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Review Article

Timing interventions in relation to temporomandibular joint closed lock duration: a systematic review of 'locking duration'

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ABSTRACT **Temporomandibular joint (TMJ) 'closed lock' (CL) is a clinical condition causing TMJ pain and limited mouth opening (painful locking) that is mostly attributed to disc displacement without reduction (DDwoR), or less commonly to anchored disc phenomenon (ADP). Both conditions are described clinically as CL that can be 'acute' or 'chronic' depending on the duration of locking. There is, however, no consensus about the duration of locking that defines the acute state and its effect on the success of interventions. This review paper, therefore, aims to provide: (i) a narrative review of the pathophysiological need for early intervention in DDwoR and the clinical implications of acute/chronic CL stages on the management pathway; (ii) a systematic review investigating the effects of locking duration on the success of interventions for CL management. Electronic and manual searches until mid-August 2013 were conducted for English-language studies of any design investigating the effects of non-surgical and surgical interventions for acute or chronic CL (DDwoR or ADP). A total of 626 records were identified, and 113 studies were included. Data extraction and quality assessment were completed for all included studies. Included studies were, however, heterogeneous and mostly of poor-quality leading to contradictory and inconsistent evidence on the effect of the duration of locking on treatment outcomes. Future high-quality trials investigating the effect of CL duration on treatment outcome are needed. At present, early intervention by 'unlock' mandibular manipulation seems to be the most practical and realistic approach that can be attempted first in every CL patient as an initial diagnostic/therapeutic approach.**

KEYWORDS: **acute closed lock, chronic closed lock, disc displacement without reduction, jaw locking, locking duration, temporomandibular joint**

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Introduction

Temporomandibular joint (TMJ) disc displacement without reduction (DDwoR) is a specific subgroup of temporomandibular disorders (TMDs) where the disc is permanently displaced, most frequently anteriorly or anteromedially, to the condyle resulting in a 'painful locking' (1–4). This condition of TMJ pain and locking is known clinically as 'closed lock' (CL) (5–8). The 'TMJ closed lock' term does not, however, always exclusively, refer to TMJ DDwoR because another condition suggested in the literature to have the same 'hypomobility' symptoms (i.e. anchored disc phenomenon 'ADP') (9). In this review, the 'closed lock' term has only been used to describe the clinical symptoms of the 'two' conditions (DDwoR and ADP).

Depending on duration of locking, CL can be acute or chronic (7, 10–13). The definition of acute and

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chronic CL stages in relation to locking duration and its implications on 'early' management is, however, controversial (13, 14). This controversy is related mostly to unproven effect of locking duration on CL treatment outcomes. This paper, therefore, aims to provide:

1 A narrative review of:

   a the evidence from a pathophysiological perspective of the need for early intervention in the DDwoR management pathway
   b the clinical definition and implications of acute and chronic CL stages.

2 A systematic review of the effects of locking duration on the success of therapeutic interventions in CL. It is explicitly restricted to examining the evidence for the effect of duration of symptoms on treatment outcome as the evidence for the effect of different treatments on DDwoR would require a systematic review of randomised clinical trials which is the subject of another review currently coming to completion (15).

Materials and methods

Search methods

A systematic search in Medline database via Ovid for TMJ CL studies was conducted (last update was on: 15th August 2013). The Medline search strategy is available in Appendix S1. Additional searches were also conducted using other sources including hand-searching the reference lists of the included studies and relevant review articles, as well as searching the Google Scholar using 'disc displacement without reduction' and 'closed lock' keywords.

Criteria for considering studies for the systematic review

Inclusion criteria. Studies of any design investigating the effects of any form of non-surgical and/or surgical interventions on patients with clinical and/or radiological diagnosis of acute or chronic DDwoR were considered in this review as long as the duration of symptoms were reported. Diagnostic criteria accepted were as follows: American Association of Orofacial Pain (AAOP) (acute or chronic DDwoR) (16); research diagnostic criteria for temporomandibular disorders (RDC/TMD) (IIb or IIc) (17); Wilkes stages III or IV (18); or any other bespoke study criteria that were compatible with, or comparable to, the aforementioned criteria. Studies involving CL patients with a 'static' or 'fixed' disc (i.e. anchored disc phenomenon 'ADP') (9, 19) were also included.

Studies that involved other heterogeneous groups of TMD patients (e.g. osteoarthritis, myofacial pain, disc displacement with reduction 'DDwR') in addition to patients with DDwoR were considered only if: separate data (e.g. success rate and/or locking duration) were provided in the study for DDwoR patients, or if the sample consisted of ≥ 80% DDwoR patients. Studies involving patients with a confirmed diagnosis of DDwoR disorder with comorbid disorders were also included.

Exclusion criteria. Studies were excluded if they did not report the duration of symptoms of their sample or if they addressed diagnoses other than 'closed lock' (DDwoR or ADP). Studies were also excluded if they addressed subject matter other than CL treatment.

Data collection and extraction

Selection of studies. The first reviewer (MA) selected eligible studies based on the inclusion/exclusion criteria with those identified as clearly irrelevant from their title/abstract being excluded. The full texts of all potentially eligible studies were retrieved and examined. Throughout the selection process, any doubt about a study's inclusion meant it was examined by the second reviewer (JD) and the decision to include or exclude the study was made by discussion with the first reviewer to reach a consensus.

Data extraction and management. A standardised table was used for data extraction. The data from eligible studies were extracted and recorded by the first reviewer (MA). The second reviewer (JD) cross-checked the extracted data's validity. The data on duration of symptoms and follow-up period were standardised in months and the data for Visual Analogue Scale (VAS) pain successful outcome were standardised, when possible, to (0–100) scale. If not provided, the mean patient age and locking duration was calculated from the raw data using SPSS statistics version 19.0 for windows*.

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Quality assessment. Two independent reviewers (MA & JD) assessed the quality of study design in the included studies using the National Health and Medical Research Council (NHMRC) level of evidence guidelines for intervention trials (20) with slight modification (Appendix S2). The level of evidence in each study was judged by its design as: (I) highest, (II-1), (II-2), (III-1), (III-2), (III-3), or (IV) lowest. Any disagreements concerning the assessment were resolved by discussion to reach a consensus.

Results

Search results

The search strategy identified a total of 626 records from electronic and manual searches (426 from MEDLINE and 200 from other sources). Of these, the full texts of 395 potentially eligible papers were retrieved and examined. Eventually, 113 studies (of 122 reports) were found eligible and included in the systematic review. The study flow diagram is available in Appendix S3.

Narrative review of DDwoR pathophysiology, and the clinical definition and implications of acute and chronic CL stages

Pathophysiology and progression of DDwoR. Patients with DDwoR are often characterised by distinct combinations of signs and symptoms: history of clicking followed by sudden onset of pain and limited mouth opening (locking without clicking) and impaired contralateral movement (2, 5, 7, 17, 21, 22). These characteristic symptoms are usually present in 'acute' DDwoR [CL] (painful limited opening) as opposed to 'chronic' DDwoR (decreased pain-improved opening), which makes the clinical diagnosis of the former more readily achievable. The latter may be difficult to diagnose clinically without magnetic resonance imaging (MRI) (11, 23). The incidence of DDwoR among TMDs is not fully determined but is estimated to occur in about 2–8% (24–27). DDwoR is, however, also diagnosed by MRI in people without any clinical signs or symptoms with a reported prevalence of 3% among the asymptomatic general population (23, 28–30).

The two predominant biomedical complaints in DDwoR are TMJ pain and limitation of jaw movements. The exact cause of pain associated with DDwoR is still not fully understood (31). The displaced disc is thought to play an important role in the pain process (32–34), but it is unlikely to be the only source of pain as disc displacement alone is not always associated with pain (29, 35–40). In addition to alteration in disc position, other factors have been suggested in the development of pain: joint effusion and inflammatory reactions (e.g. synovitis, capsulitis or retrodiscitis), and capsule impingement and/or retrodiscal tissue compression (31, 41–50).

The other predominant biomedical complaint in DDwoR is the abrupt restriction in jaw movements. This is usually attributed to mechanical obstruction by the displaced disc to the translating condylar movement (1, 2, 5, 21, 51). This condition is often, almost colloquially, termed as 'closed lock' (CL) (5–8). The 'closed lock' term, however, describes a clinical symptom and not an anatomic diagnosis and the condition of CL is not always exclusively attributed to DDwoR. Anchored disc phenomenon (ADP) has also been suggested as potentially responsible for some of the cases of CL (9, 52). The putative pathogenic processes underpinning ADP are as follows: direct mechanical injury from joint overloading, hypoxia-reperfusion injury, release of free radicals into the synovial fluid, causing degradation of hyaluronic acid and eventually a vacuum effect (suction cup effect). The end result of these proposed pathological processes leads to disc adherence to the roof of the glenoid fossa. The adhered or 'stuck' disc then totally prevents the condylar sliding movement producing a more pronounced lock but that responds better to arthrocentesis than DDwoR (9, 52–55). Whether ADP is a distinct entity from DDwoR, or a differing stage of the same clinical entity, is still debatable (56) due to the degree of similarity between the signs and symptoms of the two conditions. This similarity makes the differentiation of the two conditions based on clinical diagnosis alone virtually impossible and differentiation on the basis of MRI (19) is doubtful as all bar one ADP study (57), involve patients with displaced discs as well as normally positioned discs (55, 58, 59). Further studies with MRI evidence of a normally positioned disc in CL patients are required to gain a better understanding of ADP and whether it is a separate entity within the 'closed lock' category (57, 60).

The course of DDwoR disorder has been shown to be 'favourable' (14, 61–66). Studies on the natural

course of 'chronic' DDwoR have shown that in about two-thirds of patients, the clinical signs and symptoms tend to resolve or improve over a period of (6–30 months), while the other one-third did not improve or became worse during the observation period (14, 61, 63, 67). A recent study on the short-term natural course of 'acute' DDwoR demonstrated that signs and symptoms resolved in 95% of patients over 3 months of observation (68).

The improvement over the time in some patients with DDwoR may be attributed to stretching and remodelling of the retrodiscal tissues and 'pseudo' disc adaptation (44, 69–74). Despite the increased range of jaw motion and decreased pain, several studies have demonstrated that the displacement of the disc and the deformation of the disc/condyle complex increases (14, 61, 63, 65, 75–81). There are also some indications that the permanently displaced disc may be correlated with alterations in maxillofacial skeletal morphology in the long term (82–88).

The TMJ is a load-bearing joint and its articular tissues have a remarkable adaptive capacity to mechanical loading (89–91), but this capacity is not infinite. Sustained overloading may increase the susceptibility to degenerative joint disease (31, 71, 92–94) and other risk factors may adversely influence the adaptive capacity of the articular tissues including age, systemic illness, hormonal, nutritional, traumatic, mechanical and genetic factors (91, 92, 95–99). A degenerative state can, therefore, ensue if functional demands surpass the adaptive capacity or if the affected individual is susceptible to maladaptive responses (92). In general, the molecular events that underlie TMJ remodelling and adaptation are still not fully understood (92), and the molecular and cellular basis of DDwoR pathophysiology is still unclear, but there is some biochemical evidence of increasing susceptibility to osteoarthritic degeneration in 'chronic' CL patients (100–107).

Three models have been proposed that may be involved in the pathogenesis of degenerative TMJ diseases: the direct mechanical trauma model, the hypoxia-reperfusion model and the neurogenic inflammation model (108). The molecular events and cascades in response to mechanical stress in these models may ultimately lead to an imbalance between catabolic and anabolic events leading to catabolism (degeneration) of the articular tissues in the affected joints (91, 92). The risk of degenerative changes in joints with DDwoR was shown to be four times greater than in joints with normal disc position (109), and suggestions were made that the propensity for degenerative disease was mediated by an imbalance in the patient's adaptive capacity and functional loading of the TMJ. The study concluded that a careful, individualised, assessment of each DDwoR patient was required to evaluate the various factors that might contribute towards the progression to degenerative disease (109).

At present, the line separating normal adaptive responses from responses that result in (degenerative) disease is ill-defined. It may, therefore, be difficult to predict the DDwoR prognosis in an individual patient (71). In fact, TMJ DDwoR is a disorder with two possible scenarios. On one hand, it is a benign self-limiting disorder in which most of patients' symptoms improve with the passage of the time and do not necessarily progress to degenerative joint disease (69, 77, 110, 111). On the other hand, DDwoR can be also a debilitating disorder causing significant pain and dysfunction that disturbs the patient's quality of life with the potential for persistence of symptoms and degenerative progression in susceptible patients in the longer term (71, 109, 112–115). Both scenarios are possible in DDwoR patients, and it is still not clear which patients have, or which biomechanical and biochemical factors predict, the greatest risk of progressing to the more advanced stages (116). This means that it is important to treat all patients early in the time course of DDwoR to prevent disease progress in susceptible patients (117–119). This 'early' management will also prevent progression from an acute to a chronic condition, thereby avoiding the possibility of developing chronic pain and its psychosocial consequences in symptomatic DDwoR patients (120–122). Any initial active intervention, however, should be simpler and less invasive than waiting for possible symptomatic resolution during the 'favourable' natural course of the DDwoR disorder (68).

Clinical definition and implications of acute versus chronic CL stages. The term 'acute' is usually related to a temporary state or condition which may or may not be severe, while the term 'chronic' is related to a state or condition that is persistent or long lasting and again does not imply anything about severity (123, 124). Both medical terms are often used as measures of the time scale of a disease rather than its severity. In pain

conditions, 'acute pain' usually refers to pain of recent onset with a duration ≤1 month (≤30 days), while 'chronic pain' usually refers to a persistent pain with a longer duration (≥3 months or ≥90 days) (125, 126). In a CL condition, the terms 'acute closed lock' (ACL) and 'chronic closed lock' (CCL) are widely used in the CL literature usually describing the chronicity of DDwoR. The most reliable diagnostic criteria for TMDs (17, 22, 127–129) depend, however, primarily on the patients' signs and symptoms rather than the duration of symptoms to classify acute versus chronic DDwoR (Appendix S4). In clinical trials involving patients with DDwoR, however, most authors usually define their samples based on the duration of symptoms (i.e. locking duration or time since DDwoR onset), although there is considerable variation in the threshold that defines acute and chronic stages ranging from 1 to 6 months (Appendix S5). In the authors' opinion, a more appropriate clinical classification of acute and chronic CL could be based on the time scale for the possibility of recapturing the displaced disc to return the DDwoR to its previous condition (i.e. DDwR) with a non-invasive intervention.

In DDwoR (CL), both patient and management factors have been suggested to predict the outcomes. The predictors suggested include the following: age, gender, level of pain, range of mandibular motion, duration of locking, joint inflammation, disc mobility, severity of disc displacement, stage and degree of morphological and pathological changes in disc/condyle complex, and type, frequency, and duration of therapy (114, 130–144). The role of these factors in predicting CL treatment outcome is, however, still debatable. In fact, these 'prognostic' factors may interrelate or interact with each other to a greater or lesser degree and there are still not significant data on the role psychosocial factors may have in predicting outcome in CL. To give an example, the severity of intra-articular pathological changes and the stage of internal derangement may increase with the age of the patient and/or duration of locking. Some of the aforementioned predictive factors are, however, easily accessible through standard history and clinical examination, whereas others require either more advanced imaging (e.g. MRI) or investigations (e.g. arthroscopy). Duration of locking is very simply estimated by self-report, although the accuracy of report may be influenced by several factors including recall bias.

The possible mechanism for jaw locking and DDwoR progression from 'acute' to 'chronic' has been proposed to begin as a displaced disc obstructing the forward condylar translation resulting in restricted mouth opening (acute stage); the repeated attempts to increase mouth opening then displace the disc gradually farther forward to an anterior position, so the condyle can slide forward, and the mouth opening range increases with the 'time' (chronic stage) (2, 116, 145). From a clinical perspective, the progression from an acute to a chronic DDwoR over the time can affect treatment outcome as patients may respond differently to a similar therapeutic intervention dependent on locking duration (114, 146). This coupled with the fact that the two most frequently measured outcomes to assess treatment effectiveness tend to improve over time (increased opening and decreased pain) (131), may be one of the reasons for confusing outcomes reported in the literature around the management of DDwoR: the effectiveness of treatments and authors' findings in their studies may vary because of varying levels of chronicity in their sample. A systematic review of CL studies was, therefore, conducted to investigate the effects of locking duration on the success of therapeutic interventions.

Systematic review of effects of interventions in relation to CL duration

Multiple different non-surgical and surgical treatment modalities have been used for CL management. The interventions identified from the studies included in this review were defined according to their main treatment components: mandibular manipulation (MM); self-management (SM); physiotherapy (PT); splint therapy; combination therapy of splint + PT ± SM; arthrocentesis (AC); arthroscopy (AS); open surgery (OS). A detailed description of each treatment strategy is available in Appendix S6.

To investigate the effects of interventions in relation to locking duration, the characteristics and quality of the included studies were tabulated and summarised in Tables 1–6. The interventions' success rates provided in the tables are based on the success criteria used by each included study. The definition of success was, therefore, highly variable involving both objective and subjective factors with the most frequent measures being mouth opening and pain levels (Tables 1–6).

Table 1. Characteristics of included mandibular manipulation (unlock manipulation 'UM' or pumping manipulation 'PM') studies

		Participants' characteristics												
				Gender		Age (years)		Locking duration (months)						
Study (Year)	Study design	Sample size (drop/exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	Main Intervention assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT use)	Study design quality
Chiba and Echigo (2005) (117)	CR	1	DDwoR (ACL)	–	1	21	–	0·33	–	Farrar's UM[a] under LA + ARS	137	Decreased pain, cMMO≥40 mm, & DR on MRI	–	–	**IV**
Correa *et al.* (2009) (147)	CR	1	DDwoR	–	1	18	–	36	–	UM under LA + ARS, NSAIDs, cryotherapy	24	cMMO>40 mm	–	–	**IV**
Foster *et al.* (2000) (148)	PNCoSt	55(19)	22 CL (DDwoR) & 14 IL	7	48	15–52	24	3–48	13	Forced UM under GA + Self-care ± Splint	3	MMO≥35 mm & subjective improvement	The range of locking duration (6–48) was similar in SG & UG.	CL: 40·9% (no ITT)	**III-3**
Helkimo and Hugoson (1988) (149)	PCS	10	DDwoR	3	7	17–63	29·4	1–36	12·2	Farrar's UM under N_2O/O_2 sedation + SS	6	Improvement in: pain, jaw dysfunction (Di: I–II), LM, & MMO≥40 mm	Longer locking duration in UG 20 (12–36) than in SG 10·8 (1–30).	60%	**IV**
Hernandez and Karibe (2004) (150)	CR	1	DDwoR	–	1	–	28	0·25	–	UM under LA + Med, PT (US), SS, Self-exercises	1	MMO≥40 mm	–	–	**IV**
Jagger (1991) (151)	PCS	12	DDwoR	4	8	15–43	21·8	1–9	3	UM (own technique)	–	MMO≥35 mm	Locking Duration is not an important factor for UM success	66·7%	**IV**
Kai *et al.* (1993) (152)	PCS	12[b]	DDwoR	1	11	11–61	30·33	0·1–2	0·5 ± 0·53	UM or PM + ARS	1	Improvement in clinical symptoms & MMO≥40 mm	58·3% DR on arthrography.	66·7%	**IV**
Kurita *et al.* (1999) (132)	PNCoSt	74/215 assessed by MRI	DDwoR	7	67	–	32·5	–	11·4	Farrar's UM + ARS or NSAID or SS	Few wks	DR on MRI	No significant difference in locking duration between successful DR (10 ± 19·1) and no DR (12·8 ± 24·6).	18% (no ITT) 9% (ITT)	**III-3**
Liu *et al.* (2012) (153)	RNCoSt	36	23 CL (DDwoR) & 13 IL	6	30	13–31	19·8	<3	–	UM under LA + ARS	6	Improvement in: pain, MMO, & jaw dysfunction.	–	DDwoR: 69·6%	**IV**
Martini *et al.* (1996) (154)	PCS	13/1500 reported	DDwoR	–	–	19–56	31·4	0·23–180	36·02 ± 53·47	UM (own technique) + ARS, PT	2–24	Absence of pain, MMO≥35 mm, & DR on MRI	Locking duration is not related to UM success.	99·7%	**IV**
Minagi *et al.* (1991) (135)	PCS	35	DDwoR	2	33	12–68	35·94	0·25–18	3·26 ± 4·09	UM (own technique)	–	MMO≥40 mm	No difference in success rate between <1mo (50%) & >1mo (53%) duration.	51·4%	**IV**

(continued)

Table 1. (*continued*)

Study (Year)	Study design	Participants' characteristics: Sample size (drop/exc)	Study diagnosis	Gender: M	Gender: F	Age (years): Range	Age (years): Mean	Locking duration (months): Range	Locking duration (months): Mean ± SD	Main Intervention assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate%(ITT use)	Study design quality
Mongini *et al.* (1995; 1996) (113, 155)	PCT	75 (7)	DDwoR	7	68	13–43	27·8	0·25–120	13·3 ± 21·84	Extra-oral UM under LA + ARS, SS, Med, PT	18–147	No pain or pain present only on jaw movement & MMO≥35 mm	No difference in locking duration between SG & UG. 4·4% DR on MRI.	86·8% (no ITT)	**IV**
Muhtarogullari *et al.* (2013) (156)	PNCoSt	22	DDwoR	3	19	14–48	27·1	–	3·25	UM + ARS if unsuccessful DR: SS+ Self-exercises	6	No pain on palpation, MMO≥40 mm, normal LM & PrM	15·9% DR on MRI	100%	**III-3**
Murakami *et al.* (1987) (157)	PCS	10	DDwoR	1	9	14–46	28·9	1–9	4·7	PM + CS + ARS	6	AAOMS criteria: increase in cMMO	No difference in locking duration between SG & UG. PM helps to unlock the CL up to about 6mo	70%	**IV**
Murakami *et al.* (1995) (12)[c]	PCoSt	108	W: III(CL)	20	88	–	31·43	–	5·0 ± 8·8 *5·6 ± 6·9* *6·8 ± 10·2*	NS: Med/UM/PS, N = 63; *AC, N = 20* *AS, N = 25*	6	VAS pain<20, MMO>38 mm, LM & PrM> 6 mm, & improved DAL	Patients with >7 mo locking duration did not respond to arthrocentesis	*NS: 55·6%* *(Med:15·9%* UM:18·9% *PS: 33·3%)* *AC: 70%* *AS: 91%*	**III-2**
Ohnuki *et al.* (2006) (137)[c]	RCoSt	85	DDwoR	9	76	13–73	41·8	–	*5·1 ± 6·8* 10·4 ± 13·1 *6·6 ± 8* *14·2 ± 22·2*	*SS, N = 11* PM, N = 33 *AC, N = 9* *AS, N = 32*	12	VAS pain<20 & MMO>38 mm	No significant difference between SG regarding locking duration. 10% DR on MRI among all groups with no difference between groups.	*Med: 0%* *SS: 12·9%* PM: 44·6% *AC: 22%* *AS:100%*	**III-3**
Ozawa *et al.* (1996) (158)	RCS	40	DDwoR	4	36	16– 68	38·15	0·1–120	19·58 ± 33·99	PM ACL (0·1–0·27), N = 5; CCL (2–120), N = 35	0·07–3 (ACL:2–3dy CCL:2–3mo)	Improvement in pain & MMO≥35 mm	Higher success rate in ACL (100%) than in CCL (37·1%). PM able to release acute locking only.	68·6%	**IV**
Segami *et al.* (1990) (139)	PCS	28	DDwoR	3	25	14–57	25·4	0·07–24	4·7	Farrar's UM or PM + ARS & NSAIDs	2	No or slight pain & MMO≥40 mm	No relation between MM technique (UM or PM) & locking duration. 36·7% DR on arthrography.	100%	**IV**

(continued)

Table 1. (*continued*)

Study (Year)	Study design	Participants' characteristics: Sample size (drop/exc)	Study diagnosis	Gender: M	Gender: F	Age (years): Range	Age (years): Mean	Locking duration (months): Range	Locking duration (months): Mean ± SD	Main Intervention assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate%(ITT use)	Study design quality
Simmons (2002) (159)	CR	1	DDwoR	–	1	–	14	0·5	–	PM under IV-sedation + ARS	24	Improvement in: cMMO, LM, PrM, subjective improvement, & DR on MRI	–	–	**IV**
Singh (2010) (160)	CR	1	DDwoR (Chronic)	–	1	–	32	24	–	UM under LA with CS + IMF screws & elastics + ARS	0·25	Improvement in: VAS pain, cMMO	–	–	**IV**
Van Dyke and Goldman (1990) (161)	PCS	41	DDwoR (Acute)	–	–	–	–	≤1·5–2	–	UM under IM-LA (own tech) + ARS	–	MMO≥40 mm	–	92·7%	**IV**
Yoshida *et al.* (2005) (141)	RCT	305	DDwoR	76	229	18–74	–	0·033–<12	–	UM (own technique) + NSAID, N = 204 *NSAID only, N = 101*	0·25	VAS pain<20, MMO≥36 mm, LM≥6 mm, & DR on MRI	UM success rate drops significantly with the increase in locking duration: 1-2dy (100%), <1 wk (98·3%), <2 wk (94·6%), <3 wk (90%), <1 mo (57·1%), <2mo (16·7%), <6mo (0%).	UM: 84·3% *NSAID:0%*	**II-2**
Yoshida *et al.* (2011; 2013) (114, 162)	RCT	148	DDwoR	–	148	19–75	40	0·033–9 *0·067–11*	1·57 *1·73*	Self-UM, N = 74 *No treatment, N = 74*	10 minutes	Absence of pain & MMO>38 mm	Locking duration was shorter in SG (1·18) than in UG (2·92).	S-UM:68% Ctrl:4%	**II-2**
TOTAL	**19studies**	–	**DDwoR**	–	–	–	–	**0·03–180**	**8·93**	**UM**	–	–	**DR average success rate: 44% (range: 4·4%–99·7%)**	**67·6%**	–
	6studies	–	**DDwoR**	–	–	–	–	**0·07–120**	**7·98**	**PM**	–	–		**69·9%**	–

RCT, randomised controlled trial; Q-RCT, quasi-randomised controlled trial; PCoSt, prospective comparative study; RCoSt, retrospective comparative study; PCCSt, prospective case–control study; PNCoSt, prospective non-comparative study; RNCoSt, retrospective non-comparative study; FSt, follow-up study; PCS, prospective case series; RCS, retrospective case series; BACS, before-after case series; BACR, before-after case report; CR, case report; AAOMS, American association of oral and maxillofacial surgery; ACL, acute closed lock; ARS, anterior repositioning splint; CCL, chronic closed lock; Ch, chronic; CMI, CranioMandibular Index; cMMO, comfortable 'painless' maximum mouth opening; CS, corticosteroids; Ctrl, control; DAL, daily activity limitation; DDwoR, disc displacement without reduction; DR, disc recapturing; drop, drop-outs; dy, day; exc, excluded; Exr, exercises; F, female; GA, general anaesthesia; ID, internal derangement; IL, intermittent locking; ITT, intention-to-treat analysis; IV, intravenous; j, joint; LA, local anaesthesia; LDF, limitation in daily function; LM, lateral movement; M, male; Med, medication; MFIQ, mandibular function impairment questionnaire; mm. millimetres; MMO, maximum mouth opening; mo, month; MR, muscle relaxant; MRI, magnetic resonance imaging; N, number of patients; NS, non-surgical; NSAIDs, non-steroidal anti-inflammatory drugs; OS, open surgery, PrM, protrusive movement; PM, pumping manipulation; PS, pivot splint; PT, physiotherapy; Reh, rehabilitation; S&S, signs and symptoms; SD, standard deviation; SG, successful group; SH, sodium hyaluronate; SM, self-management; SS, stabilisation splint; Sub-ac, sub-acute; S-UM, self-unlock manipulation; UG, unsuccessful group; UM, unlock manipulation; US, ultrasound; VAS, Visual Analogue Scale; W, Wilkes staging of internal derangement; wk, week; yr, year.

[a]Description of Farrar's UM technique (2) is available in Appendix S7 (figure).

[b]Separate data provided are for DDwoR patients only.

[c]Study data are also provided in other tables according to main treatment modality assessed.

Table 2. Characteristics of included self-management (SM) and physiotherapy (PT) studies

Study (Year)	Study design	Participants' characteristics: Sample size (drop/exc)	Study diagnosis	Gender: M	Gender: F	Age (years): Range	Age (years): Mean	Locking duration(months): Range	Locking duration(months): Mean ± SD	Main interventions assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT use)	Study design quality
Braun (1987) (163)	CR	1	DDwoR	–	1	–	71	0·75	–	Self-exercises + Iontophoresis	1·5	Absence of pain, MMO>40 mm, LM>7 mm, improved jaw function, & eating normal diet	–	–	**IV**
Cleland and Palmer (2004) (164)	BACR	1	DDwoR	–	1	–	24	19	–	SM + PT	3	VAS pain<20, MMO≥40 mm, & improved jaw function	–	–	**IV**
Craane *et al.* (2012) (165)	RCT	49 (7)	DDwoR	2	47	–	36·6	wks–yrs	–	Exercises, N = 23 Education only, N = 26	13	Improvement in: VAS pain, MMO, & MFIQ	–	– (ITT)	**II-1**
Haketa *et al.* (2010) (145)[a]	RCT	52 (14)	DDwoR	6	46	–	37·6	Over 0·5	–	*Self-care+ SS, N = 25*; Self-care+ Self-exercise, N = 19	2	Improvement in: VAS pain, MMO, & LDF	–	– (ITT)	**II-1**
Minakuchi *et al.* (2001; 2004) (166, 167)[a]	RCT	69 (8)	DDwoR	7	62	–	34	–	*3·89 ± 5·56*	*Education only, N = 21*	2	Improvement in: VAS pain, MMO, & DAL	–	– (ITT)	**II-1**
									2·81 ± 5·09	Self-care/NSAIDs, N = 23					
									3·12 ± 5·03	*SS+ Exercises + Self-care/NSAIDs, N = 25*					
Nicolakis *et al.* (2001) (136)	BACS	20 (2)		5	15	–	37·3	1·2–60	15·6	Active & passive jaw exercises	6	Improvement in: VAS pain, MMO, & DLA	–	85% (ITT)	**III-3**
Schiffman *et al.* (2007; 2013) (168, 169)[a]	RCT	108 (12)	W: III–IV (DDwoR)	8	98	–	31·72	Non–ch <6 – ch≥6	–	SM + Med, N = 29 *SS + PT + CBT, N = 25* *AS + CS, N = 26* *OS, N = 26*	60	Self-reported success (Patient satisfaction)	–	SM: 72% *Reh: 81%* *AS: 76·2%* *OS: 83·3%* (ITT)	**II-1**
Srisintorn (1992) (170)	CR	1	DDwoR	–	1	–	29	2	–	Self-care/NSAID + Self-exercises	12	cMMO≥40 mm	–	–	**IV**

(continued)

Table 2. (*continued*)

		Participants' characteristics													
		Sample		Gender		Age (years)		Locking duration (months)		Main	Longest follow-up		Study findings in		Study
Study (Year)	Study design	size (drop/exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	interventions assessed	duration (months)	Success criteria	relation to CL duration	Overall success rate% (ITT use)	design quality
Yuasa and Kurita (2001) (142)	RCT	60 (NR)	DDwoR (15ACL, 45CCL)	12	48	16–69	Median28	0·53–25·07	Median 2·33	NSAIDs + self-exercise, N = 30	1	AAOMS & IAOMS modified criteria: VAS pain≤33 & MMO≥35 mm	CCL (>1 mo) responded better to treatment than non-treatment in comparison with ACL (≤1 mo)	SM: 60% *Ctrl: 33%* (ITT)	**II-1**
								0·63–41·8	Median *3·27*	*No treatment, N = 30*					
Total	**2studies**	–	**DDwoR**	–	–	–	–	–	–	**PT (Stretching exr.)**	–	–	–	–	–
	7studies	–	**DDwoR**	–	–	–	–	–	–	**SM (self-care/ Med/Exr)**	–	–	–	**66%**	–

RCT, randomised controlled trial; Q-RCT, quasi-randomised controlled trial; PCoSt, prospective comparative study; RCoSt, retrospective comparative study; PCCSt, prospective case–control study; PNCoSt, prospective non-comparative study; RNCoSt, retrospective non-comparative study; FSt, follow-up study; PCS, prospective case series; RCS, retrospective case series; BACS, before-after case series; BACR, before-after case report; CR, case report; AAOMS, American association of oral and maxillofacial surgery; AC, arthrocentesis; ACL, acute closed lock; ARS, anterior repositioning splint; AS, arthroscopy; CBT, cognitive behavioural therapy; CCL, chronic closed lock; Ch, chronic; CMI, CranioMandibular Index; cMMO, comfortable 'painless' maximum mouth opening; CS, corticosteroids; Ctrl, control; DAL, daily activity limitation; DDwoR, disc displacement without reduction; DR, disc recapturing; drop, drop-outs; dy, day; exc, excluded; Exr, exercises; F, female; GA, general anaesthesia; ID, internal derangement; IL, intermittent locking; ITT, intention-to-treat analysis; IV, intravenous; j, joint; LA, local anaesthesia; LDF, limitation in daily function; LM, lateral movement; M, male; Med, medication; MFIQ, mandibular function impairment questionnaire; mm. millimetres; MMO, maximum mouth opening; mo, month; MR, muscle relaxant; MRI, magnetic resonance imaging; N, number of patients; NS, non-surgical; NSAIDs, non-steroidal anti-inflammatory drugs; OS, open surgery, PrM, protrusive movement; PM, pumping manipulation; PS, pivot splint; PT, physiotherapy; Reh, rehabilitation; S&S, signs and symptoms; SD, standard deviation; SG, successful group; SH, sodium hyaluronate; SM, self-management; SS, stabilisation splint; Sub-ac, sub-acute; UG, unsuccessful group; UM, unlock manipulation; VAS, Visual Analogue Scale; W, Wilkes staging of internal derangement; wk, week; yr, year.

[a]Study data are also provided in other tables according to main treatment modality assessed.

Table 3. Characteristics of included splint (± other conservative) therapy studies

		Participants' characteristics												
		Sample size		Gender		Age (years)		Locking duration (months)			Longest follow-up			
Study (Year)	Study design	(drop/ exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± sd	Main intervention assessed	duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT use)	Study design quality
Choi *et al.* (1994) (171)	PCS	10	DDwoR	–	10	14–55	27	0·75–5	2 ± 1·61	SS + PT	3-4	MMO≥40 mm	DR on MRI is unlikely to happen in CCL	100%	**IV**
Diracoglu *et al.* (2009) (172) [a]	Q-RCT	120 (10)	DDwoR	16	104	15–63	34·1	max. of 0·7	–	*AC, N = 54* SS + PT, N = 56	6	Improvement in: VAS pain, MMO, LM, & PrM	Both are effective for early DDwoR but AC is superior for pain relief	- (no ITT)	**III-1**
Haketa *et al.* (2010) (145) [a]	RCT	52 (14)	DDwoR	6	46	–	37·6	Over 0·5	–	SS + Self-care, N = 25; *Self-care + Self-exercise, N = 19*	2	Improvement in: VAS pain, MMO, & LDF	–	– (ITT)	**II-1**
Harth (2012) (173)	CR	1	DDwoR	–	1	–	53	2	–	Decompression splint + Exercises	21	cMMO>38 mm	–	–	**IV**
Ismail *et al.* (2007) (174)	RCT	26	21[b] DDwoR	3	23	–	42·8	Less than 6	–	SS, N = 13 SS + Exercises, N = 13	3	Improvement in: pain & MMO	–	–	**II-2**
Israel and Syrop (1997) (175)	CRs	2	DDwoR	–	2	14–28	–	0·03–0·5	–	Splint + Self-care/ Med + PT	0·5-12	No pain, MMO≥35 mm, eating normal diet, & patient satisfaction	–	–	**IV**
Iwase *et al.* (2005) (131)	RNCoSt	52	DDwoR	8	44	–	32·1	≤12 – >12	25·71 ± 56·11	SS+ Self-Exercises+ NSAIDs	-	VAS pain≤30, cMMO≥30 mm, & patient satisfaction	Non-responders: 80%>12 mo symptoms' duration & 20%≤12 mo Responders: 75·7% >12 mo & 24·3%≤12 mo	71·2%	**IV**
Kai *et al.* (1998) (71)	PNCoSt	35	DDwoR	–	35	15–63	37·3	0·5–48	4·9	SS	25-42	Improvement in: pain & MMO≥40 mm	-	55·9%	**III-3**
Kuwahara *et al.* (1990) (176)	PCS	8	DDwoR (Acute)	–	–	13–59	–	0·5–6	–	Disc recapturing splint	6–16	MMO>35 mm	–	100%	**IV**
Le Bell and Forssell (1993) (177)	PCS	22 (2)	DDwoR	5	17	17–68	Median 27	< 1 – <12	–	SS + OA *(<1mo, N = 15; < 6mo, N = 5; > 6mo but <12mo, N = 2)*	24	Improvement in: pain & jaw movements (Helkimo anamnestic & dysfunction indices: Ai: 0 or 1, Di: II)	–	95·5% (ITT)	**IV**

(continued)

Table 3. (*continued*)

Study (Year)	Study design	Participants' characteristics: Sample size (drop/ exc)	Study diagnosis	Gender: M	Gender: F	Age (years): Range	Age (years): Mean	Locking duration (months): Range	Locking duration (months): Mean ± sd	Main intervention assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT use)	Study design quality
Lee *et al.* (2013) (178) [a]	RCoSt	43	DDwoR	3	40	–	21·9	At least 3	–	*AC + HS & SS, N = 17; SS then AC + HS, N = 13* SS only, N = 13	6	AAOMS criteria: VAS pain<30 & cMMO≥38 mm or increase cMMO≥10 mm	–	–	**III-3**
Linde *et al.* (1995) (179)	RCT	33 (2)	DDwoR	5	26	17–68	Median 37	0·5–192	Median 6	SS, N = 16 *TENS, N = 15*	1·5	VAS Pain reduction ≥50%, MMO≥40 mm, LM≥7 mm, & PrM≥7 mm	–	SS: 53%, *TENS: 6%* (no ITT)	**II-2**
Minakuchi *et al.* (2001; 2004) (166, 167) [a]	RCT	69 (8)	DDwoR	7	62	–	34	–	*3·89 ± 5·56* *2·81 ± 5·09* 3·12 ± 5·03	*Education, N = 21* *Self-care/NSAIDs, N = 23* SS+ Exercises + Self-care/NSAIDs, N = 25	2	Improvement in: VAS pain, MMO, & DAL	–	– (ITT)	**II-1**
Murakami *et al.* (1995) (12) [a]	PCoSt	108	W: III (CL)	20	88	–	31·43	–	5·0 ± 8·8 *5·6 ± 6·9* *6·8 ± 10·2*	NS: Med/UM/PS, N = 63 *AC, N = 20* *AS, N = 25*	6	VAS pain<20, MMO>38 mm, LM & PrM> 6 mm, & improved DAL	Patients with >7mo locking duration did not respond to arthrocentesis	NS: 55·6% (*Med:15·9% UM:18·9%* PS: 33·3%) *AC: 70%* *AS: 91%*	**III-2**
Murakami *et al.* (2002) (111)	FSt [c]	63 (7)	W: III (CL)	8	42	13– 75	33·2	–	5·0 ± 8·8	Med (NSAIDs + MR), or UM, or PS	120	Improvement in: VAS pain, Jaw function, & DAL	–	89·3% (ITT)	**IV**
Ohnuki *et al.* (2006) (137) [a]	RCoSt	85	DDwoR	9	76	13–73	41·8	–	5·1 ± 6·8 *10·4 ± 13·1* *6·6 ± 8* *14·2 ± 22·2*	SS, N = 11 *PM, N = 33* *AC, N = 9* *AS, N = 32*	12	VAS pain<20 & MMO>38 mm	No significant difference between SGs regarding duration of locking	SS: 12·9% *PM: 44·6%* *AC: 22%* *AS: 100%*	**III-3**
Schiffman *et al.* (2007; 2013) (168, 169) [a]	RCT	108 (12)	W: III–IV DDwoR	8	98	–	31·72	Non–ch <6 – ch≥6	–	*SM + Med, N = 29* SS + PT + CBT, N = 25; *AS + CS, N = 26; OS, N = 26*	60	Self-reported success (Patient satisfaction)	–	*SM: 72%* Reh: 81% *AS: 76·2%* *OS: 83·3%* (ITT)	**II-1**

(continued)

Table 3. (*continued*)

		Participants' characteristics													
		Sample size		Gender		Age (years)		Locking duration (months)			Longest follow-up			Overall	
Study (Year)	Study design	(drop/ exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± sd	Main intervention assessed	duration (months)	Success criteria	Study findings in relation to CL duration	success rate% (ITT use)	Study design quality
Shoji (1995) (180)	CR	1	DDwoR Chronic	–	1	–	16	6	–	SS	1·5	Reduced pain & MMO≥35 mm	–	–	**IV**
Stiesch-Scholz *et al.* (2002) (140)	PNCoSt	55	DDwoR	7	48	15–77	41·96	<0·25 – >6	–	PS acute(<3), N = 19 Sub-ac (3–6), N = 19 Ch (>6), N = 17	45–50	VAS pain=0, MMO≥40 mm, improved LM, PrM, & chewing ability	The success rate of treatment decreased with longer locking duration: acute (84·2%), Sub-acute (63·2%), & chronic (64·7%). DR in 3 patients with <1 wk.	72·7%	**III-3**
Stiesch-Scholz *et al.* (2005) (181)	RCT	40	DDwoR	5	35	18–64	33·65	–	3·83 ± 3·45 4·68 ± 2·9	SS, N = 20 PS, N = 20	3	Improvement in: pain, MMO, LM, & PrM	–	–	**II-1**
Tanaka *et al.* (2000) (182)	CR	1	W: IV DDwoR	–	1	–	22	60	–	Splint + Exercises	60	Improved pain & MMO	–	–	**IV**
Yoshida *et al.* (2005) (183)	PNCoSt	40	DDwoR	–	40	16–64	29·85	–	51·6 ± 57·6 33·6 ± 39·6	SS-UFD, N = 20 SS-DFD, N = 20	6	No pain or pain present only on jaw movement & increased MMO	–	Overall: 57·5% UFD: 20% DFD: 95%	**III-3**
TOTAL	**12studies**	–	**DDwoR**	–	–	–	–	**0·25–192**	**15·53**	**Splint only**	–	–	–	**60·1%**	–
	10studies	–	**DDwoR**	–	–	–	–	–	**10·28**	**Splint + others**	–	–	–	**84·1%**	–

RCT, randomised controlled trial; Q-RCT, quasi-randomised controlled trial; PCoSt, prospective comparative study; RCoSt, retrospective comparative study; PCCSt, prospective case–control study; PNCoSt, prospective non-comparative study; RNCoSt, retrospective non-comparative study; FSt, follow-up study; PCS, prospective case series; RCS, retrospective case series; BACS, before-after case series; BACR, before-after case report; CR, case report; AAOMS, American association of oral and maxillofacial surgery; AC, arthrocentesis; ACL, acute closed lock; ADP, anchord disc phenomeon; ARS, anterior repositioning splint; AS, arthroscopy; CBT, cognitive behavioural therapy; CCL, chronic closed lock; Ch, chronic; CMI, CranioMandibular Index; cMMO, comfortable 'painless' maximum mouth opening; CS, corticosteroids; Ctrl, control; DAL, daily activity limitation; DDwoR, disc displacement without reduction; DFD, downward flexure deformation; DR, disc recapturing; drop, drop-outs; dy, day; exc, excluded; Exr, exercises; F, female; GA, general anaesthesia; ID, internal derangement; IL, intermittent locking; ITT, intention-to-treat analysis; IV, intravenous; j, joint; LA, local anaesthesia; LDF, limitation in daily function; LM, lateral movement; M, male; Med, medication; MFIQ, mandibular function impairment questionnaire; mm. millimetres; MMO, maximum mouth opening; mo, month; MR, muscle relaxant; MRI, magnetic resonance imaging; N, number of patients; NS, non-surgical; NSAIDs, non-steroidal anti-inflammatory drugs; OS, open surgery, PrM, protrusive movement; PM, pumping manipulation; PS, pivot splint; PT, physiotherapy; Reh, rehabilitation; S&S, signs and symptoms; SD, standard deviation; SG, successful group; SH, sodium hyaluronate; SM, self-management; SS, stabilisation splint; Sub-ac, sub-acute; TENS, transcutaneous electrical nerve stimulation; UFD, upward flexure deformation; UG, unsuccessful group; UM, unlock manipulation; VAS, Visual Analogue Scale; W, Wilkes staging of internal derangement; wk, week; yr, year.

[a]Study data are also provided in other tables according to main treatment modality assessed.

[b]DDwoR patients in study sample ≥ 80%.

[c]Follow-up report of Murakami *et al.* (1995) study (12).

Table 4. Characteristics of included arthrocentesis (AC) studies

		Participants' characteristics													
		Sample size		Gender		Age (years)		Locking duration (months)							
Study (Year)	Study design	(drop/ exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	Main interventions assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	% Overall success rate (ITT used)	Study design quality
Aktas *et al.* (2010a) (184)	PCoSt	25	DDwoR	2	23	17–64	30·4	0·1–24	6·76	AC alone, N = 13 AC + SH, N = 12	12	AAOMS criteria: VAS pain≤30 mm, MMO ≥35 mm, & improved jaw function	Mean locking duration was higher in UG 9·6 (1–24) than SG 3·92 (0·1-24)	Overall 80% AC:84·6%, AC+SH: 75%	**III-2**
Aktas *et al.* (2010b) (185)	RCT	21	DDwoR	4	17	15–52	26·43	0·1–24	5·29	AC alone, N = 14 AC + TX, N = 7	6	AAOMS criteria: VAS pain≤30 mm, MMO ≥35 mm, improved jaw function	–	Overall 83·3% AC:85·7%, AC+TX: 71·4%	**II-2**
Alpaslan and Alpaslan (2001) (187)	RCT	15[a]	DDwoR (CL)	1	14	15–53	31·90	2–72	18·5	AC alone, N = 4 AC + SH, N = 11	3–28	Improvement in: pain, MMO, LM, & jaw function	–	–	**II-2**
Alpaslan *et al.* (2008) (186)	RCT	67 (12)	DDwoR	–	–	18–51	30·1	0·03–18	6·73	AC alone, N = 14 AC + soft splint, N = 9; AC + hard splint, N = 22	6	Improvement in: pain, MMO, & LM	–	– (no ITT)	**II-2**
Bhargava *et al.* (2012) (188)	CR	1	DDwoR	–	1	–	32	3	–	AC + CS	1	MMO≥35 mm & VAS pain=0	–	–	**IV**
Dhaif and Ali (2001) (189)	RNCoSt	62 (22)	ADP	9	53	16–50	28·9	0·75–12	11·43 ± 8·35	AC, N = 40	36	VAS pain<2, MMO≥38 mm, LM≥5 mm, PrM≥5 mm, improved DLA	–	95%	**IV**
Dimitroulis *et al.* (1995) (190)	FSt[b]	46	ADP	2	44	25–39	32·5	1–84	13	AC	6–30	Improvement in: VAS pain, VAS jaw dysfunction (chewing ability), & MMO	–	97·8%	**IV**
Diracoglu *et al.* (2009) (172)[c]	Q-RCT	120 (10)	DDwoR	16	104	15–63	34·1	max. of 0·7	–	AC, N = 54 *SS + PT, N = 56*	6	Improvement in: VAS pain, MMO, LM, & PrM	Both are effective for early DDwoR but AC is superior for pain relief	– (no ITT)	**III-1**
Emshoff and Rudisch (2004) (192)[d]	PNCoSt	29	DDwoR (ID III)	7	22	17–69	34·6	Non–ch≤6–Ch>6 < 24	8·76	AC (Non–ch, N = 15 Ch, N = 14)	2	Absence of DDwoR S&S and VAS Pain Reduction≥85%	Symptoms' duration was lower in SG (5·28 ± 4·03) than in UG (12·23 ± 6·83).	37·9%	**III-3**
Emshoff and Rudisch (2007) (193)[d]	PNCoSt	37	DDwoR (ID III)	6	31	17–69	28·3	–	8·68 ± 6·9	AC	2	MMO≥35 mm & pain reduction >50%	No statistical significant difference in duration of symptoms between SG (9·25 ± 5·53) and UG (7·95 ± 8·5)	56·8%	**III-3**

(continued)

Table 4. (*continued*)

		Participants' characteristics												
		Sample size		Gender		Age (years)		Locking duration (months)						
Study (Year)	Study design	(drop/ exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	Main interventions assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	% Overall success rate (ITT used)	Study design quality
Emshoff *et al.* (2000) (194)[d]	PNCoSt	15	DDwoR (ID III)	–	15	18–71	38·7	1–9	5·7	AC	2	Improvement in: VAS pain & MMO	–	–	**III-3**
Emshoff *et al.* (2003) (195)[d]	PNCoSt	38	DDwoR (ID III)	6	32	17–69	33·8	–	7·13 ± 6·1	AC	2	Absence of DDwoR symptoms (VAS pain & MMO)	No statistical significant difference in duration of symptoms between SG (7·38 ± 5·78) and UG (6·68 ± 6·8).	63·2%	**III-3**
Emshoff (2005) (130)[d]	PNCoSt	64	DDwoR (ID III)	6	58	17–69	33·4	Non–ch ≤6 – ch>6	12·31	AC	2	Absence of DDwoR symptoms (VAS pain & MMO)	The mean duration of symptoms was lower in SG (10·15 ± 9·35) than UG (14·48 ± 21·25) but the difference was not statistically significant.	53·1%	**III-3**
Emshoff *et al.* (2006) (191)[d]	PNCoSt	28	DDwoR (ID III)	8	20	17–69	30·9	Less than 12	–	AC	2	Improvement in: VAS Pain on jaw function & MMO	–	–	**III-3**
Gateno (1994) (196)[c]	CRs	2	DDwoR (ACL)	–	2	25–31	–	0·5–0·7	–	AC	3	MMO≥38 mm & VAS pain≤4	–	–	**IV**
Ghanem (2011) (197)	PCoSt	20	DDwoR (ACL)	–	20	24–54	34	Less than 1	–	AC + CS, N = 10 AC + CS & SS, N = 10	12	Improvement in: VAS Pain, MMO, LM, PrM, & jaw dysfunction	AC+SS are the treatment of choice for ACL (<1mo) with bruxism	Overall: 60% AC: 30% AC+SS: 90%	**III-2**
Hosaka *et al.* (1996) (198)	FSt[e]	20 (1)	W: III (CL)	–	–	–	31·2	–	5·6 ± 6·9	AC	36	VAS pain<2, MMO> 38 mm, LM>6 mm, PrM>6 mm, normal diet & improved jaw function, daily activity.	–	78·9%	**IV**
Kaneyama *et al.* (2007b) (57)	PCS	14	ADP	5	9	15–70	34·3	0·5–12	4 ± 4·1	AC	1–12	No or mild pain, MMO>38 mm, eating normal diet	Symptoms' duration was longer in SG (0·5–12) than UG (1–4).	64·3%	**IV**
Kaneyama *et al.* (2007a) (200)	PNCoSt	66	DDwoR	4	62	14–73	36	1–24	2	AC + CS	2–13	No or mild VAS pain, MMO>38 mm, LM>6 mm, & PrM>6 mm	–	77%	**III-3**
Kaneyama *et al.* (2004) (199)	PCS	17	DDwoR	5	12	17–76	40	0·8–60	19	AC + CS	3	No or mild VAS pain, MMO>38 mm, LM>6 mm, & PrM>6 mm	No correlation between duration of symptoms and clinical symptoms	88%	**IV**

(continued)

Table 4. (*continued*)

		Participants' characteristics												
		Sample size (drop/ exc)		Gender		Age (years)		Locking duration (months)						
Study (Year)	Study design		Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	Main interventions assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	% Overall success rate (ITT used)	Study design quality
Lee *et al.* (2013) (178)[c]	RCoSt	43	DDwoR	3	40	–	21·9	At least 3	–	AC + HS & SS, N = 17; SS then AC + HS, N = 13 *SS only, N = 13*	6	AAOMS criteria: VAS pain<30 & cMMO≥38 mm or increase cMMO≥10 mm	–	–	**III-3**
Mohanavalli *et al.* (2011) (201)	CR	1	CL	–	1	–	28	More than 12	–	AC + CS	9	VAS pain=0, MMO≥40 mm, LM & PrM≥ 6 mm, & improved function	–	–	**IV**
Murakami *et al.* (1995) (12)[c]	PCoSt	108	W: III (CL)	20	88	–	31·43	–	*5·0 ± 8·8* 5·6 ± 6·9 *6·8 ± 10·2*	*NS: Med. or UM or PS, N = 63* AC, N = 20 *AS, N = 25*	6	VAS pain<20, MMO>38 mm, LM & PrM> 6 mm, & improved DAL	Patients with >7mo locking duration not respond to AC	*NS: 55·6% (Med:15·9% UM:18·9% PS: 33·3%)* AC: 70% *AS: 91%*	**III-2**
Ness and Crawford (1996) (202)	RCS	15	CL	–	–	–	–	0·23–1 4–109	0·6 ACL 38·1 CCL	AC +CS (ACL<4 mo, N = 6; CCL>4 mo, N = 9)	–	MMO >40 mm, no or mild pain, and normal eating	–	64%	**IV**
Nishimura *et al.* (2001; 2004) (203, 204)	PNCoSt	100	95[f] DDwoR	11	89	13–73	Median 31	0·07–36	5·67	AC + CS	0·25	No or mild VAS pain & MMO>38 mm	The mean duration of locking was lower in SG 4·33 (0·033–36·5) than UG 8·43 (0·13–36·7) but the difference was not statistically significant.	70·9%	**III-3**
Nitzan *et al.* (1991) (206)	PCS	17	ADP	3	14	16–65	32·6	2–60	11·8 ± 12·9	AC + CS	4–14	VAS pain≤4 of 15, VAS jaw dysfunction≤4 of 15, MMO≥35 mm, PrM & LM>7 mm, & patient satisfaction	One patient with longest duration of symptoms (60 mo) showed marked increase in MMO but no significant decrease in pain & jaw dysfunction.	91%	**IV**
Nitzan (1994) (205)	PCS	29	ADP	8	21	–	–	–	13·9	AC + CS	Mean 22·2	Improvement in: VAS Pain, VAS jaw dysfunction, & MMO	–	96·5%	**IV**
Nitzan *et al.* (1997) (55)	PNCoSt	39	ADP	8	31	14–53	28·9	0·5–48	11·43 ± 8·35	AC	6–37	Improvement in: VAS Pain & VAS jaw dysfunction, MMO≥35 mm, PrM & LM≥5 mm, & patient satisfaction	Increased duration of symptoms seemed to affect joint function and deteriorate it.	95%	**III-3**

(continued)

Table 4. (*continued*)

Study (Year)	Study design	Participants' characteristics: Sample size (drop/ exc)	Study diagnosis	Gender: M	Gender: F	Age (years): Range	Age (years): Mean	Locking duration (months): Range	Locking duration (months): Mean ± SD	Main interventions assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	% Overall success rate (ITT used)	Study design quality
Ohnuki *et al.* (2006) (137)[c]	RCoSt	85	DDwoR	9	76	13–73	41·8	–	*5·1 ± 6·8* *10·4 ± 13·1* 6·6 ± 8 *14·2 ± 22·2*	*SS, N = 11* *PM, N = 33* AC, N = 9 *AS, N = 32*	12	VAS pain<20 & MMO>38 mm	No significant difference between SGs regarding locking duration.	*SS: 12·9%* *PM: 44·6%* AC: 22% *AS: 100%*	**III-3**
Sahlstrom *et al.* (2013) (207)	RCT	45 (8)	DDwoR	4	41	–	34·9	≤3	–	*LA only, N = 25* AC, N = 20	3	Reduction in VAS pain≥30% during jaw movement	–	*LA: 76%* AC: 55% (ITT)	**II-1**
Sakamoto *et al.* (2000) (138)	PCS	18	DDwoR	1	17	17–67	33·3	2·3–46	14 ± 12·8	AC	3	AAOMS criteria: MMO≥40 mm & VAS pain<33	Symptoms' duration in SG (8·4 ± 5·4) was significantly shorter than in UG (19·6 ± 15·6).	50%	**IV**
Sanroman (2004) (58)[c]	PCoSt	26 (2)	ADP	6	20	16–35	24·3	0·23–3	1·21	*AS + SH, N = 16* AC + SH, N = 8	24–36	VAS pain≤ 2 of 15, MMO≥35 mm, LM≥7 mm & PrM≥10 mm	–	100%	**III-2**
Sato *et al.* (1997) (210)	PCoSt	76	DDwoR	2	74	11–74	29·9	*0·1–60* *0·1–48*	*5·9* *6·5*	*Pumping SH* [R], *N = 26* *No treatment, N = 50*	6	AAOMS Criteria: little or no pain, MMO≥35 mm, LM or PrM> 4 mm, eating normal diet & improved jaw function.	–	P-SH: 73·1% *Ctrl:36%*	**III-2**
Sato *et al.* (2001) (208)	RCoSt	146 (25)	DDwoR	9	107	–	–	*3 > – 3≤*	–	*Pumping SH* [R], *N = 59/72* *No treatment, N = 62/74*	12	AAOMS Criteria: Little/no pain & MMO≥35 mm	Patients with locking duration for <3 mo are more likely to benefit from treatment than those with locking duration for ≥3 mo.	P-SH: 75% *Ctrl: 63·5%* (ITT)	**III-3**
Sato and Kawamura (2008) (209)	PCoSt	59	DDwoR	–	59	13–61	34·95	*0·2–336* *0·03–440*	*31·6* *36·4*	*Pumping SH* [R] *+ Self-exercises, N = 23* *Pumping SH, N = 36*	12	AAOMS Criteria: Little/no pain, MMO≥35 mm	–	Overall: 69·49% P-SH+ Ex: 60·9% P-SH only: 75%	**III-2**
Sembronio *et al.* (2008) (13)	PNCoSt	33	DDwoR	2	31	21–73	41·8	0·25–24	8·5	AC + SH + UM (ACL<1, N = 8 CCL>1, N = 25)	12	VAS pain< 2, MMO >38 mm, ADL <4/16, & improved jaw function, chewing & swallowing, & eating normal diet	Higher success rate in ACL (87·5%) than CCL (68%). DR was possible only in ACL and no DR in all CCL cases.	72·7%	**III-3**

(continued)

Table 4. (*continued*)

		Participants' characteristics													
		Sample size		Gender		Age (years)		Locking duration (months)			Longest follow-up				
Study (Year)	Study design	(drop/ exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	Main interventions assessed	duration (months)	Success criteria	Study findings in relation to CL duration	% Overall success rate (ITT used)	Study design quality
Thomas *et al.* (2012) (211)	PCS	32	ACL	5	27	18–27	23	1–3	–	AC	6	Improvement in: VAS pain, VAS jaw dysfunction (chewing ability), & MMO.	–	90·6%	**IV**
Yura *et al.* (2011) (143)	PNCoSt	50	DDwoR (CCL)	5	45	12–71	Median 44	3–48	Median 4	AC (under high pressure) + CS	2	Improvement in: MMO≥40 mm, VAS pain at opening≤5 mm, & VAS pain on biting=0	–	–	**III-3**
TOTAL	**32 studies**	–	**All CL**	–	–	–	–	**0·03–109**	**9·49**	**AC**	–	–	–	**72·5%**	–
	27 studies	–	**DDwoR**	–	–	–	–	**0·03–109**	**10**	**AC**	–	–	–	**65·2%**	–
	7 studies	–	**ADP**	–	–	–	–	**0·23–84**	**9·54**	**AC**	–	–	–	**91·4%**	–

RCT, randomised controlled trial; Q-RCT, quasi-randomised controlled trial; PCoSt, prospective comparative study; RCoSt, retrospective comparative study; PCCSt, prospective case–control study; PNCoSt, prospective non-comparative study; RNCoSt, retrospective non-comparative study; FSt, follow-up study; PCS, prospective case series; RCS, retrospective case series; BACS, before-after case series; BACR, before-after case report; CR, case report; AAOMS, American association of oral and maxillofacial surgery; AC, arthrocentesis; ACL, acute closed lock; ADP, anchord disc phenomeon; ARS, anterior repositioning splint; AS, arthroscopy; CBT, cognitive behavioural therapy; CCL, chronic closed lock; Ch, chronic; CMI, CranioMandibular Index; cMMO, comfortable 'painless' maximum mouth opening; CS, corticosteroids; Ctrl, control; DAL, daily activity limitation; DDwoR, disc displacement without reduction; DR, disc recapturing; drop, drop-outs; dy, day; exc, excluded; Exr, exercises; F, female; GA, general anaesthesia; ID, internal derangement; IL, intermittent locking; ITT, intention-to-treat analysis; IV, intravenous; j, joint; LA, local anaesthesia; LDF, limitation in daily function; LM, lateral movement; M, male; Med, medication; MFIQ, mandibular function impairment questionnaire; mm. millimetres; MMO, maximum mouth opening; mo, month; MR, muscle relaxant; MRI, magnetic resonance imaging; N, number of patients; NS, non-surgical; NSAIDs, non-steroidal anti-inflammatory drugs; OS, open surgery, PM, protrusive movement; PrM, pumping manipulation; PS, pivot splint; P-SH, pumping sodium hyaluronate; PT, physiotherapy; Reh, rehabilitation; S&S, signs and symptoms; SD, standard deviation; SG, successful group; SH, sodium hyaluronate; SM, self-management; SS, stabilisation splint; Sub-ac, sub-acute; Tx, tenoxicam; UG, unsuccessful group; UM, unlock manipulation; VAS, Visual Analogue Scale; W, Wilkes staging of internal derangement; wk, week; yr, year.

[a]Separate data provided are for CL patients only.

[b]Follow-up report of Nitzan and Dolwick (1991) study (9).

[c]Study data are also provided in other tables according to main treatment modality assessed.

[d]Studies seem to share part of their CL study sample in multiple publications.

[e]Follow-up study of Murakami *et al.* (1995) study (12).

[f]DDwoR patients in study sample ≥ 80%.

[g]Excluded from the total due to intervention difference.

Table 5. Characteristics of included arthroscopy (AS) studies

		Participants' characteristics												
		Sample size (drop/ exc)		Gender		Age (years)		Locking duration (months)			Longest follow-up duration (months)			
Study (Year)	Study design		Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	Main interventions assessed		Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT used)	Study design quality
Casares *et al.* (1999) (59)	PNCoSt	26	ADP (static disc)	–	26	20–56	37·5	3–24	7·8	AS	10	Pain free & MMO>30 mm	A relationship between CL duration and adhesions type was found	92·3%	**III-3**
Chen *et al.* (2010) (212)	PCS	352	W: III–IV 343/419 j[a]	50	302	15–72	33·3	2–240	24·1	AS coblation with disc suturing	3	Improvement in S&S and MRI findings	–	92·8%	**IV**
Clark *et al.* (1991) (213)	PNCoSt	18	17 DDwoR & 1 ADP	1	17	15–52	27	Sub-ac =3–9 to ch>9	12·4 ± 12	AS	21–30	Improvement in: VAS pain, jaw function, & MMO	Locking duration was not a predictor of AS success or failure.	83·3%	**III-3**
Dimitroulis (2002) (120)	PCS	56	49 DDwoR	9	47	15–70	36	1·5–12	3·4	AS + CS	1·5	Improvement in: VAS pain, MMO, & patient satisfaction	–	66%	**IV**
Furst *et al.* (2001) (214)	RCT	32	26 DDwoR	2	30	–	–	–	42·5 ± 36·1 18·5 ± 17 61·4 ± 61·3 63·3 ± 79·7	AS only AS + bupivacaine AS + morphine AS + bupivacaine & morphine	0·07	Pain reduction	–	–	**II-2**
Gateno (1994) (196)[b]	CR	1	CL	–	1	–	24	3	–	AS	–	No pain & MMO>40 mm	–	-	**IV**
Go *et al.* (1996) (215)	PCS	10	CL	–	10	20–59	31·2	0·75–3·75	2·2	AS	4–68	No or mild pain & MMO>30 mm	–	80%	**IV**
Hamada *et al.* (2003) (218)[c]	PNCoSt	69 (39)	DDwoR (CCL)	5	25	20–64	41·6	1–72	15·5	AS (2nd VGIR) + SH, N = 30	–	VAS pain<20 & <60% of preoperative level, increased cMMO, & cMMO≥38 mm	–	60% (no ITT)	**III-3**
Hamada *et al.* (2005) (217)[c]	PNCoSt	68 (20)	DDwoR (CCL)	9	39	20–70	42·8	2–127	Median 9·5	AS (2nd VGIR), N = 48	3–36	VAS pain=0 & cMMO≥38 mm	No significant correlation between duration of symptoms and treatment outcome with fibrous adhesion.	62·5% (no ITT)	**III-3**
Hamada *et al.* (2006a) (219)[c]	PNCoSt	64 (3)	DDwoR (CCL)	9	52	19–70	40·7	2–127	Median 7	AS (1st VGIR), N = 64	12	VAS pain<20 & <60% of preoperative level, increased cMMO, & cMMO≥38 mm	No significant difference in the duration of symptoms between SG 8 (2–108) and UG 5 (2–127).	72·1% (no ITT)	**III-3**

(continued)

Table 5. (*continued*)

		Participants' characteristics												
		Sample size		Gender		Age (years)		Locking duration (months)			Longest follow-up			
Study (Year)	Study design	(drop/ exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	Main interventions assessed	duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT used)	Study design quality
Hamada *et al.* (2006b) (106)[c]	PNCoSt	36 (2)	DDwoR (CCL)	6	30	27–59	46·5	IQ 3–17	Median 7·5	AS (VGIR), N = 36	–	VAS pain<20 & <60% of preoperative level, increased cMMO, & cMMO≥38 mm	No significant difference in the duration of symptoms between SG 8 (5·5–17) and UG 6 (3–8).	69·4% (no ITT)	**III-3**
Hamada *et al.* (2008a; 2008b) (216, 220)[c]	PNCoSt	58 (2)	DDwoR (CCL)	8	48	29–56	Median 46	IQ 3–12·5	Median 7	AS (1st VGIR), N = 56	6–13	VAS pain<20 & <60% of preoperative level, increased cMMO, & cMMO≥38 mm	No significant difference in duration of symptoms between SG 8 (5·8–12·3) and UG 6 (3–8).	67·9% (no ITT)	**III-3**
Holmlund *et al.* (2001) (121)	RCT	22 (2)	CCL	2	18	22–53	34·5	*2–24* 2–60	*8·5* 20·5	*OS, N = 10* AS, N = 10	12	VAS pain<20, MMO>35 mm, PrM>5 mm, MFIQ<7	No difference in improvement between patients having <6 mo & >6 mo symptoms' duration in both groups.	*OS: 70%*, AS: 50% (no ITT)	**II-2**
Kim *et al.* (2009) (221)	PCS	15	DDwoR	3	12	15–64	32·1	3–72	21·4	AS (ultrathin) + SH	10–40	VAS pain ≤20 & <60% of preoperative level, increased MMO≥5 mm, & no recurrence of symptoms.	–	80%	**IV**
Kondoh *et al.* (2003a) (222)[c]	PNCoSt	20	DDwoR	4	16	20–69	44	1–72	17·4	AS (VGIR) + SH	6	VAS pain<20 & <60% of preoperative level, & cMMO>38 mm	–	80%	**III-3**
Kumagai *et al.* (2010) (223)[c]	PNCoSt	45	DDwoR (CCL)	13	32	24–65	36·5	More than 3	–	AS (VGIR), N = 45	2–23	VAS pain <20 and <60% of preoperative level, & cMMO≥38 mm	–	71·1%	**III-3**
Kurita *et al.* (1998) (134)	PNCoSt	14	DDwoR	1	13	20–72	44·6	9–163	24·9	AS + CS	13–66	AAOMS & IAOMS criteria: No or slight dysfunction (MMO≥35 mm, VAS≤33)	No difference in locking duration between SG 27 (9–163) & UG 10 & 14 mo.	85·7%	**III-3**
Lewis (1987) (224)	CR	1	DDwoR (CCL)	–	1	–	48	12	–	AS	0·25	Little pain & MMO=35 mm	–	-	**IV**

(continued)

Table 5. (*continued*)

Study (Year)	Study design	Participants' characteristics: Sample size (drop/ exc)	Study diagnosis	Gender: M	Gender: F	Age (years): Range	Age (years): Mean	Locking duration (months): Range	Locking duration (months): Mean ± SD	Main interventions assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT used)	Study design quality
Machon *et al.* (2012) (225)	PNCoSt	50	Chronic DDwoR	–	–	–	–	(<12 – >12)	–	AS, N = 50 (<12 mo, N = 28; >12 mo, N = 22)	6	No or minimal pain (0 or 1 out 6), & MMO>35 mm	Higher success rate (89%) in patients with shorter duration of symptoms <12 mo than the rate (72%) in those with longer symptoms' duration >12 mo.	82%	**III-3**
Murakami (1990) (226)	PCS	32	DDwoR	4	28	14–70	39	1–18	6·6	AS	2–60	Little or no complaints and good jaw opening & function	Patients with ≥6 mo locking duration had poor response to AS. Higher pain relief in patients with <6mo symptoms' duration as compared to patients with longer duration.	84·4%	**IV**
Murakami *et al.* (1995) (12)[b]	PCoSt	108	W: III (CL)	20	88	–	31·43	–	*5·0 ± 8·8* *5·6 ± 6·9* 6·8 ± 10·2	*NS: Med. or UM or PS, N = 63* *AC, N = 20* AS, N = 25	6	VAS pain<20, MMO>38 mm, LM & PrM> 6 mm, & improved DAL	Patients with >7mo locking duration not respond to AC	*NS: 55·6% (Med:15·9% UM:18·9% PS: 33·3%)* *AC: 70%* AS: 91%	**III-2**
Nakaoka *et al.* (2009) (227)	PNCoSt	56 (16)	CCL	–	–	IQ 29–55	Median 43	IQ 5–12	Median 7	AS (2nd VGIR), N = 40	–	VAS pain<20 & <60% of preoperative level, increased cMMO, & cMMO≥38 mm	No significant difference in symptoms' duration between SG 8 (5·5–12·5) & UG 5 (3–12).	72·5% (no ITT)	**III-3**
Nitzan *et al.* (1990) (228)	PCS	20	8 DDwoR	–	20	19–40	26·3	6–96	34·8 ± 26·04	AS + CS	6–24	Improvement in: VAS Pain, VAS jaw dysfunction, & MMO	–	DDwoR 87·5%	**IV**
Ohnuki *et al.* (2003) (229)	RNCoSt	43	40 DDwoR	4	39	15–68	41·4	–	12·6 ± 20·1	AS + CS + SH	12	VAS pain<20 & MMO>38 mm	No statistically significant difference in locking duration between SG (14·2 ± 22·2) and UG (7·9 ± 11·4).	74·4%	**IV**
Ohnuki *et al.* (2006) (137)[b]	RCoSt	85	DDwoR	9	76	13–73	41·8	–	*5·1 ± 6·8* *10·4 ± 13·1* *6·6 ± 8* 14·2 ± 22·2	*SS, N = 11* *PM, N = 33* *AC, N = 9* AS, N = 32	12	VAS pain<20 & MMO>38 mm	No significant difference between SGs regarding locking duration.	*SS: 12·9%* *PM: 44·6%* *AC: 22%* AS: 100%	**III-3**

(continued)

Table 5. (*continued*)

Study (Year)	Study design	Participants' characteristics: Sample size (drop/ exc)	Study diagnosis	Gender: M	Gender: F	Age (years): Range	Age (years): Mean	Locking duration (months): Range	Locking duration (months): Mean ± SD	Main interventions assessed	Longest follow-up duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT used)	Study design quality
Politi *et al.* (2007) (230)[b]	RCT	20	DDwoR (CCL)	6	14	25–67	42·8	*6–27* 8–24	*15·1* 14·7	*OS, N = 10* AS + SH, N = 10	12	VAS pain≤20, MMO≥35 mm, PrM>5 mm, MFIQ ≤ 7	–	*OS: 80%*, AS: 70%	**II-2**
Saitoa *et al.* (2010) (231)	PNCoSt	64 (3)	CCL	9	52	19–70	40·7	2–127	Median 7	AS (VGIR)	3–40	VAS pain<20 & <60% of preoperative level, & cMMO≥38 mm	No statistically significant difference in locking duration between SG 8 (2–108) and UG 5 (2–127).	72·1% (no ITT)	**III-3**
Sanders (1986) (232)	PCS	21[d]	DDwoR	1	20	11–49	27·1	1–120	19·62 ± 24·2	AS + CS	7–10	Little pain & improved MMO	–	95·2%	**IV**
Sanroman (2004) (58)[b]	PCoSt	26 (2)	ADP	6	20	16–35	24·3	0·25–3	1·21	AS + SH, N = 16 *AC + SH, N = 8*	24–36	VAS pain≤ 2 of 15, MMO≥35 mm, LM≥7 mm & PrM≥10 mm	–	100%	**III-2**
Schiffman *et al.* (2007; 2013) (168, 169)[b]	RCT	108 (12)	W: III–IV (DDwoR)	8	98	–	31·72	Non-ch<6 – Ch≥6	–	*SM + Med., N = 29* *SS + PT + CBT, N = 25*; AS + CS, N = 26; *OS, N = 26*	60	Self-reported success (Patient satisfaction)	–	*SM: 72%* *Reh: 81%* AS: 76·2% *OS: 83·3%* (ITT)	**II-1**
Yoshida *et al.* (2008) (233)	PCS	55	DDwoR	–	–	–	–	2–10·5	4·25	AS (thin fibre & laser)	3	Improvement in: VAS pain, MMO, & patient satisfaction.	–	94·5%	**IV**
Zhang *et al.* (2009) (234)	RNCoSt	1506	W: III–IV 1479[a]	281	1225	12–73	29·79	0·5–96	6·97	AS Adhesion group, N = 490; Non-adhesion group, N = 1230	–	–	Locking duration was significantly higher in adhesion (6·97 ± 8·38) than non-adhesion (5·42 ± 4·34) group	–	**IV**
TOTAL	**32 studies**	–	**All CL**	–	–	–	–	**0·25–163**	**19·04**	**AS**	–	–	–	**79%**	–
	30 studies	–	**DDwoR**	–	–	–	–	**0·5–163**	**20·37**	**AS**	–	–	–	**77·7%**	–
	2 studies	–	**ADP**	–	–	–	–	**0·25–24**	**4·51**	**AS**	–	–	–	**96·2%**	–

RCT, randomised controlled trial; Q-RCT, quasi-randomised controlled trial; PCoSt, prospective comparative study; RCoSt, retrospective comparative study; PCCSt, prospective case–control study; PNCoSt, prospective non-comparative study; RNCoSt, retrospective non-comparative study; FSt, follow-up study; PCS, prospective case series; RCS, retrospective case series; BACS, before-after case series; BACR, before-after case report; CR, case report; AAOMS, American association of oral and maxillofacial surgery; AC, arthrocentesis; ACL, acute closed lock; ADP, anchord disc phenomeon; ARS, anterior repositioning splint; AS, arthroscopy; CBT, cognitive behavioural therapy; CCL, chronic closed lock; Ch, chronic; CMI, CranioMandibular Index; cMMO, comfortable 'painless' maximum mouth opening; CS, corticosteroids; Ctrl, control; DAL, daily activity limitation; DDwoR, disc displacement without reduction; DR, disc recapturing; drop, drop-outs; dy, day; exc, excluded; Exr, exercises; F, female; GA, general anaesthesia; ID, internal derangement; IL, intermittent locking; ITT, intention-to-treat analysis; IV, intravenous; j, joint; LA, local anaesthesia; LDF, limitation in daily function; LM, lateral movement; M, male; Med, medication; MFIQ, mandibular function impairment questionnaire; mm. millimetres; MMO, maximum mouth opening; mo, month; MR, muscle relaxant; MRI, magnetic resonance imaging; N, number of patients; NS, non-surgical; NSAIDs, non-steroidal anti-inflammatory drugs; OS, open surgery, PrM, protrusive movement; PM, pumping manipulation; PS, pivot splint; PT, physiotherapy; Reh, rehabilitation; S&S, signs and symptoms; SD, standard deviation; SG, successful group; SH, sodium hyaluronate; SM, self-management; SS, stabilisation splint; Sub-ac, sub-acute; UG, unsuccessful group; UM, unlock manipulation; US: ultrasound; VAS: Visual Analogue Scale; VGIR: visually guided irrigation; W, Wilkes staging of internal derangement; wk, week; yr, year.

[a]DDwoR patients in study sample ≥ 80%.

[b]Study data are also provided in other tables according to main treatment modality assessed.

[c]Studies seem to share part of their CL study sample in multiple publications.

[d]Separate data provided are for CL patients only.

Table 6. Characteristics of included open surgery (OS) studies

		Participants' characteristics													
		Sample size		Gender		Age (years)		Locking duration (months)			Longest follow-up				
Study (Year)	Study design	(drop/ exc)	Study diagnosis	M	F	Range	Mean	Range	Mean ± SD	Main interventions assessed	duration (months)	Success criteria	Study findings in relation to CL duration	Overall success rate% (ITT)	Study design quality
Holmlund *et al.* (2001) (121)[b]	RCT	22 (2)	CCL	2	18	22–53	34·5	2–24 *2–60*	8·5 *20·5*	OS (Discectomy), N = 10 *AS, N = 10*	12	VAS pain<20, MMO>35 mm, PrM>5 mm, MFIQ<7	No difference in improvement between patients having <6mo & >6mo symptoms' duration in both groups.	OS: 70%, *AS: 50%* (no ITT)	**II-2**
Kondoh *et al.* (2003b) (235)	PCS	7[a]	DDwoR (CL)	–	7	20–51	32·57	14–42	24·57 ± 9·22	Disc Reshaping without repositioning	60	Improvement in: pain & MMO	–	DDwoR 100%	**IV**
Ozkan *et al.* (2012) (236)	RNCoSt	46[a]	Uni/bilat. DDwoR	8	38	18–63	34·7	–	22·9	High condylectomy ± disc repositioning, discectomy, or osteoplasty.	18–156	Improvement in: pain, MMO, & Patient satisfaction	–	–	**IV**
Politi *et al.* (2007) (230)[b]	RCT	20	DDwoR (CCL)	6	14	25–67	42·8	6–27 *8–24*	15·1 *14·7*	OS (High condylectomy & disc repositioning), N = 10 *AS + SH, N = 10*	12	VAS pain≤20, MMO≥35 mm, PrM>5 mm, MFIQ ≤ 7	–	OS: 80%, *AS: 70%*	**II-2**
Schiffman *et al.* (2007; 2013) (168, 169)[b]	RCT	108 (12)	DDwoR (W: III–IV)	8	98	–	31·72	Non–ch<6 – ch≥6	–	*SM + Med, N = 29* *SS + PT + CBT, N = 25* *AS + CS, N = 26* OS (Arthroplasty), N = 26	60	Self-reported success (Patient satisfaction).	–	*SM: 72%* *Reh: 81%* *AS: 76·2%* OS: 83·3% (ITT)	**II-1**
Turley (1993) (237)	CR	1	DDwoR (CL)	–	1	–	23	5	–	Arthroplasty (discectomy with sialistic implant replacement)	72	MMO≥40 mm, improved function, & stable occlusion	–	–	**IV**
Widmark *et al.* (1997) (238)	RCS	20 (4)	DDwoR	1	15	21–71	37	18–150	48	Discectomy	6–42	Improvement in: VAS Pain & jaw function (CMI)	–	88% (no ITT)	**IV**
Zhang *et al.* (2010) (239)	PNCoSt	81	W: III–IV 69[c]	23	58	23–74	38·5	0·5–60	12·06	Disc repositioning by bone anchores	0·25	DR on MRI	–	96·3%	**III-3**
TOTAL	**8studies**	–	**DDwoR**	–	–	–	–	**0·5–150**	**21·86**	**OS**	–	–	–	**86·3%**	–

RCT, randomised controlled trial; Q-RCT, quasi-randomised controlled trial; PCoSt, prospective comparative study; RCoSt, retrospective comparative study; PCCSt, prospective case–control study; PNCoSt, prospective non-comparative study; RNCoSt, retrospective non-comparative study; FSt, follow-up study; PCS, prospective case series; RCS, retrospective case series; BACS, before-after case series; BACR, before-after case report; CR, case report; AC, arthrocentesis; ACL, acute closed lock; ARS, anterior repositioning splint; AS, arthroscopy; CBT, cognitive behavioural therapy; CCL, chronic closed lock; Ch, chronic; CMI, CranioMandibular Index; cMMO, comfortable 'painless' maximum mouth opening; CS, corticosteroids; Ctrl, control; DAL, daily activity limitation; DDwoR, disc displacement without reduction; DR, disc recapturing; drop, drop-outs; dy, day; exc, excluded; Exr, exercises; F, female; GA, general anaesthesia; ID, internal derangement; IL, intermittent locking; ITT, intention-to-treat analysis; IV, intravenous; j, joint; LA, local anaesthesia; LDF, limitation in daily function; LM, lateral movement; M, male; Med, medication; MFIQ, mandibular function impairment questionnaire; mm. millimetres; MMO, maximum mouth opening; mo, month; MR, muscle relaxant; MRI, magnetic resonance imaging; N, number of patients; NS, non-surgical; NSAIDs, non-steroidal anti-inflammatory drugs; OS, open surgery, PrM, protrusive movement; PM, pumping manipulation; PS, pivot splint; PT, physiotherapy; Reh, rehabilitation; S&S, signs and symptoms; SD, standard deviation; SG, successful group; SH, sodium hyaluronate; SM, self-management; SS, stabilisation splint; Sub-ac, sub-acute; UG, unsuccessful group; VAS, Visual Analogue Scale; W, Wilkes staging of internal derangement; wk, week; yr, year.

[a]Separate data provided are for CL patients only.

[b]Study data are also provided in other tables according to main treatment modality assessed.

[c]DDwoR patients in study sample ≥ 80%.

Summary of intervention effects in relation to locking duration. Mandibular manipulation (MM): Nineteen included studies used different unlock manipulation (UM) techniques on DDwoR patients with a mean locking duration of 9 months (range: 0·03–180 months). The most commonly used UM technique is Farrar's technique (2) (described in Appendix S7 'Figure'), and the most commonly used splint after recapturing the displaced disc is the anterior repositioning splint (ARS). The UM success rate was variable ranging from 9% to 100% (mean: 68%). Pumping manipulation (PM) was used in six studies on DDwoR patients with a mean locking duration of 8 months (range: 0·07–120 months) and had comparable success rate to UM. Among all the included studies on MM, nine studies used post-operative imaging to assess disc recapturing with a mean success rate of 44% (range: 4–100%) (Table 1).

Self-management (SM) and physiotherapeutic (PT) interventions: Self-management involving self-exercises with medication and self-care instructions and education was used on DDwoR patients in seven studies with a mean success rate of 66%. Only two studies evaluated the jaw stretching exercises by physiotherapists as the sole treatment on patients with DDwoR having locking duration ranging from several weeks to several years with high success rate (Table 2).

Splint therapy: Occlusal splints were used either as a main treatment strategy or as an adjunct treatment to other interventions in the management of DDwoR. In 12 studies, different types of splints were used independently as the sole treatment for DDwoR patients with a mean locking duration of 16 months (range: 0·25–192) with a variable success rate ranging from 13% to 100% (mean: 60%). The adjunctive use of splints with other conservative interventions was employed by 10 studies with DDwoR patients who had a mean locking duration of 10 months resulting in a mean success rate of 84% (range: 71–100%) (Table 3).

Arthrocentesis (AC): Arthrocentesis was used in 32 studies on patients with a mean CL duration of 10 months (range: 0·03–109 months) with a success rate ranging from 22% to 100% (mean: 73%). The AC success rate was, however, higher in ADP (91%) than DDwoR (65%) studies (Table 4).

Arthroscopy (AS): Thirty-two included studies used arthroscopy on patients with a mean CL duration of 19 months (range: 0·25–163 months) with a success rate ranging from 50% to 100% (mean: 79%) (Table 5).

Open surgery (OS): Open joint surgery was used in eight studies on CL patients with a mean locking duration of 22 months (range: 0·5–150 months) with a success rate ranging from 70% to 100% (mean: 86%) (Table 6).

Quality of included studies. Most of the included studies were of poor quality and had various methodological weaknesses in their design. Specifically, most were either uncontrolled studies or had incompletely defined or controlled for other prognostic factors that may influence treatment outcome. The level of evidence was, therefore, generally of a low grade (III–IV).

Discussion

There was considerable heterogeneity among the studies included in the systematic review of locking duration. Although the studies were grouped based on their treatment modality, there were considerable variations in the following: study design, diagnostic and inclusion criteria, intervention delivery, techniques and combinations, outcome measures, success criteria and follow-up periods. These findings were, however, expected before undertaking this review as one of the aims of this paper was to investigate whether there is any relationship between treatment outcome and CL duration rather than to identify the scientific evidence for clinical effectiveness of interventions used in managing DDwoR. The latter is best accomplished through a systematic review of randomised clinical trials in DDwoR management which is nearing completion (15).

To the best of the authors' knowledge, this is the first comprehensive and systematic review that examines the effect of duration of locking on treatment outcome. There were, however, some limitations in the review process. A systematic search was performed in only one database for English-language publications. Searching multiple databases without language restrictions may have yielded more results. Furthermore, there were large number of CL studies that did not report the duration of symptoms in their study sample and so we had to exclude them. This was also true for many surgical trials including CL patients' not-responding to non-surgical interventions

for more than 3 or 6 months (CCL). Nevertheless, the large number of studies included in this review represented all of the various treatment modalities used for acute and chronic CL management.

The quality assessment of the included studies was based solely on study design. This is a convenient way to summarise the studies according to their designs (20) but does not completely illustrate the strength of the evidence, as study design is only one of several components contributing to this.

The studies included were mostly uncontrolled and did not examine the placebo effect or the possible symptomatic resolution over time (68, 240) and only a few attempted, with adequate statistical power, to analyse the treatment effects by duration of symptoms on a large sample size. This is most likely due to difficulty in recruiting patients with a DDwoR 'acute/chronic' diagnosis that may take several years (168, 207). Given the low incidence of DDwoR among TMDs, a multicentre RCT may be the most appropriate manner by which to examine the effect of CL duration on the outcome of initial non-invasive simple treatments in DDwoR. To organise such a trial, consensus would need to be reached both on the definition of acute and chronic DDwoR to allow stratification of treatment groups, and on the standardised multidimensional outcome measures that are of importance in DDwoR. In the studies included, the most widely used outcomes to assess DDwoR improvement were pain intensity and mouth opening. In addition to these, the authors would suggest to include functional limitation, multidimensional pain assessment and some form of quality of life assessment (241–246). Standardised, but 'pragmatic', success criteria are also needed to yield more rigorous research (169).

Given the clinical and/or statistical heterogeneity of studies included, the main study findings of treatment effect in relation to CL duration were summarised by each individual study in the Tables 1–6. Overall, the evidence for the effect of locking duration on treatment outcome is contradictory and inconsistent. It may seem that the degree of intra-articular pathological changes is more important than the locking duration but this could not be established.

In general, there were a limited number of studies using clear and robust diagnostic criteria, which attempted to examine treatment effects by duration of symptoms. What we are left with is comparisons between interventions targeting many different assumed causative factors of which locking duration forms only a small part. It is doubtful that a single prognostic factor determines successful outcome in CL management, and it has to be acknowledged that it is likely that several, as yet undefined, factors influence the outcome of CL management including not only the biomedical factors but also the patients' psychosocial phenotype (247-252). It does, however, seem entirely reasonable, within the ethos of modern medicine, and consistent with recent guidance on the management of TMDs (253) that until we have a better understanding of these factors, we should avoid invasive interventions in the initial phases of CL management. Following on from this, it makes intuitive sense, therefore, to consider a stepped 'timely management' approach to treat patients with symptomatic CL (169), starting with the simplest, least invasive intervention (e.g. self-management with 'early' manipulation) and escalating the treatment only if needed (e.g. rehabilitation by splint and/or physiotherapy) and to defer surgery (e.g. first-line arthrocentesis then arthroscopy) for 6 months or more. Differences in DDwoR patients' complaints such as the presence/absence of pain or mouth opening limitation may affect the necessity for a specific treatment, but this stepped approach is, in general, the most realistic.

The simplest, least costly, quickest, and non-invasive approach that can be easily employed (by general practitioners) with symptomatic DDwoR patients at the first point of contact is the 'unlock' mandibular manipulation that has some initial evidence to support its efficacy in 'early' intervention in DDwoR. Much about this intervention, however, still remains unanswered as there was no consensus on: technique of manual manipulation applied, who delivers the intervention (patient or clinician), and what, if any, post-treatment splint type is further needed to ensure the long-term successful 'stable' results. Further research is, therefore, required in this group of interventions and should also include pre- and post-operative MRI to assess the UM effect on disc position (156). In this review, the time after which the UM should not be attempted could not be determined (i.e. time frame for 'disc recapturing' possibility). Nevertheless, this treatment modality can aid both diagnosis and treatment and unlikely to have adverse effects. There are, therefore, few significant contraindications to justify postponement of attempting to treat DDwoR through this simple approach.

Conclusion

In DDwoR management, several factors can predict the treatment outcomes, one of which is the duration of locking. The effect of locking duration on treatment outcome, however, remains a matter of controversy in the literature. Despite that, clinical staging of DDwoR based on locking duration is one of the few factors that can be easily addressed from patient's history especially in acute closed lock as the patients can usually remember the sudden onset of locking of short duration. Future diagnostic classifications for DDwoR should seek to address and define the acute versus the chronic period in relation to locking duration (i.e. time since DDwoR onset). This classification may then advance understanding and help target the available therapies more effectively. Until we have a better understanding, a stepped approach to CL management is indicated, starting with the simplest, cheapest, quickest, and most practical first diagnostic and treatment approach for this condition at the first given opportunity in the patient's healthcare journey. This intervention based on current evidence would seem to be an 'unlock' mandibular manipulation.

Conflicts of interest

No ethical approval required. This study funded by the Higher committee for education development in Iraq (HCED) and is undertaken as a part of postgraduate PhD clinical program in the Department of Oral and Maxillofacial Surgery, School of Dental Sciences, Newcastle University, UK. The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1 Medline search strategy.

Appendix S2 A modified designation of levels of evidence.

Appendix S3 Study flow diagram.

Appendix S4 Diagnostic criteria for DDwoR.

Appendix S5 Summary of studies' definition of acute/chronic closed lock stages according to locking duration.

Appendix S6 Description of reviewed interventions.

Appendix S7 Farrar's manipulation technique to 'unlock' the jaw.