.2018.08.004

Ursi, W. J., Almeida, R. R., Tavano, O., & Henriques, J. F. (1990). Assessment of mesiodistal axial inclination through panoramic radiography. *Journal of Clinical Orthodontics : JCO*, *24*(3), 166–173.

Van Der Meij, A. J. W., Baart, J. A., Prahl-Andersen, B., Kostense, P. J., Van Der Sijp, J. R., & Tuinzing, D. B. (2003). Outcome of bone grafting in relation to cleft width in unilateral cleft lip and palate patients. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, *96*(1), 19–25. https://doi.org/10.1016/s1079-2104(03)00266-x

Yilmaz, H., Karabiber, G., & Erverdi, N. (2019). A Novel Approach for the Reconstruction of Premaxilla by Archwise Distraction in Bilateral Cleft Lip and Palate. *Journal of Craniofacial Surgery*, *30*(1), E40–E43. https://doi.org/10.1097/SCS.0000000000004954

Zemann, W., & Pichelmayer, M. (2011). Maxillary segmental distraction in children with unilateral clefts of lip, palate, and alveolus. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, *111*(6), 688–692. Medline. https://doi.org/10.1016/j.tripleo.2010.08.002

Zhang, J., Zhang, W., & Shen, S. G. (2018). Segmental maxillary distraction osteogenesis with a hybrid-type distractor in the management of wide alveolar cleft. *Cleft Palate Craniofacial Journal*, *55*(8), 1133–1137. Embase. https://doi.org/10.1177/1055665618763329