Comparison of speech effects among labial, lingual, and aligner appliances: a systematic review

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Research Article

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Abstract

Background: Speech sound disorders are produced irrespective of the type of orthodontic appliance. The present systematic review aimed to compare the speech impediments created during orthodontic treatment with the labial appliances (LA), lingual appliances (LI), and orthodontic aligners (OA). Methods: The studies were searched from PubMed, Scopus, Web of Science, Embase, and Cochrane Library from 2000 to 25 Feb 2022. A manual search was also performed. The study's quality was assessed by the Cochrane Risk of Bias Tool and the Newcastle-Ottawa Quality Assessment Form. Two reviewers performed study selection and data extraction. Results: From a total of 1298 articles, 21 studies were selected, including 3 randomized clinical trials (RCTs), 15 prospective studies, 2 retrospective studies, and 1 cross-sectional study. Two RCTs were assessed as having a "low" risk of bias, and one was considered unclear. Twelve nonrandomized studies were classified as "high" and six as "moderate" quality. Six studies compared LA and LI, three studies compared LA and OA, one study compared LI and OA, and eleven studies only evaluated single orthodontic appliances. Conclusion: Based on the evidence available, LA seemed to impact minimally on speech, and the duration was the shortest; LI caused more speech impediments and had greater difficulty adapting; OA produced mild to moderate speech impediments, and the adaptation time was between the two.

Background

Orthodontic appliances play a crucial role in orthodontics. Conventional labial fixed appliances (LA) with brackets located on the labial side of the teeth have remained dominant in the development of orthodontics [1]. With the increasing esthetic concerns of patients, various aesthetic appliances have undergone constant development over the past few decades[2, 3]. Lingual fixed appliances (LI) place the brackets on the teeth's lingual surface and are widely accepted as an alternate to labial appliances [4]. Orthodontic aligners (OA), which do away with traditional fixed brackets and use thermoplastic for the purpose of moving teeth, are particularly sought after among the younger generation [5, 6].

Recent shifts in perception of health have made people's comfort and satisfaction during dental clinical practice more visible, leading to the development of the concept of oral health-related quality of life (OHRQOL)[7]. And the main complaint among orthodontic patients has always been speech sound disorders [2, 8]. Speech is essential for social interaction. A speech disorder is supposed to impair patients' socio-psychological well-being, undermine their self-image, and decrease their compliance [9–11]. Therefore, speech impediments would cause considerable damage to OHRQOL. Moreover, some scholars believe that different types of appliances may have varying degrees of influence on the severity, duration, and types of articulatory errors that lead to speech impediments [12, 13].

There have been numerous systematic evaluations of the effects produced by various orthodontic appliances [11–15]. Some focused on the treatment effects, and some focused on periodontal health. Only one systematic review has been conducted to evaluate the speech difficulties caused by orthodontic appliances [8]. However, new evidence has been published recently, especially studies assessing the contribution of orthodontic aligners to speech disorders [12, 13, 19–21]. Therefore, a thorough analysis and summary of studies is necessary for the patient and the clinician to make fully informed decisions.

Based on this scenario, the present systematic review aimed to compare the speech impediments produced during orthodontic treatment with labial, lingual, and aligner appliances.

Methods

This review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines[22]. In addition, we submitted the PROSPERO registration on 1 March 2022but the identification number has not yet published.

PICO question

The participants, intervention, comparison, outcome and study design (PICOS) model were designed as follows: Participants: healthy person with malocclusion of any age; Intervention: treatment with labial fixed appliances, lingual fixed appliances, or orthodontic aligners; Comparison,: patients before treatment; Outcomes: speech sound disorder; Study design: Randomized controlled trials (RCTs), prospective or retrospective cohort studies, and cross-sectional studies.

Search strategy

The literature was searched in PubMed (National Institutes of Health), Scopus, Web of Science, Embase (Elsevier), and Cochrane Library. The searching keywords were “(labial OR lingual OR fixed OR aligner OR Invisalign) AND orthodon* AND (Speech OR articulation OR phonetics OR pronunciation)”. The latest search was performed on February 25, 2022. Hand-searching was conducted on reference lists of all suitable studies to minimize information leakage.

Inclusion and exclusion criteria

The inclusion criteria for this systematic review were as follows: Randomized controlled trials (RCTs), prospective or retrospective cohort studies, and cross-sectional studies; Studies focused on the speech effects produced by labial, lingual, and aligner appliances.

The following exclusion criteria were applied: *in vitro* or animal studies, case reports, or case series; it is written in a non-English language; it was published before 2000.

Study selection

Study selection was performed by two independent reviewers (J.S and Q.T). After scanning the titles and abstracts, potential related studies would be collected and further assessed by the inclusion and exclusion criteria. The final included studies in this systemic review would then be selected. Decisions would be made by discussion and subsequent consensus if disagreements occur.

Assessment of risk of bias of the studies

The study’s quality was assessed via two separate tools. The bias of the RCT was assessed based on the Cochrane Risk of Bias Tool[23], while the quality of each other study was assessed by the Newcastle-Ottawa Quality Assessment Form for Cohort Studies (NOS)[24].

Data extraction and synthesis

The follow information from each included study were extracted: the name of the first author, the year of publication, the NOS score, the region of where the cohort was from, the type of the study, sample size, mean age, treatment modality, duration, and clinical outcomes of the speech impediments.

Data were collected and organized into tables to present the study and patient characteristics of the included studies and the influences of different types of appliances on speech.

Statistical analysis

No meta-analyses could be performed due to the heterogeneity in the study designs and treatment modalities.

Results

A total of 1294 records were identified through the electronic search, and 4 papers were added through manual search. After removing duplicates and irrelevant studies based on titles and abstracts, 30 articles remained. For reasons shown in Figure 1, 9 articles were excluded. Finally, 21 articles were included in this review.

Characteristics of included studies

The characteristics of the included studies are shown in Table I. Of these studies, we included three RCTs, fifteen prospective studies, two retrospective studies, and one cross-sectional study. Six studies compared LA and LI, three studies compared LA and OA, one study compared LI and OA, and the remaining studies only evaluated a single orthodontic appliance. The longest follow-up assessed was six months, and the shortest was one day. Objective acoustic analysis was used in five studies, semi-objective speech assessment was used in thirteen studies, and subjective analysis was used in eighteen studies.

Results of Quality Assessment

The quality of the included studies is shown in Table II and Figure 2. For the included RCTs, two[13, 25] were considered to have a low risk of bias, and one[26] was judged to have an unclear risk of bias (for one or more key domains) (Fig. 2). According to the NOS scale, twelve nonrandomized studies[19, 21, 27–36] were found to have relatively high quality (over 7 stars), and six studies[12, 20, 37–39] were observed to have moderate quality (Table I).

The alterations of speech performance

We found that objective, semi-objective and subjective acoustic analysis produced different results. A subjective analysis appeared to report a more negative impact in some studies[13, 19, 21]. Two studies compared LA and OA and discovered that LA did not display any significant differences in speech immediately after bonding, whereas OA demonstrated mild to moderate speech impediments[13, 19]. However, in the study by Paley[30], the LA had a variable effect on speech. Different studies found that LI had varying degrees of effect on speech due to the severity of speech impediments depending on the LI designs[25, 27, 31, 33, 35, 36, 39]. A study compared OA and LI, and reported that the speech impediment was more severe in the OA.

Duration of speech impediments

The duration varied across different studies (Table III). For the LA, four studies [26, 28, 32, 34] suggested that labial patients needed only one month to adapt to the appliances. In comparison, two other studies [30, 35] reported that speech articulation errors continued to occur after two months later. For the LI, most included studies showed patients required at least 3 months to return to baseline[21, 25, 27, 33, 36], and the longest could be up to six months [31]. Furthermore, the adaptation time for aligner patients varied from 1 month to 3 months.

Type of articulatory errors

Thirteen studies evaluated the speech sounds affected by orthodontic appliances (Table IV). Only two studies assessed the vowel sounds and found that both LA and LI harmed /l / sound, and LI was more serious[32, 34]. Other studies evaluated the consonants, and /s/ was most frequently affected. Six studies[13, 19, 26, 31, 32, 34], nine studies[20, 21, 25, 26, 29, 32–34, 39] and three studies[12, 19, 21] reported this change in LA, LI and OA, respectively. Moreover, the consonants /th, f, t, z/ also showed a greater drop in LA patients [19, 30]. And the LI caused a significant change in /z, ts, s, t, d/ [21, 29, 32]. In addition, the phoneme /ch/ was reported two times, and the phoneme /z/ was reported three times in aligner patients [12, 13, 19, 21].

Discussion

Speech impediment is not only a physical effect of orthodontic treatment but also a socio-psychological impact. In this systematic review, speech impairment was produced irrespective of the type of orthodontic appliances. Nevertheless, there were some differences among the three appliances, including the severity of speech impediments, duration, sound errors, speech rate, etc.

The severity of speech sound disorders

The LA had the least effect on pronunciation among the three appliances. Several previous studies stated that LA had no impact on speech, agreeing with Fraundorf [21] and Melo et al. [9]. However, the majority of selected studies agreed that LA caused a slight speech impediment during the initial stage, which returned to baseline after one month. In contrast, previous studies stated that LA patients required 2–3 weeks as an adaptation period[40]. Compared with LA, patients with LI experienced more speech impediments at the beginning of treatment. Most studies reviewed reported that LI patients required at least three months to adapt to the change. Only one study compared the LI and OA; both caused equal but slight impairments in speech, while OA caused even greater difficulty in the production of /s/ and /z/ sounds [23]. Nevertheless, this study did not use objective assessment, and the certainty of the evidence was low. What is certain is that OA had more limitations and difficulties in speech than LA. Besides, two studies indicated that patients with aligners spoke more slowly to attempt to better articulate [8, 21]. To date, no study has assessed whether the OA brands have had an impact on speech sound production.

Interestingly enough, LA brands were associated with the severity of speech impediment due to the different designs of brackets[41]. In the study by Khattab et al., the sharp hooks caused more irritation to the tongue compared with the round hooks. Speech performance was also affected by bracket positioning techniques. The Bonding with Equalized Specific Thickness (BEST) positioning system was significantly poorer than the Transfer Optimized Positioning (TOP) procedure. Additionally, the customized brackets were

considerably better than the prefabricated brackets. On the whole, the thinner the lingual appliances, the fewer the speech impediments. However, there are no studies comparing the speech effects caused by the self-ligating brackets and conventional brackets.

The pathology speech sound disorders

While the type of articulatory error differed between appliances, the /s/ sound was most commonly affected. The production of these phonemes is determined in part by the lip, incisor, and tongue contact. Leavy et al.[42] attributed speech sound disorders to placement errors. The anterior lingual protrusion, lingual retraction, and lateral lingual protrusion would disrupt the production of lingual-alveolar consonants, such as /s, sh, l/, while the lip excursion would affect the production of labiodental sounds, such as /f/. Understandably, the LI caused tongue space restriction and incisor morphological change, affecting the lingual-alveolar sounds the most. According to Paley et al.[30], speech sound disorders in labial patients are a result of lingual protrusion. Meanwhile, the LA affected the lip position and resulted in articulatory errors with labiodental sounds. Despite its thinness, OA produces both lingual-alveolar sounds and labiodental sounds since it covers the labial-lingual surfaces of the teeth at the same time. Aside from the aforementioned factors, lingual auxiliaries such as TPAs and Nance appliances had an effect on sound production.

Other factors

In addition to orthodontic appliances, other factors should be taken into consideration. It is apparent that there is a relationship between malocclusion and speech defects [43–45]. A study by Ahmed et al.[31] showed that Class II patients had difficulties with /p, b, m, s/ sounds, while Class III patients had difficulties with /s, z, f, v/ sounds. Furthermore, Paley et al.[30] revealed that the severity of malocclusion would affect the time needed for speech adaptation. However, only seven included studies[12, 13, 19, 20, 26, 29, 31] in the present systematic review limited the types of malocclusions. Different languages also affect speech impairment, which could explain why the results regarding speech defects differ between trials [33, 46]. Age could also affect the speech performance. According to Hohoff’s study, age-related influence can be found only after 57 years old [33], while the age for Dahan’s study is 80 years old [46].

Recommendations for clinical practice

Consider the speech impact of an appliance before choosing one for a particular patient [31]. Before treatment, orthodontists should ensure patients are fully informed about the speech impacts caused by different orthodontic appliances, including the severity, the duration, and the type of sound errors. For the fixed appliances, the upper arch and lower arch bonded at two appointments could enhance patient comfort and reduce adverse effects on speech [47]. As for LI, the thinnest is the most effectives. Choosing customized brackets, TOP techniques, and rounded hooks are all excellent choices. Besides, the use of orthodontic wax can reduce the pain in the tongue and mitigate speech problems. The aligner is the only appliance that can be removed by a patient’s will [48]. To avoid poor adherence, it should not be considered for those who take speech impediment very seriously. Sometimes, appropriate psychological intervention should be taken to boost patients' confidence and help them through the early stages of orthodontic treatment.

Limitations and Prospect

The present systematic review updated the speech effects encountered during orthodontics based on the existing evidence. Besides, studies published before 2000 were excluded to reduce bias because of the development of orthodontic appliances and assessment methods. However, there are also some limitations. First, no studies have been conducted to evaluate the speech effects caused by these three appliances simultaneously. Second, seven selected studies[20, 27, 28, 35–38] only used subjective analysis, which reduced the strength of evidence. Due to substantial heterogeneity across studies meta-analysis was not possible.

In conclusion, long-term, large sample size, well-designed, and well-controlled studies are required. Furthermore, future studies should: 1. consider the potential effects of malocclusions and auxiliaries on speech; 2. use more objective acoustic analysis to reduce the inter-individual variability and subjective judgment of speech; and 3. explore the effectiveness of different solutions in improving speech impediments.

Conclusion

Based on the evidence available, the LA had a minimal impact on speech. The duration is shortest; the fixed lingual appliances caused more speech impediments and had greater difficulty adapting; the orthodontic aligners produced mild to moderate speech impediments and the adaptation time was between the two. Further RCTs with adequately defined samples and well-designed protocols should be conducted to confirm the speech effects and improve clinicians' and patients' understanding of orthodontic treatment.

Abbreviations

LA
labial appliances
LI
lingual appliances
OA
orthodontic aligners
RCT
Randomized controlled trial
NOS
Newcastle-Ottawa Quality Assessment Form for Cohort Studies
BEST
Bonding with Equalized Specific Thickness
TOP
Transfer Optimized Positioning.

Declarations

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Authors' contributions

J.S, Q.T, and L.L designed the research and drafted the manuscript. J.S, Q.T, L.L, L.S, X.C and W.L helped organize the manuscript. J.S, Q.T, L.S, L.L X.C and W.L revised and finalized the paper. All authors have read and approved the final manuscript and, therefore, have full access to all the data in the study and take responsibility for the integrity and security of the data.

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Availability of data and materials

Not applicable.

Ethics approval and consent to participate

Not required.

Consent for publication

All authors have given final approval for publication.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table I Characteristics of included studies

Reference	Design	Country	Sample size	Malocclusion	Interventions /Groups	Longest follow-up time	Methods			Outcomes
							Objective Acoustic Analysis	Semiobjective Speech Assessment	Subjective Assessment	
Fraundorf 2021	Prospective	USA	44	Class I or Class II	OA vs. LA	2 months	✓	✓	✓	OA significantly affected speech; while LA had no effect on speech.
Melo 2021	RCT	Brazil	40	Angle Class I	OA vs. LA	6 months		✓	✓	OA significantly affected speech; while LA had no effect on speech.
Angelopoulos 2021	Prospective	Greece	47	NR	OA vs. LI	3 months		✓	✓	Both OA and LI affected speech.
Albertini 2021	Prospective	Italy	6	molar Class I	LI vs. LI	1 hour	✓			LI significantly affected speech and no lingual system was systematically better than others.
Alajmi 2020	Retrospective	Kuwait	60	Class I	OA vs. LA	NR			✓	OA had significantly more difficulties on speech than LA.
Pogal-Sussman-Gandia 2019	Cross-sectional	USA	30	Class I and Class II	OA	NR		✓	✓	OA significantly affected the articulation of speech.
Ahmed 2019	Prospective	India	30	bimaxillary protrusion	LI vs. LA:	6 months			✓	LI had more error in speech compared to LA.
Arreghini 2018	Prospective	Italy	30	NR	OA	1 day		✓	✓	F22-aligner therapy has no significant impact on patients' phonetic articulation;
Paley 2016	Prospective	USA	23	Any	LA	8-20 weeks			✓	LA had a variable effect on speech.
Haj-Younis 2016	RCT	Syria	46	NR	LI vs. LI	3 months		✓	✓	7th Generation lingual brackets had higher degrees of speech impairment than STb.
Rai 2014	Prospective	India	24	minimum to moderate crowding	LI vs. LI	1 month	✓	✓	✓	Both the LI and LA showed a comparable speech difficulty after bonding.
Rai 2013	Prospective	India	12	NR	LI vs. LA	1 month	✓	✓	✓	LI had higher degrees of

										speech impairment than LA.
Khattab 2012	RCT	Syria	34	Class I	LI vs. LA	3 months		✓	✓	Speech articulation was affected in both groups, but patients with LI had higher degrees of impairment.

Table I (continued)

Reference	Design	Country	Sample size	Malocclusion	Interventions /Groups	Longest follow-up time	Methods			Outcomes
							Objective Acoustic Analysis	Semiobjective Speech Assessment	Subjective Assessment	
Wu 2011	Prospective	China	60	NR	LI vs. LI	3 months			✓	Patients treated with LI experienced more speech impediments than LA.
Wiechmann 2008	Prospective	Germany	25	NR	LI	1 day			✓	LI significantly affected the speech.
Stamm 2005	Prospective	Germany	42	NR	LI vs. LI	3 months			✓	The customized lingual brackets had significantly fewer difficulties than prefabricated lingual brackets.
Caniklioglu 2005	Prospective	Turkey	60	NR	LI vs. LA	3 months			✓	LI had more error in speech compared to LA.
Nedwed 2005	Retrospective	Germany	54	NR	OA	3-6 months			✓	OA affected the speech.
Hohoff 2004	Prospective	Germany	41	NR	LI vs. LI	3 months			✓	The TOP technique significantly better than BEST technique.
Hohoff 2003	Prospective	Germany	12	NR	LI vs. LI vs. LI	1 day later		✓	✓	The customized lingual brackets better than the prefabricated lingual brackets.
Hohoff 2003	Prospective	Germany	23	NR	LI	3 months	✓	✓	✓	LI affected the speech.

LA: labial appliances; LI: lingual appliances; OA: orthodontic aligners; NR: not reported; BEST: Bonding with Equalized Specific Thickness; TOP: Transfer Optimized Positioning.

Table II NOS scale for cohort studies and cross-sectional studies.

Author/Year	Selection	Comparability	Outcomes	NOS score
Fraundorf 2021	4	0	3	7
Angelopoulos 2021	4	1	3	8
Albertini 2021	4	1	2	7
Alajmi 2020	3	0	1	4
Pogal-Sussman-Gandia 2019	4	0	2	6
Danish Intesaab 2019	4	0	3	7
Arreghini 2018	4	0	2	6
Paley 2016	4	0	3	7
Rai 2014	4	0	3	7
Rai 2013	4	0	3	7
Wu 2011	4	0	3	7
Wiechmann 2008	4	0	1	5
Stamm 2005	4	0	3	7
Caniklioglu 2005	4	0	3	7
Nedwed 2005	3	0	1	4
Hohoff 2004	4	0	3	7
Hohoff 2003	4	0	2	6
Hohoff 2003	4	0	3	7

Table III The time points and duration of included studies

Reference	Duration				
	T0	T1	T2	T3	T4
Fraundorf 2021	before the delivery/ bonding	immediately after delivery/bonding	2 months		
Melo 2021	before the delivery/ bonding	immediately after delivery/bonding	3 days	1 month	6months
Angelopoulos 2021	before the delivery/ bonding	1 day	3 months		
Albertini 2021	before bonding	immediately after bonding	1 hour		
Alajmi 2020	NR				
Pogal-Sussman-Gandia 2019	NR				
Ahmed 2019	before bonding	immediately after bonding	3 months	6 months	
Arreghini 2018	before the delivery	immediately after delivery	1 day		
Paley 2016	before bonding	1 week	4-5 weeks	8-20 weeks	
Haj-Younis 2016	before intervention	after extraction and before bonding	immediately after bonding	1 month	3 months
Rai 2014	before bonding	1 day	1 week	1 month	
Rai 2013	before bonding	1 day	1 week	1 month	
Khattab 2012	before bonding	1 week	1 month	3 months	
Wu 2011	1 week after bonding	1 month	3 months		
Wiechmann 2008	before bonding	1 day			
Stamm 2005	before bonding	1 day	3 months		
Caniklioglu 2005	1 month				
Nedwed 2005	3-6 months				
Hohoff 2004	before bonding	1 day	3 months		
Hohoff 2003	before bonding	10 minutes	1 day		
Hohoff 2003	before bonding	1 day	3 months		

NR: Not reported.

Table IV The phonemes affected by various orthodontic appliances.

Reference	Phonemes affected
Fraundorf 2021	OA: /s, z, zh, sh, th, ch/ LA: /s, th, f/
Melo 2021	OA: /ch/
Angelopoulos 2021	OA:/s, z/; LI: /s, z/
Albertini 2021	LI: /s, ts/
Pogal-Sussman-Gandia 2019	OA:/s, z/
Arreghini 2018	OA: /s, ts, / /
Paley 2016	LA: /s, t/
Haj-Younis 2016	LI: /s/
Rai 2014	LA:/s, l /; LI:/s, l, t, d/
Rai 2013	LA: /s, d, l / LI: /s, d, l /
Khattab 2012	LA: /s/ LI: /s/
Hohoff 2003	LI: /s/
Hohoff 2003	LI: /s/

LA: labial appliances; LI: lingual appliances; OA: orthodontic aligners;

Figures

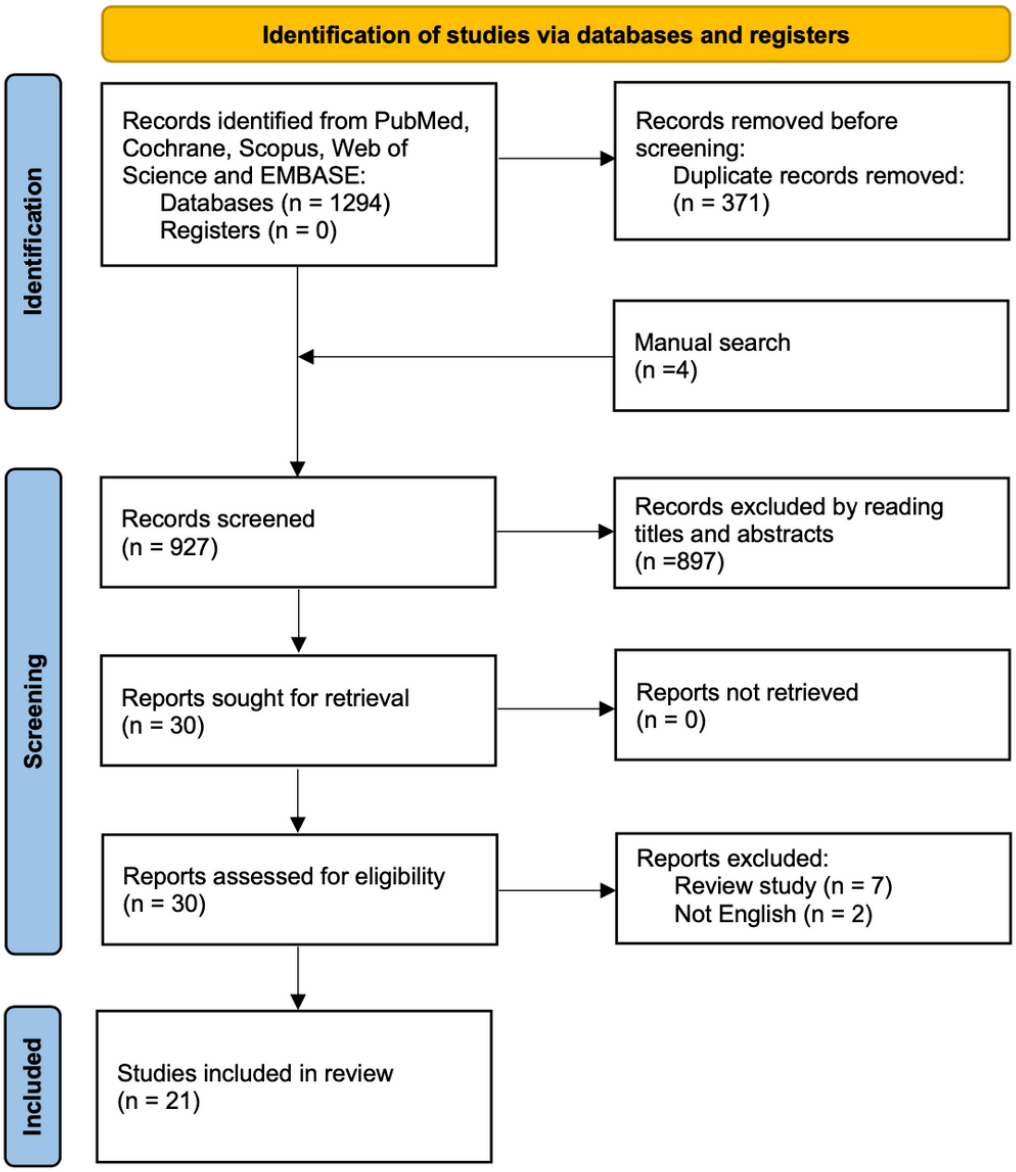

Figure 1

Flowchart of study inclusion of the systematic review performed according to the PRISMA guidelines

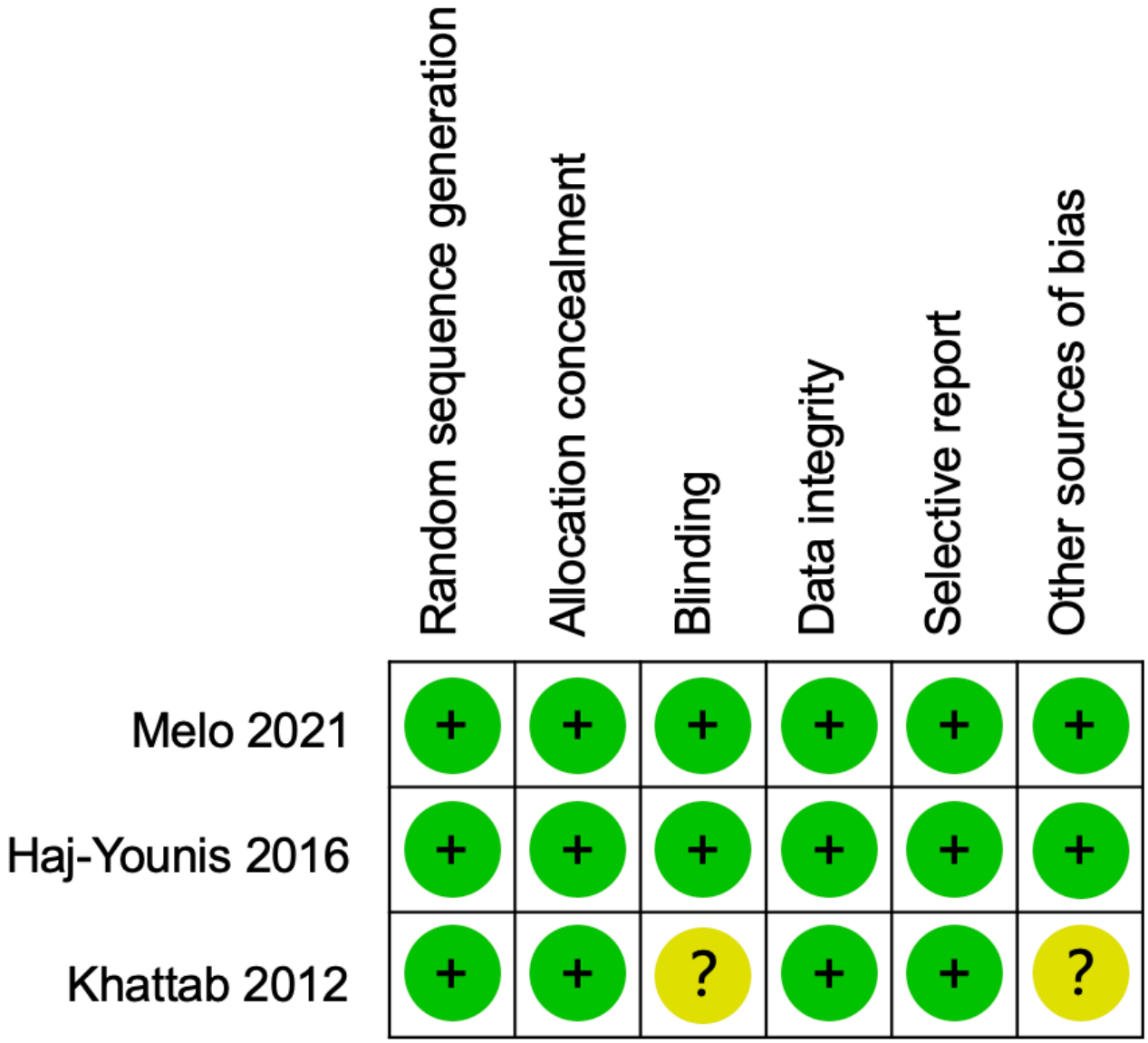

Figure 2

The Cochrane tool for assessing the risk of bias for RCTs. The low, high, or unclear risks of bias were marked as red, green, and yellow, respectively.