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REVIEW

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Updates in orthodontic treatment of temporomandibular joint disc displacement in adolescents: review of the literature

Ning Hu[1,2], Lu-xuan Cai[1,2], Yi-dan Zhang[1,2], Ning-rui Zhao[1,2], Yan-ning Guo[3,*], Xue-dong Wang[1,2,*]

[1]Department of Orthodontics, Peking University School and Hospital of Stomatology, 100081 Beijing, China
[2]National Clinical Research Center for Oral Diseases & National Engineering Laboratory for Digital and Material Technology of Stomatology, 100081 Beijing, China
[3]Dental Medical Center, China-Japan Friendship Hospital, 100029 Beijing, China

***Correspondence**
guoyanning@zryhyy.com.cn (Yan-ning Guo);
wangxuedong@bjmu.edu.cn (Xue-dong Wang)

Abstract

Temporomandibular joint disc displacement represents the most prevalent form of temporomandibular disorders. This condition often manifests with symptoms such as joint clicking, joint pain, restricted mandibular mobility, and abnormal mouth opening. A significant bilateral correlation exists between disc displacement and dentofacial deformity in adolescents, prompting the gradual integration of orthodontic approaches into clinical disc displacement management. The combination of orthodontic appliances and conventional joint treatment methods can actively contribute to pain mitigation, functional restoration, enhancement of disc-condyle relationships, and the sustained efficacy of treatment. This article explores the relationship between temporomandibular joint disc displacement and orthodontics, delves into the current state of the field, examines the advantages and disadvantages, and sheds light on the future prospects of orthodontic interventions in disc displacement therapy.

Keywords

Temporomandibular joint; Disc displacement; Malocclusion; Dentofacial deformity; Orthodontics; Functional jaw orthopedics; Therapeutics

1. Background

Disk/disc displacement (DD) is a prevalent clinical condition in the oral and maxillofacial domain and represents the most common subtype of temporomandibular disorders (TMD). DD signifies an abnormal alteration in the structural interplay of the disc-condyle complex, typically characterized by anterior disc displacement, which can lead to various stages of clinical dysfunction [1]. Among the spectrum of TMD conditions, DD holds the highest prevalence among adults/elders (ranging from 19.1% to 31.1%) and in children/adolescents (8.3% to 11.3%) [2], with a notably elevated risk among women compared to men [3]. In the younger population, the incidence of DD rises with age, peaking during adolescence (13–18 years old) [4]. Analyses of patient visits reveal a male-female ratio of approximately 1:5.52 among DD patients, with the peak age of visits occurring at 15–16 years old [5]. It is evident that DD exhibits characteristics of high incidence, early onset, and a higher predisposition in females. Although DD is characterized by self-limiting, the joint pain and limited mouth opening can impact patients' quality of life and psychological well-being in some cases, and may progress to degenerative joint disease, which impedes maxillofacial development in adolescents [6, 7]. Manfredini [8] reported that in younger patients (<25 years old) with TMD, the diagnosis of DD was 83.0%, while the diagnosis of arthralgia/osteoarthritis/osteoarthrosis was 63.8%, which indicates that many DD patients are often comorbid with other degenerative joint diseases. Consequently, the clinical management and symptom alleviation of DD for youngers hold paramount importance.

DD can be categorized into distinct subtypes based on the specific disease progression; these include disc displacement with reduction (DDwR), disc displacement with reduction with intermittent locking (DDwR with intermittent locking), disc displacement without reduction with limited opening (DDwoR with limited opening), and disc displacement without reduction without limited opening (DDwoR without limited opening) [9]. Currently, the diagnosis of DD heavily relies on magnetic resonance imaging (MRI) (Fig. 1). In a typical scenario, the temporomandibular joint (TMJ) disc exhibits a doubly concave shape, whereas an anteriorly displaced disc is associated with varying degrees of deformation. During mouth opening, the DDwR disc can relocate between the condyle and the articular tubercle, while the DDwoR disc remains anterior [10].

Commonly employed treatments for DD include physical therapy, splint therapy, joint puncture, and joint surgery, among others. Irrespective of the chosen treatment modality, the primary objective remains consistent: alleviating clinical symptoms, managing bone deterioration, and preventing further progression. Despite ongoing debates concerning the relationship between TMJ and dental occlusion [11], functional orthodontic approaches have been introduced into the DD treatment landscape and have demonstrated promising

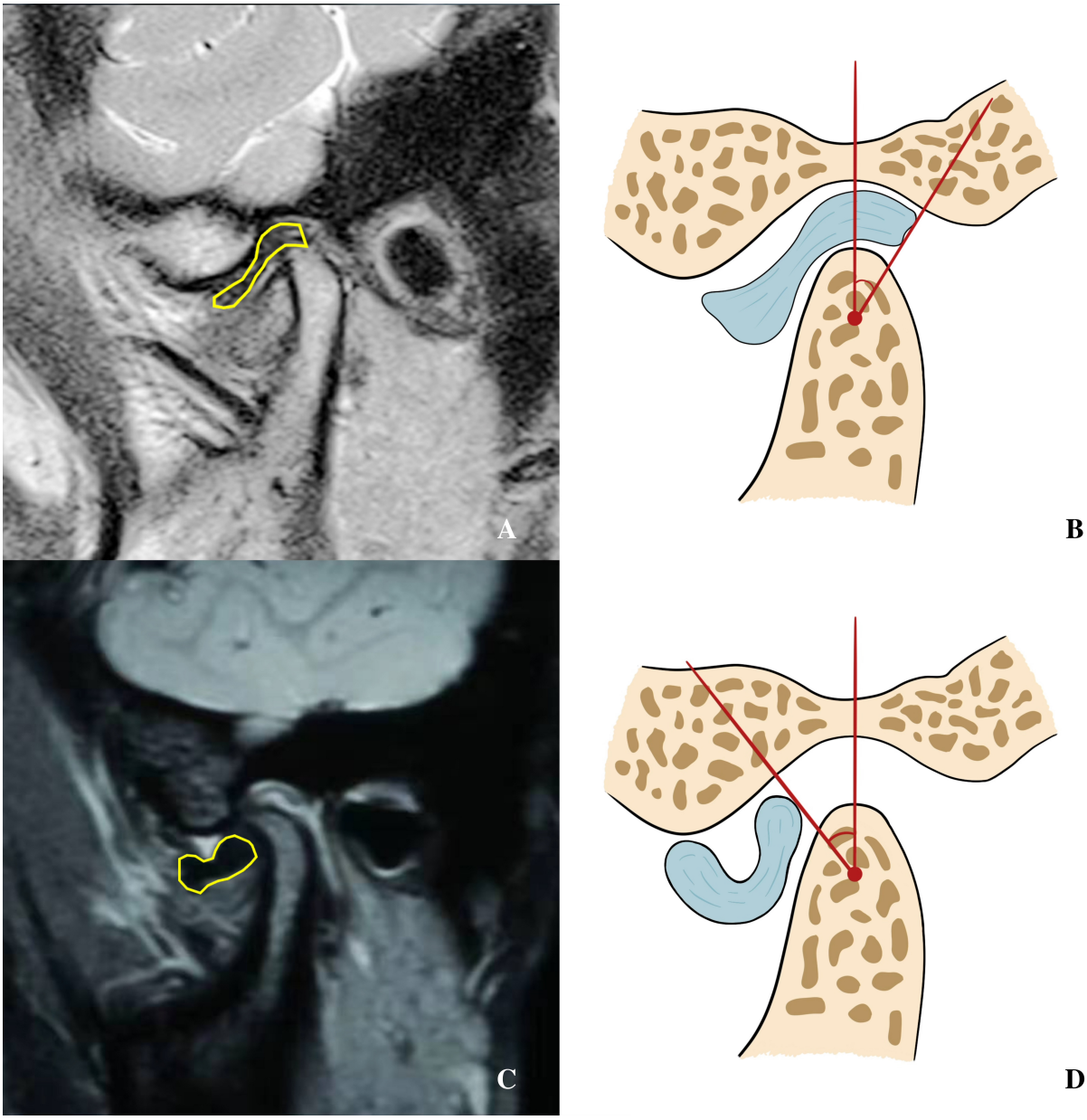

FIGURE 1. The angle diagnostic method of DD. The Chinese Stomatological Association provided guidelines in 2020 which are as follows: when the mouth is closed, the top of the condyle and the center of the condyle is used as line 1; the posterior edge of the posterior band and the center of the condyle is used as the line 2. When the angle between these two lines is larger than 15°, DD can be defined. (A,B) MRI of healthy joints. (C,D) MRI of DD joints.

outcomes. For orthodontists, it is imperative to accurately assess the patient's condition, establish a precise diagnosis, select the appropriate timing and methods, and address the occlusal aspects for patients with joint-related ailments. This paper aims to highlight the rising utilization of orthodontic techniques in the treatment of DD.

2. The association between DD and dentofacial deformity

2.1 Characteristics of dentofacial deformity in DD adolescents

The connection between DD and malocclusion has long been a topic of debate. While it is generally acknowledged that no direct causal link exists between them, numerous studies have highlighted correlations between DD and specific dental and maxillofacial abnormalities.

Among DD adolescents, the most prevalent dentofacial deformity encompass mandibular retrusion and mandibular asymmetry. Mandibular retrusion and clockwise rotation is a consequence of TMJ disc displacement, even if no TMJ symptoms are observed [12]. Moreover, osteoarthrosis secondary to DD can ulteriorly lead to inhibited condylar growth, condylar absorption, and a decrease in mandibular ramal height during the growth and development phase [13]. These changes can manifest as unilateral or bilateral mandibular retrusion and may even result in an open bite [12]. These patients often exhibit a skeletal class II facial morphology with a high angle type (Fig. 2). As DD progresses from DDwR to DDwoR, mandibular retrusion intensifies.

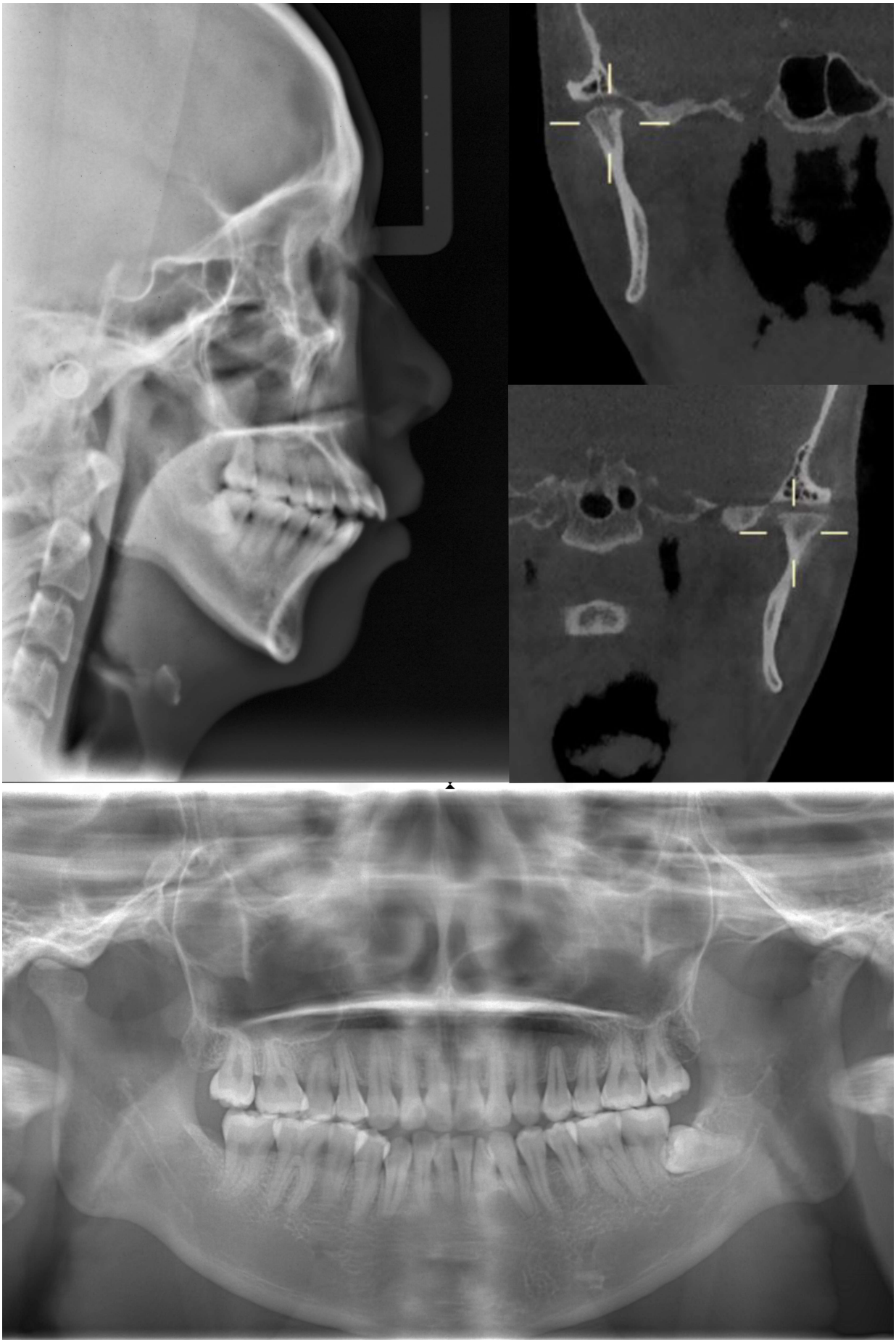

FIGURE 2. A 23-year-old woman who suffered from DD during adolescence demonstrated a skeletal Class II malocclusion with an anterior open bite.

Condyle height diminishes, mandibular clockwise rotation augments, and the class II high angle facial phenotype becomes more prominent [14]. Adolescent DD patients, who often experience estrogen disturbances, may exhibit severe condylar absorption, further exacerbating malocclusion [15]. Additionally, unilateral DD patients are more prone to mandibular asymmetry than those with bilateral DD [16]. A follow-up study of adolescents with unilateral DD revealed that the affected side's condyle underwent absorption while the unaffected side's condyle continued to grow, resulting in a mean difference in condyle height between the two sides of up to 1.68 mm. This accompanying facial and mandibular asymmetry substantially impacted joint health, occlusal stability, and facial aesthetics [17]. Early medical intervention for such adolescent patients may restore normal mandibular growth and development, potentially preventing or even reversing dentofacial deformity and reducing the need for future orthognathic surgery.

Imaging studies have uncovered that TMD are linked to morphological changes in the jaw. Common characteristics of bone morphology in DD patients include reduced posterior facial height, shortened mandibular ramal and mandibular body length, and a clockwise rotation of the mandible [12]. Notably, these changes are typically associated with TMJ malformation secondary to DD, even in the absence of joint symptoms. Some patients with shortened jaws and mandibular clockwise rotation may exhibit DD, despite a lack of joint symptoms.

2.2 Dentofacial deformity may affect DD occurrence

2.2.1 The potential effect of dentofacial deformity on DD

The prevalence of DD varies significantly among patients with different classifications of dentofacial deformity (**Supplementary Table 1**). A study involving 121 female patients with malocclusion revealed that the incidence of DDwoR in TMJs was 56.1% in skeletal class II patients and 19.3% in skeletal class III patients [18]. In another study involving 105 skeletal class III adolescent subjects, DD was not observed in Angle class I individuals but was present in 30.3% of class III patients and 12.2% of class III subclass patients [19]. The disc-condyle relationship plays a pivotal role in this variation. Class I patients tend to exhibit normal disc-condyle relationships, while class II and class III patients often display anterior movement of the disc, particularly in class II patients. This discrepancy may be attributed to differences in condyle morphology, condyle position, and articular tubercle morphology across various skeletal deformity types. Class II and class III patients often exhibit elongated posterior disc attachments, anterior disc positions, and posterior condyle positions. However, in the treatment of class II patients, the anterior movement of the mandible aids in the recapture of the TMJ disc by the condyle, resulting in a more favorable prognosis compared to class III patients [20].

Past studies have previously highlighted a close association between specific malocclusion patterns and signs and symptoms of TMD, including deep overjet, deep overbite, open bite, unilateral crossbite, mesial and distal molar relationships, among others. These were once considered predisposing factors for TMD [21]. While there is insufficient evidence to establish a causal link between occlusal dysfunction and TMD [22], it has been established that the prevalence of DD is significantly correlated with specific maxillofacial deformities, such as skeletal open bite and mandibular asymmetry. Research indicates that as the front/back facial height ratio increases, signifying hyperdivergent deformities, the severity of DD also escalates [23]. Patients with skeletal anterior open bite exhibit a much higher prevalence of DD compared to the general population, and in these cases, the occurrence of DD in unilateral or bilateral joints is strongly associated with facial asymmetry [24].

However, as these conclusions are predominantly drawn from cross-sectional studies, establishing a causal relationship between DD and dentofacial deformity remains elusive. At best, we can speculate that patients with malocclusion, particularly skeletal malocclusion, may face an elevated risk of DD compared to individuals with normal occlusion. Further prospective studies are essential to refine these conclusions.

2.2.2 The effect of orthodontics on DD

A recent systematic review and meta-analysis has shed light on the relationship between orthodontic treatment and TMD. The incidence of TMD among patients undergoing orthodontic treatment is approximately 1.84 times higher than that observed in individuals without orthodontic intervention. However, consensus remains elusive regarding whether this increase in TMD incidence is directly caused by orthodontic treatment or related to other factors, including occlusal, environmental, psychological, and social influences during the treatment process [25]. This difference may be explained that DD patients are more inclined to seek orthodontic treatment due to the dentofacial deformity caused by arthropathy. Likewise, it remains inconclusive whether the correction of malocclusion represents a risk factor for DD. Patients with malocclusion may experience slight TMJ disc displacement during the orthodontic process, most of which can be resolved upon treatment completion [26]. Some researchers believe that certain orthodontic treatments can exacerbate TMD. For example, in the management of skeletal class II patients during their growth stage, the use of upper headgear to restrain maxillary bone growth may inadvertently lead to mandibular overgrowth and dorsocranial TMJ compression. While the molar relationship is ultimately corrected to class I, serious temporomandibular joint issues may arise [27]. However, current studies exhibit high heterogeneity, and no definitive evidence exists to support the notion that orthodontic devices can induce DD [28].

DD patients often initially seek care at the temporomandibular joint department for preauricular pain and restricted mouth opening. However, given the interplay between DD and malocclusion, certain patients, particularly adolescents, may first consult the orthodontic department for malocclusion [5], even in the absence of overt joint-related symptoms. This does not preclude the presence of underlying TMJ joint structural issues [29]. Therefore, orthodontists should be attentive to the TMJ joint history and conduct a thorough TMJ evaluation when attending to patients with malocclusion, ensuring accurate

diagnosis and a rational treatment plan.

3. Orthodontic-related DD treatment methods and efficacy evaluation

Currently, the main goal of DD treatment is to alleviate clinical symptoms. However, disc displacement during pubertal growth, especially DDwoR, exhibits a decrease in condylar height and causes a severe disturbance in mandibular development [6, 7]. Lei [30] and Shen [31] have found that in adolescents, the ideal spatial disc-condyle relationship can facilitate condylar regeneration and delay TMJ degeneration secondary to DD. Many orthodontic therapies can improve mandibular position and disc-condyle relationships, which helps to regulate skeletal muscle function and alleviate clinical symptoms, as elaborated below.

3.1 Orthodontic therapies used alone to treat DD

As of July 2023, we conducted searches in the PubMed/Medline and China National Knowledge Infrastructure (CNKI) databases using the following search formula: ((disc displacement) or (disk displacement)) and ((orthodontics) or (orthodontic treatment) or (orthodontic appliance)). Following literature screening (Fig. 3), we identified eight relevant studies on the use of orthodontics for treating DD. Some of these studies focused on TMJ changes following orthodontic treatment (Table 1) [32–36], while others compared the effects of orthodontic appliances and splints (Table 2) [32, 37–39].

3.1.1 Functional appliance

Functional appliances employed in DD treatment include devices designed to guide the mandible forward, such as the Herbst appliance, Twin-block appliance, and Activator. These appliances serve a dual purpose: they promote mandibular development through orthopedic forces and restore the TMJ disc to its normal position, thereby improving both facial aesthetics and the disc-condyle relationship. For example, the Herbst appliance, anchored by premolars and the first molar, maintains the mandible in a forward position using a bilateral telescopic mechanism [38]. Functional therapy supports adaptive remodeling of the temporomandibular joint [40]. The mechanism behind functional appliances involves the rotation and sliding of the condyle, resulting in the repositioning of the anteriorly displaced disc and maintaining it in the correct location through mandibular protraction. Simultaneously, the joint space, particularly the posterior and upper joint spaces, expands, thereby reducing internal TMJ stress and promoting the reconstruction of both anterior and posterior joint attachments and ligaments. Consequently, the treatment effectively addresses internal TMJ derangements [33, 38] (Fig. 4).

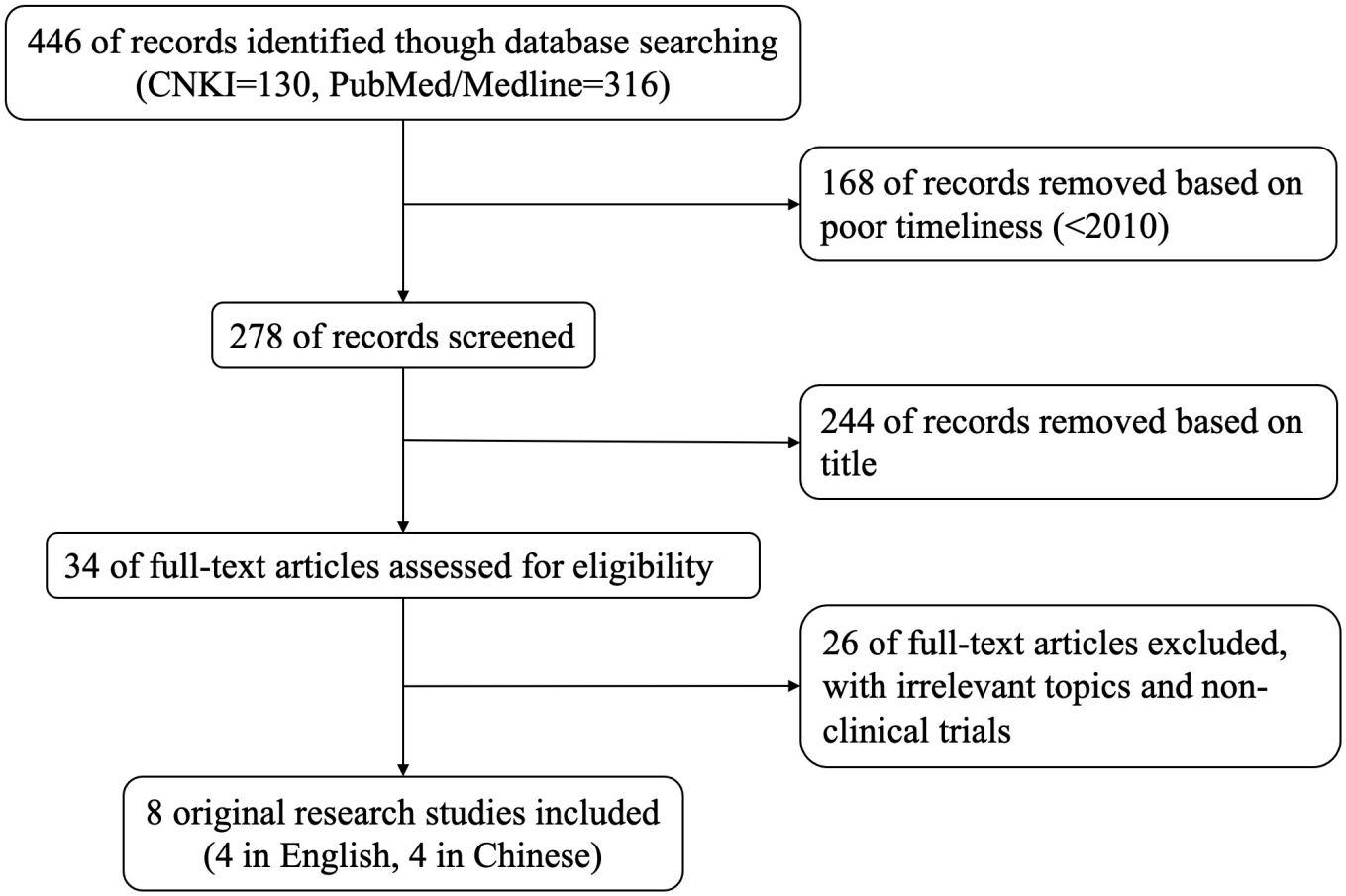

FIGURE 3. Literature screening process. CNKI: China National Knowledge Infrastructure.

TABLE 1. Cases of different orthodontic appliances used in DD treatment.

Author	Diagnosis	Age (YO)	Appliance	Sample size	Wearing duration	Curative effect	Evidence grade*
Ma Zhigui (2013)	Unilateral DDwR with mandibular asymmetry; bilateral DDwR with mandibular retrusion	12–18	Twin-block	12	8 (6–13) m; 24 h daily	The success rate of disc reduction and condylar reconstruction was 87.5%.	2b
			Herbst	12		The success rate of disc reduction and condylar reconstruction was 94.44%.	
Hu Xinxin (2017)	DDwR	20–40	Modified Twin-block	26	8 w (24 h 6 w + night 2 w)	All the discs were observed reduction by MRI without recurrence during 2 months of follow-up.	2b
Yu Xin (2017)	DD with class II malocclusion	11–16	Herbst	12	—	The joint space changed significantly in DD patients after Herbst treatment.	2b
Chen Keming (2017)	DD with class II malocclusion	19–25	Forsus	21	6–10 m	Joint symptoms and joint space improved in all patients after Forsus treatment.	2b
Alsulaimani (2022)	Unilateral DDwoR during orthodontic process	24	Fixed orthodontic appliance	1	5 m	The patient got TMJ disc reduction and returned to normal occlusion.	3b

**The evidence grade is based on the standards of the Oxford Centre for Evidence-Based Medicine (updated in March 2009).*
YO, years old; m, months; w, weeks, h, hours; DDwR, disc displacement with reduction; DDwoR, disc displacement without reduction; TMJ, temporomandibular joint; MRI, magnetic resonance imaging.

TABLE 2. Comparison of the effect of orthodontic appliances and splints.

Author	Diagnosis	Age (YO)	Appliance	Sample size	Wearing duration	Curative effect	Evidence grade*
Rohida (2010)	DD	12–20	Twin-block	10	—	Twin-block is more effective at relieving joint pain, reducing dysfunction and joint clicking.	1b
			SS	10	—		
Ma Zhigui (2013)	Unilateral DDwR with mandibular asymmetry; bilateral DDwR with mandibular retrusion	12–18	Twin-block	12	8 (6–13) m; 24 h daily	The success rate of disc reduction and condylar reconstruction in Twin-block and Herbst group was higher than ARS group.	2b
			Herbst	12			
			ARS	33			
Ma Zhigui (2014)	Unilateral DDwR	12–18	Twin-block	42	7–10 m; 24 h daily	All the joint clicking and pain disappeared, the posterior joint upper space increased, the anterior space decreased.	2b
			Herbst				
			ARS				
Tecco (2010)	DDwR	14–63	Fixed orthodontic appliance	20	6 m	Compared with ARS, fixed orthotics have a similar effect on pain relief, but are less effective on joint clicking.	1b
			ARS	20	6 m; 24 h daily		

**The evidence grade is based on the standards of the Oxford Centre for Evidence-Based Medicine (updated in March 2009).*
Abbreviation: YO, years old; m, months; w, weeks, h, hours; DDwR, disc displacement with reduction; SS, stabilization splint; ARS, anterior repositioning splint.

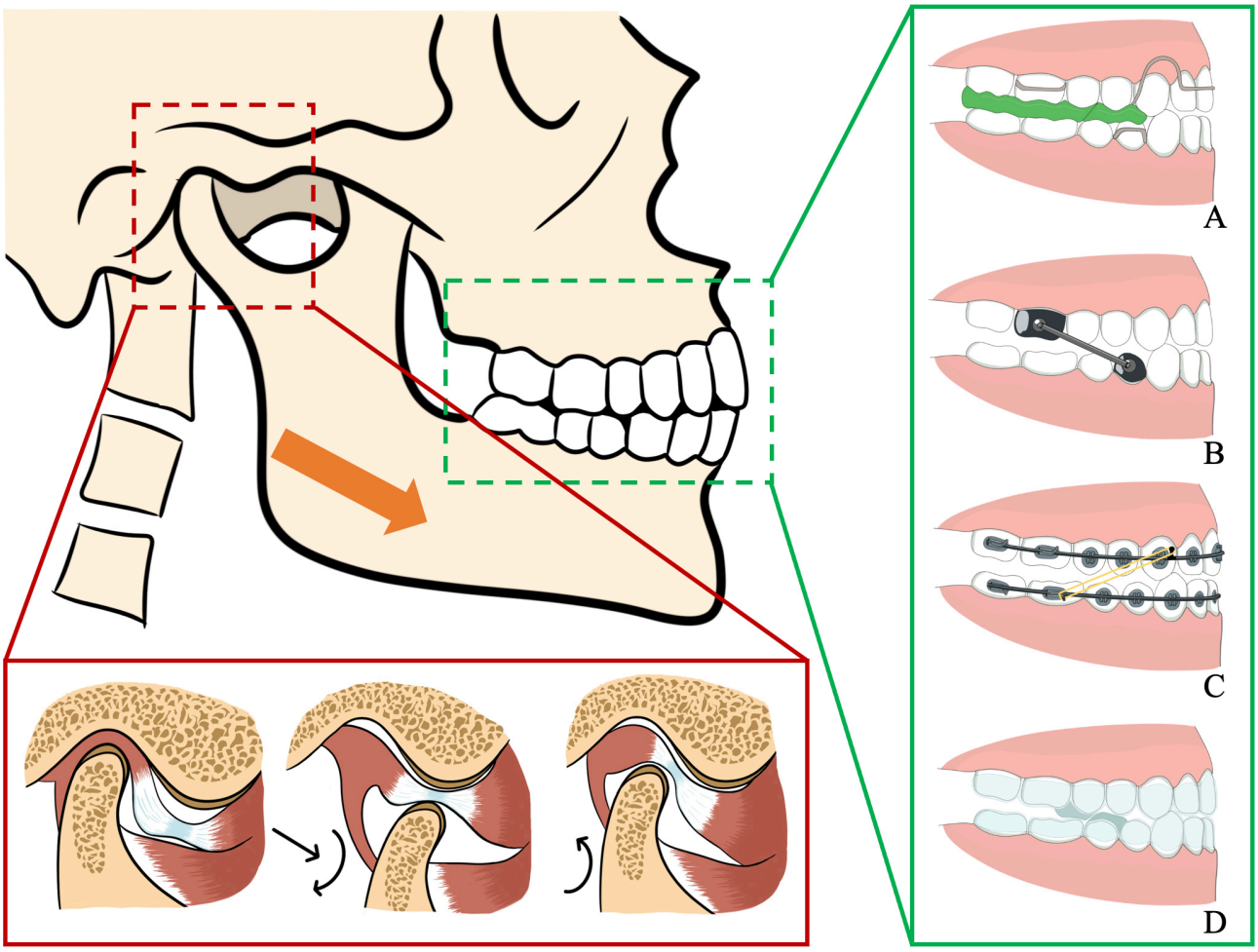

FIGURE 4. The principle of Orthodontic therapies on DD. Orthodontic methods can lead to mandibular advancement, thus causing the rotation and sliding of the condyle to catch the TMJ disc. (A) Twin-block maintains the mandible position by splints on the premolars and molars. (B) Herbst using a rigid tube that rests between the upper and lower teeth. (C) Fixed appliance promotes mandibular advancement by elastic traction and removing resistance to mandibular movement through dentition alignment. (D) Clear aligner can also work with splints.

Functional appliances are predominantly applied during adolescence, coinciding with the growth and development period. Studies by Rohida *et al.* [37] and Ma *et al.* [32] focused on adolescent DD patients and confirmed that functional appliances like Twin-block and Herbst effectively alleviate joint pain, joint clicking, and movement disorders. As reported by Trenouth [41] and Akan [42], functional appliances also improve joint space and promote condylar remodeling. It's interesting that, according to Hu Xinxin *et al.* [33], functional appliances may also yield positive results for adult DD patients, primarily because the alteration in condylar position contributes to the restoration of the TMJ disc, with little impact on condylar remodeling. However, we believe that functional appliances can be of greater significance in adolescent patients based on its special help for growth and development.

Functional appliances offer the advantage of treating both dentofacial deformity and DD simultaneously. Nevertheless, current research on their use for DD treatment is limited, with the subjects primarily consisting of class II patients. These studies are often characterized by small sample sizes, making it challenging to fully validate clinical efficacy and assess long-term outcomes. Moreover, their indications are relatively stringent: Patients must (1) have growth potential, (2) exhibit a short disease duration, and (3) be diagnosed with early DDwR, with disc reduction confirmed through MRI [32]. In other words, functional appliances may be effective primarily for milder cases of DDwR and are not suitable for DDwoR patients. Despite several successful cases, it has been suggested that employing functional appliances for DD treatment may carry a high risk of recurrence, exacerbate disc displacement, and potentially lead to condylar resorption [43].

In summary, while functional appliances may not represent the optimal treatment approach at present, they hold promise for adolescents requiring dentofacial deformity correction. However, their application requires further exploration and research.

3.1.2 Fixed orthodontic appliance

Fixed appliances can also facilitate mandibular protrusion through intermaxillary traction. In a prior study, Tecco *et al.* [39] treated DDwR patients with the Damon system self-ligating fixed appliance and anterior repositioning splint (ARS) and suggested that for DD treatment primarily aimed

at pain relief, fixed appliances could replace splints to achieve mandibular protrusion and therapeutic goals. However, for reducing joint clicking, they could only serve as a follow-up stabilization treatment after splint therapy. It is based on the theory that the use of fixed self-ligating appliance with low friction can rapidly expand the dental arch and allow the spontaneous advancement of the mandibular in a comfortable manner (Fig. 4). While this study proposed the potential application of fixed appliances in DD treatment, several limitations should be noted: (1) The changes in TMJ disc status before and after treatment were not assessed through imaging; (2) No long-term follow-up was conducted to evaluate sustained efficacy; (3) The study featured a small sample size of patients with mild conditions, limiting its broader clinical applicability.

More recently, Alsulaimani *et al*. [36] reported a case involving a skeletal class I patient who presented with unilateral DDwoR during fixed orthodontic procedures. Class II traction was applied on the affected side, using the lower first molar as a fulcrum and elastic rubber bands as the applied force to advance the condyle forward and downward, subsequently recapturing the TMJ disc. After 2 months for disc recapturing, 3 months for ensuring a stable disc-condyle relationship, and an additional 3 months for joint stability assurance, this case achieved disc reduction, functional recovery, and successfully completed malocclusion correction. The subsequent procedures in this study were all based on the successful capture of the TMJ disc, indicating the potential for greater stability and suggesting a promising application for DDwoR patients with malocclusion. However, it's important to note that this study's credibility is limited due to its status as a case report.

Based on current clinical studies, fixed orthodontic appliances may have a certain therapeutic impact on disc displacement. Although there are no definitive studies on adolescent patients, its non-removable features appear to be helpful in improving treatment compliance. However, the current research on DD treatment with fixed appliances exhibits significant methodological heterogeneity, making it challenging to conduct a systematic assessment to elucidate its indications and efficacy. The current findings are likely to be largely incidental. The use of fixed orthodontics in DD treatment remains a subject of uncertainty and may face challenges in achieving widespread adoption due to its uncertain efficacy and indications.

3.1.3 Clear aligners

The relationship between clear aligners and DD remains uncertain. Some opinions suggest that, following the principle that mandibular advancement can stimulate condylar remodeling, clear aligners designed to facilitate mandibular advancement may also encourage adaptive condylar growth and reconstruction. Clear aligners with a certain thickness can create an open bite and restore the physiological condylar position, potentially serving as a splint [44] (Fig. 4). Past reports have mentioned the use of clear aligners in combination with splints for TMD treatment, hinting at the potential for clear aligners in TMJ diseases [45]. In summary, the applicability of applicability of clear aligners in DD treatment remains unclear, with very limited relevant studies and a lack of robust evidence.

3.2 Orthodontic support for other DD therapies

Orthodontics may be considered as a complementary treatment to other DD therapies. On the one hand, functional orthodontics can help to further stabilize the mandibular position, which is particularly important as it takes time to remodel and stabilize the joint. On the other hand, although there is no definitive link between occlusion and DD, it has been proposed that individuals with TMD and those without may have varying sensitivities to occlusal factors [46]. It is plausible that a healthy occlusion may provide an advantage in joint stabilization for patients with TMD. We searched for evidence to suggest a role for orthodontics in this regard.

3.2.1 Splint treatment and orthodontic combination

Splint therapy for DD primarily encompasses ARS [47], stabilization splints [48] (SS), and soft occlusal splints [49] (SOS). Splint treatment significantly ameliorates joint pain, restricted mouth opening, and joint clicking, effectively enhancing the clinical symptoms and quality of life for DD patients across various degrees of disc displacement [50–53]. Among the different types of splints, ARS has emerged as the most suitable option for DD due to its capacity to enhance the disc-condyle relationship by anteriorly repositioning the condyle to recapture the TMJ disc and restore disc positioning [47]. However, long-term efficacy and stability of ARS treatment require improvement. A study implementing ARS for TMJ disc reduction in DDwR patients revealed that the immediate post-treatment results were satisfactory, with an 84.3% success rate in disc reduction, but only 53% of patients maintained a normal disc-condyle relationship two years later, indicating a notable decline in long-term effectiveness [54]. Similarly, Ma [50] and Chen [55] reported substantial decreases in the success rate of ARS after several months of follow-up. This suggests the need for additional measures to stabilize the outcomes of DD treatment with splints.

Enhancing TMJ joint stability following splint treatment is crucial to reduce the recurrence rate of DD. Occlusal factors in DD patients may lead to an unstable mandibular position, which can result in recurrence or exacerbation of disc displacement, and the interlocking relationship of the cuspal fossa of the teeth may stabilize the mandible. Therefore, combining orthodontic treatment with splint therapy can improve the occlusal relationship, achieving stability in both occlusion and jaw position. This approach may enhance the long-term efficacy of splint therapy and reduce recurrence. Tanaka [56] and Kurt [57] respectively published a case report, using splints to correct the condyle's position followed by orthodontic occlusal reconstruction. After treatment, clinical symptoms significantly improved, and facial deformity was mitigated. Bálint [58] introduced orthodontic intervention to 18 patients who had undergone splint treatment, including those with DDwR and DDwoR, and confirmed that orthodontics contributes to TMJ stabilization after splint treatment due to centric relation and maximum intercuspation harmony. The goal of orthodontic treatment is to establish biomechanical equilibrium among TMJ components and attain a stable occlusion to prevent joint

disease recurrence. Unfortunately, these studies were conducted in adult patients, and we still don't know if they are still effective in adolescents.

3.2.2 Disc reduction surgery and orthodontic treatment

Disc reduction surgery encompasses arthroscopic disc repositioning and disc anchorage *via* an open incision. The principle behind this procedure is to release and restore the disc to its normal anatomical position, securing it with sutures [59]. However, performing surgery in isolation may lead to changes in the occlusal relationship, increased intra-articular pressure, and instability in the disc-condyle relationship. Research has shown that patients undergoing disc anchorage surgery alone, particularly adolescents in the rapid growth stage, may experience postoperative recurrence due to the joint's growth potential, resulting in a significant increase in condylar height and an increased recurrence rate (14.8%) [60]. Combining orthodontic treatment, particularly functional orthodontics before and after surgery, can help stabilize the surgical results, improve the occlusal relationship, and facilitate the healing and reconstruction of the surgical area.

Traditionally, splints have been employed as supplementary therapy both before and after joint surgery, significantly improving patients' mouth opening, joint pain, and quality of life [59]. Certain orthodontic devices can achieve similar effects. In a study conducted by Liu *et al*. [61], 117 DDwoR patients underwent disc repositioning surgery with or without postoperative functional orthodontics, including ARS, twin-block appliances, and Herbst appliances. The results indicated that postoperative functional orthodontics could alleviate intraarticular pressure and expedite condyle remodeling. The use of functional appliances post-surgery can also address existing dentofacial deformity in patients. Zhu *et al*. [43] examined 26 adolescent patients with unilateral DDwoR complicated by mandibular asymmetry, dividing them into two treatment groups: surgical reduction alone and surgical reduction with postoperative functional orthodontics. Their findings demonstrated that wearing functional appliances could maintain the joint space created by surgery, promote condylar growth, and correct mandibular asymmetry. Furthermore, the occurrence of postoperative malocclusion after TMJ disc repositioning is exceptionally high, with 100% of patients experiencing malocclusion immediately after surgery, of which 28% required orthodontic intervention [62]. Perez [63] reported that 54% of patients developed an open bite after disc repositioning surgery. This group included class I and III patients, partly due to the downward movement of the condyle caused by the TMJ disc reduction and partly due to postoperative joint effusion. As a result, orthodontic treatment may be necessary to establish proper occlusion after the new condyle bone has stabilized. Orthodontic appliances can also be combined with arthroscopic surgery. In Gao *et al*.'s [64] study, 37 DDWoR patients who underwent arthroscopic disc repositioning surgery received functional orthodontic treatment post-operation. In cases of open bite, patients were treated with Twin-block or Herbst appliances, while ARS was applied when open bite was not present. This comprehensive approach led to improved clinical symptoms, condylar height, joint space, and facial aesthetics in all patients.

The significance of orthodontic intervention in DD surgical treatment lies in its ability to correct postoperative open bite resulting from the sudden change in disc-condyle position, re-establish joint relationships, promote condylar remodeling, maintain joint space and disc position, and enhance the stability of treatment outcomes [61, 65]. Although orthodontics is not yet widely applied in preoperative treatment, splint-based preoperative functional therapy has demonstrated its potential to create optimal joint space, establish an ideal maxillary-mandibular relationship, and provide space for TMJ disc reduction [59]. Thus, further research on the application of orthodontics in this context holds significance.

3.2.3 Orthodontic-orthognathic combined treatment

As previously discussed, DD and dentofacial deformity often exhibit a close relationship. In cases where significant skeletal deformities are present, orthognathic surgery is sometimes considered to enhance facial aesthetics and restore joint function. Currently, there remain differing opinions about the impact of orthognathic surgery on the temporomandibular joint. Some experts believe that orthognathic surgery can alleviate joint symptoms, while others contend that it may exacerbate TMJ issues [66, 67]. Sharma [68] employed a combination of orthodontic and orthognathic therapies to treat class II patients. The study found that in patients with DDwR, the TMJ disc could be repositioned and undergo bone remodeling following mandibular advancement. However, this approach was less effective for patients with DDwoR. From an evidence-based perspective, a meta-analysis revealed that many orthognathic patients with TMD experienced reduced TMD symptoms after orthognathic surgery. However, a small number of asymptomatic patients developed new joint symptoms post-surgery [69]. Nevertheless, studies with a higher level of evidence focusing on changes in TMJ disc position before and after orthognathic surgery are currently lacking.

We postulate that orthognathic surgery might positively influence the repositioning of the TMJ disc in patients requiring mandibular anterior advancement. However, achieving this effect in skeletal class III patients could be mould be more challenging. Another important consideration for orthodontists is that DD can also be a destabilizing factor in orthognathic surgery [70]. Therefore, careful attention must be paid to this factor when formulating orthodontic-orthognathic treatment plans for patients.

4. Summary and prospect of orthodontic DD treatment

Treatment of DD is particularly significant in adolescent patients, and it has been shown that early medical intervention to reset the TMJ disc can greatly improve condylar remodeling and prevent further exacerbation of the facial deformity [13]. In 2010, the American Association for Dental Research (AADR) introduced a treatment sequence for TMD that emphasizes a gradual progression from conservative to surgical interventions, with an initial focus on conservative, reversible, and evidence-based treatments [71]. Orthodontic

therapy offers a versatile approach to addressing patients with disc displacement at various stages of TMD. It can be effectively combined with conservative treatments like splints to alleviate clinical symptoms and enhance treatment outcomes, as well as stability. For DDwoR patients who do not respond to conservative treatments, preoperative and postoperative orthodontics can pave the way for surgical interventions and reduce the risk of postoperative recurrence.

Furthermore, as a standalone treatment, functional orthodontic therapy has yielded positive results for mild DDwR patients in recent years. When compared to other therapeutic approaches, the advantages of orthodontic therapy in the treatment of DD can be summarized as follows: (1) Orthodontic appliances are convenient to wear and non-invasive; (2) They can address dentofacial deformity, particularly in adolescents during growth and development. However, it's important to note the following disadvantages: (1) Patient compliance is crucial when using removable appliances; (2) Treatment cycles and daily wear times are longer; (3) The long-term stability of treatment outcomes requires further verification. Regarding DDwoR, the effectiveness of orthodontic therapy may be more limited than that of DDwR, but there is a lack of systematic studies to compare the differences. Although there is no strong evidence that the disc-condyle relationship returns to normal after orthodontic treatment, especially for DDwoR, the role of orthodontics for clinical symptomatic improvement and pain relief has shown potential.

Orthodontic treatment also plays a pivotal role following joint treatments. On one hand, joint effusion and TMJ disc adjustments often necessitate occlusal reconstruction after joint treatment [72, 73]. On the other hand, many patients have pre-existing malocclusion issues prior to joint treatment. For instance, dentofacial deformity among adolescent patients caused by DD may require orthodontic or orthognathic interventions. Orthodontic treatment aims to establish the most stable occlusal position where the condyle is optimally positioned within the articular fossa, allowing for maximum intercuspal contact at the closed mouth position. This approach helps eliminate adverse occlusal relationships that can impact joint stability and the disc-condyle relationship positively [74].

While the clinical effectiveness of orthodontic methods used in isolation or in combination with other therapies has been established, limitations persist. Standalone orthodontic appliances have stricter indications and may be challenging to use for patients with more severe conditions, often requiring them to complement other therapies. Different orthodontic devices maybe needed at various stages based on a patient's condition and treatment requirements. Additionally, the effect of orthodontics on TMJ disc reduction is not consistently stable, and recurrence rates are relatively high. There are devices available that add components that contribute to DD treatment to orthodontic devices that are known to be efficaciously stable, for example, the design of splints in clear aligners and mandibular anterior fixation devices in fixed appliances, based on the scarcity of research. The development of an orthodontic device that can be broadly applied in clinical practice, capable of both alleviating DD and preventing its recurrence, remains an area for further exploration.

5. Conclusion

DD is a relatively prevalent temporomandibular joint disorders, characterized by a high incidence, early onset, complex treatment, and the potential for recurrence. Given the bidirectional relationship between DD and dentofacial deformity, along with the beneficial impact of orthodontic interventions, functional orthodontics has emerged as an integral component of DD treatment in adolescents, while other means of orthodontics, such as fixed appliances and clear aligners, are still under exploration. A well-designed orthodontic treatment plan can facilitate TMJ disc reduction, alleviate clinical symptoms, and enhance the effectiveness, efficiency, and stability of other therapeutic modalities. This underscores a promising outlook for the continued development of orthodontic approaches in DD management.

ABBREVIATIONS

DD, disk/disc displacement; TMD, temporomandibular disorders; DDwR, disc displacement with reduction; DDwoR, disc displacement without reduction; TMJ, temporomandibular joint; ARS, anterior repositioning splint; SS, stabilization splints; SOS, soft occlusal splints; MRI, magnetic resonance imaging; CNKI, China National Knowledge Infrastructure.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

NH and LXC—helped with literature searches. YDZ and NRZ—summarized the information. NH and YNG—prepared the manuscript and figures. YNG and XDW—provided help and advice. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Informed consent has been obtained from the patients and their guardians for the image data in this article. Ethical approval is not applicable.

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CONFLICT OF INTEREST

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1896428110961623040/attachment/Supplementary%20material.docx.

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