Association between traumatic occlusal forces and periodontitis: A systematic review

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Abstract

Objective: Occlusal adjustment is commonly recommended for patients with periodontitis and traumatic occlusion. The objective of this systematic review was to analyze the available evidence for the association between traumatic occlusal forces and periodontitis.

Methods: Two focused questions were proposed: What is the effect of traumatic occlusal forces on periodontal parameters in patients with and without periodontitis? And what is the effect of occlusal interventions on periodontal parameters in patients with periodontitis? A systematic review of clinical and observational studies was performed and presented in narrative form.

Results: After title and abstract review a total of 30 articles were retrieved and of these 14 full-text articles were retrieved for analysis. Two RCTs, 1 cohort, 4 retrospective and 7 cross-sectional studies were included. Cross-sectional studies reported a significant association between occlusal discrepancies and probing depth and clinical attachment level. However, the magnitude of the effect is negligible when groups with and without occlusal discrepancies are compared. Intervention studies reported a minimal effect on probing depth and clinical attachment level after occlusal adjustment in patients with periodontitis as compared to teeth without occlusal adjustment.

Conclusions: Available human studies showed that there is limited evidence that traumatic occlusion is associated with periodontitis and to support the implementation of occlusal adjustment to significantly improve the periodontal condition in patients with periodontitis.

Key words: Traumatic occlusion, occlusal adjustment, periodontitis, clinical attachment level

Introduction

The relationship between dental occlusion and periodontal alterations has been studied. According to the American Academy of Periodontology (AAP, Glossary of periodontal terms 2001) and the Academy of Prosthodontics (AP, Glossary of prosthodontic terms 2017), ¨trauma from occlusion¨ and ¨traumatic occlusion¨ are synonyms of ¨occlusal trauma¨. Consequently, occlusal trauma is defined as the injury of the attachment apparatus of the periodontium resulting from functional or parafunctional occlusal forces that exceed its adaptive capacity. Occlusal trauma is therefore characterized by widened periodontal ligament space, bone resorption, fremitus, progressive tooth mobility, pathologic tooth migration and pain (Jepsen *et al.* 2018). Excessive occlusal forces capable of producing injuries to dental and periodontal tissues are referred to as ¨traumatogenic occlusion¨ (AP, Glossary of prosthodontic terms 2017). Dental injuries are commonly manifested with irreversible signs such as tissue wear or facets, cracked tooth syndrome and fractures. Damage to the periodontal tissues caused by traumatic occlusal forces can lead to a transitional lesion and subsequent adapting of the tissues.

Since occlusal trauma is a histologic event and the signs and symptoms are associated with other conditions, it is debatable if occlusion has any relationship with periodontitis (Fan and Caton 2018). A study by Nunn and Harrel (2001) found that teeth with occlusal discrepancies were strongly associated with deeper probing depths and

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worse prognosis ($p<0.0001$). In contrast, Reyes *et al.* (2009) concluded that premature contacts in centric relation were not statistically associated with abfractions or increased clinical attachment level. A previous systematic review concluded that there is some association between occlusal adjustment and improvement in periodontal parameters (Foz *et al.* 2012). Nonetheless, it is a common recommendation to control the occlusion as part of the periodontal treatment but scientific support for this remains inconclusive. Therefore, the objective of this systematic review was to analyze the available evidence for the association between traumatic occlusal forces and periodontitis.

Materials and methods

The protocol for this systematic review is registered at PROSPERO (CRD42018114845). In addition, the PRISMA checklist was followed (Preferred Reporting Items Systematic review and Meta-Analyses).

A general question with two focused questions were proposed:

General question:

What is the association between traumatic occlusal forces and periodontitis?

Focused questions:

1. What is the effect of traumatic occlusal forces on periodontal parameters in patients with and without periodontitis?
2. What is the effect of occlusal interventions on periodontal parameters in patients with periodontitis?

Inclusion criteria

Inclusion criteria were defined by the PI(E)COT (Patients/population, Intervention/Exposure, Comparison, Outcome and Time) strategy for questions one and two as follows:

- P: periodontal patients and patients receiving any occlusal intervention.
- I(E): exposure is traumatic occlusal forces and intervention is occlusal adjustment.
- C: comparison is no traumatic occlusal forces or no occlusal adjustment.
- O: main outcome is clinical attachment level (CAL) in teeth/subjects with and without the exposure or mean change in CAL in the intervention and comparison groups.
- T: follow-up period of at least 3 months for intervention studies.

Type of studies included: for the first question, cohort, case-control and cross-sectional studies were selected. For the second question, only randomized clinical trials (RCTs) were selected.

Studies were considered based on the following criteria:

- A study that assessed the effects of traumatic occlusal forces on periodontal parameters or had a focus on the frequency of traumatic occlusal forces or occlusal trauma in patients with and without periodontitis.
- A study that assessed occlusal interventions (occlusal grinding, occlusal adjustment) in patients with periodontitis and a follow-up period of at least 3 months.
- Included raw data or was based on results from adjusted risk ratios (RR), odds ratio (OR) and 95% confidence interval (CI).

Exclusion criteria

Animal studies, case reports, case series and reviews.

Search strategy

The search was carried out by two independent reviewers (JEB, CRM) in Medline via Pubmed, Scielo and Google Scholar to identify all the available evidence and grey literature as well. The search strategy included the following keywords:

- ((((occlusal intervention [Title/Abstract]) OR occlusal grinding [Title/Abstract]) OR occlusal adjustment [Title/Abstract]) AND periodontitis [Title/Abstract]) OR clinical attachment loss [Title/Abstract].
- (((trauma from occlusion [Title/Abstract]) OR occlusal trauma [Title/Abstract]) AND periodontitis [Title/Abstract]) OR clinical attachment loss [Title/Abstract].
- ((bruxism [Title/Abstract]) AND periodontitis [Title/Abstract]) OR clinical attachment loss [Title/Abstract].
- (((dental premature contacts [Title/Abstract]) OR occlusal discrepancies [Title/Abstract]) AND periodontitis [Title/Abstract]) OR clinical attachment loss [Title/Abstract].
- (((((traumatic occlusion [Title/Abstract]) OR excessive occlusal force [Title/Abstract]) OR pathologic occlusion [Title/Abstract]) OR dysfunctional occlusion [Title/Abstract]) AND clinical attachment loss [Title/Abstract]) OR gingival recession [Title/Abstract].
- ((((traumatic occlusion [Title/Abstract]) OR excessive occlusal force [Title/Abstract]) OR pathologic occlusion [Title/Abstract]) OR dysfunctional occlusion [Title/Abstract]) AND periodontitis [Title/Abstract].

Manual searches of the Journal of Periodontology, Journal of Periodontal Research, and the Journal of Clinical Periodontology, along with a search for unpublished studies was performed. Articles identified from reference lists of previous systematic reviews were also identified for selection. The language was limited to articles written in English, Spanish and Portuguese and focused only in human studies in adults.

Study selection

Two independent reviewers screened (JEB, CRM) the titles and abstracts to identify potential articles according to the inclusion criteria and limits. Each identified article with a possible match had a full-text evaluation. Selected studies for this systematic review were analyzed for data extraction. Any discrepancies between the reviewers were resolved with a third reviewer (JIC, CCR).

Data extraction

The following information was obtained by two independent reviewers (JEB, CRM) from each study using a predetermined data extraction form: authors, year of publication, population, type of study (RCT, cohort, case-control, cross-sectional), intervention, comparison, number of patients, mean CAL, mean probing depth (PD), mean change and standard deviation of the primary outcome (CAL) and other outcomes (PD, mobility) in the intervention and comparison groups, number of people with the exposure in the case and control groups, adjusted risk ratios (RR), odds ratio (OR) and 95% confidence interval (CI).

Quality assessment

Quality assessment was performed by two reviewers (JEB, CRM) and any discrepancies were resolved with a third reviewer (JIC, CCR). For RCTs, the quality of the study was assessed using the risk of bias tool as described in the Cochrane Handbook for Systematic Reviews of Interventions 5.1.0 (Higgins and Green 2011). Equally, for observational studies, the Newcastle-Ottawa Scale (NOS) was used (Wells *et al.* 2012).

Quantitative analysis and qualitative synthesis

A meta-analysis was not possible due to a low number of homogeneous studies. A qualitative synthesis analyzing the most relevant aspects and results of the included studies is presented. The reporting of this review is in accordance to the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) statement.

Results

Study selection

A systematic search in Medline, Scielo, Google Scholar and manual search resulted in 4900 citations over a 30-year timeframe. After title and abstract review, 4870 articles were excluded. Thirty articles were retrieved and reviewed in full-text and consequently 16 articles were excluded because they did not meet the inclusion criteria (Hakkarainen 1996, Hakkarainen *et al.* 1988, Ikeda 1998, Ishigaki *et al.* 2008, Doshi *et al.* 2010, Takeuchi *et al.* 2010, Gusmao *et al.* 2011, Krishna *et al.* 2013, Moisei *et al.* 2015, Bermudez *et al.* 2016, Martinez-Canut *et al.* 2017, Kumar *et al.* 2018, Meynardi *et al.* 2018, Kato *et al.* 2018, Popa *et al.* 2018a, Popa *et al.* 2018b). Finally, 14 articles were analyzed in full-text and included in the qualitative synthesis (figure 1).

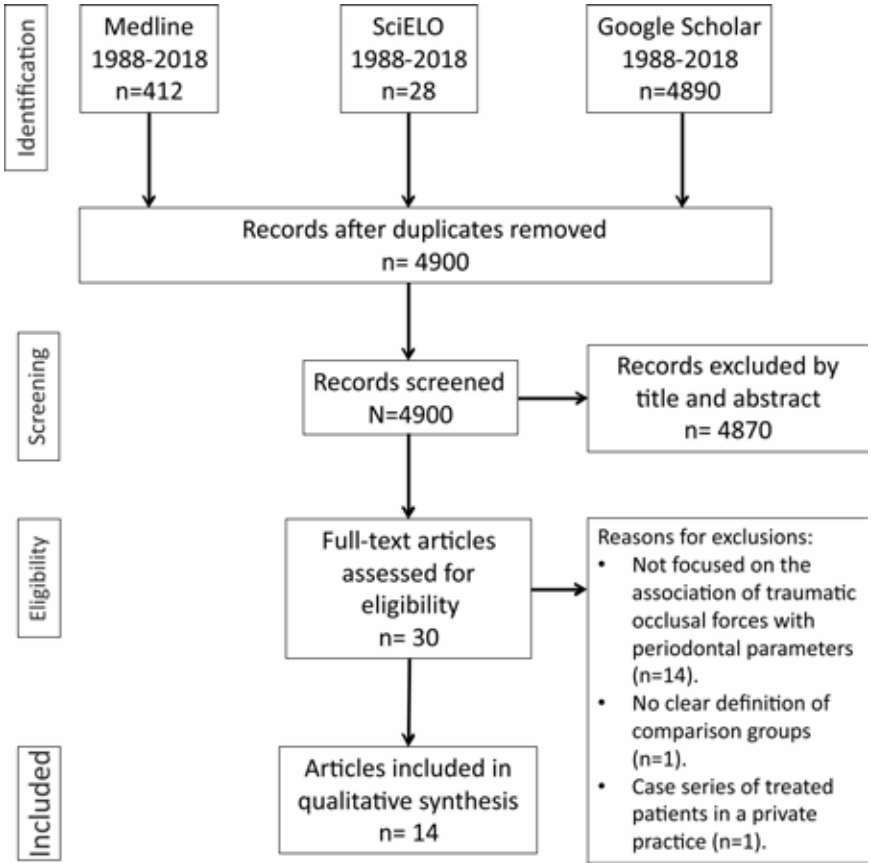

Figure 1. PRISMA flow chart of study selection inclusion.

Table 1. Cohort studies

Year / authors	Number of subjects	Objective	Follow up (years)	Population	Exposure	Comparison	Primary outcome	OR	95% CI	Main Results
2015 / Di Febo *et al.*	100	To evaluate the efficacy and complications of fixed partial dentures in patients with periodontitis	20	Periodontitis patients with fixed prostheses	Parafunction	T0: initial consultation, T1: completion of prosthodontic treatment, T2: 20 years after T1	Prosthetic abutment loss at T2	4.3	1.5-12.5	Parafunction resulted more often in failure of teeth used as abutments (OR 4.3; 95 CI 1.5-12.5). Parafunction was not associated with the progression of periodontitis.

Table 2. Newcastle-Ottawa quality assessment scale for cohort studies

Study	Selection				Comparability	Outcome		
	1) Representativeness of the exposed cohort	2) Selection of the non exposed cohort	3) Ascertainment of exposure	4) Demonstration that outcome of interest was not present at start of study	1) Comparability of cohorts on the basis of the design or analysis	1) Assessment of outcome	2) Was follow-up long enough for outcomes to occur	3) Adequacy of follow up of cohorts
2015 Di Febo *et al.*	-	-	-	-	-	-	*	*

Note: A study can be awarded a maximum of one star for each numbered item within the selection and outcome categories. A maximum of two stars can be given for Comparability.

Study characteristics

One cohort study (Di Febo *et al.* 2015), four retrospective studies (Nunn and Harrel 2001, Harrel and Nunn 2001, Harrel and Nunn 2004, Harrel and Nunn 2009), seven cross-sectional studies (Jin and Cao 1992, Bernhardt *et al.* 2006, Kundapur *et al.* 2009, Reyes *et al.* 2009, Branchosfsky *et al.* 2011, Zhou *et al.* 2017, Hutabarat and Nasution 2017) and two RCTs (Burgett *et al.* 1992, Joo *et al.* 2014) were included for analysis.

Main findings from cohort, retrospective and cross-sectional studies

Observational studies were used to answer the first focused question. A cohort study (Di Febo *et al.* 2015) on 100 patients with a follow up of 20 years was found (tables 1 and 2). The study reported that abutment teeth with parafunction resulted more often in failure (OR 4.3; 95 CI 1.5-12.5). Parafunction was not associated with the progression of periodontitis as reported by the authors.

Retrospective studies are summarized in table 3. All four articles came from a private practice sample of patients during 24 years of duration. Nevertheless, the results were presented for patients that completed a 1-year follow-up period before and after non-surgical and surgical periodontal treatment. Only data for non-surgical group was considered in this systematic review. Although patients in these studies received occlusal adjustment, the study designs could not be classified as RCTs. Overall, teeth without occlusal adjustment presented with an increase in probing depth (0.271 mm) as compared to teeth that received the intervention (0.105 mm) after adjusting for confounders. Teeth with occlusal discrepancies presented deeper initial probing depths (5.53 mm ± 1.51 vs. 4.77 mm ± 1.31; $p<0.0001$). However, the difference between groups was less than 0.8 mm. No differences in gingival width were found in teeth with and without occlusal discrepancies.

Cross-sectional studies are presented in table 4. An association between occlusal discrepancies and probing depth and clinical attachment level was found in 4 studies (Bernhardt *et al.* 2006, Branschofsky *et al.* 2011, Zhou *et al.* 2017, Hutabarat *et al.* 2017). One study found no association between premature contacts and clinical attachment level (Reyes *et al.* 2009). A significant association ($p<0.01$) between composite signs of trauma from occlusion (mobility and widened periodontal ligament) as measured by the trauma from occlusion index (TOI) and increased probing depth of 5.7 mm in TOI positive teeth as compared to probing depth of 4.2 mm in TOI negative teeth. In addition, significant ($p<0.01$) clinical attachment level of 6.1 mm in TOI positive teeth as compared to 2.7 mm in TOI negative teeth was reported. Nevertheless, the difference in probing depths and clinical attachment level was not significant between teeth with and without premature contacts (Jin and Cao 1992). There was a significant association between tooth mobility and gingival recession ($p<0.001$) with an increased odds ratio in one study (OR 6.2; 95% CI 3.1-12.5) (Kundapur *et al.* 2009). However, wear facets were not associated with gingival recession (Kundapur *et al.* 2009).

Table 3. Retrospective studies

Year / authors	Number of subjects	Objective	Follow up (years)	Population	Intervention / comparison	Primary outcome	Main Results
2001 / Nunn and Harrel	89	To investigate the relationship of occlusal trauma to the severity of periodontal disease	1	Periodontitis patients	Occlusal interferences / no occlusal interferences	Probing depth	Before treatment, teeth with occlusal discrepancies had significantly deeper initial probing depths (5.53 mm ± 1.51 vs. 4.77 mm ± 1.31; p<0.0001).
2001 / Harrel and Nunn	89	To evaluate the effect of occlusal adjustment on the progression of treated and untreated periodontal disease	1	Periodontitis patients	Occlusal adjustment / untreated occlusal discrepancies	Probing depth	Patients who received occlusal adjustment presented better improvements in prognosis. Teeth without occlusal adjustment presented significant increase in probing depth (0.271 mm) vs. teeth with occlusal adjustment (0.105 mm) after adjusting for confounders.
2004 / Harrel and Nunn	91	To evaluate the potential role of occlusal discrepancies in changes in the amount of gingiva	1	Periodontitis patients	Occlusal interferences / no occlusal interferences	Gingival width	Average gingival width in no occlusal discrepancies group 3.28 mm 95% CI 3.22-3.34 vs. the occlusal discrepancies group 3.33 mm (95% CI 3.20-3.45).
2009 / Harrel and Nunn	85	To evaluate occlusal contacts and their association with probing depths, width of gingiva, prognosis and risk factors	1	Periodontitis patients	Centric prematurity / no centric prematurity	Probing depth	Adjusted initial probing depth in the group without centric prematurity 4.85 mm 95% CI 4.69-5.01 vs. the centric prematurity group 5.74 mm 95% CI 5.50-5.98 (p<0.0001)

PD: probing depth, CAL: clinical attachment level.

Main findings from RCTs

Results from RCTs were used to answer the second focused question (table 5). Two RCTs were identified (Burgett *et al.* 1992, Joo *et al.* 2014). The study by Burgett *et al.* (1992) randomly assigned patients to occlusal adjustment or no occlusal adjustment groups and within patients, either modified Widman flap or scaling and root planing was randomly assigned. Occlusal adjustment was aimed towards obtaining stable contacts in centric relation and elimination of balancing side interferences. Data from the side that received Widman flap was not considered in this systematic review. The change in mean gain of clinical attachment level in the occlusal adjustment group at 1 and 2 years was 0.43 mm ± 0.56 and 0.46 mm ± 0.66 respectively. In comparison, the non-adjusted group presented a change in mean clinical attachment level at 1 and 2 years of -0.04 mm ± 0.39 and 0.08 mm ± 0.53 respectively. A reduction of probing depths in both groups was not significant at 1 and 2 years.

The study by Joo *et al.* (2014) included 16 patients with periodontitis and traumatic occlusal forces. After receiving initial periodontal treatment, teeth were randomly assigned to intervention (n=20) and control (n=20) groups. Occlusal reduction was performed until the target tooth was completely out of occlusion and repeated every 4-6 weeks and final reduction was less than 2 mm and until tooth mobility decreased or patient discomfort disappeared. A mean gain of clinical attachment level of 0.75 mm and 0.69 mm at 6 months in the intervention and control group was reported, respectively. In addition, a mean reduction in probing depth after 6 months of 1.14 mm in the intervention group as compared to 1.13 mm in the control group was observed. Reduction change in periotest values in the intervention group was 11.53 as compared to 2.22 in the control group. The variable that improved significantly was tooth mobility.

In summary, studies that evaluated the effect of occlusal discrepancies in clinical attachment level and probing depth, reported a difference <0.9 mm on average between teeth with and without occlusal discrepancies. Similarly, intervention studies that evaluated the effect of occlusal adjustment, reported a difference in gain of clinical attachment level and reduction in probing depth <0.8 mm on average between teeth with and without the intervention.

Quality assessment

The quality of the cohort study of Di Febo *et al.* (2015) was low quality (table 2). The two RCTs (Burgett *et al.* 1992, Joo *et al.* 2014) were low quality as they had high risk of bias (figure 2).

Table 4. Cross-sectional studies

Year / authors	Number of subjects	Objective	Population	Exposure/comparison	Outcomes	Main Results
1992 / Jin and Cao	32	To determine the reliability of signs of trauma from occlusion and their relationship with the severity of periodontitis	Periodontitis patients	Occlusal trauma / no occlusal trauma	PD, CAL, bone height, mobility	No significant differences occurred for PD (5.4 mm vs. 5 mm), CAL (4.4 mm vs. 4.2mm) between teeth with and without abnormal premature contacts. Teeth with positive signs of trauma from occlusion (TOI- trauma from occlusion index) presented deeper PD (5.7mm vs. 4.2mm), CAL (6.1mm vs. 2.7mm) and less bone height (61.4% vs. 72.3%) as compared to TOI negative teeth ($p<0.01$).
2006 / Bernhardt *et al.*	2980	To investigate potential associations between dynamic occlusal interferences and signs of periodontal disease in posterior teeth	Representative population based sample	Occlusal interferences / no occlusal interferences	PD / CAL	Statistically significant ($p<0.001$) association between non-working contacts and PD and CAL. The effect magnitude was a mean increase of 0.13 mm for probing depth and 0.14 mm loss of clinical attachment level.
2009 / Kundapur *et al.*	300	To explore the role of trauma from occlusion on the development of gingival recession	Gingivitis patients	Occlusal trauma / no occlusal trauma	Gingival recession	Class I recession was observed in 112 patients (37.3%), class II in 45 (15.0%) patients and class III in 2 (7%) patients. There were no significant association between fremitus or wear facets and gingival recession. There was a significant association between tooth mobility and gingival recession ($p<0.001$) with an increased odds ratio (OR 6.2: 95% CI 3.1-12.5).
2009 / Reyes *et al.*	46	To determine the extent to which associations exist between premature contacts and abfraction lesions and clinical attachment loss	Non periodontitis patients	Premature contacts / no premature contacts	CAL	Median CAL in teeth with premature contacts was 1mm (range 0.00 - 6) and 1mm (range 0.00-5.5) for teeth without premature contacts. The frequency of abfractions was similar in both groups.
2011 / Branschofsky *et al.*	381 (288 periodontitis, 93 healthy)	To correlate the quality and quantity of secondary trauma from occlusion with the extent and severity of periodontal disease	Periodontitis patients and periodontally healthy patients	Premature contacts / no premature contacts	CAL	The frequency of premature contacts was higher in periodontitis patients. The total amount of trauma from occlusion was correlated to the severity of periodontitis ($p<0.001$).
2017 / Zhou *et al.*	30	To determine the association of high occlusal force with the signs of occlusal trauma and periodontal conditions in periodontitis patients	Moderate and severe periodontitis	Occlusal trauma and high occlusal force / no occlusal trauma	PD, CAL, BOP	A statistically significant association ($p<0.05$) in posterior teeth between functional mobility, tooth wear, widened periodontal ligament and increased PD and CAL was found. High occlusal force was associated with increased PD. In anterior teeth, no associations were found.
2017 / Hutabarat and Nasution	8	To evaluate the relationship of trauma from occlusion and the severity of periodontitis	Periodontitis patients	Trauma from occlusion / balanced contacts	Severity of periodontitis	Teeth with trauma from occlusion presented increased probing depth 4.30 mm ± 2.18 as compared to 3.70 mm ± 1.98 in teeth without trauma. Clinical attachment level was 7.33 mm ± 2.75 in teeth with trauma from occlusion vs. 5.55 mm ± 2.44 in teeth without trauma. The proportion of teeth with severe CAL was higher in teeth with trauma from occlusion (80.8% vs. 52.8%; $p<0.05$).

PD: probing depth, CAL: clinical attachment level.

Table 5. Intervention studies

Year/ authors	Type of study	Number of subjects	Objective	Follow up (years)	Population	Intervention/ comparison	Primary outcome	Mean change Intervention (SD)	Mean change Comparison (SD)	Other outcomes Mean change Intervention (SD)	Other outcomes Mean change Comparison (SD)	Main Results
1992 / Burgett *et al.*	RCT	50	To test the influence of occlusal adjustment in association with periodontal therapy on attachment levels, pocket depth, and tooth mobility	2	Periodontitis patients	Occlusal adjustment (n=22) / no occlusal adjustment (n=28)	Clinical attachment level	0.46 mm (0.66)	0.08 mm (0.39)	PD -0.58 mm	PD -0.54 mm	Significantly more gain of clinical attachment level in the occlusal adjustment group. No difference in changes of probing depths between groups.
2014 / Joo *et al.*	RCT	16	To explore the effectiveness of occlusal reduction to improve periodontal health and tooth mobility	0.5	Periodontitis patients	Occlusal reduction (n=20 teeth)/no occlusal reduction (n=20 teeth)	Clinical attachment level	0.75 mm	0.69 mm	PD -1.14 mm; periotest value -11.53	PD -1.13 mm; periotest value -2.22	All parameters improved after periodontal therapy. Teeth that received occlusal reduction presented better improvement in probing depth and mobility ($p<0.05$).

PD: probing depth, CAL: clinical attachment level.

Discussion

To date the question to what extent a traumatic occlusion affects periodontal tissues has been without any definitive answer. This systematic review aimed to review the scientific evidence of studies performed in humans for this question. Only randomized clinical trials (RCTs) addressing the intervention of traumatic occlusion and its impact on periodontal parameters were included for analysis. Only 2 low quality RCTs (Burgett *et al.* 1992, Joo *et al.* 2014) were retrieved and these studies showed that after occlusal adjustment, the difference in the magnitude of the effect in clinical attachment level and probing depth was negligible between intervention and control groups. However, this approach has a shortcoming in that it assesses the effect of an intervention on a suspected traumatic occlusion that already has had its impact on periodontal tissues for an unknown period of time and these responded by adapting to the stimulus. It is unlikely that an adapted tissue returns to its initial state after an intervention. In order to determine if traumatic occlusion has a causal role on periodontal disease, an experiment in which a group of teeth is subjected to the exposure and a group of teeth without the exposure is used as controls would provide strong evidence. A more rational way to do a RCT for this issue would be to carefully expose some teeth to traumatic occlusal forces and observe the response on periodontal tissues as compared to control teeth in humans and then applying the intervention. But such a study would be unethical to perform based on what is already known from preclinical studies in animals as no harm should be induced in human studies.

Carefully performed observational studies offer strong scientific evidence if there is any. In this approach, the exposure is the traumatic occlusion while in the previous approach the exposure was the intervention and hence the results should be interpreted differently. However, how to define the exposure (traumatic occlusal forces) and its time sequence relationship with the resulting response on periodontal tissues is problematic. Thus one way to address these issues would be to carry out a cohort study in which some subjects are exposed to traumatic occlusion and some are not and wait for a response in time. However, in this kind of study the exposure is to occur naturally as opposed experimental induction where the trauma is induced in a controlled manner. Such a study would take considerable time to carry out and there would be a high probability that the periodontal tissues would adapt. In this context, one low quality cohort study was identified (Di Febo *et al.* 2015) that followed 100 patients for 20 years of private practice. The study showed that after prosthetic treatment, teeth with parafunction were more likely to fail due to reasons other than the progression of periodontitis.

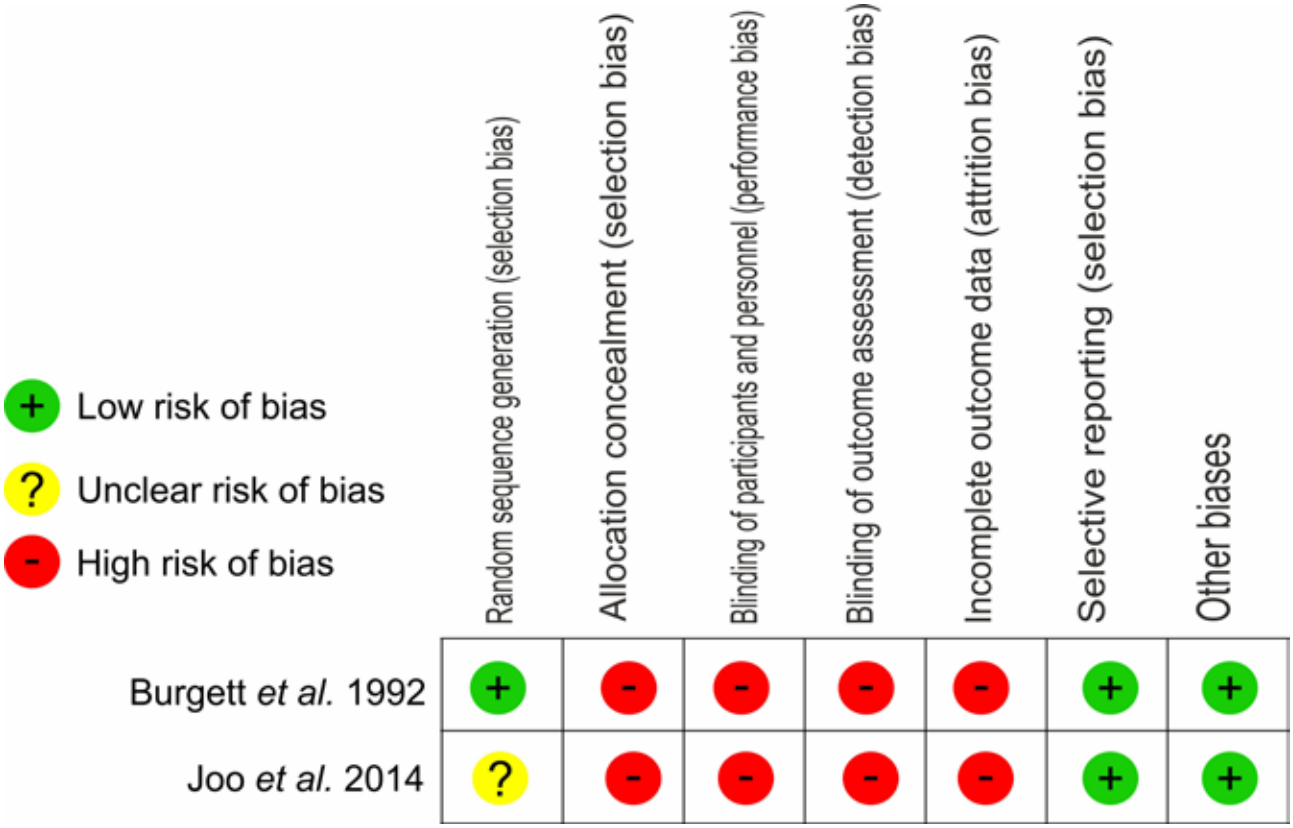

Figure 2. Summary of quality assessment of randomized clinical trials.

To circumvent the time variable, case-control studies may offer some useful information. Case-control studies focus on the disease instead of the exposure, in this case the response of periodontal tissues. Cases would be defined on the basis of having either periodontitis or loss of clinical attachment level depending on how the question is presented. Controls should be comparable to cases except that they do not have the disease. However, with these studies the problem arises that a subject could have loss of clinical attachment level and not have periodontitis (reduced periodontium) and thus making difficult to conclude that traumatic occlusion is responsible for that finding. Loss of clinical attachment level manifested by recession without increased probing depth could be related to exposures other than periodontitis. The role of excessive occlusal forces on the development of gingival recessions has been questioned and it is not possible to make a positive association. Unfortunately, no case-control studies were identified in this systematic review.

Retrospective studies analyze exposures as risk factors and their outcomes in a historic manner and hence bias and confounders could be increased. Four retrospective studies (Nunn and Harrel 2001, Harrel and Nunn 2001, Harrel and Nunn 2004, Harrel and Nunn 2009) were identified when in fact they come from the same study setting. Teeth with occlusal discrepancies presented initial deeper probing depths (5.53 mm vs. 4.77 mm; difference 0.7 mm). Teeth that received complete periodontal treatment (nonsurgical + surgical treatment) and occlusal adjustment presented an improvement in probing depths. However, the magnitude of these effects was minimum (<0.8 mm) and hence the clinical significance of the intervention remains inconclusive.

Cross-sectional studies offer limited information regarding the cause-effect approach but could help identify potential associations between factors and outcomes in certain events. Seven studies were retrieved (Jin and Cao 1992, Bernhardt *et al.* 2006, Kundapur *et al.* 2009, Reyes *et al.* 2009, Branschosfsky *et al.* 2001, Zhou *et al.* 2017, Hutabarat and Nasution 2017) and showed that there is a statistically significant association between occlusal discrepancies and probing depth and loss of clinical attachment level. In the same manner, signs of trauma from occlusion were statistically associated with increased periodontal destruction. Nonetheless, except for the study by Jin and Cao (1992), that reported a difference in clinical attachment level of 3.4 mm between groups, the magnitude of this difference between teeth with and without occlusal discrepancies in most studies is minimal (<0.9mm) and thus lacks clinical relevance.

Since the answer for the original question could not be definitively answered from human studies, we considered animal studies. Animal models allow most variables to be controlled and results can be gained quickly as opposed to human studies. This allows studying signs, symptoms and treatment strategies that would be otherwise not feasible in humans. Animal studies, now considered classic, that addressed the impact of traumatic occlusion on periodontal tissues have unequivocally concluded the following accepted statements (Ericsson and Lindhe 1982, Lindhe and Ericsson 1982, Lindhe and Svanberg 1974, Nakatsu *et al.* 2014):

- An excessive occlusal force results in inflammation of the periodontal ligament and thus increased tooth mobility.
- Angular bone resorption observed marginally is the result of an adaptive response to the excessive force.
- An excessive occlusal force does not induce loss of clinical attachment in teeth with healthy periodontium.
- An excessive occlusal force could aggravate an established periodontal plaque-induced pocket depending on the presence of local irritants and inflammation. The elimination of the excessive occlusal force will not stop further periodontal destruction induced by plaque accumulation.
- If the occlusal force is eliminated on a normal height periodontium with adequate plaque control, periodontal tissues heal without any complications.

The limited evidence obtained from the studies analyzed in this systematic review is inconclusive. Heterogeneity, tooth or subject related analyses and small sample studies might account for limitations of this systematic review, as meta-analysis could not be conducted. In the present study several studies were included that had not been analyzed in previous studies (Foz *et al.* 2012, Fan and Caton 2018). Fan and Caton (2018) searched up to 2017 and presented a narrative review of the main findings and concluded that there is ¨some association between occlusal trauma/discrepancies and progression of periodontal disease¨. Nonetheless, the magnitude of this effect was not taken into consideration and thus making the conclusion controversial. It is possible that more prospective studies in humans are necessary to overcome the limitations of the provided evidence. But the adequate study design to analyze the interaction between occlusion and periodontal tissues is yet to be determined.

The results from this systematic review should be interpreted with caution. Although, the effect of traumatic occlusal forces on periodontal parameters was not clearly discernible, it does not mean that it would not produce any damage to dental and periodontal tissues. Furthermore, even if adverse effects of occlusal adjustment were not reported, it should be performed based on clinical judgment of each specific case. Occlusion adjustment should be considered in order to provide stable occlusal contacts that are beneficial for the adaptive capability of periodontal tissues, the masticatory system and comfort of the patient and not to stop the progression of periodontitis by itself (Fan and Caton 2018).

The clinical relevance of this systematic review is to highlight that in some patients with traumatic occlusal forces and poor plaque control, there could be increased periodontal damage if the occlusion is not controlled. The successful long-term treatment of periodontitis is a complex personalized strategy that evaluates patients according to know risk factors and provide the best evidence- based treatment options.

Conclusions

What is the effect of traumatic occlusal forces on periodontal parameters in patients with and without periodontitis?

It can be concluded that there is limited evidence that traumatic occlusal forces are associated with loss of clinical attachment level or increased probing depths.

What is the effect of occlusal interventions on periodontal parameters in patients with periodontitis?

It can be concluded that there is limited evidence to support the implementation of occlusal adjustment to significantly improve periodontal parameters in patients with periodontitis.

Acknowledgements

Dr. Javier Enrique Botero is a full time professor at the University of Antioquia. The authors report no conflict of interests.

All authors contributed equally to the design and implementation of the research, analysis of the results and to the writing of the manuscript.

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