Received: 6 August 2021 | Accepted: 15 September 2021

DOI: 10.1111/jcpe.13563

SYSTEMATIC REVIEW

Journal of Clinical Periodontology WILEY

Efficacy of tooth splinting and occlusal adjustment in patients with periodontitis exhibiting masticatory dysfunction: A systematic review

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Funding information
the University of Bonn; Universität Basel; Charité—Universitätsmedizin Berlin

Abstract

Objective: To evaluate the efficacy of tooth splinting (TS) and occlusal adjustment (OA) compared to no TS or OA in patients with periodontitis exhibiting masticatory dysfunction.

Material: The primary outcome criterion was tooth loss (TL), and the secondary outcome parameters were change in probing pocket depth (PPD), change in clinical attachment level (CAL), tooth mobility (TM), and patient-reported outcome measures (PROMs). Literature search was performed on three electronic databases (from 01/1965 to 04/2021) and focused on clinical studies with at least 12 months follow-up.

Results: From a total of 1515 publications, 51 articles were identified for full-text reading, of which 2 retrospective case series on TS with low risk of bias and 1 randomized and 2 prospective studies on OA with unclear risk of bias were included. For TS, synthesis of data showed that in 72 patients, 26 out of 311 teeth (weighted mean incidence of TL 8.4%) and 156 out of 1541 teeth with no TS (weighted mean incidence of TL 10.1%) were lost over 2 years following non-surgical periodontal therapy. The randomized controlled clinical trial (RCT) indicated CAL gain for teeth with OA compared to no OA. For the effect of OA on TL, PPD, and TM, heterogeneous data were retrieved from the included studies.

Conclusions: Within the limitations of this review and based on a low level of evidence, it is concluded that TS does not improve survival of mobile teeth in patients with advanced periodontitis. OA on teeth with mobility and/or premature contacts may lead to improved CAL, while the effect of OA on the remaining periodontal parameters remains unclear.

KEYWORDS
occlusal adjustment, occlusal equilibration, periodontal splinting, periodontitis, secondary occlusal trauma, tooth survival

Clinical Relevance

Scientific rationale for this analysis: The effects of tooth splinting (TS) and occlusal adjustment (OA) as therapeutic adjuncts have not been systematically appraised when considering periodontal healing and tooth loss (TL) in patients with periodontitis and masticatory dysfunction.

Principal findings: Evidence on the effects of TS and OA in patients with stage IV periodontitis is scarce. Based on two retrospective case series, over at least 2 years, the mean TL was 8.4% for TS and 10.1% for no TS. There was limited information for a beneficial adjunctive effect of OA on clinical attachment level gain based on one randomized controlled clinical trial.

Practical implication: TS may be performed as an adjunctive intervention for teeth with a progressive increase in tooth mobility in order to improve the patient's chewing capabilities. OA is suggested as selective spot grinding at teeth exposed to traumatic occlusal forces with the intent of equalizing occlusal stress and eliminating deflective occlusal contacts.

1 | INTRODUCTION

Periodontitis is an infectious and inflammatory chronic disease leading to the destruction of tooth-supporting structures (Meyle & Chapple, 2015). If left untreated, loss of periodontal attachment, indicated by increased probing pocket depths (PPD) and radiographic alveolar bone loss (BL), will continue. Clinical signs and symptoms of advanced disease progression have been classified as stage IV periodontitis and include tooth loss (≥5 teeth due to periodontitis), increased tooth mobility (TM), tooth migration, and impaired masticatory function (Jepsen et al., 2018; Papapanou et al., 2018; Tonetti et al., 2018). Before establishing any anti-infective therapy with biofilm control in a patient with periodontitis, TM cannot be used as valid a priori indicator for tooth prognosis. Associated with the inflammatory changes in periodontal tissue, the adaptive capacity of the affected site to withstand occlusal forces can be exceeded, leading to traumatic occlusal forces. The latter has been defined as any occlusal force resulting in injury of the teeth and/or periodontal attachment apparatus (Jepsen et al., 2018). In addition to increased TM and tooth migration, signs of traumatic occlusal forces comprise fremitus (vibration perceptible on palpation when the teeth come into contact), occlusal discrepancies, wear facets, tooth fracture, thermal sensitivity, discomfort or pain on chewing, and/or radiographic indicators such as widened periodontal ligament space, root resorption, and cemental tears/hypercementosis (Fan & Caton, 2018). Depending on the amount of attachment loss and the disease progression, the threshold to withstand occlusal forces can vary and tooth mobility can increase. In an attempt to distinguish between traumatic occlusal forces applied on teeth with normal periodontal support and normal or traumatic occlusal forces applied on teeth with reduced support, the terms primary and secondary occlusal trauma are used (Armitage, 1999; Fan & Caton, 2018; Ishikawa et al., 1999; Jepsen et al., 2018).

In the first phase of contemporary comprehensive periodontal therapy, occlusal adjustment (OA) is considered as an adjunctive measure to anti-infective therapy and is defined as reshaping the occluding tooth surfaces by selective grinding to create a harmonious contact relationship between maxillary and mandibular teeth (American Academy of Periodontology, 2001). The analogous definition with modification of the occlusal form of the teeth with the intent of equalizing occlusal stress, producing simultaneous occlusal contacts or harmonizing cuspal relations, addresses "occlusal equilibration", a term which historically implies adjustment of full dentitions ("The Glossary of Prosthodontic Terms: Ninth Edition," The Journal of Prosthetic Dentistry, 2017). There is ongoing debate and insufficient evidence that eliminating signs of traumatic occlusal forces influences the outcome of periodontal therapy (Glickman et al., 1961; Ramfjord & Ash Jr., 1981; Waerhaug, 1979; Nyman & Lang, 1994; Jepsen et al., 2018). It has been shown that the amount of occlusal trauma correlates with the severity of periodontal destruction (Branschofsky et al., 2011). Furthermore, tooth splinting (TS) of two or more teeth into a rigid unit to immobilize teeth with progressive mobility is considered as adjunct for patient comfort (Jepsen et al., 2018). While regenerative periodontal treatment outcomes may be improved when reducing TM (Cortellini et al., 2001), the outcome of anti-infective non-surgical periodontal therapy was not affected by TS in a case series (Kegel et al., 1979).

The aim of this systematic review (SR) was to analyse the published evidence from controlled human studies with respect to the benefit of TS and OA on teeth with increased mobility and clinical attachment loss (CAL) as well as on teeth with increased occlusal loading in patients with stage IV periodontitis.

2 | OBJECTIVE

The objective was to evaluate the efficacy of TS and OA in patients diagnosed with stage IV periodontitis characterized by masticatory dysfunction and teeth with adaptive and progressive mobility. The question was formulated as follows: "What is the benefit of (I) TS or OA during non-surgical and surgical periodontal therapy in (P) patients with periodontitis (stage IV) when compared to (C) no TS or no OA within the same patient or in a control group, with respect to (O) TL (primary outcome parameter) and/or change in PPD, CAL change, mobility, and/or patient-reported outcome measures (PROMs) (secondary outcome parameters) for a follow-up of ≥12 months evidenced by randomized controlled clinical trials (RCTs), controlled clinical trials, retrospective and prospective case–control studies, and case series?"

3 | MATERIAL AND METHODS

3.1 | Protocol and registration

For this SR, a detailed protocol according to the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) statement was designed (Liberati et al., 2009; Moher, Liberati, Tetzlaff, Altman, & Group, 2009). Subsequently, all authors critically reviewed this protocol and agreed prior to the submission to the PROSPERO database (https://www.crd.york.ac.uk/prospero/; registration number: PROSPERO ID 180402). Literature search was performed for articles published between 1965/01/01 and 2021/04/19.

3.2 | Eligibility: Inclusion and exclusion criteria for studies

3.2.1 | Population

Patients with periodontitis stage IV in conjunction with secondary occlusal trauma (Fan & Caton, 2018), masticatory dysfunction, and TM precisely explained or graded according to Miller (Miller, 1938, 1950): 0 (physiological mobility within 0.1–0.2 mm in horizontal direction measured at the crown level), 1 (increased mobility ≤1 mm in a horizontal direction), 2 (increased mobility exceeding 1 mm in a horizontal direction), and 3 (severe mobility in horizontal and vertical directions impairing tooth function) were included.

3.2.2 | Intervention

For test groups: teeth with adaptive and progressive mobility grade 2 and 3, which received TS directly to neighbouring teeth (joining of two or more teeth into a fixed unit) and/or OA in periodontitis patients subjected to non-surgical and/or surgical periodontal therapy with sustained oral hygiene control throughout the study period. TS adjacent to implants was excluded. For surgical periodontal therapy including regenerative techniques with or without adjunctive antibiotics, at least one preceding cycle of non-surgical periodontal therapy in conjunction with a subsequent healing period was mandatory (Nibali et al., 2015).

3.2.3 | Comparison

For control groups: teeth with adaptive and progressive mobility grade 2 and 3, which did not receive splinting (no TS) and/or occlusal adjustment (no OA) within the same dentition as test or in a separate group of periodontitis patients subjected to non-surgical and/or surgical periodontal therapy.

3.2.4 | Outcome

Primary outcome was TL (after ≥12 months), and secondary outcome parameters were change in CAL, PPD, and TM after ≥12 months, and PROMs. Studies reporting primary and/or secondary outcomes were considered for inclusion. Studies referring to dental trauma, primary occlusal trauma, endo-perio lesions, endodontic lesions/symptoms as well as studies reporting no reasons for TS and splinting material, or no data on tooth survival, or PPD, or CAL, or TM, or occlusal trauma, or therapeutic interventions were excluded.

Additional obligatory (study design; year of publication; total number of subjects exhibiting mobile teeth and/or masticatory dysfunction including secondary occlusal trauma; observation period; operator; funding) and facultative parameters (drop-outs; number of teeth with grade 2 and 3 adaptive and progressive mobility; age range, mean age (years); sequence of periodontal treatment (i.e., non-surgical anti-infective therapy); mean number of teeth per patient at baseline and re-examination (tooth survival rate during observation period; TSR); full-mouth mean bleeding on probing (BOP) at re-examination; BL in percentage of root length at the splinted tooth; full-mouth mean BOP at re-examination; change in mobility; full-mouth plaque index (PI) at re-examination; mean number of supportive periodontal therapy (SPT) visits; smoking history; systemic diseases) were gathered. Data on inter-maxillary contacts in the four occlusal supporting zones (premolars and molars) were considered according to Eichner with Class A (4 occlusal zones; subgroup A1 fully edentulous; A2 one jaw fully edentulous, opposing jaw with edentulous spaces; A3 both jaws with edentulous spaces), Class B (<4 occlusal zones; subgroup B1 three; B2 two; B3 one zone; B4 anterior tooth contact outside supporting zones), and Class C (no antagonistic contacts; C1 remaining teeth in both jaws, C2 in one jaw, C3 edentulous) (Eichner, 1995).

3.2.5 | Study design and duration

The included human studies comprised randomized controlled clinical trials, controlled clinical trials, retrospective and prospective case–control studies, and case-series treatment (≥10 patients in each treatment arm or at least 20 patients per test group) over a minimum observation period of 12 months.

3.3 | Information on sources and search strategy

Literature search strategy and results are outlined in Appendix S1. Publications written in English were searched in PubMed, Scopus, and the Cochrane database from 1965 to April 2021. Subsequent to the electronic literature search, titles, abstracts, and summaries were independently screened by two reviewers (Aiste Gintaute and Julia C. Difloe-Geisert) for suitability, and inter-reviewer agreement was evaluated. Full-text reading,

methodological quality assessment, and data extraction were then conducted by four independent reviewers (Julia C. Difloe-Geisert, Aiste Gintaute, Søren Jepsen. and Clemens Walter). In the case of any disagreement, resolution was brought to due structured discussion among the four reviewers, and a fifth (Nicola U. Zitzmann) and sixth reviewer (Henrik Dommisch) were included if appropriate.

3.4 | Quality assessment of the included studies

For all included studies, quality assessment was performed (Aiste Gintaute, Julia C. Difloe-Geisert) according to adopted items of the Newcastle–Ottawa Scale (Wells et al., 2011) and the Cochrane Collaboration's tool for assessing risk of bias (Higgins et al., 2011; McGuinness & Higgins, 2021).

4 | RESULTS

4.1 | Study selection

A total of 1515 records were identified through searching electronic databases after duplicates were removed (Figure 1). No additional records could be identified through other sources, including hand search. After structured screening of titles and abstracts, 1464 articles were excluded, and the examiners reached an accordance of 95% with kappa score 0.89 (Landis & Koch, 1977).

Fifty-one articles were retrieved for full-text reading, and 46 articles were then excluded from further analysis. Reasons for exclusion are outlined in Appendix S2. Among the five studies included, two were retrospective case series on TS (Sonnenschein et al., 2017; Graetz et al., 2019), while for OA, two prospective studies (Fleszar et al., 1980; Kerry et al., 1982), and one RCT were identified (Burgett et al., 1992). In the study by Sonnenschein et al. (2017), only the period of up to 7 years of observation was initially considered due to the high drop-out rate of 59% after 10 years and 90% after 15 years (Sonnenschein et al., 2017). The limited number and heterogeneity of included articles hampered performance of a meta-analysis.

4.2 | Quality assessment

4.2.1 | Tooth splinting

Quality assessment for studies on TS was based on the Newcastle–Ottawa Scale, and both publications were rated 5 (out of possible 5 stars), indicating a low risk of bias (Table 1a). The items in the Selection category (representativeness of study cohort, ascertainment of exposure) and those in the Outcome category (assessment of outcome, follow-up time, and adequacy of follow-up) were graded as

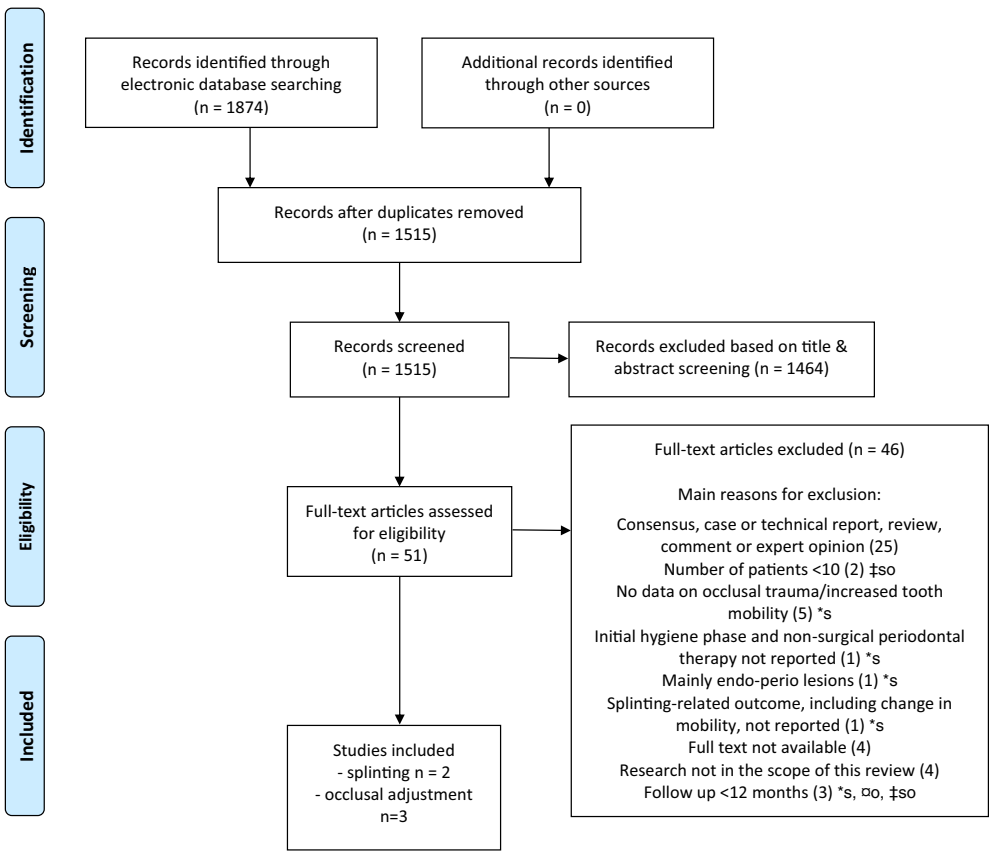


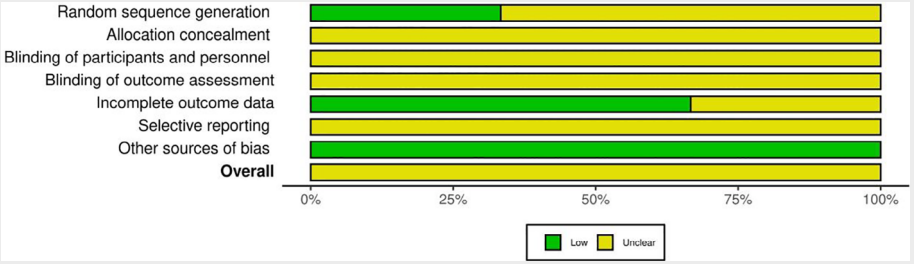
FIGURE 1 Selection process for the studies included. Procedure applied in the study: *s-splinting, ¤o-occlusal adjustment, ‡so-splinting and occlusal adjustment [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Quality assessment of included studies using the Newcastle–Ottawa Scale (a) and the Cochrane Collaboration's tool for assessing risk of bias including domain-level judgements for each result (b) and weighted bar plots of the distribution of risk-of-bias judgements within each bias domain (c)

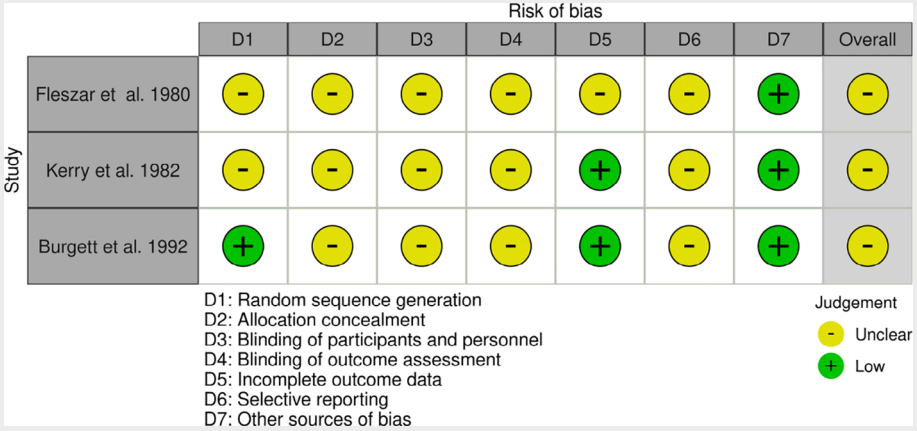
(a)

First author (year)	Selection				Comparability	Outcome			Total of stars
	Representativeness of the exposed cohort	Selection of non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur?	Adequacy of follow-up of cohorts	
Sonnenschein et al. (2017)	★	n.a.	★	n.a.	n.a.	★	★	★	5
Graetz et al. (2019)	★	n.a.	★	n.a.	n.a.	★	★	★	5

(b)



(c)



Abbreviation: n.a., not applicable.

TABLE 2 Characteristics of included studies related to splinting

First author (year) country funding	Study type study design setting[a] examiner calibration	*n* patients (*n* female) Mean age ± SD (range) *n* smokers Periodontal diagnosis Patient-related inclusion criteria tooth-related inclusion criteria	Test control	Splinting indication type and number of teeth time point material	Periodontal treatment	Follow-up (years) mean ± SD (range) time points	*n* dropouts reason
Sonnenschein et al. (2017) Germany None	Case series Retrospective University n.r. Calibrated[b]	24 patients (15 female)[c] 55.3 (37–76)[c] 1 S, 1 FS, 22 NS[c] 22 ChP, 2 AgP[c] Patient-related inclusion criteria: • ChP or AgP • APT and splint insertion ≥3 years ± 6 months before recruitment • SPT interval ≤1 year after APT Tooth-related inclusion criteria: • Splint of 2–6 anterior mandibular teeth and X-ray at splinting time ± 18 months • ≥1 tooth with increased mobility, CAL ≥5 mm and ≥50% RBL • Dental and periodontal status (PPD, CAL at 6 sites/tooth) before splinting/APT and after 3 years ± 6 months • No known oral parafunctions • No cross-bites in the front	Test: splinted teeth Control: remaining dentition	Increased mobility combined with CAL ≥5 mm at ≥1 site of the affected tooth and ≥50% RBL mandibular incisors and canines Four patients with composite adhered pontic 2 teeth (4 patients), 3 teeth (5 patients), 4 teeth (6 patients), 5 teeth (2 patients), 6 teeth (7 patients) splinted 17 splints before APT, 7 splints between FMD and completion of APT[d] composite (20 splints) or fibre glass reinforced composite splint (4 splints)[e]	APT: oral hygiene assessment, motivation and instruction, professional tooth cleaning with hand instruments, polishing, fluoride application, subgingival debridement under local anaesthesia (FMD), periodontal surgery after 3–6 months if required SPT: ≥ 1/year, oral hygiene assessment, re-motivation and re-instruction, professional tooth cleaning with hand instruments, subgingival reinstrumentation if PPD = 4 mm with BOP and/or ≥ 5 mm (PPD and CAL ≥1/year), polishing, fluoride application	n.r. (3–15[f] ± 0.5 months) 5, 7, 10, 12, 15	9 after 5 years, 6 after 7 years, 8 after 10 years, 8 after 12 years, 4 after 15 years SPT interval < 1 visit/year
Graetz et al. (2019) Germany None	Case series Retrospective University n.r. n.r.	57 patients (38 female) 48.9 ± 13.1 (23–72) 18 S, 1 FS, 38 NS 49 ChP, 8 AgP Patient-related inclusion criteria: • 18–80 years • finished APT • SPT for ≥2 years with ≥1 visit/year	Test: splinted teeth Control: non-splinted teeth	High mobility, usually combined with extensive bone loss Type of teeth: n.r. ≥ 2 teeth (to 1 tooth or to both sides) 10 teeth (9 patients) had amputation of 1–2 roots prior to splinting	APT: subgingival debridement with, if indicated, additional access flap and/or adjunctive systemic antibiotic therapy, re-evaluation after 3–6 months	11.0 ± 7.2 (2.0–32.4) Prior to APT (control group); prior to splinting (test group); end of investigation (test and control group)	n.a.

(Continues)

TABLE 2 (Continued)

First author (year) country funding	Study type study design setting[a] examiner calibration	*n* patients (*n* female) Mean age ± SD (range) *n* smokers Periodontal diagnosis Patient-related inclusion criteria tooth-related inclusion criteria	Test control	Splinting indication type and number of teeth time point material	Periodontal treatment	Follow-up (years) mean ± SD (range) time points	*n* dropouts reason
		Tooth-related inclusion criteria: • Splint of ≥2 teeth; • Annual PPD and X-ray at splint insertion or 1 year after and at last SPT visit		mean *n* of splinted teeth/patient: 4.1 ± 2.4 (1–11) mean splints/patient: 1.7 ± 1.0 (1–5) Splinting during or after APT Composite or glass-fibre/metal-reinforced composite splint	SPT: oral hygiene re-motivation and re-instruction, professional tooth cleaning with subgingival reinstrumentation of residual pockets and polishing by a dental auxiliary; individualized intervals of 3–12 months; if necessary surgery with or without systemic adjunct antibiotic therapy		

Abbreviations: AgP, aggressive periodontitis; APT, active periodontal therapy; BL, bone loss; BOP, bleeding on probing; CAL, clinical attachment loss; ChP, chronic periodontitis; FS, former smoker; GBR, gingival bleeding index; FMD, full mouth disinfection;; n.r., not reported; NS, non-smoker; PCR, plaque control record; PPD, probing pocket depth; RBL, relative bone loss; S, smoker; SPT, supportive periodontal therapy.

[a]University/practice.

[b]Calibrated for study re-examination.

[c]Recalculation by the reviewers based on the provided original data from Sonnenschein et al., 2017.

[d]Time period from first oral hygiene training until successful completion of APT, that is, no site with PPD ≥6 mm.

[e]Isolation of treated teeth.

[f]After splint insertion.

secure for both single-centre analyses (Sonnenschein et al., 2017; Graetz et al., 2019).

4.2.2 | Occlusal adjustment

Quality assessment of the three studies included was based on the Cochrane Collaboration's tool for assessing risk of bias resulting in an unclear risk of bias (Table 1b,c). All three studies were performed by the same research group, thus indicating a research-centre bias.

4.3 | Population

4.3.1 | Tooth splinting

Regarding the two retrospective case series related to TS, data from a total of 81 patients were further analysed, and 321 splinted teeth were followed over a time period of 3–15 years (Sonnenschein et al., 2017) and of 2–32.4 years (Graetz et al., 2019). At baseline TM grades, TL, PPD, and BL were reported in both studies (Sonnenschein et al., 2017; Graetz et al., 2019), whereas the clinical parameters CAL, PI, and bleeding index (BI) were presented in the article by Sonnenschein et al. (2017) (Table 2). Prior to TS, at least one tooth with mobility grade 1–3 was present (Sonnenschein et al., 2017; Graetz et al., 2019). Further, Sonnenschein et al. excluded patients exhibiting cross-bites in the frontal region and/or oral parafunctions. Among the 24 included patients, 12 patients with Eichner class A, 3 patients with Eichner class B1, 5 patients with class B2, B3, and B4 with one patient each, and 2 patients with class C2 were identified, and functional loading of the splinted teeth by natural antagonists was given (Sonnenschein et al., 2017). In the study by Graetz et al., bruxism was determined as a potential cofactor at baseline, and the 57 included patients presented with various Eichner Classes including Class A, Class B1, B2, and B2, as well as Class C (no antagonistic contacts) (Graetz et al., 2019).

At the 7-year re-examination, Sonnenschein et al. (2017) evaluated 93 splinted lower anterior teeth and 294 teeth of the remaining dentition without further stratification into tooth type, position, or TM in 24 patients with 22.38 (±6.3) teeth on average. In the study by Graetz et al. (2019), splinted teeth were compared to 1069 non-splinted teeth at the time of re-examination (2–32.4 years) in 57 patients with 22.3 (±3.9) teeth on average. The analysis was then stratified into groups of upper anterior, lower anterior, and posterior teeth (Graetz et al., 2019).

4.3.2 | Occlusal adjustment

The studies related to OA included 82 patients with 1974 teeth (Fleszar et al., 1980), 93 patients with 2421 teeth (Kerry et al., 1982), and 50 patients with a mean number of 27 teeth (range 20–32) (Burgett et al., 1992). Burgett et al. reported CAL, PPD, and TM; Fleszar et al. reported TM and CAL in respect to initial PPD; and Kerry et al. reported TM (Table 3. In all three studies, patients were diagnosed with moderate to severe periodontal disease with PPD >4 mm (Table 4.

4.4 | Indications and intervention

4.4.1 | Tooth splinting

In the included TS studies, the periodontal treatment regimens consisted of non-surgical periodontal therapy in combination with open-flap debridement and adjunctive antibiotic treatment (Graetz et al., 2019), resective surgery in four cases, and regenerative periodontal surgery in three cases (Sonnenschein et al., 2017). The non-surgical periodontal therapy included motivation and instruction for optimal individual plaque control (Sonnenschein et al., 2017; Graetz et al., 2019). Sonnenschein et al. performed subgingival debridement following the adapted protocol proposed by Quirynen et al. (1995).

TS was indicated in teeth with increased mobility and performed before, during, or after completion of the phase of active periodontal therapy (APT) (Sonnenschein et al., 2017; Graetz et al., 2019). In addition, the study by Sonnenschein et al. (2017) defined a CAL ≥5 mm at ≥1 site of the affected tooth and ≥50% BL as complementary indicators for splinting. The allocated mobile teeth were splinted with composite with or without reinforcements with glass fibre including 2–6 teeth, or with or without glass fibre or metal wire at one or both adjacent teeth (Graetz et al., 2019). Sonnenschein et al. (2017) focused on the outcome following splinting of mandibular incisors and canines and included 94 splinted teeth at baseline. In the study by Graetz et al., upper and lower anterior teeth as well as posterior mandibular and maxillary teeth were included for TS, and in 10 teeth (in nine patients) amputation of one or two roots was conducted prior to TS (Graetz et al., 2019). For both studies, patients (teeth) receiving regenerative or resective periodontal surgery were excluded from further analysis (see Comparison). Following APT, patients received SPT with ≥1 visit/year (Sonnenschein et al., 2017; Graetz et al., 2019).

4.4.2 | Occlusal adjustment

In the included OA studies, the periodontal treatment consisted of an initial phase with oral hygiene instructions and scaling and root planing (SRP) and a surgical phase. While two studies included OA as part of the initial phase (Fleszar et al., 1980; Kerry et al., 1982), one study allocated OA randomly, facilitating a comparison of patients with OA ($n = 22$) and no OA ($n = 28$) (Burgett et al., 1992). The concept of OA was based on earlier described principles (Ramfjord & Ash Jr., 1981) and aimed at even and stable tooth contacts in centric relation, freedom in centric smooth gliding contacts in centric and eccentric mandibular motion, and elimination of balancing side interferences (Burgett et al., 1992).

TABLE 3 Outcome parameters of included studies related to occlusal adjustment

First author (year)	Group	Time point	*n* teeth (maxilla/ mandible)	*n* (%) teeth with mobility grade 0, I, II, III	*n* tooth loss (%)	PPD (mm)	BL (%) (range; median)	CAL (mm)	PI (%)	BI (%)
Fleszar et al. (1980)	Test	Baseline	1974 (n.r)	n.r. (pooled data on patient level of tooth mobility from 0 to III)	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
		After 8 years	1083 (n.r.)	n.r. (pooled data on patient level of tooth mobility from 0 to III)	n.r.	n.r.	n.r.	Pooled data on patient level after 1–8 years initial pocket depth of 1–3 mm and mobility 0: −0.27 to −0.61 I: −0.38 to −0.83 II: −0.59 to −1.05 III: −0.76 to −1.08 initial pocket depth of 4–6 mm and mobility 0: 0.69 to 0.49 I: 0.61 to 0.25 II: 0.31 to 0.01 III: −0.11 to 0.21 initial pocket depth of 7–12 mm and mobility 0: 2.57 to 2.31 I: 1.90 to 1.89 II: 1.64 to 1.20 III: 0.95 to n.a.	n.r.	n.r.
	Control n.a.									
Kerry et al. (1982)	Test	Baseline	2421 (n.r.)	979[a] (40.4[a]), 1226[a] (50.6[a]), 216[a] (9[a]), n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
		After 2 years	2421 (n.r.)	1304[a] (53.9[a]), 1035[a] (42.8[a]), 82[a] (3.3[a]), n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
	Control n.a.									
Burgett et al. (1992)	Test	Baseline	n.r.	n.r.	n.r.	Data on patient level: 3.66 ± 0.75 (srp) 3.64 ± 0.61 (mW)	n.r.	Mean data on patient level: −3.52 ± 0.81 (srp) −3.48 ± 0.76 (mW)	n.r.	n.r.
		After 2 years	n.r.	n.r.	n.r.	3.08 ± 0.41 (srp) 2.90 ± 0.33 (mW)	n.r.	0.46 ± 0.66 (srp) 0.37 ± 0.68 (mW)	n.r.	n.r.

(Continues)

TABLE 3 (Continued)

First author (year)	Group	Time point	n teeth (maxilla/ mandible)	n (%) teeth with mobility grade 0, I, II, III	n tooth loss (%)	PPD (mm)	BL (%) (range; median)	CAL (mm)	PI (%)	BI (%)
	Control	Baseline	n.r.	n.r.	n.r.	Data on patient level: 3.58 ± 0.58 (srp) 3.62 ± 0.68 (mW)	n.r.	Mean data on patient level: −3.44 ± 1.20 (srp) −3.50 ± 1.19 (mW)	n.r.	n.r.
		After 2 years	n.r.	n.r.	n.r.	3.04 ± 0.43 (srp) 2.89 ± 0.41 (mW)	n.r.	0.08 ± 0.53 (srp) −0.03 ± 0.54 (mW)	n.r.	n.r.

Note: If not otherwise indicated, parameters are presented as means ± SD.

Abbreviations: BI, gingival bleeding index; BL, bone loss; CAL, clinical attachment loss (+ = gain; − = loss); mW, modified Widman flap; *n*, number; n.a., not applicable; n.r., not reported; PI, plaque index; PPD, probing pocket depth; srp, scaling and root planning.

[a]Calculated by the authors.

In Fleszar et al. (1980) and Kerry et al. (1982), no control group for OA was included, and randomization within the same patient to surgical procedures subgingival curettage (SC), modified Widman flap (mWF) or pocket elimination (PE), and non-surgical SRP, respectively, was performed. In the RCT by Burgett et al. (1992), the patients were randomly assigned to OA or no OA, and within each patient, randomization of interventions, SRP, and mWF was assigned in a split-mouth design. All three included studies reported a maintenance protocol including prophylaxis every 3 months and annual scoring (Fleszar et al., 1980; Kerry et al., 1982; Burgett et al., 1992).

Tables 2 and 4 summarize characteristics, indications, and interventions. Table 5 presents a summary of original data considering the follow-up time period up to 12 years (Sonnenschein et al., 2017; Graetz et al., 2019), and Table 3 presents a summary of original data considering the studies on OA (Fleszar et al., 1980; Kerry et al., 1982; Burgett et al., 1992).

4.5 | Comparison

4.5.1 | Tooth splinting

In the articles on TS, non-splinted teeth were defined within the same patients receiving similar interventions (Sonnenschein et al., 2017; Graetz et al., 2019). As the original publication by Sonnenschein et al. presented data for splinted teeth and all teeth (entire dentition including splinted teeth), detailed data on number of teeth with TS and no TS (including PPD) and number of teeth with surgical intervention were provided by the first author (Sonnenschein) on request to facilitate re-calculation of data for 24 patients with a follow-up of 7 years for the current analysis. A TL rate of 0.1% for splinted mandibular anterior teeth and 14.5% for the remaining unsplinted dentition was observed after 7 years (Table 6). All patients exhibited full anterior and posterior occlusal support (Sonnenschein et al., 2017). For splinted teeth, the mean PPD, mean CAL, mean BL, and plaque scores did not change significantly during the observation time (Sonnenschein et al., 2017).

In the study by Graetz et al., an overall TL rate of 11.5% for teeth with TS and 10.1% for teeth with no-TS was re-calculated for follow-ups ranging from 2 to 32.4 years (Graetz et al., 2019) (Table 5). Prior to TS, teeth considered for splinting revealed higher TM and worse periodontal baseline conditions (higher PPD and BL) than teeth with no TS. Multivariate analyses did not reveal an association between TL and gender, smoking, TM, bruxism, and splinting, while the risk of TL was increased by age, with PPD >6 mm and BL >50%, in posterior versus anterior teeth, and in patients with Eichner classifications B1, B3, and C1 compared to full occlusal contacts (Graetz et al., 2019). PROMs and BOP were not reported in either study (Sonnenschein et al., 2017; Graetz et al., 2019).

4.5.2 | Occlusal adjustment

In the included OA studies, no information regarding TSR was presented. Fleszar et al. (1980) and Kerry et al. (1982) did not provide a

TABLE 4 Characteristics of included studies related to occlusal adjustment

First author (year) country funding	Study type study design setting[a] examiner calibration[b]	*n* patients (*n* female) mean age ± SD (range) *n* smokers periodontal diagnosis patient-related inclusion criteria tooth-related inclusion criteria	Test control	Occlusal adjustment indication type and number of teeth time point	Periodontal treatment	Follow-up (years) mean ± SD (range) time points	*n* drop-outs (reason)
Fleszar et al. (1980) USA None	Case series Prospective[c] University n.r. n.r.	82 patients (n.r.) n.r. n.r. moderate to severe periodontitis Patient-related inclusion criteria: • Completion at least the first 1-year recall and scoring • One or more periodontal pockets >4 mm Tooth-related inclusion criteria with three severity groups: • Group1—initial pocket/sulcus depth 1–3 mm • Group 2—initial pocket/sulcus depth 4–6 mm • Group 3—initial pocket/sulcus depth 7–12 mm	Test: occlusal adjustment control: n.a.	OA of entire dentitions during initial treatment phase	Initial therapy: scaling, root planning, oral hygiene instruction, occlusal adjustment APT: all patients on randomized basis had each half of their mouth treated with one of the following surgical procedures: subgingival curettage, modified Widman flap surgery, pocket elimination surgery SPT: recall every 3 months for prophylaxis	8 n.r. annually 1–8 years	10 after 5 years, 29 after 8 years (n.r.)
Kerry et al. (1982) USA Grant No. DE 02731	Case series Prospective University n.r. n.r.	93 patients (n.r.) n.r. n.r. Moderate to severe periodontitis Patient-related inclusion criteria: n.r. Tooth-related inclusion criteria: n.r.	Test: occlusal adjustment control: n.a.	OA of entire dentitions during initial treatment phase	Initial therapy: scaling, root planning, oral hygiene instruction, occlusal adjustment APT: all patients had each quadrant treated with one of the following surgical procedures randomly assigned: pocket elimination, subgingival curettage, modified Widman flap surgery, scaling & root planning by a periodontist SPT: recall every 3 months	2 n.r. baseline; after initial therapy; 1 month, 1 and 2 years after APT	n.r.

(Continues)

TABLE 4 (Continued)

First author (year) country funding	Study type study design setting[a] examiner calibration[b]	*n* patients (*n* female) mean age ± SD (range) *n* smokers periodontal diagnosis patient-related inclusion criteria tooth-related inclusion criteria	Test control	Occlusal adjustment indication type and number of teeth time point	Periodontal treatment	Follow-up (years) mean ± SD (range) time points	*n* drop-outs (reason)
Burgett et al. (1992) USA None	RCT University n.r. n.r.	50 patients (29 female) 44.2 ± 11.2 (25–69) n.r. Moderate to advanced periodontitis Patient-related inclusion criteria: • Adults diagnosed with moderate or advanced periodontitis Tooth-related inclusion criteria: n.r.	Test: occlusal adjustment ($n = 22$) Control: no occlusal adjustment ($n = 28$)	Random allocation of patients to OA (entire dentitions) and no OA during initial treatment phase	Initial therapy: scaling, root planning, smoothing of restorations, polishing of the teeth, oral hygiene instruction, fluoride treatment, occlusal adjustment (test group) APT 2 months after initial therapy: Split-mouth design with random allocation to Widman flap on one side and scaling and root planning on the other side SPT: recall every 3 months	2 n.r. baseline; 1 and 2 years after APT	n.r.

Abbreviations: APT, active periodontal therapy; OA, occlusal adjustment; n.a., not applicable; n.r., not reported; RCT, randomized clinical trial; SPT, supportive periodontal therapy.

[a]University/practice.

[b]Calibrated for study re-examination.

[c]Data from Ramfjord et al. (1973).

TABLE 5 Outcome parameters of included studies related to splinting after a follow-up time ≥ 7 years

First author (year)	Group	Time point	*n* teeth (maxilla/mandible)	*n* (%) teeth with mobility grade 0, I, II, III[c]	*n* tooth loss (%)	PPD (mm)	BL (%) (range; median)	CAL (mm)	PI (%)	BI (%)	Complications (e.g., splinting fracture)	Mean time of splint retention
Sonnenschein et al. (2017)	Test	Base line	162 (0/162)	0, 6 (15.4)[d], 24 (61.5)[e], 9 (23.1)[e] patients	n.a.	3.39 ± 1.41	72 ± 14[f] (50–100;70)	5.61 ± 1.66	35.9 ± 31.3[g]	12.8 ± 23.5[i]	n.a.	n.r.
		After 12 years	30 (n.r.)	n.r.	2 (1.2[b]) (endodontic failure)[$]	2.18 ± 0.69	After 10 years: 63 ± 17 (42–95; 59) in 11 patients Increase (3 patients), refill of bone defect (6 patients), stable bone level (2 patients)	4.70 ± 0.58	41.9 ± 29.7[g,h]	6.1 ± 12.2[h,i]	No caries, no restorations, regenerative surgery at splinted teeth (3 patients) Survival rate of splints until fracture or debonding after 10 years: 67.3%	
	Overall dentition[a]	Baseline	21.23 ± 5.47	n.r.	n.a.	3.55 ± 1.25	n.r.	n.r.	34.2 ± 22.0[g]	9.5 ± 14.0[i]	n.a.	n.a.
		After 12 years	17.63 ± 5.22	n.r.	n.r.	2.28 ± 0.30	n.r.	n.r.	35.2 ± 18.8[g,h]	5.1 ± 6.8[h,i]	n.a.	n.a.
Graetz et al. (2019)	Test	Baseline	227 (148/79)	104 (45.8[b]), 38 (16.7[b]), 33 (14.5[b]), 22 (9.6[b])	n.a.	5.4 ± 1.8	61.7 ± 20.5	n.r.	n.r.	n.r.	Repair in 75.3% (171 teeth) Mean 2.6 ± 1.9 (1.0–8.0) Repairs/splint 0.4 ± 0.6 (0.0–3.5) Repairs per splint/year	7.3 ± 5.7 (0.1–22.7)
		After 11 (±7.2) years	201 (n.r.)	n.r.	26 (11.5[b])	3.2 ± 1.0	59.3 ± 18.3	n.r.	n.r.	n.r.	n.r.	n.r.
	Control	Baseline	1197[b] (n.r.)	766 (63.9[b]), 129 (10.7[b]), 69 (5.7[b]), 36 (3.0[b])	n.a.	4.5 ± 1.6	44.0 ± 21.5	n.r.	n.r.	n.r.	n.a.	n.a.
		After 11 (±7.2) years	1069[b] (n.r.)	n.r.	128[b] (10.7[b])	3.0 ± 0.7	41.0 ± 19.2	n.r.	n.r.	n.r.	n.a.	n.a.

Abbreviations: BI, gingival bleeding index; BL, bone loss; CAL, clinical attachment loss; *n*, number; n.a., not applicable; n.r., not reported; PI, plaque index; PPD, probing pocket depth. If not otherwise indicated, parameters are presented as means ± SD.

[a]According to the original publication overall dention includes splinted (test) and non-splinted teeth (remaining dentition).

[b]Calculated by the authors.

[c]Prior to/without splinting; according to Lindhe and Nyman (1977).

[d]In ≥2 adjacent teeth.

[e]≥1 tooth.

[f]Relative bone loss.

[g]According to O'Leary et al. (1972).

[h]After splinting (exact time point not reported).

[i]According to Ainamo and Bay (1975).

[$]Root fracture and persistent apical inflammation after second revision.

TABLE 6 Subanalysis for patients that received non-surgical periodontal therapy only ($n = 24$) based on Sonnenschein et al. (2017)[a] after a follow-up time ≤ 7 years

First author (year)	Group	Time point	*n* teeth (maxilla/mandible)	*n* tooth loss (%)	PPD (mm)
Sonnenschein et al. (2017)	Test	Baseline	94 (0/162)	n.a.	3.38 ± 1.47
		After 7 years	93 (n.r.)	1 (0.99[c]) (endodontic failure)	2.24 ± 1.05
	Overall dentition[b]	Baseline	344	n.a.	3.65 ± 1.32
		After 7 years	294	50[c,d]	2.33 ± 0.45

Abbreviation: *n*, number; n.a., not applicable; n.r., not reported; PPD, probing pocket depth. If not otherwise indicated, parameters are presented as means ± standard deviation.
[a]Sub-analysis was created on the basis of specific raw data provided by the first author.
[b]Calculated by the authors.
[c]Reason for extraction not reported for this sub-analysis.
[d]According to the original publication overall dention includes splinted (test) and non-splinted teeth (remaining dentition).

control group with respect to OA. In the study by Fleszar et al., CAL changes were reported in TM subgroups (0–1, 2, 3) with moderately (4–6 mm initial PPD) or severely diseased sites (7–12 mm initial PPD), and CAL gain was observed in all subgroups except moderately diseased sites with TM 3, in which CAL loss was found within the first year post operation.

Kerry et al. reported a significant reduction in TM (1 and 2 mobility) with an increased proportion of non-mobile teeth (TM 0) following non-surgical therapy including OA. During the surgical therapeutic phase, SC and mWF exhibited a reduction of class 2 mobility after 2 years, while no additional changes were detected for PE and additional SRP (Kerry et al., 1982).

Burgett et al. (1992) reported the therapeutic outcome following either SRP or mWF in patients who were randomly allocated to OA compared to patients without OA (no-OA group). In the OA group, improved mean CAL (0.4 mm) was detected when compared to the no-OA group during the 2-year follow-up, and SRP showed more favourable CAL response than mWF surgery after 1 year but not after 2 years. In addition, no difference in CAL change was detected with respect to the initial PPD when OA was compared to no-OA (Burgett et al., 1992). Analyses did not reveal a difference in PPD reduction following OA compared to the no-OA group, while PPD reduction was greater at sites treated with mWF compared to SRP. Further, no reduction of TM could be identified in the OA and no-OA groups (Burgett et al., 1992).

4.6 | Observation: Synthesis of data

4.6.1 | Tooth splinting

For the synthesis of TS data, the calculation was based on 24 patients (baseline: 94 splinted teeth; Sonnenschein et al., 2017) and 48 patients (baseline: 217 splinted teeth; Graetz et al., 2019) who received non-surgical therapy. From the study by Sonnenschein et al., outcome data from the 3-year follow-up cohort (24 patients; 94 splinted teeth; 306 non-splinted teeth) were included (Sonnenschein et al., 2017). Graetz et al. (2019) provided data for 48 patients (191 splinted teeth; 1079 non-splinted teeth) who received non-surgical therapy and re-examination for 2–32.4 years. Together, both studies analysed 72 patients with 311 splinted teeth, and a total of 26 splinted teeth were lost for the considered follow-up time range (Sonnenschein et al., 2017; Graetz et al., 2019). After a minimum of 2 years following non-surgical periodontal therapy, synthesis of data revealed a weighted mean incidence of 8.4% TL for TS compared to 10.1% TL for no TS.

4.6.2 | Occlusal adjustment

A total of 205 patients were included in the three studies (Fleszar et al., 1980; Kerry et al., 1982; Burgett et al., 1992) but none of them reported on TL. OA on teeth with TM 0–1 and moderate pockets (PPD 4–6 mm) as well as on teeth with TM 0–3 and deep pockets (PPD >6 mm) led to CAL gain (Fleszar et al., 1980; Burgett et al., 1992), while no effect on PPD and TM was observed when comparing OA and no OA (Burgett et al., 1992). In the study by Graetz et al. (2019), it was mentioned that occlusal trauma was initially treated as a general prerequisite.

4.7 | Discussion

In this SR, the potential benefit of TS and OA in patients with periodontitis exhibiting mobile teeth with increased PPD and reduced CAL was evaluated, and a weak evidence was found for reduced CAL with OA, while no effect was found for TS.

4.7.1 | Tooth splinting

The included articles on TS aimed at the evaluation of long-term outcome following splinting to eliminate the factor of mobility during APT as well as SPT (Sonnenschein et al., 2017; Graetz et al., 2019). In addition, some patients received various surgical periodontal therapies in both studies. For consistency, patients and teeth with surgical interventions were excluded from the analysis so that only data for splinted teeth treated by non-surgical

periodontal therapy were presented. Thus, a total of 72 patients exhibiting 311 splinted teeth were included, and a weighted mean incidence of 8.4% TL for teeth with TS compared to a 10.1% for teeth with no TS was determined. Graetz et al. (2019) found that splinted and non-splinted anterior and posterior teeth with comparable disease progression patterns were at equal risk for TL regardless of TM.

Regarding the included articles on TS, clear comparison and interpretation of TL for TS versus non-TS are limited in this SR, as in both groups teeth did not show the same clinical features with respect to CAL, BL, TM, and occlusal forces. In this context, no direct statistical comparison of TL of teeth with and without TS was performed in the original publications (Sonnenschein et al., 2017; Graetz et al., 2019) nor on calculated data in this SR.

Synthesis of data for survival of splinted teeth could be based only on the shortest follow-up evaluation time point (2 years) due to the wide range of follow-up (2–32.4 years) in the analysis by Graetz et al. (2019). When reviewing results from the study by Sonnenschein et al., only the 3-year follow-up could be included in the analysis for tooth survival, as the number of evaluated patients (teeth) was similar to baseline. Sonnenschein et al. further reported data from the 5-, 7-, 10-, 12-, and 15-year follow-up but with increasing numbers for drop-outs with unclear reasons as well as ongoing surgical interventions on the remaining dentition.

Variations in the splinting procedure possibly influenced the outcome, and splint fracture or debonding was documented in 25.6% of the patients after 3 years (Sonnenschein et al., 2017) and in 75.3% of the patients after 2–32.4 years (Graetz et al., 2019). The results of this SR suggest no detrimental effect of splinting on either TL or further CAL provided that current adhesion protocols with polishing ensure smooth surfaces and allow for optimal oral hygiene. In earlier case series with 7 and 10 patients, more invasive intra-coronal wire-reinforced acrylic splints were placed in contralateral posterior sextants, removed, and replaced for data-recording of mobility changes, while the remaining posterior sextants served as control (Galler et al., 1979; Kegel et al., 1979). It was clearly demonstrated that reduction in TM was achieved by periodontal therapy with reduction in inflammation in both splinted and unsplinted sites (Kegel et al., 1979). Subsequent open-flap debridement led to an initial increase in mobility and a decrease over 24 weeks to nearly pre-surgical values for splinted and unsplinted teeth (Galler et al., 1979). In these studies, occlusal adjustments aiming at occlusal contacts in maximum intercuspation per tooth in conjunction with canine guidance were an integral part of the initial therapy (Kegel et al., 1979).

4.7.2 | Occlusal adjustment

For decades, there has been ongoing debate regarding the influence of occlusal loading and trauma on the initiation and progression of periodontal inflammation. Existing evidence showed that occlusal trauma or excessive occlusal forces are not the primary causative factors for the initiation of periodontitis (Fan & Caton, 2018). On the other hand, it was found that the simultaneous presence of periodontitis and occlusal trauma could accelerate periodontal inflammatory tissue destruction, and therefore OA has been proposed as a part of the periodontal treatment regimen to reduce mobility and load during masticatory function and to increase patient comfort (Fan & Caton, 2018). Both periodontal tissue destruction due to periodontitis and increased occlusal load add to the phenomenon of TM. In this context, it was demonstrated that mobile teeth exhibit more attachment loss, greater PPD, and increased periodontal BL (Jin & Cao, 1992). Furthermore, recent evidence has indicated that mobile teeth are at higher risk for extraction (Helal et al., 2019). However, TM can be the consequence of periodontitis, and successful elimination of the inflammation is commonly associated with decreased TM.

The three included articles on OA, published in 1980, 1982, and 1992, were published by the same research group (University of Michigan) and involved OA in the initial non-surgical phase of periodontal therapy (Fleszar et al., 1980; Kerry et al., 1982; Burgett et al., 1992). At that time, OA of the full dentition was carried out in the presence of periodontal trauma from occlusion, while splinting was added only when mobility progressively increased and/or affected patient's health and comfort (Ramfjord & Ash Jr., 1981). Only Burgett et al. (1992) selected a random allocation to OAs and demonstrated greater attachment gains 2 years after periodontal therapy in the OA group irrespective of the initial TM. However, TM and PPD were not affected by OA (Burgett et al., 1992). Although CAL gain could be demonstrated (Fleszar et al., 1980; Burgett et al., 1992), the overall effect of OA on TSR, TM, and PPD remains unclear.

Despite the weak evidence for a positive effect of OA on CAL change, drawing general conclusions is limited, since treatment concepts during the period 1980–1992 are not entirely in line with recently published guidelines for periodontal therapy. While surgical interventions were applied quadrant-wise after the initial non-surgical phase, today periodontal therapy with step 1 and step 2 includes a re-evaluation after the non-surgical phase and strict site-specific indications for surgical intervention in step 3 (Sanz et al., 2020). In contrast to earlier concepts of full equilibration with complete OAs including most or all teeth, today selective OA is considered as "spot grinding" at single or several teeth to eliminate deflective (premature, interceptive) occlusal contacts (prematurities that deflect the position of a tooth, a denture, or the condyles and/or divert the mandible from its intended path of closure) (McNeill, 1997).

4.7.3 | Limitations of this SR

The available data provided only limited information to address the phrased clinically relevant PICOS question. Structured literature search did not detect studies investigating the effect of OA on tooth survival or outcome of periodontal therapy in patients with masticatory dysfunction. Further, none of the included studies

addressed the impact of splinting on patients' oral-health-related quality of life (OHRQoL). However, there is strong evidence from recent SRs that increased TM, tooth movement ("drifting teeth"), and TL with subsequent loss of intermaxillary contacts have an impact on quality of life in patients with periodontal disease (Needleman et al., 2004; Gerritsen et al., 2010; Christensen et al., 2012; Eltas & Uslu, 2013; Buset et al., 2016). In recently published preliminary data investigating OHRQoL in periodontitis patients, mobile mandibular incisors were randomly allocated to splinting or no splinting. Three months after non-surgical periodontal therapy, a positive impact on the OHIP-14 summary scores was documented in both groups, while a trend towards improvements in a greater number of subdomains was found in the group with splinting (Sonnenschein et al., 2021).

5 | CONCLUSION

Within the limitations of this review based on two studies for TS and three studies for OA providing low to unclear level of evidence, it is concluded that TS does not improve survival of mobile teeth in patients with stage IV periodontitis. Based on the available data, a definitive conclusion about the efficacy of splinting cannot be drawn. However, TS may be feasible to reduce TM in teeth with reduced periodontal attachment, and it may be beneficial for patients with impaired chewing comfort. According to the best available evidence today, a beneficial effect of OA on CAL was found, but the influence of OA on changes in PPD, TM, and TL in patients with periodontitis remained unclear. Future research should address the effectiveness of TS and OA on periodontal disease progression, masticatory function, and patients' OHRQoL in a prospective manner by RCTs or well-controlled studies.

ACKNOWLEDGEMENTS

The authors thank Sarah Sonnenschein for kindly providing additional data. They acknowledge the contribution of Jens Christoph Türp (University Center for Dental Medicine Basel) to clarify terminology related to occlusion, and Klaus Lang (Professor Emeritus, University of Berne) and Philippe Bouchard (Université de Paris, Paris, and Rothschild Hospital [AP-HP]) for critical discussions on the definition of tooth mobility and occlusal adjustment. Furthermore, the authors receive their salary from Charité—Universitätsmedizin Berlin (Henrik Dommisch), Universität Basel (Nicola U. Zitzmann, Clemens Walter, Aiste Gintaute, Julia C. Difloe-Geisert), and the University of Bonn (Søren Jepsen).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Henrik Dommisch: conception, design, data acquisition and interpretation, statistical analyses, drafting, and critical revision of the manuscript. **Clemens Walter:** conception, design, data acquisition and interpretation, and critical revision of the manuscript. **Julia C. Difloe-Geisert:** conception, design, data acquisition and interpretation, statistical analyses, and critical revision of the manuscript. **Aiste Gintaute:** conception, design, data acquisition and interpretation, and critical revision of the manuscript; **Søren Jepsen:** conception, design, data acquisition and interpretation, and critical revision of the manuscript. **Nicola U. Zitzmann:** conception, design, data acquisition and interpretation, statistical analyses, and drafting and critical revision of the manuscript.

ETHICS STATEMENT

A statement regarding ethics is not applicable due to the nature of a systematic review.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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How to cite this article: Dommisch, H., Walter, C., Difloe-Geisert, J. C., Gintaute, A., Jepsen, S., & Zitzmann, N. U. (2022). Efficacy of tooth splinting and occlusal adjustment in patients with periodontitis exhibiting masticatory dysfunction: A systematic review. *Journal of Clinical Periodontology*, *49* (Suppl. 24), 149–166. https://doi.org/10.1111/jcpe.13563